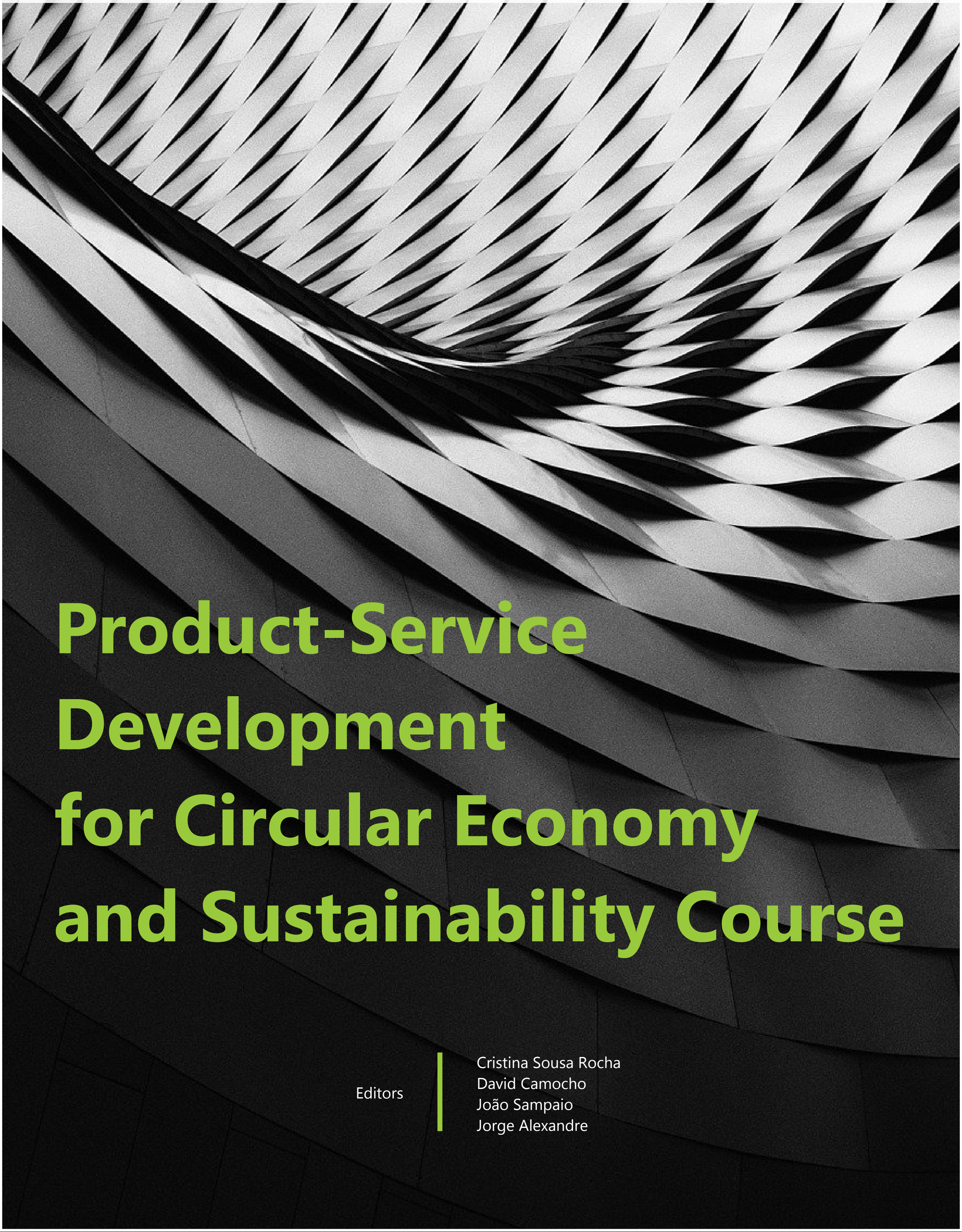
KATCH-e

Knowledge Alliance on Product-Service Development towards Circular Economy and Sustainability in Higher Education



Product-Service Development for Circular Economy and Sustainability Course

Editors

Cristina Sousa Rocha
David Camocho
João Sampaio
Jorge Alexandre

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www.katche.eu

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CONTENTS

01

INTRODUCTION TO THE CIRCULAR ECONOMY

Executive summary 03
1.1 The global sustainability challenge and why we need a new approach 05
1.2 Defining circular economy, underlying principles and related strategies 09
1.3 Circular economy and sustainability 17
1.4 Design and innovation for a circular economy 20
1.5 Circular economy requires new business models 23
1.6 Main challenges and drivers in shifting to a circular economy 25
1.7 EU policy and legislation for circular economy 27
1.8 Sustainable production and consumption 31
1.9 Circular economy in the construction and furniture sectors 36
1.10 Tools for introducing circular economy 62
1.11 The ten KATCH_e essentials of circular economy 65
Bibliography 67

02

BUSINESS MODELS

Executive summary 75
2.1 What constitutes a circular business model? 76
2.2 Economic opportunities and financial implications of circular business models 94
2.3 The conceptualisation of business models 107
2.4 From linear to circular business models 122
2.5 Examples 129
Bibliography 142

03

VALUE CHAINS

Executive summary 147
3.1 Introduction to the concept of circular value chains and networks 148
3.2 Why change to a circular value network? 159
3.3 How to optimise supply chains through reverse networks 163
3.4 Business strategies/models that support the implementation of circular value networks 171
3.5 Stakeholders engagement and management: how to establish a circular value network 178
3.6 Existing tools for the management of value chains towards sustainability 182
Bibliography 184

04

PROCESSES AND MATERIALS

Executive summary 189
4.1 Introduction 190
4.2 Characteristics of materials and processes from a circular economy perspective 194
4.3 Design and development strategies vs characteristics of materials and processes 197
4.4 Compilation of processes related to circular economy 199
4.5 Compilation of characteristics of materials related to circular economy 212
4.6 Trade-offs in the circular economy 224
Bibliography 228

05

DESIGN AND DEVELOPMENT

Executive summary 239
5.1 From ecodesign to design for the circular economy and sustainability 241
5.2 The role of design in circular economy 250
5.3 KATCH_e strategies of design for a CE 253
5.4 Product and service design step-by-step 269
5.5 Design for CE in the construction sector 274
5.6 Tools for product and service design for CE 277
5.7 Examples 283
Bibliography 289

06

RADICAL INNOVATION AND COLLABORATIVE DESIGN PROCESSES

Executive summary 297
6.1 Introduction to innovation 298
6.2 Circular economy as an input for the innovation process 305
6.3 Product-service system design 310
6.4 Collaborative and participatory design for innovative processes 323
6.5 Open-source as a mean to feed innovation and disseminate results 332
6.6 Examples 334
Bibliography 337

07

LIFE CYCLE PERSPECTIVE

Executive summary 341
7.1 Introduction to Life cycle thinking 342
7.2 Impact assessment along the life cycle 345
7.3 The life cycle of products and discussing circular loops 368
7.4 Assessment and communication on building and component level 377
7.5 Examples 394
Bibliography 399

08

COMMUNICATION

Executive summary 407
8.1 Introduction to communicating circularity 408
8.2 Guidelines and techniques for communicating circularity 414
8.3 CE specific communication tools 429
8.4 Environmental labelling and Product Declarations and their relation with CE 438
8.5 Examples 441
Bibliography 446

Preface

This book is an output of the ERASMUS+ **KATCH_e project**. KATCH_e stands for "Knowledge Alliance on Product-Service Development towards Circular Economy and Sustainability in Higher Education". This was a 3-year project (2017-2019), aiming to address the challenge of reinforcing skills and competences in Higher Education and within the business community, in the field of **product-service development for the circular economy and sustainability**, with a particular focus on **the construction and furniture sectors**.

There is nowadays a myriad of training courses, books, manuals, standards, reports, tools and all sorts of resources related to the circular economy. Therefore, one of the main challenges for the consortium was to bring novelty to what is already available and this was achieved through (i) the systemizing of existing, disperse, knowledge, keeping in mind the applicability in Higher Education study programmes and in companies, together with the target sectors; and (ii) the development of new contents and tools where gaps existed. From an academic point of view, the main focus of KATCH_e is design-related disciplines integrated in study programs of e.g. Construction Engineering, Furniture Design, Sustainable Design, Ecodesign, Environmental Engineering, Environmental Management, etc.

The approach followed is framed by the understanding of circular economy in KATCH_e: *"Circular economy is a system that is restorative and regenerative by intention and design, which supports ecosystem functioning and human well-being with the aim of accomplishing sustainable development. It replaces the end-of-life concept with closing, slowing and narrowing the resource flows in production, distribution and consumption processes, extracting economical value and usefulness of materials, equipment and goods for the longest possible time, in cycles energized by renewable sources. It is enabled by design, innovation, new business and organizational models and responsible production and consumption".*

Following this understanding, KATCH_e resulted in numerous outputs that can be found for free on the website of the project (www.katche.eu). This book presents a compilation of the **eight theoretical modules** (here shown as chapters) written by the consortium, which are organized according to four main areas:

1. **Basics:** Basic knowledge on circular economy that supports the understanding of the other training materials;
2. **Business:** The business approach, required for the success of new, more circular and sustainable products or product-services;
3. **Design:** Product and product-service system design according to circularity and sustainability criteria; and
4. **Assessment and communication:** A support area with contents regarding assessment and communication in circular economy with a life cycle perspective.

The modules are closely related to a set of **KATCH_e tools**, intended to complement the theoretical contents but that can also stand on their own and can be applied individually, especially in a company-oriented context.

	Modules	Tools
Basics	– Introduction to the circular economy	– KATCH-Up Board Game
Business	– Business models – Value chains	– CE Strategist – CE Value chains
Design	– Processes and materials – Design and development – Radical innovation and collaborative design processes	– CE Designer – CE Journey
Assessment and communication	– Life cycle perspective – Communication	– CE Analyst – KATCHing Carbon

All these materials have been subject of extensive testing in the four partner countries (Austria, Denmark, Portugal and Spain) in academic and business contexts, benefiting from the presence of company partners in the consortium, besides the knowledge partners (universities and research institutes). Therefore, this book is the result of a long iterative process of collaboration within the partnership and including a robust stakeholder engagement process.

We recommend a visit to the project website and its knowledge platform, where in addition to this book, the theoretical **modules** and the **tools**, other resources that resulted from the project can be found:

- A **MOOC** (Massive Open Online Course) with narrated presentations of the modules, quizzes, a final exam and links to the tools and the glossary. The MOOC may, for instance, be used by teachers and supervisors to support their student-related activities on circular economy, and by professionals working with developing circular solutions in organizations;
- The **study programme of the Product-Service Development for the Circular Economy and Sustainability Course**;
- The **ten KATCH_e essentials** that serve as guidelines to the complex process of working with circular economy;
- 16 **case studies** describing the experience of applying KATCH_e tools and related methods in companies' products, services and business models, from the four partner countries;
- Numerous **examples** of circular economy in practice gathered from external sources, including their relationship to the KATCH_e materials;
- The **Situation Analysis** Report (and Executive Summary), containing the main outputs of an analysis of the training and competence needs and gaps on topics related to circular economy conducted during the first stage of the KATCH_e project;

- A list of **external resources** on circular economy consisting of books, papers, guides, thesis, projects, databases, tools, ecolabels and standards, webs and platforms and university training offer;
- A manual with **didactic recommendations** that serves as guidance material for the application of the KATCH_e training materials either in a classroom setting, workshop or self-study. The guide provides Recommendations for Higher Education institutions as well as for policy-makers in the field of Higher Education.

Carrying out KATCH_e has been a long journey and a very rich learning process, and the outputs have by far exceeded what could be expected at the beginning of the project. This was only possible through the excellence of the contributions and engagement of all partners and many people in their networks. The consortium is confident that these results will remain relevant and inspiring beyond the funded period and will contribute to a better alignment of the training and education offers and the needs of a more sustainable society.

The KATCH_e Coordination Team, July 2020

01

INTRODUCTION TO THE CIRCULAR ECONOMY

Authors: Kirsten Schmidt, Anja Bundgaard, Stig Hirsbak, Cristina Sousa Rocha, David Camocho and Jorge Alexandre
Collaboration: Irina Celades, Teresa Ros Dosdá, Filipe Barros and Salomé Agudo

Introduction to the circular economy

Contents

Executive summary 3

1.1 The global sustainability challenge and why we need a new approach 5

1.2 Defining circular economy, underlying principles and related strategies 9

1.2.1 Understanding the concept towards a KATCH_e definition of CE 9

1.2.2 Principles and strategies 15

1.3 Circular economy and sustainability 17

1.4 Design and innovation for a circular economy 20

1.4.1 How to define a circular product? 21

1.5 Circular economy requires new business models 23

1.6 Main challenges and drivers in shifting to a circular economy 25

1.7 EU policy and legislation for circular economy 27

1.7.1 The EU initiatives supporting CE 27

1.8 Sustainable production and consumption 31

1.9 Circular economy in the construction and furniture sectors 36

1.9.1 Construction sector 36

1.9.2 Furniture sector 47

1.10 Tools for introducing circular economy 62

1.10.1 KATCH_UP Board game 62

1.10.2 Other tools 64

1.11 The ten KATCH_e essentials of circular economy 65

Bibliography 67

Executive summary

1.1 The global sustainability challenge and why we need a new approach

Section 1.1 deals with the global sustainability challenge and why we need a new approach to production and consumption. Humanity is exceeding the Earth's carrying capacity and it can have severe consequences for our living conditions. This overexploitation of the biological system is partly a result of the increasing resource consumption linked with the linear economy or the take-make-waste paradigm.

Thinking circular can help to address many of these challenges. In essence, a circular economy represents a fundamental alternative to the linear take-make-consume-dispose economic model that currently predominates. This linear model is based on the assumption that natural resources are available, abundant, easy to source and cheap to dispose of, but it is not sustainable. So, we need a fundamental transition into a more sustainable production and consumption system.

1.2 Defining circular economy, underlying principles and related strategies

Since there is not one, common definition of circular economy, but a larger number with different foci, we have defined how circular economy and the underlying principles and strategies are understood in the KATCH_e project. Our definition, developed from a number of other definitions, goes:

Circular economy is a system that is restorative and regenerative by intention and design, which supports ecosystem functioning and human well-being with the aim of accomplishing sustainable development. It replaces the end-of-life concept with closing, slowing and narrowing the resource flows in production, distribution and consumption processes, extracting economical value and usefulness of materials, equipment and goods for the longest possible time, in cycles energized by renewable sources. It is enabled by design, innovation, new business and organizational models and responsible production and consumption.

1.3 Circular economy and sustainability

Circular economy can be seen as a tool to operationalize sustainable development principles through efficient and eco-effective use of resources. It is, however, not always obvious that a circular solution is sustainable. For example, if hazardous chemicals through recycling enter new product life cycles, and it is important to understand how life cycles of products are altered in circular solutions. Design and innovation for a circular economy is the core of the KATCH_e materials.

1.4 Design and innovation for a circular economy

This section presents the main design strategies for a circular economy in our two target sectors – based on the principles of slowing, narrowing and closing material and energy loops. The strategies are further elaborated in the *Design and development* chapter.

1.5 Circular economy requires new business models

Circular economy also requires new business models since it represents a new way of understanding value in the economic system. This section introduces some main aspects to consider when developing circular business models and related value chains, and the *Business models and Value chains* chapters present methods and approaches for working with these aspects.

1.6 Main challenges and drivers in shifting to a circular economy

Circular economy as an idea and a concept is not new, and many companies have already come to know both challenges and enablers in shifting to a circular economy. This section gives an overview of the main types of the barriers and drivers on three levels: society, market and organization.

1.7 EU policy and legislation for circular economy

Legislation is both an enabler and a barrier for the transition towards circular economy, and this section highlights the main EU policies and regulation influencing the development.

1.8 Sustainable production and consumption

Market trends and the development in our consumption patterns are extremely important, also in the circular economy, and this is the topic for this section.

1.9 Circular economy in the construction and furniture sectors

Since the training materials are targeting the construction and furniture sectors, this section presents the two sectors, the main market trends and circular economy aspects and challenges. The section also includes several examples on, how organizations in the two sectors deal with circular economy.

1.10 Tools for introducing circular economy

In this section, tools that may support one’s way into understanding and working with circular economy are presented.

1.11 The ten KATCH_e essentials of circular economy

The final section concludes the introduction by pointing at ten essentials of working with circular economy from a more practical perspective.

1.1 The global sustainability challenge and why we need a new approach

In the last hundred years, the shift of an increasing number of countries from low to high levels of industrial development has brought an unprecedented increase in natural resource use. Driven initially by economic development in Europe and North America, and subsequently elsewhere, world gross domestic product (GDP) has increased 25-fold since 1900, bringing a 10-fold rise in global resource extraction (EEA, 2016).

During the next 40 years, the world population is expected to rise from 7 to 10 billion people which will demand three times more resources than can be provided, unless resources are recycled (footprintnetwork.org; Population Reference Bureau, prb.org).

During the last 30 years, global material extraction has more than doubled from around 36 billion tonnes in 1980 to almost 85 billion tonnes in 2013, see figure 1.1 (Vienna University, 2016). Especially, industrial and construction minerals acquisition has increased significantly with more than 240% as a result of increasing material needs to build housing, energy and transport infrastructure in emerging economies (Vienna University, 2016).

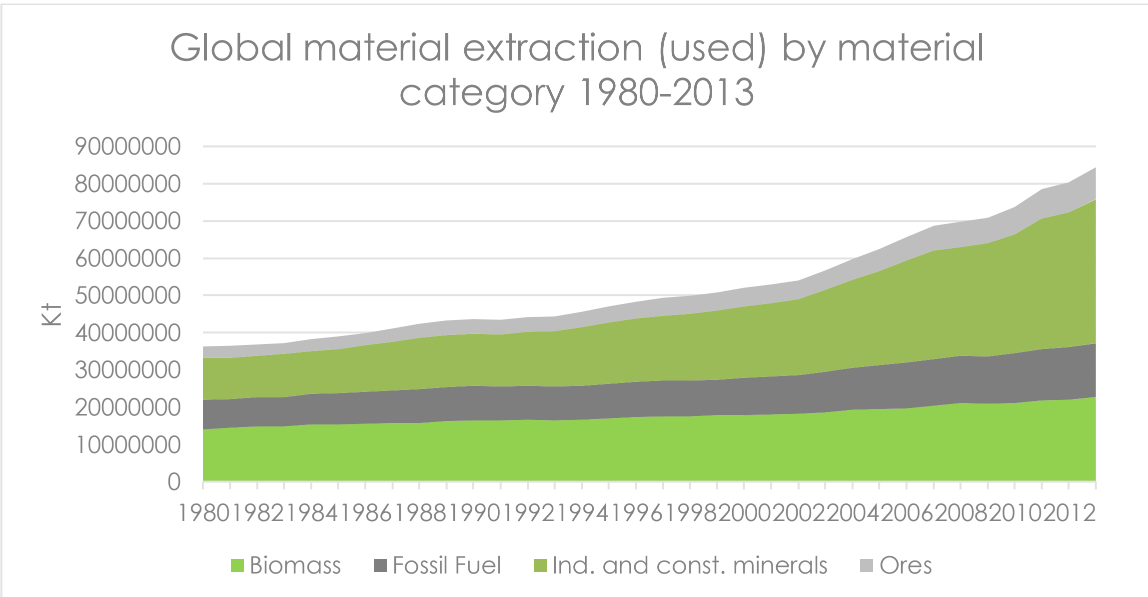


Figure 1.1 – Global material extraction (used) by material category 2980-2013 (Global Material Flows Database, Vienna University, 2012).

The increasing material extraction rates seen during the last 30 years conveys the notion that the resources available on Earth are unconstrained. However, this is far from the truth. In fact, the Earth is a closed system and, with the exception of solar energy and wind power, the resources available on the Earth are constant (Boulding, 1966). Due to these constraints on available resources, the Earth also has a certain carrying capacity, which we today are overexploiting. Two indicators are the ecological footprint (from the demand side) and the biocapacity (from the supply side), developed by the Global Footprint Network (figure 1.2) (Global Footprint Network, 2013). Ecological footprint is a measure of how much biologically productive land and water is needed to produce all the resources consumed and absorb all the waste generated. Biocapacity is a measure for the capacity of an ecosystem to produce the biological materials used by humans and to absorb the waste generated by humans. As illustrated in figure 2, the ecological footprint has since 1970 exceeded the biocapacity of the Earth, and consequently there has been an ecological deficit. In 2013, the ecological deficit was so large that we needed 1.68 Earths to produce all the resources we consumed and absorb all the waste we generated.

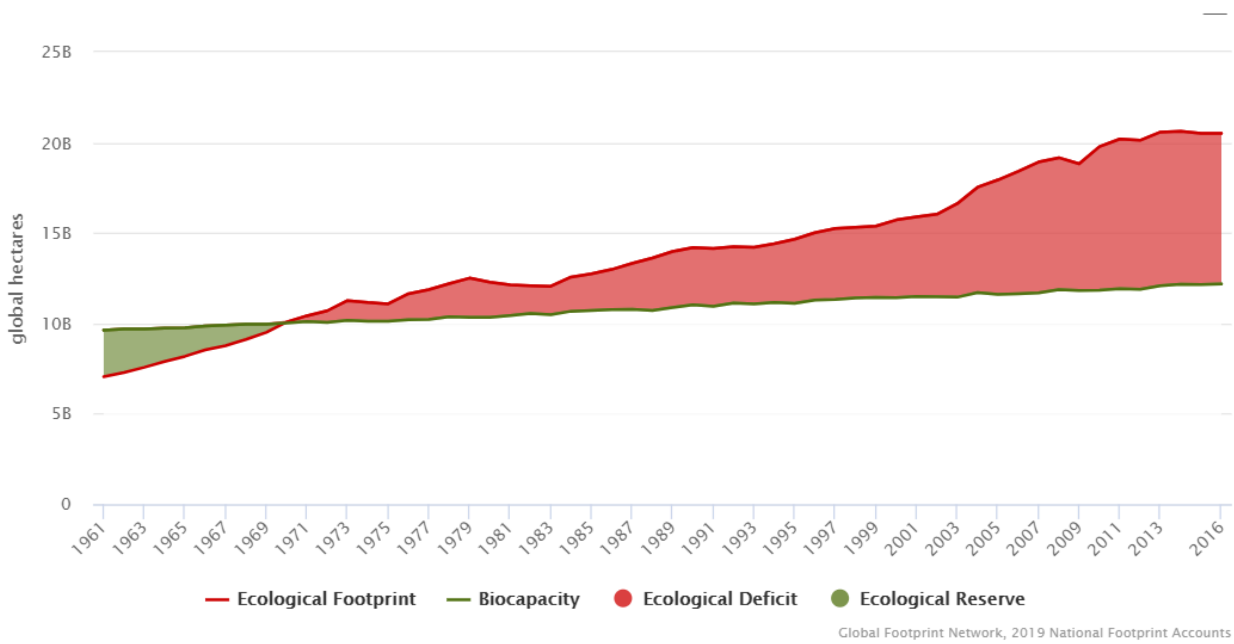


Figure 1.2 – Ecological footprint vs biocapacity measured in global hectares (Global Footprint Network, 2019).

At the same time, rapid increases in extraction and exploitation of natural resources are having a wide range of negative environmental impacts in Europe and beyond (EEA, 2016). Air, water and soil pollution, acidification of ecosystems, biodiversity loss, climate change and waste generation put immediate, medium- and long-term economic and social well-being at risk. While resource use in Europe has become more efficient in recent years, resulting in absolute reductions in emissions of greenhouse gases and pollutants, the continent's burden on global ecosystems remains considerable, particularly if pressures in the countries of origin of imported products and materials are taken fully into account (EEA, 2016).

This overconsumption has had strong implications for the well-being of the biosphere, and thereby also the outset for our living conditions. Rockström et al. (2009) have defined nine of what they call planetary boundaries defining the safe operating space for humanity in terms of the planet's biophysical subsystems or processes, see figure 1.3.

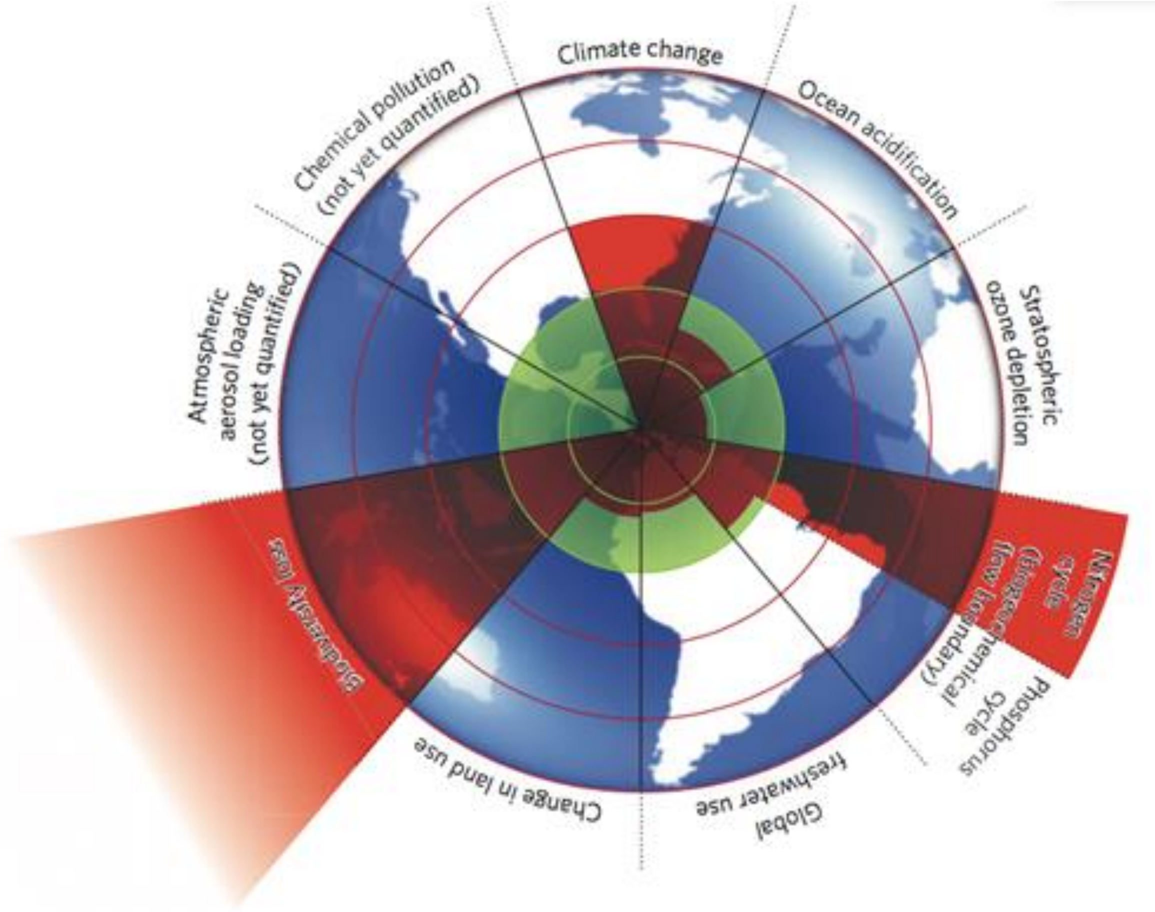


Figure 1.3 – Planetary boundaries the green colour represents the proposed safe operating space, the red colour represents the estimated current position for each of the nine planetary system (Rockström et al., 2009: 472).

As figure 1.3 shows, three of the nine planetary systems have exceeded the safe operating space including climate change, the nitrogen cycle and biodiversity. Furthermore, humanity is approaching the planetary boundary for global freshwater use, changes in land use, ocean acidification and the global phosphorous cycle (Rockström et al., 2009). Hence, humanity is exceeding the Earth's carrying capacity and it can have severe consequences for our living conditions. This overexploitation of the biological system is partly a result of the increasing resource consumption linked with the linear economy or the take-make-waste paradigm.

Thinking circular can help to address many of these challenges. In essence, a circular economy represents a fundamental alternative to the linear take-make-consume-dispose economic model that currently predominates. This linear model is based on the assumption that natural resources are available, abundant, easy to source and cheap to dispose of, but it is not sustainable, as the world is moving towards, and is in some cases exceeding, planetary boundaries (EEA, 2016). Therefore, we need a fundamental transition into a more sustainable consumption and production system. In a circular model, on the other side, waste and pollution are designed out, products and materials are kept in use and values sustained for as long as possible – and natural systems are regenerated (Ellen MacArthur Foundation, 2012).

The process of change necessarily involves (Rocha, 2010):

- Companies (placing more sustainable products on the market, promoting sustainability design and new business models such as product-service systems, which dissociate profit from natural resource consumption, and promote responsible marketing, for example);
- Policy makers (through legislation, financial incentives, environmental and social labelling schemes, awareness-raising campaigns geared to different socio-economic segments, and by adopting sustainability criteria in public procurement and thereby power of the government, as a client, to influence the market);
- Organized civil society (more and more non-governmental organizations dedicated to sustainable consumption, with an important role in informing citizens);
- Citizens, as individual consumers, who are facing the first major challenge that is to be aware of the implications of their choices and how they meet their welfare needs.

Assignment 1.1

Argue for three main reasons for a transition from the linear business as usual approach.

1.2 Defining circular economy, underlying principles and related strategies

1.2.1 Understanding the concept towards a KATCH_e definition of CE

The idea of a circular economy is not new but goes back to the 60s and 70s (Boulding, 1966; Nicholas Georgescu-Roegen, 1975). However, it was not until the beginning of the 90s that the term circular economy emerged, when introduced by Pearce and Turner in 1990. In 2012, the concept re-emerged as the Ellen MacArthur Foundation published their first of many publications on circular economy (Ellen MacArthur Foundation, 2012). Since then, the concept has spread to the political arena with amongst other the European Commission's Action Plan to a Circular Economy (European Commission, 2015), and a revision of a number of directives such as the waste framework directive and the directive on packaging waste (see section 1.7 on EU CE Policy and Regulation). Moreover, since the re-emerge in 2012, a large number of publications, research papers, etc. suggesting definitions, models and strategies to circular economy has been developed. As a result, there is no shared and common understanding and definition of circular economy (Kirchherr, Reike, & Hekkert, 2017). These authors analysed nothing else than 114 definitions, which indicates that the meaning of circular economy is far from consensual.

Just like there is no single agreed upon definition of circular economy there are also various notions on what are the fundamental principles behind circular economy. Furthermore, there is no clear distinction between a CE strategy and a CE principle. In the KATCH_e context, we understand a principle as a basic idea or rule, whereas a strategy sets out more specific indications of which actions to take.

In the KATCH_e project, the consortium developed its own definition of circular economy that will be presented below and is meant to suite the projects' objectives, operational approach and sectors. It has its roots in several existing definitions: the one provided by the Ellen MacArthur Foundation (EMF) serves as a starting point since it is often enhanced as the most prominent definition of circular economy. The EMF definition defines circular economy as:

> "an industrial system that is restorative or regenerative by intention and design. It replaces the "end-of-life" concept with restoration, shifts towards the use of renewable energy, eliminates the use of toxic chemicals, which impairs reuse, and aims for the elimination of waste through the superior design of materials, products, systems and within this, business models."
>
> Ellen MacArthur Foundation, 2012: 7.

The EMF definition can be criticized for not specifying the need for reducing consumption levels and not including the social aspects of sustainability.

To overcome the weak point related to the need of reducing consumption rates, we include the definition of CE developed by Geissdoerfer et al. (2017):

> "a regenerative system in which resource input and waste, emission, and energy leakage are minimized by slowing, closing, and narrowing material and energy loops. This can be achieved through long-lasting design, maintenance, repair, reuse, remanufacturing, refurbishing, and recycling."
>
> Geissdoerfer et al., 2017: 759

This definition applies three strategies to move towards a circular economy: slowing, closing and narrowing, see figure 1.4:

- Slowing resource loops is to extend or intensify the utilization period of a product resulting in a slowdown of resource consumption. This can be done through designing products with a long lifespan, repair and remanufacturing.
- Closing resource loops is to close the loop between post-use and production through recycling.
- Narrowing resource loops is to use fewer resources per product, thus also considering reduction of the resources used (Bocken et al, 2016).

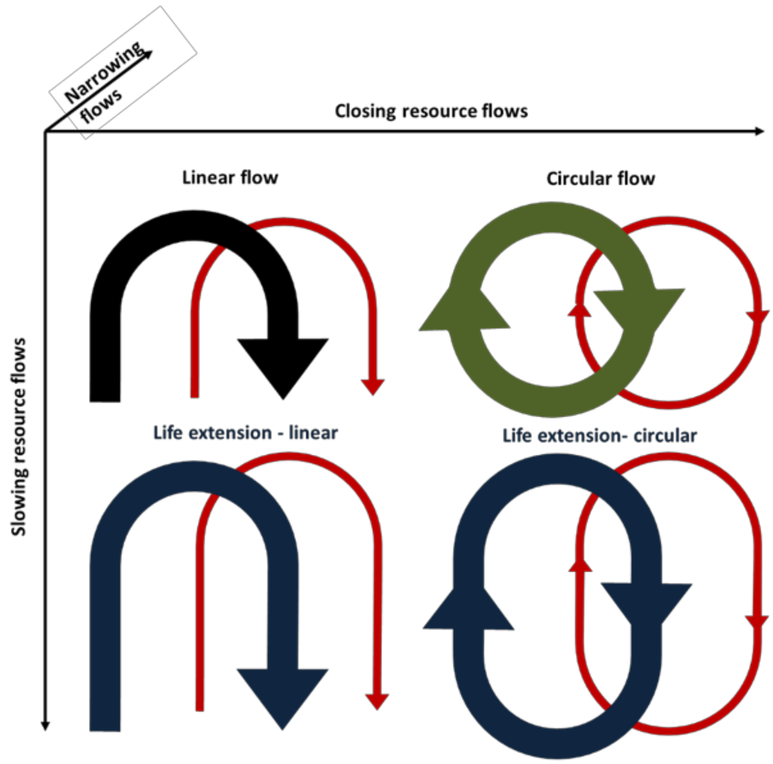


Figure 1.4 – Categorization of linear and circular approaches for reducing resource use. (Bocken et al, 2016).

Throughout the chapter there are several examples on how to work with the slowing, closing and narrowing strategies.

The Geissdoerfer et al. (2017) definition, however, like the one from EMF (2012), does not specifically include a reference to the social aspects of sustainability. Therefore, we include a third definition in KATCH_e's understanding of circular economy.

Murray, Skene and Hayes (2015) include human well-being in their definition, which opens for taking into account important moral and ethical issues like diversity and social equity. Their definitions goes:

> "The Circular Economy is an economic model wherein planning, resourcing, procurement, production and reprocessing are designed and managed, as both process and output, to maximize ecosystem functioning and human well-being"
>
> Murray, Skene, & Haynes, 2017: 377

The strength of this definition lies exclusively on the gap it intends to fill in - the focus on human well-being.

With all these considerations in mind, and in order to frame the development of the KATCH_e training materials and tools, the following definition and basic strategies applies:

> Circular economy is a system that is restorative and regenerative by intention and design, which supports ecosystem functioning and human well-being with the aim of accomplishing sustainable development. It replaces the end-of-life concept with closing, slowing and narrowing the resource flows in production, distribution and consumption processes, extracting economical value and usefulness of materials, equipment and goods for the longest possible time, in cycles energized by renewable sources. It is enabled by design, innovation, new business and organizational models and responsible production and consumption.

Figure 1.5 illustrates how other existing definitions are used to develop the KATCH_e definition.

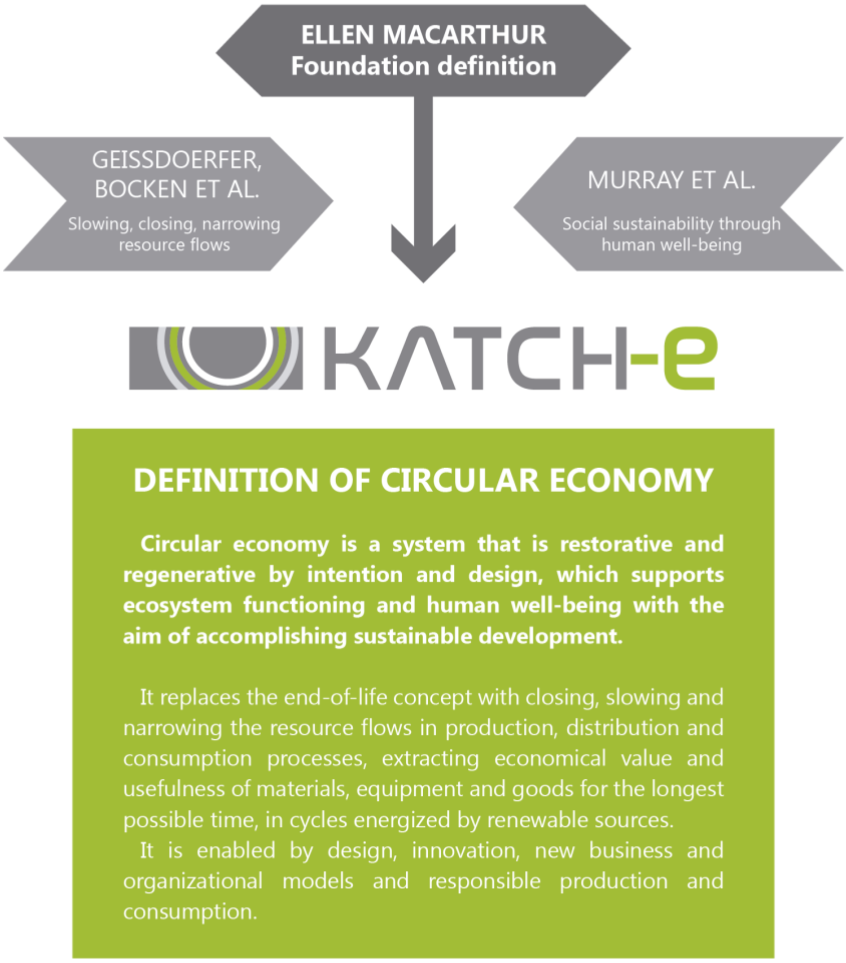


Figure 1.5 – Development of the KATCH_e definition of circular economy.

Since the KATCH_e definition of CE takes a point of departure in the work of Ellen MacArthur Foundation (EMF) who focus on designing out waste and keep all materials and values in technical or biological loops. Their model, known as the CE butterfly diagram, see figure 1.6, deserves more explanation. The understanding of circular economy applied by the EMF is influenced by the cradle-to-cradle concept developed by Braungart and McDonough (2002).

On the left hand side of the model, there are loops related to biological nutrients, which are "consumption products". This means that they are used up during the act of consumption, such as food, soap, etc. Once they serve their purpose, they enter the biosphere through the soil, water or air, and there they should be safe nutrients to the biosphere and renewable resources for new products.

On the right hand side, the diagram shows the metabolism of technical nutrients or "service products". These are not consumed while fulfilling their purpose and examples are cars, textiles, furniture, etc. These are the types of products that concern the KATCH_e project as it focus on construction and furniture.

It is true that a piece of wooden furniture could in principle fit the left hand side circular strategies, especially if no chemicals (such as preservatives, varnishes, etc.) have been applied to it. But if the idea is not only to close loops but also to keep products in the economy for the longest feasible time, the right hand side strategies are the ones that are going to be explored in the project (figure 1.6). In principle, the closer to the inner circles/loops the better, since this will preserve as much value as possible, and demand less resources and energy in processing products and materials into new uses.

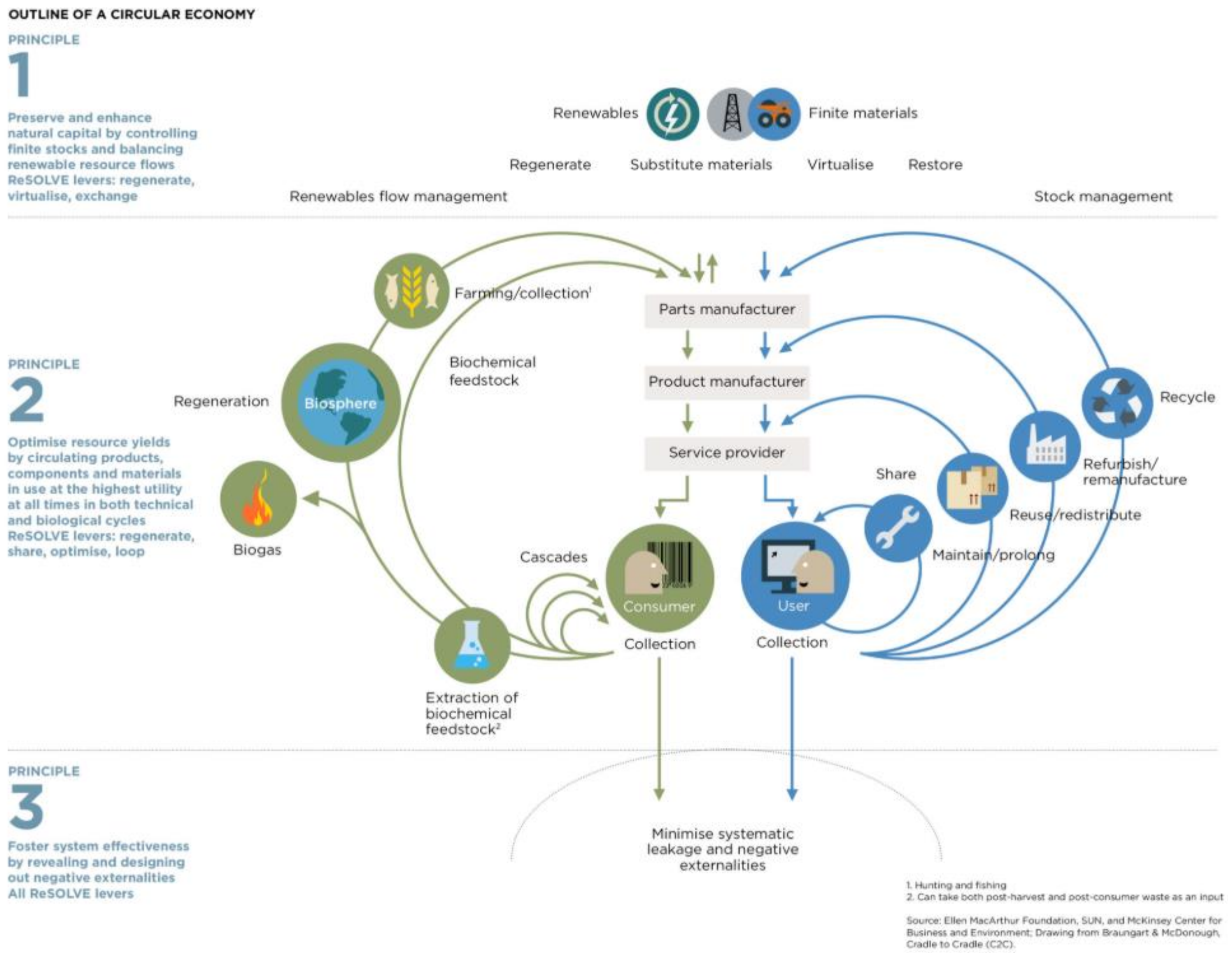


Figure 1.6 – The "Butterfly" model of circular economy, Ellen MacArthur Foundation. Section 1.2.2 further explains the 3 principles (Source: https://www.ellenmacarthurfoundation.org/circular-economy/infographic).

Assignment 1.2

Discuss different CE definitions and which understanding of CE they represent.

1.2.2 Principles and strategies

A definition of circular economy is helpful in creating an understanding on a conceptual level, but it does not in itself provide guidance on, how to work with CE in practice. Therefore, we also need some basic principles and related strategies. The Ellen MacArthur Foundation developed the following three principles as a basis for their work:

Principle 1: Preserve *and enhance natural capital by controlling finite stock and balancing renewable resource flows*. The principle concerns the optimal use of our natural resources for example through dematerialisation, using, when possible, virtual utilities instead of physical products. However, when the use of resources are unavoidable then a wisely use of resource should be ensured by selecting technologies and processes that rely on renewable or better-performing resources (Ellen MacArthur Foundation, 2015a).

Principle 2: *Optimise resource yields by circulating products components and materials in use at the highest utility at all times in both technical and biological cycles*. This principle concerns the design of products, components and materials. Here, the design should ensure that products, components and materials can be circulated and continuously contribute to the economy through actions such as remanufacturing, refurbishing and recycling. A circular system should use inner loops (see figure 1.6 – the butterfly), when possible to preserve energy and value – and to extend product life and enhance reuse (Ellen MacArthur Foundation, 2015a).

Principle 3: *Foster system effectiveness by revealing and designing out negative externalities*. The third principle is about reducing the damage to human utility such as food, shelter, mobility, health and education. Furthermore, it concerns the management of externalities such as land use, water, air and noise pollution, climate change and the release of toxic substances (Ellen MacArthur Foundation, 2015a).

The principles are further developed into the ReSOLVE strategic framework providing more specific actions on how to reach a circular economy (see table 1.1).

Table 1.1 – The ReSOLVE framework (Ellen MacArthur Foundation, 2015a)

Regenerate	Change to renewable energy and materials
Share	Keep product loop speed slow and maximize the use of products by sharing
Optimize	Increase performance and efficiency of product in a life cycle perspective
Loop	Keep materials and components in closed loops and priorities inner loops
Virtualize	Supply utility virtually
Exchange	Exchange old materials with advanced non-renewable materials, use new technologies, select new products and services

Section 1.4 on Design and innovation for a circular economy will look more at principles and strategies, but first, we look into how circular economy and sustainability are related.

1.3 Circular economy and sustainability

Circular economy is often closely linked to sustainability. The links between circular economy and sustainability are, however, subject to debate, and at least two different views on the links exist. Some believe that circular economy surpasses sustainable development because sustainable development is rooted in linear thinking strategies, while others see circular economy as a tool to reach sustainability and thereby circular economy becomes a tool to operationalize sustainable development principles (Merli et al., 2017), especially from the environmental perspective. KATCH_e is in line with the latter approach.

Coming back to the definition above and the narrowing, slowing and closing loops: some authors argue that narrowing loops is related to resource efficiency and this is aligned with a linear economy (Bocken et al., 2016). For many reasons including rebound effects, efficiency ("doing things right") has proven short in the goal of achieving a sustainable development. The EMF evokes the concept of "eco-effectiveness" ("doing the right things"), where "products and their associated material flows such that they form a supportive relationship with ecological systems and future economic growth. The goal is not to minimise the cradle-to-grave flow of materials, but to generate cyclical, cradle-to-cradle 'metabolisms' that enable materials to maintain their status as resources and accumulate intelligence over time (…)". (Source: https://www.ellenmacarthurfoundation.org/circular-economy/interactive-diagram/efficiency-vs-effectiveness).

The KATCH_e consortium agrees that a smart combination of three types of loops is necessary, as illustrated in section 1.2: in theory, the cycles of materials need to be not only longer and circular, but also thinner. The three loops, however, do not consider another important approach to sustainability, namely "sufficiency". Sufficiency requires serious changes in mentality and behaviour, since the right to consume (more and more) is questioned. From a business perspective, sufficiency clearly brings challenges, since – in a simple understanding – it's about consumers buying less, which is not attractive in a traditional linear business model. Therefore, new business models are needed. Section 1.5 and the *Business models* chapter look more into this challenge.

It is not always obvious that a circular solution is also sustainable. For example, recycling of products containing hazardous chemicals or materials may create new or unknown environmental effects when they enter a product life cycle that it was not intended for. Another example is the establishment of a take-back system, where one will need a car to hand in products for recycling. It will augment environmental impacts from the transport, and may also have a potentially negative social impact for people not having a car. Another case concerns a research conducted in relation to LED products: it is not straightforward that longer life-times have lower environmental impacts; improved efficiency, improved material design and decarbonisation of electricity supply need to be considered to come up to a conclusion (Richter et al., 2013).

A main difference between CE and sustainability is related to the social aspects. Sustainability on a conceptual level focus on all three pillars of sustainability (the social, the environmental and the economic), while circular economy as it is used today tends to focus more on the environmental aspects combined with an economic evaluation. The social dimension is not systematically included in the practical solutions so far (Merli et al., 2017). However, to be sustainable, systems for production and consumption will have to take aspects like for example the uneven distribution of wealth and resources, access to welfare, and human rights into account. That said, many initiatives declared sustainable are also not giving the social aspects the same attention as the environmental and economic ones.

In a circular economy, there will be easier access to reuse of products, which may benefit people with lower incomes and give them a possibility for consumption, they would not have had. On the other hand, this may lead to a raise in the consumption level in total. So, in a transition towards more circular and sustainable societies, the question of who has the "right" to consume when resources are restricted becomes important. This is a question with no simple answers, but it will require new and innovative design strategies and business models, including solutions that can fulfil people's needs with much less materials.

Assignment 1.3

Give examples and related argumentation on where circular solutions may not be sustainable.

Companies have traditionally paid most attention to the environmental, social and economic impacts related to their production sites and manufacturing processes, and not so much to their products, by applying strategies such as pollution prevention and cleaner production. However, the increasingly globalised and complex product chains need another perspective including the whole value chain. Here, the concept of life cycle thinking becomes relevant as a way to understand the environmental, social and economic impacts of a product or service in the entire life cycle of the product or product-service from cradle to grave. Or, preferably, from cradle to cradle, where products, components and materials are reused, recycled or recovered into new products. The main objective of life cycle thinking is to reduce the resource use, reduce the emissions to the environmental and improve the socio-economic performance throughout the products entire life cycle (Remmen, Astrup, & Frydendal, 2007). It requires a close cooperation within the value chain, for example in developing new solutions with suppliers, facilitating the customers' handling of the products with the aim of minimizing the environmental impacts during use and when discarding the product.

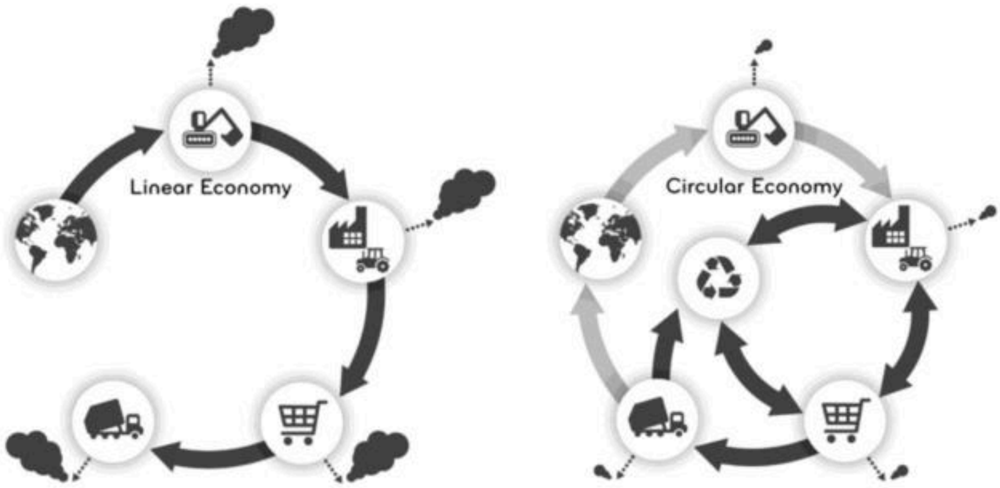


Figure 1.7 – Life cycle thinking in a linear and a circular economy (Sauvé et al. 2016).

In a linear economy, some recycling may take place, but as illustrated to the left in figure 1.7, the cycles are not necessarily closed. As they will be in a circular economy, illustrated to the right in figure 1.7. Recycling and closing of material loops can take many forms, as illustrated by the EMF butterfly model in figure 1.6, involving all phases of the life cycle – not just the ones included in this figure.

The life cycle thinking and how to assess the environmental and social impacts through life cycle assessments is further unfolded in the *Life cycle perspective* chapter.

Assignment 1.4

Give examples on how life cycle thinking in a circular economy may differ from life cycle thinking in a linear economy.

1.4 Design and innovation for a circular economy

To reach a circular economy, materials and products should be designed for closed loops. However, the majority of products today are not designed for circulation, but are designed to fit into a linear economy with fast replacement rates (Andrews, 2015). Therefore, to create a circular economy we need to consider circularity already in the product design (Andrews, 2015; Bocken et al., 2016; Moreno et al., 2016). Design for circular economy is a relatively new design approach, it takes, however, the outset in more established design approaches such as ecodesign, design for the environment and design for sustainability. Thereby, design for circular economy can be considered as an additional focus when designing for sustainability.

However, what does design for a circular economy imply? In connection with the KATCH_e a definition of design for circular economy has been developed and it reads:

> Design for Circular Economy is the design and development of products, services and product-service systems that replaces the conventional end-of-life concept by closing, slowing and narrowing the resource flows in production, distribution and consumption processes.
>
> It is enabled by innovation and novel business and organizational models and aims to accomplish sustainable development through supporting of ecosystem functioning and human well-being, and through responsible production and consumption.

To understand the actual implementation of design for circular economy, an outset can be taken in the practical implementation of circular economy and its links to the three overall circular economy strategies closing, slowing and narrowing resource flows. The practical implementation of circular economy are often linked to the "3Rs" reduce, reuse and recycle (Dajian, 2004; Ghisellini et al., 2016; Goyal et al., 2016; Lieder and Rashid, 2016; Su et al., 2013). Van Buren et al. (2016) and Potting et al. (2017) expanded the "3Rs" framework to the "9Rs" framework adding refuse, repair, refurbish, remanufacture, repurpose and recover energy. Hence, when designing for a circular economy we need to consider if we actually need a physical product or if we can replace or refuse it. We also need to consider if we can rethink the design the product and product system, so we can use the product more intensively through sharing products. Then, we need to design products which are as efficient as possible by reducing energy and resource consumption throughout the products entire life cycle.

Finally, we need to design products that can be reused, repaired, refurbished, remanufactured, repurposed, recycled and recovered.

Design for circular economy is further unfolded in the *Design and development* chapter, including eight main strategies as illustrated in table 1.2. Furthermore, in *the Radical innovation and collaborative design processes* chapter, the focus is precisely on the role of radical innovation to attain sustainability and circularity and different types of innovation are discussed. Related to both chapters, KATCH_e tools are provided to support the practical work of designing innovative, circular solutions.

Table 1.2 – KATCH_e Design strategies for developing circular solutions

Slowing loops	– Design of long-life products[1] – Design for product-life extension[1] – Design of product-oriented services)[2] – Design of use- or result-oriented services[2]
Narrowing loops	– Design for materials sustainability[1] – Design for energy sustainability[1]
Closing loops	– Design for remanufacturing[1] – Design for recycling[1]

Note: [1] product design; [2] service design

1.4.1 How to define a circular product?

During the design process, you will also have to consider, whether or when a product or a solution is circular. For example, is a product more circular because it has a longer serviceable life, even if at end of use it is being landfilled? The answer is not simple, but it can be "yes", if the longer lifetime will save a large amount of resources. In any case, an assessment will be needed, and the *Life cycle perspective* chapter presents methods for evaluation.

From a material resource perspective, the Ellen MacArthur Foundation has defined a circular versus a linear product: A 100% linear product is a product that is manufactured only using virgin feedstock and ends up in landfill. A 100% circular product, on the other hand, contains no virgin feedstock and is completely collected for recycling or reuse at the end of its use phase (Ellen MacArthur Foundation, 2016).

The 100% circular product is theoretical, because the collection, recycling and reuse will never be a 100% efficient process, there are losses. Thus the emphasis on slowing and narrowing resource loops, in addition to closing resource loops is needed.

The *Processes and materials* chapter and the related KATCH_e tools explain and give examples on benefits and challenges related to different types of materials and production processes.

Assignment 1.5

Design goes beyond the product. Discuss, eventually for a given product, what “designing” should include to create a sustainable, circular solution

1.5 Circular economy requires new business models

Circular economy represents a new way of understanding value in the economic system. In the linear economy, the success of the economy is measured by the amount of throughput going through the system, an example being gross national product. In the circular economy, on the other hand, the primary concern is to maintain the stock and the values of the resources (Boulding, 1966). Thereby, the circular economy represents a new way for companies or producers to create value compared to the more traditional linear business model of production where profits is generated from selling products (Bocken et al., 2016). In the circular economy, the companies need to generate profits from the flow of materials and products over time (Bocken et al., 2016).

This calls for the development of new business models such as product service systems, leasing, collaborative consumption, sharing platforms and business models based on maintenance and repair (Bocken et al., 2016). Stahel also introduced in the 1990s the functional service economy with the purpose of selling performance instead for a selling a product (Stahel, 2013). Circular economy is also linked to the sharing economy, where the consumer buys access to a product instead of owning it (Hobson and Lynch, 2016). Many of these circular business models assign the consumer with a new role, which is further developed in the *Business models* chapter.

A circular business model should create value while at the same time close, slow or narrow the resource flows. In a "closing" model, materials are recycled into the production process of the same type or other types of products. In such a solution, however, values may be lost. When using crushed materials from demolished buildings, for example, only about 15% of the economic value is recaptured, compared to the value if the building element was reused as a building element (Sommer, 2018).

As for a product, a business model is never 100% linear or 100% circular. This is shown in figure 1.8.

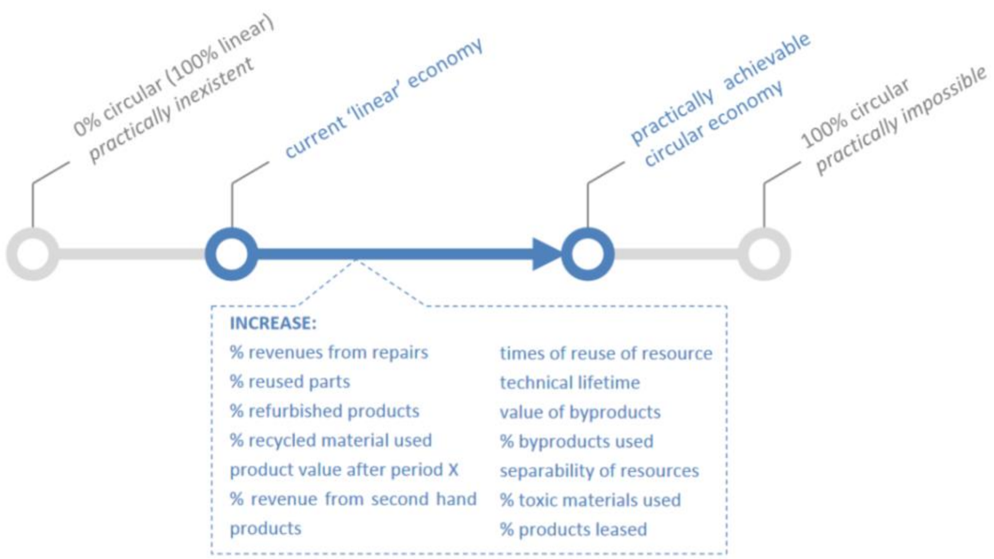


Figure 1.8 – From 100% linear to 100% circular business models (Mentink 2014).

A circular business model requires a shift in the value proposition from quantity to quality. As linear business models are generally sales oriented, there is an inherent incentive to build products with a short lifespan to maximise revenues. By extracting resources from the earth, refining them further within the manufacturing process, assembling them into products and distributing and selling them to consumers, value is added every step of the way. At the point of sale the value is at its highest. Due to the incentives described, the value is quickly lost after a short use phase. Products end up in landfills or are incinerated. Circular business models, on the other hand, create value based on a product's longevity and the closing of resource cycles. The *Business models* chapter takes the discussion further and illustrates how to develop new circular business models, and the related challenges.

In this context, the success of implementing a circular economy strategy and a circular business model strongly relies on the capacity of an organization to clearly understand how the value of a product or a service is and can be created within and across value chains and networks, as well as on its capacity to establish the right interactions and relationships among relevant stakeholders in order to create this value.

This way, businesses and organizations need to focus on optimizing and creating value along the entire system in a holistic way, through cooperation with different stakeholders (within an organization, between organizations and/or with consumers) (Kraaijenhagen et al., 2016; Bicket et al., 2014). A change of mind-set is needed, shifting from a traditional supply chain thinking to a value chain approach (Cassell et al., 2016; WEF, 2016). The value chain must be understood as part of wider networks and systems, that allows different flows of resources, knowledge and skills and in short, a new way of thinking and doing things, leading to the launching of more sustainable solutions to the market, based on a circular value chain approach. As an example, the Danish Architect company Lendager Group, who specialized in developing circular solutions in the construction sector, has established a new business unit for recycling of concrete to facilitate the use of this material in new buildings.

The *Value chains* chapter focuses on how value chains and value networks should be understood and managed to benefit a circular economy. Moreover, communication plays a crucial role in documenting and stimulating new circular and sustainable solutions, which is explored in the *Communication* chapter.

Assignment 1.6

Discuss for a given product how you would expect a circular solution will affect the traditional business model and the value chain.

1.6 Main challenges and drivers in shifting to a circular economy

As illustrated in the previous sections, the transition towards a circular economy is complex, both on an organizational, a market and a societal level. There are dilemmas, for example a circular product where the environmental impacts may be higher compared to a traditional product – but where the circular one is prepared for reuse, recycling and cascading of materials. Methods to measure and assess value and risks related to circular products, business models, etc. are only in the beginning. As stated by Arup and bam (2016, p.15): "Current financial models use past performance to predict future results".

On the way towards circularity, an organization will come to face many different types of barriers and challenges – but also drivers; internally, in relation to the market and on an overall systems level, since policies, regulation, infrastructures, economic structures, traditions, mind-set, knowledge and skills, etc. are set up for the linear economy. Figure 1.9 illustrates the main types of challenges – and the need for thinking across traditional disciplines and professions and for building new relations within the organization, with the suppliers and customers, and with stakeholders. Clearly, such a transition will need a high level of radical innovation, but also willingness to break old routines and to face economic, practical and cultural risks.

To overcome regulation and market barriers, the Danish company Gamle Mursten (Old Bricks) had to develop a new technical description for the European CE-label (safety and quality), to be able to market recycled, old bricks in EU. The recycled bricks are now approved for use in masonry, where the requirement to the rock strength does not exceed 20 MPa.

Figure 1.9 – Different types of challenges in changing to a circular economy (Based on Ramanathan et al., 2014; Valkokari et al., 2014; EMF, 2015b; Arup and bam, 2016; European Environmental Bureau, 2017; Ritzén and Sandström, 2017; Celades et al., 2017).

In the categories illustrated in the figure, there are also drivers, accelerators and enablers of circular economy. For example:

– Technology drivers such as Internet of Things; Asset tracking; mobile computing; 3D printing of spare parts, construction elements; integration of new technologies, etc.
– Regulatory drivers like taxes to limit consumption of certain resources; or reduced VAT for refurbishment of buildings instead of building new
– Custom and habit drivers such as stewardship; changing consumption patterns; open sourcing; sharing or leasing (access to) products as alternatives to owning, etc.
– Market drivers such as competition, ethical and fair trade approaches, companies acting as motivators for other organizations, stakeholder pressures
– Organizations' internal dynamics, including awareness raising among employees

Assignment 1.7

Argue for what you see as the 3 main enablers and 3 main challenges for circular economy in the construction and the furniture sectors. How to address the challenges?

1.7 EU policy and legislation for circular economy

Policy and legislation set the framework for the requirements that products, packaging and services must meet in order to enter the EU market. Ideally, policies establish visions and overall strategies for societal developments across or within nations, bridge different stakeholder perspectives and create a platform for businesses' license-to-operate. Policies and legislation can thus stimulate new agendas like the transition to sustainability and circular economy. However, existing legislation established with other purposes may also become a serious barrier to new developments and therefore hamper innovation. This section gives an overview of the development of the CE agenda on EU level and related policies and regulation from a non-sector specific perspective.

1.7.1 The EU initiatives supporting CE

Over the last decade, the European Commission has developed several initiatives aiming at improving resource efficiency and, more recently, supporting the transition to a circular economy. The initiatives are shown in figure 1.10.

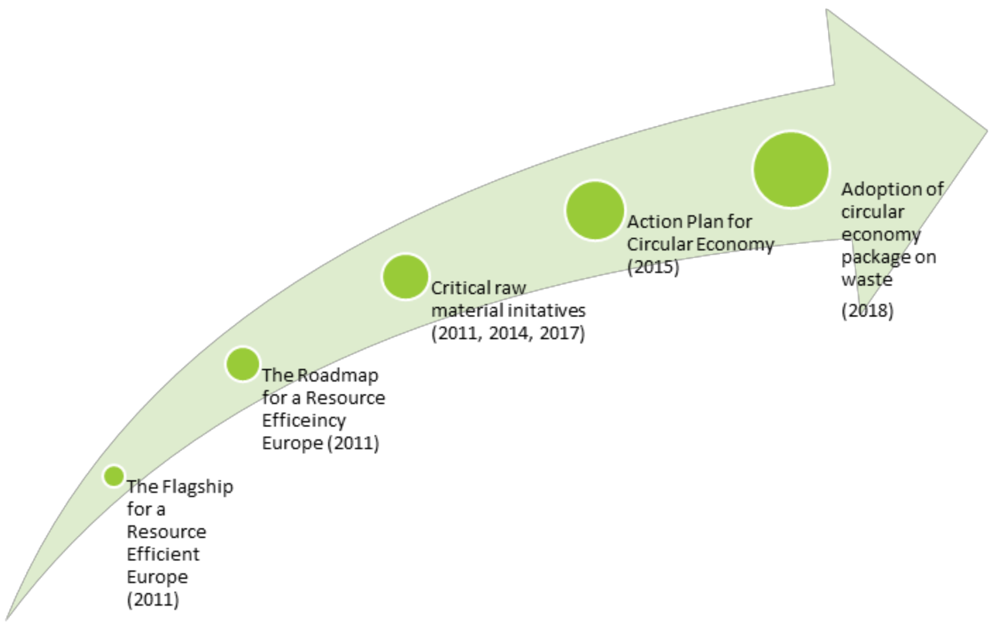


Figure 1.10 – EU initiatives for improving resource efficiency.

The Flagship on resource efficiency sets out a policy framework that can support the change in Europe towards a resource efficient and low carbon economy (European Commission, 2011a), whereas the Roadmap to resource efficiency specify objectives and targets. Another important initiative is the publication of critical raw materials lists in 2011, 2014 and 2017. Critical raw materials are "raw materials with a high supply-risk and a high economic importance to which reliable and unhindered access is a concern for European industry and value chains" (European Commission, 2014).

In 2015, the European Commission took a step further in publishing "Closing the loop - An EU action plan for the Circular Economy". The action plan defines circular economy as an economy,

> "where the value of products, materials and resources is maintained in the economy for as long as possible, and the generation of waste minimised''. The transition to a more circular economy would make "an essential contribution to the EU's efforts to develop a sustainable, low-carbon, resource-efficient and competitive economy''
>
> (European Commission, 2015: 2)

In connection with the 2018 circular economy waste legislation package, the meaning of circular was further elaborated on in relation to product and material flows:

> "In a circular economy, products and the materials they contain are valued highly, unlike in the traditional, linear economic model, based on a 'take-make-consume-throw away' pattern. In practice, a circular economy implies reducing waste to a minimum as well as re-using, repairing, refurbishing and recycling existing materials and products. Moving towards a more circular economy could deliver benefits, among which reduced pressures on the environment, enhanced security of supply of raw materials, increased competitiveness, innovation, and growth and jobs. However, it would also face challenges, among which finance, key economic enablers, skills, consumer behaviour and business models, and multi-level governance"
>
> (European Parliament Thinktank, 2018)

The action plan from 2015 established a coherent vision for developing a circular economy in EU including four key areas or strategies to close the loops in the circular economy: production, consumption, waste management and from waste to resources. The related initiatives and strategies were strongly linked to legislation and the set-up of the existing European regulatory framework. As an on-going process, the focus in the initiatives is to remove regulatory barriers and create requirements and incentives to support a circular economy. Many of the earlier policy instruments were revised to further support a transition to a circular economy. The consumption phase is mostly regulated through voluntary initiatives like Ecolabels and Green Public Procurement. Section 1.8 on sustainable production and consumption explains the initiatives, and the section 1.9.2 on circular economy in the European regulatory framework for the furniture sector details the type of criteria set in the European Ecolabel Scheme and in Green Public Procurement.

Four years later, the 54 actions specified in the plan were delivered or being implemented. Among the key initiatives are:

- an EU strategy for plastics adopting a material-specific lifecycle approach to integrate circular design, use, reuse and recycling activities into plastics value chains, and stating inter alia, that by 2030 all plastic packaging placed on the European market is recyclable or reusable;
- a revised waste legislative framework implemented in 2018 and including e.g. the EU waste hierarchy; targets for reduction of waste and for recycling rates, clarified legal status of recycled materials, and minimum requirements to improve the governance of extended producer responsibility schemes;
- implementation of the Ecodesign Working Plan 2016-2019 to promote the circular design of products, together with energy efficiency objectives. Ecodesign and Energy Labelling measures for several products now include rules on material efficiency requirements such as availability of spare parts, ease of repair, and facilitating end-of-life treatment.

Read more on the implementation of the circular economy action plan, including the related regulation: http://ec.europa.eu/environment/circular-economy/index_en.htm.

Following the EU waste hierarchy, prevention, re-use and recycling present the most favourable options in terms of maintaining the highest possible value of products or components as illustrated in figure 1.11.

Figure 1.11 – The EU waste hierarchy (European Commission, 2008).

But one needs to be aware that the waste hierarchy is not fully in accordance to the circular economy concept, in the sense that it assumes that products will inevitably become waste in a certain period of time. As discussed in this section, circular economy challenges this idea.

As an example, the cascading use of renewable resources like wood, be it construction elements or wooden furniture, should be encouraged where appropriate with several reuse and recycling cycles.

One of the initiatives in the action plan, a monitoring framework including ten indicators was established in 2018 to measure the progress towards circular economy in a way that encompasses its various dimensions at all stages of the lifecycle of resources, products and services. The indicators are grouped into four aspects: 1) Production and consumption, 2) Waste management, 3) Secondary raw materials, and 4) Competitiveness and innovation (see figure 1.12).

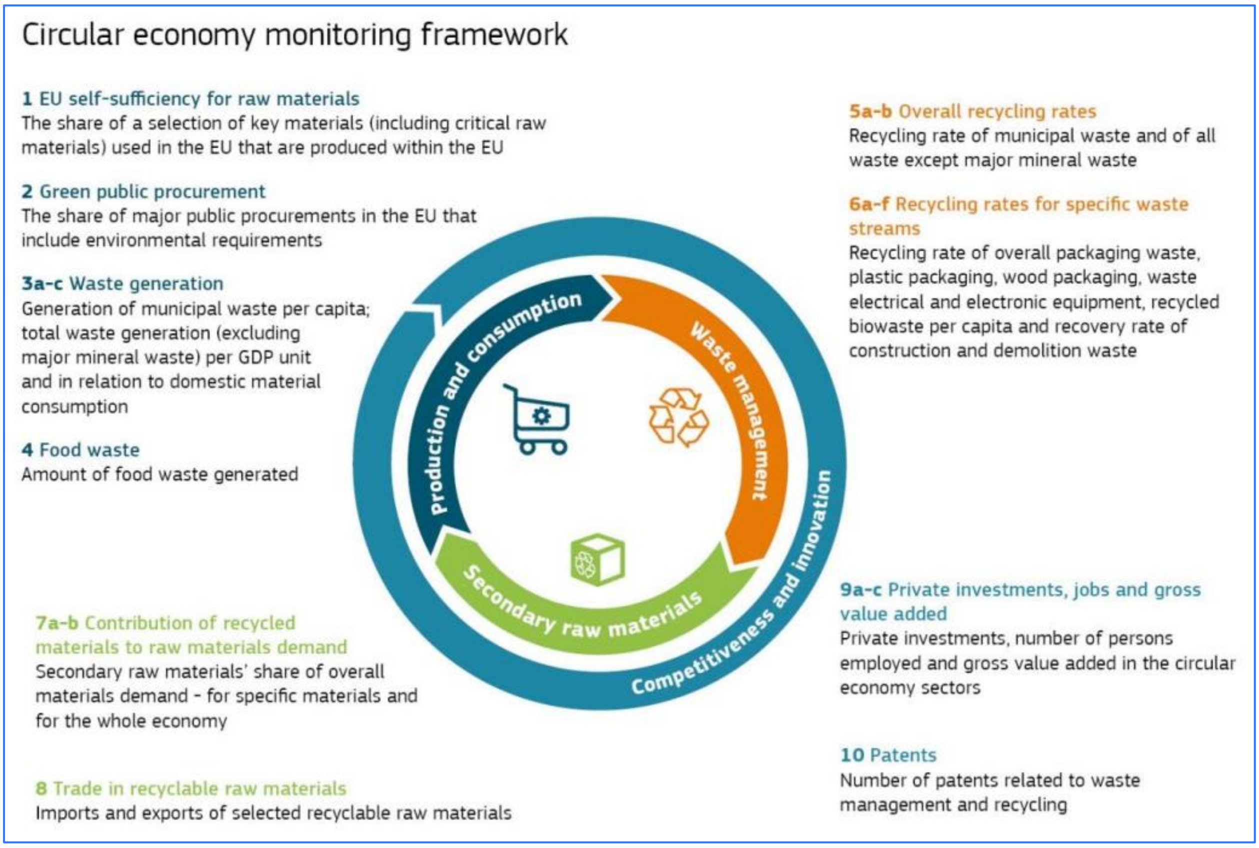


Figure 1.12 – EU Commission's circular economy monitoring framework (EU Commission 2018).

The CE action plan also highlighted five priority areas: plastics, food waste, critical raw materials, construction and demolition, and biomass and bio-based products (European Commission, 2015). As for construction and demolition, the EU Commission developed actions to ensure recovery of valuable resources and adequate waste management, and to facilitate assessment of the environmental performance of buildings, the so-called "Level(s)" initiative (European Commission, 2019a). Read more in section 1.9.1.

1.8 Sustainable production and consumption

Production and consumption represent two sides of the same coin. Clients and consumers shape the market and send messages to decision-makers in governments, industries, companies, designers and other stakeholders through their consumption and purchasing choices and by supporting or dismissing certain practices. Companies also create needs and demands by offering (new) products on the market. Thus, the way we consume will determine supply and the way production is organized will influence demand, in a complex relation. This happens in the consumer market (where clients are individuals or families), in the business market (in which clients are companies and other professional organizations not ruled by public procurement rules) and in the government market (formed by public organizations, subject to public procurement rules).

The transition to a circular economy is a complex process and managing the transition will require a better understanding of broad societal trends and the drivers of production and consumption patterns. Responsible action is required from both production and consumption sides; it is not enough that producers provide more sustainable products and services, it is crucial that consumers and clients accept them (Inaba, 2004) or even are the driving force for them. Therefore, many initiatives to set up a sustainable consumption and production agenda have been developed, including the establishment of a goal related to "responsible consumption and production" within the Sustainable Development Goals (see figure 1.13) that came into effect in January 2016 and guide the United Nations Development Programme's policy and funding until 2030.

Goal 12: Ensure sustainable consumption and production patterns

Targets (selected):

- By 2030, achieve the sustainable management and efficient use of natural resources
- By 2020, achieve the environmentally sound management of chemicals and all wastes throughout their life cycle, in accordance with agreed international frameworks, and significantly reduce their release to air, water and soil in order to minimize their adverse impacts on human health and the environment
- By 2030, substantially reduce waste generation through prevention, reduction, recycling and reuse
- Encourage companies, especially large and transnational companies, to adopt sustainable practices and to integrate sustainability information into their reporting cycle
- Promote public procurement practices that are sustainable, in accordance with national policies and priorities
- By 2030, ensure that people everywhere have the relevant information and awareness for sustainable development and lifestyles in harmony with nature

Figure 1.13 – Overview of Sustainable Development Goals and selected targets of SDG 12 – Responsible consumption and production, adopted in the United Nations General Assembly Resolution "Transforming our word: the 2030 Agenda for Sustainable Development" (Own elaboration, based on: https://commons.wikimedia.org/wiki/File:Sustainable_Development_Goals.jpg https://www.un.org/sustainabledevelopment/sustainable-development-goals/).

On a political level, the European Action Plan for the Circular Economy (EU, 2015) has identified a number of aspects that are being addressed and concern consumption. These include:

1) The use of **labels** as part of an effort to make green claims more trustworthy and influencing greener consumer choices. The trend is that existing labels at EU level include a new criterion on durability (see *Communication* chapter).

2) Promoting **reuse and repair**: beside action at different levels to promote reuse and repair, for example design measures to make products easy to repair, or political measures such as taxation

benefits in repair shops, it is crucial that clients and consumers are willing to accept reuse and repair, instead of opting for buying new as a first choice. The Bower cooperative (http://bower.org.au) refers to a "reuse and repair" culture and points out that values of mass consumption include convenience, standardisation, disposability, being in vogue and aspirational status (see section 1.2). According to them, these same values can be met through investing in repair culture – for instance, items that are upcycled are often unique and therefore unobtainable by others, providing status.

3) Promoting **innovative forms of consumption**, such as **collaborative consumption**. The consumption patterns and the way people consume to satisfy their needs is changing in parallel with the changes in business models. Collaborative consumption is a new way to consume related to the reinvention of traditional market behaviours based on different approaches like renting, lending, swapping, sharing, bartering, gifting, etc., through technology and only possible with the evolution of internet (www.fastcompany.com). While peer-to-peer interactions have long been practised on a local scale, the new concepts have developed into a different dimension through the use of online sharing marketplaces and platforms, through which the demand for certain assets, products or services is matched with their supply, usually through consumer-to-consumer (C2C) channels (EEA, 2017). This consumption model has a higher potential within Circular Economy. According to a global online survey (2014) 54% of European respondents were willing to share or rent out their possessions, while 44 % were happy to rent goods and services from others (Nielsen, 2014). From a business perspective, this model allows to drastically lower the costs of certain services for clients and increase revenues by minimizing expenses and investments, which may bring important sustainability benefits:

- From an environmental point of view, decrease in the use of natural resources, energy and emissions throughout production and consumption cycles based on longer or more intensive use of existing products.
- Social benefits, measured through enhanced social interaction and cohesion, as well as job creation.
- Economic benefits related to consumer access to a broader selection of products and services without incurring the liabilities and risks associated with ownership.

On the other hand, the collaborative consumption approach can trigger negative sustainability impacts by promoting the longer use of inefficient appliances, an increase in transport and an increase in the consumption. The rapid growth of some internet-based consumer-to-consumer business models and platforms has sparked discussion about fair competition, safety, risk allocation, workers' rights, etc.

Another innovative form of consumption highlighted by the EU Action Plan on Circular Economy is **consuming services rather than products**. Examples: a printing contract using a pay-per-copy model, in which the supplier provides all equipment, repairs, replacements and training rather than simply selling copy supplies; a contract according to which what is sold is light instead of light bulbs. The focus is on the needs of the user (copies, lighting) and not on the product (copy machines, light bulbs).

Circular public procurement, which can be defined as the process by which public authorities purchase works, goods or services that seek to contribute to closed energy and material loops within supply chains, whilst minimising, and in the best case avoiding, negative environmental impacts and waste creation across their whole life-cycle (European Commission, 2017). Public procurement can have a tremendous impact on the market and can create demand and lead by example, since the amount of this public money represents approximately 19% of the EU GDP or more than 2.3 trillion euros (www.interregeurope.eu).

Slowing, closing and narrowing resource loops are important principles in designing circular solutions, but what do they mean in terms of consumption? Table 1.3 gives some examples.

Table 1.3 – Slowing, closing and narrowing loops from a consumption perspective (Bocken et al, 2016)

Slowing consumption is to extend or intensify the utilization period of a product resulting in a slowdown of resource consumption	- Choosing long life products in detriment of short lived products - Extending product life through maintenance, reuse and repair during the use phase - Choosing sharing, leasing or renting services instead of buying products - Buying a result instead of buying products	CORT company provides a furniture rental service for home and office, and other services. After its rental life is complete, almost all furniture (97%) is discounted and resold to the public, making the reuse rate between 2 and 6 times longer than direct sale models and producing 49% fewer greenhouse gasses. www.cort.com
Closing resource loops through consumption is to focus on recycling	- Choosing products made of recycled material - When products have to be discarded, sort them for recycling	EcoKalçada is an innovative sidewalk product, resulting from 100% recycled rubber from used tires with the combination of virgin or recycled coloured rubbers. The product has a high resistance, durability and capacity of absorption of impact. www.eco-solutions.pt
Narrowing resource flows through consumption is to use fewer resources per product, thus also considering reduction of the resources used	- Choosing products that are lighter or smaller - Choosing products that minimize or eliminate the need of water, materials and energy during use - Choosing products in which packaging has been eliminated or minimized	Swiss Eco Line consists of sustainable energy and water efficient bathroom and wellness products that reduces the water consumption by 90 percent. 100% energy saving due to cold water. No costs for warm water preparation No unpleasant feeling of coldness on the skin due to a special spray technology https://www.swissecoline.com

Changing consumer values in a more sustainable direction raises many questions. If it is acceptable that sustainable production and consumption should be able to satisfy the needs of all (as proposed by the definition of sustainable development in the Brundtland's Report (Brundtland et al., 1987), the question concerns the overconsumption related to wants or desires. Jackson et al. (2004:15) note "(...) it is particularly vital to be able to identify which bits of consumption contribute to human needs satisfaction, and which simply operate as pseudo-satisfiers and destroyers" (Sto et al., 2008).

As for attitudes (more specific than values, more constant in human behaviour), the main conclusion of studies related to sustainable consumer behaviour is that there is a weak correspondence between reported attitudes and actual behaviour (Sto et al., 2008).

In order to promote the knowledge of consumers about the environmental and ethical profiles of products, several methods have been used, including campaigns, green marketing and claims. The most successful ones seem to be eco-labelling schemes (Rubik and Frankl, cited in Sto et al, 2008). It is therefore very important to disclose reliable informative instruments. Nevertheless, eco-labelled alternatives are often more expensive than the non-labelled products and the question is whether or not consumers are willing to pay more. Studies on this matter are inconclusive, but if the difference in price is not significant (some 5%), consumers are willing to award greener alternatives (Sto at al., 2008).

Consumers' choices are not always rational, in the sense that they often are based on evaluations beyond the value for money evaluation. Symbolic aspects such as the story that is associated with a product or a service are very important and consumers often use this to boycott products that are associated with bad social and environmental practices (Sto et al, 2008). On the contrary, sustainability values (equity, human rights, care for nature) should become a common part of the 'intangible' symbolic value related to consumer goods and firm brands. This implies articulation of such values in society, via government, consumer organisations, or action (Tukker, 2006). Sto et al. (2008) highlight that habits and routines are also a non-rational aspect of consumption and it is decisive to create routines that stimulate sustainability, although it is not easy to perform this, given the obligations and time constraints one faces, even if we are well informed and motivated. Therefore, it is very important to explore windows of opportunity (see next point). Windows of opportunity, in this context, occur when people make fundamental changes in their life, such as changing home, having children, getting married or divorced, etc. These are times that are susceptible of changes in other aspects than the core of the situation, so routines are broken anyway.

Assignment 1.8

Think of your daily life at home, at school or in the office. Which other examples of consumption choices that are aligned with slowing, closing and narrowing loops can you come up with?

1.9 Circular economy in the construction and furniture sectors

1.9.1 Construction sector

The built environment comprises the man-made elements of our surroundings such as buildings as well as infrastructure including transportation, telecommunications, energy, water and waste systems. Design, planning, and construction contribute to the quality of the built environment, which has a significant impact on human health, well-being and productivity. The construction sector generates about 9% of GDP in EU and provides 18 million direct jobs and is therefore a significant part of our society (European Commission, 2016).

Even if the products delivered by the sector, namely buildings and infrastructure, seem stable and have long lifetimes, the sector is constantly influenced by social trends as illustrated in table 1.4.

Table 1.4 – Main trends for the construction sector

Trend	Description	Source
High performing buildings	This can relate to sustainability, environmental impact, effect on the occupants (including a healthy environment), life cycle asset value or resiliency.	https://esub.com/important-construction-trends/
Greater emphasis sustainable consumption	A recent U.S. Green Building Council study found that green construction was outpacing overall construction growth. Increasing concern about environmental sustainability is reflected in the choice of more environmentally friendly materials. Large buildings made from timber are now possible. Also, intelligent lighting systems and improved planning on power generation will reduce environmental damage.	https://blog.capterra.com/2018-construction-industry-trends-heres-what-to-expect/ https://www.verdict.co.uk/five-trends-changing-construction-industry/

Trend	Description	Source
Collaborative contract approach	Especially the growing public-private partnership (P3) model — which involves funding and construction collaboration between private and public entities — have picked up steam in the industry. It is important people understand how complicated this is and manage relationships. Usually P3 relate to big and complex projects and such multi stakeholder processes allow for more creativity.	https://esub.com/important-construction-trends/
Focus on local markets and core business	This is due to better local market conditions and supply chain pressure and the trend of digital construction. In a post-economic crisis era, as markets rebound and demand for buildings increases, the adaptation of new technologies in the construction industry is finally booming.	European_construction_monitor 2016_2017
Technology is moving in	Prefabrication has come a long way in recent years and is no longer limited to cheap, poorly constructed uninteresting designs. Top architects are getting involved in the prefabrication and modular construction business. Lower cost, quicker build and portability are pros, whereas cons are: difficulty to customize, high costs of transport (need of proximity to the factory) and potential incompatibility with zoning rules	https://blog.capterra.com/2018-construction-industry-trends-heres-what-to-expect/ https://blog.capterra.com/the-pros-cons-and-cost-of-modular-homes/

Trend	Description	Source
Influence of end consumer is increasing	End consumers – in the construction sector these are the building owners and users – increasingly demand products that exactly fulfil their individual needs. To this end, all markets are developing new dynamic processes in order to better adapt to these consumer preferences.	https://www.vaillant.info/architects-planners/magazines/new-opportunities-for-architects-and-the-construction-industry/
Influence of end consumer is increasing	End consumers – in the construction sector these are the building owners and users – increasingly demand products that exactly fulfil their individual needs. To this end, all markets are developing new dynamic processes in order to better adapt to these consumer preferences.	https://www.vaillant.info/architects-planners/magazines/new-opportunities-for-architects-and-the-construction-industry/
Changes in lifestyles and family structures	More people living in cities, diversification of the family structure with an increase of single person or single-parent households and ageing population are some of the trends that mark the need of buildings that respond to new and changing needs of higher adaptability of houses.	European Commission (2013) Oláh (2015)

Construction products affect the performance of buildings with respect to safety, health, environmental performance and energy efficiency. Sustainable use of resources relates to recyclability, durability and the use of environmentally compatible materials.

Environmental impacts from the sector arise at different stages of a building's life-cycle including the manufacturing of construction products, building construction, use phase, refurbishment, reform and the management of building waste (COM(2014) 445 final).

The construction and use of buildings in the EU count for about half of all our extracted materials and energy consumption, and about a third of our water consumption (COM(2014) 445 final). Moreover, construction and demolition waste accounts for approximately 25-30% of all waste arising in the EU. In Europe, 2,7 billion tons of waste was generated in 2010, and only 40% was reused, recycled, composted or digested, but even during recycling values may be lost. As an example, in the case of

Denmark, the construction sector reuse or recycle 84% of the waste, however it is done in a way where most of the material value is lost during demolition (Sommer, 2018).

Reducing the amount of waste we produce however, is far more than simply ordering the right quantity of materials. Current construction practices have waste built into the design. This is especially apparent where standard material sizes are used, for example sheet materials and traditional masonry (Arup and bam, 2016).

A building is an entity of many components with a variety of materials, consumption of resources like energy and water, and therefore with different challenges and options when designing for sustainable and circular buildings with long lifetimes. For example, the basic building shell has a lifespan of 50-100 years, a façade lasts 25-50 years, installations in 15-25 years, and finally fixtures and fittings have a typical lifespan of 5-15 years. Furthermore, users and owners may change over time, introducing new needs and ideas for the use of the building (GXN and Responsible Assets, 2018).

CE and the construction sector

Ellen MacArthur Foundation (EMF) published the report "Delivering the circular economy – a toolkit for policy makers" based on Denmark as a case study. The report aimed at identifying circular economy opportunities, barriers and policy interventions to overcome these barriers. Key barriers proved to be unintended consequences of existing regulations, social factors such as lack of experience, and market failures such as imperfect information and unaccounted, negative externalities.

The report looked into five sectors, where construction and real estate showed the largest, economic potential, which is probably recognizable in most European countries. Figure 1.14 gives an overview of these potentials, and of the key barriers and identified policy options.

CONSTRUCTION & REAL ESTATE

Industrialised production and 3D printing of building modules, reducing time and material cost of construction and renovation, could lead to a net value of EUR 450–600 (40–60) million p.a. by 2035 (2020).

Key barriers include:

- inadequately defined legal frameworks;
- immature 3D printing technology;
- custom and habit and capabilities and skills in the industry.

Identified policy options include:

- augmenting building codes;
- supporting the development of module production facilities;
- setting a clear legal framework for 3D printing materials.

Reuse and high-value recycling of components and materials, enabled by, e.g., design for disassembly and new business models, could lead to a net value of EUR 100–150 (10–12) million p.a. by 2035 (2020).

Key barriers include:

- split incentives and lack of information across the construction value chain;
- custom and habit;
- capabilities and skills.

Identified policy options include:

- augmenting building codes;
- running industry-wide training programmes;
- creating support for material inventory software and databanks.

Sharing and multi-purposing of buildings to increase the utility of existing floor space could lead to a net value of EUR 300–450 (100–140) million p.a. by 2035 (2020).

Key barriers include:

- inadequately defined legal frameworks;
- unintended consequences of existing regulation.

Identified policy options include:

- clarifying the existing legislation;
- providing financial incentives or support to new business models;
- creating portals for public building availability.

Figure 1.14 – CE opportunities in the Danish Construction and real estate sector (EMF, 2015b).

The application of circular economy to the construction industry requires a systems-thinking approach, one which gives an understanding of the whole building lifecycle and the construction value chain, or in other words, understanding the wider context in which development takes place. The complexity of the external environment still works to the advantage of the current linear model. Looking at the construction industry in particular, inherent contradictions pose challenges to the adoption of circular business models (CBMs). To overcome these contradictions, the value chain needs to take the following points into consideration (Arup and bam, 2016):

– Long term thinking
– Design for deconstruction
– Innovation
– Flexibility vs durability
– Utilize new models of production and consumption
– Collaboration

Minimizing negative externalities is a core aim of the circular economy. In the built environment these include climate change, water, soil, noise and air pollution. They also include less tangible impacts on human and animal welfare, health, employment and social equality. These externalities can apply to both the operation of assets and the sourcing, manufacture, transportation, installation of materials and components, and disassembly. Preventing or minimizing these impacts is critical to enhancing natural capital and maximizing the use and value of resources (Arup and bam, 2016).

Enabling factors for CE in the construction sector are (Arup and bam, 2016):

- Eco-design (deconstruction, reassembly, future flexibility, etc.).
- Information (cost/condition, resource productivity, life cycle data, ownership, warranty, traceability).
- Collaboration (share incentives, transparency, innovation→new products, long term business models vs short term).

CE value is added by increasing the ability of assets to respond flexibly to market conditions, increasing asset use, diversifying income streams and maximizing the residual value of a building's materials (Arup and bam, 2016).

Design should be incorporated at an earlier stage with other disciplines to ensure that the product is designed for longevity, changing user needs, flexibility, reuse and deconstruction. Designers should discuss the future strategy of the building with local authorities and the asset owners to ensure that re-figuration is possible by using a modular approach allowing for easy disassembly and assembly of components (Arup and bam, 2016). Another example is to design a ventilation system that allows for energy recovery.

The adoption of circular construction will require collaboration between the entire value chain (architects, engineers, builders, customers, etc.) in order to reduce the use of resources and increase the reuse after deconstruction by having this in consideration since the design phase.

The idea of short-term solutions for construction does not apply. For example, 75-90% of the existing buildings will still be in use by 2050. Other data indicate that 80% of these buildings were built before 1990 and half of them before 1960. This points to an average lifetime between 60 to 90 years.

Buildings are constructed of standard manufactured products, but when these are assembled they create a unique, complex, long-lived and ever-transforming entity.

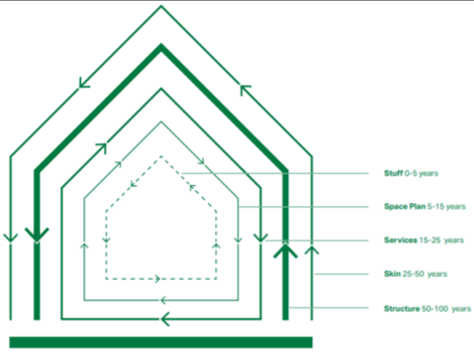
Therefore, one of the main challenges is to conciliate high durability of buildings and building products (which is desirable from a circular economy perspective) with adaptability/versatility required by the market trends and evolution in lifestyles.

Examples of CE in the construction sector

Pay per lux, by Philips and Turntoo

Description	Architect Thomas Rau worked with Philips to purchase light as a service. The end result was a bespoke 'pay-per-lux' intelligent lighting system to fit the requirements of the space, at a manageable price. Philips retain control over the items they produce, enabling better maintenance, reconditioning and recovery. A collaborative project between Philips and Turntoo is a showcase for the pioneering 'Pay-per-lux' model.
Organization and country	Philips and Turntoo, The Netherlands
Sources	https://www.lighting.philips.com/cases https://www.turntoo.com/en
Images	
Image source or credits	https://www.lighting.philips.com/main/cases/cases/industry-and-logistics/bruynzeel
Sector	Construction
Circularity approach(es)	Slowing, narrowing loops
Design strategy(ies)	Design of products as services Design for materials sustainability Design for energy sustainability
Business strategy(ies)	Use-oriented services

Denmark's first circular housing project, by Circle House

Description	The Circle House project consists of 60 general housing units, which are expected to be completed in 2020. In addition to serving as housing, Circle House is a scalable demonstration project that can give the building industry new knowledge about circular construction. Circle House consists of a range of building systems that can be assembled, disassembled and reassembled into other buildings while keeping their economic and aesthetic values intact.
Organization and country	Circle House, Denmark Circle House — Denmark's first circular housing project
Sources	https://gxn.3xn.com/wp-content/uploads/sites/4/2019/02/CircleHouse_ENG_2018.pdf
Images	 
Images' source or credits	https://gxn.3xn.com/wp-content/uploads/sites/4/2019/02/CircleHouse_ENG_2018.pdf https://gxn.3xn.com/wp-content/uploads/sites/4/2019/02/CircleHouse_ENG_2018.pdf
Sector	Construction
Circularity approach(es)	Slowing, closing, narrowing loops
Design strategy(ies)	Design of long-life products Design for product-life extension Design for recycling Design for materials sustainability Design for energy sustainability
Business strategy(ies)	Recycling Remanufacturing, refurbishment, upgrade Long life Circular design Maximizing product efficiency

Designing steel products for reuse, by Tata Steel

Description	Buildings and structures can be designed to allow component parts to be easily separated and recycled. Standardisation of components will also facilitate this process and increase recyclability. Designing for reuse has the potential to significantly reduce carbon emissions and mitigate fluctuating materials prices. For Tata Steel, calculations showed lower environmental impacts and resource use for both recycling and reuse of steel at the end of life of two buildings. This revealed potential savings of 6–27% for a warehouse, 9–43% for an office and 2–10% for a whole building.
Organization and country	Tata Steel, Indian origin, now worldwide
Sources	https://www.tatasteel.com/products-solutions/europe/ Arup and bam, 2016: Circular business models for the built environment
Image	
Image source or credits	Arup and bam, 2016: Circular business models for the built environment
Sector	Construction
Circularity approach(es)	Narrowing, closing loops
Design strategy(ies)	Design for reuse and recycling Design for materials sustainability Design for energy sustainability
Business strategy(ies)	Logistic/recycling Material recapture

Assignment 1.9

Select a number of trends mentioned in Table 4 and that are relevant to the neighbourhood/town/city where you live. Based on a group debate, identify circular design specifications for a construction element (e.g. a wall) at your choice.

CE in the European Regulatory framework for the construction sector

The construction sector is covered by a vast European regulatory framework, thus not all is relevant in relation to a circular economy. However, the EU Construction and Demolition Waste Protocol and Guidelines are key. The protocol was established in 2018, and is expected to develop over time. Read more: https://ec.europa.eu/growth/content/eu-construction-and-demolition-waste-protocol-0_en.

Moreover, the Construction Products Regulation (CPR) lays down harmonized rules for the marketing of construction products in the EU. Read more: http://ec.europa.eu/growth/sectors/construction/product-regulation_en.

Buildings are responsible for approximately 40% of energy consumption and 36% of CO_2 emissions in the EU, making them the single largest energy consumer in Europe. The EU has set a target for all new buildings to be nearly zero-energy by 2020. Read more: https://ec.europa.eu/energy/en/topics/energy-efficiency/energy-performance-of-buildings.

The newest initiative, Level(s), is a voluntary reporting framework to improve the total sustainability of buildings. The framework includes indicators within a number of areas: 1) Greenhouse gas emissions throughout the building's life cycle, 2) Resource efficient and circular material life cycles, 3) Efficient use of water resources, 4) Healthy and comfortable spaces, 5) Adaptation and resilience to climate change, and 6) Life cycle cost and value. Read more: http://ec.europa.eu/environment/eussd/buildings.htm.

Figure 1.15 illustrates some main elements of the European regulatory framework for buildings covering circular aspects. The figure does not claim to be complete or fully updated.

Figure 1.15 – EU Regulation for the construction sector. Developed from Herczeg et al (2014) and EU: https://ec.europa.eu/environment/eusdd

Barriers in the construction sector

As a part of developing the first Danish circular housing, "The Circle House" an analysis was made on the legal barriers to building circular. The overall conclusion stated, that the existing regulation does not exclude circular construction. On the other hand, the legislation does not promote circularity either, which in practice creates some barriers. First of all, tenders are not based on life cycle costing, but on initial investment. Secondly, it is difficult to declare the quality (performance, content and durability) of recycled construction materials. Moreover, there are too few legal requirements on resource optimization (GXN and Responsible Assets, 2018).

However, the barriers are not only related to regulation. One of the partners in the Circle House project, the contractor MT Højgaard, highlights the need to change both the mind-set and structures of a highly conservative sector: "In the construction sector, we like to highlight our high level of recycling, more than 80%. But we destroy most of the value because we crush the materials in the demolition process. We need to change the mind-set and the practices. (....) The sector is extremely focused on risk handling, and therefore very conservative. In the future, we will see (and need) new types of services: consulting, assessments, insurances, warranties, take-back warranties, etc. Some services may be delivered by existing contractors, others may come from new companies specializing in that type of service" (Sommer, 2018).

1.9.2 Furniture sector

Around a quarter of the world's furniture is manufactured within EU, representing a € 84 billion market, employing approximately 1 million European workers and consisting of primarily small and medium sized enterprises, SMEs. The domestic sector accounts for around 82% of the furniture consumption, and B2B accounts for around 18%. Public sector spend on office furniture represents 15% of the market (EEB, 2017).

In terms of materials, the most common material used for furniture is wood (56% of the pieces of furniture) metal is the second most commonly used material (12% of items produced), followed by plastics (6% of items produced) (European Commission, 2013).

Furniture products can cause very different environmental impacts depending on the type of furniture considered (office, kitchen, etc.), the materials and processes used in the manufacturing, the energy source (fossil fuels, or renewable) and origin of the wood (local, from sustainable forest, etc.).

Table 1.5 illustrates the main trends in the sector.

Table 1.5 – Main trends for the furniture sector

Trend	Description	Source
Changing in the work conditions and increase of home-based work leads to a **higher demand for home office furniture.**	The need for home offices increased during the financial crisis in 2008-2009 and the European debt crisis in 2011-2012, and the changes in home-based work habits is increasing the demand for new, office furniture.	https://blog.marketresearch.com/5-top-trends-in-the-furniture-industry
Multi-functionality and versatile furniture is gaining popularity	Multi-functional furniture is gaining in popularity in the home furniture market in Europe.	https://www.prnewswire.com/news-releases/european-home-furnishings-market-report-2016-2020---multi-functional-furniture-is-gaining-in-popularity---research-and-markets-300295269.html
Transition to e-commerce - Changes in market to online retail stores	Online retailing has been around for some time but it will continue to grow, especially for millennials. With instant access to **catalogues and price lists**, customers have a clearer idea of what they want and they can use online **software to design and experience** the use of products.	www.cmtc.com/
Increase in demand for **luxury and quality** furniture	Linked to the evolution and growth of the economy, more consumers are willing to buy luxury items for their living and work environments. The global luxury furniture	https://blog.marketresearch.com/5-top-trends-in-the-furniture-industry

Trend	Description	Source
	market is expected to grow. Europe has the largest market for luxury furniture.	
Sustainability concern is increasing	A trend which is positively impacting the market is the rising demand for eco-friendly furnishings. Growing environmental consciousness and concern for a healthy and green environment have led to the increased demand for eco-friendly furniture and other furnishings. Awareness of the effect of deforestation on climate change and the effects of toxic finishes in the air inside homes has led to many furniture manufacturers going green.	www.prnewswire.com
Increase in **renting of homes**	The constant rising prices of home, and the delay of millennials to start their own families are some of the reasons owning a home is not a priority currently. A growing trend is leading toward consumers to choose **smaller furniture** to fit their rental homes or apartments where space may be limited.	www.cmtc.com/
Single-person households are increasing	Single-person households are expected to increase over the next years, and smaller households are opting to live in apartments or smaller homes. This demands for **more modular, space-saving and multifunctional furniture**, and furniture for **storage**.	https://www.cmtc.com/blog/furniture-manufacturing-challenges-trends-2016
Changing **lifestyles**	With lower disposable income and higher levels of debt, millennials tend to delay the decision to start a household. The generational demographic of consumers demands for furniture manufacturers to **diversify their products to meet the specific needs of each group**. While this may mean additional investment on new development, design and innovation, it also leads to new possibilities for additional revenue sources and a motivation to embrace more sustainable processes and resources.	www.cmtc.com/
Increase in **tourism** leads to an evolution of the furniture for the hospitality sector	European manufacturers and contractors serving the **hospitality market** can count on a **demand** driven by a constant increase of international tourist arrivals.	https://www.iffs.com.sg/csil-special-report-contract-furniture-furnishing-market-europe/

Trend	Description	Source
Home **improving/renovation market** is increasing	The growth of the home improvement and renovation market is likely to play a major role in market growth. The home improvement market is highly diversified, providing many opportunities for manufacturers to explore the market with new products and services.	www.prnewswire.com

Assignment 1.10

Select a number of trends mentioned in Table 5 and that are relevant to a space of your choice (classroom, canteen, garden, museum gallery, house). Based on a group debate, identify circular design specifications for a piece of furniture at your choice.

CE and the furniture sector

The challenge faced by the furniture sector is to find a sustainable balance between implementing circular solutions and satisfying consumers' needs. (EFIC n.d.).

In Europe, despite the increasing demand for sustainable products, each year, around 10 million tonnes of furniture are discarded by businesses and consumers, the majority of which is destined for either landfill or incineration.

Figure 1.16 shows the distribution of furniture waste per EU28 country in absolute numbers (EEB, 2017), where larger countries in population have a higher contribution, but also reflecting national habits of furniture substitution.

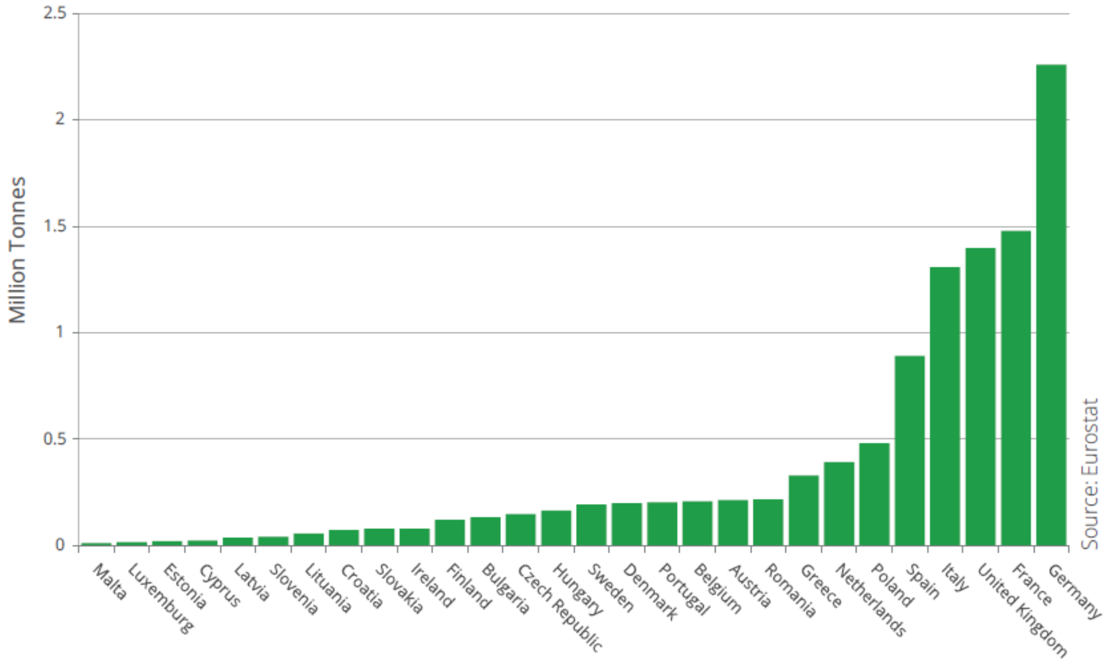


Figure 1.16 – Annual production of furniture waste by EU member state. (EEB, 2017)

The EU Waste Framework Directive requires 50% of household waste to be recycled by 2020, and the European Environmental Bureau (2017) estimates that household furniture represents between 2% and 5% of Municipal Solid Waste in the EU28. So, even if the waste volume in the furniture sector is lower than in the construction sector, there is still a large potential for circularity, also in terms of business. The size of the European remanufacturing sector is estimated to have € 300 million turnover and employing 3.400 workers – which is less than 0.1% of the total furniture industry. (EEB, 2017).

Circular economy interventions have the potential to help counter these trends, with repair, refurbishment and remanufacture allowing value recovery, economic growth and job creation within the European furniture industry, while saving on resources and the environment. Yet, realizing these economic, environmental and social benefits will require the adoption of appropriate demand and supply chain levers, to support a significant step change across the industry. Figure 1.17 gives an overview of the CE potentials (EEB, 2017).

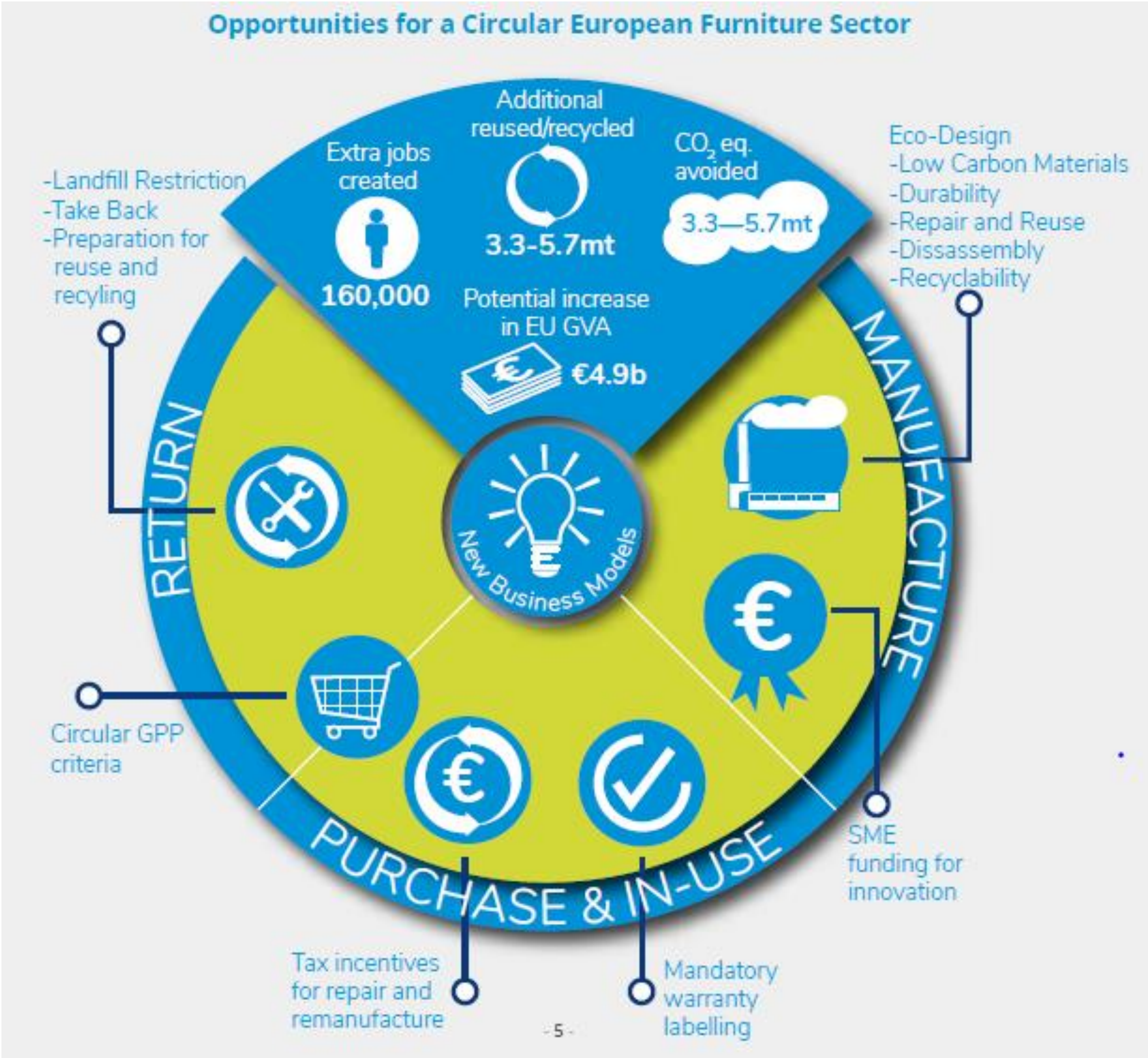


Figure 1.17 – Opportunities for circular economy in the furniture sector. (EEB, 2017, p.5)

The furniture industry can contribute to the Circular Economy Strategy in several ways. In the production phase, one can apply eco-design focusing on the following 5 criteria: 1) Increase the life cycle, 2) Better reparability, 3) Recyclability, 4) Efficient use of material, 5) Avoid environmental unfriendly materials.

Other important aspects are related to consumer information, promotion of circular tendering, extended producer responsibility schemes, and a smart chemical policy. (EFIC, n.d).

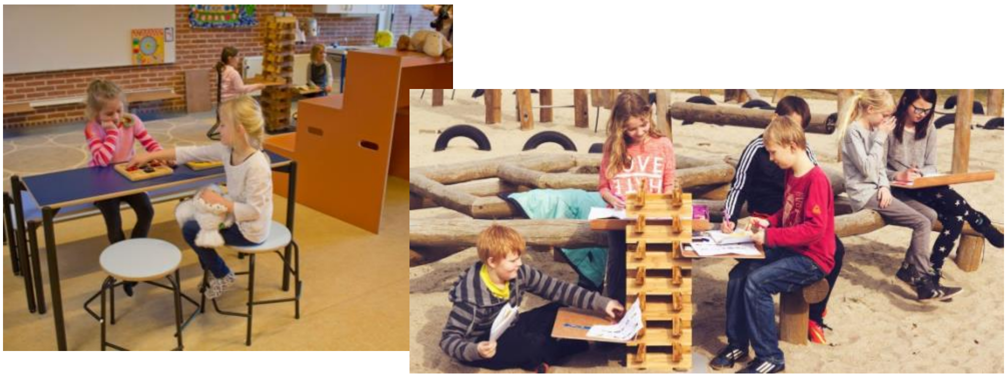
There are various initiatives, which aim to move in the direction of a circular economy. Still, environmental policies in the furniture sector are mainly concerned with energy efficiency in production and during usage, recycling and human health. The more innovative CE approaches that promote a holistic economic system with efficient resource cycles (furniture leasing, product service systems, etc.) are in the early stages.

Reuse of furniture is common, but it tends to be on a small scale and with local, social goals in mind rather than larger scale environmental and economic ones. Reuse mostly takes place through commercial second-hand shops, social enterprise companies or charities.

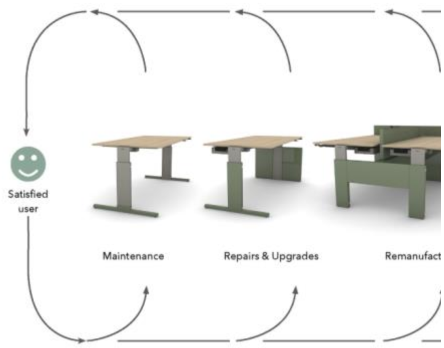
The environmental benefits associated with the reuse are not necessarily higher than the recycling benefits, even where the latter can be properly calculated. Much depends on whether the reused article results in the avoided purchase of a new manufactured article. Where this is the case, the environmental benefits of reusing that article are likely to be more substantial than those of recycling. This is because the impacts associated with producing the constituent materials contained in furniture are typically higher than the impacts associated with recycling the constituent components. However, where reused articles are purchased by lower income households who would otherwise not have purchased anything, the benefit associated with avoided production does not occur. Transport impacts may also be higher for the reuse scenario, and there may also be additional energy associated with the preparation for reuse, although the latter typically results in only a relatively small impact.

Examples of CE in the furniture sector

Circularity in school furniture, by Højer Møbler

Description	Højer Møbler, producer of furniture and related services for schools, won the first public procurement scheme in Denmark where circularity principles were included. At the schools, new, reused and refurbished furniture are combined into activating learning spaces allowing for new pedagogic learning where school kids can learn in different ways. Saving resources, also economic, allow the schools to re-equip their classrooms faster since they don't have to invest in brand new furniture all over.
Organization and country	Højer Møbler, Denmark
Sources	https://wwwhojermobler.dk
Images	
Images' source or credits	Højer Møbler
Sector	Furniture
Circularity approach(es)	Slowing, closing loops
Design strategy(ies)	Design of long-life products Design for product-life extension Design for repair and refurbishment Design for materials sustainability
Business strategy(ies)	Remanufacturing, refurbishment, upgrade Closed loop recycling

Eco-design, leasing and take-back business models, by Gispen

Description	Whilst principally focused around design and manufacturing, Gispen's business model has shifted towards delivering facility management services to its customer base. The approach to design and supply circular furniture products follows guiding principles, including sustainable material selection, disassembly potential, maintenance and upgradability, and recyclability. Post installation, Gispen also offers reverse logistics for furniture, and furniture updating and reconfiguring services, as office furniture requirements for office spaces evolve. Gispen provides a variety of financing models to its customers, including pay-per-use. The amount customers pay is reflected in the number of workstations required, functional and aesthetic need, and the period of use / intensity of usage.
Organization and country	Gispen, The Netherlands
Sources	https://www.gispen.com/en/circular-economy EEB, 2017: Circular economy opportunities in the furniture sector
Images	
Image source	https://www.gispen.com/en/circular-economy/cimo-circular-modular-workstation-highlighted
Sector	Furniture
Circularity approach(es)	Slowing, closing loops

Range of modular furniture, by IKEA

Description	IKEA launched a modular furniture range as a part of its continued commitment to product-life extension. This will enable customers to customize and build up/add to or extend the function of individual products. This encompasses standardized design to enable customers to upgrade or convert furniture items into alternative uses – including for example conversion of a sofa to a bed, replacement of arm rests, addition of side tables, or transforming a storage to a wardrobe.
Organization and country	IKEA, Sweden
Sources	https://www.ikea.com/gb/en/ikeacontentcatalog/this-is-ikea/people-planet/energy-resources/waste/
Images	
Image source	https://www.ikea.com/gb/en/this-is-ikea/people-planet/energy-resources/waste/
Sector	Furniture
Circularity approach(es)	Slowing loops

Reduced furniture waste, by Éco-Mobilier

Description	In France, end-of-life furniture is managed in line with the Extended Producer Responsibility regulation. The main objectives of the French EPR include: - Decreasing waste furniture sent to landfill; - Achieving a 45% recycling/reuse target; and - Driving eco-design principles within the furniture manufacturing sector. In 2015, the domestic EPR scheme achieved a 55% recycling and 86% recovery rate, and in 2016 Eco Modulation Criteria for new furniture placed on the market introduced a reduced levy on furniture fulfilling specific eco-design criteria.
Organization and country	Éco-Mobilier, France
Sources	https://www.eco-mobilier.fr/ (Information in French only) Source in English: European Environmental Bureau, 2017: Circular economy opportunities in the furniture sector
Images	 
Images source	https://www.facebook.com/Eco-mobilier-292944897807583/
Sector	Furniture
Circularity approach(es)	Slowing, closing loops

Assignment 1.11

Discuss what you see as the potential outcomes of a CE approach in the construction or the furniture sectors on a social and on a company level.

CE in the European Regulatory framework for the furniture sector

The furniture sector is covered by EU regulation on e.g. safety, consumer rights, waste and chemicals for packaging and products as illustrated in figure 1.18.

Figure 1.18 – EU regulation in the furniture sector (https://eur-lex.europa.eu/legal-content; https://eur-lex.europa.eu/legal-content)

Moreover, two voluntary initiatives linked to the consumption of furniture are important - the European Ecolabel Scheme and Green Public Procurement.

The European Ecolabel Scheme

The EU Ecolabel was established in 1992 as a voluntary tool to encourage businesses to develop products with a reduced environmental impact throughout their whole life cycle, and to help consumers find the best environmentally performing products in their category. The EU Ecolabel is multi-criteria, based on scientific evidence and life-cycle based approach, third party certified and revised regularly to follow technological evolution (European Commission, 2019b).

For the product group “furniture”, the Ecolabel criteria concern:

– Criteria for use of certified raw materials;
– Avoidance of hazardous substances in products and production processes;

– Prohibition of use of certain substances (e.g. biocidal, flame retardants, Vinyl Chloride Monomers etc.);
– Fitness for use;
– Reparability;
– Design for disassembly;
– Emissions of VOC and formaldehyde;
– Information to consumers.

Read more: http://ec.europa.eu/environment/ecolabel/products-groups-and-criteria.html.

The European Green Public Procurement

Green Public Procurement (GPP) is a voluntary instrument with the aim of using the market forces of the public sector to stimulate sustainable and circular products and services. The GPP criteria for furniture are divided into three areas: A) Refurbishment service for existing used furniture, B) The procurement of new furniture items, and C) The procurement of furniture end-of-life services, which include collection and reuse of existing furniture stock. (European Commission, 2019b).

The proposed GPP criteria follow some general principles illustrated in table 1.6.

Table 1.6 – Proposed EU GPP criteria for furniture (European Commission, 2018b)

Key environmental impacts during furniture lifecycle	Proposed EU-GPP approach
Loss of biodiversity and soil erosion as a result of unsustainable forest management and illegal logging	Procure timber from legal sources
Depletion of resources due to the use of non-renewable resources such as oil/natural gas for plastics. CO2 and other emissions as a result of energy consumption in the production of several materials.	Use materials made partly or totally from renewable materials such as wood
Risk to workers, consumers or to the wider environment of the release of toxic substances. Contribution to poor indoor air quality due to Volatile Organic Compounds (VOC) emissions from indoor furniture products.	Set maximum limits for total VOC emissions from furniture items and specific formaldehyde emission limits for wood-based panels and upholstery materials
Wasted materials due to premature End of Life of substandard quality furniture.	Procure durable and fit-for-use furniture complying with relevant EN standards
Wasted materials due to difficulties with repairing, acquiring spare parts or separating parts for recycling.	Procure easy-to-disassemble, repairable and recyclable furniture that is covered by a warranty

Case: Public tender on learning environments for schools in Aalborg

In 2017, Aalborg was one of the first municipalities in Denmark to introduce circular economy into their public tenders through a tender on school furniture. Besides a focus on circular economy, municipality also wanted to stimulate inspiring learning environments suitable for differentiated learning instead of traditional school furniture.

The final criteria in the tender included seven environmental criteria, which were minimum requirements, and four award criteria. The award criteria covered the following aspects and had the following weighting: circularity (40%), quality of the offered interior design (20%), quality of advice (20%) and economy (20 %). Hence, circularity was the award criteria with the highest weighting and economy only weighted 20%. More specifically, the circularity award criteria covered aspects such as life-time, service and maintenance, reuse, refurbishment and material recycling. The specific aspects are further described in table 1.7.

Table 1.7 – The criteria included in the circular procurement for sustainable learning environments in Aalborg (http://ec.europa.eu/environment/gpp/pdf/news_alert/Issue79_Case_Study_155_Aalborg.pdf)

The minimum environmental criteria	A minimum five-year guarantee on the lifetime of new furniture
	A minimum two-year guarantee on the lifetime of the refurbished part of the furniture
	A minimum five-year guarantee on spare parts
	A service which informs schools once a year (during the warranty period) of the relevant maintenance service available and advised for each product
	Packaging made from recycled materials
	Labelling of plastic parts above 50 grams for recycling
	Minimum 70% of wood used should come from sustainable sources

The circular award criteria covering circulatory	
	Service and maintenance (25%) – Spare part guarantee which exceed the minimum requirement of five years – Products can be disassembled into different parts for replacement and refurbishment **Reuse (20%)** – Reuse of existing furniture – Handling of furniture for reuse, that is, minimisation of environmental impacts in the process, such as transport impacts **Refurbishment (15%)** – Refurbishment of existing furniture; that is, replacing a table top, or recoating and repainting, etc. – Refurbishment is carried out by employees on special terms, that is, employees who are disabled or receive social assistance **Material recycling (10%)** – New furniture is made of recycled materials and/or materials recycled with the refurbishment of any existing furniture at the schools – Any leftover furniture parts are recycled

Barriers in the furniture sector

The European Environmental Bureau (EEB, 2017) analysed the barriers to a circular furniture sector and pointed at the following:

- Lower quality materials and poor design
  - the move away from solid wood and metal furniture to cheaper materials, which restricts the potential for a successful second life. Weak product design and specification drivers – in relation to recycled content, reuse of components, product durability, and design for disassembly/reassembly, repair, reuse, remanufacture and recycling, the drivers for improvement are weak or absent.
- REACH Regulation (on Registration, Evaluation, Authorisation and Restriction of Chemicals)
  - legacy hazardous substances pose challenges and additional costs for recyclers, together with a lack of information on chemicals contained in products and on ways how to deal with them appropriately.
- Poor consumer information and availability of spares
  - consumers are rarely given guidance on how to maintain and repair furniture, in order to prolong and extend the product lifespan. A lack of availability of spare parts encourages the purchase of new furniture over circular consumer patterns.
- Limited collection and reverse logistics infrastructure
  - currently there are weak drivers and underinvestment in the collection and logistics for furniture takeback. Producer responsibility mechanisms are not widely used in the furniture sector.
- High cost of repair and refurbishment

- in many parts of the EU, transport and labour costs are high, making any significant repair and refurbishment costly, particularly where re-upholstery is required. In general, economies of scale and economic incentives are needed to make repair and refurbishment viable.

– Weak demand for second-hand furniture

- the price differential between new furniture against the cost of second-life furniture, is not significant enough to drive more sustainable purchasing behaviour. This is coupled with poor awareness of the availability and benefits of sustainable furniture options, for both domestic and commercial purposes.

– Poor demand for recycled materials

- end markets for recycled materials, post deconstruction, are underdeveloped, and in some cases, already saturated, with these associated market failures restricting further investment in recovery.

– Weak over-arching policy drivers

- typically furniture is not managed in accordance with the waste hierarchy, with reuse failing to be prioritised over recycling, incineration and landfill. Underinvestment in reuse, repair and remanufacturing infrastructure limits the potential for furniture being managed in accordance with the principles of the waste hierarchy or the circular economy.

1.10 Tools for introducing circular economy

Seven tools are developed in the KATCH_e project, as illustrated below:

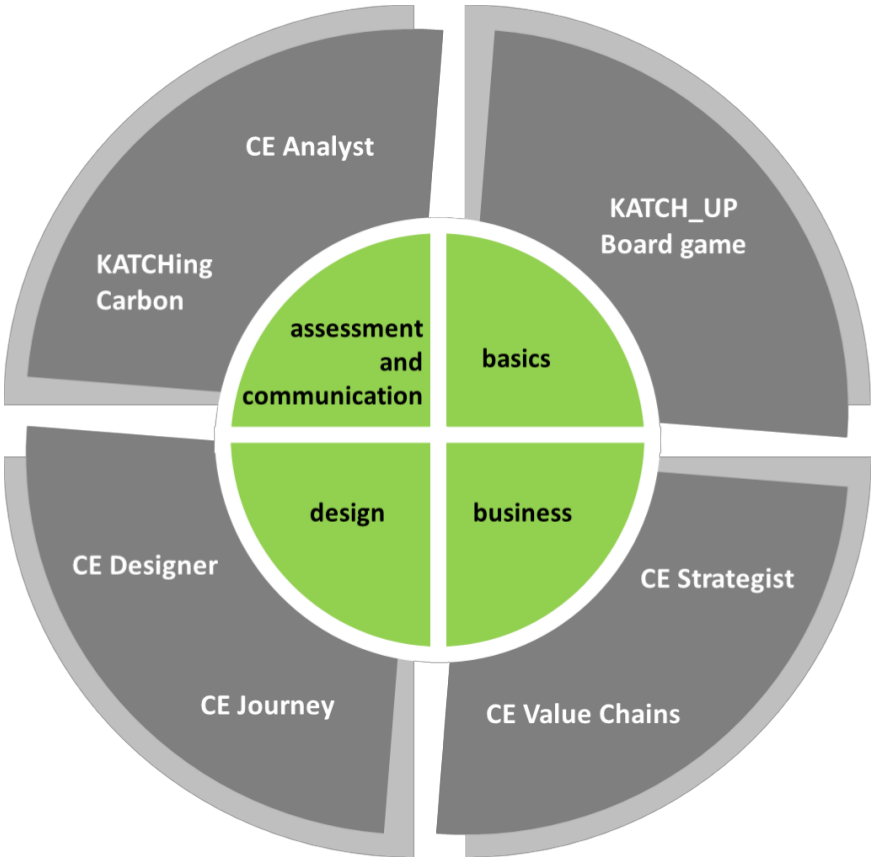


Figure 1.19 – Tools developed within the KATCH_e project

The tools are presented in the chapters, they are related to. For introducing how to think about circularity in a business context, you could play the KATCH UP Board game.

1.10.1 KATCH_UP Board game

The objective of this game is to stimulate the users to generate value ideas from a business challenge, applying circular design and circular business strategies. The game acts as a guide to get an idea about an innovative product-service or to solve a real business problem and generate opportunities.

No previous knowledge of circular economy (CE) is required, however, having knowledge about CE design and business strategies is preferred, as the application of the tool will be more agile, efficient and effective, leading to better defined ideas.

Creation of a product-service idea applying circular design and circular business strategies to solve problems from case studies or your own company issues.

This tool can be applied under different situations: Company, academia and worshops. When this game is played in companies, real cases can be applied, i.e., to a specific product-service category and to solve specific company challenges. When this game is played in classrooms or workshops, the game offers hypothetical contexts to work on them.

PREPARATION: Form groups of 3-4 people and prepare the board and its elements

PLAYING: The game has 6 basic steps:

Step 1 – Problem context:

Presentation of the product-service category, business challenge and target group;

Step 2 – Way to the solution:

Presentation of CE strategies that can be used to deal with the problem context;

Step 3 – Idea creation:

Development of the innovative idea that will solve the initial problem;

Step 4 – Business model:

Definition of the most appropriate business model;

Step 5 – Market launch:

Definition of how your product-service will be launched to the market;

Step 6 – Presentation and scoring:

CE ideas got as a result of the game should be pitched by the groups and scored using a Likert scale (1-5).

1.10.2 Other tools

Tool	Description	Source
Circular Economy Toolkit	The CET is a free resource for businesses to find opportunities in the Circular Economy. With the vast number of possibilities for creating value out of the Circular Economy and cradle-to-cradle thinking, it can be challenging to assess all the options. The Circular Economy Toolkit has consolidated all the opportunities and provided information on how your company could start finding benefits. The Assessment tool offers a questionaire to evaluate circular strategies Besides the assement features, the tools provides useful information in each strategy.	http://circulareconomytoolkit.org/Assessmenttool.html
In the Loop	The "In the Loop" game simulates complex, global resource supply chains and triggers players to find solutions. Players take on the role of a manufacturing company and try to be the first to seven 'Progress Points' by collecting resources and building products. Along the way, they face difficult strategic decisions while navigating through constricted resource mines and unpredictable world events.	https://intheloopgame.com/
Circulab	The Circulab homepage offers a number of tools, games, etc. for developing circular business strategies, inspiring creativity and stimulating teamwork for developing circular solutions.	https://circulab.eu/tools/#creatif
Biomimicards	A game to explore biomimicry by travelling through continents including 25 examples, the players discover the superpowers of nature and thus the value of biomimicry.	https://biomimicards.com/

1.11. The ten KATCH_e essentials of circular economy

Through the introduction to the circular economy, you have probably realized that the subject is vast, complex and challenging. Going to work with designing circular solutions, a number of key points may guide the process. We call these points "The Ten Essentials of Circular Economy":

1. Think circularity already in the design phase of products and business models;
2. Think in functionality instead of products;

3. Analyse where value is created and destroyed, to understand how it can be captured;
4. Any circular solution should also be sustainable;
5. Assess the consequences and relevance of your solutions from a life cycle perspective to avoid moving problems, or creating new ones;
6. Involve the stakeholders along the value chain in developing new solutions;
7. Adopt a stewardship role and lead the transition to a circular economy by example;
8. Understand which new, or changed, consumer practices are needed to make your circular solution work;
9. Make the circular solutions attractive for the users and be a part of the solution, not the problem;
10. Consider the local, social value. For example, job creation, inclusion, development of new services.

The chapters in this book can support you in working with the essentials.

Assignment 1.12

Brainstorm on questions you find relevant to consider for each of the 10 essentials.

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02

BUSINESS MODELS

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Business models

Contents

Executive summary 75

2.1 What constitutes a circular business model? 76

2.1.1 Framing the economic preconditions – introducing the Doughnut 76

2.1.2 Framing the circular business model and the meaning of value 80

2.1.3 Three categories of business strategies – the value hill 86

2.1.4 Defining circular business strategies along the life cycle 88

2.1.5 Circular business strategies in the construction and furniture sector 93

2.2 Economic opportunities and financial implications of circular business models 94

2.2.1 Economic opportunities of circular business models 94

2.2.2 Financial implications of circular business models 96

2.3 The conceptualisation of business models 107

2.3.1 Definitions and concepts 109

2.3.2 The nine elements of the business model 110

2.3.3 The Business Model Canvas (BMC) 113

2.3.4 Zooming Out – the business model environment 114

2.3.5 Limitations of the Business model canvas framework 118

2.4 From linear to circular business models 122

2.4.1 The 4I framework of BM innovation 122

2.4.2 The CE Strategist tool and the BM innovation process 123

2.5 Examples 129

Bibliography 142

Executive summary

2.1 What constitutes a circular business model?

If taken seriously, the Circular Economy must be framed within the wider discussion of strong sustainability. Section 2.1 describes the economic conditions necessary for a CE to thrive, and the need for a broader meaning or the term “value”, beyond merely financial profitability. The concept of the Value Hill then shows how value is typically lost in linear life cycle and showcases opportunities of value capture. Based on where in the life-cylce of products the value is mainly captured, the framework differentiates between three groups of circular business strategies: Uphill (production and design-focused), Tophill (focused on the use-phase) and Downhill (focusing on the End-of-life-phase). The resulting twelve strategies are further explained and categorized with best-practice examples.

2.2 Economic opportunities and financial implications of circular business models

Describes the main economic benefits that CBMs entail, along with the explanation of how BMs main financial elements may differ in a circular and in a linear economy. BMs applying a circular approach may have some financial implications that may difficult its practical implementation. These main implications are described in the section, including as well some financial resources that may minimize these difficulties and therefore, facilitate the financeability of CBMs.

2.3 The conceptualisation of business models

Introduces the traditional and widely applied framework of the Business model canvas. The section explains, what building blocks are distinguished and how they relate to each other and how outside forces shape the different elements of business models, especially in the context of a Circular Economy. The section is completed by reflecting on the shortcomings related to sustainablitity concerns of the BMC-model and presents similar sustainability-related BM-frameworks.

2.4 From linear to circular business models

Describes the typical process of creating or changing the business model with the four phases of Initiation, Ideation, Integration and Implementation. Additionally the tool CE Strategist, which covers the whole business model design process is introduced for the final assignment.

2.1 What constitutes a circular business model?

2.1.1 Framing the economic preconditions – introducing the Doughnut

The view that businesses must broaden their value capture perspective from the bottom line (meaning the measurement of success only in terms of economic profits or losses) to the triple bottom line (accounting also for social and environmental concerns) is already quite mainstream. The growing practice of corporate social responsibility (CSR) as an organizational tool to incorporate sustainability is a testament to that. CSR-practices have grown both in their scope and their application. Within the past decades CSR-practices advanced from self-regulation and voluntary measures to mandatory schemes at regional, national and even transnational levels. The growth of its application can be measured for instance in the practice of sustainability reporting. In 2011 only 20% of the S&P 500 companies (a widely used stock market index, covering the 500 largest corporations listed on the New York Stock Exchange) published a CSR-report. Only four years later in 2015 the statistic flipped, and 81% of the companies were publishing reports. In the year 2017 the quota has risen to 85%. (Coppola, 2018).

The "doughnut" further builds on the triple bottom line approach, by concretely defining quantitative limits to the social and environmental sphere. The term "doughnut-economy" stems from the author Kate Raworth and her book of the same name. The term describes the 21st century challenge of the global economy to meet the needs of all within the means of the planet. In other words, "to ensure that no one falls short on life's essential (from food and housing to political voice), while ensuring that collectively we do not overshoot our pressure on Earth's life supporting system, on which we fundamentally depend - such as a stable climate, fertile soil and a protective ozone layer." (Raworth, 2017).

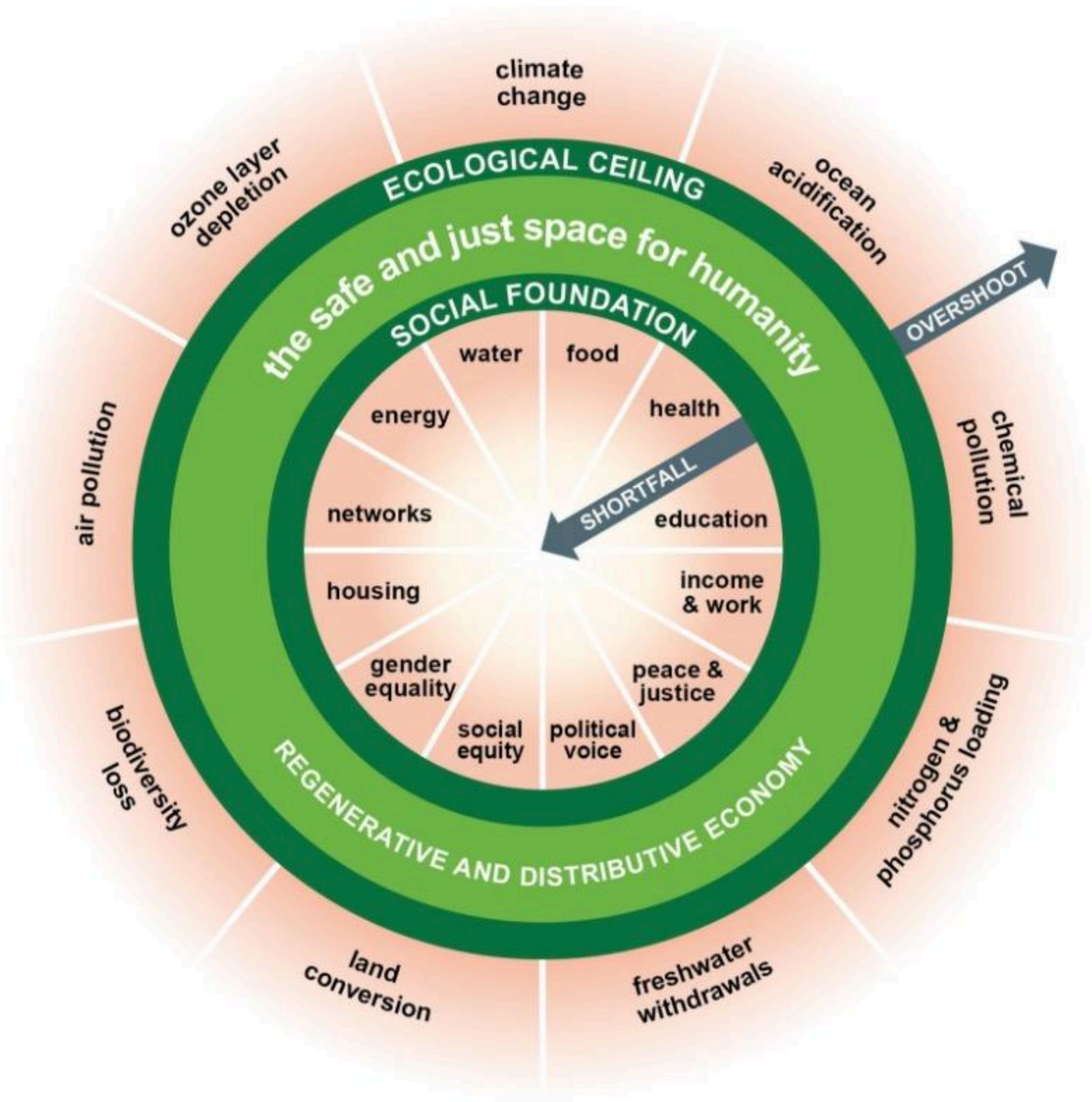


Figure 2.1 - The Doughnut of social and planetary boundaries (Raworth, 2017).

The defined environmental limits are based on the framework of the planetary boundaries, which represent the ecological ceiling of economic activity. The planetary boundaries are a scientific concept with the aim to define a "safe operating space for humanity" (for an overview and description of the individual boundaries, see also: http://www.stockholmresilience.org/research/planetary-boundaries) There are currently nine defined earth system process thresholds. Beyond these boundaries lies unacceptable environmental degradation and tipping points with unforeseen consequences. Seven of those have scientifically defined limits, while two are not yet quantified. Of the seven boundaries, four boundaries are already crossed (Climate change, biodiversity loss, land conversion and nitrogen & phosphorus loading). The social dimension represents the foundation of economic activity. Its twelve dimensions represent internationally agreed social minimum standards, as identified within the

Sustainable Development Goals of 2015. Millions of people currently fall short of these minimum standards related to nutrition, housing, income and others.

The safe and just space for the economy, is represented by the doughnut-shaped area within the social foundation and the environmental ceiling. Figure 2.2 provides a snapshot of the current planetary condition. On a global scale, four of the ecological boundaries are already crossed, while there is a shortfall on every sustainable development goal (see Figure 2.2).

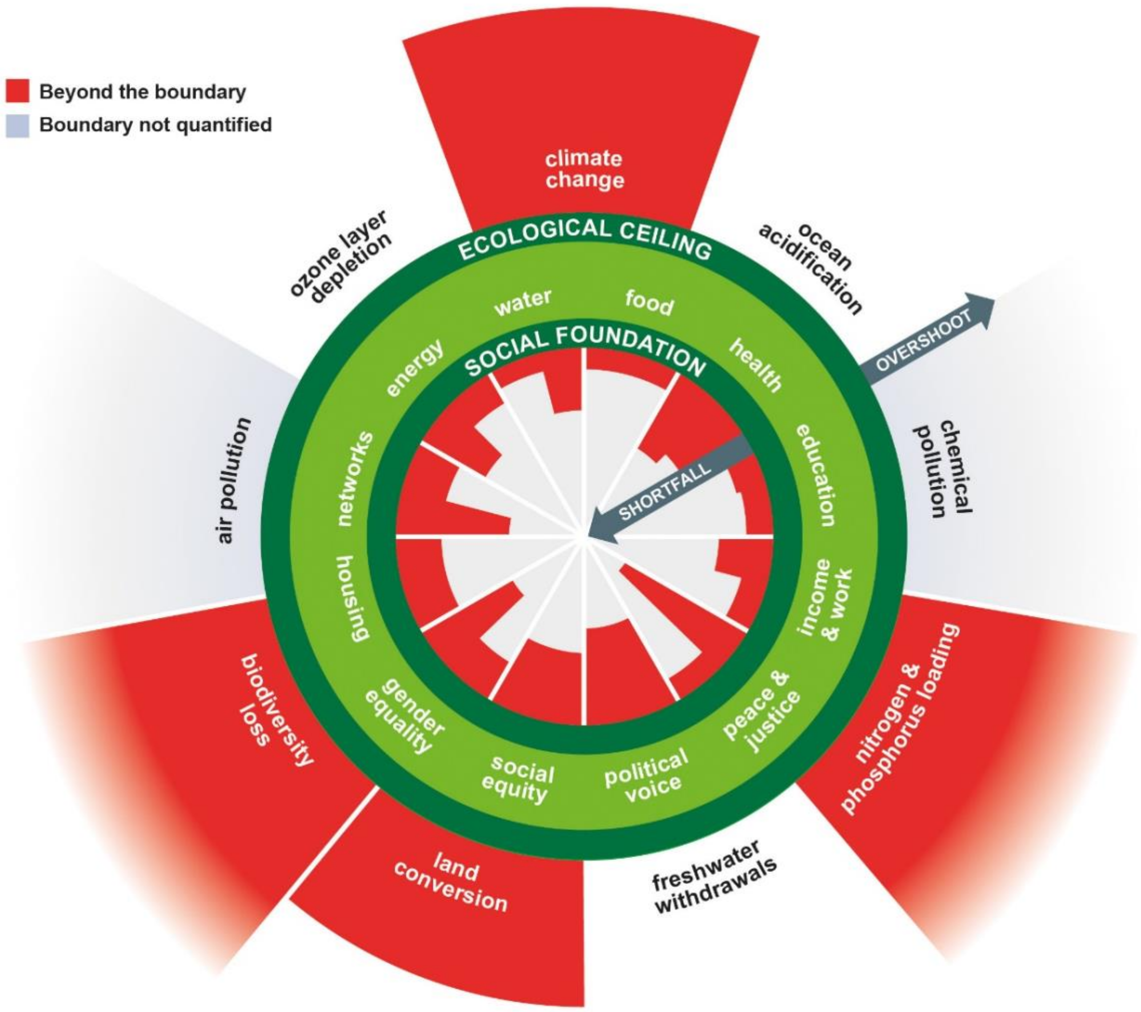


Figure 2.2 - The current planetary condition as described by the doughnut framework (Raworth, 2017).

We introduce the framework of the doughnut economy as we think of it as a useful model, uniting the three dimensions of sustainability and showing how they relate to each other. It shows the importance of addressing environmental sustainability and social justice together. Any viable form of economic activity must take these spheres into account - the doughnut provides a suitable image to convey this message.

Furthermore, the thresholds provide a way to quantify social and environmental developments. The concept and its boundaries are evolving and adapting continually as both environmental and social boundaries are the result of scientific research and public debate.

The doughnut relates to the CE, as the concept describes the preconditions of the economy to thrive in. With its focus on resource use the CE is also very much related to a number of boundaries (e.g. climate change relates to the use of fossil fuels and consumption). Other iterations of the doughnut also address resource use more directly by extending the model with a material footprint indicator (see also: https://goodlife.leeds.ac.uk/countries/).

The doughnut can also be seen as a model for "strong sustainability". In contrast to weak sustainability its proponents argue that the substitutability of natural capital is severely limited, thereby certain boundaries are inevitable. This is also the a priori position of the contents of this course. Table 2.1 lists key differences between the concepts of weak and strong sustainability.

Table 2.1 - Differences between the concepts of strong and weak sustainability. Adapted from Mancebo (2010)

	Strong sustainability	Weak sustainability
Key idea	Substitutability of natural capital is severely limited	Natural capital and other types of capital (e.g. manufactured) are perfectly substitutable
Key concept	Critical natural capital	Optimal allocation of scarce resources
Consequences	Certain human actions entail irreversible consequences	Environmental degradation is compensated by technological innovation and monetary compensation
Sustainability issue	Conserving the irreplaceable "stocks" of critical natural capital for the sake of future generations	The total value of the aggregated stock of capital is at least maintained or ideally increased for future generations

To get a sense of what a strongly sustainable economy within the defined boundaries might look like, the following list of characteristics is inspired by the economist Tim Jacksons' book "Prosperity without Growth – Economics for a finite Planet":

- A system that encourages minimising consumption, or imposes personal and institutional caps of resources (fossil energy, water, goods, etc.);

- A system which is designed to maximise societal and environmental benefit, rather than prioritising economic growth;
- A closed loop system where nothing is allowed to be wasted or discarded into the environment, which repairs, reuses and remakes in preference to recycling;
- A system which emphasises the delivery of functionality and experience rather than product ownership;
- A system designed to provide fulfilling, rewarding work experiences, which enhance human creativity and skills;
- A system built on collaboration and sharing, rather than aggressive competition

These characteristics require fundamental changes in the way business is conducted. Changing the way how to do business – in other words "business model innovation" – is one way to approach the required changes. The following section frames the meaning of sustainable and circular business models to get a sense of how to get there.

2.1.2 Framing the circular business model and the meaning of value

First off, it must be mentioned that research into circular business models is quite new and is best understood as an emerging research field. New definitions and frameworks are developed continually and are mostly based on the examination of successful case studies. The same is true for the following definitions, concepts and frameworks introduced.

The circular economy is based on the idea of putting private businesses into the service of the transition to a more sustainable development. Therefore, we consider the circular business model (CBM) as a particular set of strategies within the broader discussion of sustainable business models (SBM). A widely accepted definition of an SBM is the following:

A sustainable business model, is a business model that creates competitive advantage through superior customer value and contributes to a sustainable development of the company and society. (Lüdeke-Freund, 2010)

Within our chapter, CBMs fit the criteria of SBMs, but emphasize the efficient use of resources by narrowing, slowing and closing resource flows within the business model. line with the circular economy definition adopted in the KATCH_e project, CBM's as understood in this chapter also address other environmental and social concerns in the broader range of sustainable development.

The term "value" is central to the business model. This can be derived from the definition of a BM, as it refers to the way a company creates, delivers and captures value. It is essential that within the context of a CBM, the definition of value must imply more than financial profits.

Therefore, value covers not only monetary value, but also a wider range of value for the environment and society in general. Value for the environment might be measured with energy efficiency measures, resource efficiency, carbon emissions, biodiversity protection, pollution prevention, etc. Social value might refer to the well-being of employees, community development and matters of health and safety. Furthermore, economical value refers to more than short-term profit, but considers also factors such as the long-term viability of the company and its financial resilience. Secondly, value refers not only to the one delivered to the customers but any affected party of the BM, such as the partners, governments, end users, etc. (see also Figure 2.3).

To better understand, how environmental, social and long-term economic value can be quantified. There, different forms impact assessments are introduced, which aim to improve the environmental- (life cycle assessment, LCA), the social- (social life cycle assessment, SLCA) and the long term economic- (life cycle costing, LCC) profile of products and processes.

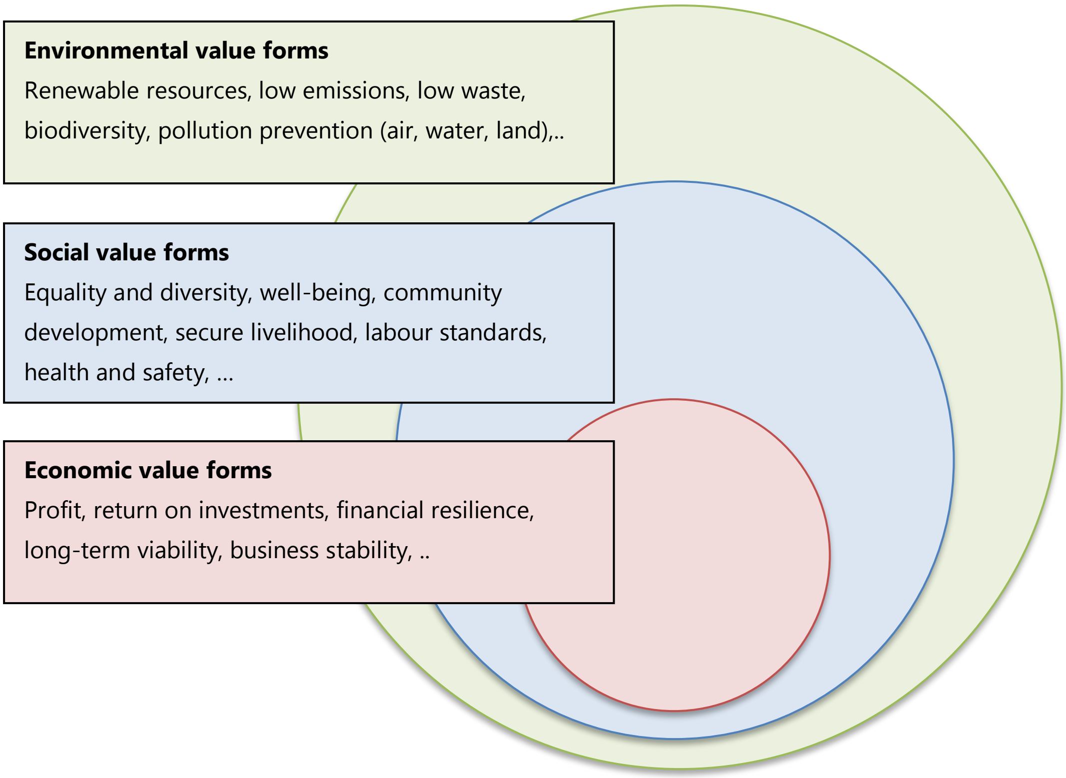


Figure 2.3 - Different forms of value. Adapted from Evans et al. (2017).

To further explore this concept of broadening the meaning of value, we introduce the term "Value uncaptured", emphasising on a potential value that could be captured within a CBM but has not been captured yet.

Thinking of sustainability in terms of value uncaptured in the current BM might help uncovering new sources of value within a new circular business model. The concept helps to think about *how much* and to *what extent* value is exchanged within a business model. The traditional concept of the

Business model canvas -which will be explained in section 2.3 - only explains *how*, *what* and *with whom* value is exchanged. (Yang et al., 2017)

Table 2.2 - Exemplary sources of value uncaptured in the different life cycle phases, adapted from Yang et al. (2017)

Life cycle phase	Exemplary sources of value uncaptured
Beginning of life	– Design (redundant, insufficient, excess, too early, lack of theory, etc.) – Production (wasteful, inefficient, polluting, ..) – Operations Management (unflexible, not cooperating, unadaptable, ..) – Personnel (excess capacities, inefficient use, ..) – Customer needs (unclear, unknown, future needs, ..) – R&D (lack of basic scientific research, lack of IP protection, ..) – Knowledge & technology (wasted knowledge, technology, experience, skills,..) – ..
Middle of life	– Customers Value Uncaptured (wasted resources, products, by-products, unprofessional use, pollution, missed applications, insufficient communication between manufacturer and customer,..) – Customer Needs (unknown, inaccurate understanding, changes, ..) – Operation Management (lack of regulation, workflows, service scheduling, flexibility, ..) – Service personnel (lack of or excess capacity, inefficient use, allocation or communication) – Service (excess, missed, poor, lack of experience, low charges,..) – Co-products or by products (inefficient use, unknown applications, ..) – Resource and energy waste in the use phase (underutilised, overused, ..) – Service Contract risks (responsibilities, market risks, lack of experience,..) – ..
End of Life	– Reuse (lack of awareness; lack of idle, usable, purchasable products; usable products discarded by user; poor customer acceptance and demand of reused products; lack of take back mechanism,..) – Remanufacturing / Refurbishing (lack of knowledge, awareness, guidance and methods; lack of capacity to undertake remanufacturing; need for technology; low value, customer acceptance and demand, lack of take back mechanism,..) – Recycling (lack of knowledge, awareness, guidance and methods; lack of separability of materials) – ..

The following table provides an overview of a study, where employees of six different manufacturing companies, aiming to transform their business model into a more sustainable Product-Service-System, were asked to name potential sources of value uncaptured within their companies, considering the whole product life cycle. The study differentiated between the Beginning of life (the pre-use phase of the product), the middle of life (the use phase of the product) and the end of life (the post-use phase) (Yang et al., 2017). Table 2.2 provides an exemplary list of sources of value uncaptured that were named within this study. The concept differentiates between four different forms of both tangible (e.g. physical resources) or intangible (e.g. work, expertise, etc.) value (Lenssen et al. 2013; Yang et al., 2017).

The study also points out the fact, that especially at the end of life stage, few sources of value uncaptured were identified. The study states poor awareness and knowledge regarding this life cycle stage as a reason. (Yang et al., 2017) This might be important to keep in mind, as the assessment and realisation of End of Life-potentials is key for a CE.

To further strengthen the understanding of value capture opportunities we introduce the Value mapping tool (Lenssen et al., 2013) for the following assignment.

The tool should help its users to:

– Understand positive and negative aspects of value, within a network of stakeholders;
– Identify conflicting values (a benefit for one stakeholder is a negative for another);
– Identify opportunities for a redesign of the business model.

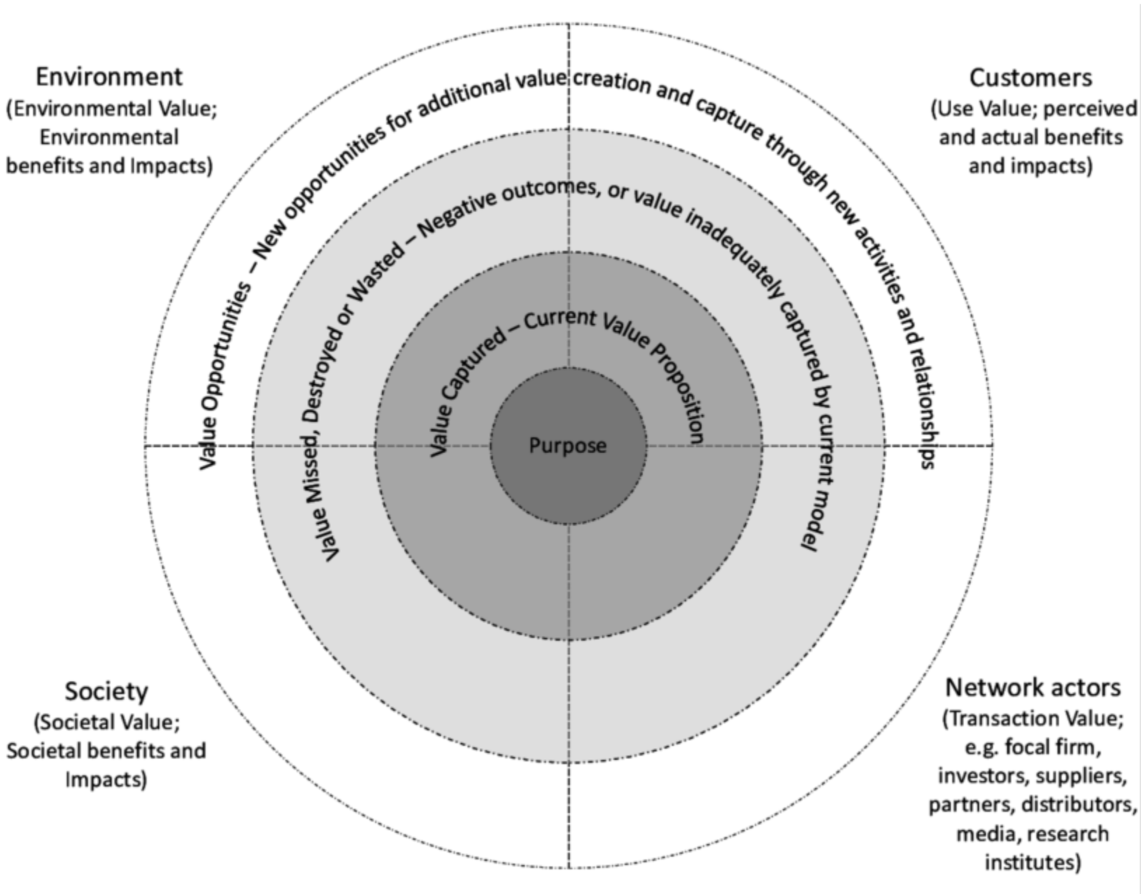


Figure 2.4 - Value mapping tool (Lenssen et al., 2013)

Assignment 2.1 – Thinking about value capture opportunities:

To develop your circular business model, think about what value is going to be captured within it, by using the value mapping tool. Each ring of the diagram represents a different brainstorm. During these rounds of brainstorming, four different categories of stakeholders need to be considered (customers, network actors, society and environment). If the idea is not based on the adaption of an existing BM, and therefore a sufficient understanding of the current value network is missing, it might be useful to apply the tool to a traditional linear business model, e.g. from a competitor. Use the results from assignment 2.1, describing the business model environment, to help with the process.
Brainstorm 1: Discuss the purpose of the business. Why is the business here in the first place? What product or service is offered? What is the primary reason for its existence (besides financial viability)?

Brainstorm 2: What value is created for the different types of stakeholder? What positive value is created and what negative value do all stakeholders mitigate?

Brainstorm 3: What value is destroyed or missed? What are the negative outcomes for the stakeholder groups (e.g. employment, health, resource squandering, etc.)? Is the business missing an opportunity to capture value? Are assets, capacities or capabilities under-utilised? Are potentially useful resources landfilled?

Brainstorm 4: Can some of the negative impacts be transformed into positives? What new value might the network create for its stakeholders through certain activities and collaborations? What can be learned from competitors, suppliers, customers or other industries?
The results should be helpful for assignment 2.4.

2.1.3 Three categories of business strategies – the value hill

With the background knowledge of the business model framework, a broadened understanding of a more sustainable economy and the meaning of value, this and the following sections put together a framework of circular business strategies. Strategies are different to a business model in the sense that they are non-exclusive. This means that a multitude of strategies can be applied within a business model. Later on in this chapter, we specifically look at the effects of different strategies on the business model. Furthermore, a tool to identify the best fitting circular business strategies for individual products will be introduced. The tool is called CE Strategist and is available under tools.katche.eu.

What is the main difference between a linear and a circular business model? Linear business models are generally sales oriented. Higher sales figures result in higher revenues. Built in, is an inherent incentive to build products with a short lifespan to maximise revenues.

On the other hand, circular business models focus on the value generated of a product or a service, and try to capture value throughout its life, therefore the BM is created around a products' longevity, the provision of a service or the closing of resource cycles. Ideally, the business model incentivises the company to conserve resources and behave in a sustainable manner. CBMs might also be sales oriented, but certain characteristics of the business model prevent resource-squandering behaviour.

To understand this better, it is useful to look at the lifecycle of products: By extracting resources from the earth, refining them further within the manufacturing process, assembling them into products and distributing and selling them to consumers, value is added every step of the way. At the point of sale the value is at its highest. Due to the incentives in a linear model, the value is quickly lost after a short use phase. Products end up in landfills or are incinerated. This is described in **Error! Reference source not found.** – the Value Hill.

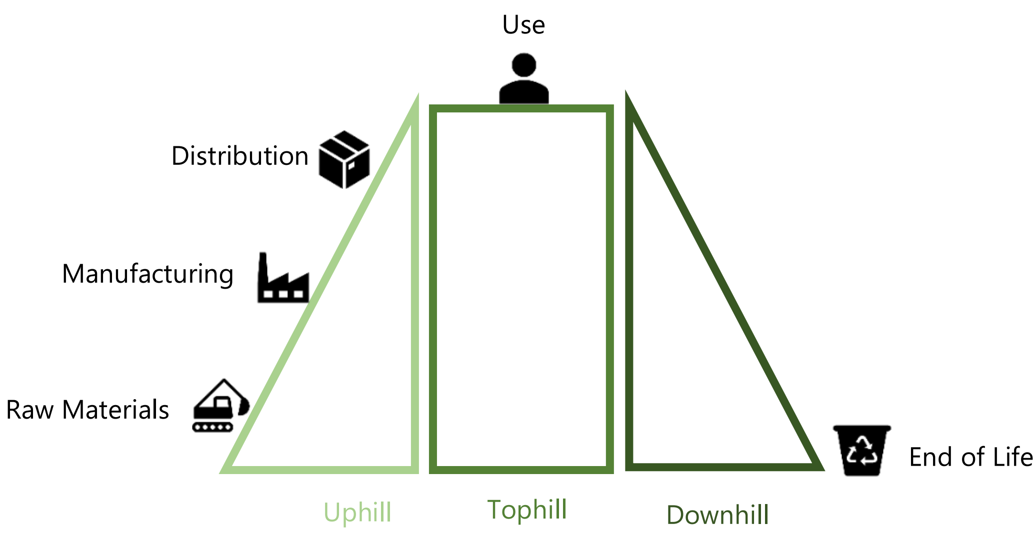


Figure 2.5 - The value hill in a linear economy. Adapted from Achterberg et al. (2016).

As explained, within a CBM businesses aim to retain a products' value for as long as possible (see Figure 2.5). On the way uphill, value is continually added. In this stage products are already designed to be long lasting, repairable, upgradeable during the use phase resulting in the slowing of resource flows. A longer or more intense use phase can be incentivised through the provision of services in the use phase (e.g. renting, pay per use, etc.) – this has the potential to slow resource flows. On the way downhill, further strategies for slowing and closing loops are encouraged and built into the business model (such as redistribution, remanufacturing and recycling).

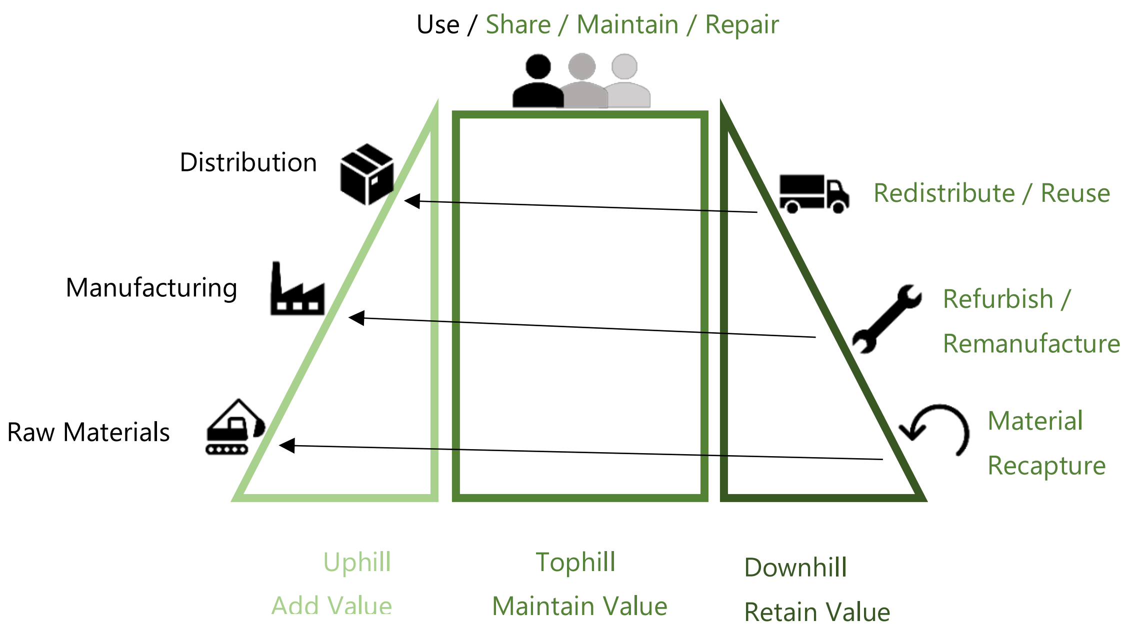


Figure 2.5 - The Value hill in a circular Economy. Adapted from Achterberg et al. (2016).

The main challenges to fulfil the CE potentials shown in the value hill graphic are:

- to maintain the control over the resources once they are no longer in use, and
- to keep products at their highest value.

Businesses can follow different strategies to meet these challenges. Dependent on where on the value hill measures are set three different strategies are distinguished: uphill (optimal production and design), top-hill (optimal use) and downhill (value recovery). These are not mutually exclusive, meaning that business often follow multiple strategies to maintain value along the lifecycle. In order to establish the connections between the pre-use, the use- and the post-use phase, collaboration within the network is essential.

Uphill: optimal production and design

On the upward slope of the hill, value is continually added (from raw material extraction until distribution) until the product reaches its use phase. The decisions that are made through the design of products are crucial to influence the use and post-use phase positively by slowing (repair, remanufacturing, etc.) and closing resource flows (material recycling). Furthermore, in the uphill phase there is also the chance to narrow resource flows (using less materials, virtualising products).

Top-hill: optimal use

Optimal use summarizes business activities that slow resource flows in the operational phase of a product. Generally, there are two ways to shape the use-phase more resource-friendly: The life-time of a product is prolonged (e.g. through repair and maintenance services) or the productivity of the asset is intensified (e.g. through sharing platforms). In terms of the business activities product-service-systems are particularly promising for two reasons. Businesses keep being the owners of products, which addresses the challenge of resource control and reverse logistics. Secondly, when users pay per use or pay only for the performance they utilise, the profit incentive shifts from selling more products to providing a better service with fewer resources.

Downhill: value recovery

In the post-use phase, on the way downhill, the goal is to keep the products or parts of it at their highest value. Resource flows are slowed by remanufacturing, refurbishing or redistribution and closed by material recycling. Businesses generate their revenues by recapturing value that would otherwise be lost.

2.1.4 Defining circular business strategies along the life cycle

The strategies introduced can be applied to a broad range of sectors. They are especially relevant for resource-intensive manufacturing industries, where products are conceived, developed and produced. However, as the CE and its business models often require cooperation within the value chain, the strategies are also relevant for other actors, such as service providers, re-sellers, logistics providers, etc. Generally, the applicability of different strategies is also dependent on a range of other factors (such as industry, product characteristics, customer expectations, value network, etc.). The CE Strategist tool (available on the KATCH_e website), should help with the process of finding relevant strategies and apply them in a specific context.

When talking about the construction sector in the context of this chapter we are mainly referring to companies providing building materials (such as floorings, windows, bricks) or services around a building (such as machinery, elevators, energy providers, etc.). The same is true for the furniture sector, meaning that our focus is on the product level and the business model logic behind it. Some of the principles and strategies can also be applied to a building as a whole, but the developed framework as well as the case studies focus on companies and their business strategies.

The following Table 2.4 to Table 2.6 give an overview of 11 different types of circular strategies, grouped by their value hill category (uphill, tophill, downhill). The tables also include a graphic for each strategy, highlighting the affected life cycle stages within the value hill framework. E.g. Long-life design is about using durable, high-quality materials (*raw material phase*), prolonging the life-time of the product during the *use* phase, and enabling a *reuse* value due to the high quality.

Additionally, the strategies are categorized by their main focus of sustainable value capture - e.g. within the uphill phase through focusing on production processes and management, material selection used or measures of product design. Through that categorization, it also becomes obvious how multiple strategies might be applicable to a product. Furthermore, the categorization along the lifecycle helps companies to position their activities on the value hill and identify possible strategies and cooperation potentials.

The developed classification builds on the categorization from (Achterberg et al., 2016) but also draws inspiration and inputs from other sources (Bocken, Pauw, Bakker, & van der Grinten, 2016; Bocken, Short, Rana, & Evans, 2014; Tukker, 2004; Yang et al., 2017, Achterberg et al., 2016; Bakker, 2014).

Table 2.3 - Circular business strategies in the pre-use phase of the value hill

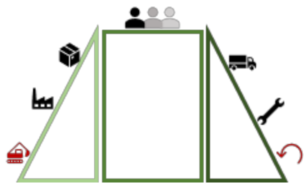
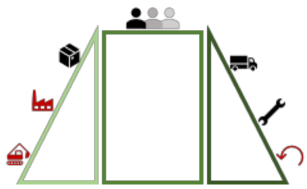
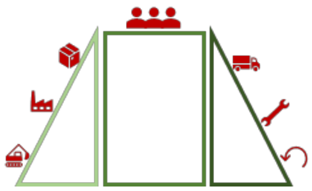
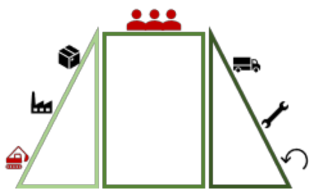
Value capture	Main affected life cycle stages	Circular business strategy	Description
Material-focused		**Circular sourcing**	Using resources as production inputs that are renewable, recoverable, bio-based, less resource intensive or existing pollutants in the biosphere (e.g. Cradle 2 Cradle, localisation, biomimicry, blue economy, green chemistry, etc.).
Production-focused		**Maximising production efficiency**	Describes a number of manufacturing principles that focus both on maximising the material and energy efficiency in the production process, such as industrial symbiosis, low carbon manufacturing, additive manufacturing, on demand production, dematerialisation, renewable energy, etc.
Design-focused		**Circular design**	Make use of product design strategies that are actively considering end of use strategies, such as repair, upgradability, modularity, repurposing, closed loop recycling, etc.
		**Long life design**	Focusing on delivering long-lasting and energy-efficient products the customers are attached to. Products are often comparatively expensive when acquired. Durability and sustainability is a major part of the company's communication.

Table 2.4 - Circular business strategies in the use phase of the value hill

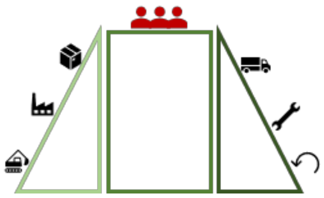
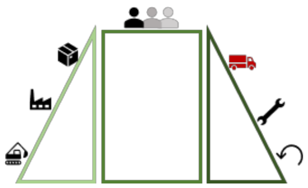
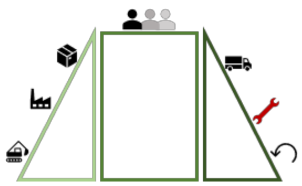
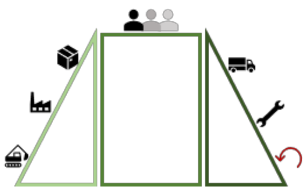
Value capture	Main affected life cycle stages	Circular business strategy	Description
Product-focused		**Life extension services**	Selling consumables, spare parts, and add-ons, which support the longevity of products and/or providing repair & maintenance services.
		Product oriented services	Products are sold to consumers with extra services aiming to prolong the use phase of the product. Examples include extended warranties, service contracts, supply of consumables, take-back agreement, consultancy, etc.
Service-focused		**Use oriented services**	The ownership of the product remains with the service provider. It is made available in a different form and is sometimes shared by a number of users. Examples include: leasing and renting (single user), sharing (sequential use by different users) and pooling (simultaneous use by various users).
		Result oriented services	Clients and providers agree on a specific result and not necessarily a pre-determined product. All resources used to deliver the result are becoming cost factors for the provider, creating a financial incentive to use them as efficiently as possible. Examples are highly individual and sector specific: activity management/outsourcing (e.g. catering, energy contracting), pay-per service unit (e.g. pay per sheet in copying, pay per km in fleet management, pay per airplane landing, in tire management).

Table 2.5 - Circular business strategies in the post-use phase of the value hill

Value capture	Main affected life cycle stages	Circular business strategy	Description
Resale-focused		**Reuse**	Providing used products to new customers.
		**Remanufacturing/ refurbishment**	Restoration of a used product to a condition as good as new either.
Recovery-focused		**Material recapture / recycling**	Recapturing materials and/or transforming waste into new materials substituting the use of virgin materials

Assignment 2.2 – Get acquainted with circular strategies

1. Find an example for each value hill category (uphill, tophill, downhill) for the construction/furniture sector.
2. Identify the realised circular business strategies.
3. Describe the difference to a linear model by applying the framework of the BMC and its elements.

2.1.5 Circular business strategies in the construction and furniture sector

To better understand the implications of the circular business strategies, **Table 2.6** shows a list of best-practice examples. A detailed description of the bold-formatted examples can be found in the Annex.

Table 2.6 - List of examples categorized by their dominant circular business strategy

Circular business strategy	Examples from the construction or furniture sector	Examples from other sectors
Circular sourcing	**Ecovative Structures** **ECOR boards**	Freitag Apparel Toast Ale (brewed with surplus bread) Bureo skateboards (from recycled plastics) Pure Waste (made 100% of recycled textile waste)
Maximising production Efficiency	**Kalundborg Symbiosis**	Symbiosis Matchmaking Platform Print on Demand Service for Books
Circular design	**Daas baksteen (ClickBrick)** Vitsoe modular furniture Biohm Triagomy (panel-based construction system from biomaterials)	Fairphone Edit (Modular Self-driving car)
Long life design	**Miele White Goods** Team 7 Grüne Erde	Patagonia Outdoor Wear Epson EcoTank Printer (designed with refillable ink tanks)
Life extension	**Fischer LED ReThinKit** Giroflex Chairs	Sodastream
Product-oriented-services	**Löffler Furniture** Gaulhofer windows (with 30 years warranty)	Splosh Cleaning Products
Use-oriented services	**Hilti Fleet Management** **Desso Carpet Leading**	Sanergy, Riversimple , Vigga children clothing subscription
Result-oriented services	**Vertical Mobility as a Service (Mitsubishi Elevators)** Pay per lux (Philips)	Michelin Fleet Solution Rolls Royce "Power per Hour" plane turbines Ricoh pay per page
Reuse	**IKEA Second Life Program**	Yerdle ThreadUp (Clothes) ReWinner (CH)
Remanufacturing / refurbishment / upgrade	**Caterpillar Remanufacturing** **Steelcase Phase 2 Program** Rype Office Furniture	Refurb (refurbishment of IT equipment) Gazelle (Electronics) AFB (Computers, Smartphones) Dell (certified refurbished PCs)
Material recapture / recycling	**Niaga Carpet** Gamle Mursten (Brick Reuse) Desso closed loop recycling	Terracycle ecoATM (for electric devices) Urban Mining Company (Rare Earth Recycling)

2.2 Economic opportunities and financial implications of circular business models

As already seen in previous chapters and sections, the CE offers large potential economic gains to companies transitioning from a linear economy to a closed looped based activity, among other factors, due to materials and energy cost savings, new markets and revenue sources, as well as due to a greater resilience to external shocks.

Developing circular business models that allow these gains usually requires the implementation of financial models that differ from the more traditional financial approaches. For instance, the pay-per-use model has a very different cash flow structure to the traditional pay-for-ownership approach. These new approaches impact the businesses' cost structure, and therefore also the financing requirements (Working group finance, 2016).

The following subsections will present both main economic opportunities and main financial implications of circular business models.

2.2.1 Economic opportunities of circular business models

Businesses applying CE principles are **highly rewarded economically**. Indeed, as stated by the "finanCE" working group, composed by 13 financial organisations from the Netherlands (Working Group finanCE, 2016), the potential economic gains of a transition to the circular economy for businesses, include:

- The opportunity for enhanced resource productivity;
- Improved asset utilisation;
- Strengthened customer relationships and greater revenue visibility;
- Margin stability and improvement in quality of earnings;
- Enhanced return on capital invested;
- Higher residual value of the products in many cases.

The **increase of revenue streams** can clearly be understood by the following examples:

- Leasing a product, instead of selling it, turns a one-time income into longer-lasting revenue, improving customer retention;
- Adding complementary services, such as maintenance or upgrades can bring additional revenue streams;
- Selling end-of-use products or byproducts to third parties can raise new revenues.

As well as this, businesses can clearly **reduce their productions costs** when becoming circular. Strategies include; the implementation of inner circle approaches, such as reuse or refurbishment, that preserve more of the value of products, as well as the offer of more durable products that make a better use of embedded materials, energy and labour costs, decreasing this way the average cost over the use of the product.

Moreover, there are two other **main long-term positive impacts** of circular economy that businesses get benefited from; independence of price risks and of supply risks.

- Businesses adopting a circular approach may mitigate the risk of volatile resource prices as their dependency on finite resources is reduced, having more control on the resources cost;
- Circular business models are less dependent on imported resources, and therefore, supply disruption risks are reduce too.

This way, circular businesses could have a higher value regarding their revenue in the long term, in comparison to traditional models, due to the establishment of deeper long-term relationships, higher expected growth potential and decreased risk of volatility and margin.

All these economic opportunities can be related to the three previously defined value phases, along the life cycle, as economic value capture opportunities. The following graphic lists these potential profit sources along the up-, top- and downhill phase.

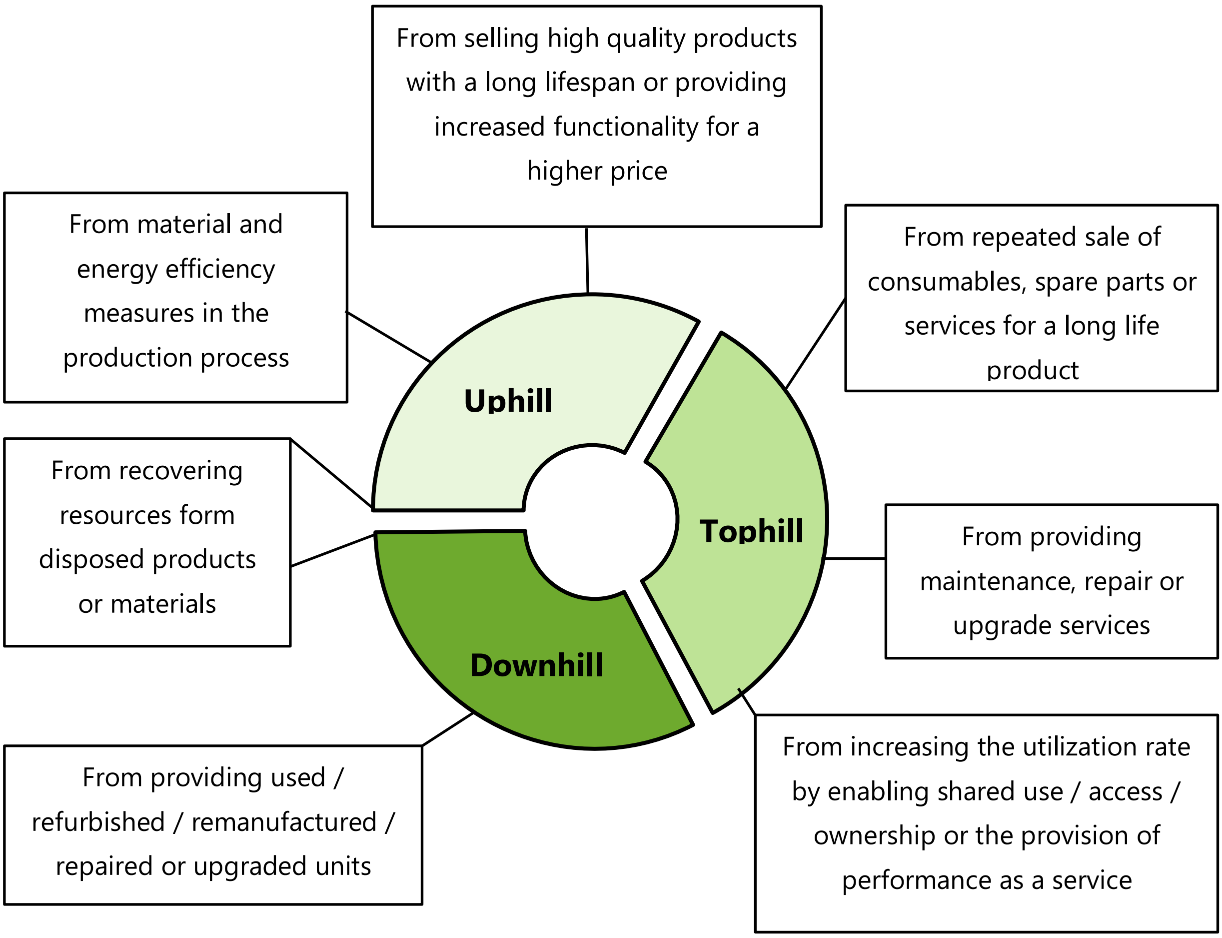


Figure 2.6 - Potential Profit Sources along the Uphill, Tophill and Downhill phase. Adapted from Moreno et al. (2016)

2.2.2 Financial implications of circular business models

Financial models followed by businesses differ in linear or circular scenarios, due to the prioritization of different elements and the identification of additional values beyond monetary ones. Table 2.7 identifies these main differences that directly impact on the implementation of different financial models.

Table 2.7 - Different financial elements of linear and circular business models. Adapted from ING Economics Department (2015).

	Linear business models	Circular business models
Earning model	Producers determine **sales price** of products	Producers may charge **price for the use** of the product
Multiple values and principles	**Money** is the dominant value in business models	Business are based on **multiple values**; financial alongside environmental and social values (see also section 2.0)
Supply chain	Companies improve efficiencies **in isolation** of each other	Companies work together along the supply chain; **risk and benefits are shared** upstream and downstream
Transaction	Transactions emerge in **B2B or B2C markets** with money as medium of exchange.	**New market segments** arise in which consumers interact with other consumers (**C2C**) and in which economic agents act both as manufacturer as well as consumer (**C2B**). Money is the main medium of exchange
Success measurement	Success is measured in a **financial cost benefit analysis for the parties involved** in the transaction (seller and buyer).	Success is measured in a **cost benefit analysis** primarily based on financial value for the stakeholders involved, but which can incorporate **nonfinancial values to stakeholder and society**.

In this context, the transition to a circular business model has different financial implications for companies. These implications include among others, the increased working capital needs related to the balance sheet extension and the spreading of cash flows over time due to the retention of ownership of products by the company (i.e. leasing, "pay per use"). Table 2.8 identifies the main financial implications of circular business models.

Table 2.8 - Main financial implications of circular business models. Adapted from ING Economics Department (2015).

Circular Aspect	Implication	Impact / Result
Value added	Circular business models can produce products or services that customers value more.	Increased pricing power, revenues or competitive advantage.
Pay per use	Implementing a pay per use scheme increases the demand for working capital in comparison to a 'sell after production' business model.	Increased working capital demand, spreading of cash flows over time, increased costs for receivables management and possibly increased credit risk on clients.
Cost of materials/ production	Increased return flows of used products or materials can lower production costs and the need for working capital if virgin materials are more expensive to source.	Possible lower working capital demand and lower production costs can boost profit margins
Ownership	If producers retain ownership of products during their life cycle it provides them with strong incentives to look after these products, maintain them well and make them valuable at the end of life. From a circular point of view this has strong advantages, but it comes with increased financial obligations.	Balance sheet extension increases capital demand. Ownership also raises the question how to value goods on the balance sheet (valuation).
Asset tracking	Tracking sold products and services in order to perform maintenance over the life span or take them back at the end of the lifecycle requires knowledge about the whereabouts and conditions the product. Innovations like the 'internet of things' make tracking possible but require investments.	Increased R&D costs or investments in tracking and tracing devices.
Return flow	The return flow of products might be costly to handle	Increased transportation and handling costs.

The following subsections identify specific financial implications, based on the life cycle and the circular business model category (uphill, tophill, downhill phase).

Financial implications for uphill business strategies

The business strategies that focus on the development phase, design the products to last longer and/or be easy to maintain, repair, upgrade, refurbish, remanufacture or recycle, give much importance to innovate in processes and materials. Therefore, the main financial implications for these circular businesses are related to high technological and operational risks that may impede the finance ability of these models, especially due to:

- Technological risks due to the no performance track record linked to the novelty of processes and products;
- Operational risks due to the uncertainty about operational costs and the uncertainty about the necessary inputs and feedstock.

Here are some ways to address these challenges:

Collaborative chain financing - alignment of incentives:

Adjusting different companies within the supply chain to apply circular economy principles and make the activity economically viable requires an alignment of incentives. If the supply chain collaborates, all the companies in the chain are equipped to make the product move through the chain in multiple cycles, providing added value for the consumer and for all chain partners. For example, if companies are able to make products that are easy to disassemble and refurbish, their production costs may decrease, and they are able to offer products for lease at a lower cumulated cost to the customer than buying the product. To make this work, a collaboration between service provider, producer, product designer, and manufacturer is essential.

Supply chain finance - factoring and reverse factoring:

Supply chain financing allows businesses to optimise the cash flow by lengthening their payment terms to suppliers. This can be done through:

- Factoring: the seller of a product or service sells its accounts receivables to financial institutions to mitigate the risk of non-payment;
- Reverse factoring: this method frees liquidity for both suppliers and buyers. Financial institution is responsible of the outgoing payments from the buyer to its suppliers, ensuring this way that the supplier gets paid immediately and the buyer gets more time to pay.

Figure 2.7 represents in an easy way how supply chain finance works.

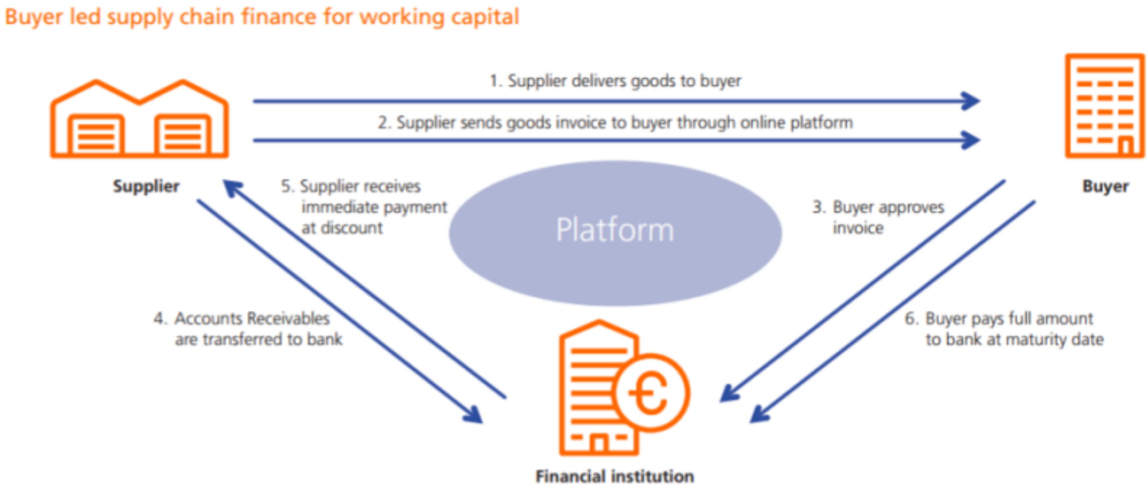


Figure 2.7 - Steps followed in a supply chain finance model (ING Economics Department, 2015).

"Circle design" is a good example to better understand these financial challenges and how to face them (see page 49).

Financial implications for tophill business models

These business models focus on the use phase by optimally using the product and preserving its added value, retaining ownership of the product and/or taking responsibility of the product throughout its lifetime. The finance model financing these circular business models usually consists of lease finance or "pay per use models"[1] and they apply to products with a predictable residual value.

Figure 2.9 presents an example to compare the cost of buying a product and the cost of leasing it in exchange of monthly payment during 20 years, from the consumer perspective.

Figure 2.8 - A comparison of the costs linked to buying a product and leasing it fully serviced from the consumer's perspective (Working Group FINANCE, 2016).

1 Different concepts are used interchangeably when talking about PSS models: finance lease, operating lease, full service lease, pay-per-use and rent. See the Glossary list to better understand the difference.

Figure 2.8 shows a graph, where a consumer buys a new product (in this case a washing machine) paying 1.500€. During the use time of 20 years, additional repairs amount to 600€. After 20 years, the consumer has to buy a new product, paying again 1.500€. Therefore, the consumer has to assume a total cost of 3.600€ during a period of 20 years to use the product. The other example shows a business model where the consumers pays a fixed amount of 15€ per month. Repair and maintenance are included in this model, which makes it more convenient for the user, while the total associated costs are the same. What is not considered in this example, is the fact that, the sale scenario incentivises companies to sell cheap products with a short lifetime. The second scenario with a fixed monthly rate, incentivises companies to build long-life products, while the investments cost of products remain low.

However, providing the service of using a product, instead of transferring ownership has financial consequences for both businesses and consumers. These implications come from the cash flow changes: increasing working capital is needed to pre-finance clients, the balance sheet grows and the residual value must be revised. Related challenges lie in product tracking and legal issues linked to the ownership. Finally, there are specific risks associated with the behaviour and creditworthiness of the customer (i.e. missed payments) (Working Group finanCE, 2016).

– In order to face these financial issues, establishing long-term lease contracts and shortened payback periods seems to be the best solution, as depicted in Figure 2.9, where revenues are analysed considering two different payback periods.

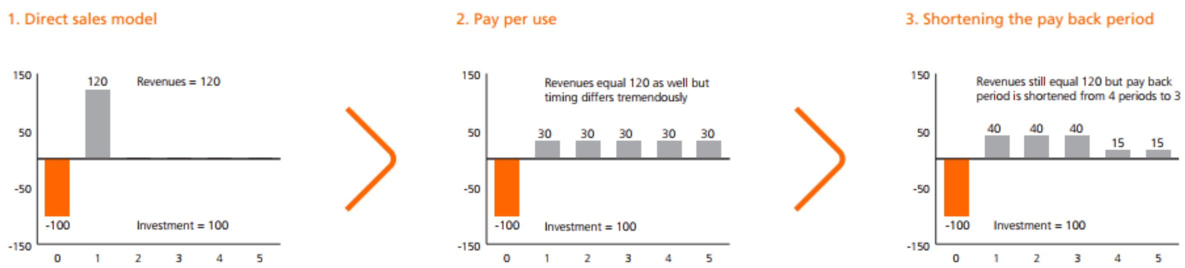


Figure 2.9 - Effects of shortening the payback period on the revenues of the circular business model (ING Economics Department, 2015).

The first graphs presents a direct sales model, where the company invests 100€ to get a revenue of 120€ directly after the sale is made, in the first month (no circular business model).

The second graph presents a "pay per use" model, where the company invests 100€ (the same as before), and gets a revenue of 30€ each month, achieving the total amount of 120€ after the 4th month (4 periods).

In order to increase the financeability of the company, this is, to get revenue before the 4th month, the company can shorten the payback period, increasing the monthly fee to be paid by the customer from 30€ to 40€ during the first months, lowering it during the last months (to 15€). This way, the revenue equals 120€ after the 3rd year, optimising the business' cash flow (3 periods).

"Circle design" is a good example to better understand uphill and tophill financial challenges and how to face them. Additionally, "BMA Ergonomics" is another good example for tophill and downhill circular business models.

CIRCLE DESIGN (Furniture) www.circledesign.nl uphill and tophill example.

"*I am too poor to buy cheap products*" – Hugo van der Kallen (CEO Circle Design)

Case description: Circle design provides the customer with designer furniture made of high-quality and durable wood and metal elements that can be added, interchanged or reshaped at any time.

Main challenges:

- High-end expensive product: circle design sells high-end products, representing an investment for the customer. As the products are designed for ease of reuse and redesign, the company has opted to, in addition to simply selling their products, has adopted its business models with options such as buy-back guarantees, operating lease and finance lease. These models serve both the company and the customer: the customer has easy access to a durable design product and the company can retain ownership of the product or otherwise ensure the return of the product for reuse at the end of the life cycle.
- Pre-financing: As lease financing requires pre-financing, this can be a problem for small companies like circle design: external financing maybe expensive, so having financial partners who support these strategic decisions is critical.
- Access to funding requires specific legal and financial knowledge. Especially for small companies this is often a challenge.

Future vision: circle design is exploring ways to print metal and plastic corners through 3D-printing technologies to optimise resource use and reduce labour costs. In addition, the more experienced and successful circle design becomes and the more products are returned to them, the higher the more beneficial renting and leasing models will become-.

Financial aspects:

In this business model ownership will eventually be transferred to the customer. Finance lease enables customers who perceive the sales price as too high to purchase the product on account. While the product in itself is still designed for circularity, the end-of-life treatment in this business model is outside the scope of the company.

- Sell with buy-back guarantee (percentage of revenue): The sale with buy-back is structured as a regular invoice where a paragraph is added that the customer can always resell the product to the seller:
- This buy-back guarantee is valid for five years.
- The minimum buy-back price is €50 per piece of furniture, but the actual price will be dependent on the state and age of the product as well as the residual value of the material and labour.

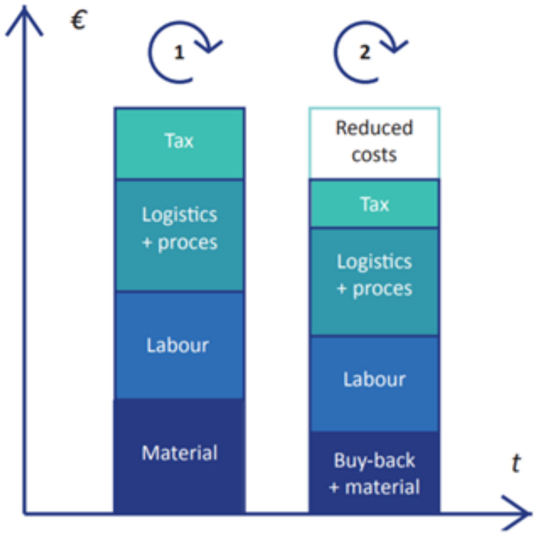


Figure 2.10 - Saving material costs and taxes in the 2nd Life Cycle

- Selling products: at the moment, direct sales comprise the majority of total revenues. However, in the future a combination of different models (see below) will replace the sales model. The selling price of designer furniture is relatively high, meaning that purchase will be too expensive for some customers, and leasing of the product will be the preferable option. The advantages are clear: the customer receives a guaranteed price for unwanted 'waste' furniture and circle design can produce new designer furniture of the same quality but saves material and labour expenses.
- Operating lease: circle design retains ownership of the product and is responsible for its preservation and maintenance; 10% is added to the sales price for this maintenance. The lease is based on the annuity model with financing costs of 7%, of which 3.5% is the interest rate and 3.5% covers administration and processing costs. After the five-year lease period, the product is fully written off and paid for by the customer. If the customer continues leasing the product after this period, then this cash flow is, with the exception of maintenance and preservation costs, pure profit. The customer is able to buy the product within the lease period for the original price minus the amount of depreciation that has already been paid by the customer, or through finance lease.
- Finance lease: circle design takes responsibility for the preservation and maintenance of the product during the two-year lease period. For maintenance and preservation of the product 10% is added to the lease sum. The lease is based on the annuity model with financing costs of 7%, of which 3.5% is the interest rate and 3.5% covers administration and processing costs. After the lease period, the product is fully written off and paid fully by the customer and ownership is transferred to the customer. If the customer fails to pay the regular lease fee, the piece of furniture is claimed.

Source: (Working Group FINANCE, 2016).

Financial implications for downhill business models

Finally, these business models focus on the after-use phase of products (i.e. extracting raw materials from waste). In general, as the costs associated with implementing these business models are much lower than the costs associated with creating a product from virgin resources, no specific financing problems have been found for this business model category. However, two specific concepts may increase the financial feasibility of this business models: second hand markets and forecasting the residual value.

Second hand markets: It is important that second hand markets fulfil some characteristics:

- They are large enough and liquid (i.e. several sellers and buyers);
- There are transparent ways to match supply and demand (i.e. through online platforms, auctions or intermediaries);
- Prices are relatively stable.

> A good example for second hand markets is the buyback scheme for used tiles offered by the company Interface. They clean the tiles in their factory and sort the tiles according to quality. Used tiles are sold in second hand markets for 6 to 8 times their recycling value. This way, much value is retained from the used tiles and recycling is postponed. Interface is exploring the possibilities to set up a warehouse for used carpet tiles in the Netherlands, to match supply and demand, either on a company or industry level.

Consideration of the "end of life value", the residual value:

Forecasting and considering the residual value of a product can increase the financial feasibility of circular businesses. For instance, businesses designing their products for easy disassembly, will reduce disassembly costs at the end of life of the product, facilitating that most of the valuable resources can be retrieved. This has a clear positive impact on businesses' financial accounting. In this sense, if financers develop and apply more accurate forecasting models and tools to predict the residual valueof the products, businesses would more easily consider this positive residual value in their financial model. See "BMA Ergonomics" example to better understand tophill and downhill circular business.

BMA Ergonomics (Furniture) www.bma-ergonomics.com

Case description: BMA ergonomics ("BMA") is a chairs manufacturer, who sets out the following goals:

- Social purpose: chairs to improve the productivity of people by reducing fatigue and discomfort.
- Environmental purpose: designed for easy disassembly, as a means to improve the efficient use of resources and the circularity of the business model.

Characteristics of the CBM:

- Pay per use: The service 'sitting' or the use of the chairs.
- Circle the chair: Clients have to return the chairs to BMA after the use to enable reuse.

This CBM offers chairs (rental) for a 10-year period. Customers pay a fixed fee for the first five years and a fee of nearly 50% lower for years 6 to 10. In year 5, BMA offers on-site maintenance and repair services at no extra cost. To close the loops on the chairs and its components, at the start of the contract the customer pays a deposit, which is refunded when the chairs are returned, whether this is during or at the end of the contract. In addition, if the customer wants to decrease (or increase) the number of chairs rented, up to 10% decrease is done at no extra costs, resulting in more flexibility and value for the customer.

Benefits for BMA:

This circular model offers several opportunities: There is near certainty that chairs will be returned, which can be made refurbished and reused at relatively little additional costs. This also lowers the cost of the sold goods. The relationship with the client is long term, which strengthens the customer relationship and creates the opportunity for recurring income.

Financial implications: A comparison of linear and circular models

The effects on the gross margin and the working capital differ depending on the business model applied.

- Gross margin: The shift from selling to renting has a big impact on the gross margin. In the linear model the margin is steady, while in the circular model the gross margin starts low and increases as time goes by, meaning that the production costs are not covered by the first rental payment. But eventually, the gross margin of the circular business model is higher than the linear one (see Figure 2.11).

- Working capital: Pre-financing the production and purchase of chairs in the circular model increases the working capital demand. In the CBM the working capital position is negative for the first years indicating a financing need. However, if the deposits that BMA receives are considered, there are more current assets than liabilities and no need for financing occurs. As these deposits have to be paid back to customers when returning chairs, the questions arises if this money can be used by BMA to finance its working capital, or if this money is reserved for customers and therefore 'trapped' and not at BMA's disposal (see Figure 2.11, right graph).

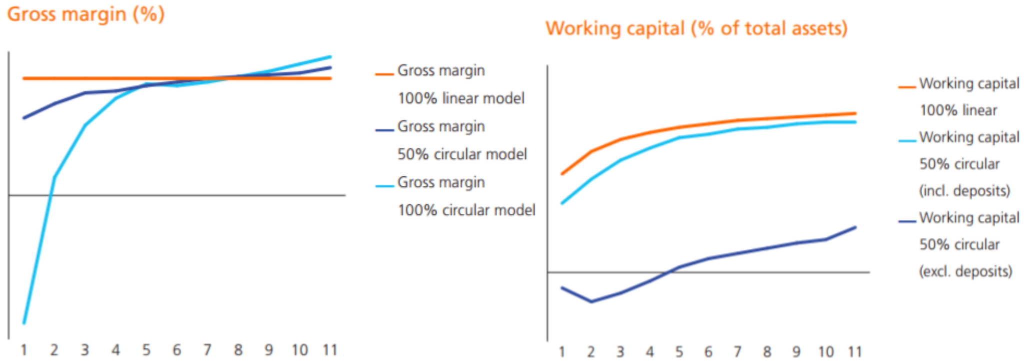


Figure 2.11 - Impacts of circular and linear business models on gross margin and working capital

Financial consequences for customers: Both BMA and customers will benefit from this model. Figure 2.12 compares the total cost of ownership of a chair during the 10 years, to the costs of the circular model, where the customer pays an annual fee and a deposit, which is returned at the end of the contract. When the customer buys the chair, many costs arise that may not be recognized immediately such as depreciation, maintenance and financing costs.

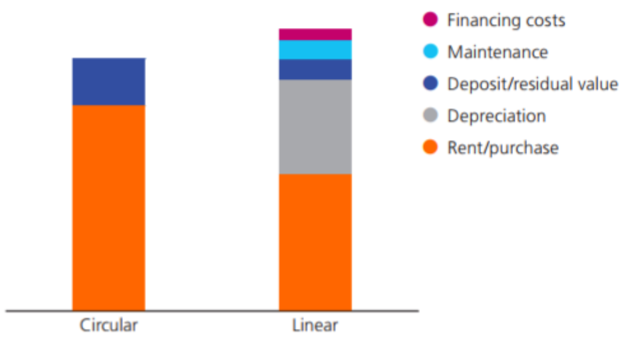


Figure 2.12 - Reduction of costs when shifting a circular business model

Taken all costs into account, the "circular" chair is not only cheaper, it also decreases the amount of work and time spent by the customer to take care it.

Assignment 2.3 – Identify economic benefits and financial implications

Once you have done assignments from section 2.1 and section 2.2, you already may have drafted a possible circular business model. Select one circular business model of your choice and identify the following concepts:

1. Economic benefits on the basis of the value capture opportunities
2. Related financial implications when financing the model
3. Possible solutions to minimize the identified financial implications

2.3 The conceptualisation of business models

2.3.1 Definitions and concepts

A business model (BM) describes the functioning of a firm, especially focusing on the specific nature of how profits are generated. There are varying definitions on what a business model constitutes. One of the most widespread definitions comes from the book "Business Model Generation":

A business model describes the rationale of how an organization creates, delivers and captures value. (Osterwalder & Pigneur, 2013).

There are a number of concepts, which further define individual elements of a BM. Most commonly known is the classification by Osterwalder and Pigneur within the Business model canvas, introduced in the following section. Table 2.9 also provides the wordings of other notable frameworks. The table shows that the general structure of a BM remains similar, throughout all the definitions, differentiating between four different pillars.

Table 2.9 - Elements of a BM from different sources

From the definition	Osterwalder & Pigneur (2013)	Boons & Lüdeke-Freund (2013)	Frankenberger et al. (2013)
Create value	Value proposition	Value proposition	What? – the value proposition
Create value	Key activities Key resources Key partners	Supply chain	How? – activities, processes, resources and capabilities
Deliver value	Customer segments Channels Customer relationships	Customer interface	Who? – customer segments
Capture value	Cost structure Revenue streams	Financial model	Why? – revenue model

To further understand what a business model is, the following clarifications might be helpful (Mentink, 2014):

– BMs are models of a company, and not of an entire sector or industry. This also means that companies might apply a number of different BMs for different products or customer segments.
– BMs represent an abstract level and don't explain details of a company.
– BMs are systems of interrelated components. If one component changes, others often have to change as well. E.g. a new product (value proposition) might require new partners.
– BMs are not business strategies. Strategies are plans to create and defend a unique and valuable position in the market, while BMs are a set of choices to carry out the strategy. Therefore strategies are dictating the field of possible BMs.
– BMs are not business plans, which are written documents containing the goals of a business, the methods to achieve them and the timeframe of achievement. They are often required to obtain a bank loan or other financing.
– BMs are dynamic and change over time as they are under constant pressure to change due to market pressures.

2.3.2 The nine elements of the business model

This chapter builds on the concept of the Business Model Canvas (BMC), as it constitutes a very most widely used framework. The BMC is strategic tool for deriving BMs. Possible aims of using the Canvas are:

– Understanding one's business better;
– Differentiate a business against its competitors;
– Understanding current weaknesses;
– Analysing the scalability of a BM;
– …

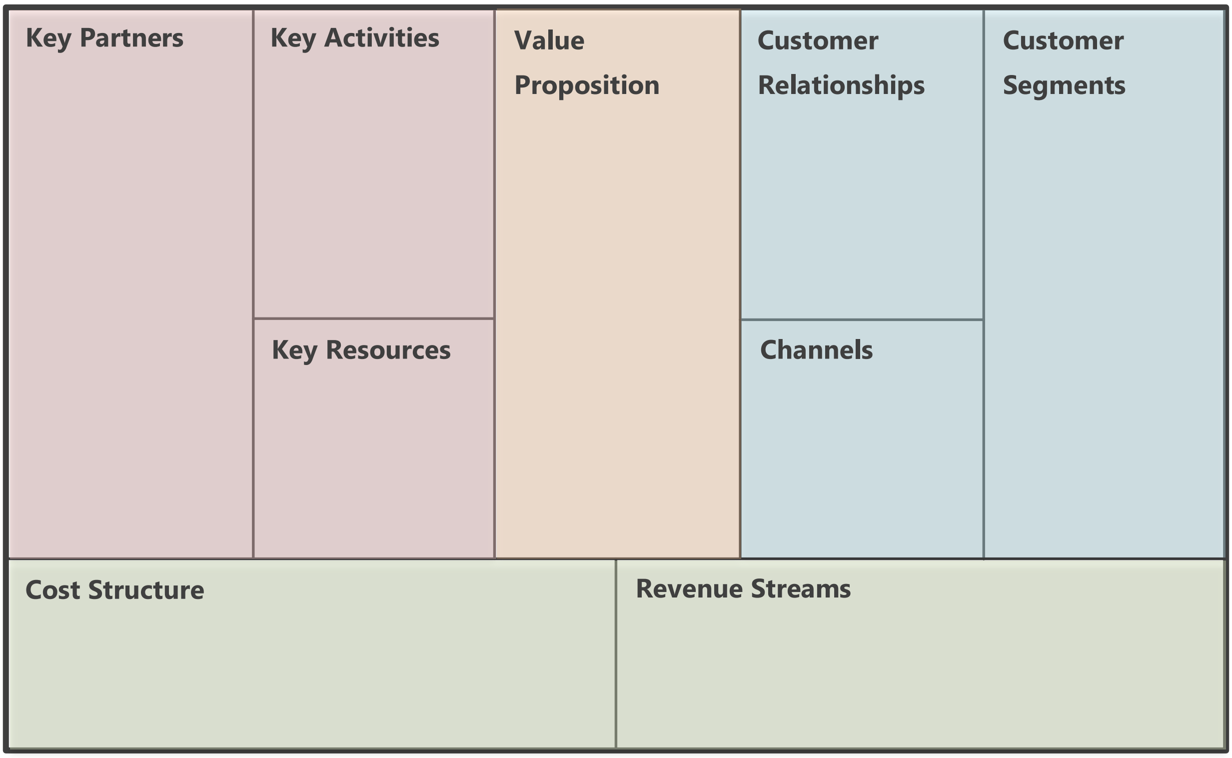


Figure 2.13 - Business Model Canvas. Adapted from Osterwalder & Pigneur (2013).

Within this chapter the canvas and its elements are mainly used to understand and analyse current "linear" BMs and understand the opportunities and challenges of establishing more "circular" BMs. To do so the contents start with a description of the individual canvas-elements. Further describing the meaning of each building block of the Canvas also shows the relationship of the elements to each of the BM-Pillars (Frankenberger, 2013) as well as helpful questions guiding the use of the canvas (Osterwalder & Pigneur, 2013).

Table 2.10 - Description of the elements of a Business Model Canvas

BM pillar	BM element	Description	Related questions
What?	**Value proposition**	Describes the bundle of products and services that create value for a specific customer segment. (e.g.: newness, design, price, brand, sustainability, performance, convenience, usability, etc.)	What value do we deliver to the customer? Which customer problems are we helping to solve? Which customer needs are we satisfying?
Who?	**Customer segments**	Defines the different groups of people or organizations an enterprise aims to reach and serve. (e.g.: mass market, niche market, segmented, diversified or multi-sided platforms)	Who are our most important customers? For whom are we creating value?
	Channels	Describes how a company communicates with and reaches its customer segments (e.g.: web sale, stores, partner stores, wholesale, sales force, etc.)	Through which channels do our customers want to be reached? Which channels work best?
	Customer relationships	Describes the types of relationships a company establishes with specific customer segments (e.g.: dedicated personal assistance, self-service, automated services, co-creation, etc.)	What type of relationship does each of our customer segments expect us to establish and maintain with them? How are they integrated with the rest of our business model?
How?	**Key activities**	Describes the most important things a company must do to make its business model work (e.g. production, sales, assembly, platform/network, etc.)	What Key activities do our Value propositions / Channels / Customer relationships / Revenue streams require?
	Key resources	Describes the most important assets required to make a business model work. (e.g.: physical, intellectual, human, financial)	What Key Resources do our Value propositions / Distribution channels / Customer relationships / Revenue streams require?
	Key partners	Describes the network of suppliers and partners that make the business model work (e.g.: strategic alliances, joint ventures, etc.)	Who are our Key partners? Which Key Resources are we acquiring from them? Which Key activities do they perform?

Why?	**Cost structure**	Describes all costs incurred to operate a business model. (e.g. cost-drive, value driven, fixed costs, variable costs)	What are the most important costs inherent in our business model? Which sectors are most expensive?
	Revenue streams	Represents the cash a company generates from each customer segment (e.g.: asset sale, usage fee, subscription fee, renting, leasing, licensing, advertising, etc.)	For what value are our customers really willing to pay? How much does each Revenue Stream contribute to overall revenues?

2.3.3 The Business Model Canvas (BMC)

The individual elements of the canvas relate and influence each other. Changing the "variables" of a BM, results in effects on other elements, e.g. focusing on different customers segments might require a change of the value proposition. The need of reused materials (key resources) requires new sources in the value chain (key partners) and might also change the associated costs (cost structure).

The BMC elements can be divided into backend and frontend-elements (see Figure 2.14). The Frontend summarizes the "customer-facing" parts of the BM containing the customer relationships, the customer segments and the channels. These are together responsible for creating the revenues of a company.

On the other hand, the backend of the BM is responsible for "making the frontend happen" by combining its key resources with its key activities and key partners. These three elements structure the costs of the BM.

The back- and frontend of businesses are not only separated within the BMC model, but also often geographically. For example: labour extensive products are often produced where the related costs are low (backend), while they are marketed and sold (frontend) in locations where the spending capacity is sufficiently high. Back- and frontend are also often distinguished by the terms "product" on the left side and "market" on the right side.

The back- and frontend intersect within the value proposition, which results from both the potential of the inputs on the "product" side and the potential recipients of these on the "market" side. Other than the differentiation of the two sides of the business model, Figure 2.14 shows how the elements relate to each other. This is not to say that the graphic is able to provide a complete overview of the interconnectedness of canvas elements, but it further underlines that the adjacency of the different elements is far from random.

In general, the BMC is a qualitative tool, which presents a loose framework to organise and describe the inner workings of a business. How a business is described, very much depends on the users and their viewpoints. This also means there is no "right" example to showcase its application., which is why we do not want to add examples of filled out BMCs in this chapter. However, we can refer to the website of Vizologi, which collects examples of filled out BMCs: https://vizologi.com/free-business-model-examples/. The site offers a database of user-generated BMC profiles of different companies, which helps to understand the logic and strengths of the BMC-framework.

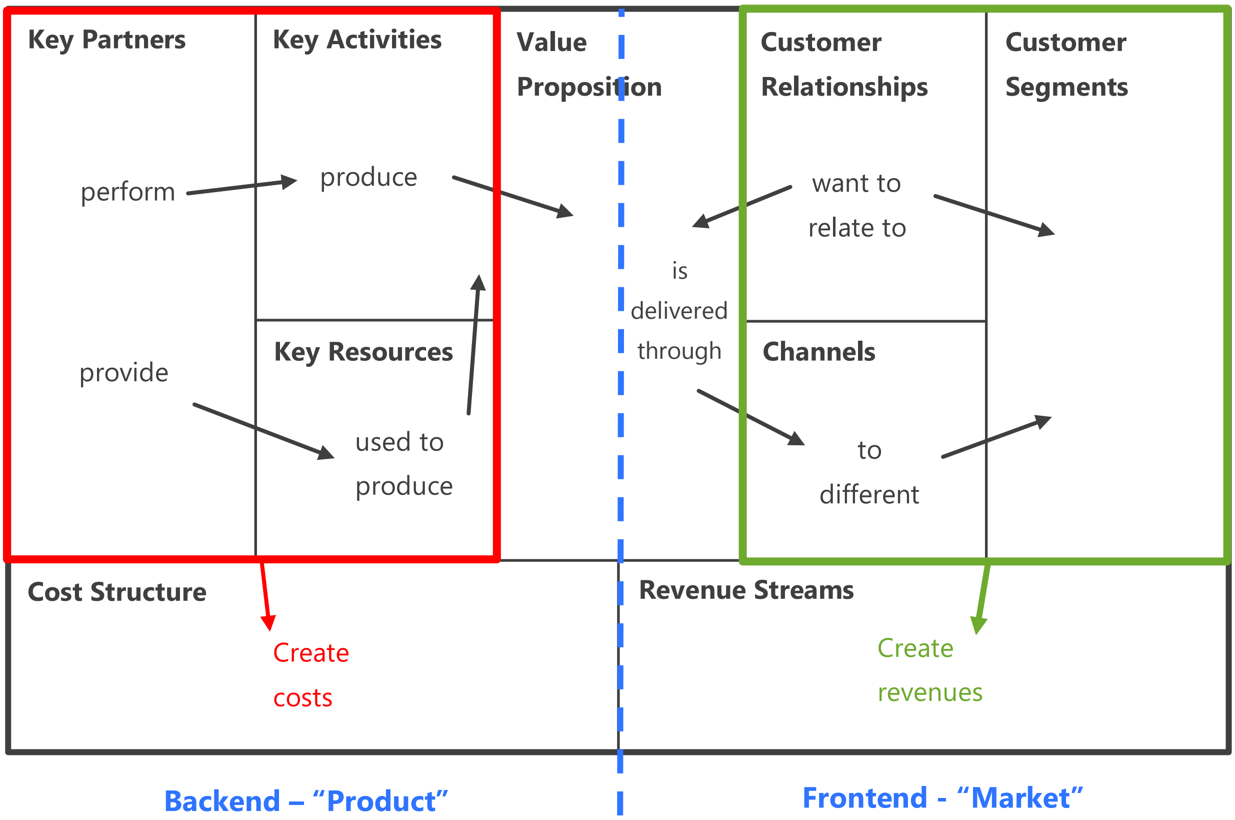


Figure 2.14 - Relationships and dependencies of Canvas elements. Adapted from Mentink (2014); Osterwalder & Pigneur, (2013).

2.3.4 Zooming out – the business model environment

Business models don't exist in a vacuum but are rather emerging from outside conditions within a certain environment. This section summarizes these forces into four categories and explains them within the context of a circular economy and the BMC.

On the backend of the canvas are the **industry forces**. These forces summarize the conditions provided by actors within the respective industry, such as partners in the value chain, competitors, incumbents and technology providers. Within the context of a CE, the latter - key technologies - are often mentioned as important drivers for change. keywords such as Big Data, Blockchains, BIM

(Building Information Modeling), IoT (Internet of things) and 3D-Printing are often cited as important enablers of a CE. Another important force is the transformation to a cooperative Value chain.

The frontend is influenced by **market forces**. These summarize all issues connected with market conditions and the customers' expectations. The latter are often an important driver for a more circular behaviour. Customers continually demand more transparency related to the backend of a BM, e.g. the products' origin, the related labour conditions, the implied carbon footprint, the resources used, etc. In that sense green public procurement often also plays an important role, especially within the furniture and construction sectors.

The financial model (cost structure and revenue streams) of a BM exists within certain **macroeconomic forces**. These describe the factors such as the current condition of the global market and the economic infrastructure. Within a CE the relationship to commodity and resource prices is especially noteworthy. Due to factors such as rising living standards, longer life expectancy and global population growth especially the costs of finite resources are expected to rise. This is one of the important drivers for keeping them in loops and adopting a more circular behaviour.

Besides macroeconomic, market- and industry-related forces, there are also **key trends** shaping the BM. The term summarizes different societal developments, such as cultural, technological, regulatory and cultural trends which are mentioned throughout a number of chapters.

Figure 2.15 shows the business model environment (Osterwalder & Pigneur, 2013), while Fehler a list of forces shaping the circular economy , building on the same basic frame of reference (based on Ellen MacArthur Foundation & SUN, McKinsey Center for Business and Environment, 2015; Kok et al., 2013; Mentink, 2014).

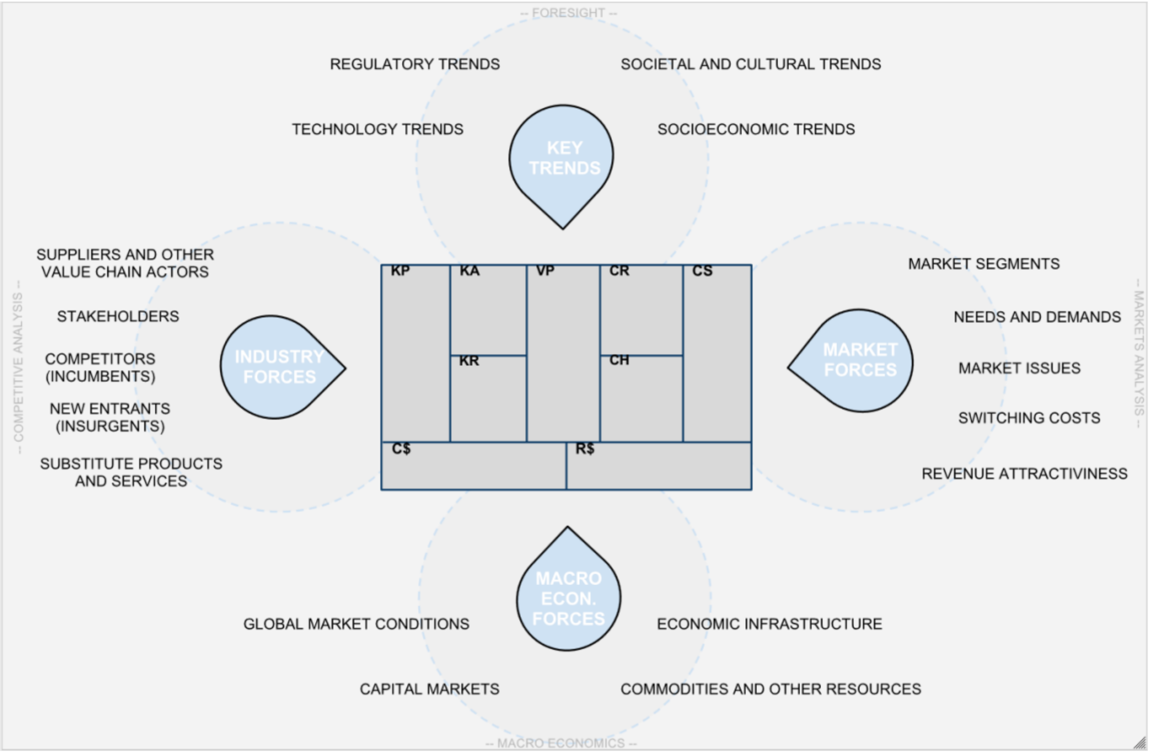


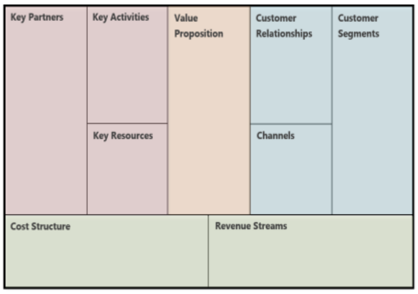
Figure 2.15 - Outside forces shaping the BM (Osterwalder & Pigneur,, 2013, p. 201).

Key Trends

- Climate Change
- Environmental degradation and pollution
- Resource Depletion
- Environmental Regulation
- Emerging Key Technologies (Digitization, IoT, Big Data, etc.)
- ..

Industry Forces

- Industry Standards (e.g. ISO 14000)
- Supply Risk of scarce resources
- Value Chain cooperation
- Extended Producer Responsibility
- Energy efficiency and material productivity
- Environmental Stewardship Schemes
- CSR Practices and Reporting (B-Corporations, GRI, etc.)
- Standardisation
- Innovations
- ..



Market Forces

- Green Public Procurement
- Socially responsible Consumption
- Demand for sustainable Products and Services
- Eco-Labelling and LCA
- Customer Loyalty
- Employment
- Collaborative Consumption and "Access over Ownership"
- ..

Macroeconomic Forces

- Rising Commodity and Resource Prices
- Waste Handling Costs
- Taxation and Subsidies
- Resilience to Global Market Conditions
- Accounting for Externalities
- Geopolitics and political instability
- ..

Figure 2.16 - An incomplete list of forces CE-related forces shaping new business models

Assignment 2.4 – Outlining the business model environment

Assignment 2.5 will aim to define a new circular business model. To start this process, choose an industry of your choice and think about the outside forces shaping business models within this industry. This should especially relate to CE and sustainability. Use the Framework of the Business Model Environment with the four categories:

- Industry forces
- Market forces
- Macroeconomic forces
- Key trends

2.3.5 Limitations of the Business Model Canvas framework

This section shortly discusses the limitations of the Business model canvas framework and introduces a few adapted models, which were developed to enhance the framework.

The BMC framework has a strong emphasis on the financial viability and profitability of business models. On the other hand, negative social or environmental effects are outside the defined boundaries of the model and therefore not sufficiently considered. They are treated as so-called "externalities".

The following (incomplete) list contains various criticisms of the concept related to sustainability (Upward & Jones, 2015):

- **Stakeholders**: The framework is mainly focused on customers and how to deliver "value" to them. Other stakeholders and their interests and needs are excluded. Sustainability requires the integration of a wide range of stakeholders;
- **Value proposition**: The framework conceives value as only being created for customers. Therefore noncustomer wishes from other stakeholders are outside the framework. Furthermore it considers only the positive value without thinking about negative effects of the value proposition;
- **Environmental impacts**: Impacts such as climate change, ozone depletion, effects on biodiversity, etc. are only included in the model if there are financial costs associated to them;
- **Resources**: The use of (finite) resources is not accounted for outside of the costs related to them. This is especially relevant in relation to the ideal of a circular economy;
- **Social impacts**: The production of customer value can result in societal externalities which are not conceptualized in the framework;
- ...

Various models have been introduced to expand the model of the BMC (e.g. by adding additional elements or layers) to address these shortcomings related to sustainability. Examples include the following tools:

The **Sustainable Business Model Canvas** (SBMC) introduces two additional fields below the cost structure and revenue streams: eco-social costs and eco-social benefits. With these, the aim is to think about ecological and social consequences of the business activity and address the three dimensions of sustainability. However, we believe that this extension is not sufficient, to integrate sustainability holistically into the BM as sustainability essentially relates to all fields.

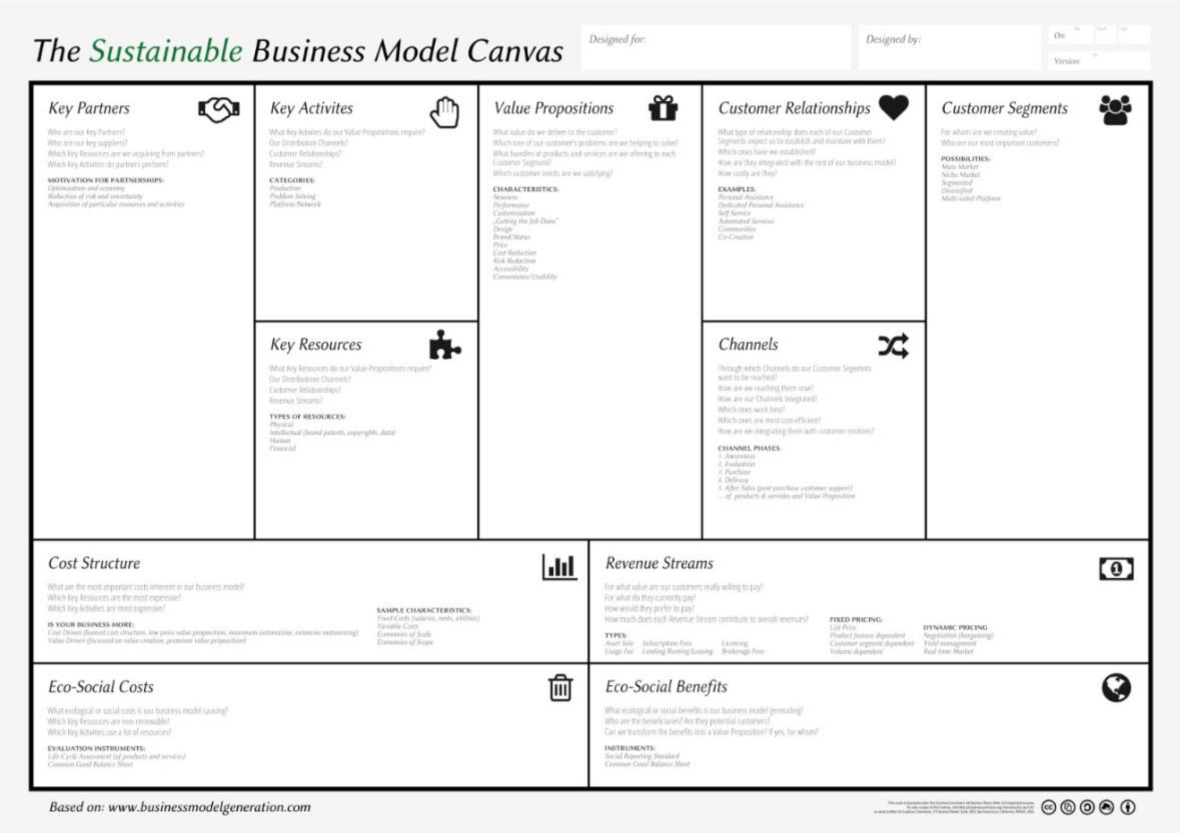


Figure 2.17 - The Sustainable Business Model Canvas. Source: https://www.case-ka.eu/

The **Triple Layered Business Model Canvas** (TLBMC) provides a tool specifically designed to apply the triple bottom line perspective (social, environmental and financial considerations) to the BM design process. It expands on the original BMC by adding two additional layers with the same canvas structure concerned with the environmental and social impacts. For example: While the "Key resources"-field on the financial layer in the TLBMC (=the original BMC) is mainly concerned with the costs of resources, the environmental layer field named "Materials" describes the effects on the environment of using them, and the social layer relates to the well-being of the employees. Advantages of the tool are its vertical and horizontal coherence of and the direct relationship to the layers of sustainability (Joyce & Paquin, 2016).

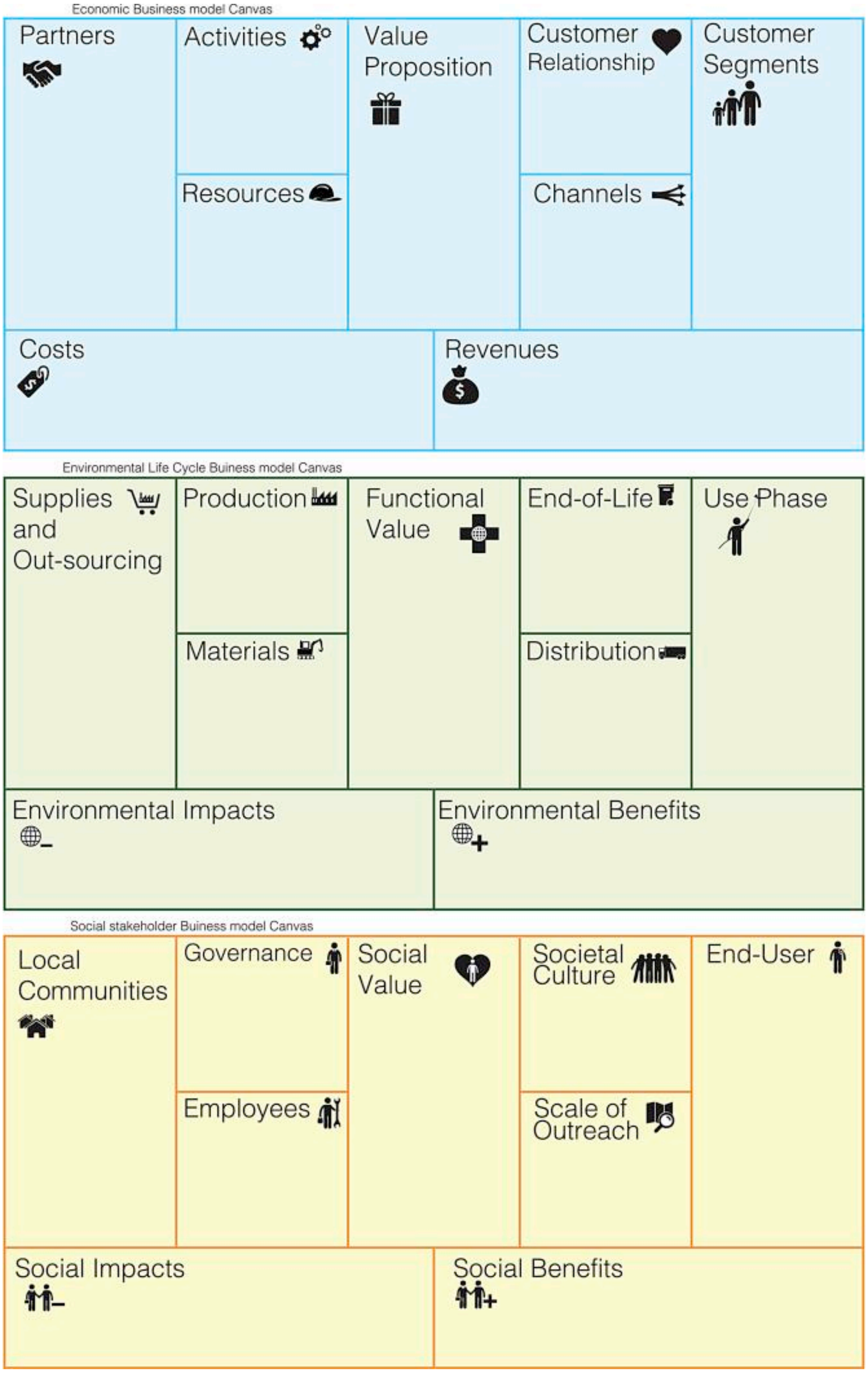


Figure 2.18 - The economic, social and environmental layer of the TLBMC. Source: Joyce & Paquin (2016).

The **Circulab board** was particularly designed to address the challenges of the circular economy. It rearranges and merges different elements of the BMC and introduces new ones within four different groupings (activities and partners, resources, value proposition and users, Distribution and upcycling). It additionally focuses on positive and negative impacts (environmental and social) and relates these to the four groupings. With the focus on circularity, the model differentiates and distinguishes between different resources and also encourages to think about business opportunities by using "inner cycles".

Figure 2.19 - The Circulab board. Source: http://circulab.eu/en/tools/.

Within this chapter the framework of the original BMC is going to be used, while trying to expand beyond the financial focus of the model and integrate social and environmental concerns wherever possible and necessary. This has the advantage that the well established structure and logic of the BMC can be uses, while highlighting elements where adoption and a broader understanding is needed. This approach is similar to the Triple layered BMC, but rather than using a tool with three different layers, the goal is to use the Canvas as it is, while broadening the meaning of each element.

2.4 From linear to circular business models

This section provides a theoretic structure to the process of changing the business model, as well as a practical tool to put the theory into practice. To do so, we introduce the 4 I-framework of Business model innovation and link the chapters contents to the different steps. Secondly, we show how the CE Strategist tool (available under: tools.katche.eu), fits into this process and describe its application.

2.4.1 The 4I framework of BM innovation

Figure 2.20 provides an overview of the 4I-Framework for business model innovation, a widely used tool, which structures the process into the following 4 different phases, each with unique challenges (Frankenberger et al., 2013):

- Initiation – analysing the ecosystem
- Ideation – generating new ideas
- Integration – building a new business model
- Implementation

It has to be emphasized that the process is iterative in its nature, meaning that in practice there are often multiple steps back and forth in between the different phases. The first feedback loop is described as the external fit, referring to changes in the business model environment (e.g. resource scarcity, new technologies). The second feedback loop, described as the internal fit, refers to the adaptation of internal resources, which the aspired new business model requires. The third feedback loop refers to adaptations made, triggered by implemented new business models (Frankenberger et al., 2013).

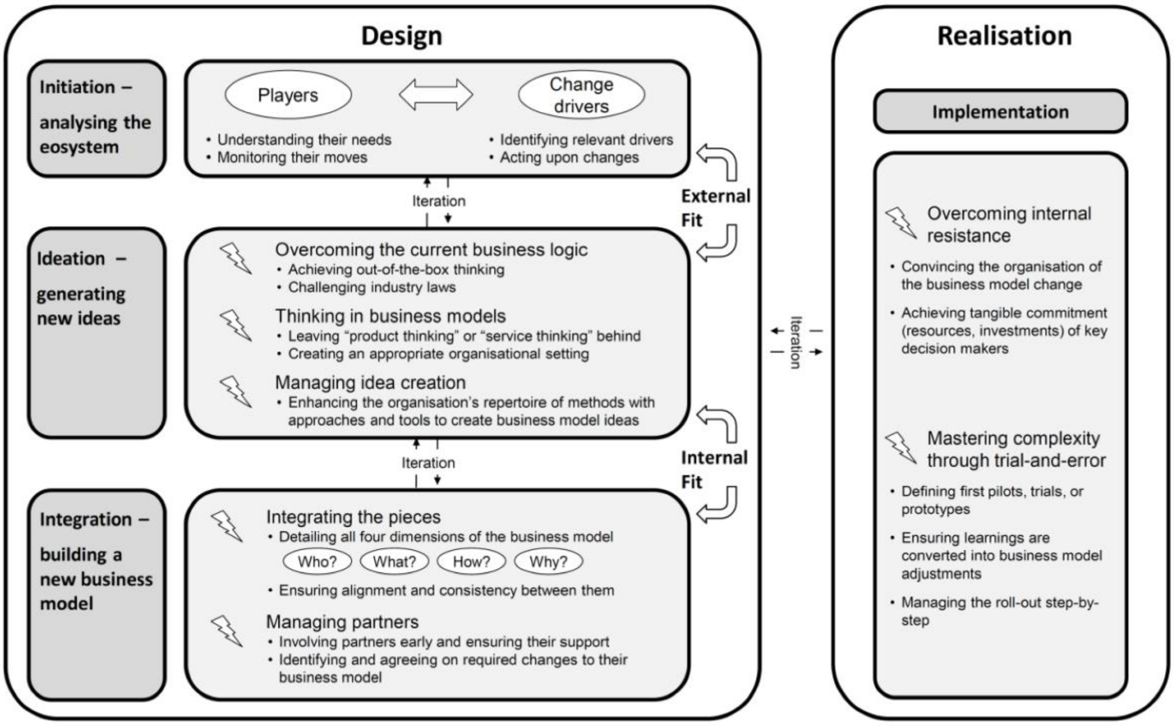


Figure 2.20 - The 4I-Framework for business model innovation (Frankenberger et al., 2013).

This chapter covers the first three phases of the process, summarized in the figure as BM Design. Its theoretical contents aim to provide the needed background knowledge for adopting a CBM, while the assignments are structured along the 4I-Framework for innovation, within the specific challenge of adopting sustainable and circular business strategies.

2.4.2 The CE Strategist tool and the BM innovation process

The goal of the CE Strategist tool (available under tools.katche.eu) is that it provides ideas and inspirations along the whole process of business model design in the context of a CE. Table 2.11 links the steps of the applying the tool as well as the assignments throughout the chapter to the phases of the innovation process.

The tool targets product designers and product developers – professionals and students alike. The examples in the tool relate specifically to the construction and furniture industry, but the logic can also be applied to other production sectors. To use the tool the user should have a specific product system in mind (company, market, region, customers, production method, etc.).

Table 2.11 - The phases of Business model innovation and the links to the assignments, tools and frameworks of this chapter

Phase	Characteristics and challenges	Assignments in this chapter	Steps in the CE Strategist
Initiation – analysing the ecosystem	Understand change drivers, stakeholders and their needs	Thinking about value capture opportunities Getting acquainted with circular strategies	Step 1- Describe the current business model
Ideation – generating new ideas	Overcoming the current **linear** logic Thinking in business models Create new **circular** business ideas	Financial implications of circular strategies Outlining the business model Environment	Step 2 - Evaluate opportunities of the CE Step 3 – Choose fitting CE strategies
Integration – building a new business model	Integrating all pieces Coordinate partners	Drafting a circular business model	Step 4 - Define your CE business model
Implementation - realisation	Overcome internal resistance Master complexity through trial and error		

As a first step the tool offers to describe the current business model with the traditional framework of the BMC. Alternatively, a business model which is typical within the industry is described. This step can also be skipped.

The second step revolves around the identification of opportunities. Dependent on the current business model and the products' characteristics, different options emerge. The tool covers the 11 predefined Circular business strategies which were already covered in section 2.2 relating to all product life cycles (see also Table 2.3 - Table 2.5). To see which strategy fits best within the investigated context, the tool offers an evaluation scheme.

Dependent on this evaluation of the product system, the tool then suggests in a third step the best fitting strategy. From there, the user can choose which strategies should be followed-up within a detailed definition of a new business model. Users are encouraged to follow up more than one strategy. For example, are the uphill strategies, are often the enablers of a value capture in later phases. For example, products need to be designed a certain way in the Uphill phase (modular, accessible, separable, etc.), to enable an efficient life extension during the use phase.

Step 4 is concerned with a detailed definition of a new CE-oriented business model. The user is guided back to the canvas to redefine the business model. To help this process, the tool looks at the relationship of the strategies with the elements of the canvas. E.g. How might Remanufacturing relate to the channels of the business model? How do result-oriented product-service systems change the value Proposition? The tool looks at these questions and provides prefilled items in the new Canvas; e.g. The strategy remanufacturing requires certain *return channels* for used products. The strategy will also open up the possibility of a new *re-sale channel* for remanufactured products. Result-oriented Product-service system typically shift the focus of the value proposition more in the direction of the products' *performance*, which is now at the core of the business model.

Figure 2.23 shows some typical influences of the defined circular strategies on the individual BMC fields. In this last step the user how these influences are addressed in the new business model. The results also allow for a comparison of the two different BM variants.

The previous section already mentioned the limitations of the BMC model. The main criticism relates to the narrow focus of the financial viability of BMs. The result often is that environmental and social concerns are not sufficiently integrated in the design process.

On the other hand, the BMC is very widely applied in the business community. To draw attention to matters of sustainability and circularity, we therefore enhance the BMC and the meaning of the individual elements by additional guiding questions. The questions *in italics* (see Figure 2.22) aim to integrate questions of sustainability and circularity into the BM elements.

The following two Business model canvas templates can be used for the last assignment. Figure 2.22 provides a BMC template with guiding questions for each field (see also section 2.1).

In general terms would especially emphasise the following points, when designing a circular BM:

- With the **Value proposition** at the very heart of every BM, the all questions related to sustainability and circularity should be integrated here. This means that measurable social, environmental and long-term economic value propositions should be defined. The results from using the Value mapping tool in assignment 2.2 should be helpful here. The Value proposition should also at least consider the effects on other stakeholders than customers.
- **Channels** need to be understood broader in the context of a CE. With the focus on resource loops the possibility of reverse logistics needs to be considered here. Secondly, one should focus on the potential of inner loops rather than material recycling, such as repair, remanufacture, refurbishing, etc.
- **Key partners** are very important to consider within CBM design, as the CE emphasises on collaboration in the Value chain and the use of new technologies (e.g. asset tracking, internet of things, Big data, Apps, etc).
- Naturally, **Key resources** is also one of the essential fields. The focus here should be on the impact of the materials used (especially non-renewables), their substitutability and the potential to recapture them.
- The **Cost structure** and **Revenue streams** must be understood more broadly in terms of sustainable value (see also Figure 2.3). Therefore these fields must also consider effects such as resource depletion, waste, CO2-footprint and social concerns, such as employee happiness and human health.

Assignment 2.5 - Drafting a circular business model

Use the Business model canvas template to draft a circular business model. Try to integrate the gathered information and ideas from the assignments before.
As supporting tools you can draw inspiration from the circular strategies and its examples. You can also use the CE Strategist tool (available under tools.katche.eu) and the additional resources provided in this section.

Key Partners

Who are our Key Partners?

Which Key Resources do we acquire from them?

Which Key Activities do they perform?

Can we integrate our partners in the value chain to enable more circularity?

Are there emerging technologies which could enable a more circular BM?

Do we need new partnerships for our VP?

Key Activities

What Key Activities do our Value Propositions / Channels / Customer Relationships / Revenue Streams require?

How can we align our activities with our enhanced, sustainable VP?

Key Resources

What Key Resources do our Value Propositions / Channels / Customer Relationships / Revenue Streams require?

What natural, energy and technological resources? How can these (or others) be used more sustainably?

Value Proposition

What value do we deliver to the customer?

Which customer problems do we solve?

Which customer needs are we satisfying?

How can the environmental and social VP be measured? (e.g. Life Cycle Assessment, Social Reporting)

What value is created (or destroyed) for other stakeholders than the customers?

How do our customers use our product? What happens at the end of life? Do they need to own the product? What is the customers "job to be done"?

Customer Relationships

What type of relationship do each of our customer segments expect us to establish and maintain with them?

How are they integrated with the rest of our business model?

How can our sustainability efforts be communicated to our customers and other stakeholders?

Channels

Through which channels do our customers want to be reached?

Which channels work best?

How can value be captured after the use phase (repair, refurbish,..)? How could reverse logistics be designed to support that?

Customer Segments

What are our most important customers?

For whom are we creating value?

What other stakeholders are affected by our VP negatively and how can the effects be mitigated?

Cost Structure

What are the most important costs inherent in our Business Model?

Which sectors are most expensive?

What ecological or social costs is our business model causing and how can these be mitigated?

What waste is produced?

Revenue Streams

For what value are our customers willing to pay?

How much does each revenue stream contribute to overall revenues?

How can revenues remain high, while using fewer physical resources?

How is success measured other than in financial profits (long-term viability, employee happiness, environmental performance, etc.)?

What ecological or social benefits is our business model generating? Can we transform the benefits into a Value Proposition? If yes, for whom?

Figure 2.21 - BMC for circular business models Adapted from Smith-Gillespie (2017); Upward & Jones (2015); Joyce & Paquin (2016)

Key Partners

Technology – partners providing key technologies (e.g. logistics, asset tracking, IoT applications, Apps, etc.)

Circular Material Suppliers – e.g. Recycling facilities, Waste Management, Collection Systems

Reverse logistics – product, component or material recovery provided by a third party

Customer – by initiating new valuable company processes such as remanufacturing, repair, etc.

Key Activities

CE Design Strategies – strategies focusing on repair, remanufacturing, long life, upgrades, etc.

Service Provision – e.g. support, contracts, diagnostics, etc.

Reverse Logistics – product, component or material recovery executed within the company

Key Resources

Use-Phase Asset Management – tracking, managing, booking, servicing assets

Post- Use Phase Asset- Mgmt. – store remanufacture, resell products after the use phase

Value Proposition

Lower Lifetime costs – through lower prices, longer life time, lower ownership costs, additional use cases, etc.

Performance – Improving on the customers "job to be done"

Access – Improving on the availability, flexibility, range of choices, etc.

Sustainability – providing an environmental or social benefit, valued by the customer

Customer Relationships

Recurring Relationship – e.g. through updates, maintenance, repairs, add-ons, etc.

Long Term Relationship – through contracts such as subscriptions, leasing, services, etc.

Channels

Return Channel – Product Collection after first use phase

Re-Sale Channel –separate secondary use channel

Customer Segments

New Horizontal Customers – a new Value Proposition opens up access to new customer segments

New Vertical Customers – Customer segments open up, from an industry sector outside the main value chain

Cost Structure

Product Return Incentive – Mechanisms such as deposits or credits are enforced to incentivise product take-back
Labour Costs – due to services provided, specialised production, etc.
Material Costs – due to substitution, new sources, minimised use, etc.
Financing Costs – insurance cost, leasing costs, upfront investments, etc.
Manufacturing Costs – changing materials, processes, energy needs, etc.

Revenue Streams

New Sale Revenues – component, material, used product sale revenues
Bundled Product-Service Revenues – revenues from the sale of customer-owned product-service bundles
Service Revenues – from maintenance, repair, etc.
Waste as Value – revenues from waste avoidance e.g. by closed loops, longer life cycles, circular supplies, etc.

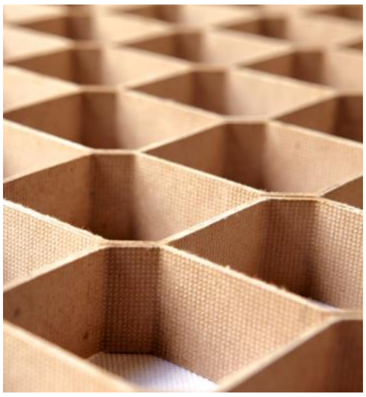
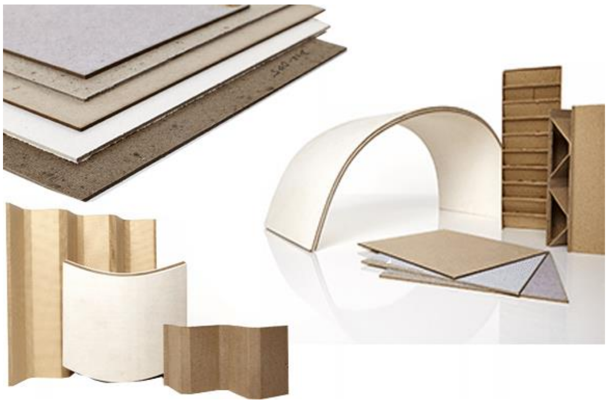
Figure 2.22 - Overview of influences of circular strategies on BMC fields. Adapted from Smith-Gillespie (2017).

2.5 Examples

Mycelium materials, by Ecovative

Description	Ecovative's core mission is to envision, develop, produce, and market Earth friendly materials, which, unlike conventional synthetics, can have a positive impact on mainly for packaging, but soon the company will also provide insulation materials our planet's ecosystem. The company has developed a biomaterial platform technology using fungal mycelium (mushroom roots) which bind together agricultural by-products (e.g. corn stalks), aiming to replace rival petrochemical plastics. At their production facility, agricultural waste particles are pasteurised, saturated with water and combined with fungal cells which grow billions of tiny fibres around the waste. The process self-assembles into any shape, growing at room temperature, in the dark and without fossil fuel inputs. A drying process to kill the organism stops the growth phase. The result is a compostable, biobased, fastly renewable, low-energy material. The company sources their production inputs from local farmers, creating additional revenues for otherwise unused by-products. Currently the material is and alternatives to wood-based MDF-boards for the construction sector. Furthermore, the company also sells grow-it-yourself material and forms.
Organization and country	Ecovative, Green Island, New York, USA
Sources	https://ecovativedesign.com https://tinyurl.com/yabou439
Images	– Tower made of grown bricks  – Lampshade Grown from Mycelium 
Image sources	tinyurl.com/yazboskc tinyurl.com/ydxpua85
Circularity approach(es)	Closing loops
Business strategy(ies)	Circular sourcing, circular design, maximising production efficiency

ECOR boards, by Noble

Description	ECOR is a composite panel, mainly used for interior furnishings. It contains no glue, harmful chemicals or other toxic ingredient and is made using only water, heat, waste fiber and pressure. It is 100% bio-based, fully made from recycled materials and at the end of life fully recyclable. The fiber is sourced from old cardboards, new papers, office waste, agricultural fibers and other waste sources. The company also actively consults potential supply chain partners, by offering to analyse their waste streams for the suitability to be used as a resource for new ECOR panels. The applications of the boards are wide-ranging, including the use as display boards, as decorative surfaces or for interior sound insulation, among others.
Organization and country	Noble Environmental Company, San Diego, USA
Sources	https://ecorglobal.com/ https://tinyurl.com/y9adoxkf
Images	 
Circularity approach(es)	Closing loops
Business strategy(ies)	Circular sourcing, circular design

Kalundborg symbiosis

Description

The Kalundborg Symbiosis in Denmark is a local partnership between eight public and private entities, which was first established in 1972. It began with collaborative agreements between a few industrial companys to share water, and take advantage of waste resources (heat, steam and gas). Over its more than 45 years of existence it grew larger, with additional members joining the network. For most of this time there was no central coordinatinating authority.

The main principle of their cooperation is that residue from one company becomes the resource of another, resulting in an efficient production requiring less resources. The following graphic gives an overview of the flows of materials, water and energy between the partners.

Organization and country

Kalundborg Eco-Industrial Park, Kalundborg, Denmark

Sources

http://www.symbiosis.dk/en/
https://tinyurl.com/y874nfjf
https://tinyurl.com/y8n2frpn

Images

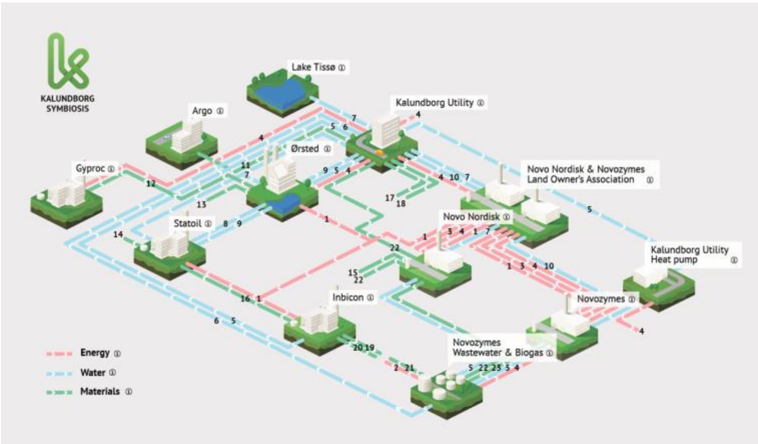


Image source

http://www.symbiosis.dk/en/

Circularity approach(es)

Narrowing, closing loops

Business strategy(ies)

Maximising production efficiency, circular sourcing

Washing machines rental service, by Miele

Description	Miele is Germanys third-largest supplier of household appliances. The company's primary revenue comes from the sale of their appliances. Their washing machines have a guaranteed functional lifespan of 20 years, where comparable products often only have an average lifespan of 10 years. Its machines are also characterised by a comparatively low energy and consumption of detergents. Miele therefore decided for a rental service of their machines and runs its own service company. The rental contract covers the use of the machine and all maintenance including the cost of fitting spare parts and last for 1 till 4 years, after 4 years the client can purchase the machine or return it to Miele.
Organization and country	Gütersloh, Germany
Sources	www.miele.at https://www.gore.com/resources/gore-packaging-vents-provide-a-sustainable-solution-keeping-miele-s-forever-better
Images	
Circularity approach(es)	Slowing loops
Business strategy(ies)	Product-oriented services, long life design

LED fixtures, by Fischer Lightning

Description

Currently, a large number of lightning fixtures are outdated (e.g. because they are made only for halogen lamps) in the sense that they do not support an upgrade to more energy-efficient LED lamps. A transition to LEDs would usually require new LED fixtures. The existing fixtures are usually made of materials such as aluminium and that would support a longer use time. To address this, the company Fischer lightning developed a number or patented LED kits, which can be installed in almost every type of existing fixture on the market today. After the upgrades, Fischer Lightning sends the replaced electronic parts to a local recycling company. This reduces the material need and waste, eases the upgrade process, and provides a cost advantage together with environmental benefits. An LCA study confirmed that up to 57% of CO2–emissions are reduced, compared to installing new fixtures.

Organization and country

Geleen, Netherlands

FISCHER LIGHTING

Sources

www.fischer-ligthning.com

www.circulary.eu/project/fischer-lighting/

Images

Circularity approach(es)

Slowing loops

Business strategy(ies)

Life extension

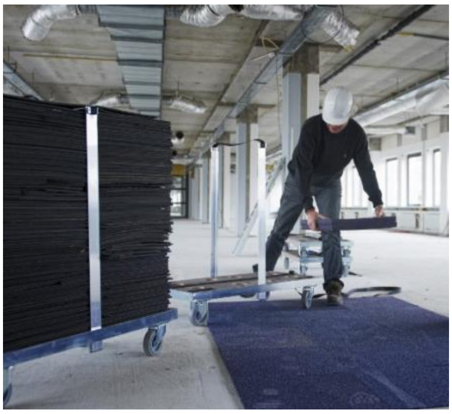
Long life furniture, by Löffler

Description	The goal of the company Löffler is to deliver durable, high-quality furniture with a long lifetime. This is underlined by their business strategy of providing a 30-year warranty for all their products, for no extra costs. Additionally, the company offers an extended takeback period of 31 days, where customers can return office chairs for free. Furthermore, Löffler provides spare parts and repair services for its products.
Organization and country	Dresden, Germany — LÖFFLER
Sources	www.loeffler-moebel.de
Images	
Circularity approach(es)	Slowing loops
Business strategy(ies)	Product-oriented services, long life design

Fleet management, by Hilti

Description	Hilti is multinational company that develops, manufactures and markets premium power tools for the construction and mining industry. The company offers a service, called fleet management, where an individual selection of tools is rented for a fixed monthly rate, which includes service and repair costs. This business model has a multitude of advantages related to the cost, productivity and efficiency for both parties involved. In contrast to purchasing new tools, there are no upfront investment costs. With the monthly use rate, customers are incentivised to maximise the average utilization rate of each product, reducing the overall material footprint. On the other hand, the company has an incentive to produce high quality, low maintenance, upgradeable products. The business model is highly successful and led to a significantly higher customer loyalty level. In 2015 the company managed 1,5 million tools in 40 countries under fleet management contracts, resulting in a contract value of more than 1,2 billion swiss francs (compared to 4,5 billion swiss francs in sales). The concept launched already in the year 2001 building upon a sequence of service innovations, such as warranties and repair guarantees. Even after more than 15 years, the business model is still widely discussed as a state-of-the art example for business model innovation.
Organization and country	**Schaan, Liechtenstein** HILTI
Sources	https://tinyurl.com/yd54pkea https://tinyurl.com/y7zj783t
Images	
Circularity approach(es)	Slowing loops
Business strategy(ies)	Use-oriented product-service systems, long life design

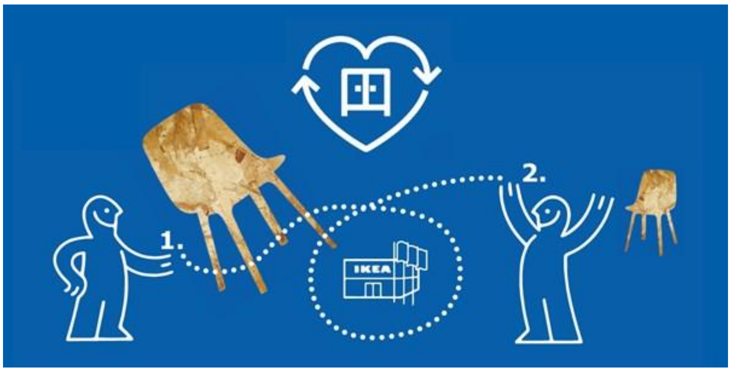
Carpet take back, by Desso

Description	Desso, a global carpets, carpet tiles and sports pitches company, designs many of their products with the aim of closing the loop by using materials that are safely recyclable. The polyolefin-based layer of the DESSO EcoBase® carpet tile backing is 100% recyclable in Desso's own production processes, while the Nylon 6-based top yarn can be functionally recycled into new Nylon 6 over and over again. This in turn can be transformed into 100% regenerated nylon yarn by yarn supplier Aquafil. The company has developed a take-back programme since 2008, collecting end-of-use carpet tiles to recover materials from old carpets, which would generate significant materials savings once scaled up.
Organization and country	Desso, Netherlands — DESSO A Tarkett Company
Sources	https://tinyurl.com/yby6uknx https://www.desso-marine.com/take-back™-programme
Images	 
Circularity approach(es)	Closing loops
Business strategy(ies)	Circular design, material recapture

M-Use, by Mitsubishi

Description	The Company Mitsubishi Elevators Europe is offering their elevators in the form of a new business model as a vertical-mobility service. The client pays on a per use basis, while the manufacturer remains ownership of the product. This model has advantages for both parties, as the incentives, which typically reward linear behaviour in conventional business models are turned on its head. A product provided as a service, is more economically viable the longer its lifetime, the better its performance is provided, and the less maintenance and repair is needed. All these costs are now internalised, and therefore they aim to be minimised by the company. In the case of the so-called "M-use concept" of Mitsubishi, the company sells the service with individual contracts, where factors such as the annual use rate and the length of the use phase (up to 40 years) are determined. At the end of the contract period, the client can take over the elevator for an agreed sum, or Mitsubishi disassembles the elevator and reuses components of it. During the use phase the elevators performance is measured with various sensors, which allow for predictive maintenance schedules, maximising both the availability of the elevator and the efficiency of the service personnel. For the client, the traditional short-term cost-driven focus associated with the building sector shifts to a long-term life cycle costing perspective with foreseeable costs. This enables more competitiveness with cheaper products of lower quality. Mitsubishi Elevators has already realised more than 100 projects with the M-Use concept. The challenges related with the business model mostly concern legal aspects, associated with the transfer of ownership, risks and building rights.
Organization and country	Mitsubishi Elevator Europe, Utrecht, Netherlands MITSUBISHI ELECTRIC MITSUBISHI ELEVATOR EUROPE
Sources	https://tinyurl.com/ycouvhx9 https://tinyurl.com/yc79uwej
Circularity approach(es)	Slowing, closing loops
Business strategy(ies)	Result-oriented product service system

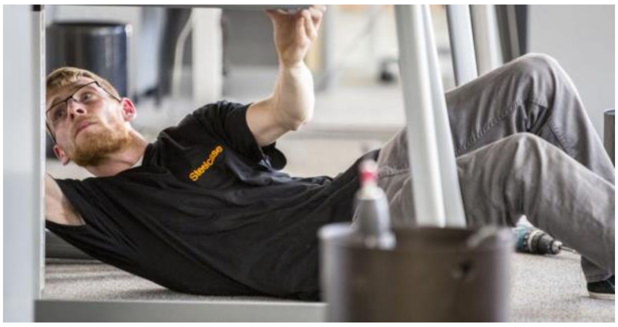
Second life, by Ikea

Description	Since July 2018 Ikea Austria offers to rebuy used furniture from its customers, and thereby promotes a high-level value captures. The program covers a wide range of products, (e.g. cabinets, desks, tables, chairs, etc.). The conditions are that the furniture is in good condition, is fully assembled and can be returned as such. The return process starts via an online platform, where users upload pictures and a short description of the furniture item. The items are then reviewed by IKEA employees, and the customer receives a price suggestions for the item. The price range equals up to 30% of the last sales price. The customers can than return the assembled product together with the price suggestion to a store and receive a gift certificate. The items are then sold for the same price in the store.
Organization	IKEA, Leiden, Netherlands
Sources	https://tinyurl.com/yapmlcv2 https://tinyurl.com/ybefurj7
Images	
Image source	https://tinyurl.com/y7phl9cx
Circularity approach(es)	Slowing loops
Business strategy(ies)	Reuse

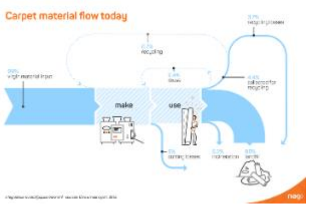
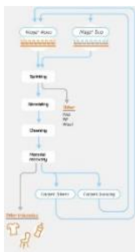
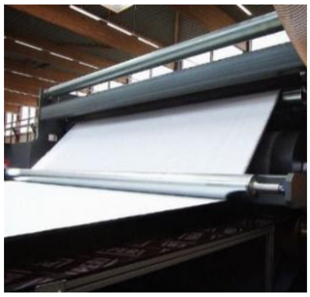
Remanufacturing and rebuild, by Caterpillar

Description	Caterpillar is a manufacturer of construction and mining equipment, engines and turbines. The multinational company employs about 100.000 people. Already in 1973, Caterpillar started its Remanufacturing Program, which today employs more than 4.000 people at 17 locations and covers more than 7000 parts (mainly motor parts). The remanufactured components are sold with a warranty (the same as new ones) for a price between 40 – 60 % of newly produced ones, but they are only sold in return for used parts. New products include a deposit on the price of parts that can be remanufactured later on in the life cycle. This pricing policy encourages product returns. Between 2011 and 2015 the actual rate of returns ranged between 93 – 95 % of eligible components. The successful practice of remanufacturing also had substantial feedback on the product design, which was characterised by modularisation. The core components to last for about 3 life cycles (two remanufacturing periods). The Rebuild program of the company relates to complete machines. Used machines can be returned, are then completely overhauled, get a new serial number and are resold at a fraction of the cost of a comparable new machine with a like-new warranty.
Organization	Peoria, Illinois, USA
Sources	https://tinyurl.com/ybdlhnv7 https://tinyurl.com/yawtoxuu https://tinyurl.com/ycn6dc6j
Images	
Image source	https://tinyurl.com/yan8b6cl
Circularity approach(es)	Slowing loops
Business strategy(ies)	Remanufacturing, circular design

Phase 2 program, by Steelcase

Description	Each year, over 8.5 million tons of office furniture find their way into landfills across the globe, permanently removing useful materials from the value stream. As one of the early sustainability innovators in its sector (e.g. having a large portfolio of Cradle to Cradle products and EPDs), Steelcase is actively trying to address this problem. The Eco-Services Program in Europe and the Phase 2 Program in North America aim to redeploy under-leveraged assets at the end-of-use phase. In case your office furniture is no longer needed consultants from the company offer different options, ranging from resale, charitable reuse, refurbishment to recycling. The aim is always to keep products at their highest value and avoid landfilling altogether. In 2016 the company handled 30.600 cubic meters of materials within the European Eco-Services Program.
Organization	Steelcase, Grand Rapids, Michigan, USA
Sources	https://www.steelcase.com/ https://tinyurl.com/y7c7thd6 https://tinyurl.com/y9aualxb
Images	
Image source	https://tinyurl.com/y9aualxb
Circularity approach(es)	Slowing, closing loops
Business strategy(ies)	Reuse, material recapture, refurbishing

Fully recyclable carpet, by Niaga

Description	Carpets are usually made of a complex array of chemicals, including Latex and PVC, rendering the carpets' materials unrecoverable. In the US carpets take up the second-most landfill space, behind only to diapers. Yearly, about 1.600.000 tons of carpets are landfilled in the US alone, amounting to a material value loss of about 5 billion $. The company Niaga ("again" spelled backwards) has developed a carpet material, which can be restored fully. Carpets are created either of pure polyester or a combination of polyester and polyamide, polypropylene or wool. To allow the decoupling of the two materials, Niaga invented an adhesive that decouples on demand. At the end of its use phase, a recycler is able to "unclick" the adhesive for harvesting two pure material streams. The company actively supports the recycling process by endorsing product- take back, sharing recycling manuals with recyclers, reaching out to consumers and working together with manufacturers and retailers to stimulate the return flow
Organization and country	Niaga, Geleen, Netherlands
Sources	https://www.dsm-niaga.com/carpet/benefits.html https://tinyurl.com/ya8s4hm2 https://tinyurl.com/y8mvfdmc http://www.circulary.eu/project/dsm-niaga
Image sources	https://tinyurl.com/y8mvfdmc https://www.dsm-niaga.com/carpet/benefits.html https://tinyurl.com/y8o4pzybb
Images	  
Circularity approach(es)	Closing loops
Business strategy(ies)	Material recapture / closed loop recycling, circular design

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03

VALUE CHAINS

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Collaboration: Stephan Schmidt, Rainer Pamminger, Laura Ruiz-Pastor and Elena Mulet

Value chains

Contents

Executive summary **147**

3.1 Introduction to the concept of circular value chains and networks **148**

3.1.1 Value chain vs circular value chain 148

3.1.2 The concept of circular value network 151

3.1.3 The concept of circular supply chain 155

3.2 Why change to a circular value network? **159**

3.2.1 Benefits of establishing a value network for circular chain cross collaboration 159

3.2.2 Facilitators and barriers for the establishment of a value network for circular chain cross collaboration 159

3.3 How to optimise supply chains through reverse networks **163**

3.3.1 Reverse network solutions 163

3.3.2 Reverse logistics infrastructure 165

3.3.3 Reverse logistics in the construction sector 168

3.4 Business strategies/models that support the implementation of circular value networks. **171**

3.4.1 Circular Strategies and their influence on different business models 172

3.5 Stakeholders engagement and management: how to establish a circular value network... **178**

3.5.1 Main steps to establish a value network for circular chain cross collaboration and engage suppliers and other stakeholders. 178

3.6 Existing tools for the management of value chains towards sustainability **182**

3.6.1 Achilles 183

3.6.2 EcoVadis 183

Bibliography **184**

Executive summary

3.1 Introduction to the concept of circular value chains and networks

A circular value network is understood as a dynamic co-creation network that is based on the engagement and interaction of stakeholders from the business world and other societal stakeholders, to guarantee the circular flows of both tangible and intangible values. Different circular value network strategies can be developed by companies and organisations, including among others, "take back management", "platform approaches", "industrial symbiosis" or "value network collaboration".

3.2 Why change to a circular value network?

This section highlights some clear benefits of establishing a value network for circular chain cross collaboration. However, establishing a circular value network may be quite challenging, as several barriers may arise; among others, barriers related to data, relational, cultural or personal conflicts.

3.3 How to optimise supply chains through reverse networks

One key aspect to optimise supply chains and to make them more circular is the development of reverse networks and logistics. Reverse logistics is a key step in capturing the value of end-of-life goods and facilitating the reuse and recycle pillars of the circular model. This covers not only the collection and transport of materials and products but value-added activities such as testing, sorting, refurbishing, recycling and redistribution.

3.4 Business strategies/models that support the implementation of circular value networks

This section addresses the questions of how value networks are related to the Business Model Canvas (BMC) and what influence circular business strategies (CBS) have on the value networks.
In this context, getting the involvement of relevant stakeholders as key partners is an essential requirement towards the sustainability and circularity of value chains

3.5 Stakeholders engagement and management: how to establish a circular value network

Establishing a value network through the engagement of key stakeholders allows the creation of closed loops, and at the same time, reinforces the corporate social responsibility (CSR) policy of companies and organisations.

3.6 Existing tools for the management of value chains towards sustainability

This section gives an overview of the main tools that are available currently in the market to manage value chains towards sustainability, paying special attention to Achilles and Eco-Vadis tools.

3.1 Introduction to the concept of circular value chains and networks

As already explained in previous chapters, the concept of circular economy aims to keep material resources circling in loops, to make them last and reduce and eliminate waste generation. **Materials keep moving from one value chain to the next, and therefore, moving towards a circular economy not only requires changes in society, but also it involves large implications for every value chain of products** and services. Understanding how value chains are composed and how the different links and areas are interconected is a key aspect for both design processes of products and services and other managerial and technical processes.

Implementing and scaling-up circular economy practices often requires **system thinking**, as it may involve changes in one or more areas of a system, and therefore, collaboration is essential. Indeed, circular economy can be understood as "an economy in which stakeholders collaborate in order to maximise the value of products and materials, and as such, contribute to minimising the depletion of natural resources and create positive societal and environmental impacts" (Kraaijenhagen et al., 2016, p. 14).

This system thinking demands that businesses and organisations focus on optimising and creating value along the entire system in a holistic way, through **cooperation with different stakeholders** (within an organisation, between organisations and/or with consumers) (Kraaijenhagen et al., 2016; Bicket et al., 2014). A change of mind-set is needed, shifting from a traditional supply chain thinking to a value chain approach (Cassell et al., 2016; WEF, 2016).

3.1.1 Value chain vs circular value chain

The value chain concept was originally developed by Michael Porter as "a powerful tool for disaggregating a company into its strategically relevant activities in order to focus on the **sources of competitive advantage**, that is, the specific activities that result in higher prices or lower costs". The **value chain** is "the summ of activities involved in delivering value to customers", as depicted in figure (Harvard Business School, 2018). The design process, together with other activities such as production, marketing, distribution or support to the final consumer are included here.

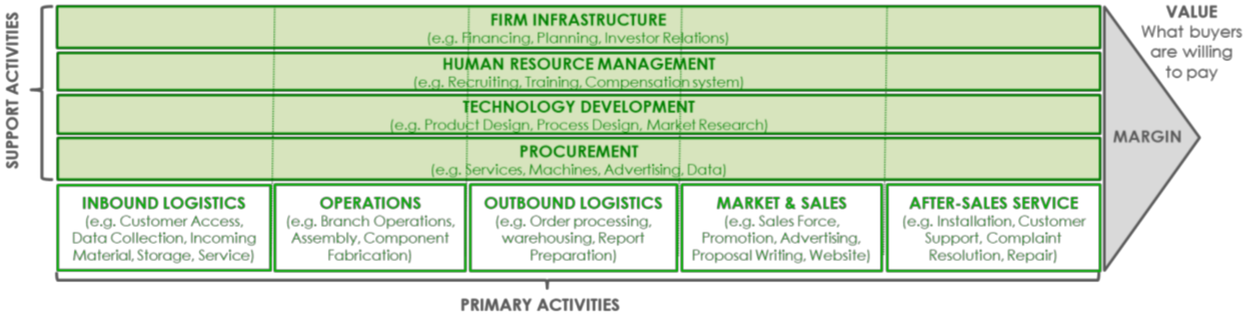


Figure 3.1 – Activities involved in a Value Chain (Harvard Business School, 2018).

In this sense, as explained by The Global Value Chains Initiative (2018), "the value chain describes the full range of activities that firms and workers do to bring a product from its conception **to its end use and beyond**". The Greenhouse Gas Protocol (2011) states how the value chain "refers to **all of the upstream and downstream activities** associated with the operations of a company, including the use of sold products by consumers and the end- of-life treatment of sold products after consumer use". Additionally, Talmon-Gross and Miedzinski (2015, p. 8) understands a value chain as "the **interconnected system of actors and processes** that creates the accumulated value of products and services offered to the end-users". These activities, that can be integrated within a single firm or divided among different firms, can cover a single geographical location or spread over wider areas.

Figure 3.2 and figure 3.3 present two different ways of representing a value chain, for the furniture and the construction sector.

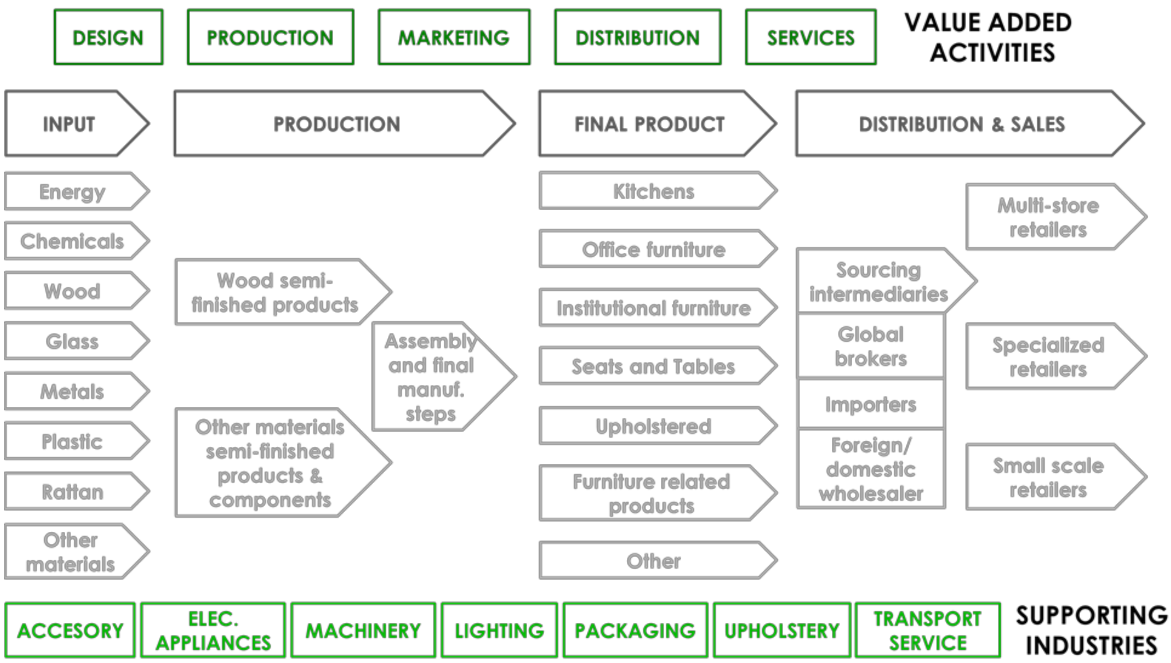


Figure 3.2 – Traditional/linear value chain of the furniture sector (De Marchi et al., 2013).

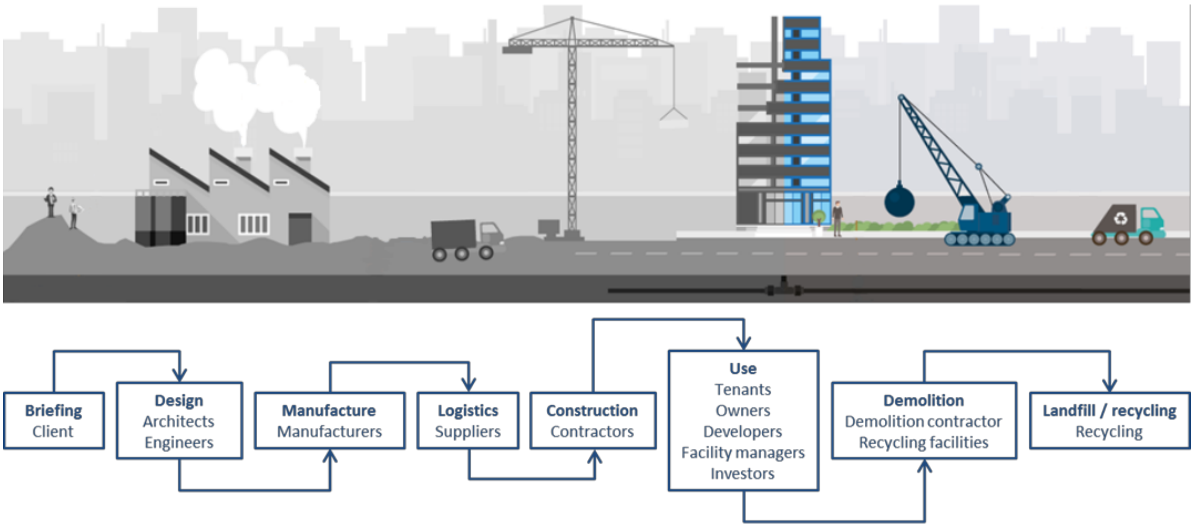


Figure 3.3 – Traditional/linear value chain of the construction sector (Carra & Madgani, 2017)

In **a circular economy context**, the value chain must be understood as **part of wider networks and systems**, that allows different flows of resources, knowledge and skills and in short, a new way of thinking and doing things, leading to the launching of more sustainable solutions to the market and based on a circular value chain approach. This **circular value chain concept** is defined as "a chain of consecutive parties and their activities (i.e. links) along a product's value cycle, who **combine, share, exchange and co-develop resources** for a substantial improvement of their material utilisation" (Jordens, 2015, p. vii).

3.1.2 The concept of circular value network

A circular value network is understood as a **dynamic co-creation network that is based on the engagement and interaction of stakeholders** from the business world and other societal stakeholders, to guarantee the **circular flows of both tangible and intangible values** (Antikainen & Valkokari, 2016). A circular value network goes beyond the concept of circular value chain, as both internal and external stakeholders involved in the value-creation process are considered, as illustrated by figure 3.4.

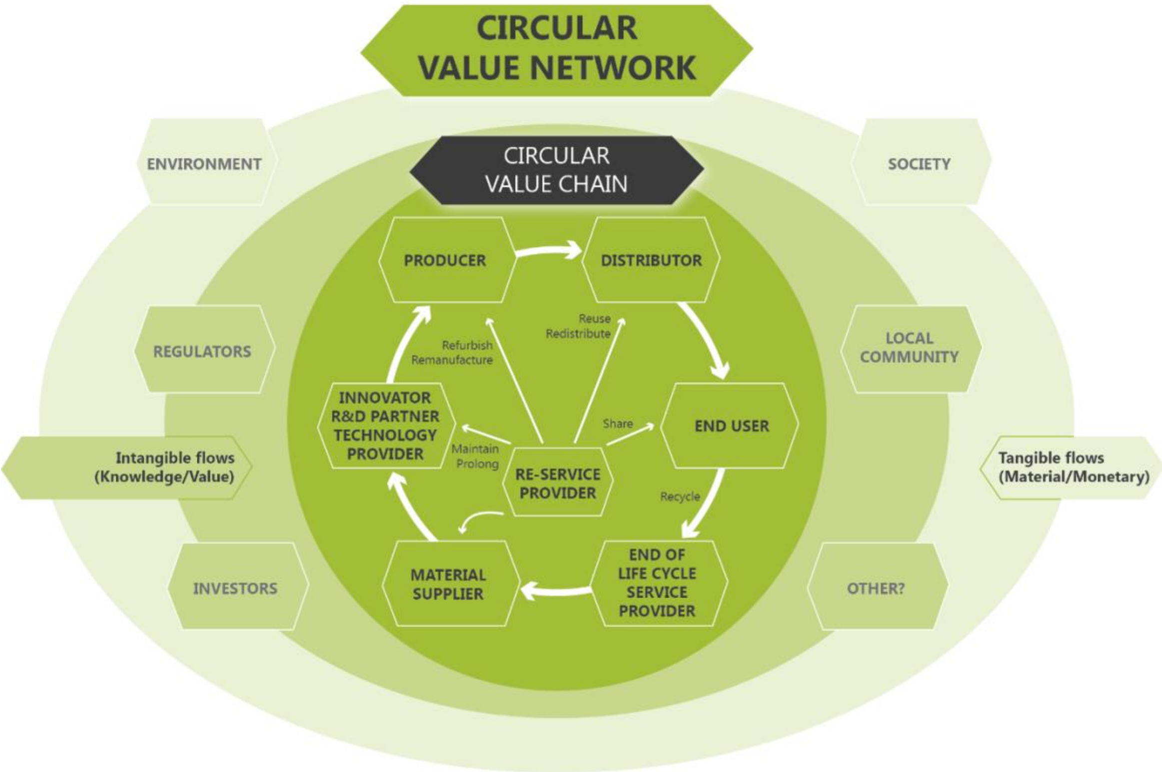


Figure 3.4 – Stakeholders involved in a circular economy co-creation value network (Adapted from Aminoff et al., 2016)

Therefore, collaboration, communication and cooperation of these interdependent but independent stakeholders is necessary (Antikainen & Valkokari, 2016). Indeed, the success for implementing circular economy practices will come from the involvement of all the relevant stakeholders and their ability to link and to exchange patterns (Ghisellini et al., 2016).

"To master the circularity of a product without having control over all stages of a product's lifecycle, collaboration with other companies downstream and upstream the value chain, and/or with customers and other stakeholders is key. Companies that put their strategic focus on building circular value networks are up to a challenging task (i.e. due to new types of risks and uncertainties), but with possibly the greatest business rewards in the long run"

The Circulator Project, 2018

This chapter will focus on the circular value network concept, understanding that this network concept already considers the circular value chain concept.

Stakeholders involved in a circular value network in the construction industry

Several stakeholders may be involved in a circular value network of the construction sector, as defined in the following figure 3.5.

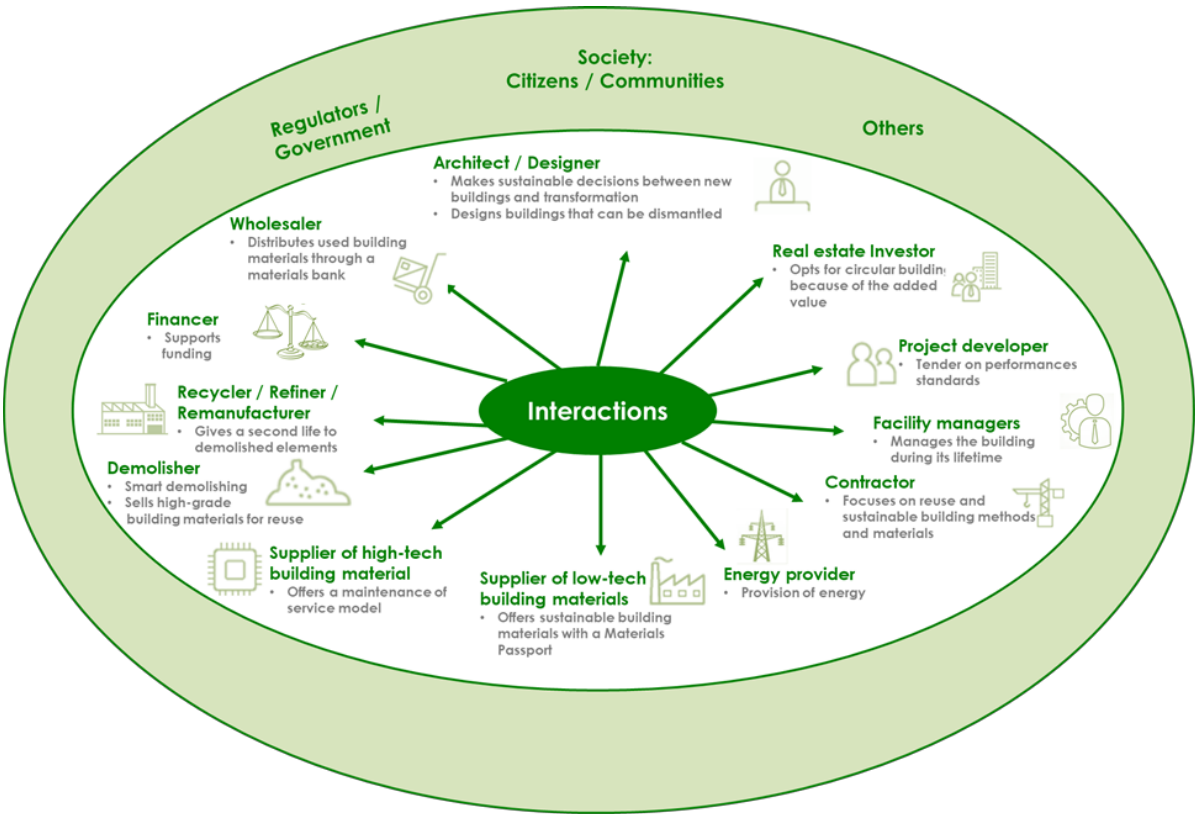


Figure 3.5 – Stakeholders involved in a circular value network in the construction industry (Adapted from ING Economics Department, 2017 and BAMB, 2017)

Circular value network strategies

Companies and organisations can develop different **value network strategies** in a circular economy. This subsection gives an overview of the main strategies to consider (The Circulator Project, 2018). More detail of of these strategies can be found in next sections and other external references, as specified in each case :

- Industrial Symbiosis: The waste stream of one company is used as input for other company/companies, usually in a specific regional setting. There is an physical exchange of by-products, materials, energy or water (Chertow, 2000). SYMBIOSE and SAREBOX are good examples of this;
    1. "SYMBIOSE offers a matchmaking service to valorise industrial waste streams and excess resources (waste heat, infrastructure, technology, spare parts, staff ...) in Flanders (Belgium). One company's 'waste' can be another company's raw material, so SYMBIOSE brings these possible partners together". This platform brings together 235 organisations, more than 1.400 resources and approx. 475 potential sinergies. The economic value added for each successful synergy is 85.000€/year on average. See link: http://www.smartsymbiose.com/
    2. SHAREBOX aims to develop a secure platform for the flexible management of shared process resources with intelligent decision support tools, in order to optimise symbiotic connections (plant, energy, water, residues and recycled materials) with other companies. See link: http://sharebox-project.eu/
- Take back management: Organising logistics (ie. via network collaboration) for taking back end-of-life products from the customer, facilitating the execution of a sustainable materials management strategy (Ie. returning furniture once the client does not want to continue using it, or when it needs to be remanufactured for a second life). More information and examples are included in section 3.3. See the *Processes and materials* chapter too.
- Platform approaches: An online or on-site solution enabling shared use of assets (ie. materials, knolwedge, infrastructures, time, or even space). Some interesting sharing platform examples, include the following ones.
    3. FLOOW2 – "The first business-to-business sharing marketplace that enables companies and institutions to share overcapacity of equipment, knowledge and skills of personnel" It integrates in a huge range of sectors, including construction sector and it is aimed at small and medium sized businesses located near each other (within a five miles radius). See link: https://www.floow2.com/sharing-marketplace.html
    4. FURNISHARE – An online marketplace that allows furniture to be kept in use for longer cycles. See link: https://furnishare.com/
    5. NetHire - The Danish company NetHire, a sister company to Garant Udlejning (Leasing) has developed an app, where workmen and construction sites can on-site order tools and other equipment needed in the working process instead of having to invest in everything on their own. There are economic benefits, but also environmental since the coefficient of utilisation become bigger before the tools are technically degraded. See link: www.nethire.com

- Cooperation with customer: Organisation in which company and customer effectively collaborate to create and capture value, developing new circular business models. This strategy maybe closely related to previously mentioned take-back systems too. More information and examples are included within the section 3.4 of this chapter.
- Promixity or localisation: Organising the physical flows of resources and products on a local scale (i.e. local supply chain management, local 3D manufacturing, ...). Products based on proximity are part of this strategy; zero mile domestic products. Subsection 3.1.3. gives additional information on this.
- Value network collaboration: Collaboration between different businesses, government bodies, local communities, NGOs or other organisations throughout the value network to achieve a common goal. Examples of this are included in section 3.5. See the *Business models* chapter too.

Assignment 3.1

Think of a circular product or service, and discuss about the different links and main stakeholders that conform the value network; highlight the most relevant interactions between these stakeholders.

Can this value network become more circular by modifying its composition? Is any stakeholder missing?

Can it be improved by implementing any other circular value collaboration strategy? How?

3.1.3 The concept of circular supply chain

Although it is common to use "value chain" and "supply chain" concepts interchangebly, there is a significant difference. The **value chain concept goes beyond the supply chain**, as this last concept refers to "*the system and resources required to move a product or service from supplier to customer*". The value chain concept is based on the supply chain, but with a larger scope, focusing on the idea of the ideas of "value" and "competitive advantage". Indeed, the value chain considers how the value is added or lost along the chain, both to products and services and actors involved.

Indeed, when talking about circular value chains and networks, special attention has been given to the supply chain as a key unit of action to drive change towards circularity of resources and materials (WEF, 2014). The vast majority of today's supply chains are linear, based on a take-make-dispose logistics approach. However, taking into account the higher price instability and scarcity of some critical raw materials and commodities, more and more companies decide to adopt a circular supply chain approach; thus, reducing waste and providing an alternative source of inputs, introducing fully renewable, recyclable or biodegradable materials that can be used in consecutive life cycles to reduce costs and increase predictability and control (Lacy & Rutqvist, 2015).

> "Leaders have to rethink their supply chain economy as a network, not as a collection of single companies. The interdependence between companies is going to be suddenly much higher, which means they have to better choreograph the movement between materials and goods. Often, the biggest barrier in modern supply chains is communication: Can you handle all these transactions in a seamless way, enabling your partners and suppliers to coordinate more efficiently?"
>
> Lanng, C., Chairman at Tradeshift, 2014

Archetypes of supply chains and loops

Ellen Macarthur Foundation identifies 4 archetypes of supply chains and loops, taking into account the geographical dispersion of manufacturing and consumption points, as depicted in figure 3.6. As seen there, linear supply chains are the ones where the manufacturing and consumption points are the most dispersed ones (and therefore, the least sustainable ones). The rest of archetypes present several combinations with different possible routes of products.

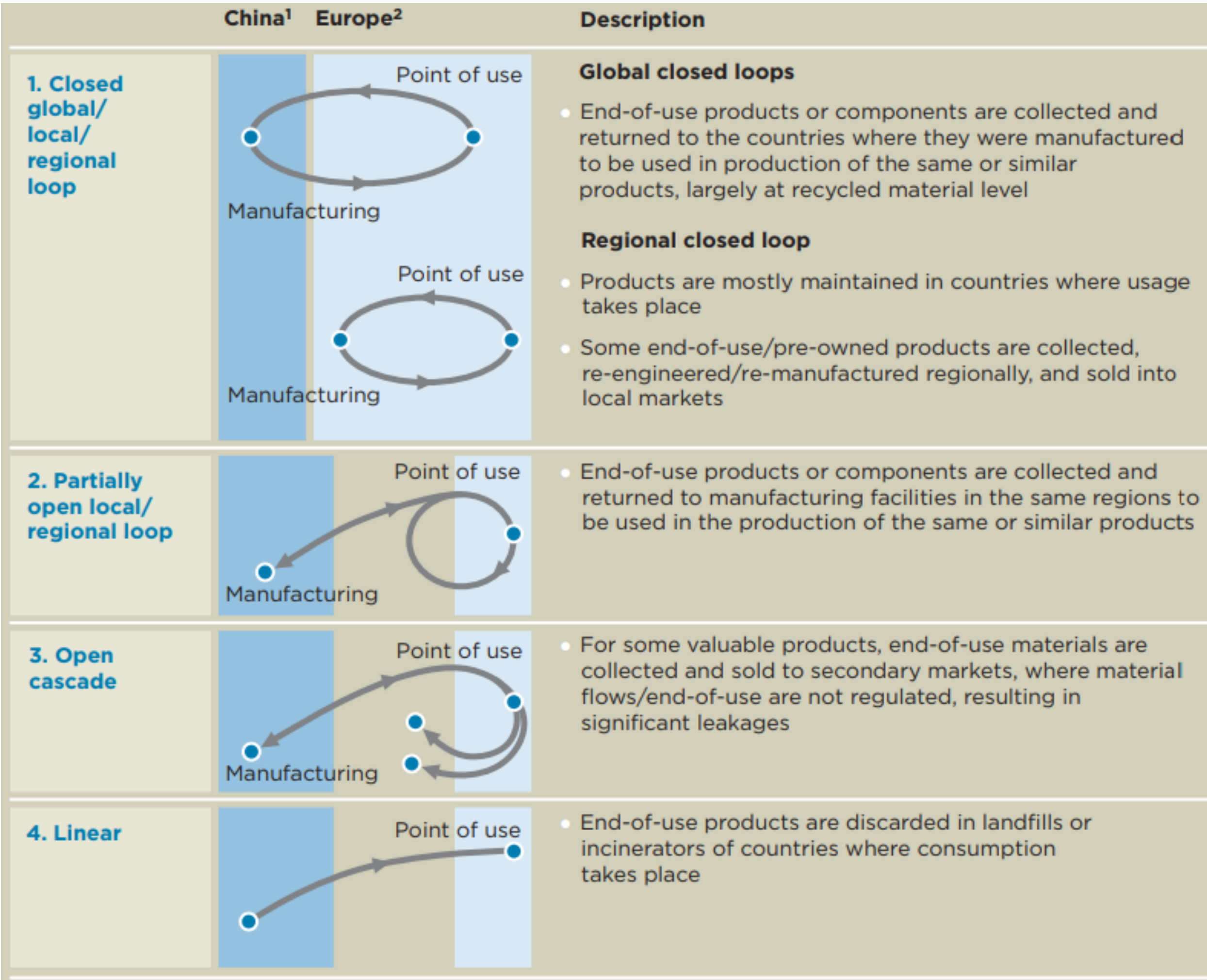


Figure 3.6 – Archetypes of supply chains and loops (EMF, 2014)

Note: 1 Or other manufacturing country outside Europe / 2 Analogue to the USA of other importing regions

Indeed, **closed regional and local loops** are out of these arquetypes the most attractive and environmental and economically beneficial, as they are based on close proximity between points of production and use. Supply chain logistics can be organised at relatively low transport costs.

Returnable glass bottle system is a clear example of a regional and local loop. "Returnable glass bottle systems are a good example of closed regional and local loops that give bottling companies full control of their materials flows. For instance, South African Breweries (SAB), currently sells more than 85% of volume in a closed loop returnable bottle system. If these were converted to a one-way packaging and distribution system, the country's glass output would have to be doubled just to cater for the increase in demand for beer bottles. Modeling shows that in beer beverage packaging the economics of these return systems for reuse are far superior to those of one-way systems, even compared with 100% recyclable PET bottles". Figure 7 represents graphically the economic benefits of a take-back system applied to glass bottles.

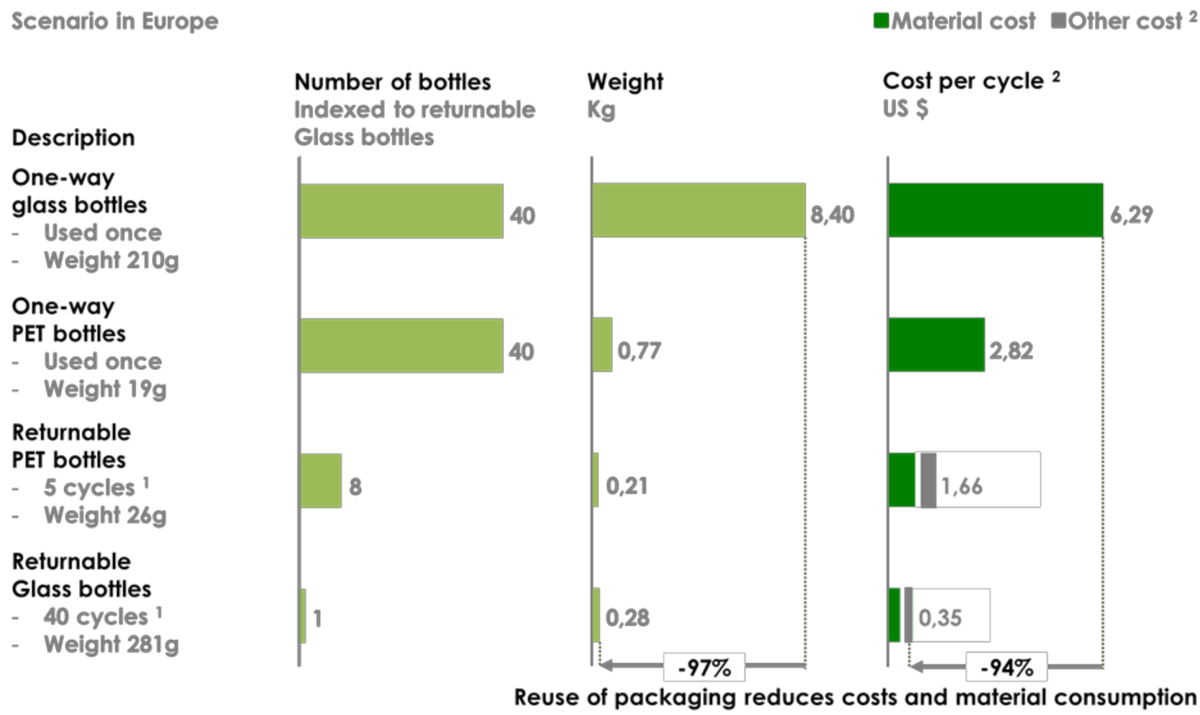


Figure 3.7 – An example of economic benefits of a returnable glass bottle take-back system (EMF, 2014)

Note: 1 Cost for collecting (storage cost at store), cleaning, and transport by truck (150 km on average) / 2 Incremental costs from reverse cycle: store collection and washing cost and transport costs for returnables

Construction materials represent further potential for closed regional and local loops, as these are generally manufactured and used locally or regionally. Leighton Holdings, an Australian construction company that procures raw materials for their pre-fabricated (precast) concrete from Asia, manufactures the products and then uses them in those regions, is a good example of this. Options for closing the loop **include local reuse of end-of-use precasts** or **functional recycling of the raw materials**, such as steel and concrete, in new products. This would allow the company to reduce the amount of new raw materials required.

Regarding the **furniture sector**, another interesting example of regional and local loop is the take-back system of carpet tiles developed by Desso. "Desso, a global carpets, carpet tiles and sports pitches company, designs many of their products with the aim of closing the loop by using materials that are safely **recyclable**. The polyolefin-based layer of the DESSO EcoBase® carpet tile backing is 100% recyclable in Desso's own production processes, while the Nylon 6-based top yarn can be functionally recycled into new Nylon 6 over and over again. This in turn can be transformed into 100% regenerated nylon yarn by yarn supplier Aquafil. The company has developed a **take-back programme** since 2008, **collecting end-of-use carpet tiles** to recover materials from old carpets, which would generate significant materials savings once scaled up" (EMF, 2014).

What does a supply chain need to become circular?

"Tradeshift", the Responsible Supply Chain Alliance, identifies some requirements that businesses need to meet in order to shift from a linear to a circular supply chain, as depicted in figure 3.8. Regarding….:

- Impact: Supply chain's environmental and economic impact need to be measured in real time.
- Product lifecycle: Data needs to be managed end-to-end on products and their lifecycles.
- Inputs and outputs: Materials need to be tracked in forward and reverse loops.
- Certification: Supplier certifications and material standards need to be tracked.
- Data exchange: Data needs to be exchanged between businesses across the supply chain.

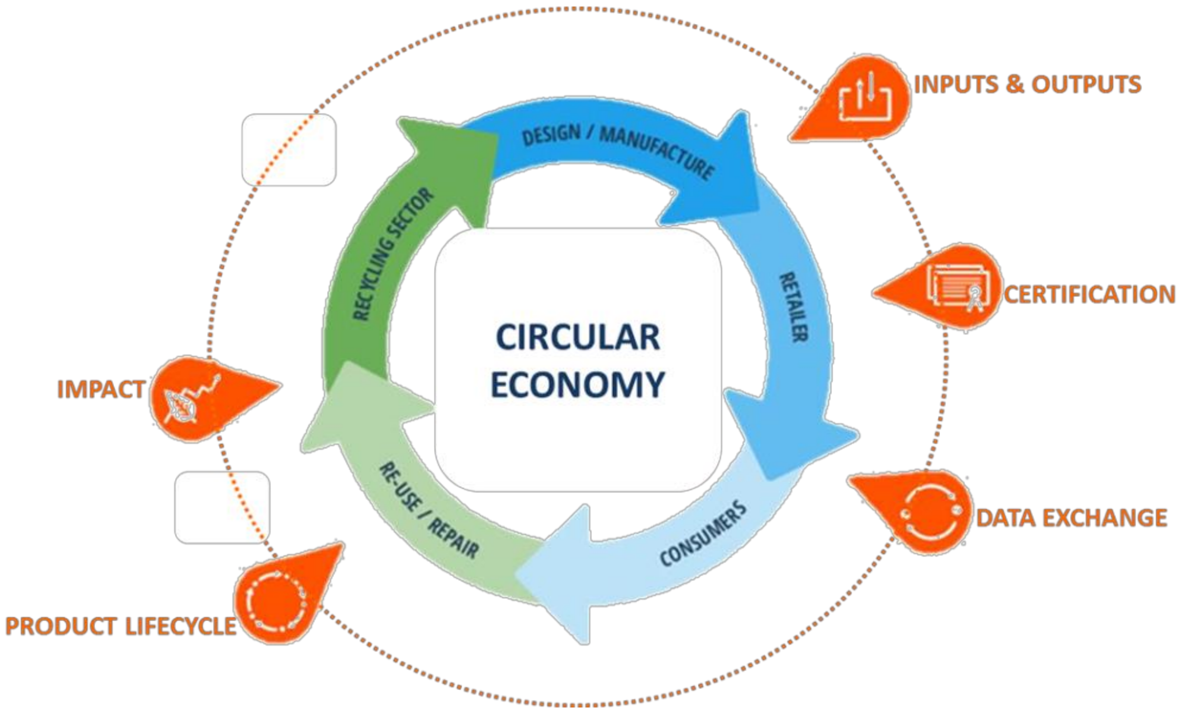


Figure 3.8 – Requirements for a circular supply chain (Tradeshift, 2018)

3.2 Why change to a circular value network?

Connecting and reinforcing a network of actors within their supply chain and beyond, this is, creating a value chain network, by managing transparency of data, transactions, material flows, responsibilities and sharing benefits is a key factor for closing resource loops and implementing circular practices (Leising, 2016). This section gives an overview of main benefits and drivers, facilitators and barriers for the establishment of value chain networks.

3.2.1 Benefits of establishing a value network for circular chain cross collaboration

Several authors have highlighted the benefits of collaboration between businesses and other stakeholders, both within the known supply and value chain and outside them. Some of these benefits, applicable to circular value networks, include the following ones (Vachon & Klassen, 2008; Sheu, 2014):

- There is an exchange of information that facilitates knowledge integration between the parties, enabling the development of additional organisational capabilities and skills.
- Collaboration enhances the obtaining of key complementary resources as different kind of internal resources are combined with resources of involved partners.
- A more extended influence area with customers and providers is attained (i.e. new customers, new markets…).
- It does not only improve the environmental performance, but also the operational one (i.e. better transport, logistics and infrastructure solutions), increasing the productivity through a lower cost and a better quality, and therefore, it generates a superior competitive advantage.
- The financial performance of the business is highly improved too. On the one hand, wider opportunities for co-fund research appear; on the other hand, agreements between stakeholders of the value network can facilitate the financing of circular processes, as for instance, through supply chain finance or reversed factoring (see the *Business models* chapter for further detail about "collaborative chain financing").
- This way, stakeholders that share goals, resources, knowledge, capabilities and perspectives see how their transitions costs are reduced, the risks sharing under environmental uncertainties is improved and the economic performance and advantage increased too.

3.2.2 Facilitators and barriers for the establishment of a value network for circular chain cross collaboration

Benefits of establishing a value network are clear; however, how easy is it? This sub-section identifies the main factors that could act as enablers for successful collaboration relationships between businesses and other organisations when creating circular value networks are identified as follows, as well as the main barriers that may difficult this collaboration, as described in table 3.1.

Table 3.1 - Facilitators and barriers for the establishment of a value network for circular chain cross collaboration

Facilitators	Barriers
– Guaranteeing a transparent communication and exchange of information and knowledge (i.e. about products, processes…) with all involved stakeholders (within and/or across value chains and sectors). – Switching from protective approaches towards more open and collaborative structures. – Making sure that collaboration is pragmatic. – Having a common understanding of the relation established and mutual trust. – Agreeing on a strategic long-term vision and framework by all involved stakeholers. – Guaranteeing that all partners are committed, sharing common goals, values, expectations and mutual opportunities (i.e. long term views and short term gains). – Understanding the entire value chain and identifying the extra value gained through the establishment of the collaboration. – Providing mutual support. – Establishing a progressive leadership that is able to identify strategic champions, promote shared values and mindsets and involve relevant stakeholders. – Clear chain coordination, contracting, and financial mechanisms.	– Data conflicts, as a result of lack of information or differences on interpretations – Relationship conflicts, due to the existence of stereotypes, miscommunication or strong emotions and negative behaviours – Difficulties to change organisations' culture and organisational foundations – Legal and administrative burdens (i.e. institutional system that is aligned with the principles of linear economy) – Mental, personal barriers – Structural conflicts, including time/geography related constraints, differences in role assignments and unbalanced power levels over resources – Lack of ICT solutions that may guarantee the availability of efficiency data for all stakeholders in a transparent way – Obstacles arising from differences in the objectives and values of involved stakeholders – Complexity of value chains – Lack of a skilled staff – Difficulties that industrial customers may have for understanding the value or the life-cycle perspective of products and services – Potential conflicts between sustainability and profitability – Lack of agreement on how to spread the costs involved in developing circular solutions and the lack of financial solutions – Lack of support for the integration of sustainability objectives in products and services

Box 1. Example of a successful Value Network Collaboration Strategy – Net-Works programme, by Interface

In 2013, Interface launched Net-Works, a disruptive, cross-sector, ongoing partnership between Interface, fibre manufacturer Aquafil (supplier) and the NGO Zoological Society of London (ZSL). Net-Works involves the recovery of discarded fishing nets in the Philippines and the recycling of them into high quality nylon (through the ECONYL technology developed by Aquafil) to be used in manufactured goods such as the yarn for Interface's carpet tiles. Net recovery is undertaken by partnering village communities through a mutually agreed social enterprise model, with significant positive environmental, social and economic impacts.

The value network collaboration, initiated by Interface, with Aquafil and ZSL joining at an early stage, had the support of the Imperial College London (academia), who beyond providing knowledge and advice, facillitated the connection with local villages in the Philippines.

Main factors that have contributed to the success of the Net-Works programme:

- Developed capabilities and experience from past projects and other innovation activities.
- Commitment to a social goal, broadening the search and making unusual connections (ie. with the fishing communities, villages).
- A high level sustainability vision and public commitment, driving the activity from the top down.
- Entrepreneurial culture and a permissive management approach (ie. allowing a "safe failure space").
- Involvement of academia as an advisor at an early stage, bringing marine conservation expertise and local knowledge of the village communities, as well as new connections (ie. with ZSL).
- Involvement of a NGO as a provider of advocacy for sustainability aspects and of credibility and transparency.
- Receptive customer base; sensitivity of the design and architecture community to sustainability issues.
- Engagement of supply chain with sustainability.
- All the involve partners get benefited (win-win situations):
    - Interface: launching of new sustainable products to the market.
    - ZSL (NGO): contributing to its own goals of conservation of animals and their habitats, and by gaining an example of a multi-dimensional conservation partnership.
    - Aquafil (Fibre manufacturer and supplier): clear market opportunities as developer of the ECONYL technology to process waste into new products for Interface.
    - Village communities: clear social, economic and environmental positive impacts.
    - Imperial London College (Academia): opportunities related to academia/research purposes.

Sources: Interface, 2018 and Luqmani et al., 2016

Assignment 3.2

Come back to the value network of the circular product or service that you analysed in the previous assignment and brainstorm about the main benefits of establishing the analysed interactions and collaboration. Would these benefits be achieved in a linear value chain?

3.3 How to optimise supply chains through reverse networks

Reverse logistics is considered to be a key aspect to the circular economy. It is an essential step in capturing the value of end-of-life goods and facilitating the reuse and recycle pillars of the circular model. This covers not only the collection and transport of materials and products but value-added activities such as testing, sorting, refurbishing, recycling and redistribution.

Companies have spent a lot of time and money fine-tuning their logistics. Today they need to give just as much thought to their reverse logistics. Companies who want to join the circular economy and expand their supply chain to include the return of used products and materials for recovery must understand the requirements and maturity of their reverse logistics infrastructure.

In order to close the circular loop within the supply chain, companies should set up a successful reverse logistics strategy. Businesses should evaluate their entire system, looking at the wider business model and the design phase to make sure that products and materials can be reused, remanufactured, recycled, repaired...

In order to scale up the circular economy and make it mainstream, organisations need to manage the return, recovery and remarketing of the product models. Logistics is a major enabler when it comes to overcoming these challenges and scaling-up implementation of circular economy approaches across industries. Just as important as forward logistics, which powers global trade through the transport of materials, goods and information, is reverse logistics (EMF, 2014).

3.3.1 Reverse network solutions

There are 3 main reverse logistics solutions to turn global supply chains into supply loop or cycles:

- Create reverse networks.
- Reorganise and streamline material flows.
- Develop innovative demand-focused business models.

Create reverse networks

Creating value in a circular economy can mean the reuse, maintenance, refurbishment/repairability, and remanufacturing of components and products. To leverage this value it must be easy to retrieve these products and components easily.

Organisations can develop global and sophisticated reverse networks. Together with their partners in the forward and reverse supply cycles, they need to carefully evaluate the arbitrage opportunities. What control can the stakeholders exert (whether jointly or individually)?

To arbitrage the residual value of a product or materials flow, companies will ideally organise their reverse cycle network across different product and materials components with the same sophistication as they have evolved for their forward multi-layer supplier networks (EMF, 2014).

Reorganise and streamline material flows

To get the full value from closing material loops, it is important to establish smooth and pure material flows across the value chain. This goes back to the roots of supply chain management: basic high-volume materials, complemented by speciality materials where needed.

Unlocking the full potential of the circular economy for basic materials thus means reorganising and streamlining materials into global flows and loops of standardised purity.

Collaborative approaches might be required to organise supply chains that make reprocessing materials more efficient and cost effective, which cooperate along the supply cycles, and cooperate with competitors.

One of the major problems furniture companies face when working with circular processes and increased recycling and/or remanufacturing is the presence of harmful chemicals in the material to be reused. There are a number of chemicals imposing serious problems for the material flow, including e.g. heavy metals, phthalates, soil repellent chemical.

Develop innovative demand-focused business models

New, innovative business models can help keep control of products and get them back after use. Business model innovation will be critical to mainstreaming the uptake of circular economy ideas.

Business models are needed that allow better access to products, components and materials during and within the post-usage loops. Business model innovation will be critical to main-streaming the uptake of the circular economy principle in more B2B setups, and in B2C. It will also be important to fully capture the potential of the shift to a sharing economy already discussed. Therefore, in this case business model innovation could take into account different circular design strategies, as for instance; design of product-life extention-services, that is oriented to a product; and design of products as a service, that is use-oriented and result-oriented (See the *Design and development* chapter).

Advancing new access-over-ownership and take-back models will further accelerate the adoption of circular economy business models because they drive the greater use of existing idle assets.

Ikea, for example, is working on its reverse logistics as part of the company's sustainability strategy, challenging the perception that its products are disposable by creating opportunities to recycle and reuse products. Ikea has recognised that old, broken, and unwanted products are an opportunity. Through these innovative reverse logistics initiatives, Ikea is not only acting in a more sustainable manner and reducing the company's environmental footprint, it is also increasing engagement with consumers and creating positive economic opportunities for the company. They include programmes that allow consumers to return plastics, batteries, furniture, compact fluorescent light bulbs, mattress, and textiles to the store. These items are then sold “as-is” or recycled.

3.3.2 Reverse logistics infrastructure

Just as there is forward logistics "from the factory to the store", an infrastructure is also necessary to ensure the collection of the discarded products and their transport to the recovery process.

Reverse logistics and its high transactions costs is one of the main problems in the efficacy of circular business solutions. Once a product is produced and sold, the manufacturer’s control level over the further fate of the product reduces dramatically and it is generally rather difficult to track where the products are, at what state they reach end-of-life and how to return them back for remanufacturing. Tracking and managing used products collection information, and organising the return for remanufacturing, material recycling and energy recovery represents a high share of transaction costs.

In order to close the loops of resources and materials and realise the reverse logistics of used furniture products, for example, first, used products need to be collected, then either prepared for reuse by simply repairing and reselling to second hand market or remanufacturing for reselling, then, the rest are sent to material recycling or energy and material recovery.

Transport

Within the reverse logistics, two types of transport can be differentiated. The first one is the one responsible for collecting and transferring the product from the user to the collection point, where the selection and sorting of the products is carried out for their subsequent treatment. This first transport is the most controversial since it depends to a large extent on factors that are difficult to control:

- The willingness or degree of information of the user: there are those who are not willing to deposit the product where it belongs because they do not want to, and there are those who are not sufficiently informed to know where to deposit their discarded product.
- The availability of collection points: they are not found in all the towns, neighborhoods, establishments, etc.

In a circular economy these obstacles must be saved to ensure the success of the first transport. Because users of end-of-life or end-of-use products trigger reverse flows, they need to be included in the reverse logistics. To get their products back, companies can incentivise their users to return them.

The second transport moves the product from the collection point to the centre in which the revalorisation process will be carried out. This transport is not so problematic since these routes are already developed and are easier to control and monitor, although it does depend on the type of product.

Figure 3.9 – Transport routes (Ihobe, 2017)

Engaging users to return discarded items

Users are more willing to take part in the logistics of returning the item if they perceive it to have value. Incentives can be used to motivate users to return discarded products. The key motivators are reward and convenience. Users will more likely return an item if it is easy to do it or if they are rewarded somehow.

If the value is low or non-existent, it needs to be very easy for the user to return it, for example, by taking it to the recycling bins. Items of medium value can be recovered using take- back programmes. This is the case of the glass bottles which are taken to collection points in supermarkets for example.When items have a high value, users are likely to sell it or swap it. Users are then willing to invest time and effort in the process of selling through platforms such as olx, ebay or wallapop.

In the case of the furniture industry, most companies offer to pick up the old furniture when the new one is delivered, for an on-the-spot swop. In this case, the size of the furniture is a driver for recollecting the discarded products.

Types of reverse logistics

There are two main types of reverse logistics: centralised and decentralised ones. The reverse logistics is more centralised when the official manufacturer is involved because they provide more revalorisation options and therefore ensure a more efficient revalorisation, taylored to each type of product.

In contrast, decentralised reverse logistics is more unpredictable and less effective:

– The time elapsed between the disposal by the user and the recovery process can be extended and there are products for which time is a critical factor.

– There is more likelihood that the product will get stuck on the way and never receive a recovery treatment.

– The further away a collection point is from the official manufacturer, the recovery options are reduced.

Once the sorting is made, the optimal revalorisation process for the product is determined. The revalorisation processes are those that add value to the discarded products in order to they remain in the economy the maximum possible number of cycles.

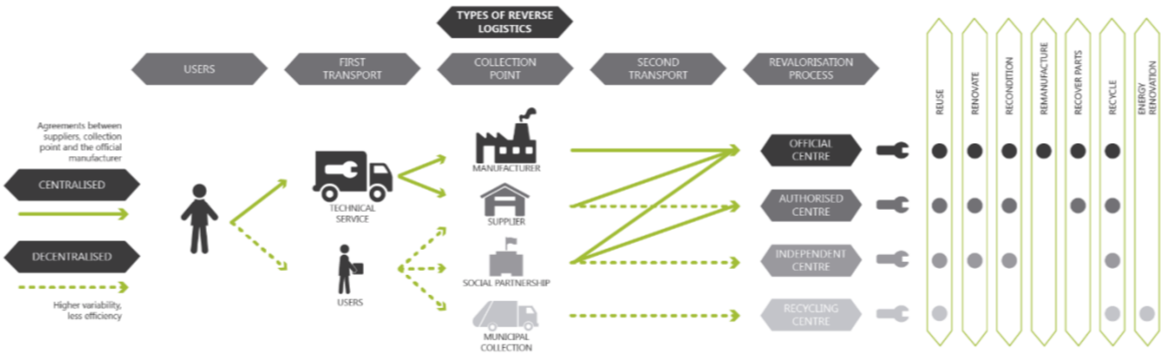


Figure 3.10 – Types of reverse logistics (Ihobe, 2017)

Revalorisation

In a Circular Economy, the following are considered revalorisation processes: Reuse (1st hand, by the same user), Repair, Reuse (2nd hand, changing the user), Renovate, Recondition, Remanufacture, Recovery of parts, Recycle and Energy revalorisation.

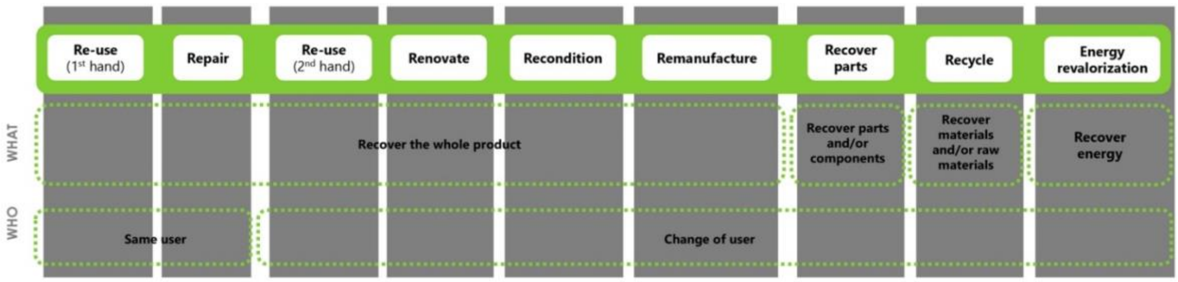


Figure 3.11 – Different revalorisation processes (Ihobe, 2017)

Barriers related to revalorisation in the furniture sector (EBB, 2017):

– Reuse: whilst reuse of furniture is common, this tends to be on a small scale and with local social goals in mind rather than larger scale environmental and economic ones.

- Repair and refurbishment: in many parts of the EU, transport and labour costs are high, making any significant repair and refurbishment costly, particularly where re-upholstery is required. In general, economies of scale and economic incentives are needed to make repair and refurbishment viable.
- 2nd hand market: weak demand for second-hand furniture - the price differential between new furniture against the cost of second-life furniture, is not significant enough to drive more sustainable purchasing behaviour.
- Recovery of parts: limited collection and reverse logistics infrastructure – currently there are weak drivers and underinvestment in the collection and logistics for furniture takeback.
- Recycle: poor demand for recycled materials - end markets for recycled materials, post deconstruction, are underdeveloped, and in some cases, already saturated, with these associated market failures restricting further investment in recovery.

3.3.3 Reverse logistics in the construction sector

Reverse logistics in the construction sector has to be seen in a broader context when it comes to the dismantling phase of a building. After the long use phase (compared to most products) the final main resource impact occurs after decades. Taking this into account, the planning of those logistic processes has to be different.

Some essential aspects that have to be considered from property project developers are included below. This conclusions are the result of the the pilot actions developed as part of the consortium BauKarussel (2018):

- The concept of preparing for reuse, given in the Waste framework directive, leads directly to the question how the necessary transports must be organised. Transports increase the costs and the risks that the reuse-ability gets lost due to mechanical damage. Three different concepts deal with this:

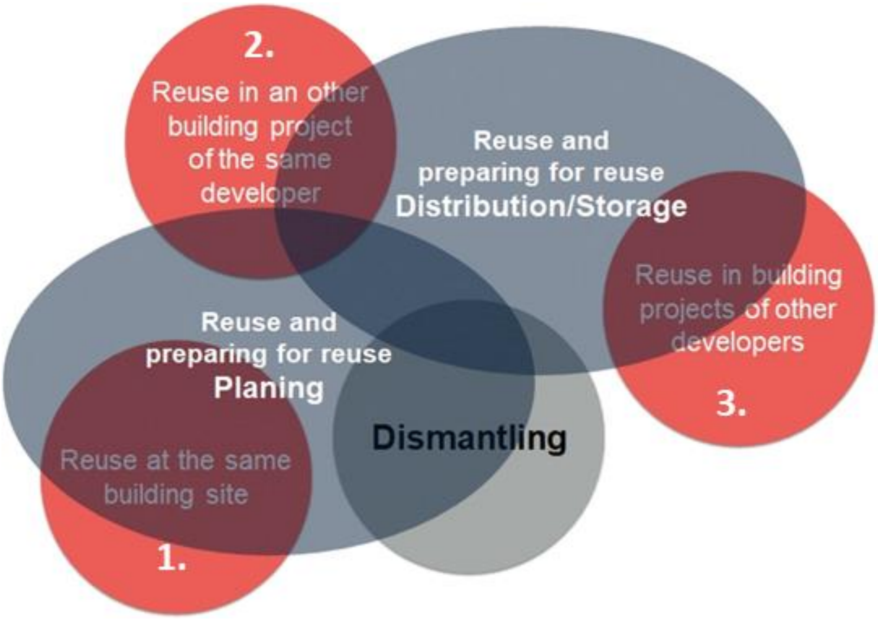


Figure 3.12 – Different concepts when preparing for reuse (BauKarussell, 2018)

1. **Reuse at the same construction site**: The architects manage to reuse distinctive parts, materials, or products that are part of the object that will be dismantled, in the new building at the same construction site. Transports are minimised. If the material can be reused as it is the only questions are where to store it and in what kind of manner. If the material needs to be refurbished it has to be packed in a reliable transport packaging and brought to the plant where the refurbishing takes place. After that it can be stored there and the transport to the construction site will be ordered on demand.
2. **Reuse at another construction site of the same project developer**: The process gets an additional complexity because two independent planning processes have to be matched. At construction site 1 the dismantling of the building leads to potential recyclable construction material. In case we find the need for that material at construction site 2 it can be delivered. In most cases (like recycling material from concrete) some measurements are required to ensure product characteristics and quality control. In Austria, for example, as in some other countries, the question ofwhether it is waste, or notis crucial because additional restrictions are related to that juristical classification.
3. **The reuse at construction sites of other project developers**: This case is from highest complexity because it is linked to a change of ownership. Therefore warranty and liability have to be negotiated. The chance in that case is, that material can be stored intermediately to bridge distinctive time schedules.

– The earlier experts analyse the potential for reuse and high quality recycling the higher the chances are to realise those potentials. The moment the construction machines start their work is far too late, because then work has to happen fast.
– To analyse the potential regarding circular economy the knowledge of the material composition forms the absolut basement. The Austrian dismantling guide therefore defines two concepts to be

worked out before the operational work starts. The Schad&Störstofferkunfung and the dismantling concept.

- Project developers should take the chance to use those mandatory papers to gain information to perform appropriate tenderings and strictly avoid blanket tenderings.
- The use of Building Information Modeling (BIM) to plan and design a new building is common sense. This instrument can help to plan the dismantling process in the same way like the construction phase. The BIM provides all necessary data to work out functional requirements for the tenderings. This will lead to comparable offers and best quality decisions.

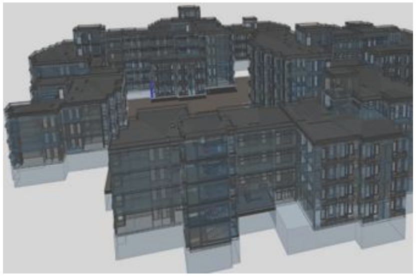


Figure 3.13 – An example of a BIM design (BauKarussell, 2018)

Taking into account the circular economy principles a huge change for all stakeholders in the value chain of the dismantling sector occurs. Companies facing this in an early stage act as frontrunners and create knowledge within their companies.

Assignment 3.3

Group discussion: Now that you understand how reverse logistics works, in groups think about a product you recently discarded/ returned and describe the different steps you imagine it went through from the moment you decided to discard it to the type of revalorisation process it will go through. Remember to think about the centralised/decentralised option, the type of transport, the collection point, the second transport, the agents involved, the materials flow,

3.4 Business strategies/models that support the implementation of circular value networks

This section aims to provide a link to the *Business models* chapter. It addresses the questions of how value networks are related to the Business Model Canvas (BMC) and what influence circular business strategies (CBS) have on the value networks (for more details, check the *Business models* chapter).

Following the framework from Osterwalder and Pigneur and the BMC (see figure 3.14), value networks relate to the question of "how a business creates value" and are part of the "backend" of a business model. The backend includes all internal support activities that do not require face-to-face interactions with customers, such as distribution, engineering, personnel, accounting, inventory, manufacturing, resources, etc. In the BMC these activities are summarised by the fields Key Partners (or stakeholders), Key Resources and Key Activities. Another way to put it, is that the backend is mainly concerned with things that cost money.

On the other hand, the frontend of the business model summarises the relationships with the customer, describing the relationship, the channels and the segments. The frontend is therefore concerned with things that make money. Put together the frontend and the backend provide the opportunities for the Value Proposition.

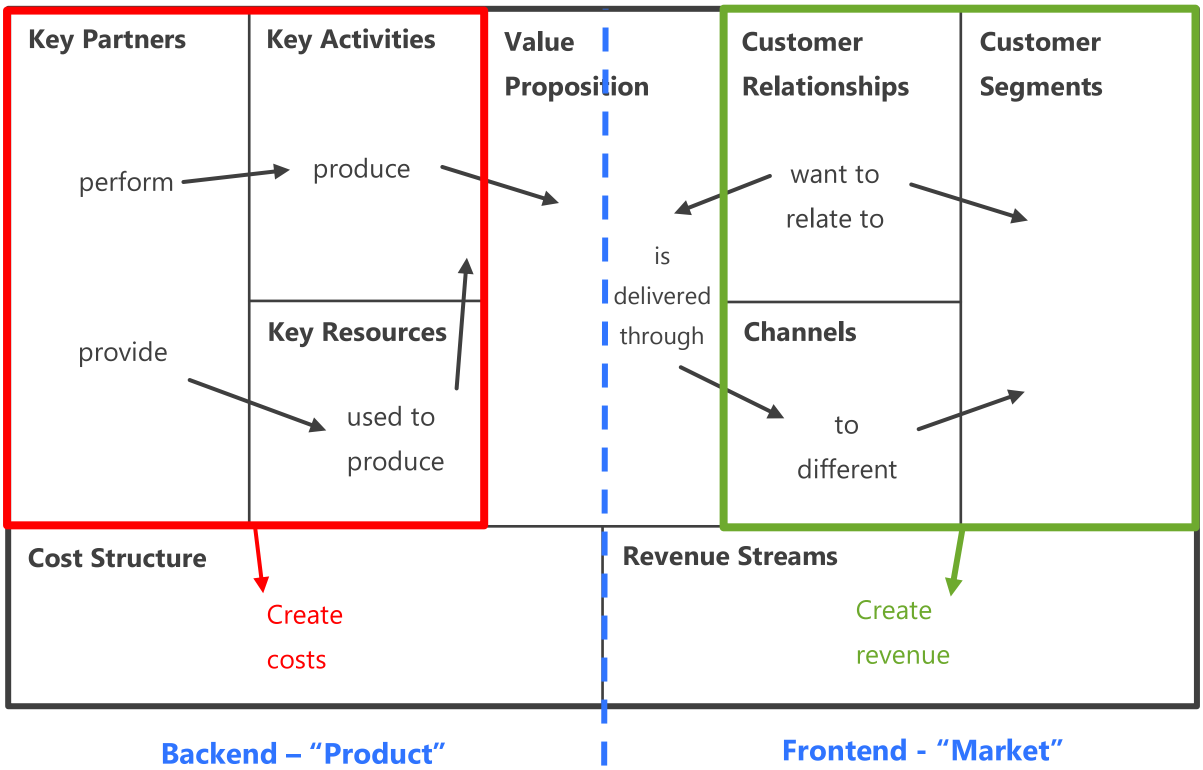


Figure 3.14 – The Business Model Canvas and how the Key Partners influence the Business model (adapted from (Mentink, 2014 & Osterwalder & Pigneur, 2013)

The value network of a business in the BMC is therefore represented within the field key partners. It describes the network of suppliers and partners that make the business model work. Questions related to this field are:

- Who are our key partners?
- Which key resources are we acquiring from them?
- Which key activities do they perform?

The key partners in the value network may also perform and influence the key activities of the company. Furthermore the Key partners also directly influence the resources used and the costs associated with it. One can see the influence the value networks has on the entire backend and from there on core of the business – the Value proposition.

3.4.1 Circular strategies and their influence on different business models

The aim of the following subsections is to describe the effects of circular strategies on the Key Partners in the context of some examples.

In the *Business models* chapter, three categories of business strategies are described, based on the lifecycle phase and the inherent value of the concerned product. The distinction is made between the pre-use or (Value-)"Uphill", the Use or "Tophill" phase and the After-Use or "Downhill" phase. The following table gives an overview of the different circular strategies defined in that chapter and reflects on how these strategies relate to the establishment of new partnerships in the value network.

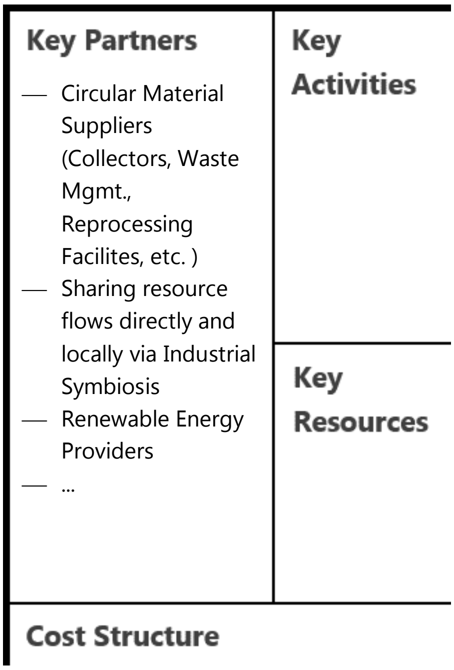
One can see how the "requirements for new partnerships" are very different. Collaboration is often necessary within downhill strategies when reverse logistics are applied, which are often realised by third parties. Other examples of strategies which require collaboration are some of the tophill strategies, e.g. within the management of sharing platforms or for asset tracking. On the other hand, there are also a number of circular strategies which are often realisable within the current value network (see figure 3.8)

However, finding a generically applicable rule, which relates strategies directly to specific partners is impossible, due to the unique surroundings and contexts of individual BMs. The connections drawn below mainly build on existing examples, and should provoke further exploration.

Table 3.2 - Examples of partners connections for each BM category

	Circular strategy	Main focus is on	New key partners and roles	Example from furniture or construction sector
Uphill category pre-use- phase	**Maximising production efficiency**	Production processes and management	Local Industries providing resource flows, Renewable Energy Providers	Kalundborg Symbiosis Eco-Industrial Park (sharing resource flows between different industries)
	Circular sourcing	Material inputs	Circular Material Suppliers (Recycling facilities, waste management, Collection Systems, etc.)	Interface carpet made from discarded fishing nets
	Adding value	Product design		Green Leaf façade (bio reactive façade generating energy for the building)
	Long life			Gaulhofer Windows with a warranty of 30 years
	Circular design			ClickBrick (demountable bricks without mortar)
Tophill category use-phase	**Life extension**	Product life		Giroflex Chairs (providing repair services for their office chairs)
	Product-oriented-services			
	Use-oriented services	Provision of services	Providing know-how and expertise (e.g. on performance contracts), Key technology providers (asset tracking, monitoring software, etc.)	Desso Carpet Leasing
	Result-oriented services			Pay per Lux (charging for the performance [lux] provided)
	Sharing platforms		Key technologies (platforms, apps)	Furnishare (online platform for buying and selling used furniture)
Downhill category after-use-phase	**Second-hand seller**	Resale of products	Reverse logistics for product or component	3R and Rype Office Furniture (refurbish and sell used office furnishings)
	Refurbishment			
	Remanufacturing			
	Material recapture	Material recovery	Reverse logistics for Materials	
	Recycling			

Uphill Business strategies and the role of the value network



Uphill strategies apply to the the raw material and manufacturing phase. The five defined strategies related to it, focus on:

– **Production Processes and Management** (e.g. Industrial Symbiosis, On Demand Production, Low Carbon Manufacturing, etc.)

– **Material Inputs** (e.g. Recovered, bio-based, renewable, etc.)

– **Product Design** (e.g. adding functionalities, Long Lifetime, Adaptability, etc.)

Strategies with a design focus, are not categorically related to the value network, as the relationship to key partners is individual to the context. On the other hand, strategies related the production inputs require particular circular material suppliers and therefore adaptations of the value network.

In the case of Production processes, Industrial Symbiosis is a particular collaboration-extensive strategy, where industries (often from different sectors) work together sharing their waste streams which become raw materials for others.

Example: The company Van De Sant uses recovered plastic waste from the ocean as a production input for their furniture. The plastic is used for bed and chair frames and upholstery fabric.

Figure 3.15 – Chair from Van de Sart

Related business Strategy: Circular Sourcing
Key Partners: Ocean Plastic Collectors, Recycling Facilities
Chair from Van de Sant, made from: Recycled and recyclable frame; from recovered plastics; Anodized recyclable arms; Recycled and recyclable foam; Stainless steel connecting material; Fabric.

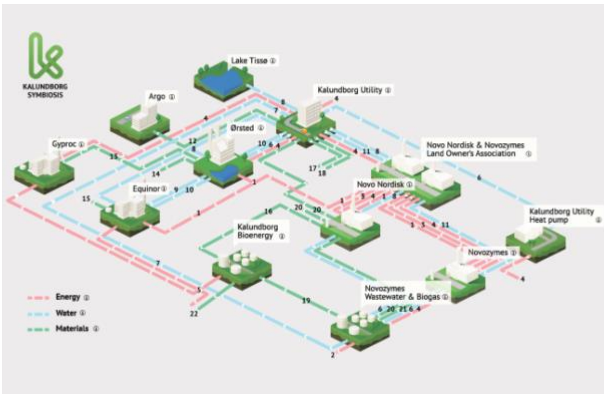
Source: www.vandesant.com/products

Example: The Kalundborg Symbiosis in Denmark is a local partnership between eight companies, established in 1972. The main principle of their cooperation is that residue from one company becomes the resource of another, resulting in an efficient production requiring less resources. The following graphic gives an overview of the flows of materials, water and energy between the partners.

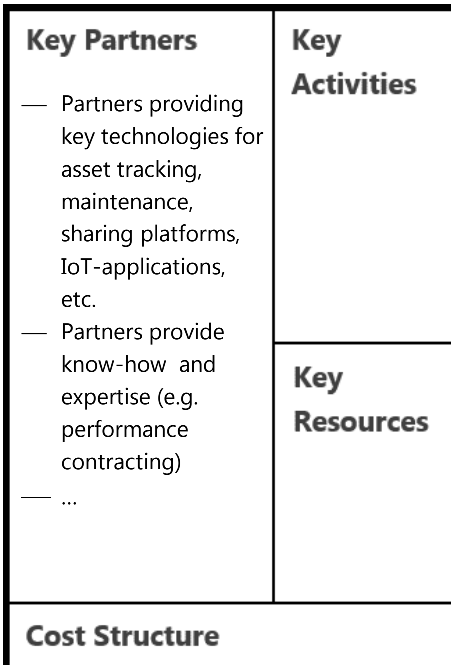
Figure 3.16 – Example of the Kalundborg symbiosis process

Related business Strategy: Maximise Production Efficiency
Key Partners: Neighbouring Industries providing material, energy and water flows

Source: http://www.symbiosis.dk/en/



Tophill Business strategies and the role of the value network



Tophill strategies are concerned with lengthening the use(ful) phase of products. The strategies related focus on

– **Prolonging Product Life** (e.g. selling consumables or spare parts, providing maintenance and repair, etc.)

– **Provision of Services** (e.g. renting, sharing, selling performance, etc.)

The prolongment of product life is often handled internally and not necessarily related to collaboration within the value network. In some cases, partnerships may be relevant for providing service personell or servicing stations (e.g. Car repair shops), but no general rule is applicable.

On the other hand, use-oriented and result-oriented Product-Service-Systems as well as Sharing Platforms often require substantial collaboration, due to the radical change of the BM in connection to it. Platforms often require a strong online presence and mobile applications for widening the reach. For result-oriented services (such as in the pay-per-lux example below) there is also often a need for consultancy or technological capabilities, such as asset tracking and monitoring (for the products which are now owned by the service provider).

Downhill Business strategies and the role of the value network

Key Partners	Key Activities
— Partners providing reverse logistics for products, components and materials (take-back-systems, collection services, etc.) — Partners facilitating the trade of secondary materials or reused products — ...	**Key Resources**
Cost Structure	

Downhill Strategies focus on keeping the value of products, components and materials after the use phase at its highest. The strategies focus on

— **Resale of products** (by introducing Second-Hand Markets, refurbishing used products, remanufacturing used components)

— **Recovering materials** (e.g. by recapturing materials from used products or by recycling processes)

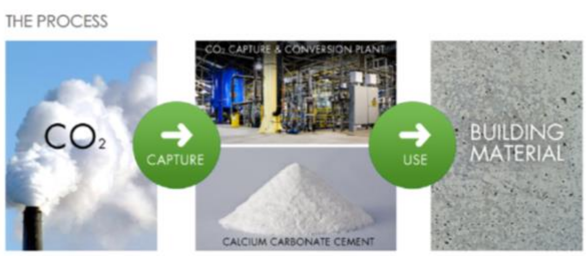
Both strategies often require reverse logistics, handled either by third parties (e.g. waste collection services, deposit systems) or internally. The applicability of the two often depends on the assets' value, meaning that assets with a high economic value, are often handled internally (e.g Caterpillar Remanufacturing Services for its engines), while "low-value" assets are often handled by third parties (e.g. through recycling facilities).

Example: The Company Calera captures emitted carbon (e.g. from coal-fired plants) and converses it with calcium to a solid calcium carbonate. This is then used as a profitable feedstock within there manufacturing plant for a variety of construction products, such as wallboards. Besides permanently binding the emitted CO_2 these boards substitute the use of other materials such as gypsum or portland cement, which typically have high environmental impacts.

Figure 3.17 – Example of the Calera process

Related business strategy: Material Recapture
Key Partners: CO2-emitting industries

Source: www.calera.com



Assignment 3.4

Following the Business Model Canvas, work in pairs to define the three fields - Key Partners, Key Resources and Key Activities - for three realised circular business strategies (one uphill, one tophill and one from the downhill category).

– For each business model define the company's key partners.

– For those key partners, which are different to the linear business model answer?

Which key resources is the company acquiring from their key partners and which key

3.5 Stakeholders engagement and management: how to establish a circular value network

As seen in previous sections of this chapter, getting the involvement of relevant stakeholders as key partners is an essential requirement towards the sustainability and circularity of value chains. Establishing a value network through the engagement of key stakeholders allows the creation of closed loops, and at the same time, reinforces the corporate social responsibility (CSR) policy of companies and organisations.

In this context of circular value networks, it is worth noting the link to the concept of social responsibility. On the one hand, the development of a CSR policy or strategy supports the establishment of interactions and relationships with relevant stakheolders, that may facilitate the creation of a circular value network; on the other hand, the creation of the circular value network itself, supports the development of the CSR policy or strategy. This way, social responsibility tools and frameworks, as the ISO 26000 guidance standard on Social Responsibility (ISO, 2010) or the Global Reporting Initiative (GRI, 2018), among others, can become a powerful asset in the establishment of circular value networks, as a way to strengthen stakeholders' involvement and gurantee company's transparency and credibility.

This said, this section will focus on how to support the establishment of circular value networks, with the aim of helping companies to collaborate with relevant stakeholders across value chains.

3.5.1 Main steps to establish a value network for circular chain cross collaboration and engage suppliers and other stakeholders.

Getting the required engagement and collaboration from relevant stakeholders may not be easy, but following some steps, may facilitate the process, as shown in the following figures (Cassell et al., 2016; Leising, 2016).

Figure 3.18 - Steps for the establishment of a circular value network (Adapted from Cassell et al., 2016 and Leising, 2016)

4 steps for the establishment of a circular value network:

Table 3.3 - Steps for the establishment of a circular value network (Adapted from Cassell et al., 2016 and Leising, 2016)

Steps	Circular value network
Step 1 Vision development	**"The best collaborations – and the best results – can come from moving away from traditional transactional supply chain relationships, towards a shared vision and mutual opportunities to achieve sustainable, long-term goals".** – Establishing a clear leadership to guide the process and to involve the organization to create support. – Creating shared values to inspire innovation and build trust.
Step 2 Value chain mapping & involvement of stakeholders	**"Mapping the key stakeholders and the subsequent material and financial flows allows identification of closed loops that deliver the greatest value, giving the business case added strength and weight".** – Value chain mapping to better understand the whole value chain and for the identification of win-win situations regarding environmental, economic and social benefits (i.e. material, financial, commercial and contractual issues) to achieve long term sustainability goals. – Value chain mapping for the identification of stakeholder groups with aligned interests that can contribute to realise that value. – Priorization and involvement of stakeholders that create value. – Creation of multidisciplinary teams.
Step 3 Managing stakeholder complexity	**"Transforming a value chain involves commitment from a wide range of stakeholders. It is essential that a thorough stakeholder communications and engagement plan is in place from the outset".** – The number and complexity of stakeholders increases in circular approach, in comparison to a linear approach, therefore defining clear responsibilities and roles within a co-creative process is essential. – Establishing and agreeing on these responsibilities and commitments at early stages to avoid misunderstandings and other potential issues. – Establishing non-traditional contracting mechanisms. – Establishment of incentive schemes for collaboration. – Establishing materials and data tracking mechanisms.

Steps	Circular value network
Step 4 Telling the story in stakeholders terms	**"Understanding the motivations and communications needs of each stakeholder enables the creation of a strong and compelling narrative for each audience, strengthening commitments and relationships".** – Defining a communication plan with clear and concise messages to explain and gurantee the understanding of measurable benefits of the collaboration for all partners, beyond agreed responsibilities and commitments. – Adapting the messages to different stakeholder groups. – Establishing open communication channels to facilitate coordination, transparency and trust.

These 4 steps can applicable to all kind of sectors, tailoring each action to the sectorial and contextual needs.

Additionally, the following table provides an example of stakeholders mapping when analysing a value network of the construction sector in the Netherlands. As seen there, different kind or stakeholder groups are considered, including as well key agents from the government and knowledge networks, together with other influening agents.

Table 3.4 - An example of types of organisations to potentially consider when analysing a construction value network in the Netherlands (Leising, 2016)

Stakeholder group	Types of organisations
Principals, initiators	– Real estate developers, housing corporations, government (local or national), private and other principals
Investors	– Investment funds, Private equity, crowd funding
Designers	– Architects and structural engineers, Consultants
Contractors	– General construction contractors, (Non-) residential building contractors, Civil building contractors, Building contractors maintenance, Demolition contractor
Suppliers	– Direct suppliers, Construction material merchandisers
Subcontractors	– Subcontractors and specialised subcontractors
Users/residents	– Companies, Residents, Government, Other
Government	– EU (European Commission), National government (Ministry of Infrastructure and the Environment, Ministry of Economic Affairs, Ministry of the Interior and Kingdom Relations), Local government (Provinces and municipalities)
Industry organisations	– Trade unions (FNV, CNV, De Unie), Trade organisations (Bouwend Nederland, BNA, MKB Bouw, MKB Infra)
Research and knowledge institutes	– General knowledge institutes: – Universities (TU Delft, TU Eindhoven, Wageningen University) – Other (KNAW, SenterNovem, TNO, Deltares) – Knowledge institutes for construction information (STABU, IBR, SBR, CROW) – Knowledge institutes built environment (PSIBouw, Klimaat voor Ruimte)
Influencing agents	– MVO Nederland, Circle Economy, C2C certified

Assignment 3.5

Come back to the value network of the circular product or service that you analysed in the first assignment; brainstorm about the different steps that you would follow for the creation of that value network in a circular economy context and explain them to your partner.

3.6 Existing tools for the management of value chains towards sustainability

This section aims at providing an overview on some of the existing tools that companies can use to manage value chains. Two important value chains analysts are Achilles and EcoVadis. There are also open source tools for this purpose, highlighting the following ones:

- OpenBoxes (https://openboxes.com) is an open source tool that helps companies to improve their environmental performance as it increases stock visibility, allows better forecasting and traceability and eliminates stockouts and reduces wastage.
- Fair Factories Clearinghouse (FFC) (http://www.fairfactories.org) provides web-based software to manage and share information about workplace conditions on labour, ethics, health & safety, environmental and security issues, leading to improved supply chain/workplace efficiency, oversight, accountability and economy. FFC Membership provides a company full access to an all-inclusive supply chain/workplace management technical solution.
- xTuple (https://xtuple.com) offers supply chain management software for businesses by consolidating all manufacturing and distribution processes into a single business system. xTuple helps companies of all sizes implement open source Enterprise Resource Planning (ERP) software at an affordable cost.
- Apache OFBiz (http://ofbiz.apache.org/index.html) is a flexible suite of business applications to be used across any industry, including, among others, suply chain fullfillment features.
- Odoo (https://www.odoo.com/es_ES) is an integrated software to manage an organisation's processes, available only in Spanish. It facilitates the traceability of stocks and logistics along with sales and post-sales operations, among many others.

These software sources help companies to manage all their processes: value chains, manufacturing or distribution, between others. They are not specific Circular Economy tools, but the information management they perform helps companies to generate opportunities for resource optimisation and industrial symbiosis.

3.6.1 Achilles

Achilles Supply Chain Mapping is a company specialised in supply chains and risk analysis. This company delivers a picture of the extended supply chain, identifying all the suppliers and sub-suppliers contributing to the production of a specific ingredient or component. In the same way, it enables suppliers to develop a supply chain map for the products and services they supply, increasing their awareness of and establishing accountability for suppliers in their downward supply chain.

Using a questionnaire, this tool helps buyers by identifying:

– Interdependencies and risk points in the supply chain
– Areas of convergence – potential single points of failure
– Supplier clusters across high-risk regions
– Impact of major events or incidents on global production.

3.6.2 EcoVadis

EcoVadis has developed networked collaboration tools to share information that enhances the value chains created between suppliers. Was created with the aim of contributing to the the social and environmental practices of companies improvement by taking advantage of the influence of global supply chains. EcoVadis connects buyers and suppliers to promote sustainability and Corporate Social Responsibility (CSR) criteria in 180 sectors and 150 countries. It has 21 criteria divided into 4 topics: environment, fair working conditions, business ethics and supply chain.

EcoVadis controls a collaborative platform that provides supplier sustainability ratings for global supply chains. It presents an approach based on the maintenance of quality and integrity. They offer: account management, incorporation of suppliers, formation, consultancy, customised Information Technologies services and integration and association of collaborators.

Figure 3.19 – Ecovadis: sustainable suppliers network (www.ecovadis.com, 2019)

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04

PROCESSES AND MATERIALS

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Processes and materials

Contents

Executive summary 189

4.1 Introduction 190

4.2 Characteristics of materials and processes from a circular economy perspective 194

4.3 Design and development strategies vs characteristics of materials and processes 197

4.4 Compilation of processes related to circular economy 199

4.5 Compilation of characteristics of materials related to circular economy 211

4.6 Trade-offs in the circular economy 224

Bibliography 228

Executive summary

4.1 Introduction

This section presents a contextualization of the role played by processes and the characteristics of materials in the development and design phase of products in the target sectors. This section presents a circular economy overview and what is understood here as processes and materials could be influenced in a vision of the CE.

4.2 Characteristics of materials and processes from a circular economy perspective

Helps to reflect on issues that designers and planners should address for achieving a better performance along the whole life cycle of products or systems, e.g. a façade or a house, and finally, it lists some characteristics of materials and processes that play a key role in the transition to a circular economy.

4.3 Design and development strategies vs characteristics of materials and processes

The connection between Circular Design Strategies and processes and characteristics of materials from a CE point of view, is presented. This connection can be used as a guide to choose the most appropriate materials and/or processes characteristics for the circular design and development strategies of products and products-services.

4.4 Compilation of processes related to circular economy

Some practical examples of characteristics of processes to be taken into account by developers in the design process of a new product from circular economy perspective will be presented.

4.5 Compilation of characteristics of materials related to circular economy

Some practical examples of characteristics of materials regarding circularity will be presented. Those characteristics are not exclusive, and they do not conform an exhaustive and closed list.

4.6 Trade-offs in the circular economy

Addresses the subject of possible trade-offs when making decisions with potential contradictory effects. Some methods used to deal with these trade-offs and achieve a balanced compromise are listed.

4.1 Introduction

The increasing demand of technology, coupled with the continued growth of the human population, consumes resources at an ever-increasing rate. Although the earth's resources are very large, there is increasing awareness that limits do exist, that we are approaching some of them; it is clear that current human activities exceed this threshold with increasing frequency, diminishing the quality of the world in which we now live and threatening the well-being of future generations. In 1972, a group of scientists known as the Club of Rome reported their modelling of the interaction of population growth, resource depletion, and pollution, concluding that "if (current trends) continue unchanged, humanity is destined to reach the natural limits of development within the next 100 years". Part of this impact, at least, derives from the manufacture, use, and disposal of products, and products -without exception- are made from materials.

The reasons why consumers choose to discard some products and buy new ones depend on several factors: the type of product, the failure or deterioration of the product, or the desire to own a newer one with novel and additional functionalities, and the design or achievement of status and image through the product.

The end of life of a product can occur for a variety of reasons:

- end of physical life (the product has lost physical qualities that condition its functioning or aesthetic deterioration)
- end of functional life (the product is no longer capable of performing the functions for which it has been designed or efficiency/performance has decreased)
- end of economic life (the operation of the product generates some extra costs, compared to other new products that meet the same functionality)
- end of legal life (a product that can no longer be used for legal imperatives)
- end of life for loss of desirability (the user is not interested in that product and simply decides to stop using it), among others (Cheung et al., 2015).

In most of these cases, the end of life is intimately related to the materials with which it is manufactured and to the manufacturing or operating processes.

Figure 4.1 shows the consumption of the materials used in the largest quantities (the scale is logarithmic). The big ones are the materials of the construction industry. In addition to hydrocarbon fuels, the materials with the highest consumption are those directly related to construction and furniture: concrete, wood, steel, asphalt, glass and natural fibres. Polymers come next. Fifty years ago, their consumption was tiny; today the consumption of commodity polymers polyethylene (PE), polyvinyl chloride (PVC), polypropylene (PP), and polyethylene-terephthalate (PET) exceeds that of any metal except steel (Ashby, 2015)

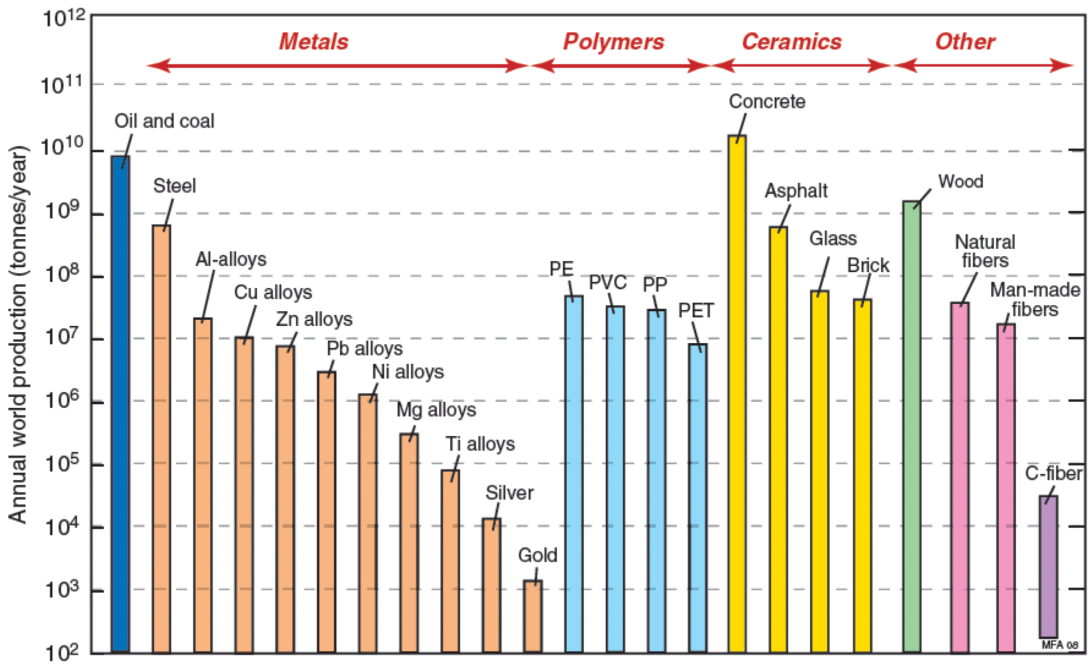


Figure 4.1 - Annual world production of 23 materials on which industrialized society depends. (From: Ashby, 2015).

The products, processes and circular materials aim to reduce the generation of waste, as well as the dependence of our economy on the extraction and import of resources. Therefore, circularity has the potential to bring both environmental and economic benefits and is increasingly recognized as a mechanism that would enable social and environmental sustainability.

It can happen that, at the moment of the design and development of a product, there is a lack of knowledge or lack of information regarding the choice of the type of material to be used, or the most optimal processes to apply in the different stages of the product life cycle. It is important to bear in mind that the processes and materials within CE (see below the definition of CE according to the KATCH_e project) must comply with a series of characteristics, which in a more or less innovative way, must be adjusted to the needs of the users.

> Circular economy is a system that is restorative and regenerative by intention and design, which supports ecosystem functioning and human well-being with the aim of accomplishing sustainable development.

> It replaces the end-of-life concept with closing, slowing and narrowing the resource flows in the production, distribution and consumption processes, extracting economical value and usefulness of materials, equipment and goods for the longest possible time, in cycles energized by renewable sources. It is enabled by design, innovation, new business and organizational models and responsible production and consumption.

In the next sections, some processes and characteristics of materials to be considered by professionals to design as much of a circular product as possible will be suggested. Further on, we will provide the information to assist in the decision-making process about the choice and management of materials and processes associated with products and products-services in the furniture and construction sectors with a life cycle perspective, helping users to make tangible previous selected circular design strategies.

To ensure the correct understanding of the content of this section, processes and characteristics of materials are defined as follows:

- **Process** can be defined as a set or succession of unitary operations to which a certain quantity of matter is subjected to elaborate or transform it. A unitary operation is understood as an action that allows the characteristics of matter to be modified in order to make it comply with a specific purpose or acquire specific properties. The changes that take place in matter as a consequence of being subjected to a unitary transformation operation can take place in three different ways: modifying the mass and/or the composition, modifying the energy level or quality it possesses or modifying its amount of movement.
- **Characteristics of materials** are those properties of materials that enable them to meet the technical and quality requirements for a given application. These include mechanical, chemical, thermal and physical properties. These engineering properties are well characterized. They are measured with sophisticated equipment according to internationally accepted standards and are reported in widely accessible handbooks and databases. Additional properties are needed to incorporate eco-objectives into the design process. Those relating to the environment are less familiar, therefore requiring further explanation. The accuracy of a large number of ecodata is relatively low and most are found in commercial Life Cycle Analysis databases such as Ecoinvent, GaBi or ELCD.

Assignment 1

Perform a brainstorming session in small groups to get a list of processes and characteristics of materials that may be interesting to consider when designing and developing products or product-services in the furniture and construction sector. Then, try to obtain examples of products or products-services, which are thought to be interesting in a circular economy and discuss them.

4.2 Characteristics of materials and processes from a circular economy perspective

One of the first points that designers need to consider when developing a circular product is to identify which process/processes and material/materials are better to use or are available and therefore, which the best way to apply them is. Some questions a designer will need to face are: Which characteristics should a product have in order to be circular? Which profile of products do consumers need? Which materials and contents? Which processes are relevant to consider? In this stage, it is also important to clearly align the objectives of the development project with the strategy of professionals, stakeholders, the company and the facilities.

In the case of construction and furniture sectors, defining the use and performance span of the product and product-service must be a part of the design process for materials and process choices to be adjusted to its optimality from the sustainable perspective (Ellen MacArthur Foundation, 2015).

A very practical tool for CE related materials is Sustainable Materials Management (SMM). SMM is a systemic approach for using and reusing materials more productively over their entire life cycles. This challenge involves a change of perspective on the use of natural resources and environmental protection, and a life cycle perspective is recommended for comprehensive and complete management. SMM requires the evaluation of all environmental impacts involved in the lifecycle of materials in order to identify where, and how, resources are being consumed, and where and how pollution and other wastes are occurring. By mapping out environmental impacts both by material type, and industrial process, SMM helps to identify the materials and processes with the greatest environmental challenges and most significant opportunities to drive change (Silverstein, 2014).

From the organizational point of view, companies and organizations are as efficient as their processes are. Process Management can be conceptualized as the way to manage the entire organization based on processes. A sustainable management of processes is carried out when the eco-efficiency of the processes is analysed, awareness of their relevance and importance is generated and inefficiencies are reacted to in order to address a common objective and work with a customer-oriented vision.

Selecting materials and processes involves seeking the best match between design requirements and both material properties and characteristics of processes that might be used to make the product (Ashby, 2009).

In production processes, the design requirements for a component or product are many times developed to a usage phase by consumers, but not much relevance is given to which properties or characteristics the materials should have to produce a concrete product. To solve this question, Ashby et al., 2007 proposed four steps to investigate a large population of materials to be selected.

Here, an adaptation to include both processes and the linear economy point of view has been done (Table 4.1). The first step is the ***translation***, that means converting the design requirements into functions, constraints and objectives that can be applied to the materials and processes database attributes (drawn from suppliers' data sheets, handbooks, Web-based sources, or software specifically designed for material selection). The outcome of this step is basically a list of design-limiting properties and constraints they must meet. The second one is the ***screening,*** which eliminates the materials and processes that cannot meet the constraints. In other words, it eliminates candidates that cannot do the job at all because one or more of their attributes lies outside the limits set by the constraints. The third step is the ***ranking*** or ordering the materials and processes considering their ability to meet a criterion of excellence, such as that of cost minimization, embodied energy, or carbon footprint. The last one is called ***documentation*** and deals with exploring the most promising characteristics of materials and processes in depth, analysing how they are used at present or how best to design and work with them. It can be descriptive by graphical or pictorial illustration: case studies of previous uses of the material, etc. Documentation helps narrowing the shortlist to a final choice, allowing for a definitive match to be made between design requirements and material choices.

Table 4.1 - Four steps strategy (translation, screening, ranking and documentation) to choose materials and processes (Source: Ashby, 2009).

All materials and alternative processes
Translate design requirements: Express as function, constraints, objectives and free variables .
Screen using constraints: Eliminate materials and processes that cannot do the job.
Rank using objectives: Find the screened materials and processes that do the job best.
Seek documentation: Research the family history of top-ranked candidates.
Final materials and processes choices

In the last two steps proposed, the use of the life cycle analysis method is recommended. In the first case, the application of this method allows for identifies hot spots in the life cycle of the product and thus allows for focusing on opportunities for improvement from the sustainability point of view.

The following identifies some characteristics/properties of materials and processes with a key role in the transition to circularity and are especially useful in the process of designing products and services.

Table 4.2 presents characteristics of materials and processes identified in KATCH_e and in scientific paper review. Here, the technology of the processes is not explained, unlike the general aspects to be considered and further selection of the best technology/technique to carry out a product manufacturing. This is NOT a closed and exhaustive list, and the order of items does not have a priority indication.

Table 4.2 - Processes and characteristics of materials to circularity.

Process to CE	Characteristics of material to CE
– Recycling process – Modular Design Process – Disassembly process – Re-assembly process – Reparability process – Energy recovery – Remanufacturing – By-product valorization process – Labour condition – BAT – Process optimization	– Material recyclability; – Recycled content – Material resistance; – Material toxicity; – Material biodegradability; – Resource cascading; – Low embodied energy; – Availability/scarcity renewability – Water footprint – Carbon footprint

Assignment 2

Group discussion about the following topics:

- What do you think are the main characteristics of materials and processe within the linear economy?
- Which are the current trends in the furniture and construction sector concerning materials and processes?

4.3 Design and development strategies vs characteristics of materials and processes

Design and development strategies have been classified under three categories: slowing loops, narrowing loops and closing loops. These strategies need to be addressed considering the characteristics of processes and materials.

Table 4.3 shows the relationship between circular design strategies and processes and characteristics of materials to circularity. This table can be used as a guide to help the user implement design strategies for the development of more circular products and products-services by choosing the most appropriate material characteristics and/or processes. The suggested relationships are not closed and definitive, since new technologies and processes will appear and the relation of some strategies and characteristics of materials and processes to CE should be adapted according to each situation of further designing.

Assignment 3

Think of a product in the furniture or construction sector.
Choose two or three design strategies for circularity from Table 4.2 that best apply to the type of product you have in mind.
For these strategies, check and discuss the related characteristics of processes and materials and indicate whether there are any unidentified additional ones to achieve sustainability in life cycle and circular economy thinking.

Table 4.3 - Relationship between circular design strategies and characteristics of materials and processes.

CE crossover points	Circular Design Strategies										
	SLOWING LOOPS				NARROWING LOOPS			CLOSING LOOPS			
Materials and processes characteristics of circularity	Design of long life products	Design for product life extension	Design of product-life extension-service (product-oriented)	Design of products as services (use-oriented and result-oriented)	Design for materials sustainability	Design for energy sustainability	Design for water sustainability	Design for dis- and reassembly	Design for recycling	Design for remanufacturing	Design of reverse logistics services
Re-assembly process		x	x	x				x	x	x	
Energy recovery					x	x					
Disassembly process				x	x			x	x	x	x
Repairability process	x	x	x	x				x			x
Modular process design				x	x	x	x	x	x	x	x
Remanufacturing			x	x	x	x	x	x		x	x
BAT					x	x	x				
Labour condition					x	x	x				
By-products valorization					x	x	x				
Recycling process					x	x	x	x	x		x
Process optimization					x	x	x				x
Material resistance	x	x	x	x						x	x
Material toxicity					x		x				
Material biodegradability	x			x	x						
Resources cascading					x	x	x	x	x	x	x
Recycled content					x	x	x		x		x
Material recyclability					x	x	x	x	x		x
Low embodied energy					x	x			x		x
Availability/Scarcity and renewability	x				x	x	x	x	x	x	x
Water footprint					x		x		x		
Carbon footprint	x	x			x	x			x	x	x

4.4 Compilation of processes related to circular economy

In this section, some practical examples of characteristics of processes to be taken into account by developers in the design process of a new product from circular economy perspective will be presented. Table 4.4 summarizes the fields used to describe the characteristics.

Table 4.4 - Base line points of each process and material characteristic.

FIELDS OF INFORMATION	
Definition:	Definition of the process or characteristic of material.
Complementary information:	Further explanation or description of the characteristic.
Example (with images):	Description or reference to the example.

In this section, some characteristics of processes commonly used in the circular economy were identified. Some processes can exhibit more than one characteristic since some of them are often interlinked. Those processes are not exclusive, and they do not conform an exhaustive and closed list. The considered processes in this section are:

- Recycling process.
- Modular process design.
- Disassembly process.
- Reassembly process.
- Reparability process.
- Energy recovery.
- Remanufacturing.
- By-product valorization process.
- Labour condition.
- Best Available Techniques.
- Process optimization.

Table 4.5 - Recycling process

RECYCLING PROCESS	
Definition	Recycling means any recovery operation through which waste materials are reprocessed into products, materials or substances whether for the original or other purposes (DIRECTIVE 2008/98/EC). Note: Energy recovery and backfilling is not including in recycling.
Complementary information	Three types of recycling processes can be classified according to the value contributed by the recycled waste in the new product: **Re-cycling**: Any recovery operation by which -in part or in full- a substance or material or an object that has become waste but cannot be reused is reprocessed into raw materials of the same purpose/value as that of the original; **Down-cycling**: Any recovery operation by which -in part or in full- a substance or material or an object that has become waste but cannot be reused is reprocessed into raw materials of lower/lesser purpose/value than the original; and **Up-cycling**: Any recovery operation by which -in part or in full- a substance or material or an object that has become waste but cannot be reused is reprocessed into raw materials of higher purpose/value than the original; This is the most desirable option. (Brown & Buranakarn, 2003). Different types of recycling processes can be considered according to the following criteria: internal and external. **Internal recycling** is the use in a manufacturing process of materials that are a waste product of that process (Nilson, 2007). The internal recycling process could provide some advantages, such as re-utilization of materials, reduction of amount of materials purchased, closing of loops (water and energy), waste prevention and cost-reduction. **External recycling** is the recovery of materials not generated in the plant where they are recovered; it can be generated by other manufacturing plants or from a product that has been worn down or has become obsolete. It is worth mentioning that the most interesting strategy is to minimize the generation of waste at source.
Example	 http://wiki.bk.tudelft.nl/mw_bk-wiki/images/thumb/2/22/Monsterkast_168_1.jpg/400px-Monsterkast_168_1.jpg The inert part of demolition and construction waste can be recycled for various purposes, e.g. as filler material (recovery), as raw material in other construction materials etc. In any case, the most common recycling process for this type of inert waste, following a correct selective separation, is crushing, the intensity of which, i.e. obtaining a more or less fine grain size, will depend on the function that the recycled material will fulfil in the second system. Other example is aluminium, which is cleaned, crushed and melted to obtain a new raw material (Bravo et al., 2015).

Table 4.6 - Modular process design

MODULAR PROCESS DESIGN	
Definition	Modularity is a process design approach that allows for the subdivision of a system into smaller parts called modules or skids, that can be independently created and then used in different systems. This allows designs to be customized, upgraded, repaired and for parts to be reused (da Rocha & Kemmer, 2018).
Complementary information	Modularity is a notion which indicates the level up to which the components of a system can be divided and combined again and, following this concept, modularity can be recognized as a product which is amenable to a combination and re-assembly of its parts. Designing modularity, a component in a product design performs a function within a system of interrelated components whose collective functioning make up the product itself. Relationships between components are defined by the specifications linking components or connectors in a design. The modular process design offers opportunities during the life cycle and also at the end of life of cycle for easy replacement, design change to better meet user needs, and in some cases, allows for the use of different materials. It can also be a strategy to reduce product catalogues and stock. The modularity is stimulating companies to create sustainable products and do new and more business in comparison to traditional construction and furniture industries, since the versatility provided by modularity can expand the market niche. Knowledge about materials used (quantity and quality) and the possibilities for maintenance, repair, refurbishment, reuse, remanufacturing and recycling could stimulate the design for modularity (Ribas & Cachim, 2019).
Example	 www.inhabitat.com/new-gomos-system-allows-tiny-homes-in-portugal-to-be-builtin-mere-days and www.farcimar.ptamuel GOMOS - modular systems of reinforced concrete. The Gomos system results from a collaborative R&D project between architects and engineering companies (18 companies). It is a modular system of reinforced concrete that simplifies and speeds up the construction process. It is scalable, in which each module, comes out of the factory completely ready, including all the necessary parts. The assembly takes place in a few days, simply adding these modules. The construction is flexible enough to be reused, expanded or disassembled for recycling, and its design and materials allow for low energy-consumption.

Table 4.7 - Disassembly process

DISASSEMBLY PROCESS	
Definition	Disassembly means that a product or building can be easily separated into its components or parts (Bovea et al., 2018).
Complementary information	Disassembly process is remarkably interesting in CE, since the separation of the different parts of a product makes it possible for the application of different management operations, such as: easier reparation and replacement of parts, reuse in others or in the same type of products, material recovering, design and manufacturing cost reduction, recycling, etc. (Chiodo, 2005). Some products are easy to design for end of life optimization and the number of material types used in an assembly could be minimized. The disassembly process and separation of products into components requires a system of evaluation for feasibility and reliability. The disassembly operations can be performed manually or automatically, depending of the type and complexity of the product. This process can be categorized into two types: (a) **complete disassembly** and (b) **incomplete disassembly** (Durmisevic & Brouwer, 2002; Government of the Netherlands, 2016). A complete or full disassembly is the process in which every single component of the product is separated. This is rarely done due to high technical constraints (particularly the complexity and uncertainties involved in the operation) and high labour costs. On the other hand, the incomplete or selective disassembly separates only the desired components or subassemblies and terminates when the desired depth of disassembly is reached. Other classification for disassembly operations can be broadly categorized into three types: **non-destructive, semi-destructive, and destructive disassembly** (Predeville & Bocken, 2015).
Example	 http://www.jetsongreen.com/2016/08/furniture-can-be-fun-to-assemble-and-take-apart.html This disassembly process of the selected furniture line is called CRISSCROSS and consists of flat pack cupboards, wardrobes and desks. It is easy to pack up and take with you when you're moving. The furniture system is made up of wooden panels, which resemble pegboards at first glance. These panels are CNC-cut, and only FSC-certified birch is used. The panels are designed to be joined together into various pieces of furniture using removable brackets and locknuts, which are made of high-grade, anodized aluminium. These simple construction blocks can be used to construct all the necessary pieces of furniture.

Table 4.8 - Reassembly process

REASSEMBLY PROCESS	
Definition	Reassembly is basically defined as ensuring products and parts that can assembled again in the same product, through the operations to finalize products for optimal usage. (Fu et al., 2015).
Complementary information	Assembly processes can be reversible or irreversible depending on the type of joints and connections between the different parts and, in some cases, this process may be limited by the intensity and mode of use and even maintenance (Mascle & Xing 2009; Bakker 2014). Design for reassembly and disassembly through component design and product architecture shares many of the Circular design principles However, not everything that is reassembled can be disassembled later, thus limiting certain advantages described above in the disassembly process (table 4.6), such as reparation, replacement of the different parts, or material recovery, among others.
Example	 https://www.ecosia.org/images?q=Herman+Miller%27s+disassembly#id=D9393A3C4977361E7489C67C1F1520B384EA5720 Herman Miller's approach to circular design is broad. The design of his furniture makes it possible to assemble and disassemble the various components to repair, replace, recycle and reuse chair parts in other systems once their useful life is over.

Table 4.9 - Reparability process

REPARABILITY PROCESS	
Definition	Repairability covers a combination of all technical and associated administrative actions during the service life associated with corrective, responsive or reactive treatment of a product to return it to an acceptable condition in which it can perform its required functional and technical performance. (EN 15804:2012+A1:2013).
Complementary information	Repairability process is also defined as the set of techniques that allow for repairs and keep the products in good quality during their life cycle. This process can also extend the products and materials lifespan. Repairability also includes the preservation of the aesthetic qualities of a product or material. This characteristic could be considered during the product design, including the selection of material and connections (easy to find and accessible) to support the repairability process during the life cycle until the end-of-life. In construction, reparability processes of an element or system are considered as refurbishment, which also includes the process of replacement (EN 15804:2012+A1:2013).
Example	 www.freeusable.co.uk Hub67 is a community hub located in Hackney Wick, which has been created by reusing modular cabins. The hub is a prime example of how assets can be repaired and repurposed applying CE strategies. Several contractors were able to achieve high levels of reuse while using repaired/refurbished materials. In the case of construction, careful removal and storage is essential to achieving reuse and easy reparation of parts from other constructions.

Table 4.10 - Energy recovery

ENERGY RECOVERY	
Definition	Energy recovery refers to the process of harnessing energy that would otherwise be lost or emitted to the environment. Energy can be recovered mostly in the form of thermal energy and, to a lesser extent, electricity. (ISO 18605:2013). This broad definition includes energy valorisation of wastes as energy recovery, mainly thermal energy, from diverse production processes. Energy recovery can be applied in the different life cycle stages.
Complementary information	Energy recovery includes any technique or method of minimizing the input of energy to an overall system by the exchange of energy from one sub-system of the overall system with another. The energy can be in any form in either subsystem, but most energy recovery systems exchange thermal energy in latent form. (Allwood, 2014). Basically, there are three types of technologies for the valorisation of energy from wastes: **Thermo-chemical**: conversion process which extracts energy from waste through elevated temperatures. Types: combustion (waste to energy), gasification, pyrolysis and liquefaction. **Chemical: conversion process** which extracts energy through esterification, this is, the creation of ester due to a reaction between alcohol and an acid. **Bio-chemical:** conversion process which extracts energy using bio-decomposition of waste. Types: biogas from anaerobic digestion or landfill, bio-hydrogen and bioethanol from fermentation and microbial fuel cells. Energy recovery from wastes is a preferable waste treatment process than sending to a landfill, which should be reduced to an absolute minimum because of the CH4 and leachate generation. However, to achieve a higher level of circularity it should be considered as one of the last options at the end of life, after reuse, refurbishing and recycling.
Example	 Several ceramic tile manufacturing stages require thermal energy, generally from the combustion of natural gas. In the kiln, after crossing the peak temperature zone, the tiles are cooled down by direct contact with ambient air that is fed into the kiln. Cooling gases are usually exhausted through the cooling stack. Some of these gases are recovered as combustion air in the burners of the same kiln, but can be also recovered in other stages, such as dryers. For this purpose, an intermediate fluid, in this case thermal oil, is used, thus reducing the energy input required from the natural gas burners in the dryers (Mezquita et al., 2014).

Table 4.11 - Remanufacturing

REMANUFACTURING	
Definition	Remanufacturing is an industrial process where used products are restored to an 'as-new quality' through different operations (Stahel, W. R. 2016).
Complementary information	Remanufacturing differs from manufacturing in many ways. For example, there are activities in the remanufacturing process which do not exist in manufacturing, such as disassembly, cleaning, inspection and sorting. The level of automation is also low within remanufacturing and the batch sizes are in general small (Siddiqi, et al., 2019). For remanufacturing, a product is disassembled at the component level (rather than into separate materials), broken/outdated parts are replaced and then the item is reassembled. The cost saving is a key factor to consider its feasibility. Remanufacturing can be regarded as a "win-win-win". In many cases the customer has to pay less, the remanufacturing companies earn more, and the environment will benefit from it since fewer new components are needed if the process is efficient (Seitz & Peattie, 2004). Remanufacturing could save energy, reduce pollution and waste, conserve natural resources and extend their availability (Seitz, 2007). From a CE perspective, while remanufacturing process provides a basis for slowing resource loops, it is mainly regarded within a repairability and refurbishment system. It's important to distinguish the differences between remanufacturing and redesign, which offers potential for design innovation. Remanufacturing, as primarily involving the refurbishment of an existing product in a linear sequence, is relatively limited in scope. Redesign opens the opportunity for the innovative use of components for potentially different applications in the new remanufactured product (Gao & Wang, 2017).
Example	 http://www.rypeoffice.com/what-is-remanufactured-office-furniture/ Office furniture is a logical candidate for remanufacturing because it has very long- life components like steel bases which are expensive to make from virgin resources. These can be reused and the softer parts around them replaced. The result, depending on the level of quality required, can be indistinguishable from new and carry the same warranty. In the case of Rype Office, for office refits and moves, many companies remanufacture some existing furniture, source some remanufactured pieces and combine these with new items to benefit from the latest trends like soft-furnished collaborative space.

Table 4.12 - By-products valorisation process

BY-PRODUCTS VALORIZATION PROCESS	
Definition	By-product is a substance or object, resulting from a production process, the primary aim of which is not the production of that item. By-products can come from a wide range of business sectors and can have very different environmental impacts. An incorrect classification of wastes could be the cause of environmental damage or unnecessary costs for business. (Hultman & Corvellec, 2012)
Complementary information	The difference between by-products and co-products is that co-products are normally produced along with a main product which has the same importance as the main products, while by-products are not planned products and have less economic importance than main products. Co-products are planned products and are used in the same industry to make some profit, but by-products are less used in general. From the circular economy perspective, both need to be considered as resources. The correct implementation of best practices and good awareness management could help to introduce by-products in the value chain, thus contributing to reducing resources, cost associated and emissions to the environment, among others.
Example	 http://www.chiangraitimes.com/men-dying-over-the-dream-of-changing-their-lives-by-aloeswood.html The valorisation of industrial waste from marine pine wood is one application of new technologies to make use of wood waste. Essential oil of *Pinus pinaster* is extracted by steam distillation and hydro distillation techniques at normal temperature and pressure, thus adding value to the by-product of wood waste. In this process, a total of 27 compounds were extracted and identified in different concentrations. The marine pine by-product valorisation can be considerably interesting for oil application in high-class perfumes, flavours and other formulations (Mellouk et al., 2016).

Table 4.13 - Labour condition to circular economy

LABOUR CONDITION	
Definition	Labour/working conditions are at the core of paid work and employment relationships. Working conditions cover a broad range of topics and issues, from working time (hours of work, rest periods, and work schedules) to remuneration, as well as the physical conditions and mental demands existing in the workplace (ILO, 2012).
Complementary information	Not only from the CE perspective, but for any business, the workforce is an asset, and a sound worker-management relationship is a key ingredient to the long-term sustainability of the enterprise. Failure to establish and foster a sound worker-management relationship can undermine worker commitment and retention, result in labour strikes, and can jeopardize a client's/investee's operations. Conversely, through a constructive worker-management relationship, and by treating the workers fairly and providing them with safe and healthy working conditions, clients/investees may create tangible benefits, such as enhancement of the efficiency and productivity of their operations (IFC, 2018; Circle Economy, 2017)
Example	 https://www.unison.org.uk/get-help/knowledge/health-and-safety/working-conditions/ In the case of UNISON Company, the following criteria for fair labour conditions are applied: Maintenance of workplace; Ventilation of enclosed workplaces; Temperature regulation; Lighting must be suitable and efficient and natural as far as it is reasonably practical; Cleanliness; Spaces such as workrooms have enough floor area, height and unoccupied space; Workstations must be suitable for the worker and work; Floors must be suitable and not uneven or slippery, presenting a safety risk; Falls - take suitable and sufficient measures for prevention; Windows as transparent and translucent surfaces, consist of safe material, are clearly marked. Safety; Traffic allows safe traffic circulation; Doors meet safety specifications; Escalators follow safety specifications; Toilets - provide suitable and sufficient sanitary conveniences at readily accessible places; Water - providing an adequate supply. Restrooms provide suitable and sufficient rest facilities at readily accessible places.

Table 4.14 - Best Available Technologies (BAT) to circular economy.

BEST AVAILABLE TECHNIQUES (BAT)	
Definition	The most effective and advanced stage in the development of activities and their operation methods, which indicates the practical suitability of particular techniques for providing the basis for emission limit values and other conditions designed to prevent and, where that is not practicable, to reduce emissions and the impact on the environment as a whole (IED Directive 75/2010/EU).
Complementary information	In this case, 'techniques' include both the technology used, and the installation is designed, built, maintained, operated and decommissioned. This approach can be applied for all economic sectors, including KATCH_e target sectors. The BAT concept itself is an umbrella whose objective is to reduce environmental impacts as a whole, through the reduction, for example, of natural resources, energy, emissions to atmosphere & water and waste generation, among others. To support public authorities to regulate the economic activities under the scope of IED Directive, the EC produces the best available technique reference documents or BREF notes. These documents, specific for each group of industrial activities, provide useful information about the different manufacturing process, the main impacts and key environmental indicators. Apart from this, these documents establish the BAT-Associated Emission Limit Values (BAT-AELs), considering primary and secondary techniques and generic and specific ones depending on the sector. There are BREFs for different construction or furniture materials such as glass, steel, panels made of wood or ceramics, among others. To check current BREFs and their status: https://eippcb.jrc.ec.europa.eu/reference/. The European Commission is updating BREF documents and the updated versions also include "BAT conclusion documents". These contain emission limits associated with BAT ('BAT AELs') which must be complied with unless the Environment Agency agrees certain criteria have been met (Directive 75/2010/EU (IED Directive). In this sense, companies should consider BATs to be applied in their processes, as they ensure the accomplishment of legislative requirements. Moreover, companies are flexible to go for any other alternative technique, although this is not an official "BAT". In this sense, this alternative technique should provide a level of environmental protection equivalent to the proper BAT. Given the case where the alternative technique does not provide equivalent environmental protection, but you want to make a case that is justified on cost-profit grounds, you should provide a justification in the operating techniques section of the form and through your risk assessment and cost benefit analysis (IED Directive; UKEA, 2016).
Example	The CER BREF includes, among other chapters, the BAT conclusions including associated environmental performance levels and the associated consumption and emission levels (CER BREF, 2007). There are nine subsectors within the CER BREF: ceramic tiles, bricks and roof tiles, table- and ornamental ware, refractory products, sanitary ware, technical ceramics, vitrified clay pipes, expanded clay aggregates and inorganic bonded abrasives. BATs can be generic and/or specific, depending on the key environmental indicators (KEIs) identified for each subsector. The following are some of the KEIs identified in the CER BREF:

	Emissions to air: particulate matter/dust, gaseous emissions and chlorine compounds, organic compounds and heavy metals; **Emissions to water**: process wastewater. This mainly contains mineral components and also further inorganic materials, small quantities of numerous organic materials as well as some heavy metals. **Process losses/waste**: process losses originating from the manufacture of ceramic products, mainly consist of different kinds of sludge, broken ware, solid residues (dust, ashes) and packaging waste; **Energy consumption/CO_2 emissions**: all sectors of the ceramic industry are energy intensive, involving drying followed by firing where temperatures reached are in the range between 800 and 2000 ºC.

Table 4.15 - Process optimization to circular economy.

PROCESS OPTIMIZATION

Description	Process optimization is the discipline of adjusting a process so as to optimize some specified sets of parameters with no constrain violation, minimizing costs and maximizing throughput and/or efficiency. In process optimization, the resource should add as much value as possible. (ISO 15746-1:2015).
Complementary information	For a long time, process optimization was considered as the task of quality management, but today it is increasingly grown as a part of a comprehensive and integrated process management in organizations. Process optimization allows for a more efficient use of resources, both human and machinery related, reduction of downtime and activities that do not add value, which translates into an increase in production capacity at a lower cost (Miller et al. 2010). Some approaches to optimize a process are: BPR – Business process reengineering; Lean Management; Kaizen (CIP); Six Sigma and TQM – Total Quality Management. In any case, the company should study the better tool or tools to implement in the process or entire system management according to their characteristics and needs (Cosima project, 2015).
Example	 http://www.jiem.org/index.php/jiem/article/viewFile/156/50 Grand Rapids Chair Company has integrated lean tools and sustainability concepts applying simulation modelling and analysis as well as mathematical optimization to make a positive impact on the environment, society and its own financial success. The principles of lean manufacturing that aid in the elimination of waste have helped the company meet ever increasing customer demands while preserving valuable resources for future generations. The implementation of lean and sustainable manufacturing was aided by the simulation and optimization to overcome deficits in lean's traditional implementation strategies. Basically, the company improved two steps of their production using LEAN strategies as: a recycling project resulted from a Lean Process Kaizen and an event concerning the solid waste disposal process, which led to the recycling of a significant amount of material previously disposed of as waste and to optimizing the supplier selection project. This showed that the use of quantitative analysis tools makes a lean transformation more precise and thus leaner.

Assignment 4

Develop a list of examples of processes that can be considered relevant for CE in the furniture or construction sector. Try to focus on regional examples, if possible.

4.5 Compilation of characteristics of materials related to circular economy

In this section, some practical examples of characteristics of materials regarding circularity will be presented. Those characteristics are not exclusive, and they do not conform an exhaustive and closed list. The considered characteristics in this section are:

- Material recyclability.
- Recycled content.
- Material resistance.
- Material toxicity.
- Material biodegradability.
- Resource cascading.
- Low embodied energy.
- Availability/scarcity renewability.
- Water footprint.
- Carbon footprint

Table 4.16 - Material recyclability

MATERIAL RECYCLABILITY	
Definition	Recyclability is the capacity or ability of a material to be captured and separated from the waste stream or another source for conversion or reuse to build other products for the same or different purpose. (Di Maria et al., 2018; ISO 14021:2016).
Complementary information	The recyclability of materials depends on several variables, such as the technology and economics of the recycling processes, the quality of recycled materials, the environmental impact of waste and, also those policies related to recycling. The recyclability is different depending on the type of material, the capacity it has to be separated selectively from other materials and the ratio of efficiency or substitution, the total possible number of recycling loops, etc. Despite recyclability being one of the final processes within the CE, in order to achieve circularity, it is necessary to improve the process to close the resource loop, invest in more technology to recover the waste and reduce waste in origin, as well as water and energy. Recycling becomes economically attractive when the cost of reprocessing waste or recycled material is less than that of treating and disposing of the materials or of processing primary raw materials. When materials are recycled, they can have different properties and quality compared to virgin material which is substituted. For example, paper is a material where recyclability is higher, but the tendency of deterioration is so pronounced that it can be recycled around five to seven times before its wood fibres become too short and brittle. In the case of plastics, both recyclability and the number of loops is also limited. Glass and metals can theoretically be recycled any number of times without serious alteration of their properties. (Villalba, 2002). In a company which is making an environmental claim of recyclability, the use of a symbol is optional. In the affirmative case, the Möbius loop must be used. If the loop is combined with a percentage, the content of recycling material is indicated, whereas if only the symbol is shown, the material can be recycled. (ISO 14021:2016). 
Example	 Wood recyclability in CE means that the maximum value of the whole life cycle of biomass is gained through optimizing the use of biomass for multiple services. Wood recyclability from construction, furniture and paper is high in the case of Finland, and almost reached its technically possible maximum (Mantau, 2012). Innovative use of recycled wood waste into cement-bonded particleboard has been proposed as an appealing technology. While waste wood has higher biodegradability, complementary addition of cement significantly reinforces the strength performance and structure durability of wood particleboard. The wood particles act as a granular skeleton in the recycled particleboard that may present added values of lightweight and thermal-/noise-insulating materials for reuse (Faria et al., 2013).

Table 4.17 - Recycled content

RECYCLED CONTENT

Definition

Proportion, by mass, of recycled material in a product or packaging. Only pre- consumer and post-consumer materials shall be considered as recycled content. (ISO 14021:2016).

Complementary information

The recycled content in a product can be pre-distinguished in **pre-consumer and post-consumer**: Pre-Consumer material is diverted from the waste stream during the manufacturing process. Excluded is the reutilization of materials such as rework, regrind or scrap generated in a process and capable of being reclaimed within the same process that generated it. Post-Consumer material is generated by households or by commercial, industrial, and institutional facilities in their role as end-users of the product which can no longer be used for its intended purpose. This includes returns of materials from the distribution chain (ISO 14021:2016).
It’s important to **differentiate the characteristic of recyclability and the content of recycled materials.**

For the purposes of claiming or identification, products made of recyclable materials should show the Möbius loop. In the case of the company making an environmental claim of recyclability, the use of a symbol is optional.

If a percentage of recyclable material has not been described, this symbol is considered to mark a material that can be recycled. (ISO 14021:2016).

If a symbol is used for the environmental claim of recycled content, the Möbius loop accompanied by a percentage value declared with "X %" where X is the recycled content, expressed as a whole number, must be used. The percentage value must be located inside the Möbius loop or outside it, immediately adjacent to the figure of the loop (Dubreuil, 2010).
In the case of the percentage being variable, it can be expressed with statements, such as at least "X%" or greater than "X%".

Möbius loop (recycled content)

Example

The carpet brand EGE meets the demands of the international standards Cradle to Cradle. Some of its carpets contain a high content of post-consumer recycled material thanks to its Recover by ege program. Recover by ege is a take-back program for the return and recycling of used carpets. The program streamlines the use of materials to utilize them for as long as possible rather than transporting the carpets for incineration.

https://www.egecarpets.com/sustainability

Table 4.18 - Material resistance

MATERIAL RESISTANCE	
Definition	Resistance is the physical or chemical ability of a material and/or product to remain functional, without requiring excessive maintenance or repairs, when faced with the challenges of normal operation over its lifetime. The resistance can be focused on mechanical strengths, chemical resistance to stains, to fire, to moisture (phenotypic factors, meteorological factors) etc. (Stahel, 2010).
Complementary information	The resistance of furniture and construction goods is relevant for sustainable consumption and could be associated with a product lifespans in many cases; greater resistance helps to prolong the useful life of the products, so that in a defined period of time, a longer-lived product will require less maintenance, repairability and replacement. To demonstrate this characteristic, the construction and furniture products normally have a technical product datasheet that shows technical information about this field, and the Environmental Product Declaration (EPD) can also present the values of the resistance tests. Product resistance can be enhanced by possible addition of some additives to extend the use stage, for example, some covering resins.
Example	 Ceramic flooring is extremely resistant, and the tiles are difficult to crack. A quality installation can last for 50 years and longer, if well installed. Porcelain is considered as one of the most reliable and easy to maintain surfaces for residential and commercial spaces, since it is easy to maintain and does not have many sensitive properties. https://www.lovetiles.com/pt/prd/pulse/210352

Table 4.19 - Material toxicity

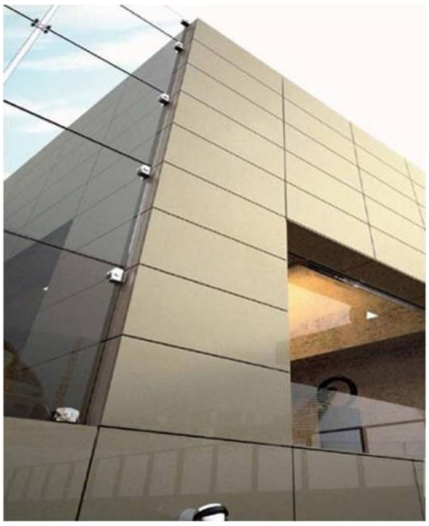
MATERIAL TOXICITY	
Definition	Toxicity is the degree to which a chemical substance or a particular mixture of substances can damage an organism. Toxicity can refer to the effect on a whole organism, such as humans, animals, bacteria, or plants, as well as the effect on a substructure of the organism. (Wilt et al., 2011). Here, toxicity refers to some substance that can be found in some parts of furniture or in some construction products.
Complementary information	The toxicity of construction materials and furniture is not easy to identify through visual inspections. The common building components that are found to be hazardous, toxic and carcinogenic such as asbestos, lead, volatile organic compounds (VOCs), solvents and adhesives are widely used in construction projects or in furniture. These materials can be dangerous when they become degraded, disturbed or airborne during construction, demolition, reconstruction and/or maintenance (Isnin & Ahmad, 2012). Labelling contains basic product information, such as key ingredients, quantity, quality, name and address of the manufacturer, dealer or importer, durability of the product, instructions for use/care and country of origin. This is a first method to find whether the material could have some toxic compounds. There is information available, which could be used to ensure that users are informed on the content, risks and safety measures from the building materials used or some furniture components. The information format varies depending on the test standards, assessment criteria, level of hazards and toxicity, certification, and product labelling. The requirement is in line with a statement in the Hazard Communication, Occupational Safety and Health Act (OSHA). (Isnin & Ahmad, 2012). In order to improve the protection of human health and the environment from the risks that can be posed by chemicals, the European Union approved the REACH regulation adopted for all member states (Registration, Evaluation, Authorization and Restriction of Chemicals). This regulation also aims at enhancing the competitiveness of the EU chemical industry and promotes alternative methods for the hazard assessment of substances (ECHA, 2019).
Examples	 BionicTile® is a façade tile, but it is not just an attractive exterior surface for buildings. BionicTile® is also able to remove harmful nitrogen oxides (NOx) from the air we breathe. One square meter of BionicTile® removes 25.09 micrograms of NOx every hour, and 240 square meters allow ten people each year to breath air that is NOx free. In the case of material toxicity, this is a perfect example of how an innovation on materials can help to mitigate pollutants in air quality, reducing toxically particles of air. http://www.khdlandscapesolutions.com.au/stone-products/bionictile/

Table 4.20 - Material biodegradability

MATERIAL BIODEGRADABILITY	
Definition	Degradability is a function of susceptibility to changes in chemical structure. Consequential changes in physical and mechanical properties lead to the disintegration of the product or material. (ISO 14855-2:2007 and ISO 17088:2012). A material that is "biodegradable" is one that can be placed into a composition of decaying biodegradable materials, and eventually turns into a nutrient-rich material. It is almost synonymous with "compostable", except it is limited to solid materials and does not refer to liquids. Biodegradability occurs in nature every day as fallen leaves and tree limbs biodegrade into the forest floor.
Complementary information	A material that is "biodegradable" is one that can be placed into a composition of decaying biodegradable materials, and eventually turns into a nutrient-rich material. It is almost synonymous with "compostable", except it is limited to solid materials and does not refer to liquids. Biodegradability occurs in nature every day as fallen leaves and tree limbs biodegrade into the forest floor. In order to recognize that a product is fully biodegradable, the product has to meet all the requirements in the European Norm EN 13432. Both specifications require that biodegradable/compostable products completely decompose in a composting setting in a specific time frame, leaving no harmful residues behind (Avella et al., 2001). ISO 14855:2007 considers compostable/biodegradability under controlled composting conditions. The acceptance level is 90%, which must be reached in less than 6 months. A biodegradable material is not necessarily compostable, since it must also break up during one composting cycle. On the other hand, a material that breaks up over one composting cycle into microscopic pieces that are not totally biodegradable, is not compostable (EN 13432).
Example	 https://www.fastcompany.com/1669598/philippe-starck-s-miss-sissi-lamp-now-made-from-sugar-waste Biodegradability is an increasingly important issue, even in the furniture sector. The example is Miss Sissi bio-on lamp by Philippe Stark. It is designed and made with the world's first design object manufactured with polyhydroxyalkanoates (PHAs), a water-biodegradable biopolymer made from the waste of sugar beet and cane production, 100% biodegradable within soil and water.

Table 4.21 - Resources cascading

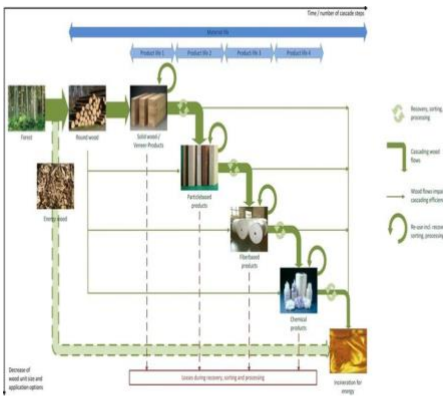
RESOURCE CASCADING	
Definition	The term cascading refers to what happens when a material is sequentially recycled into another type of product after its end of life (Ellen MacArthur Foundation, 2013; Carus, 2017). The terminology includes "downcycling" process, in which a material is converted to materials of lower quality and reduced functionality. Resource cascading is therefore a fundamental component of the CE, and conscious cascading also contributes to increased resource efficiency in the whole system (Carus, 2017).
Complementary information	The resource cascading concept is often associated with the forestry sector, in which cascading use can be effectively demonstrated. For example, a resource effective cascade may start with recently harvested, solid wood that goes into veneer wood products. After one life cycle, it then becomes particle-based products, which then become fibre-based products, which then become bio-based chemical products, which then become energy for electricity and heating. The benefit of resource cascading in the recycled renewables over fossil-derived material in terms of climate mitigation is lower than that for virgin materials, since the carbon in the materials is already in circulation and there is no substitution effect. Considering the resource cascading of a material during the product design could contribute to choose the best materials to build a more sustainable and circular product. Resource cascading maximizes resource effectiveness by using biomass in products that create the most economic value over multiple lifetimes. This approach to production and consumption states that energy recovery should be the last option, and only after all higher-value products and services have been exhausted. There are some advantages in applying resource cascading, as recycling and cascading wood and fiber systems creates a succession of livelihoods and wealth creating new opportunities, as well as highlighting responsible forest management by recognizing and, in many cases, increasing the potential wealth associated with the sustainable use of forest products. Some disadvantages, such as the current regulatory policies, often hinder the cascading of wood products due to conflicting environmental or economic objectives and, as said by WBCSD Forest Solution Group, there's little to no coordination on policies across wood-based sectors to promote the most resource-efficient uses of wood.
Example	 WWF and Mondi are in a partnership to promote resilient landscape and responsible products manufacturing and consumption. As part of their work program, both partners want to share a common understanding on the most efficient use of wood through Cascading use. https://www.mondigroup.com/media/5901/cascading-use-of-wood.pdf

Table 4.22 - Low embodied energy

LOW EMBODIED ENERGY

Definition

Embodied energy is the total energy required in the creation of a product including both the direct and indirect energy used in the extraction, transport and manufacturing (Haynes, 2010; Reddy & Jagadish, 2003). In this sense, low embodied energy is the minimum total primary energy required to create a material or product (Ashby, 2015).

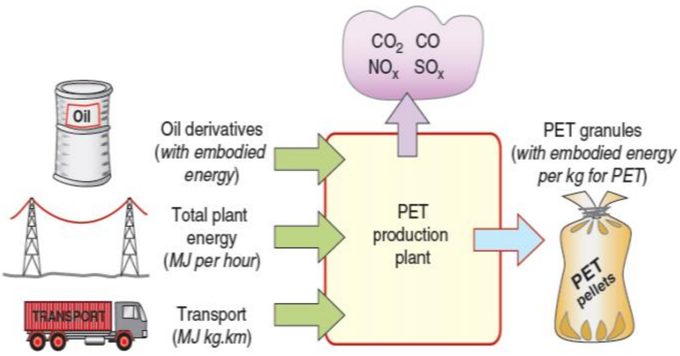
Complementary information

Currently, there are many definitions of embodied energy. Ding G., 2004 states that embodied energy comprises the energy consumed during the extraction and processing of raw materials, transportation of the original raw materials, manufacturing of materials and components and the energy used for various processes during the end of life.

On the other hand, the total life cycle energy of a product includes both embodied energy and operating energy (Dixit M.D., 2012). *Embodied energy* (*EE*): sequestered in materials during all processes of production, assembly or construction, and end of life; and *Operating energy* (*OE*): expended in the use stage, for instance, in the case of buildings, maintaining the inside environment through processes such as heating and cooling, lighting and operating appliances.

From a CE perspective, low embodied energy factor is important to be considered by designers in the creation of a product. According to Dixit et al., 2010 embodied energy data depends on ten parameters which can cause variations in the embedded energy depending on both the geographical zone and the production process used. Some of these parameters are system boundaries, methods of embodied energy analysis, geographic location of the study area, primary and delivered energy, age of data sources, data source and completeness, technology of manufacturing processes, feedstock energy consideration, and temporal representativeness.

Example



For example, cement has an embodied energy of 4.5 MJ/kg, but it also has an embodied carbon value of 0.73 kg CO_2/kg (University of Bath ICE, 2013). The units of measurement for embodied energy are represented as Mega joule per kilogram (MJ/kg). This is the energy density of a material. Embodied energy can also be expressed in terms of MJ/m_2.

A higher embodied energy material or component may sometimes be justified, for example, if it reduces operational energy requirements (such as higher efficiency building services, high performance glazing, or high durability).

Table 4.23 - Material availability/scarcity renewability

AVAILABILITY/SCARCITY AND RENEWABILITY	
Definition	Resource scarcity depicts a situation where raw materials are only available on a limited scale due to shortage, high costs, dependency on particular regions and social, ecological, political and technological limitations. It affects the construction industry in particular, as 50% of all raw materials worldwide incur in the building sector (Haas, 2016).
Complementary information	Critical raw materials (CRMs) for the EU and the underlying European Commission (EC) criticality assessment methodology are key instruments in the context of the EU raw materials policy (COM/2017/0490 final). CRMs are both of high economic importance for the EU and have a high risk of supply disruption. Examples of CRMs include rare earth elements, such as cobalt and niobium. On the EU action plan for the Circular Economy (COM/2015/614 final.), critical raw materials are identified as one of the five priority areas where actions should be taken. A good measure of the circular use of critical raw materials is the renewability contribution by recycling strategies to meeting materials demand in the EU (Blengini et al., 2017). A few CRMs, namely vanadium, tungsten, cobalt and antimony have a high recycling input rate. Some other CRMs have a good rate of recycling at end-of-life (e.g. recycling rates for platinum group metals reaches up to 95 % for industrial catalysts and 50-60 % for automotive catalysts) but this gives a contribution that is largely insufficient to meet the growing demand and, thus, the recycling input rate is low (Ardente & Mathieux, 2014).
Example	On a global scale, approximately 50% of all raw materials and 36% of all energy used is related to the construction industry. Therefore, the construction industry is a very resource-and-energy intensive industry, facing many situations where scarcity might occur. In recent years, the focus was on energy saving and shifting to energy neutral construction, which -on the one hand- is a very positive development, but on the other hand entails that even more of some specific resources are required. For renewable energy systems like wind turbines or PV cells, REE (Rare Earth Elements) are needed. At the same time, the rise of smart homes and all the smart technologies involved (computers, smartphones, TVs etc.), increase the demand of these elements even further. In general, building activities are prone to rise due to the rise in the world population (Haas, 2016). Apart from REEs, buildings also consume other materials with limited availability. Common building materials like metals or ceramics are recovered from ores, some of which have already passed their production peaks or are approaching them. In addition, peak oil might be an issue in the construction industry, as it is needed, for example, to produce polymer-based building materials. Additionally, metallic minerals are required in many parts of a building (e.g. concrete reinforcements and structural steel, pipes, ducts, wiring etc.). While their global availability is not limited, the mining may become critical because of social and environmental impacts on local population and ecosystems. Furthermore, land is a limited resource and building activities cause irreversible changes to land and soil (Ruska & Häkkinen 2014). In order to improve the availability of scarce resources, recycling is the most sustainable option. In this way, a limited resource becomes a circular one and waste turns into a resource (De Boer & Lammertsma 2013). Another way to counteract scarcity of resources is material efficiency and the entailed demand reduction of building materials (Ruska & Häkkinen 2014).

Table 4.24 - Water footprint

WATER FOOTPRINT

Definition

The water footprint is an indicator of freshwater use that looks not only at direct water use by a consumer or producer, but also at the indirect water use, that can be measured from humanity's appropriation of fresh water in volumes of water consumed and/or polluted (Hoekstra, 2003).

Complementary information

The water footprint is regarded as a comprehensive indicator of freshwater resources appropriation that measures the amount of water used to produce each of the goods and services we use. It can be measured through a single process, such as growing rice measured over the full supply chain. The water footprint can also tell us how much water is being consumed by a particular country – or globally – in a specific river basin or from an aquifer. All components of a total water footprint are specified geographically and temporally.

The water footprint has three components: **green, blue and grey**. Together, these components provide a comprehensive picture of water use by delineating the source of water consumed, either as rainfall/soil moisture or surface/groundwater, and the volume of fresh water required for assimilation of pollutants.

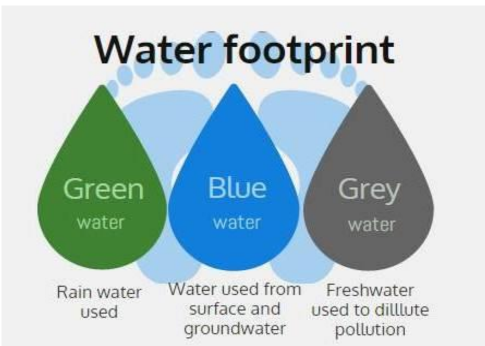
Green water footprint is the consumption of rainwater insofar as it does not become run-off. In other words, this is water from precipitation that is stored in the root zone of the soil and evaporated, transpired or incorporated by plants. This is particularly relevant for agricultural, horticultural and forestry products (Hoekstra, & Mekonnen 2012).

Blue water footprint is the consumption of water surface and groundwater along the supply chain of a product. In other words, this is the water that has been sourced from surface or groundwater resources and is either evaporated, incorporated into a product or taken from one body of water and returned to another, or returned at a different time. Irrigated agriculture, industry and domestic water use can each have a blue water footprint (Aldaya et al., 2012).

Grey water footprint is the volume of freshwater that is required to assimilate the load of pollutants given natural background concentrations and existing ambient water quality standards. In other words, this is the pollution, or the amount of fresh water required to assimilate pollutants to meet specific water quality standards. The grey water footprint considers point-source pollution discharged to a freshwater resource directly through a pipe or indirectly through runoff or leaching from the soil, impervious surfaces, or other diffuse source (Gerbens-Leenes *et al.*, 2018).

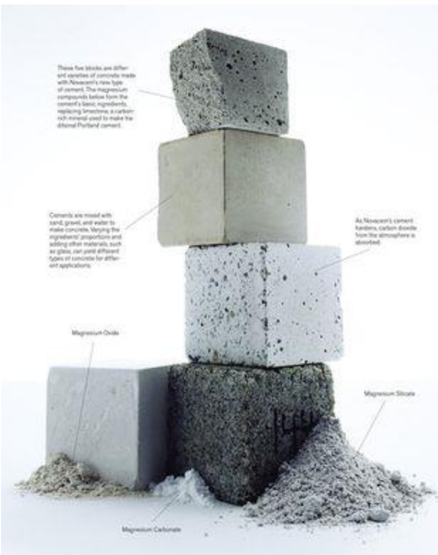
Example

The water footprint of the global average consumer in the period 1996-2005 was 1385 m^3/yr. About 92% of the water footprint is related to the consumption of agricultural products, 5% to the consumption of industrial goods, and 4% to domestic water use.



The average consumer in the US has a water footprint of 2842 m^3/yr, while the average citizens in China and India have water footprints of 1071 m^3/yr and 1089 m^3/yr respectively. The contribution of different consumption categories to the total water footprint varies across countries (Mekonnen & Hoekstra, (2011).

Table 4.25 - Carbon footprint

CARBON FOOTPRINT	
Definition	The Carbon Footprint (CF) measures the total amount of greenhouse gas (GHG) emissions that are directly and indirectly caused by an activity, or that are accumulated over the life stages of a product (Wiedmann & Minx, 2008).
Complementary information	The Carbon Footprint includes activities of individuals, companies, populations, governments, organizations, processes, etc. In any case, all direct (on-site, internal) and indirect (off-site, external, embodied, upstream, and downstream) emissions need to be considered in the account (Liu et al., 2010, Cui et al., 2015). Specific aspects such as which GHGs are included and how double counting is addressed/avoided may vary (Wiedmann & Minx, 2008). The CF is not expressed in terms of area; the total amount of greenhouse gases is simply measured in mass units (kg, t, etc.). Any conversion into a land area would have to be based on a variety of assumptions that would increase the uncertainties associated with a particular carbon footprint estimate. The CF calculation includes many elements, but when only CO_2 is included, the unit is kg CO_2; if other GHGs, e.g. methane (CH_4,) are included the unit, it becomes kg CO_2-e, which involves expressing the mass of CO_2-equivalents. Those are calculated by multiplying the actual mass of a gas times the global warming potential factor for this particular gas; here: 25 times, making the global warming effects of different GHGs comparable and additive (Chen & Chen, 2013). CF is correlated to the energy footprint because the fossil fuel-based socioeconomic system (around 80% of the global TPED is currently covered by nonrenewable energy, basically oil, gas and coal) CO_2 emissions are closely linked to human development. Nowadays, energy is the fundamental factor for producing the goods and services linked to human welfare and development, but at the same time, it has an evident impact (Steckel et al., 2013).
Example	 http://www2.technologyreview.com/news/418542/tr10-green-concrete/ As an example of Portland cement CF calculation, the GHG emission calculation is expressed in terms of carbon dioxide equivalent (CO_2-e), which refers to the global warming potential (GWP) with respect to one unit of carbon dioxide (Zhang et al., 2014). Assuming an average CO_2 release from Portland cement production (reported for California Cement Climate Action Team), each pound of Portland cement has a production carbon footprint of 0.86 pounds (Constantz et al., 2010). https://patents.google.com/patent/US7815880B2/en

Assignment 5

Organize the class into groups of 4-5 students. The students should choose a material and propose the best process/es to create a circular product. At the end, they will have to present the results to the class.

Note: In the book: *Materials and sustainable development* (Ashby, 2015), a of double-page data sheet for 47 of the most common materials used in current products (cars, cement, polymers, among others) is compiled. The sheets list the annual production and reserves, the embodied energy, energy consumption and the carbon footprints associated with them. Other parameters listed are mechanical, thermal, and electrical properties. This are important because they determine the environmental consequences/impacts during the use phase. Moreover, basic information about recycling at end of life is provided. This information can be very useful to design a new product or product-service from the CE perspective.

The most common materials used in the construction and furniture sectors appearing in this document are:

- Metals and alloys: Aluminum alloys, Stainless steel, Cast iron, Copper alloys;
- Polymers and elastomers: ABS, Polyamide (PA), Polypropylene (PP), Polyethylene (PE, PET, PVC), Polystyrene (PS), Polyester (EVA);
- Construction materials: Brick, natural stone, concrete and glass;
- Hybrids: composites, foams, and natural materials: Rigid polymer foam, Flexible polymer foam, Paper and cardboard, Plywood, wood.

4.6 Trade-offs in the circular economy

The material selection to develop any product often requires a compromise between cross media effects that can be opposite or have contradictory objectives. In the previous sections, a compilation list of the characteristics of the materials and the related process was presented, with suggestions pointing to the circularity of the products. The choice of materials and processes that best meet CE objectives does not necessarily have to be the one best meeting the current company reality; the lightest material, for instance, will generally not be the cheapest one, nor the one with the lowest embodied energy. To make a progress, designers and planners need a way of trading weight against cost, new practices and performance implications and design innovation initiatives as potential patterns of sustainable supply ((Rao & Holt, 2005, Zhu et al., 2008, 2005, Lee et al., 2012, Green et al., 2012). Lee et al. (2012) argued that inter-organizational linkage and collaboration could lead to improvements in environmental performance and consequently economic benefits (Rao & Holt, 2005).

This section describes suggestions and ways to find a balance and solutions for other conflicts of circularity (Bourell, 1997).

Such conflicts are not new; engineers have sought methods to overcome them for at least a century: (Ashby, 2015).

– **Weight factors:**

Weight factors seek to quantify judgment. In this method, the key properties or indices are identified, and the values are tabulated. Since their absolute values can differ widely and depend on the units in which they are measured, each one is firstly scaled by dividing it by the largest index of each group. Therefore, the largest one, after scaling, has value 1.

– **Systematic tradeoff strategies:**

Systematic tradeoff deals with the choice of material to minimize mass and cost while meeting a set of constraints, such as a required strength or durability in a certain environment and also its final cost. Considering the standard terminology of optimizations theory, a solution is defined as a viable choice of material, meeting all the constraints but not necessarily being optimal for either of the objectives.

– **Penalty functions:**

Penalty functions consider first the case in which one of the objectives to be minimized is cost and the other is mass, using: $Z = C + \alpha m$, as: C (units: $) and (units: kg).

– **Values for the exchange constants, α:**

Values for the exchange constants, α is the value or "utility" of a unit change in a performance metric. For example, it is the utility (€) of saving 1 kg of weight. Its magnitude and sign depend on the application.

Thus, the utility of weight saving in a small house, though significant, is much larger in a motorhome. The utility of heat transfer in house insulation is directly related to the cost of the energy used to heat the house; that in a heat exchanger for electronics can be much higher because high heat transfer allows faster data processing, something worth far more. The utility can be real, meaning that it measures a true cost saving.

It can also be perceived since the consumer, influenced by scarcity, will pay more or less than the true value of the performance metric.

- **Exchange constants for eco-design:**

Exchange constants for eco-design deals with the interventions that use taxes, subsidies, and trading schemes to assign a monetary value to resource consumption, energy, emissions, and waste, effectively establishing an exchange constant.

For a better understanding of assessment methods to the circularity of processes, material and also product.

Below, an example of trade-off in the ceramic manufacturing sector and automotive sector is presented.

Example 1: Ceramic tile manufacturing – Humid *vs* dry route production

Ceramic tile manufacturing is an energy-intensive process (30-40 kWh/m2 for an average specific weight of 22±1 kg/m2) (Ibáñez-Forés et al., 2011; Mezquita et al., 2017; Monfort et al., 2010; Ros-Dosdá et al., 2018a), thermal energy being the most important demand. This energy is mainly obtained by combustion of natural gas, which represents 90% of the overall direct energy consumption. Thermal energy consumption mainly takes place in three process stages: spray drying carried out in the preparation of raw materials (36%), drying of the formed ceramic tile bodies (9%), and ceramic tile firing (55%) (EIPPCB, 2007; Monfort et al., 2010).

This stage of the production process involves obtaining an intimate and homogeneous mixture of the various raw materials of the ceramic body through the milling process. This process can be done in presence or absence of water (Mezquita et al., 2017). In Europe and worldwide, except anecdotal minority, the raw materials of porcelain stoneware tile are subjected to a wet milling process followed by drying to obtain the spray-dried granules (EIPPCB, 2007; Shu et al., 2012a, 2012b). Generally, a heat and electric energy cogeneration system (CS) is installed at the spray dryer (Mezquita et al., 2017; Monfort et al., 2014).

The dry route may seem a very promising alternative to reduce the high consumption of water and thermal energy required in wet milling and in fact, there are numerous studies in this regard (Bonucchi, 2012; Melchiades et al., 2010; Mezquita et al., 2017; Schianchi, 2012; Shu et al., 2012a, 2011).

However, studies in Life Cycle Assessment show that the implementation of dry grinding effectively reduces the demand for water and natural gas but increases the demand for electricity and the advantages of cogenerated energy are lost (Ros-Dosdá et al., 2018b).

In this sense, a way to solve this trade-off is needed. In this case, one option could be to rely on renewable energy for the electricity consumption required in dry milling.

Another alternative to reduce water consumption in wet route could be the incorporation, as a raw material, of reclaimed water from urban wastewater treatment plant, which is currently being discharged into the sea.

Example 2: The car- economical cost *vs* environmental impacts (From: Ashby, M. F. (2009)).

You need a new car. To meet your needs, it must be a midsized four-door family car with a petrol engine delivering at least 150 horsepower —enough to tow your sailboat. Given all of these requirements, you want the car to cost as little to own and run as possible.

You are an environmentally responsible person; you want to minimize the CO_2 rating as well as the cost of ownership. The choice to meet two objectives is more complicated than that of meeting just one. The problem is that the car that best satisfies one objective —minimizing cost, for example — might not be the one that minimizes the other (CO_2), and vice versa, so it is not possible to minimize both at the same time. A compromise has to be reached, and that requires trade-off methods (see figure 4.2).

Its axes are the two objectives: cost of ownership and CO_2 rating. Suppose a friend has recommended a particular car, shown as a red dot at the centre of the diagram. Your research has revealed cars with combinations of cost and carbon, shown by the other dots. Several —the purple ones in the upper right —have higher values of both; they lie in the "unacceptable" quadrant. Several —the blue ones — either have lower cost or lower carbon, but not both. One —the green one —is both cheaper and produces less carbon; it ranks higher in both objectives.

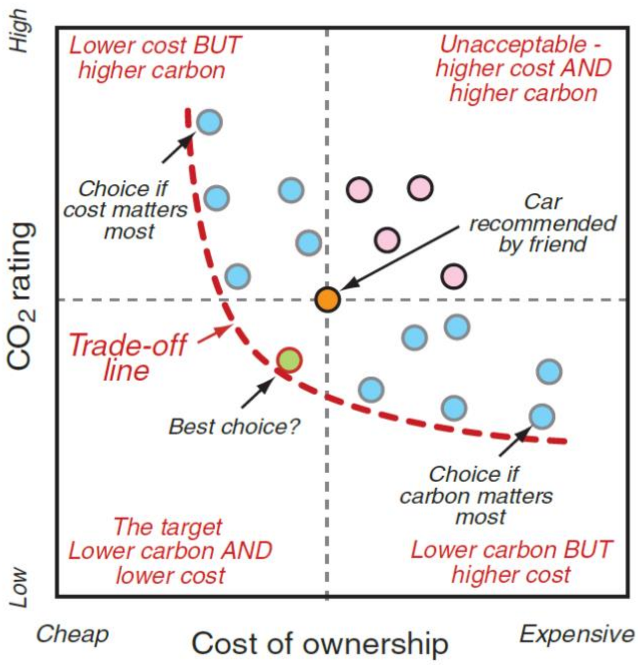


Figure 4.2 - The trade-off between carbon footprint and cost of ownership (From: Ashby, 2009)

Thus, it is the obvious choice. Or is it not? That depends on the value you attach to low carbon footprint.

If you think it is a good idea as long as you do not have to pay, the car marked "Choice if cost matters most" is the best. If, instead, you are ready to pay whatever it takes to minimize CO_2 emissions, the car marked "Choice if carbon matters most" is the one to go for.

All three choices lie, with several others that are compromises between them, on the boundary of the occupied region of the figure. The envelope of these — the broken line — is called the trade-off line. Cars that lie on or near this line have the best compromise combination of cost and carbon.

So, even if we can't reach a single definitive choice (at least without knowing exactly what you think a low carbon footprint is worth), we have made progress. The viable candidates are those on or close to the trade-off line. All others are definitely not that good.

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05

DESIGN AND DEVELOPMENT

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Design and development

Contents

Executive summary **239**

5.1 From ecodesign to design for the circular economy and sustainability **241**

5.1.1 Ecodesign, design for sustainability and design for the circular economy: complementary concepts 241

5.1.2 Product-service systems 245

5.2 The role of design in circular economy **250**

5.3 KATCH_e strategies of design for a CE **253**

5.3.1 Introduction 253

5.3.2 Strategies for slowing resource loops 255

5.3.3 Strategies for closing resource loops 262

5.3.4 Strategies for narrowing loops 265

5.4 Product and service design step-by-step **269**

5.5 Design for CE in the construction sector **274**

5.6 Tools for product and service design for CE **277**

5.6.1 KATCH_e Tools 277

5.6.2 Other tools 280

5.7 Examples **283**

Bibliography **289**

Executive summary

5.1 From ecodesign to design for the circular economy and sustainability

This section deals with key concepts to understand the rest of the section. While the relationship between circular economy and sustainability is not well established, the KATCH_e project adopted a broad definition of the former, and thus design for the circular economy is here defined as "a product-service design and development that replaces conventional end-of-life concept by closing, slowing and narrowing the resource flows in production, distribution and consumption processes. It is enabled by innovation and novel business models and aims to accomplish sustainable development through maximising of ecosystem functioning and human well-being, and through responsible production and consumption".

Building upon existing literature in the field, it distinguishes design approaches for slowing, closing and narrowing resource loops and dedicates one section to product-service systems, as the transition from selling products to adding and providing services is at the core of circular economy.

5.2 The role of design in circular economy

This section is important for design students and professionals to reflect on their role to promote circular economy. As Michael Braungart and William McDonough (2002) put it, "We don't have a waste problem, we have a design problem".

5.3 KATCH_e strategies of design for a CE

Within the project, eight design for circular economy strategies have been developed and are explained in this section. They are in line with the project's understanding that the circularity concept needs to be placed within the overall goal of sustainable development. Therefore, there are social sustainability criteria integrated into the different strategies.

The eight strategies concern product and service development. They are:

– Design of long-life products
– Design for product-life extension
– Design of product-oriented services
– Design of use- or result-oriented services
– Design for recycling
– Design for remanufacturing
– Design for materials sustainability
– Design for energy sustainability

5.4 Product and service design step-by-step

This section proposes a methodology based on eight general steps that should be adjusted to each particular project. The steps firstly describe the work performed in product design, in this case having in mind circular design. Then, the description of services design follows, highlighting when needed the related specificities.

5.5 Design for CE in the construction sector

This section discusses the characteristics of products to be integrated into buildings where circularity is an objective. The challenge of combining long life spans with adaptability in buildings is reflected in construction products' design. The shearing layers of a building defined by Stewart Brand in 1974 deserve new attention in the context of circularity and are included in this section to discuss different life spans of construction products.

5.6 Tools for product and service design for CE

This section addresses the topic of tools. Within KATCH_e, three tools have been developed that are relevant for this section: (i) the CE Designer checklists, a semi-quantitative tool for prioritization, assessment and idea finding of circular solutions for product and/or service (re)design, following the eight strategies presented in section 5.3; (ii) CE Journey, which helps users to assess the overall product, service and system journey and (iii) KATCH_Up Board Game, that stimulates the players to generate value ideas from a business challenge, applying circular design and circular business strategies. In addition, several other tools that can be found in the literature.

5.7 Examples

Examples, both from the construction and furniture sectors, are provided in this section.

5.1 From ecodesign to design for the circular economy and sustainability

5.1.1 Ecodesign, design for sustainability and design for the circular economy: complementary concepts

The integration of environmental considerations into product design with the objective of reducing products' environmental impacts along their life cycle (ecodesign, also known as life cycle design (LCD) and design for the environment (DfE)) has been developed and implemented in companies since 1990's (de Pauw et al., 2014; Stevels, 2009). It is at the design stage that most of the characteristics of a product throughout its life cycle (from raw-materials extraction and processing, manufacturing, distribution, use, end of life) are defined. Thus, the role of design in influencing products' environmental impacts has been the subject of great attention in the academic and practitioners communities.

Key characteristics of ecodesign include:

Life cycle thinking (i.e. considering the environmental aspects – inputs and outputs – and associated impacts, such as climate change, resources depletion, toxicity, air, water, and soil pollution, etc., at each life cycle stage) (Thrane and Eagan, 2005);

Early integration (i.e., addressing environmental considerations at the earliest possible stage of product development, when there is more room for introducing radical changes to the product concept and optimize outcomes) (Thrane and Eagan, 2005);

Functional thinking: it is not only a single product to be designed that matters, but the function delivered by the product itself (Vezzoli and Ceschin, 2011).

To deal with the challenges that underlie the sustainable development concept, companies have to change drastically the way they address product and service design and development. The ecodesign concept has evolved to broader design dimensions described as design for sustainability (DfS) (figure 5.1).

In contrast to the current practice of ecodesign, where in most of the cases only incremental environmental improvements to existing products and services are achieved, DfS aims at radical improvements in the three dimensions of sustainability: not only the environmental and economic ones but also the social dimension.

Some definitions of ecodesign derived to distinguish it from mainstream design, go beyond incremental gains. However, these definitions were made in the absence of DfS as an additional category (Spangenberg et al., 2010). DfS broadens the horizon and challenges established practices. It creates an additional level of complexity and makes solutions less clear-cut and therefore riskier (which is inevitable in leapfrogging solutions when compared to incremental improvements). Figure 5.1 also highlights that whereas in ecodesign the social dimension of sustainability is not considered, such dimension is inherently part of DfS. Examples of socially oriented design strategies are inclusive design, design products that do not require dangerous tools to promote good working conditions in production, involving communities in design, etc. (Rocha and Schmidt, 2014).

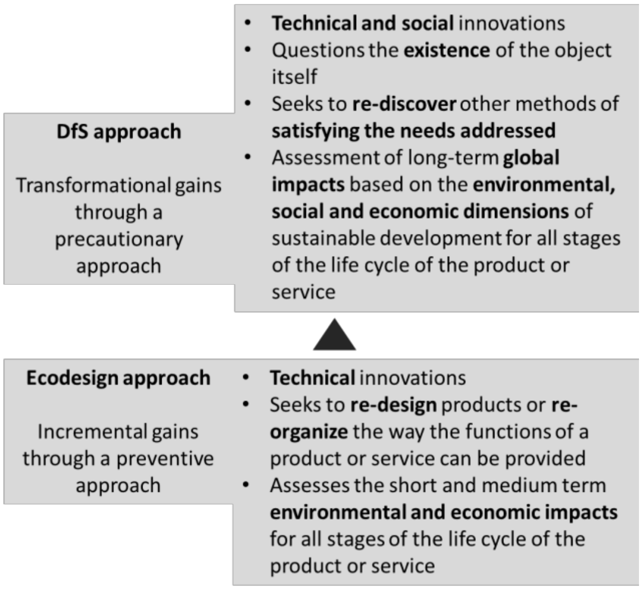


Figure 5.1 – From ecodesign to DfS (Spangenberg et al., 2010).

The ecodesign and DfS concepts have been developed within a linear or quasi-linear economic model, to which CE offers a practical alternative, fuelled by the widespread adoption of disruptive technologies (such as ICT – Information and communication technologies) that allow massive and fast change (Het Groene Brein, n.d.). Therefore, design for the circular economy (CE) is gaining remarkable attention.

CE is about "maintaining the function and value of products, components, and materials at the highest possible level and extend their lifespan". The right combinations of product and service design strategies support circular economy by (Bocken et al., 2016):

Closing resource flows: through recycling, the loop between post-use and production is closed, resulting in a circular flow of resources

Slowing resource flows: the utilization period of products is extended and/or intensified, resulting in a slowdown of the flow of resources

Narrowing flows: using fewer resources per product or service unit.

Figure 5.2 illustrates the closing, slowing and narrowing resource flows that is demanded by CE and the implications for product and product-service systems (PSS) design and development will be discussed. It should be noted that for these products and services to be successful in the market, companies need to develop adequate business models (see the *Business models* chapter).

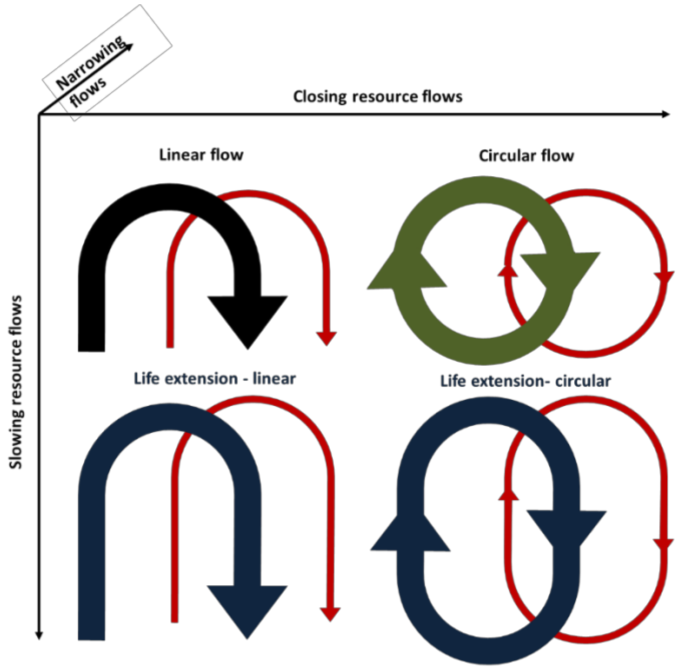


Figure 5.2 – Categorization of linear and circular approaches for reducing resource use. (Bocken et al., 2016)

The KATCH_e project proposes to adopt an integrative approach to the concept and practice of design for the circular economy. Unlike most publications and experiences in the field, that focus on slowing and closing resource loops (and disregard the dimension of narrowing loops since it applies also to a linear model) and do not consider the social dimension of sustainability, the KATCH_e project adopted the following definition:

> Design for circular economy is a product-service design and development that replaces conventional end-of-life concept by closing, slowing and narrowing the resource flows in production, distribution and consumption processes. It is enabled by innovation and novel business models and aims to accomplish sustainable development through supporting ecosystem functioning and human well-being, and through responsible production and consumption.

When it comes to product and service design, what do "slowing loops", "closing loops" and "narrowing loops" mean? Table 5.1 presents examples of design approaches to make products more durable, to avoid that they become waste and to increase their use of resources. These approaches and strategies are further developed in section 5.3.

Table 5.1 - Product design approaches for the circular economy

Product design approaches to slow loops = Design for durability
– To design long-life products – To foster a strong product-user relationship – To produce resistant, easy to maintain and repairable products – To use modularity, to allow the upgrading and adaptation of products
Product design approaches to close loops = Design for recycling
– To develop products in such a way that the materials can be continuously and safely recycled into new materials and products – To use safe and healthy materials for those products that are consumed or worn during use, and thus create food for the natural systems – To make it easy to dis- and reassemble products
Product design approaches to narrow loops = Design for resource conservation
– To use a preventive approach in which products and services are designed so that resources use is minimized in the whole life cycle – In addition to quantity, to choose more sustainable materials and energy sources when designing a product or a service

Assignment 5.1

Think of a specific product, e.g. a wooden floor. Discuss what does each type of approach (slowing loops, closing loops, narrowing loops) mean for this product: how do these approaches change the product? And what are the environmental, social and economic implications?

Assignment 5.2

Identify products you know that illustrate design approaches to slow, close and narrow resource loops.

Design for the circular economy or circular design takes a new angle when dealing with environmental considerations in design:

Inspiration by natural systems, where materials flow in cycles and there is no waste – everything should be a nutrient in the biosphere and the technosphere; this is a step forward, compared to previous approaches like ecodesign, which assumed that all products inevitably become waste at a certain point in time;

Dematerialization, through the transition from selling products to providing services or product-service system solutions that drastically reduce the intensity of materials per unit of service provided (see the section on product-service systems);

"More good instead of less bad": unlike in a traditional eco-design approach, which focuses on eco-efficiency with the goal of minimizing the cradle-to-grave flow of materials, circular design aims at eco-effectiveness, i.e. the transformation of products and their associated material flows so that they form a supportive relationship with ecological systems and future economic growth (Ellen MacArthur Foundation, 2015). The aim is to have a positive impact. As a matter of fact, eco-efficiency is necessary but needs to be coupled with other strategies to counteract potential rebound effects (selling more products, even if each one is more eco-efficient, may result in a greater environmental impact).

The Inertia principle: "Do not repair what is not broken, do not remanufacture something that can be repaired, do not recycle a product that can be remanufactured. Replace or treat only the smallest possible part to maintain the existing economic value of the technical system" (Stahel 2010, 195). The starting point for designers is the original products, it is about product integrity. On the other hand, in ecodesign one of the guiding principles is the waste hierarchy, in which the definitions of prevention (the preferred option), reuse, recovery, recycling, and disposal (the least preferred option) all are based on the assumption that eventually a product becomes waste, and a priority order for managing waste is provided. This focus on waste does not make sense in a CE (den Hollander et al., 2017) because, theoretically, the phase when a product is disposed of does not exist and after its use, all materials should be incorporated in the loop.

Systems thinking: circular design elevates design to a systems-level (van den Berg and Bakker, 2015). This means understanding the complex and interconnected nature of any system of which a product is part, e.g. by identifying all components and material inputs in the life cycle, the ways the natural systems are impacted and the stakeholders involved (including the users), and understanding how decisions regarding such product interact with the wider system (BSI, 2017). Systems thinking can help designers to manage complexity more effectively (BSI, 2017) and avoid the negative consequences of poor planning.

5.1.2 Product-service systems

The product-service systems (PSS's) concept has been a matter of great attention for sustainability experts due to its potential to decouple revenues from material flows and to increase resource productivity. In other words, whereas in the traditional product-oriented business model, the company revenues depend on the number of units sold (and the pressure to continuously grow in sales leads to unsustainability), in a service-oriented business model the company sells a result or an access and owns the products: the less products they need, or the longer the products last with good quality to provide the service, the better for the company. Product-service systems have a high potential for circularity and sustainability (if developed with circular and sustainability criteria) and are based on business models which deliver added-value products and services that meet the needs of users more sustainably (see the *Business models* chapter). In these systems, the focus is in the service that the user receives from a product and on the way the customer uses a product's function, rather than on the product itself. This systemic approach has a crucial role in the transition to a more circular economy.

PSS's are an innovative approach to sustainable business and may allow a company to (Crul and Diehl, 2009):

- Identify new markets and ways to profit;
- Survive and adapt to rapidly changing markets;
- Increase efficiency and reduce resource consumption;
- Compete in the market and generate value and social quality, while decreasing total negative environmental and social impact (directly or indirectly).

To implement circular economy in practice, focusing on an efficient transition from the linear model to a circular model, the way users' needs are fulfilled needs to change and innovative systems and business models have to be created. In this context, innovation is considered to be fundamental in guiding businesses towards a transformation of practices influenced by the design and functions (see the *Radical innovation and collaborative design processes* chapter).

PSS's are not a new concept, but when properly designed they have the potential to change production and consumption patterns towards a circular and sustainable future. Figure 5.3 offers a possible systemization of PSS's.

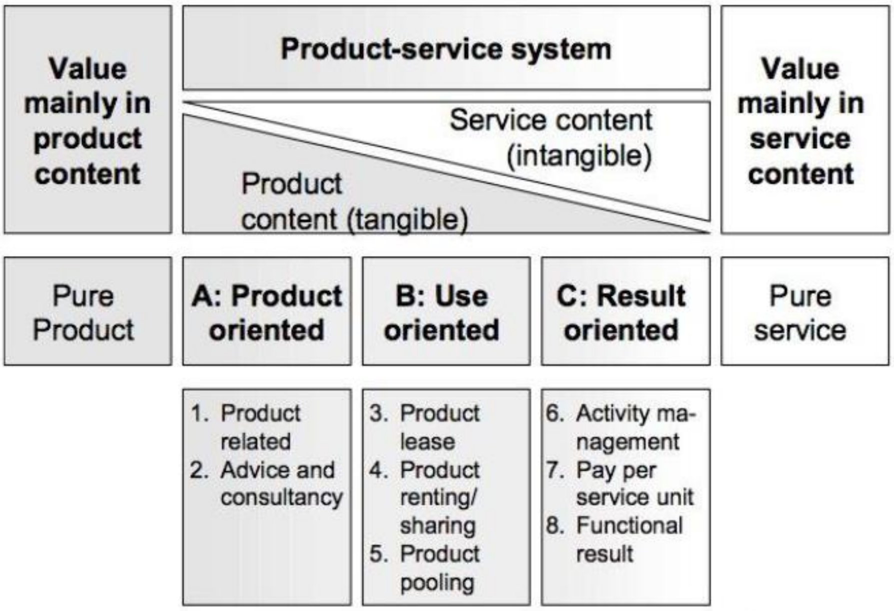


Figure 5.3 – Eight types of PSS's (Tukker, 2004)

Several categories of PSS's can be identified and the distinctions among the different forms are based on the extent of product ownership, the type of products involved, and the value-added of the service level (Tukker et al., 2006). The expression PSS highlights that there are neither "pure products" nor "pure services", but rather combinations of both. For simplicity, from this point onwards this section refers simply to services instead of PSS's, disregard the weight of the tangible or the intangible component.

Category A: **Product-oriented services**. Here, the focus is still mainly geared towards sales of products that are owned by the user or consumer, but some extra services are added.

Category B: **Use-oriented services**. The traditional product still plays a central role, but the business model is not geared towards selling products. Product is owned by the service provider who sells functions instead of products, through modified distribution, payment systems and sometimes the product is shared by several users.

Category C: **Result-oriented services**. Here, the client and provider agree on a result, and there is no pre-determined product involved.

Table 5.2 - Categories of services with examples

Category A: Product-oriented services – The product is owned by the user/consumer
Product extension service, the value of a product is increased through additional services, e.g. upgrading, repair, guarantees, financing schemes, the supply of consumables, etc. **Advice and consultancy** concerning the most efficient use of the product. **Vertical Integration**, meaning modified delivering strategies to supply products to customers, retailers and/ or customers who get directly involved in the process of production, e.g. production on demand.
Category B: Use oriented services – The product is owned by the service provider who sells functions instead of products, through modified distribution and payment systems
Leasing. The provider retains ownership and is often responsible for maintenance, repair, and control. The leaser pays a regular fee for the use of the product and normally has an individual and unlimited access to the leased product. **Renting or Sharing**, similar to leasing but the user does not have unlimited and individual access to the product. The same product is sequentially used by different users. **Pooling**, which is similar to sharing but there is a simultaneous use of the product.
Category C: Result oriented services – There is not a pre-determined product involved in this category
Activity Management, the supplier gives incentives for the customer to consume more efficiently and optimises a system e.g. by using modified payment systems, e.g. contracting. **Pay-per-service unit**, the user buys the output of the product e.g. pay per lux by Philips, a service in which the user buy light, and nothing else. **Functional result**, products are substituted by new solutions; the delivery is a result which is not related to a specific technology system anymore. Examples are pest control service instead of pesticides, delivery of a "pleasant climate" instead of selling heating or cooling equipment, etc.

Sources: INEDIC project; Tukker, van den Berg, & Tischner, (2006) Tukker, (2003) As shown in table 5.2 the ownership and reliance on a physical product decrease from the first type to the last one. On the other side, the freedom of the provider increases. In the last examples, the user does not want a specific product or service, he/she wants a function, something to solve a problem or need, and the provider is free to find any type of solution to solve the problem (Tukker, 2004).

In the context of circular economy, it is again possible to relate the slowing and closing resource loops to the three types of services above presented (table 5.3).

Table 5.3 - Services for the circular economy (BSI, 2017)

Services to slow loops = product-oriented, use-oriented and result-oriented
Maintenance, repairing, reuse services that extend the lifetime of products (product-oriented) Sharing, leasing and renting are services that provide the capability to satisfy user expectations without needing to own physical products (use-oriented, sharing economy, "from consumer to the use") In services that deliver performance, the client or consumer is only interested in the result and not at all in the product or technology behind it (result-oriented)
Services to close loops = reverse logistics
Collection and sourcing of otherwise "wasted" materials or products to turn them into new forms of value such as reuse, remanufacturing or recycling.
Services to narrow loops = digitalization
Delivery of a function with no or reduced requirement for materials; digitalization is a very strong enabler for reducing material resources use.

Assignment 5.3

Identify services you know that illustrate design approaches to slow, close and narrow resource loops.

5.2 The role of design in circular economy

> "We don't have a waste problem, we have a design problem"
>
> Michael Braungart and William McDonough, Founders of the Cradle2Cradle concept

Design plays a crucial role in circular economy and this is not only about recycling, but also about maintenance, repair, sharing, reuse, refurbishment and remanufacturing. Design has the power of enabling or hindering these features. It determines the circularity potential of products, services and systems. Traditionally, designers would focus exclusively on products, but their role is evolving. The power of design lies on its ability to ask fundamental questions, such as: What is the real purpose of this product? Which is the need that this product fulfils? Are there other solutions to respond to such need, e.g. through a service? Is it possible to increase well-being and happiness through this design? Does this design have a negative impact on the environment? A zero one? A positive one, contributing to the regeneration of ecosystems? And in society? (De Groene Zaak and Ethica, 2015).

Traditional manufacturing is wasteful because it focuses exclusively on the end-user. The circular economy mind-set looks much wider, to consider everyone who extracts, builds, uses, and disposes of things. By zooming out from users, to consider the wider network of stakeholders, we can unlock value at every stage of the process. As a designer, that includes building feedback loops into your work; knowing the life cycle of materials you use; collaborating with other industry stakeholders; and considering unintended consequences (Ellen MacArthur Foundation and IDEO, 2017).

Given that the design of a product directly influences the way a value chain will be managed, building circular, globally sustainable value chains inevitably signifies a fundamental change in the practice of design. A variety of new capabilities are key to design for a sustainable future; these range from a deeper knowledge of material composition to a rich understanding of social behaviour (De los Rios and Charnley, 2017).

Many examples illustrate the role of design in a circular economy. In the KATCH_e Knowledge Platform (KATCH_e, n.d.) there is a large collection of them from the construction and furniture sectors. The last section of this section also provides various examples where different design strategies (see section 5.3) have been applied.

One interesting case comes from the British company CRISSCROSS Furniture Ltd. (Crisscross, n.d.). They offer modular, flat-pack furniture, whose main novelty relates to the easiness of assembling and disassembling and the possibility of reconfiguring the furniture. The furniture collection, designed by Sam Wrigley, comprises cupboards, wardrobes, a bedside table and desk. They are assembled using modules that are slotted into pre-existing holes in the boards and can be fixed in place without the use of any tools, allowing them to be easily removed and reused.

The relevance of this example, from the point of view of circular design, relates to:

The use of eco-friendly materials: birch plywood from sustainable FSC© certified forests and natural plant-based wood waxes;

The durability of the products: they are made of high-quality materials; in order to endure frequent use and disassembly, the brackets, hinges, and locknuts are made from high-grade aluminium that is anodised black. Furthermore, the easiness of disassembly and reassembly with different configurations and without the need of tools gives the possibility of adapting the furniture to different needs and spaces over time;

The recyclability: the products and packaging are 100% recyclable.

Figure 5.4 – CRISSCROSS furniture. Source: http://www.crisscrossfurniture.com/

Product design determines the circularity potential of a product because it establishes to a large extent its characteristics and features, which is the functionality, which materials are used in the product, how long it is supposed to last, its reparability and recyclability, etc. However, whether or not this potential is realised depends on how the product is managed throughout its life cycle (European Environment Agency, 2017).

The circularity of a product depends not only on its intrinsic properties but also on the system in which the product is integrated (European Environment Agency, 2017). For instance, the reparability of a product comes into effect if there are repair services and proper business models in place. The role of designers has expanded from product design to service, business models and systems design (Ceschin & Gaziulusoy, 2016). The KATCH_e project addresses these dimensions of the designers' work in different modules, as shown in figure 5.5. The remaining modules (*Introduction to the circular economy, Processes and materials, Life cycle perspective and Communication*) offer foundations that support this work. Although figure 5.5 concerns "designers for sustainable development", it applies also to "designers for a circular economy".

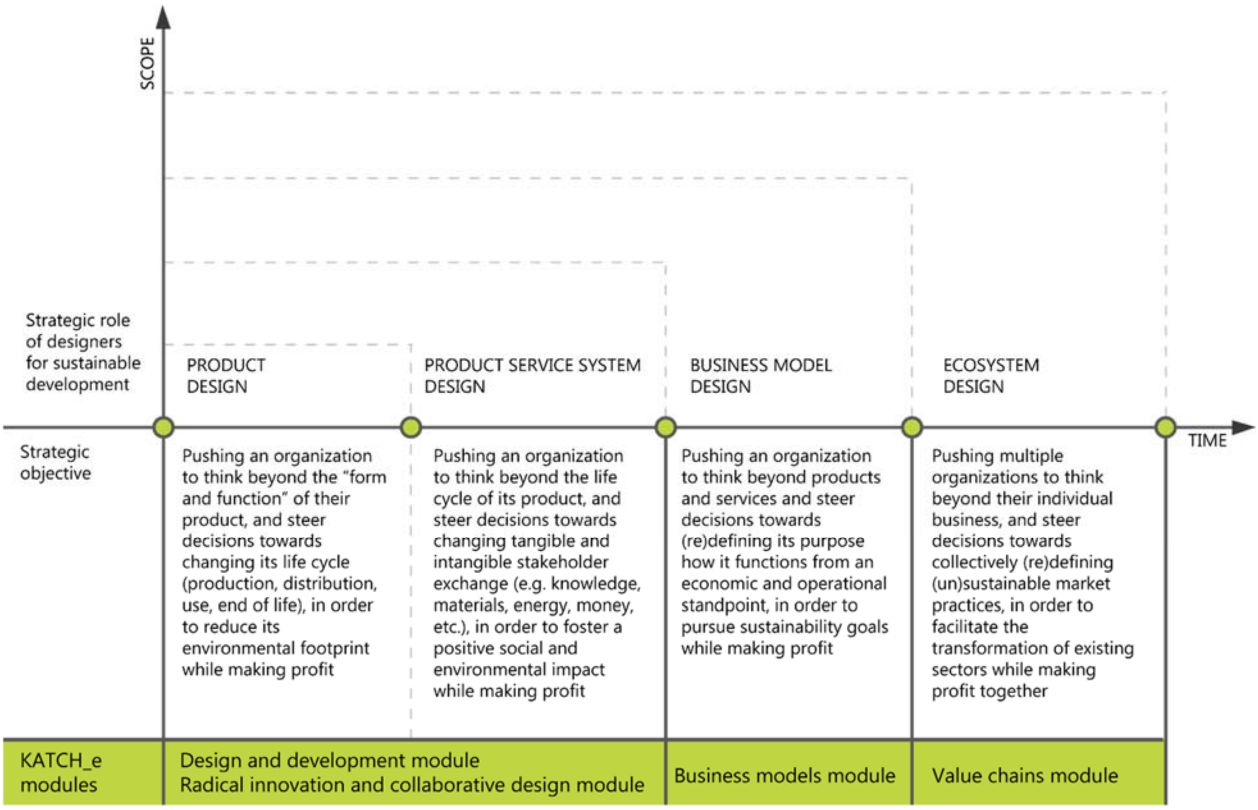


Figure 5.5 – Evolution of the strategic role of designers for sustainable development (Baldassarre et al., 2019) and KATCH_e modules contributing to the different roles.

Assignment 5.4

Group discussion: what are the main differences between the design profession in a traditional, linear economic model and a circular economy model? Think of designers as having a broad role in the company, not only product designers but also service and business model designers.
Note: this assignment can be performed separately or be integrated into the last assignment of this chapter.

Finally, we need to design products that can be reused, repaired, refurbished, remanufactured, repurposed, recycled and recovered.

Design for circular economy is further unfolded in the *Design and development* chapter, including eight main strategies as illustrated in table 1.2. Furthermore, in *the Radical innovation and collaborative design processes* chapter, the focus is precisely on the role of radical innovation to attain sustainability and circularity and different types of innovation are discussed. Related to both chapters, KATCH_e tools are provided to support the practical work of designing innovative, circular solutions.

Table 1.2 – KATCH_e Design strategies for developing circular solutions

Slowing loops	– Design of long-life products(1) – Design for product-life extension(1) – Design of product-oriented services)(2) – Design of use- or result-oriented services(2)
Narrowing loops	– Design for materials sustainability(1) – Design for energy sustainability(1)
Closing loops	– Design for remanufacturing(1) – Design for recycling(1)

Note: (1) product design; (2) service design

1.4.1 How to define a circular product?

During the design process, you will also have to consider, whether or when a product or a solution is circular. For example, is a product more circular because it has a longer serviceable life, even if at end of use it is being landfilled? The answer is not simple, but it can be "yes", if the longer lifetime will save a large amount of resources. In any case, an assessment will be needed, and the *Life cycle perspective* chapter presents methods for evaluation.

From a material resource perspective, the Ellen MacArthur Foundation has defined a circular versus a linear product: A 100% linear product is a product that is manufactured only using virgin feedstock and ends up in landfill. A 100% circular product, on the other hand, contains no virgin feedstock and is completely collected for recycling or reuse at the end of its use phase (Ellen MacArthur Foundation, 2016).

The 100% circular product is theoretical, because the collection, recycling and reuse will never be a 100% efficient process, there are losses. Thus the emphasis on slowing and narrowing resource loops, in addition to closing resource loops is needed.

The *Processes and materials* chapter and the related KATCH_e tools explain and give examples on benefits and challenges related to different types of materials and production processes.

5.3 KATCH_e strategies of design for a CE

5.3.1 Introduction

The KATCH_e strategies of design for circular economy have been developed using a significant amount of literature and guidelines related to circular design. Nevertheless, given the understanding of design for a CE in the context of the project, special attention has been devoted to include the social dimension of sustainability and strategies related to "narrowing loops", as explained in section 5.1. Section 5.3 provides an explanation of the strategies and the link to the KATCH_e **CE Designer**, which is a dedicated tool also created, tested and validated in the project, which provides practical support to the implementation of circularity in the design process.

The strategies are organized and were established having the following assumptions in mind:

- They are in line with the project's understanding that the circularity concept needs to be placed within the **overall goal of sustainable development**. Therefore, there are social sustainability criteria integrated into the different strategies;
- They are organized according to the **three main types of loops in CE** as they were presented in section 5.1 (see the *Introduction* chapter): *slowing resource loops*, where the key idea is *durability*, and *closing resource loops*, where the key idea is *recycling*; they correspond to the design strategies in the left and right column of table 5.4; such strategies ought to be combined with those related to *narrowing resource loops* (that includes efficiency and has a life cycle perspective), which were not born within the CE concept and understanding, but need to be considered so that solutions are potentially circular *and* sustainable (column in the centre of the table);
- They should be looked at **holistically**, which means that rather than concentrating on a single strategy, readers or users of this section and related design for circular economy checklists should consider the different strategies, their **interdependence, and complementarity**;
- None of the strategies is a guarantee of sustainability; the implementation of a specific strategy or a combination of strategies will have **negative externalities and trade-offs** that need to be evaluated using life cycle thinking and addressed, preferably through innovation;
- These strategies concern both **product design and service design** and are mutually supportive; often, business models are mentioned because circular product and service design is intertwined with business models that companies adopt to put them into the market.

Table 5.4 - KATCH_e design strategies for a circular economy, organized according to resource loops and phases of the life cycle they relate to

Phase	KATCH_e design strategies for a circular economy		
	Slowing loops	**Narrowing loops**	**Closing loops**
Uphill			
Tophill	Design of long-life products (1) Design for product-life extension (1) Design of product-oriented services (2) Design of use-oriented or result-oriented services (2)	Design for materials sustainability (1) Design for energy sustainability (1)	
Downhill			Design for recycling (1) Design for remanufacturing (1)

Note: (1) product design; (2) service design

It should be noted that the strategies related to narrowing loops stem from the eco-efficiency paradigm and should always be used in combination with those from slowing and closing loops, as they are complementary. In other words, it does not make sense to design a long-life product without caring for the energy and materials (including water) sustainability along the life cycle. This idea is illustrated in table 5.4, where the KATCH_e strategies of design for a circular economy are distributed along a simplified version of the products' life cycle, also known as the "Value Hill" (Achterberg et al., 2016): (i) Up-hill - before use (encompassing extraction of raw materials, manufacturing, assembly and retail), (ii) Top-of-the-hill - during use and (iii) Down-hill - after use (including reuse, refurbish, remanufacture and recycling – and eventually final disposal). The table shows the most direct relationship, but one should keep in mind that potentially the entire life cycle is affected by each of the strategies – for instance, moving from a product to a service approach, although it concerns the use phase because the use/consumption model is changed, may lead to less products needed for the same function, which means fewer resources extracted and processed, less waste, etc.

5.3.2 Strategies for slowing resource loops

Design of long-life products

Currently, in most design projects the material efficiency component (that is, designing products with less material) is already considered as it is directly related to the costs reduction, thus being considered good commercial practice for companies (Bakker et al.). On the other hand, the product life and product recycling are not usually considered in a design project (Hatcher et al., 2011).

The feasibility of long-life products in a business context and the associated consequences for product design, have remained largely unexplored (Hollander, 2012) however there are several ways to extend the useful life (and value) of a product that designers should consider strategically in their projects.

The design of the products in this strategy has as the main goal, the durability of the product considering technological and emotional aspects in different levels. (Nancy Bocken 2016; Martijn Gerrittsen 2015).

At a technological level, the design should consider:

– the durability of materials and processes;
– the durability of components and the relations between components;
– the technical solutions that allow a physical performance of the product during a long time without the need for maintenance or repair actions;

At an emotional level, the design must consider the relationship between the product and the user for a longer time. This kind of solutions should consider aspects such as aesthetics, ergonomics, trust or value for money. Product attachment implies the existence of an emotional connection between a person and an object. When a person becomes attached to an object, he or she is more likely to handle the object with care, repair it when it breaks down, and postpone its replacement as long as possible. So, fostering a strong product-user relationship can lead to lengthening the life span of many durable consumer products (Schifferstein & Zwartkruis-Pelgrim, 2008). The highest levels of attachment are registered for recently acquired products (<1 year) and for products owned for more than 20 years. However, attachment is determined by multiple themes, many of which are circumstantial to consumers' experiences and therefore difficult for designers to control (Page, 2014). So far, different studies reveal that for new products, enjoyment and pleasure may be the main driver of attachment, whereas for old products memories may be more important. Appearance and reliability also have considerable influence on participants' attitudes towards replacement. Designers should create products that are both useful and enjoyable. This asks for products that evoke sensory and aesthetic pleasure.

Design criteria for long-life products include:	
– Strong product-user relation – Durable and wear-resistant materials and components – Timeless and customized design – Reliability – Lifespan information to clients/consumers – User-friendliness	
Example: Swiss army knife	
Lifetime warranty, high-quality materials, after-sales services, strong product-user relationship	
Source: www.swissarmy.com	

Design for product-life extension

Product life extension is an increase in the utilization period of products, which results in a slowdown of the flow of materials through the economy (den Hollander & Bakker, 2012).

Designers can and should incorporate features that enable products to serve their originally planned functions over a longer period without losing their performance or that can be maintained or even, upgraded to extend their life and maintain the attractiveness throughout time to its user. The extension of life is the counter-strategy to the implanted programmed obsolescence, in which the products are designed to lose part or all of their performance after a specific time.

This strategy is complementary to the promotion of a set of services linked to the product that enables the technological and emotional extension of the function of the product. The design of the product must, from the initial stages of the process, foresee that an action by the user or expert services can be applied in the product or components, to reset or upgrade the function for which the product was designed.

For the effectiveness of the strategy, the design process must take into account simple solutions for disassembly/assembly and modularity/standardization, to promote easy maintenance and repair, upgrade, and reuse of the product or components (Nancy Bocken 2016; Martijn Gerrittsen 2015). Designers have several different methods available to them for designing adaptable products, with product architectures that provide robust support for adapting products to meet changes in functional and environmental requirements, as well as advances in technology (Levandowski et al, 2015; Zhang et al, 2015).

According to Stahel (1998, p.29), the key to extending product life "lies in transforming an industrial economy focused on the real linear output to a service economy focused on the use of loops." In the background, this is a concise perspective of the thinking that the design practice has to move towards a circular economy.

In order to extend the life of products, design should consider the following criteria:

- Easy replacement of components
- Aesthetic and/or technical upgradeability
- Durable and wear-resistant materials and components
- Use of modular solutions
- Simplified product architecture
- Choice of tools needed for dis- and reassembly
- Minimize connecting elements
- Facilitate access and detection of connecting elements
- Standard connection elements

Example: Fairphone

Modularity, upgradeability, components available to the user, simplified disassembly

Source: www.fairphone.com

Design of product-oriented services

This strategy includes different types of services that prolong the lifetime of products. They concern consumer products as well as business-to-business situations. The business model is still mainly based on the sales of products, but some extra services are added (Tukker, 2004) (see the *Business models* chapter). For these services to be successful, products must be designed in such way that they are easy to disassemble, repair, maintain, refurbish, clean or upgrade. Often, these services are linked to the selling of consumables, spare parts, and add-ons to support the life cycle of long-lasting products (Achterberg et al. 2016). Since these services are additional to (and not replacing) the selling of products, the life cycle costs of the products are not retained by the provider, and thus the incentive to extend their lifetime at the maximum possible may not exist, unless if the client or consumer clearly rewards that or if the revenues related to repair or maintenance are significant. The sustainability potential of these services depends on the actual increase in the lifetime of the goods.

Services for a long life of products typically bring the following benefits:

- They are the most efficient way to retain or restore the system back to normal working conditions (Ajukumar and Gandhi, 2013);
- They are a source of competitive advantage and business opportunity (Armistead and Clarke 1992);
- They may generate more than three times the turnover of the original purchase (Wise and Baumgartner, 1999);
- They provide protection, pollution prevention, personnel safety and waste disposal (Ajukumar and Gandhi, 2013).

Examples of product-life extension services:

Maintenance, repair, refurbishment and cleaning services: e.g. repair cafes, services provided by the product manufacturing company (very common e.g. in the automotive and technology product firms, that in this way generate a fair percentage of their total revenues (Cusumano, Kahl, & Suarez, 2008), services provided by retailers, services offered by specialized companies.

Technological upgradeability: computers, telephone systems and copiers are examples of products prone to this type of services (Entrepreneur, n.d.) They can be offered by manufacturers, retailers and specialized companies.

Aesthetic/cultural upgradeability: examples of this service can be found in the furniture, apparel and decorative objects industries, mostly offered by small workshops. In the construction industry, on the contrary, aesthetic upgradeability is a very big business and often part of larger renovation works. Examples can be found in Galgani (2014).

Advice, consultancy and training concerning prolonging the lifetime of products. This can be offered by the product provider, by other companies or even by individuals, (a typical example are all the videos available on YouTube on "how to fix…" or "how to repair…" all kinds of appliances, cars, furniture, apparel, etc.).

Design criteria for this kind of services include:
– Geographic accessibility of services – Variety of offers in terms of available services – Customer satisfaction – Added-value (for customers) – Employment creation and good working conditions – Transportation sustainability – Involvement and promotion of local community

Example: Repair café

Promotion of repair, organization of repair workshops, sharing knowledge, tools available, strengthen social links.

Source: www.circulareconomy.pt

Design of use- or result-oriented services

In this strategy, the keyword is "ownership". The provider retains the ownership of the product and makes it accessible to the clients (again, individuals or organizations) through different business models (Tukker, 2004). For the description of use-oriented services, such as leasing, renting and sharing, pooling, and result-oriented services, see subsection 5.1.2. Here, the sustainability potential of the different types of services is discussed.

Leasing: In terms of sustainability, this kind of services may be interesting if the provider may influence the design of the product since it is his/her own interest that the product lasts a long time. If the provider cannot influence the product design, the potential benefit relates to more efficient use of energy or consumables by better maintenance, repair and control. This service has tangible value for the user since various costs and activities are shifted to the provider.

Renting and sharing: The sustainability potential can be high if the life cycle impacts are mainly related to manufacturing, as a less number of products may accomplish the needs of multiple users when compared to the traditional product ownership model. Renting and sharing may represent a significant effort by the user into getting access to the product, but the tangible benefit is related to not needing to bear the capital costs. Renting normally does not contribute to self-esteem or intangible experiences, except if the product-service combination is designed with that purpose (e.g. possibility to customize a rented car).

Pooling: The access to the product may put even more challenges to the users then renting or sharing, related to the simultaneous use. On the other hand, the intensity of use of products is even higher and the benefits in terms of environmental impact can be significant, especially if the life cycle impacts of the product are related to the use phase.

Result-oriented services: Like in the above types, the ownership of products is not transferred to the client; since all life cycle costs stay with the provider, he/she will try to find innovative ways to reduce costs and liabilities and has more room for manoeuvre to design a low impact system with high customer satisfaction. Examples of this strategy are the "pay per lux" service offered by Philips at Schiphol Airport, the "power by the hour" of service of Rolls-Royce engines in Boeing aircraft or Nor-Line vessels, or the "pay per mile driven" service (tires), by Michelin. Taking this last example: customers pay per miles driven; they don't own the tire and don't have to worry about maintenance are any problems that occur with the tires. On the other hand, Michelin has an incentive to design long-lasting tires and, by taking back worn-out tires, the company is motivated to design them so that they can be reprocessed into a valuable input for new tires or another product (Accenture, 2014).

Information and communication technologies (ICT's) have a very important role as enablers and facilitators of 'products as services': "they allow for establishing real-time information exchanges among users, machines and management systems. These technologies are intrinsically customer-focused and provide the information and connections needed to maintain a relationship far beyond the point of sale" (Accenture – circular advantage report). Examples of application are apps for sharing and pooling platforms, materials tracking in the built environment, etc.

The more intense the use of 'products as services' is, the more their potential to contribute to a CE is unlocked. Therefore, they should be easily accessible, add value to the customers and be designed and operated to achieve a high level of customers' satisfaction. Other considerations to render higher levels of sustainability relate to transportation and involvement of local communities.

Design criteria for these services are similar to the previous ones, but include specific topics, such as the influence of the service in product design and the existence of ICT:

- Accessibility
- Influence in product design
- Impact of the service in resources use intensity
- Existence of easy and affordable ICT - Information and communication technologies
- Customer satisfaction
- Added-value (for customers)
- Transportation sustainability
- Involvement and promotion of local community
- Employment creation

Example: Lime scooters

Electric scooters renting service for urban mobility.

Source: www.li.me

5.3.3 Strategies for closing resource loops

Design for recycling

The objective of this strategy is to develop products in such a way that the materials ("technical nutrients") can be continuously and safely recycled into new materials and products (Bocken et al, 2016). Although in many cases recycling is one of the last strategies to consider in the development of products and services within circular economy, design for recycling is a strategy to be considered by design teams. Designers must understand the process and the conditions for efficient and quality recycling, resulting in quality materials that can be used as valuable input material in the product or service cycle. The potential of recyclability of a product can be enhanced by the easiness to disassemble the product.

Recycling is the process of recovering materials for the original purpose or other purposes, excluding energy recover. To establish a continuous flow of resources in the technological cycle, the "waste" resources are to be recycled into materials having properties equivalent (or even superior, in a process, called upcycling) to those of the original material (Bocken at al., 2016). In the majority of nowadays recycling operations, what occurs is downcycling (reprocessing into products requiring lower properties), which does not enable a circular flow of resources, but only delays the linear flow of resources from production to waste (McDonough & Braungart, 2002).

Design for recycling aims at designing products which materials that can be recycled without property losses (and therefore endlessly, in theory). As for the use of recycled materials in the product, that is part of the quality of input materials and is addressed in strategy Design for materials sustainability.

Design for recycling should contemplate the following criteria:

- Choice and variety of materials for easy recycling
- Marking of materials for recycling
- Easy separation of technological from biological materials
- Minimize connecting elements
- Facilitate access and detection of connecting elements
- Standard connection elements
- Avoid the use of dangerous tools and processes
- Employment creation and good working conditions

Example: Ecotech Tile

Floor tile produced with recycled materials from internal production

Source: www.revigres.pt

Design for remanufacturing

Through remanufacturing, a used product returns to a "like-new condition"; it is a process of recapturing the value of the material when a product was first manufactured. Remanufacturing results in the reduction of energy and material consumption, and of production costs (Gray & Charter, 2007), allowing the manufacturer to increase the productivity as well as the profitability in the business. (Fegade, Shrivatsava, & Kale, 2015)

Remanufacture can offer a business model for sustainable prosperity, with reputed double profit margins alongside a significant reduction in carbon emissions and the energy required in manufacture.

The potential or remanufacture is affected by the physical characteristics specified during the design phase, like the complexity and modularity of the products, the possibility to maintain or adapt technologies, the quality and durability of the materials and the solutions adopted in the product, etc. Design for Remanufacture is enabled by business models which recognise the benefits of remanufacturing and services like reverse logistics which allow that the products return to the factory at an affordable cost.

Remanufacture views end-of-life products and components as a resource. Promotion of remanufacturing can, therefore, benefit both the economy and the environment. Design for Remanufacture can optimise the process of remanufacturing, increase the practice of remanufacturing and therefore increase the significant economic development opportunities for businesses and people.

This strategy also avoids that valuable material materials and components ends low valued valorisation or in a landfill and creates a market for skilled employment and, in principle, is preferable to recycling. The value of materials and components is maintained by returning products to working order, whereas recycling simply reduces the used product to its raw material value (Ijomah, McMahon, Hammond, & Newman, 2007).

Although in theory any product can be remanufactured, the business case, which would make remanufacture economically feasible, varies between sectors and products, and the integration of other considerations like design for disassembly, which enables the process. Design for remanufacturing optimizes remanufacture through consideration of both the business model and the detailed product design and must be considered in the initial design of the product (Gray, 2007).

The following criteria should be considered in design for remanufacturing:

- Technology integration/stable technologies over the lifetime
- Use of modular solutions
- Existence of a take-back system
- Optimize reverse logistics (RL) network and involve the supply chain in RL planning
- Durable and wear-resistant materials and components
- Simplified product architecture
- Minimize connecting elements
- Facilitate access and detection of connecting elements
- Standard connection elements
- Employment creation and good working conditions

Example: Cannon refurbishment program

Refurbished products with comprehensive quality assurance inspections, replacing parts showcase the company’s dedication to product excellence

Source: https://shop.usa.canon.com

5.3.4 Strategies for narrowing loops

Design for materials sustainability

The selection of materials, (including water and components) and the quantity of material used, are key elements in the definition of the potential impact of a product or a service. In the design phase, the design teams can choose materials and components with lower impact by itself, or that have a positive influence on the product or service systems and can adopt measures to reduce the number of materials used by implementing efficiency strategies in the design. Decisions taken in the conceptual design phase are fundamental to influence the efficiency and optimization of material consumption in the life cycle of the product or service.

It is difficult to fully describe what a sustainable material is. It depends not only on the materials but the conditions in which it is transformed, applied and used. However, we can affirm that sustainable materials are ones that have a lower embodied energy as well as a lack of emissions, waste and making sure that the material continues to be created or grown rather than deplete its stocks.

Another way to describe them can be by looking at them as the materials whose use achieves environmental benefits, unlike other conventional materials.

Apart from the reduction of resource consumption, other strategies, influencing the efficiency in the life cycle can be adopted. Optimizing resource cascading can be an option to prolong the lifecycle of resources.

Resource cascading is the sequential exploitation of the full potential of a resource to improve resource efficiency. Resource cascading allows for significantly extending a resource's useful life through repeated utilization. This approach to production and consumption states that energy recovery should be the last option, and only after all higher-value products and services have been exhausted.

This concept is often associated with the forestry sector, in which cascading use can be effectively demonstrated.

Several sustainability issues must be considered in the selection of input materials and components that constitute the product or that are necessary to provide the product-service. Are the materials hazardous, non-renewable or scarce? Are they virgin or recycled? Can they be recycled? Do suppliers have good environmental and social practices? Are the materials and components local, or do they have to travel long distances and do not support the local or regional communities' economies? Based on the materials and components used in the product or product-service and the processes necessary to manufacture them, the possibility of using alternative ones with better environmental, social and economic performance must be analysed.

Designers who can develop solutions to fulfil the needs of the users using less and more sustainable resources (materials and water), have a higher potential to succeed in the creation of more circular and sustainable solutions.

The following design criteria apply:

- Optimize products' design (shape, size, weight, etc.) to reduce material consumption
- Avoid consumable components and materials in the use phase
- Use of recycled materials
- Eliminate the use of toxic materials in the product
- Promote the use of renewable materials in the product
- Use of locally produced raw materials and components
- Avoid the use of scarce and/or critical materials and promote the use of abundant materials
- Use of raw materials and components from suppliers with good social responsibility practices
- Information on product sustainability to consumers
- Influence sustainable consumer behaviour regarding consumables in the use phase

Example: Corks products

Cork is a material of vegetal origin from the bark (*suber*) of cork oaks (*Quercus suber)*, light and with great insulating power

Source: www.amorimcork.com

Design for energy sustainability

Like in other areas, product design should take into account the energy that the product will need to meet user needs, taking the whole life cycle into account. For energy-using products (e.g. electronics, cars, lighting), the use phase may be the most important one; however, for many other non-energy consuming products (such as furniture or packaging), the manufacturing phase can represent a significant portion of energy consumption.

Another emerging area is related to technologies in the field of renewable energy, such as small fuel cells, flexible photovoltaic solar cells and human power. As renewable energy sources develop and become smaller and more flexible, possibilities of integrating them into the product design have emerged. However, until recently, renewable energy technologies have been more or less "pasted" upon the products instead of being integrated into the design of the product. It is a big challenge to find the appropriate products or functions for these new technologies and to integrate them into the total design of the product (Mestre & Diehl, 2005).

This strategy thus encompasses energy efficiency in the various stages of the life cycle through design options, the use of solutions that incorporate renewable energy and influencing consumer behaviour regarding energy consumption.

The related design criteria include:

- Reduce energy consumption in production
- Reduce energy consumption in use
- Reduce energy consumption in transport
- Energy plus
- Replace non-renewable by renewable energy
- Use low embodied energy materials
- Information on energy consumption to clients/consumers
- Influence consumer behaviour regarding energy consumption

Example: SunPack

A backpack with a removable solar charger.

Source: www.kickstarter.com/projects/flexsolar

Assignment 5.5

Select two strategies and search for examples of products or services that correspond to those strategies.

Describe the examples using the same criteria as in the section and discuss the overlapping and complementarity between strategies.

Assignment 5.6

Read the following product features and identify the CE design strategy(ies) that best fit with them:

1. A textile upholstery for sofas made with 100% recyclable textile.
2. A durable kitchen worktop material.
3. An easy to repair kitchen worktop material.
4. Leasable furniture.
5. An armchair frame made with wasted wood generated in the manufacturing of ships
6. Furniture for kids that grow with the child.
7. A modular windows frame design that is capable to adapt to future changes: bigger windows or need to partial replacement of the window frame.
8. Wall shelves made with disposed doors.

5.4 Product and service design step-by-step

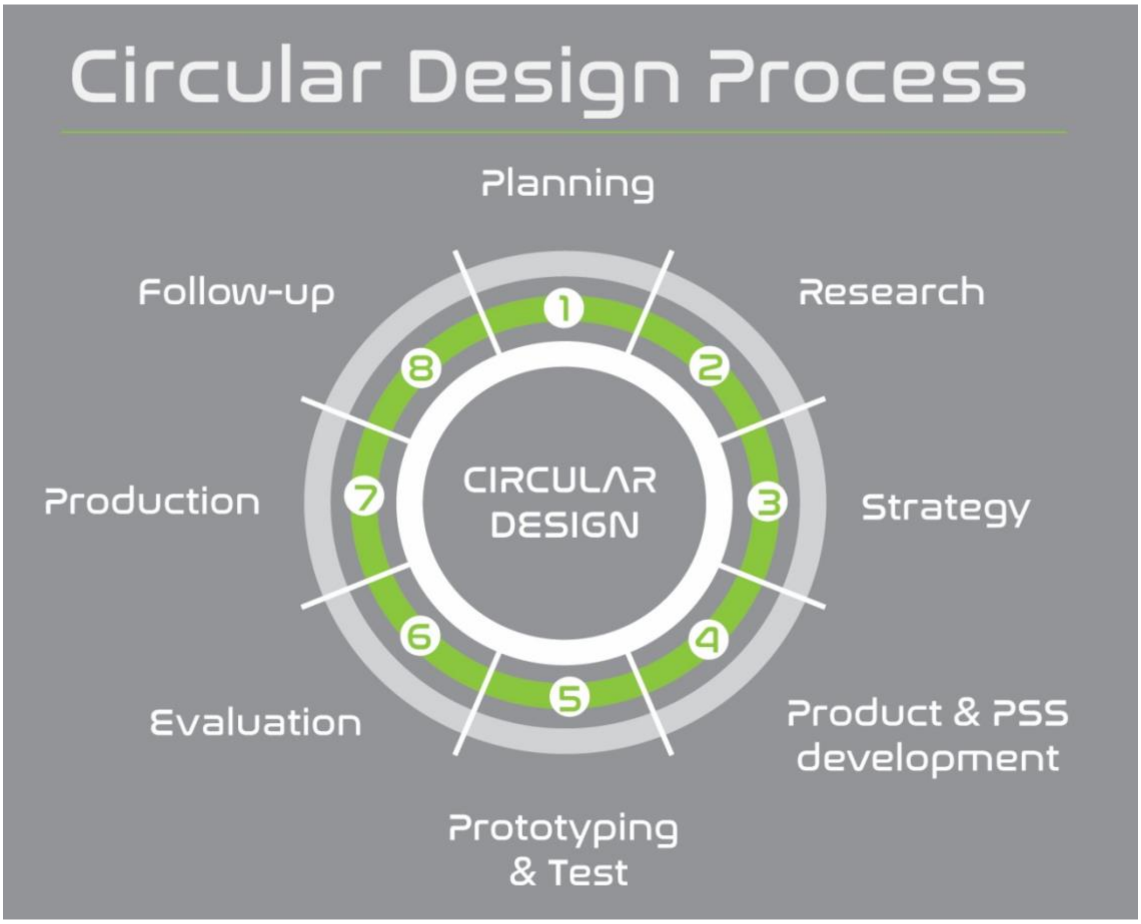


Figure 5.6 – Product-service development step-by-step

Design for circular economy, or circular design (as does design in general) has the responsibility to solve product or service problems, integrating several criteria in problem-solving in an innovative way and adjusted to the needs of users. In the circular economy, the designer has the function of translating the strategies and concepts of circularity in the development of products, services and systems that promote the transition from a linear model to a circular model focused on the closure of cycles, in the efficiency and sustainability of the entire system.

A design process is a method that leads to the conceptualisation and creation of the future, by developing new things that do not exist; design interacts and changes the world and society. The innovative solutions cannot be predetermined but the methodology used to develop solutions can be more predictable in accordance with the innovation level required and desired for the project.

For product design, the methodology has been defined by now and has been supported by several tools, widely adopted. Circular services have a higher potential for sustainability if developed with sustainability criteria and are based on business models which deliver added value to products and services that meet the needs of users in a more sustainable and circular way. These services are capable to meet the needs of users in a more sustainable way and to deliver more value to the customer and companies focusing on new and circular business models. In these systems, the focus is on the service that the user receives from a product and on the way he/she uses a product's function, rather than on the product itself.

Circular products and services are a challenge and at the same time an excellent opportunity to innovate at a higher scale in multidisciplinary teams – in which designers have an important and strategic role and hereafter are designated as design and development teams. However, services are more complex than products and their design and development implies using several methods. These complex scenarios imply holistic methods and approaches of design thinking, which sometimes do not begin with a fully defined or stabilized brief. The integration of a circularity perspective in the system is also a challenge that designers have to deal with. Several approaches can be applied, and the process will depend on the problem addressed, the companies involved, the design teams, the stakeholders and many different factors linked to the system. (UNEP, 2009)

The development process for circular services includes a smart combination of product design and service design. The design and development teams have more degrees of freedom in addressing the system's functionality than usual. This implies a wider range of responsibility but also a wider scope of opportunity (Müller and Blessing, 2007).

Several methods and definitions are available in practice and literature. In this section, we propose a structure for the design practice for circularity that is based on the design for sustainability process that has been widely applied and validated in numerous projects worldwide.

Although the idea of a process implies a linear sequence of events, this can be misleading (Kumar, 2013). According to their nature, many projects are actually non-linear and promote iterative processes.

Innovative and circular design processes start on a full understanding of the context of intervention by creating abstractions and conceptual models that help us to reframe the problem in new ways. After that, we explore new concepts in abstractions to evaluate them before their implementation in the real world. This promotes a thinking approach between real and abstract. Through a process of analysis and synthesis during the abstract stage, we engage the process of realization proposals leading to the realization of the proposal with the goal of its implementation, passing from the abstract understanding to the making for the real context (Kumar, 2013).

The methodology is based on eight general steps that should be adjusted to each particular project. The steps firstly describe the work performed in product design, in this case having in mind circular design. Then, the description of services design follows, highlighting when needed the related specificities.

Step 01 – Planning of the project

The first stage of the circular design process concerns understanding the context of the problem that the design and development team has to solve. The problem definition will help the designers to generate a holistic understanding of the context and gather great ideas to establish features, functions and any other elements that will allow them to solve the problems.

Often, projects start without a proper plan, with a poor definition of objectives and without a commitment from key elements, such as top management, project teams and other *stakeholders*. The definition of the brief for the circular design project is also an objective of this step. The brief is a well-known element by all project teams but often underestimated.

Step 02 – Needs analysis – research

In this step, the relevant baseline information concerning the need or opportunity that emerges from the previous step has to be gathered and analysed so that the circular strategies for the new solutions are appropriately defined based on a solid rationale. The main objectives are to determine the circularity, environmental, economic, social and market aspects of the reference product, to identify the "hot spots" in the life cycle, in dialogue with the stakeholders, to identify legal requirements applicable to the new solutions, and to adjust or modify the brief defined in the previous step, if needed. For a circular service, it is fundamental to increase the system's boundaries and analyse the functions that need to be fulfilled and the requirements and drivers from stakeholders for the circular service.

Step 03 – Definition of the circular design strategy

This step aims at identifying and selecting the most promising circular and sustainable design strategies for the product or service (see section 5.3).

The strategies help the development teams to (i) analyse the circularity and the life cycle of the reference product/service and (ii) to identify improvement options for new concepts. For a circular product or service, defining the strategy includes the identification of functions and target specifications for the new solution. For the circular service, it is necessary to define the value proposition and performance standards. A global approach for validation along with the several project stakeholders is relevant to ensure a solid project definition.

Step 04 – Product and PSS development

The development of a new concept has two distinct moments. The divergent thinking moment, in which several possible ideas are created, and a second moment, the convergent thinking moment in which the ideas are refined and narrowed down to the best idea. In order to discover which ideas are best, the creative process is iterative. This means that ideas are developed, tested and refined several times, with weak ideas dropped in the process. The selection of the best idea to be further developed must include an evaluation of its circularity and sustainability potential.

At this point, the team should have the needed circularity and sustainability information from the previous steps to support the development of a new and more sustainable product or service.

During the development phase, the whole system, the stakeholders and all the interactions must be clarified and established, and the relations between the physical products and the service components must be developed and detailed.

Partnerships with stakeholders have to be established, specific products may need to be developed and/or purchased, the system structure has to be defined, the interface and software has to be designed, adjusted or purchased and the promotion and communication need to be developed and implemented.

Step 05 – Prototyping and testing

The prototype is generally used to test and evaluate the new solution and to provide specifications for a real, working system rather than a theoretical one. The goal of a prototype is to test products and services' ideas before the development of the final solution, including the test of the circularity and sustainability potential.

Prototyping is essential to identify and resolve several issues before launch. It can also reveal areas that need improvement, allowing the development team to go back and adjust the initial concept.

Step 06 – Evaluation of the new product/service and of the project

This step aims to analyse the circularity and sustainability performance of the product and/or service against the defined objectives and the effectiveness and procedural aspects of the project. Firstly, the company should consider whether the process used for the project is actually appropriate, and secondly, the company should evaluate the new product or service having as a basis the objectives defined in the brief. Apart from circular and sustainability aspects of the new product or service, functionality and technical qualities should also be evaluated during this phase.

Step 07 – Production

If the new circular product or service has a good evaluation, the company can start the production and placement in the market.

To guarantee the circularity of the system, all aspects of production and placement of the product/ service have to be considered and aligned with the previous steps. To attain a higher degree of circularity and sustainability, it is essential that the entire company (and relevant potential stakeholders involved in co-design) follow the process.

For this purpose, it is also important that the company performs an internal promotion of the procedures and process of the new product or service, also with the promotion and commitment of relevant stakeholders.

Step 08 – Follow-up activities

The company must define follow up activities after having made an evaluation of the product or service and the project, as described in the previous steps. Follow-up activities should promote a circular approach to project development based on a continuous improvement idea.

Assignment 5.7

- Think of a furniture product to be redesigned in a circular design project.
- Consider the eight steps of the project:
  1. Planning of the project
  2. Needs analysis – research
  3. Definition of the circular design strategy
  4. Product and service development
  5. Prototyping and testing
  6. Evaluation of the new product or service and of the project
  7. Production
  8. Follow-up activities
- Identify at least two tasks in each step to align your project with circularity and sustainability.

5.5 Design for CE in the construction sector

In the previous sections, a generalist approach was taken when describing the strategies and methods for product and service design for circular economy. However, the construction sector presents specific challenges that will be discussed below.

It is important, however, to clearly state the scope of this section. Firstly, there are some distinctions to be made: are we talking about building design (i.e., the domain of architects, engineers, contractors, investors, and users) or about construction products design (i.e., the domain of designer and manufacturers)? This section focuses on the latter, but it is impossible to think of "circular construction products" without relating to the building into which they are incorporated. As Geldermans and Jacobson (2015) put it, when it comes to sustainable construction, products need to fulfil **intrinsic properties** (high quality, of sustainable origin, non-harmful and consistent with biological and technological cycles) as well as **relational properties** (i.e., how the product relates to the design and use of the building anticipating multiple future user scenarios), such as dimensions, connections and life span. The **circular value** of products for the construction industry is, according to those authors, in the **intersection of those properties** (figure 5.7).

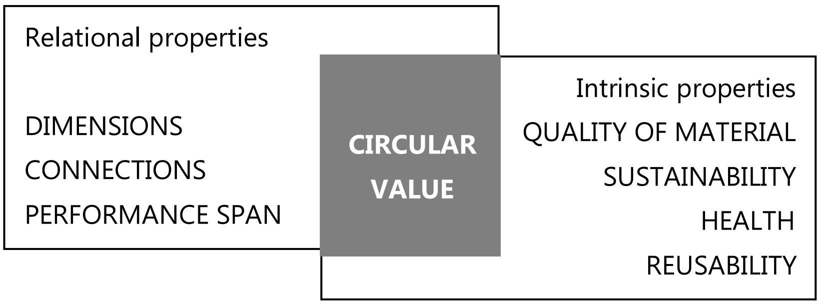


Figure 5.7 – Circular value as the intersection of relational and intrinsic properties of building products. (Geldermans and Jacobson, 2015)

Buildings are a dynamic set of subsystems (Geldermans and Jacobson, 2015) in which different circular economy strategies vary in applicability (e.g. the lease concept may be uninteresting for a whole building due to its very long life span, but may be feasible to elements with a shorter life span (Evert, S., Crielaard, M., Mesman M., (2015). Brandt's layers of change (site, structure, skin, services, space plan and stuff) help in working out those differences (figure 5.8).

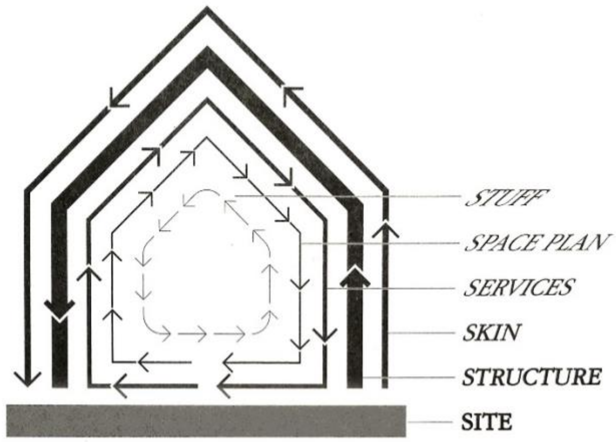


Figure 5.8 – Six dynamics that characterise a building, according to Stewart Brand. (Brand, 1994)

The layers and respective lifespan are (Brand, 1994):

- Site: the geographical setting, the urban location and the legally defined lot
- Structure: the foundation and load-bearing elements (30-300 years)
- Skin: exterior surfaces (20 years)
- Services: working functions of a building, e.g. communications and electrical wiring, plumbing, sprinkler system, HAVAC Heating, ventilating and air conditioning) and moving parts like escalators and elevators (7-15 years)
- Space plan: interior layout (3-30 years)
- Stuff: all non-fixed furniture, i.e. things that twitch around more frequently

In a circular economy, it is crucial that a building does not lose its utility over time. To this endeavour, it is necessary to focus on **building design for adaptability**, **building design for relocation and building design for deconstruction and reuse** (Potemans, 2017). What does this mean for the construction materials and products, keeping in mind the building layers as defined by Brandt (1994)? The following design approaches apply, based on the work of Schut et al. (2015) and Geldermans and Jacobson (2016):

Minimize materials' use: the most effective way to prevent it in construction sites is to use existing buildings or reuse materials and elements and industrially pre-fab construction elements (Schut et al., 2015).

Intelligent dimensioning given the planned function, performance and lifespan. This seems to be a contradiction with the previous point, but the goal of facilitating changes in the future may imply over-dimension, even if this means a surplus of material consumption; in the total lifespan of a building it can prove beneficial if the amount of material demand for adaptation is reduced (Geldermans and Jacobson, 2016);

Modular design: an optimum life is assumed for parts of a building, and the goal is to replace building sections by modules (off-site manufacturing) effectively and efficiently (Schut et al., 2015);

Design for deconstruction: designing construction elements in such a way that they can be taken apart ("LEGO approach");

Design for high-quality future reuse and recycling: in the context of CE, this means not only in one cycle, but with a longer time frame in mind – second, third, etc. lives; this requires good quality recycling, or upcycling following principles of design for disassembly and flexibility (Schut et al., 2015; Geldermans and Jacobson, 2016).

Circular economy is also about dematerialization and renewable energy sources. This requires:

- **Designing services** such as infrastructure sharing, co-housing, co-working, etc.;
- Designing construction elements that allow the use of solar, wind, biomass and other **sources of renewable energy**.

Assignment 5.8

a) Observe the room you are in (classroom, office room, at home, etc.).
b) Define a different use for the room in 20 years' time (for instance, the room will be a dance room because the building's purpose will change into a performing arts centre).
c) Identify one element of the space plan and stuff layers (according to Brand) that will need to be adapted for the new purpose and discuss design options for this element according to the eight KATCH_e design for circular economy strategies.

5.6 Tools for product and service design for CE

5.6.1 KATCH_e Tools

CE Designer

What is the tool for?

The CE Designer is a semi-quantitative tool for prioritization, assessment and idea finding of circular solutions for product and/or service (re)design. The tool is e organized according to 8 strategies that address the most relevant issues a design team needs to consider in the development process of new products or services to support the transition to a more circular society.

What is the information needed before using the tool?

The user should have a good knowledge of the sustainability profile of the reference product or service along the life cycle or be provided with such information (in the case of the tool being used in an academic context). Previous knowledge about CE and the strategies is recommended.

What results can be expected?

A prioritization of applicable design strategies for a more circular and sustainable product/ service;

The analysis of a reference product or service according to the chosen design for circular economy strategies;

Immediate improvement ideas and opportunities, through the reflection and assessment of each strategy and related criteria;

Background information for a brainstorming or other creativity session;

A graphic comparison between the reference product or service and the new one(s). With this feature, the team can communicate where and how the new solution performs better.

How is the tool used?

Prioritization of strategies: The user evaluates the importance of each of the 8 strategies according to the requirements of the project, the company and its business strategy, etc. and selects the ones that should be assessed in the next phase.

Assessment:

Step 1: for each strategy selected, the user indicates the importance of each criterion. By default, all are rated as very important.

Step 2: the user evaluates each applicable criterion with an ABC scoring system. The weighted sum of the performance of all criteria results in the final score of the strategy for the reference product/service. The Score A means that the criterion is fulfilled by the current solution, the B means that it is partially fulfilled and there are opportunities to improve and, C, means that the criterion is not fulfilled, and that is a hotspot of the reference situation that should be improved if possible.

Step 3: the user inserts improvement ideas or measures linked to each criterion. This can be used in a brainstorming session after filling the tool for the reference product or service. After the filling in of all relevant strategies and related criteria, the user can go the results spreadsheet, in which a chart with the score of the strategies and the information resulting from the analysis are displayed. This information may then be used to support a creativity session to define a new concept for a product and/or a service.

Step 4: After the development of a new product and/or service, the analysis according to what was described in step 2 is repeated. This will allow a comparison between the reference situation and a new one, also displayed graphically in the results area.

CE Journey

What is the tool for?

This tool supports the players and/or stakeholders to assess the overall Product / Service / System journey, in the three stages (uphill, top hill and downhill) according to with several factors: materials, producers, stakeholders and users. Through a visual representation of the journey, it aims to identify the touchpoints between the factors identified: materials, producers, stakeholders and users, providing a model for analysis and identification of opportunities to optimize the journey and to enhance the closing of the loops to present a more circular solution.

What information is needed before using the tool?

The user should have a specific product/service in a specific context (materials, producers, stakeholders and users) in mind, which is then analysed further.

What results can be expected?

A visual canvas that allows you to see the journey and touchpoints of the products, producers, stakeholders and users to optimize the journey and closing of the loops.

How is the tool used?

Step 1. Print all the cards and canvas and gather necessary materials per group.

Step 2. Gather the group/groups in a room and explain the activity, tasks and overall goals.

Step 3. Identity each participants role and link them with the possible cards and material(s).

Step 4. Introduce task by task:

- **1st SUPERPOWERS -** Identify major actors and resources in terms of materials, producers, partners and users;

- 2nd **CHALLENGES -** Each actor should get familiar with the different types of challenges and resource in terms of materials, producers, partners and users;

- **3rd JOURNEY Canvas -** In collaboration, participants must fill the canvas based on the journey identified, where they must try to identify their touchpoints. Aim for optimizing the solution in its economic, environmental and social dimensions.

  During the process, always keep in mind the Circular Economy focus (purple card).

Step 5. In the end, you can redo the canvas aiming to optimize the solution in order of: closing loops, waste as resources, assets sharing and feeding loops.

KATCH_UP board game

The objective of this game is to stimulate the users to generate value ideas from a business challenge, applying circular design and circular business strategies. The game acts as a guide to get an idea about an innovative product-service or to solve a real business problem and generate improvement opportunities.

What information is needed before using the tool?

No previous knowledge of circular economy is required, however, having knowledge about CE design and business strategies are preferred, as the application of the tool will be more agile, efficient and effective, leading to better-defined ideas.

What results can be expected?

Creation of a product-service idea applying circular design and circular business strategies to solve problems from case studies or your own company issues.

How is the tool used?

This tool can be applied under different situations: Company, academia and workshops. When this game is played in companies, real cases can be applied, i.e., to a specific product-service category and to solve specific company challenges. When this game is played in classrooms or workshops, the game offers hypothetical contexts to work on them.

PREPARATION: Form groups of 3-4 people and prepare the board and its elements

PLAYING: The game has 6 basic steps:

Step 1. Problem context:

a. Presentation of the product-service category, business challenge and target group;

Step 2. Way to the solution:

b. Presentation of the design for circular economy strategies that can be used to deal with the problem context;

Step 3. Idea creation:

c. Development of the innovative idea that will solve the initial problem;

Step 4. Business model:

d. Definition of the most appropriate business model;

Step 5. Market launch:

e. Definition of how your product-service will be launched to the market;

Step 6. Presentation and scoring:

f. CE ideas got as a result of the game should be pitched by the groups and scored using a Likert scale (1-5).

5.6.2 Other tools

Tool	Description	Source
Circular Economy Toolkit	The Circular Economy Toolkit is a free resource for businesses to find opportunities in the Circular Economy. With the vast number of possibilities for creating value out of the Circular Economy and cradle-to-cradle thinking, it can be challenging to assess all the options. The Circular Economy Toolkit has consolidated all the opportunities and provided information on how your company could start finding benefits. The Assessment tool offers a questionnaire to evaluate circular strategies and besides the assessment features, the tools provide useful information in each strategy.	http://circulareconomytoolkit.org/Assessmenttool.html
Material Circularity Indicator	The Material Circularity Indicator measures how restorative the material flows of a product or company are, and includes complementary indicators that allow additional impacts and risks to be taken into account. The indicators may be used by product designers, as well as for internal reporting, procurement decisions, and the evaluation or rating of companies.	https://www.ellenmacarthurfoundation.org/assets/downloads/insight/Circularity-Indicators_MCI-Product-Level-Dynamic-Modelling-Tool_May2015.xlsx

Tool	Description	Source
	The Material Circularity Indicator for a product measures the extent to which the linear flow has been minimised and restorative flow is maximised for its component materials, and how long and intensively it is used compared to a similar industry-average product. The MCI is essentially constructed from a combination of three product characteristics: the mass of virgin raw material used in manufacture, the mass of unrecoverable waste that is attributed to the product, and a utility factor that accounts for the length and intensity of the product's use.	
Circularity Check	The Circularity Check is a self-assessment tool without external verification. The Checklist consists of a free questionnaire of about 60 questions that can be filled out online. It is meant to assess if a particular product/service is "circular", and if so how circular. The basic idea is to first look at the circular economy aspects used and then perform a sustainability check. For each circular economy aspect used in your product/service, scores are acquired. The higher the scores the better, but you can get them in many different ways. Red flags are raised if you score zero on one of the phases of the value cycle, or on sustainability. Is the product circular and sustainable, and if so, to what extent? A score is assigned to each question. The higher the score the better. The outcome of the check is a % that indicates how circular your product/service is. The tool also provides partial scores on design/ procurement/ manufacturing, delivery, use, recovery, and sustainability. The Circularity Check is primarily intended as a product-based tool for self-evaluation by companies, from SMEs to multinationals.	https://www.wesustain-esm.com/circularity-check/main.html/?page=SUB_HOME&portal=1680lbeg

Assignment 5.9

Exercise with the CE Designer:

Using a specific product, service or problem, apply the tool to analyse the circularity profile and identify improvement measures according with the results of the tool. The following example of the coffee machine can be used as a basis to perform the exercise (the product and data were developed for the exercise and are fictitious).

Reference product – Coffee machine

Lifetime – 10 years

Capacity – 0,5 L (equivalent to two cups)

Use – Average 2x/day

Production:

- Produced and assembled in Europe
- Heating components made in Asia
- Materials of the body – PP and glass (pot)
- Packaging – Single use, made with cardboard, EPS and LPDE
- Certifications – ISO 14001 and SA 8000
- Electric cables in PVC and copper

Use:

- High consumption of energy, mainly to maintain the temperature of the coffee

End-of-life:

- 50% disposed in electronic equipment waste containers for valorisation (aware consumers)
- 50% disposed in common urban waste containers (non-aware consumers)

Exercises with other tools:

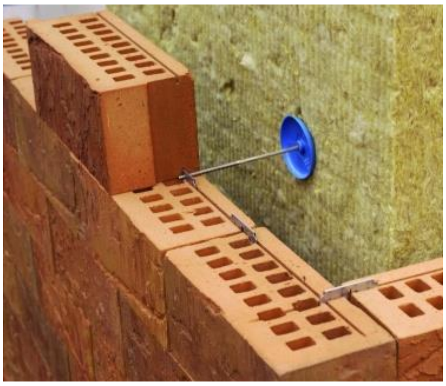
Use the same product and data and apply it to the other tools presented in section 5.6.2. Compare and discuss the results attained with the different tools.

5.7 Examples

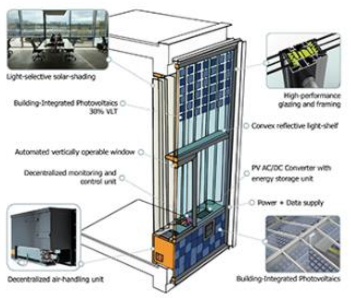
REVICONFORT, by Revigres

Description	REVICONFORT is a porcelain stoneware flooring for interior areas, public or residential, removable and reusable, quick and easy to apply. It does not require adhesives, cement or specialized manpower and can be used immediately after application. It is a versatile, innovative solution in the ceramic world, which revolutionizes the concept of fixed flooring. REVICONFORT brings together, in a single product, the technical characteristics of porcelain stoneware, the economic advantages of a simplified placement, the profitability of time in its placement, ease of mobility, ease of use and easy maintenance.
Organization and country	REVIGRÉS, Portugal
Sources	Company Website: ww.revigres.pt
Image	
Image source	http://revigres.pt/wp-content/uploads/2018/02/CAT_REVIGRES_PRO_2018.pdf
Sector	Construction
Circularity approaches	Slowing loops Narrowing loops
Design Strategies	Design of long-life products Design for product-life extension Design for materials sustainability

ClickBrick, by Daas Baksteen

Description	The Clickbrick system is designed for reusability and a long life without maintenance. The bricks are dry stacked, assembled with steel clips, without using mortar. This results in fewer materials being used with an inherent ventilation system avoiding moisture. Whereas traditional bricks are usually at best downcycled at their end of life, the ClickBricks can be disassembled and reused for the same purpose.
Organization and country	Daas Basksteen, The Netherlands
Sources	Company Website: http://www.daasbaksteen.com/en/Facade-systems/ClickBrick/page.aspx/67 http://www.zi-online.info/en/artikel/zi_2011-03_ClickBrick_for_a_wall_without_joints_1090523.html
Images	 
Images' source or credits	http://wiki.bk.tudelft.nl/mw_bk-wiki/images/thumb/2/22/Monsterkast_168_1.jpg/400px-Monsterkast_168_1.jpg http://www.c2c-centre.com/sites/default/files/styles/v2-single-page/public/clickbrick.jpg?itok=rss7Dko
Sector	Construction
Circularity approaches	Slowing loops Narrowing loops
Design Strategies	Design of long-life products Design for product-life extension Design for materials sustainability Design for energy sustainability

Façade Leasing by TUDelft

Description	An interdisciplinary research team within the Faculty of Architecture and the Built Environment developed a circular business model based on the use of multifunctional façades as performance-delivering tools. Under this scheme, the client is no longer the owner of the building envelope and its integrated building services, but instead leases them from a service provider through a long-term performance contract. Rather than purchase the façade panels as a product, the client hires the energy performance and user comfort services delivered to his building by this new façade system.
Organization and country	TU Delft, The Netherlands
Sources	https://www.tudelft.nl/en/architecture-and-the-built-environment/research/projects/green-building-innovation/facade-leasing/facade-leasing-pilot-project-at-tu-delft/
Images	 
Images' source or credits	https://d1rkab7tlqy5f1.cloudfront.net/BK/Onderzoek/Projecten/RTEmagicC_Facade_Leasing_pilot_project_TUD_Panel2_Breakdown.png.png https://d1rkab7tlqy5f1.cloudfront.net/_processed_/8/9/csm_Leasing_facade_d6c5c7fb68.jpg
Sector	Construction
Circularity approaches	Slowing loops Narrowing loops
Design Strategies	Design of long-life products Design for product-life extension Design of use- or result-oriented services Design for materials sustainability Design for energy sustainability

Treehouse Riga, by Jular

Description	Treehouse Riga is a modular home that can be easily adapted to the owner's needs. It is a prefab home, with less construction waste as compared to traditional construction methods, and expanding it to accommodate a growing family, for example, is a breeze. The basic version of Treehouse Riga measures 474 sq ft (44 sq m) and features two bedrooms. It is made of just two modules. Each module measures 236 sq ft (22 sq m) and they are joined together in an offset way, which creates exterior spaces that slightly are different from each other. Presumably, more modules can simply be attached to the home, to create additional spaces such as extra rooms, a studio, a second bathroom and so on.
Organization and country	Jular, Portugal
Sources	www.jular.pt | https://www.treehouse.pt/construcao-modular/
Images	 
Image source or credits	www.jular.pt
Sector	Construction
Circularity approach	Narrowing loops
Design Strategies	Design for materials sustainability Design for energy sustainability

Remade – G64-R office chair, by Orangebox

Description	Products that are reaching the end of their commercial life span are now being given a second chance, thanks to Orangebox Remade. The first product to be offered under this initiative is the G64, a very successful and durable office chair. 98% of the G64-R's parts are recyclable, with removed components either being kept for reuse or returned for material reprocessing. With a recycled content of around 80% (by weight), each remanufactured chair delivers a 60% reduction in CO_2 emissions and saves 75% of water consumption compared to new.
Organization and country	Orange, UK
Sources	www.orangebox.com | https://www.orangebox.com/about/responsibility/remade
Images	
Image source or credits	www.orangebox.com
Sector	Furniture
Circularity approaches	Closing loops Narrowing loops Slowing loops
Design Strategies	Design of long-life products Design for recycling Design for remanufacturing Design for materials sustainability

Care Changing Table, by Stokke

Description	This design converts the changing table into a practical desk. It prolongs the use of the nursery product as the child grows, as it can be used as a place to play, draw or do the homework. Easy assembly.
Organization and country	STOKKE AS, Norway
Sources	www.stokke.com
Images	
Image source or credits	https://www.stokke.com/en-za/164103.html
Sector	Furniture
Circularity approaches	Slowing loops Narrowing loops
Design Strategies	Design of long-life products Design for product-life extension Design for materials sustainability

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06

RADICAL INNOVATION AND COLLABORATIVE DESIGN PROCESSES

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Radical innovation and collaborative design processes

Contents

Executive summary 297

6.1 Introduction to innovation 298

6.1.1 Different categories, types and levels of innovation 298

6.1.2 Disruptive innovation for societal transformation 301

6.1.3 Social innovation, organizational innovation 302

6.2 Circular economy as an input for the innovation process 305

6.2.1 Why is innovation important for CE? 306

6.2.2 Sustainability challenges as a way to innovate 306

6.2.3 Guidelines for policy and decision-making 308

6.3 Product-service system design 310

6.3.1 Product-service design innovation: examples 312

6.3.2 Business models and innovation pipeline 320

6.4 Collaborative and participatory design for innovative processes 323

6.4.1 How to develop new strategies to adopt collaborative and participatory design processes in and between companies 323

6.4.2 Methods for collaboration: lateral thinking and the creative process 325

Creative tools and processes examples: 326

6.5 Open-source as a mean to feed innovation and disseminate results 332

6.5.1 The importance of open-source to disseminate best practices for CE 332

6.5.2 Open-source as a mean to allow replication of sustainable initiatives 332

6.5.3 Open-source as crowdsource (web 2.0) 333

6.6 Examples 334

Bibliography 337

Executive summary

6.1 Introduction to innovation

This section gives a comprehensive review of what is innovation and explores different types of innovation and their relationship with product-service development, contributing to the thematic of the project.

The assignment associated intends to promote reflection on each type of innovation presented and, on their differences, and possible applications.

6.2 Circular economy as an input for the innovation process

Considering the strategies associated to sustainability and circular economy implementation in product and service development, this section reasons how these concepts can give resourceful inputs and guidelines for innovation.

Having previous knowledge about the essentials of circular economy provided in previous chapters, this section's assignment starts on a given example to apply possible circular strategies for innovation.

6.3 Product-service system design

Referring to the *Design and development* chapter, this section introduces product-service systems design and its relevance for circular development, through considering sustainability and circular economy principles, stakeholders and business model.

6.4 Collaborative and participatory design for innovative processes

This section addresses collaborative and participatory design processes, including several tools applied to product/service development. A challenge will be given in order to test one of the tools presented.

6.5 Open-source as a mean to feed innovation and disseminate results

The final section discusses how can open source provide tools and means to potentiate sustainable and circular development and suggests reflecting in examples that can provide open source outcomes.

6.1 Introduction to innovation

A broad concept of innovation is linked to characteristics, actions or contexts. It's possible to be related to something new (from latin *novus*), that's derived from from latin "*in+novare*" that means *to make new,* focus on action/process and *to innovate* in terms of contexts, introduce *something new to* a particular scenario.

> "innovation is the embodiment, combination, and/or synthesis of knowledge in novel, relevant, valued new product, processes or services"
>
> Leonard and Swap, 1999

When reflecting about **innovation** is relevant to consider the impacts of design activity on industry and society at large, and how it can change behaviours and mindsets, specially related to sustainable consumption and environmental education. By that, we are reflecting the relevance of **circular economy** concept, not just focus on the final product but promoting analytical and constructive frameworks that allow us to develop and optimized the overall process to meet innovative sustainable economy and consumption.

6.1.1 Different categories, types and levels of innovation

In this section the focus is upon categories and types of innovation for products or services.

According to Schumpeter (1942) innovation can be defined in two major categories: **product** and **process innovation** that are subdivided in five types of innovation: process innovation – new production methods or a new source of supply of raw material or semi-finished goods; and product innovation - a new good, a new quality of a good or new market, and new industry structure as the creation or destruction of a monopoly position (Bilge and Alpay, 2003).

On the other hand, OECD (1992) also categorizes innovations as product innovations, that can be major and incremental. Process innovations are distinguished by technological innovations as other category of innovation that contains both product and process innovations. According to OECD (1992), technological innovations, is similar to 'inventions', and has to be implemented in a product or process to become an innovation that has a commercial value.

Based on a similar base of categories of innovation, it's introduced the concept, of degrees of novelty, as seen on figure6.1, that vary from minor, incremental improvements to radical changes on how a product is perceived or a process is held in an industry (Tidd et al., 2001).

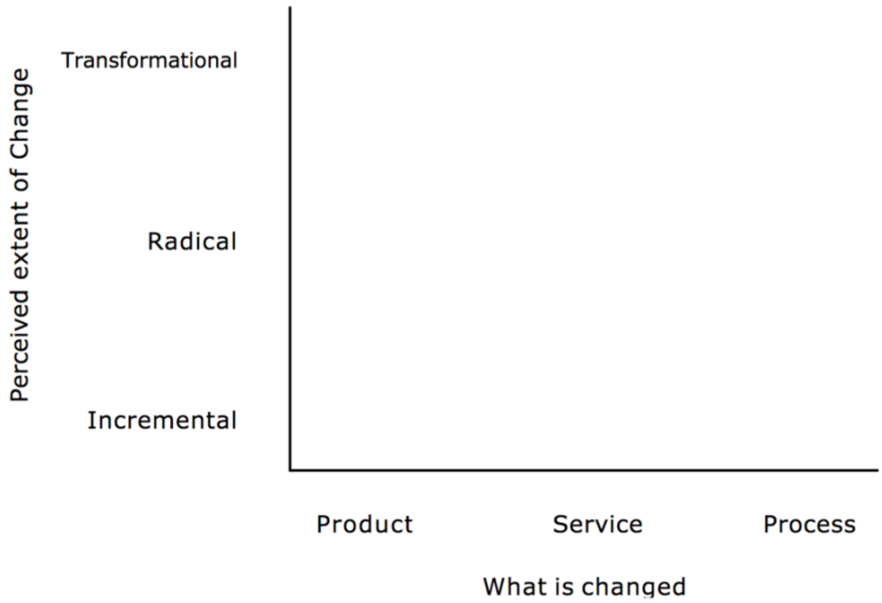


Figure 6.1 – Dimensions of innovation space (Tidd et al., 2001).

Innovation can be classified and defined in different types according to the object of innovation: socio-cultural systems, ecosystems, business models, products, services, processes, organizations, institutional arrangements, etc; and to the drivers of innovation itself: technology, market, users, etc.), or to the intensity of innovation: incremental, disruptive, radical, systemic, etc. The success of product design or services are based on these differences types aspects (Norman and Verganti, 2014). As you can see on figure6.2, it's possible to define in two opposite quadrants: incremental innovation (lower left quadrant) and radical innovation (top right quadrant). This proposal is focussed on people, assuming innovation in relation to people, market and context, exploring cultural, symbolic, economic and environmental levels that comes along with the solutions.

Incremental innovation: Improvements within a given frame of solutions ("doing better what we already do"); often occurs in traditional human-centred design (HCD) approach, and although it allows for local, linear changes in technology and meaning, it keeps the product within the lower left quadrant (Norman and Verganti, 2014).

Radical innovation: A change of frame ("doing what we did not do before"), is driven by two major possibilities: the development of a new enabling technology, or the change in meaning of the object (Norman and Verganti, 2014).

Most of the writing on innovation within the design community focuses upon radical innovation. It is often characterized as disruptive or breakthrough, with all these labels sharing the same concept that radical innovation implies a discontinuity with the past (Garcia and Calantone, 2002). Radical innovation is the centre of attention of design studies, where it is taught in design schools, and advocated by people discussing innovation and "design thinking". Although it's the main goal, successful radical innovation is surprisingly rare, most attempts at radical innovation fail (Sandberg, 2008). Larry Keeley, president of the Doblin Group estimates that 96% fail (Bloomberg Business Week 2005, August 1). Successful radical innovation occurs infrequently within any particular area, perhaps once every 5 – 10 years.

Radical changes in technology can lead to radical technology-driven innovation: for example, the introduction of colour TV. Radical changes in meaning can lead to radical meaning-driven innovation, as in the switch from watch as tool to watch as fashion accessory. The biggest change comes about when both the technology and meaning change, as when Wii used new technology and new meaning to radically change the space of video games. This dual change is rare and more dangerous: consumers tend to resist massive changes.

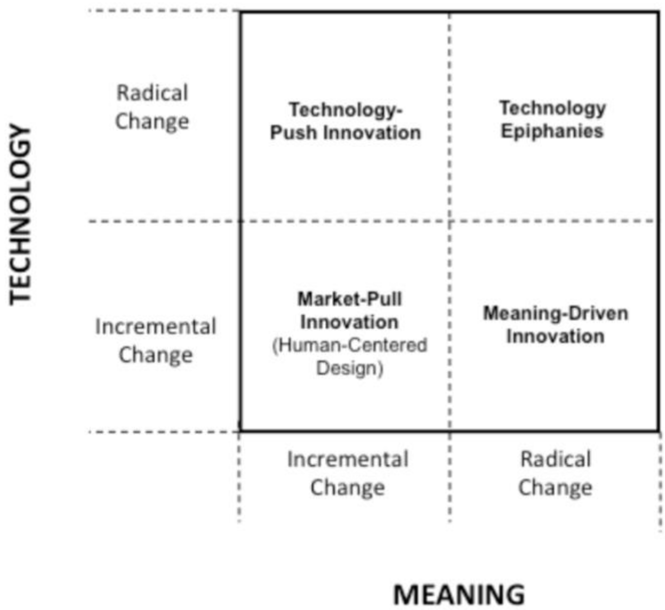


Figure 6.2 – Relations between the two dimensions and four types of innovation (Norman & Verganti, 2014).

Based on figure 6.2 it's possible to define four types of innovation:

- **Technology-push innovation** comes from radical changes in technology without any change in the meaning of products. (example: touch-screens)
- **Meaning-driven innovation** starts from the comprehension of subtle and unspoken dynamics in socio-cultural models and results in radically new meanings and languages, often implying a change in socio-cultural regimes. (example: ipod)
- **Technology Epiphanies** that bring a radical change in meaning enabled by the emergence of new technologies or the use of existing technologies in totally new contexts. (example: nintendo wii)
- **Market-pull innovation** that starts from an analysis of user needs and then develops products to satisfy them. (example: digital camera)

6.1.2 Disruptive innovation for societal transformation

> "disruptive innovation, in which disruptive refers to the absence of a well-established frame of reference"
>
> Hummels and Frens, 2011

By this statement Caroline Hummels and Joep Frens, refer to innovation through design process not only the product as such is new, but it also refers to the creation of a radical new meaning for the user, the market and society. As said before technological innovations, can introduce fast and innovative changes, shaping societies, reforming meanings and habits. In the meanwhile, we are also facing wicked problems (Rittel and Webber, 1984) and complex societal challenges due to fluid scientific and social development (Bauman, 2000). Facing new types of problems like healthy living and aging, mobility and sustainability, there is a need for a new type approaches and innovation that can transform the way they experience and interact in and with the world (Hummels and Frens, 2011).

All artefacts that are designed (being products or services) are inextricably intertwined with society and they have impact to change our society (in med to long terms). The ones that arise in a social context are consequently a reflection of that society (Hummels and Frens, 2011). The ones that are introduced by the market in society can also steer it and influence the behaviour and user experience. Designing can act as a disruptive innovation and a way to change society, or to promote exploration for social and societal transformation (Hummels and Frens, 2011). Roberto Verganti (2009), refers that we are moving towards design-driven innovation, that is based on a strong vision to create new markets. This type of innovation is not obtained by scrutinising user needs, which generally leads to incremental development (close to HCD), but by developing a holistic vision that can guide disruptive innovation (Hummels and Frens, 2011).

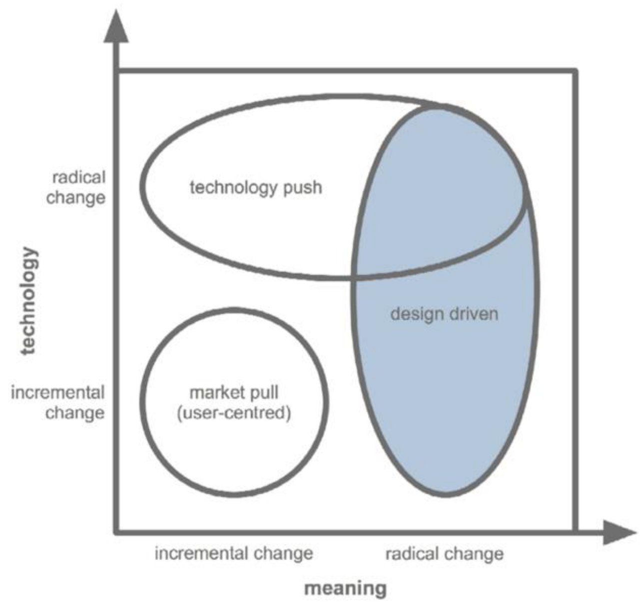


Figure 6.3 – The strategy of design-driven innovation through a radical change of meaning (Verganti, 2009).

In order to act in a design-driven innovation, as shown in figure 6.3 propose to that:

- Industry must build upon the community of players (people that deeply understand the context the product) (Verganti 2009);
- Understand the concept meaning[1] of the product/service in people lifes (Verganti 2009);
- Designing products with not well-established frame of reference for users, the market and society (Verganti 2009),
- Use different design process than is often used up till now (Verganti 2009) and (Norman 2010);
- disruptive innovation and a radical shift of meaning is the importance of intuition and design action during the design process. Enable designers to explore the unknown by trusting their senses, exploring resistance and ambiguity, and by tapping into their intuition (Hummels and Frens, 2011).

By this approach we can move forward to network of interactions: passing from context of use base on the binominal (user-technology), to trinomial (user A-technology – user B), and to a network with several users and technologies.

6.1.3 Social innovation, organizational innovation

According to Mulgan (2007) innovation is relevant when problems are getting worse and complex, when systems are not working or when institutions reflect past rather than present problems. Among several definitions of Social Innovation, it's possible can refer:

- Social innovation as new ideas that work to meet pressing unmet needs and improve people's' lives (Mulgan, 2007);
- Social innovation can be seen as a process of change emerging from the creative re-combination of existing assets (social capital, historical heritage traditional craftsmanship, accessible advanced technology) and aiming at achieving socially recognized goals in new ways (DESIS Network, 2016)[2].

Innovation driven by social demands in opposite to market or techno-scientific research involve people/actors instead of specialist. These new processes and solution have been generating new forms of social organization, oriented to sustainable ways of living and participation in society. In

[1] **Meaning definition** "How we think about the world is … rooted in how we interact with it before we think, and so our intellectual thoughts cannot be used to explain away that pre-reflective experience. We move about the world, make use of the objects in it, respond to situations emotionally, act in order to change it, and so on. All these and other ways of interacting with the world give rise to its meaningfulness, so that the meaning of things in a sense, exist neither 'inside' our minds nor in the world itself, but in the space between us and the world, in the interaction" (Matthews, 2006, p.33)

these new forms of organization, we can define it in three (bottom-up, top-down and hybrid) that have particular characteristics (Manzini, 2014):

- **Bottom-up:** initiates promoted by bottom or beginning of a hierarchy or process upwards; non-hierarchical; people and communities directly involved;
  - (1) (re)discover the power of cooperation;
  - (2) recombine, in a creative way, already existing products, services, places, knowledge, skills and traditions;
  - (3) count on their own resources, without waiting for a general change in the politics, in the economy, or in the institutional and infrastructural assets of the system. example: Help Us Green (https://www.helpusgreen.com), The Restart Project (https://therestartproject.org/restart-your-workplace/)
- **Top-down:** initiatives promoted by a system of government or management in which actions and policies are initiated at the highest level; hierarchical; experts, decision makers or political activists;
  - (1) Recognition of a real problem and, most importantly, of the social resources that might be able to solve it (communities and their capabilities);
  - (2) Proposal of (organisational and economic) structures that activate these resources;
  - (3) Building (and communication) an overall vision able to connect a myriad of local activities and orient them coherently.
- **Hybrid:** initiatives promoted in partnership with bottom of the hierarchy and the system of government or management.
  - (1) Aim to sustainable changes on a regional scale;
  - (2) Share an explicit goal and set of objectives, activating citizen participation;
  - (3) Driven by some specific design initiatives (led by design, by design agency and/or by design schools or research groups).

Social innovations are important because they promote behavioral changes, which are essential to approach society problems in a holistic way. Although technologic solutions can have positive social sustainable impact, people's' behaviors should go along the society needs for change. We can acknowledge that most productive way to manage change is through small scale test and experiments, many times with the society and social entrepreneurs, by opposition to other strategies like implementing new policies or restrictions (Mulgan, 2007).

By promoting these change in modus operandi we are stimulating new organizational concepts, that promotes: highly dynamic processes by using co-design processes and consensus building that help decision-making processes; creative and proactive activities, where designers' act as mediators (between actors/stakeholders) and facilitators (of other participants' ideas and initiatives), but involves more skills and, most importantly, it includes the designers' specificity in terms of creativity and design knowledge (to conceive and realize design initiatives and their correspondent design devices); and complex co-design activities that support creative and visual (2D or 3D Models) that support innovation (Manzini, 2014).

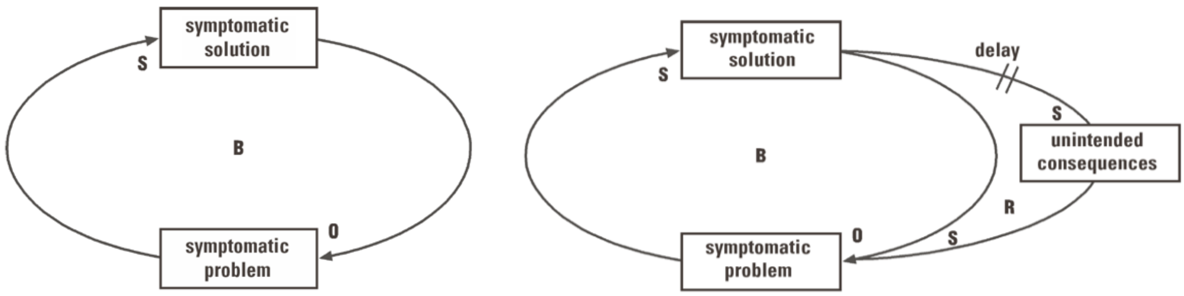
Assignment 6.1

Search for one example of each type of innovation presented and reflect on their differences.

6.2 Circular economy as an input for the innovation process

> "Innovation is crucial for the new world of sustainability because it helps to distinguish between the 'leaders' and the 'followers' (...)"
>
> Woodhead, J., 2011

Based on Ehrefeld's (2008) vision that defines eco-efficiency as "more value for less impact". The definition of eco-efficiency seduces the industry ability to respond continuously supply market needs but with significant reductions to the environment and with possible economic and legislative advantages over the strategy taken. However, the focus of this analysis leads us to question the difference between efficiency and effectiveness and its different methodologies, as a means of arriving at the notion of effectiveness.



B - Balance Cycle; S – Solution, O – Opposite effect; R - Cycle reinforcement

Figure 6.4 – Balance cycles Ecology (Ehrenfeld, 2008).

Traditional problem-solving models are limited in the sense that they focus on a small scoop of the problem by isolating it from the metabolism to which it belongs (Sampaio, 2009). Represented in figure 6.4 (left), the balanced cycle, is the basic process of solving a problem, is superficial and symptomatic. This model of resolution leads to unintended side effects, as illustrated in figure 4 (right). A more holistic approach explores a broader analysis meeting several needs applied in a circular economy context:

- To structure a balanced system of exchanges between mankind and nature as a way to create a healthy environment;
- To structure a balanced system of exchanges between biological and technical metabolisms processes as a means of creating and maintaining a balanced environment;
- To structure a balanced system of exchanges between social and science as a way to create and maintain a resolution system of problems.
- To evolve from a linear model to circular models and cycles.

This restructure approach and global systemic interpretation allows us to evolve, understanding mankind as an element of the system and not an external and dominant element of it. Applying this framework to industry and CE, this challenge aims to solve problems (in the sense of solvency, dilution of problem) that aims integration of a solution and not it imposition.

6.2.1 Why is innovation important for CE?

In line with the everything that's been said, it's possible to frame the importance of innovation in this process to move forward to a more sustainable society. The importance given to cradle-to-cradle and upcycle concepts, a proposal that aims a methodological approach through which it implementation should generate nutrients for both metabolism: food-for-cycles. The CE ideology replaces the end-of-life concept with restoration, it goes further to use of renewable energy, eliminates the use of toxic chemicals and by that it aims to eliminate waste while it maxims competitiveness through better design proposals o product-service systems and business models (Ellen MacArthur Foundation, 2012). Although innovation can be seen as process of trial (failure and success), to achieve effective sustainable changes in terms of CE there is a need to: implement technological innovations that help to move forward to a more sustainable ways of consuming and living; but they most go along with innovative and different ways and models of action, habits and *modus operandi* from individual citizens, to companies and governance; that reflect the need involve several actors not only in the final output of this innovation process but by exploring the opportunity to embedded then in the beginning, during and along the process. In a process of construction of a shared vision and goal we held a better understanding and demonstrate how central these can be building a more sustainable future that can meet needs and ambitions of several parties in a win-win relationship.

Companies like Nike can be example with initiates' where they engage a wide variety of stakeholders on sustainability issues as part of product development. These company used a crow-sourcing technique to engage with customers on the sustainability characteristics of their products. These processes generate a broad spectrum of new ideas on ways to improve supply chain, logistics, resource use, energy and end of life cycle impacts. In the meanwhile, and along these processes there is a need to evaluate the impact and viability of which ideas have potential to go further on and worked until they reached the market.

6.2.2 Sustainability challenges as a way to innovate

Economic crises, resource scarcity and pollution strategy pressure industries that are facing increasing problems like material scarcity leading to rising costs and introduction of regulations by governance for extended producer responsibility. If we take examples like the one referred, it's possible to highlight the main role that people have in innovation pipeline processes. This framework urges for changes to meet new organizational structures, methods, skills and patterns of workflow. As wheel explore new paradigms on what is the role of people, organizations and governances' structures as well concepts like product life cycle, product life time, use, possession and share. In conclusion, toward a sustainable innovation meeting CE and referring Charnley (2015) approach, as shown in figure 6.5, we have three main topics that often intertwine: materials use, product, service that impact on new work skills in multidisciplinary teams and new methods.

Focus	***Value Flows*** *(Ellen MacArthur Foundation, 2013)*	***Primary Source of Revenue*** *(Lacy et al., 2014; Bakker et al., 2014)*	***Economic Activities to Close Loops*** *(Stahel, 2013)*
Services	Cycling smaller – using less energy and fewer resources	Profit from increased utilisation rate of products, enabling shared use/access/ownership.	Reuse and remarket of manufactured goods
		Profit from selling access to a product for a specific period of time or 'uses', and retaining material ownership.	
Manufactured products	Cycling for longer	Profit from providing maintenance services or sales of refurbished, remanufactured or repaired units	Product-life extension activities for goods
		Profit from repeated sales of consumables or services for a long-life product	
		Profit from selling high quality products with a long lifespan at a high price	
	Cascaded uses	Profit from recovering resources/energy out of disposed products or by-products from the same or other company, upcycling or recycling them.	Material efficiency / recycling molecules
Materials	Pure or regenerative cycles	Profit from providing renewable energy, bio based- or fully recyclable materials to replace single-lifecycle inputs.	

Figure 6.5 – Categorization of business making for CE according to value form, sources of revenue and economic activities (Charnley, 2015).

Given that the design of a product directly influences the way a value chain will be managed, building circular, globally sustainable value chains inevitably signifies a fundamental change in the practice of design. A variety of new capabilities are key to design for a sustainable future; these range from a deeper knowledge of material composition to a rich understanding of social behavior (De los Rios and Charnley, 2017). Necessary organisational changes to foster a CE model of production and consumption primarily encourage changes in the way industries profit.

Being said we focus on the major challenges in these transitory process to sustainable innovation along with CE principals.

Design

- influence consumer perceptions and consumption habits to aid industry and society towards sustainable life patterns;
- explore new tools and methods to engage creativity and innovation
- implementation of refurbishing and remanufacturing at large scales to extend the life of electrical and electronic goods and motor vehicles.
- promote the use of life cycle assessment (LCA) tools as key to enable producers and designers to assess the life costs of a product and subsequently manage material choices for ecological optimisations
- improve ease of disassembly, material and component separation and reassembly for circular products have been a fruitful topic of research
- majority of design for sustainability tools and guidelines only concern themselves with the technical design criteria, disregarding the bigger picture of circular life cycle strategies.

Enterprises

- Organisational changes to foster a CE model of production and consumption
- Explore new BM;
- Aim to profit from existing resources and reduce new resource dependency;
- Stimulate servitization;
- Reduce supply risk;
- Improved customer relation and loyalty;
- development of new revenue streams.

Governance

- to promote CE as a plausible road towards sustainable social growth;
- to stimulate 'close loops' and renewing both biological and technical materials;
- to promote habits changing, without the need of taxes, fees or legislations.
- To define a local, regional, national and world plan that stimulate sustainable innovation and facilitate circular economy.

6.2.3 Guidelines for policy and decision-making

Being a complex and long process to implement sustainable innovation toward CE implies political, social and economic agreement. This scenario value long-term, stable and consistent strategic framework to promote a transition to more sustainable systems (Foxon, et al. 2004). Such framework encourages strategic program definition and investment in sustainable innovation for the long term. This commitment defends concrete empirical and comparative analyses of innovation systems (OECD, 2002), bringing to light their failure aiming it rectification. According to Foxon, et al. (2004), it is possible to identify two conditions for public intervention in a market economy systems:

- a problem must exist, i.e. a situation in which market mechanisms and firms fail to achieve objectives that have been socially-defined, through a public policy process;
- the state and its agencies must also have the ability to solve or mitigate the problem effectively (i.e. the issue of potential government and bureaucratic failure must be addressed).

To simplify or promote an easy implementation a new form of concerted action between market and government systems must be considered (Foxon et al., 2004):

- Relationships built on mutual trust: stakeholders want to be able to rely on a policy line not being changed unexpectedly once adopted, through commitment to the direction taken, the approach and the main roads formulated. The government places trust in market players by offering them ‘experimentation space’;
- Partnership: government, market and society are partners in the process of setting policy aims, creating opportunities and undertaking transition experiments, e.g. through ministries setting up ‘one stop shops’ for advice and problem solving;
- Brokerage: the government facilitates the building of networks and coalitions between actors in transition paths;
- Leadership: stakeholders require the government to declare itself clearly in favour of a long-term agenda of sustainability and innovation that is set for a long time, and to tailor current policy to it;

Foxon et al. (2004) suggestion for SI policy process of guidance addresses five key features and attributes of SI policy regime entailing: formulation of clear, long-term sustainability goals; understanding of both innovation and policy-making as systemic processes; advancement of the procedural and institutional basis for delivery of SI policy aims; and the incorporation of ‘policy learning’, both within individual policy processes and between different policy jurisdictions.

Assignment 6.2

Assuming the furniture and building industry (organization, market or industry) as a starting point, circular brainstorm and indicate a possible strategy of how can you innovate by defining new possible partnerships, governance, markets, users or technologies.

6.3 Product-service system design

As you can see in *Design and development* chapter it was define what is a PSS and it several categories. It's also possible to understand that PSS's has the potential to meet the needs of users in a more sustainable and circular way and to deliver more value to the customer and companies focusing in new business models.

In this approach, people and objects are part of the solutions where the possible positive impact can act as a game changer into creating social, economic, environmental and cultural benefits.

In a PSS design process, the relations between people and people with things can be and is changed. People interact with each other and with things in different ways, and things interact with people and between its selves, creates a new meaningful "space" - physical and virtual where it seems everything flows to reach a positive impact in our daily lives (Franqueira and Gomes, 2018). Based on this scenario design, the relation and concept of possession, use, share, rent are taking into perspective and introduce on the design process. On the creation of product-service systems allows to adopt a sensitive approach to the dialogue between design and society, environment and economy. This approach reflects the need to provide and develop specific design skills and tools, to generate essential knowledge about the holistic process of design and the critical analysis of reality, structural to the acquisition of essential knowledge for an innovative design. Although in can find several benefits not only for designers but for companies and users:

PSS' Benefits to companies:

- Add extra value to product or service provided;
- Base a growth strategy on innovation;
- Improve consumer relations by increasing contact and flow of information on consumer preferences;
- Improve total value to customer due to increasing maintenance and service components, which include activities and schemes that make products more durable (upgrade and refurbishment);
- Control in life cycle (recycling and reuse of parts or the whole product).

PSS' Benefits to users:

- Pay what he/she consumes;
- Possibility to make more ecological and social choices;
- Decreases potential charges with maintenance or exchange;
- Greater support and relationship with the brand;
- Possibility to co-create or to have impact in the experience.

In designer perspective, it's also relevant to identify value, quality and holistic approaches in order for these professionals explore CE as major asset.

PSS' Benefits to designers:

- Opportunity to explore different design methods, tools and co-creative approaches;
- Closer integration of all actors within the life cycle of a product-service system;
- Implement different strategies of product end of life;
- Promote solutions based on business partnerships, like maintenance and repairs, or transports services, ensuring maximum optimization of product life cycle;
- Create of alternative scenarios of product use;
- Have impact on strategies creation to raise awareness and promote environmental production and use more acceptable and present in society.
- Define alternative scenarios of product maintenance may also be given at the point of sale to ensure proper operation of the product during the use phase.

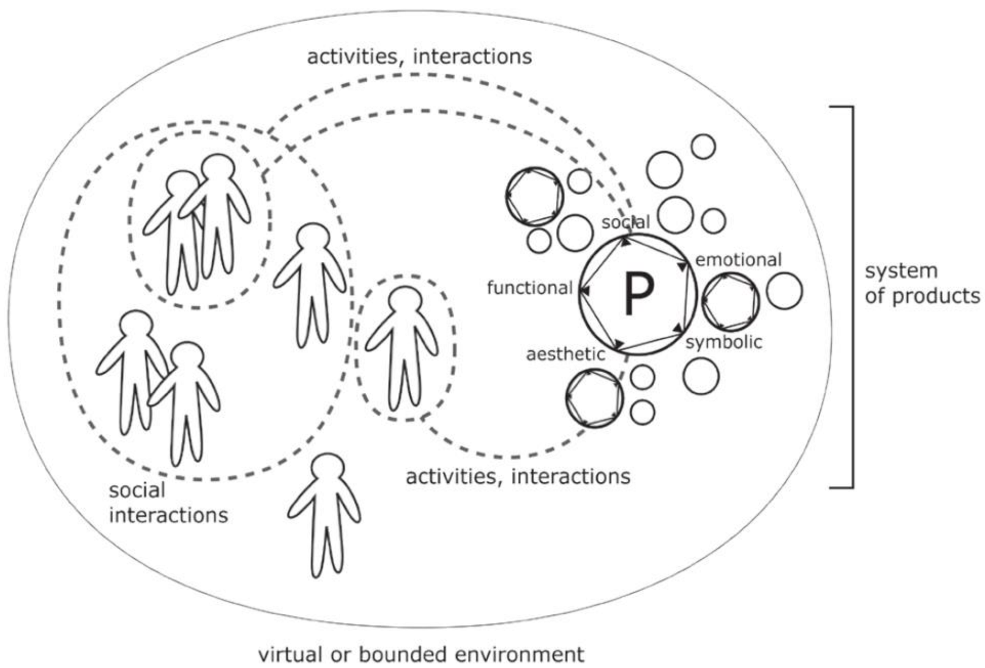


Figure 6.6 – Schematic diagram of the Product Ecology (Forlizzi., 2007).

As can be seen in figure 6.6, the product place and how product ecology framework represents different social relationships with products, that help us to define and describe dynamic issues of product use (Forlizzi, 2007):

- each instance of a product has its own ecology, a subjective and individual experience in using the same product.;

– factors in the ecology are adaptive and interconnected in several ways;
– Products help people in a variety of activities and experiences, supporting independence and wellbeing, mediating activities, and helping people to accomplish goals;
– product ecology can be geographically or virtually bounded, delimited by a group of people in close proximity, or a group that is spread out over a great distance.

All these aspects referred to above, bring attention to the changing potential that PSS' implementation bring to society in terms of social, economic organization and environmental care. Like referred by Forlizzi (2007), it's possible to identify how several aspects interfere in a possible positive result:

– Place/context - define by a physical space and social and environmental norms, the physical context plays a role in how people interact socially;
– Multiple perspectives - find differences among individuals that help form patterns relative to product use and adoption;
– Time - designers must pay attention to the ebbs and flows of time, and the phrasing of interactions with products, combined with particular hours, days, and seasons and the ages and life stages of key people using a product to best understand how to shape the experience that results.

To design along these frameworks, designers need to develop tools and strategies that involve a closer integration of all actors and explore participatory and collaborative creative approaches like cultural probes, role storming, scenario building, etc. that will be refer further on the chapter.

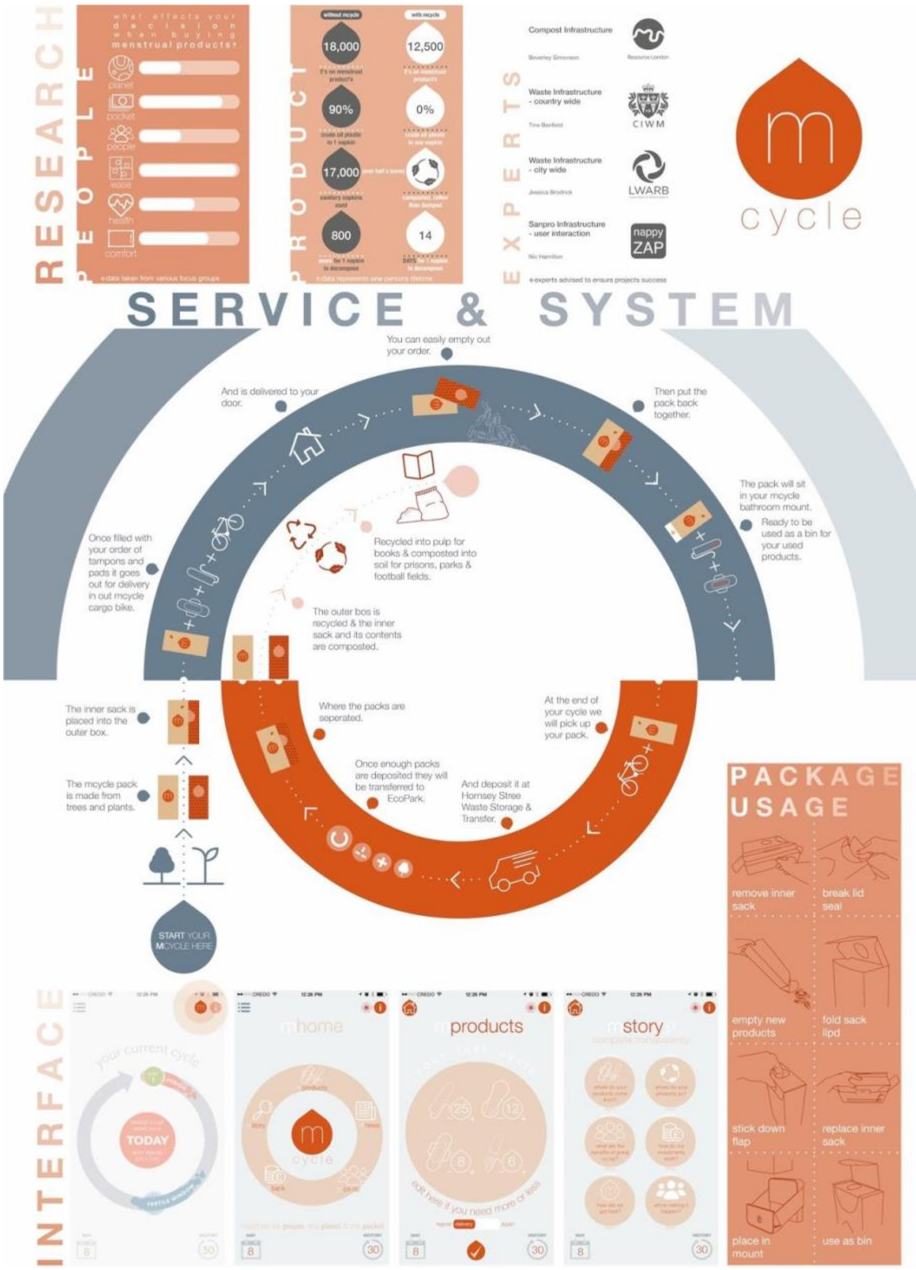
6.3.1 Product-service design innovation: examples

There are several examples of how to introduce innovative services in the traditional system, that will be addressed next.

mCycle, by Kaye Toland

Description	Every month, mCycle delivers – by bicycle – organic tampons and sanitary pads in a box that transforms into a bin. Once used and collected it's composted into non-food soil for prison parks and football fields. mCycle is a co-operative company which puts control into the users' hands and creates a local online community in which they can share their experiences of menstruation and their bodies. As a co-operative, the products get cheaper over time making them more affordable. The designer Kaye Toland, a master student at Central Saint Martins and the author of this project - mCycle has won the Unilever Sustainability Award 2017. Now, mCycle is close to moving from concept to reality following pilot schemes could be set up in places like the Netherlands, Germany or Sweden"
Organization and country	Kaye Toland, UK
Sources	https://www.circulardesignguide.com/story/how-i-felt-inspired-by-a-design-brief
Images	

mCycle service-system (Toland, 2017).



Images' source or credits	Circular Design Guide	https://www.circulardesignguide.com/story/how-i-felt-inspired-by-a-design-brief

MetroMile, by Metromile Inc.

Description

The Metromile Pulse device tracks your mileage. The free device plugs into the diagnostic port of your car and transmits data to the insurer. Unlike other usage-based car insurance programs, Metromile doesn't determine premiums based on other data such as speed, cornering or braking.

Metromile's mobile app is where you can check your mileage as recorded by the Pulse device. You can also view policy documents, your auto insurance ID cards and next month's charges based on mileage. Other app features include:

- Parking: Find your parked car and get street sweeping alerts to avoid tickets
- Trip data, including speed, distance and how much you spend on gas
- Car health, which tells you what your check-engine light means and where to find a mechanic

Organization and country

MetroMile, USA

Sources

https://www.metromile.com/

Images

Images' source or credits

Metromile Inc., USA https://www.metromile.com/

Remanufacturing office furniture, by Rype Office

Description	Rype Office is a UK -based furniture producer which specializes in remaking office furniture that launch ed in 2014. For traditional office furniture, iron ore, timber or oil is sourced in a foreign country, sent for refining and processing, shipped to a manufacturer for shaping then 45 to another for assembly. The furniture is finally transported to the final country to a warehouse and then to a distributor. Therefore, the traditional supply chain costs much in money, resources and transportation distances. Rype Office remakes furniture by using a mixture of modern technology and traditional upholstery craftsmanship. In Rype Office's own words, by remaking furniture it can save money, create local (UK) jobs, reduce landfill waste, reduce biodiversity damage, preserve finite resources, and lower GHG emissions. The company has won a number of awards for the business concept in the UK.
Organization and country	Rype Office, UK
Sources	https://www.ellenmacarthurfoundation.org/case-studies/circular-economy-options-in-office-furnishing
Images	
Images' source or credits	Rype Office https://www.rypeoffice.com/

BAUX Acoustic Pulp panel, by BAUX

Description	Baux was founded in 2013 by Joham Ronnestam, Fredrik Franzon and the founding members of Form Us With Love (Jonas Petterson, John Löfgren and Petrus Palmer) set out to innovate the world of acoustic materials. They belief that building materials should be sustainable, functional ans remarkably beautiful. Baux acoustic tiles, are made of woodwool, cement and water. The natural componenets together provida many functional characteristics and are available in 7 patterns: Quilted, Check, Stripes, Lines, Diagonal, Arch and Curve. All designed to be combined into infinity. The BAUX Acoustic Pulp is another product, 100% bio-based made by harvested Swedish fir and pine trees, recycled water, non-gmo wheat, barn, potato starch, plant-derived wax, citrus fruit peels with zero chemical in it composition.
Organization and country	BAUX, SE BAUX
Sources	http://www.baux.se
Images	
Images' source or credits	BAUX, SE http://www.baux.se

The Restart Project

Description	The Restart Project is a people-powered social enterprise that aims to fix our relationship with electronics. The Restart Project was born in 2013 out of the frustration with the throwaway, consumerist model of electronics that we've been sold, and the growing mountain of e-waste that it's leaving behind. By bringing people together to share skills and gain the confidence to open up their stuff, this project gives people a hands-on way of making a difference, as well as a way to talk about the wider issue of what kind of products we want. It's based in London, UK, and their message, and their parties, are spreading across the world. Their motto is: don't despair, just repair!
Organization and country	The Restart Project, UK restart
Sources	https://therestartproject.org/
Images	
	
Images' source or credits	The Restart Project, UK https://therestartproject.org/

Assignment 6.3

Based on a given context reflect how you can optimize it considering sustainability and circular economy principles, stakeholders and business model.

6.3.2 Business models and innovation pipeline

An accurate understanding by the company of which type of business model (BM) they are running is relevant to the success of it. Generally, a BM describes the functioning of a firm, focusing on nine elements: value proposition, customer relationships and segments, channels, key activities, partners and resources and finalize the structures of cost and revenue streams (Osterwalder & Pigneur, 2013). A clear and well balance structure helps the company do define it strategy of market placement and differentiation. By these approaches we can focus on four major questions: what, who, how and why. All this information will be explored in a more profound manner in the *Business models* chapter.

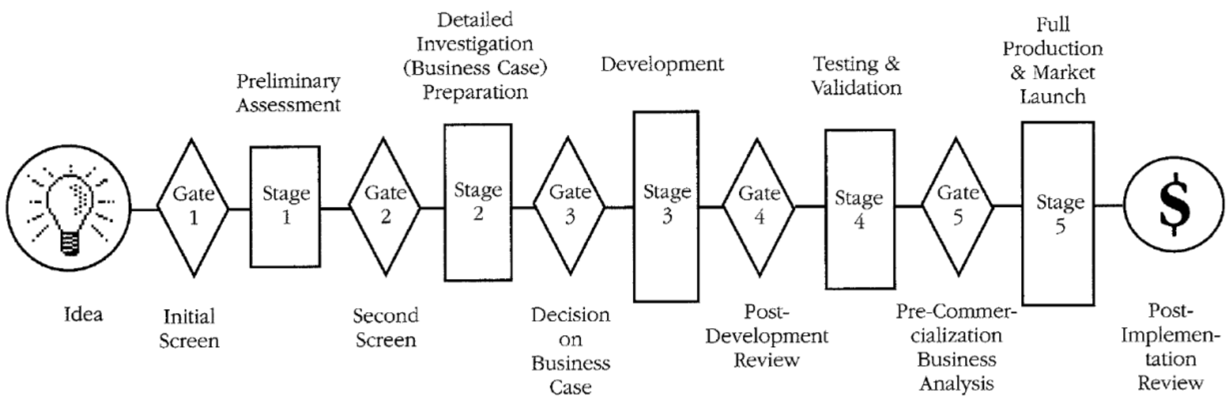


Figure 6.7 – Stage Gate System (Cooper, 1990).

Innovation pipeline or innovation funnel is a contemporary concept that is based on a Stage-gate system presented by Robert Cooper (1990), as shown in figure 6.7, that has been updated over the year by the author (2014) as shown in figure 6.8. This system Stage-gate systems use similar methods to manage the innovation process (Cooper, 1990). Although there is a similar principal, idea-to-market launch approach, the iterative approach among the user reveals one major difference that is in line with disruptive innovation referred above, that is the involvement of people, users, specialist or community players. These scenarios places us on one of two innovation pulls that can be stimulated either by market (here interpreted in a broad sense, including social actors, users, people, etc) and by technology inventions. In this sense, we can talk about open innovation (Chesbrough, 2003), refers to an open flow, in which resources move easily between business and market, in opposite to closed innovation, that refers to a limiting process of internal knowledge use from the company and not making use of or only a little use of external knowledge.

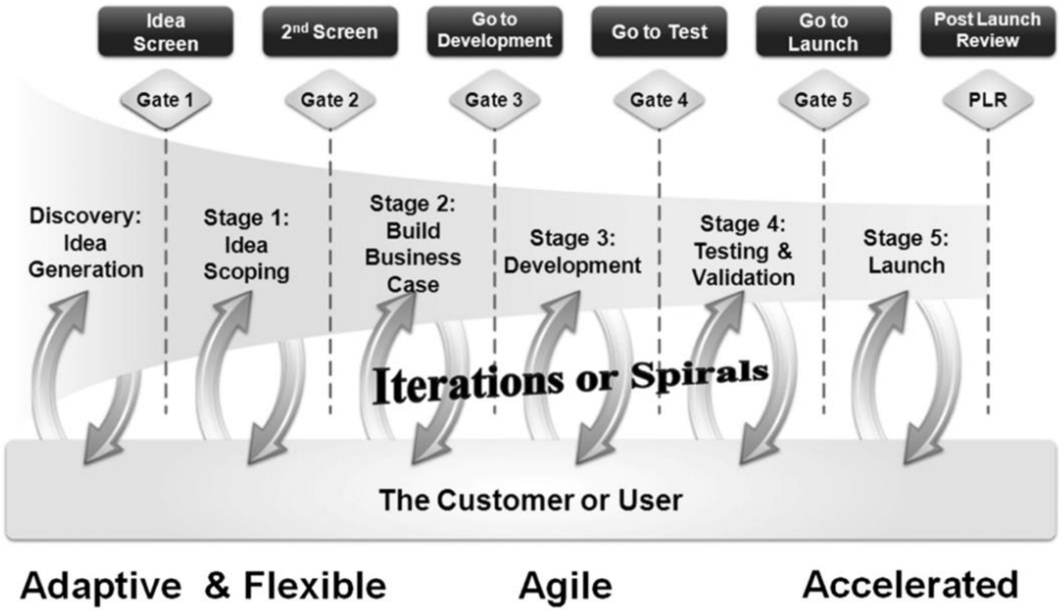


Figure 6.8 - The next-generation idea-to-launch system (Cooper, 2014).

By these innovation funnel approach businesses enables ideas to be evaluated for viability, applying a process of filters, gates and rules. Through each stage from idea generation either to validation stages, filters or gates, the proposals start to be more specific failing or meeting the criteria to be further develop. The main goal is to generate a large number of ideas that can be relevant to the current business situation to promote growth.

Discover - Pre-work, to discover and identify business opportunities and generate new ideas, from multiple scenarios, constituents and place along business goals.

Stage 1 – Scope

– Initial, quick and inexpensive preliminary investigation to project proposal. Mainly desk research task.

Stage 2 – Design

– Brief definition and investigation involving users, market, specialists, leading to a business case including product requirements and project definition and preliminary plan for development.

Stage 3 – Develop

– Project design and development definition of a new product, design task or production process required for possible full-scale production.

Stage 4 – Scale Up

– Tests or trials indoor, marketplace or real case scenario to analyze and validate the product or service, and production or operations plans.

Stage 5 – Launch

– Commercialization: the beginning of full-scale operations or production, marketing and sales.

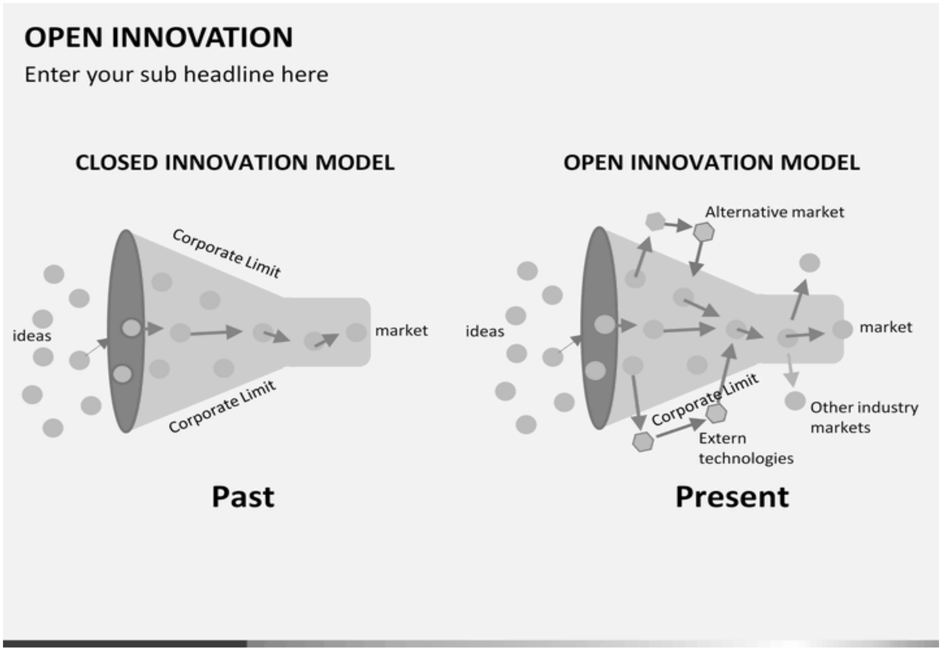


Figure 6.9 - Close innovation model vs open innovation model.

In figure 6.9, it's illustrated a broader and holistic approach that evolves from the relation between the organization with the user, by being sensitive to alternative markets, extern technologies and partnerships. This mindset of openness and holistic approach to the market, industry, organizations and people, can enhance a faster and solid path towards innovation.

6.4 Collaborative and participatory design for innovative processes

There are two main approaches in design that integrate the user in the design process. The user-centered design approach sees the user as a subject and uses their opinions about existing or already generated design concepts of others. This approach is an increasing exercise among industrial practice and education where researchers observe and interview 'passive users' to develop an 'expert's perspective.'

6.4.1 How to develop new strategies to adopt collaborative and participatory design processes in and between companies

The role of the user is usually seen influential in the early stages of design as: informing, ideating and conceptualizing. The participatory approach on the other hand sees the user as partner in the design process. Recently, the two approaches are influencing each other in ways that promote acts of collective creativity (Sanders & Stappers 2008) as shown on the image below.

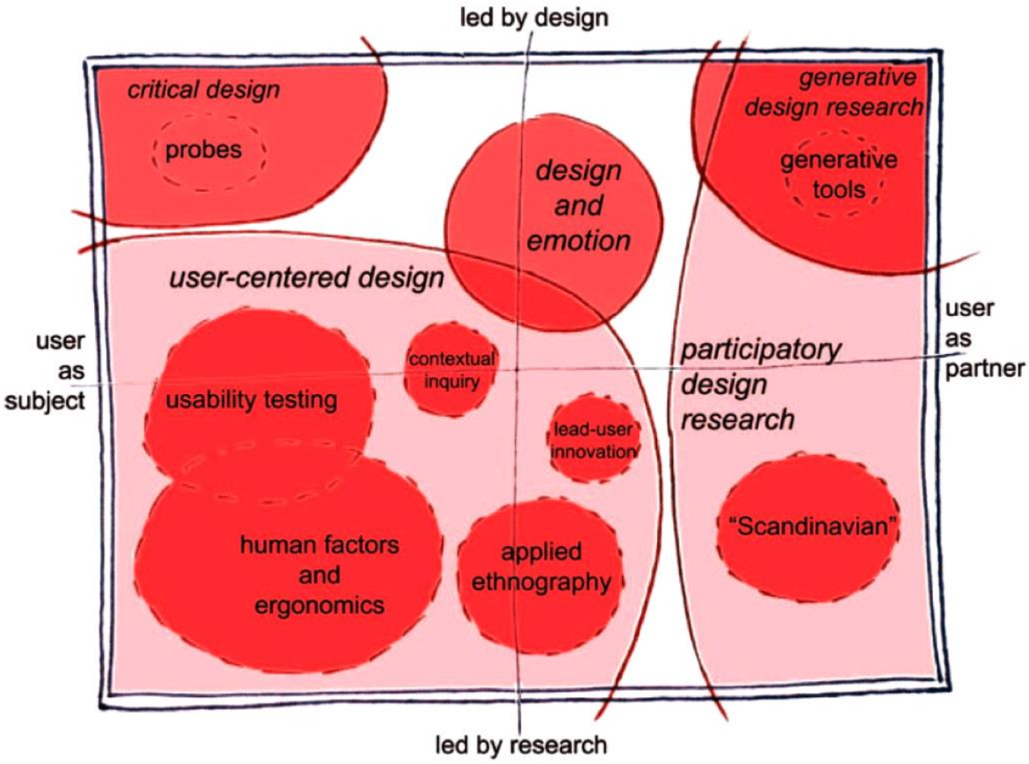


Figure 6.10 - The current landscape of human-centered design research as practiced in the design and development of products and services (Sanders & Stappers 2008).

The map shows different design research approaches along the two axes. The horizontal one represents the role of the user, and the vertical one the approach of the user. There are different views about the role and level of involvement of the actors of this collective creativity in the design process.

According to Sanders & Stappers (2008), any act of collective creativity shared between people is co-creation. Most well-known design led approaches to co-design are probes (upper left) and generative toolkits (upper right). Probes are implicit responses of users that are inspirational sources for designers whereas generative toolkits serve more explicit information for a more deliberate design process that are used to make artefacts (Sanders & Stappers 2014).

The phases of a design process can be broken down to four phases as: pre-design, generative, evaluative and post-design. When these phases are overlapped with design research methods; tools, probes and generative toolkits are usually seen in the pre-design and generative phases as shown on the figure 6.11. This revised version of design process developed by Sanders & Stappers (2014) introduces two mindsets: designing for and designing with, which correspond to the user as subject and as partner. In this new proposed model, the mindset areas are overlapping with each other expressing the changing role and participation of the user with the designer. This new designing with approach is also called co-design.

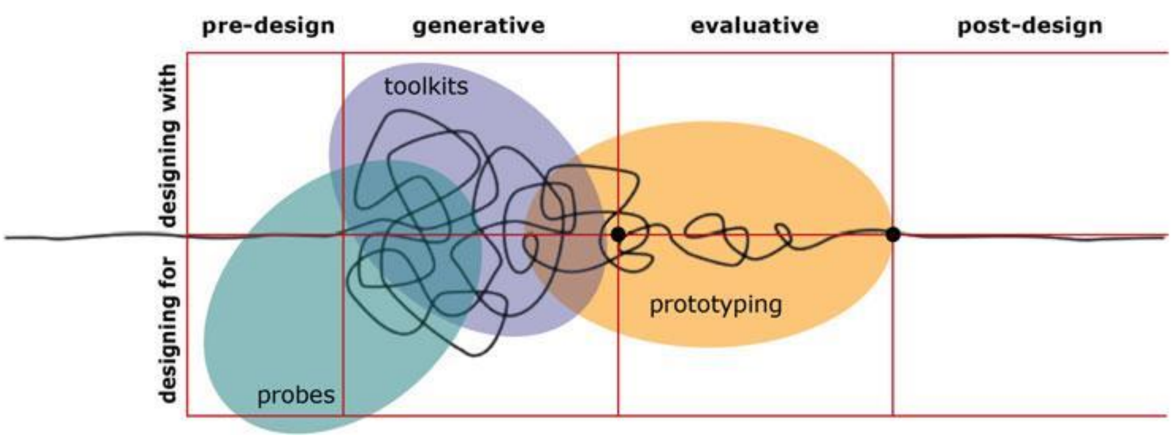


Figure 6.11 - Design research phases relative to the mindsets (Sanders & Stappers 2014).

Co-design is a collective act of creativity that expands throughout the whole design process where designers and people not trained in design fields work together. The roles of these key players are defined according to their level of expertise, which may be used in different stages of the design process such as knowledge development, idea generation and concept development (Sanders & Stappers, 2008). However, the level of knowledge and expertise input expected from designers are usually dominant and critical in the form giving stages of the project (Sleeswijk at al., 2005). By this mindset, we are implementing a holistic approach that enhance innovative analysis and solutions based on the larger spectrum of information and inflows of knowledge.

As good as it all sounds, existing practices to co-design projects in general are limited to probes, where the users share their stories and experiences while using the related artefacts. The challenge here is the designer's ability to understand the user generative problems which may vary from technical to cultural challenges. The designer's role is then identified to develop products that are consciously integrated with the knowledge gathered from appropriate research methods. However according to Lee (2008), major attempts to cultural challenges are still limited to aesthetic stereotypes that lack solid theoretical and cultural frameworks.

The level of involvement of the user is usually limited in the early stages of the design process. However, the true aim of co-design should aim to integrate the user in the design process at all levels. Another extreme case to the changing role of the user and the designer is the design-by-doing approach, where the role of the user is dominating the one of the designers. The methods that differentiate the design-by-doing approach from the design thinking approach are the actions, tools and strategies applied to problem solving methods.

6.4.2 Methods for collaboration: lateral thinking and the creative process

According to Edward de Bono (1970) it's possible to divide thinking into two methods:

Vertical thinking uses the processes of logic, social concepts and knowledge based on traditional, historical method; lateral thinking, that involves disrupting an apparent thinking sequence and arriving at the solution from another angle. Focusing on lateral thinking methods it's possible to provide a deliberate, systematic process that will result in innovative thinking.

Edward de Bono does not find creative thinking as talent, but a skill that can be learned. It empowers people to improve creativity and innovation solutions, which lead to increased productivity and profit. Creativity and innovation are the only engines that will drive lasting, global success. Being said, design methods and design thinking approaches and tools enables stakeholders to be an active task force in order to further developed proposals, bringing non-designers to creative project development stages.

Creative tools and processes examples:

Tool 01 - Six Hats Thinking

Source:
de Bono, Edward (1985). Six Thinking Hats: An Essential Approach to Business Management. Little, Brown, & Company. ISBN 0-316-17791-1 (hardback) and 0316178314 (paperback).

Description:
The premise of the method is that the human brain thinks in a number of distinct ways which can be deliberately challenged, and hence planned for use in a structured way allowing one to develop tactics for thinking about particular issues. De Bono identifies six distinct directions in which the brain can be challenged. In each of these directions the brain will identify and bring into conscious thought certain aspects of issues being considered (e.g. gut instinct, pessimistic judgement, neutral facts). None of these directions is a completely natural way of thinking, but rather how some of us already represent the results of our thinking

Six distinct directions are identified and assigned a color. The six directions are:

- **Managing Blue:** what is the subject? what are we thinking about? what is the goal? Can look at the big picture.
- **Information White:** considering purely what information is available, what are the facts?
- **Emotions Red:** intuitive or instinctive gut reactions or statements of emotional feeling (but not any justification).
- **Discernment Black:** logic applied to identifying reasons to be cautious and conservative. Practical, realistic.
- **Optimistic response Yellow:** logic applied to identifying benefits, seeking harmony. Sees the brighter, sunny side of situations.
- **Creativity Green:** statements of provocation and investigation, seeing where a thought goes. Thinks creatively, outside the box.

Tool 02 - Circular BrainStorming

Source:
https://www.circulardesignguide.com/post/brainstorm-circular-solutions

Description:
Brainstorming is a well-known and effective method to generate new ideas. It is “a problem-solving technique by a group of people in any field and involves the spontaneous and uncensored contribution of ideas from all members of the group. It is a popular method for generating ideas in the design field.” Circular brainstorming consists of applying the brainstorming method to find ideas for a question about circular economy. IDEO © provides examples of these questions: How might we make our product or service more modular/adaptable? How might our product be inspired by living systems? (see Biomimicry technique - https://toolbox.biomimicry.org/) How might we turn our product offering into a service? How might our product be refurbished over time? More examples of questions to brainstorm for circularity are: Which wastes could be used as raw materials for this product? How could the materials and parts be used in another product of the same or different type when the use phase finishes?

Assignment 6.4

Based on a given context reflect how you can optimize it considering sustainability and circular economy principles, stakeholders and business model. Redesign the chair where you are seated, applying the circular economy thinking and using the Circular BrainStorming method. The steps are the ones that follow:

1. Create groups of 5 people maximum (and recommended)
2. Select the questions you want to use
3. Individual work thinking about the design solution
4. Presentation of the design proposals and discussion with your group members
5. Selection of the design proposal to de developed

Tool 03 - RoleStorming

Source:

R. E. Griggs, "A storm of ideas", Training, vol. 22, pp. 66, November 1985. VanGundy, A.B. (1988), Techniques of Structured Problem Solving, 2nd ed., Van Nostrand Reinhold, New York, NY

Description:

Rolestorming is a derived method from brainstorming, whereby every participant assumes a different role and provides with proposals, solutions, demands or arguments based in the point of view of the character they are playing. The most common roles suggested in product design are: scientist, engineers and user. You can see this technique as an evolution from role play (http://www.servicedesigntools.org/tools/42) and six hats thinking techniques. Some actors, the sample users or the designers themselves perform a hypothetical service experience. The implied condition is thinking that the service really exists and then building a potential journey through some of its functionalities. A possible evolution of this tool consists in the performance of the same scene several times, changing the character profiles on each scene in order to understand how different users would act in the same situation.

Assignment 6.5

Design a concept of domestic vegetable garden furniture, applying the circular economy thinking and using RoleStorming method. The steps are the ones that follow:

1. Create groups of 5 people maximum (and recommended)
2. Choose each member of the team one of the 5 roles in Rolestorming (randomly or by consensus.
3. Discuss about the design solution

Tool 04 - Idea Speed Dating

Source:
https://projectofhow.com/methods/idea-speed-dating/

Description:
Each person notes 1 idea on paper in front of them. They can use drawings, graphics, keywords and short phrases.

After time is up, tell everyone to move one place to the left. In this new round, they have another 2 minutes to evolve and build on the ideas that the person previously left behind.

They can use the ideas on paper or carry a new drive card.

Repeat this process 5-6 times or until everyone returns to their starting points.

Tool 05 - The Kipling method

Source:
https://projectofhow.com/methods/the-kipling-method/

Description:
This is a great way for a group to quickly come up with many ideas and to have people build on other's ideas. The end result is a beautiful mural of thoughts that can be used as inspiration throughout events now and in the future.

Tool 06 - Scenario Building

Source:
Design scenarios. Approaches and tools for building the future within the design processes
Zindat, Danila https://www.politesi.polimi.it/handle/10589/117861

Description:
With the help of forecasting and scenario building techniques, designers provide organizations with a link between the future and strategy (Evans & Sommerville, 2005). Scenario building is a way to generate shared visions within a large system of actors. The term scenario is considered as a synonym for an overall vision of something complex and articulated: a set of possible conditions, or transformations, affecting the domain under consideration. In addition, Design Orienting Scenarios (DOS) have to demonstrate a clear motivation (what the scenario is aiming at?) and practicality (the concrete actions that have to be taken in order to favour its implementation).

Assignment 6.6

Design a concept of bathroom furniture or component, applying the circular economy thinking
and using Scenario Building method. The steps are the ones that follow:

1. Create groups of 5 people maximum (and recommended)
2. Apply the different steps for generate different scenarios
3. For each scenario make different product design proposals
4. Choose the proposal you think that most seems to meet the objectives
5. Discuss about the design solution
6. At the end, present your proposal to the other groups

Tool 07 - Biomimicry Toolbox

Source:
https://toolbox.biomimicry.org/

Description:
By applying nature's design lessons, we can create solutions that help support a healthy planet. This digital resource site from the Biomimicry Institute provides a quick-start guide to biomimicry, introducing the core concepts and methods that are essential to successfully incorporate insights from nature into design.

Assignment 6.7

Design a concept of a product for organic matter composting in neighborhood communities, applying the circular economy thinking and using the Biomimicry method. The steps are the ones that follow:

1. Create groups of 5 people maximum (and recommended)
2. Review the strategies of nature and the life principles
3. Think about nature solutions to improve the design. You can use the sheets or any other strategy
4. Fill in the concept sheets

6.5 Open-source as a mean to feed innovation and disseminate results

Open-source is a concept usually linked to software, in which the concepts of open-source innovation the other definition of open innovation is built on. The term 'open innovation' was introduced in 2003 by Henry Chesbrough. Open innovation is defined by the use of purposive inflows and outflows of knowledge to accelerate internal innovation and expand the market for external use of innovation (Chesbrough, 2006). By adopting an open innovation approach, companies' access to external innovation as an ongoing source of external innovation, or to spinoff technologies that cannot be developed and commercialized internally by the firm. In the Meanwhile, the company can also contribute and combine efforts to use opensource too (West & Gallagher, 2006) building a network of partners or communities. There are two models of community building: the model of a community-founded project, which is the most familiar model of open source development, and, more recently, the sponsored model (Da Silva, 2008).

6.5.1 The importance of open-source to disseminate best practices for CE

As previously discussed, in one hand innovation is dependent on company's boundaries that can be closed or open. On the other hand, open innovation can be understood as depend on the directions of knowledge flows across this boundary: outside-in (or inbound) and inside-out (or outbound) (Da Silva, 2018). A third type of open innovation is referred by Da Silva (2008), so-called coupled open innovation, links outside-in and inside-out, and involves combining knowledge inflows and outflows between firms or agents (Gassmann & Enkel,2004). This modus operandi can be beneficial for the several actors, since they can share knowledge, resources (human, productive, economic, etc.) and be positively influence towards more sustainable and holistic approaches in line with CE principles. Although Da Silva (2018) points out some open innovation challenges to managers of commercial firms: how to maximize returns to internal innovation, incorporating external innovation; how to motivate the generation and contribution of external knowledge; and how to involves a paradox: Why would firms contribute resources, including intellectual property, to open source projects that will benefit others, including their rivals?

6.5.2 Open-source as a mean to allow replication of sustainable initiatives

The development of open source models or solutions can have a major impact on future sustainability, not just by it potential of replication but also as boosters for solution creating, as triggers for awareness for new habits and as educators means. This leads us not only for new designs but also to new business models that unlike franchising and close solutions models do not have the possibility to adapt, to be optimize and to be further develop by the creative class (Florida, 2004) to a specific context or CE loops. The development and free-sharing of models, helps the possibility of replication and spread of word, increasing implementation and knowledge share. When everybody designs it's possible to evolve, interact and generate creative and knowledge hubs, in line with specific contexts or opportunities, fulfilling lives, education, and economics needs or goals.

6.5.3 Open-source as crowdsource (web 2.0)

> "This principle [the 'wisdom of crowds'] states that a large, distributed, and loosely associated network of individuals can accomplish more than a tightly managed hierarchical team"
>
> Rigby, 2008

The phenomenon named "crowdsourcing" was first refer by Jeff Howe, in his article "The Rise of Crowdsourcing" that was published in the journal Wired Magazine in 2006. Since then, has been emerging several collaborative platforms and innovation that demonstrate the potential of internet to flourish and held different kind of business models. This scenario allows us to see the Web 2.0 and a factor to increase the role of consumers in their business relationship. According to HODGKINSON (2007) we can framework web 2.0 into several models: technology, social, content and business models. This model promotes different social models, jobs, business, services and product along with: communities of trust, sharing, collaboration, co-creation, empower global and local people and better use of their talents. With Web 2.0 we can also talk introduce the notion of the possibility for enterprise 2.0, that through people interacting, flexibility, new collaborative approaches as ground stones for new models of collaboration between enterprises, governance, communities to provide sustainable innovation and development.

Assignment 6.8

Search for one example that provide open source outcomes linked to circular economy and reflect on their replication capacity.

6.6 Examples

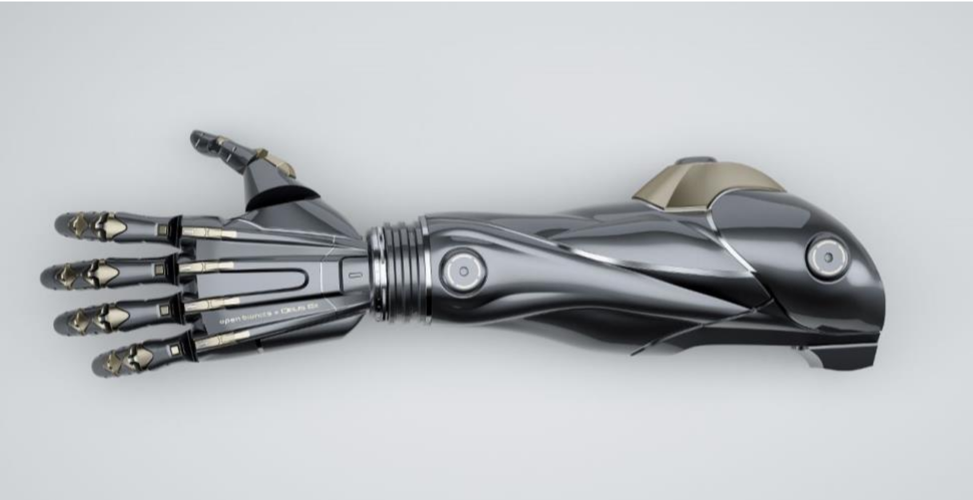
There are several examples of how to create a sustainable and innovative project through open-source initiatives, that will be presented next.

Precious Plastic, by Dave Hakkens	
Description	The Precious Plastic is a global community of hundreds of people working towards a solution to plastic pollution. Knowledge, tools and techniques are shared online, for free. So, everyone can start it. Precious Plastic was started in 2013 by Dave Hakkens and is now at its third iteration (version) counting on dozens of people working on the project, remotely or on site.
Organization and country	Precious Plastic Project, NL
Sources	https://preciousplastic.com/
Images	
Images' source or credits	Precious Plastic Project

AdaFruit, by Limor Fried

Description	Adafruit was founded in 2005 by MIT hacker & engineer, Limor "Ladyada" Fried. Her goal was to create the best place online for learning electronics and making the best designed products for makers of all ages and skill levels. Adafruit has grown to over 100+ employees in the heart of NYC with a 50,000+ sq ft. factory. Adafruit has expanded offerings to include tools, equipment, and electronics that Limor personally selects, tests, and approves before going in to the Adafruit store. Adafruit is a 100% woman owned company.
Organization and country	AdaFruit, USA
Sources	https://www.adafruit.com/
Images	
Images' source or credits	AdaFruit https://www.adafruit.com/

Open Bionics, by Joel Gibbard and Samantha Payne

Description	The world's first clinically tested, medically certified, and FDA registered 3D-printed bionic arm. Grab, pinch, high-five, fist bump, thumbs-up. Welcome to the future, where disabilities are superpowers. The OpenBionics project is focused on developing an open-source, light-weight, modular prosthetic device. They have come up with a unique hand that is inexpensive, light-weight, and can be reproduced with fairly inexpensive tools like a consumer-grade 3D printer. This innovative project will have a major impact on people in need a of prosthetics, and is a promising design for use in robotics. It was recognized as 2nd Prize winner in the 2015 Hackaday Prize. This talk on OpenBionics was presented by Minas Liarokapis at the 2015 Hackaday SuperConference.	
Organization and country	Open Bionics, UK	
Sources	https://openbionics.com/	
Image		
Images' source or credits	Open Bionics	https://blog.p2pfoundation.net/openbionics-revolutionizing-prosthetics-open-source-dissemination/2016/10/07

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07

LIFE CYCLE PERSPECTIVE

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Life cycle perspective

Contents

Executive summary ... **341**

7.1 Introduction to life cycle thinking ... **342**

7.2 Impact assessment along the life cycle ... **345**

7.2.1 Environmental life cycle assessment ... 346

7.2.2 Life cycle costing ... 356

7.2.3 Social life cycle assessment ... 361

7.3 The life cycle of products and discussing circular loops ... **366**

7.3.1 Discussion on furniture and impacts of design decisions ... 366

7.3.2 Discussion on building components at their end of life ... 374

7.4 Assessment and communication on building and component level ... **377**

7.4.1 European standards for the assessment in the construction sector ... 377

7.4.2 Assessment and certification schemes on building level ... 378

7.4.3 Assessment and communication on product level ... 384

7.4.4 Limitations of comparability of different assessment and labelling approaches ... 385

7.4.5 Circularity indicators and KATCH_e tools ... 386

7.5 Examples ... **394**

Bibliography ... **399**

Executive summary

7.1 Introduction to life cycle thinking

Life cycle thinking (LCT) is a concept that considers all life stages of a product including their interdependencies from the very beginning to the very end. LCT is crucial when establishing a Circular Economy as it takes positive and negative impacts of the entire life cycle into account and prevents burden shifting from one life stage to another. Because of the high complexity and the extremely long lifetime, LCT is particularly important when working on buildings.

7.2 Impact Assessment along the life cycle

In order to enhance positive and minimise negative impacts of products or processes, the environmental, social and economic performance along the life cycle must be assessed. A common tool for this task is the Life Cycle Sustainability Assessment (LCSA), which is, according to the three pillars of sustainability, further divided into Life Cycle Assessment, Life Cycle Costing and Social Life Cycle Assessment.

7.3 The life cycle of products and discussing circular loops

This section reflects on the impact of furniture and building products along their life cycle and options to reach a higher circularity level are presented. Specific examples visualise corresponding design strategies and services.

7.4 Assessment and communication on building and component level

Buildings and components have a long and complex life cycle with many involved stakeholders and their assessment will thus be discussed in detail in this section. The framework for the Life Cycle Sustainability Assessment is determined by the European Standards for Sustainability of Construction Works as well as several building certification schemes. The environmental impact of a product can be communicated by means of Environmental Product Declarations (EPD), which contains detailed information on the environmental performance of a product based on Life Cycle Assessment. Different circularity indicators are currently under development, their potential for the integration in existing methods and applicability will be reflected.

7.5 Examples

Examples, both from the building and furniture sectors, complemented by case studies developed in the context of students' internships in partner companies, are provided in this section.

7.1 Introduction to life cycle thinking

During a product's life cycle, material, energy and money flows occur in all stages (see figure 7.1), but often they are only visible in calculations of specific stages, e.g. in the production phase. Therefore, the overall impacts along the value chain are rarely considered. The concept of **life cycle thinking** (LCT) presents a helpful assistance to identify and to reduce negative or improve positive impacts and consider the most relevant aspects with the biggest lever along the value chain. Implementing LCT already in early design stages of products, product-services systems and buildings is crucial, as in these early stages, a large share of impacts is set. Mostly, this happens unintendedly because design pursues many different objectives and impacts which can be forecast in the pre or postproduction and construction stages are often not considered (see the *Design and developments, Value chains* and *Business models* chapters).

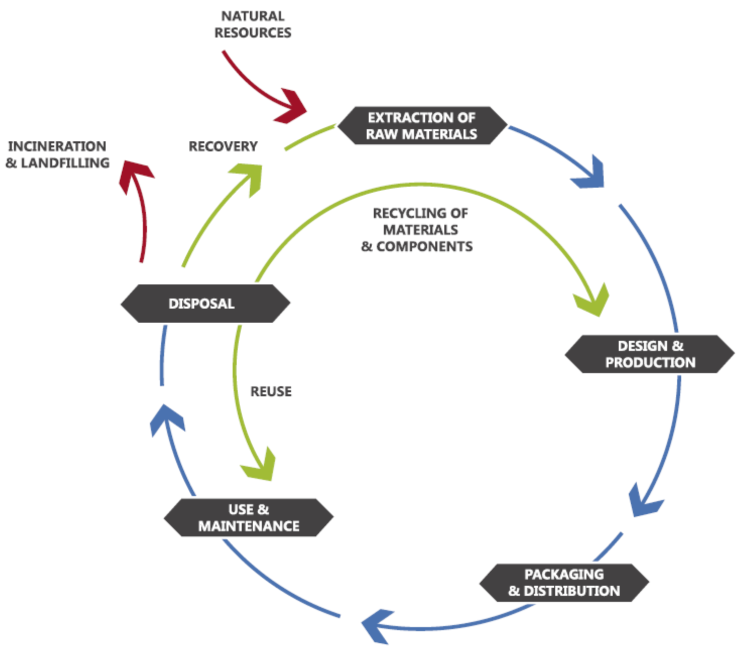


Figure 7.1 – Product Life Cycle Diagram (after https://www.lifecycleinitiative.org).

When considering products or services in a holistic view, the life cycle perspective brings powerful insights. To prevent burden shifting, all stages of the life cycle need to be considered. This ensures that improvements in one stage of the life cycle do not adversely affect another phase, unintentionally leading to larger environmental impact. The figure above shows a typical life cycle, the blue arrows describing a linear flow (take-make-use-dispose) and the green ones describing the contact points where the course is set for a circular flow of resources. The red arrows mark the points where resources enter, and residuals leave the cycle as a totally circular system is only considered to work in natural systems.

LCT can be considered as a MUST within establishing a circular economy (CE) and implementing circular strategies into the own business and product or product-service systems as in each life cycle stage there is the potential to reduce resource consumption and improve the performance of products (see also the *Introduction to the circular economy* chapter).

Sometimes, LCT highlights sustainability concerns that would be counterintuitive. It therefore helps in making informed decisions, making the best choices and undertaking responsibility. Take the example of energy consuming products: if a much more energy efficient alternative is put on the market (e.g. LED lamps), may it be better to replace the old product by a new one, even if the old product is still functional? From a CE perspective, the question is also what to do with the old product – disassemble it, reuse parts, recycle materials? LCT can help comparing different scenarios. The assessment of (negative) impacts delivers hot spots where there is a need for action and the chance to transform negative into positive impacts.
In each life cycle stage, there is the potential to reduce resource consumption and improve the performance of a product. Not only the environmental but also the economic and social profile over the life cycle should be imparted and interdependencies between relevant aspects highlighted. Long-term impacts should be considered in early design stages, but architects, civil engineers or developers are rarely considering downstream phases like use or deconstruction.

Assessing buildings is especially challenging because the following points need to be considered:

1. Buildings are products with a **high complexity** (including hundreds of products and numerous stakeholders who often do not interact a lot) and an **extremely long lifetime** e.g. Wilhelminian style architecture exists since more than 120 years; in Austria one calculates ecological impact for 100 years. Both aspects – the complexity AND the long-life span need to be considered!
2. In the most cases, the building investors are not the users of the building; so, **investment costs are separated from operation and maintenance costs**.
3. LCT considering cost models as well as ecological risks is needed to overcome this separation of investors and users e.g. by assessing maintenance, resource efforts, disposal efforts.
4. The **finiteness and austerity of land use** for buildings is a limiting factor.

The following figure shows the life cycle of buildings and periodic decisions to make which affect the resource and energy consumption significantly.

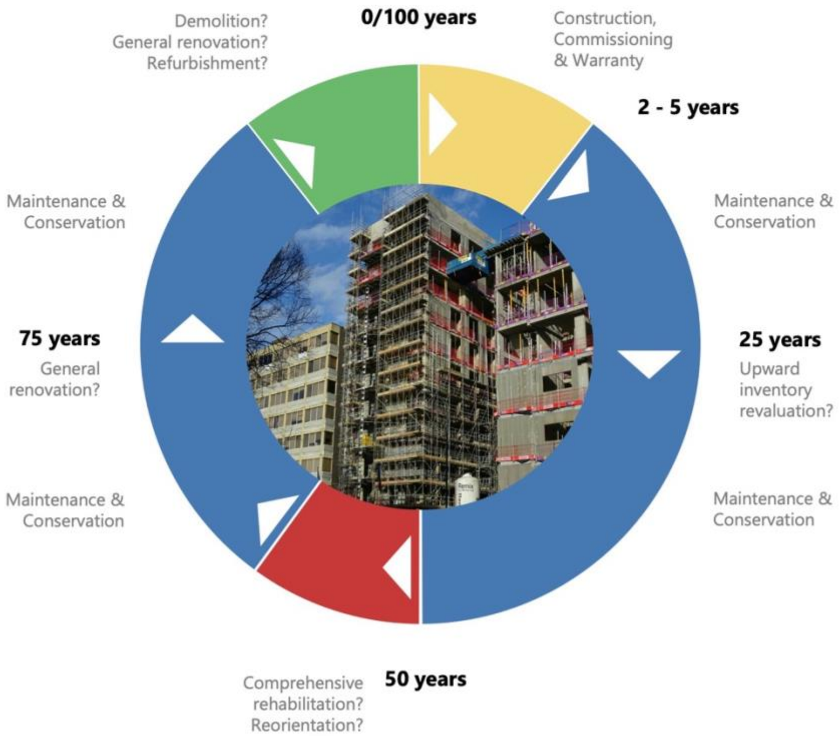


Figure 7.2 – Decisions along the Life cycle of buildings (AIE, 2019; based on ÖGNB, s.a.).

Life cycle thinking is fundamental in the development of low impact products or product-service-systems and to provides decision makers with information on the effects (environmental, economic and social) of different choices. For example, different parts of the building have different life cycles and different life spans. This requires a variation of maintenance strategies for the different parts of the building, and the architect/constructor should consider how to create easy access to the parts with a shorter life span.

Assignment 7.1 - Implications of planning and design on later steps

Group discussion: How do planning and design decisions affect later steps in the value chain? Think of a piece of furniture. Try to state interdependencies between the choice of materials and the production process and the use phase. How does the choice of materials affect the producer or the user?

7.2 Impact assessment along the life cycle

The overall goal of the assessment approach is to improve environmental and social performance of products and processes along with sustained economic profitability. In general, not having impacts is what is desired from an environmental point of view, which is impossible for industrial products. The **results of the sustainability assessment can be used to identify hotspots** by performing a preliminary analysis of a reference product; comparing different products or determining the sustainable benefits of possible improvement measures. The assessment can be performed **at product (components or furniture) and more complex construction systems or building level.**

Different methods will be introduced in the following. The application of these methods is complex, time consuming and requires additional training and effort. This chapter is not intended to enable the reader to apply the methodologies proposed here; instead, **the reader should become familiar with different aspects and understand the usefulness and applicability of the results**. A detailed focus will be laid on circularity strategies in the furniture and construction sector and how to assess their benefits and trade-offs with existing or new methods.

To investigate the environmental impacts of products and services through the whole life cycle, **Life cycle assessment** (LCA) is a widely used standard method to assess potential environmental impacts. It is also common in other contexts than Circular Economy. **Life cycle costing** (LCC) is used to look at the complete economic implications of the life span of a product or service and calculates costs arising during the entire life cycle. **Social life cycle assessment** (S-LCA) is a method that assesses the social and socio-economic impacts throughout the life cycle.

Figure 7.3 – Overview of life cycle sustainability assessment (Schau et al., 2012).

Understanding, quantifying and communicating the impacts behind products presents a stringent necessity to keep track and reduce negative impacts and – even better - shift towards more positive impacts within a Circular Economy. In order to see the whole picture, it is necessary to include all three dimensions of sustainability. This means carrying out an assessment combining the mentioned methods by conducting an overarching **life cycle sustainability assessment** (LCSA) (UNEP/SETAC Life Cycle Initiative, 2011). The next sections introduce the three life cycle based methods (LCC, LCA and sLCA) which can be combined to an overarching LCSA.

Both furniture and construction industry operate on the global market, **design decisions create impacts on regional, national and global level,** e.g. the social, economic and environmental burdens associated with resource extraction. The erection of buildings naturally takes place locally whereas construction products might be imported from distant places. Small furniture crafters try to compete with giants acting internationally. In order to **make impacts visible and comparable**, the whole life cycle needs to be considered and data is needed for assessment. Building certification schemes and environmental labels already set the focus on depicting impacts or branding outstanding properties (see also *Communication* chapter) for customers or decision makers.

7.2.1 Environmental life cycle assessment

Life Cycle Assessment is a **science-based assessment method of the potential environmental impacts** of (product, service) systems. All important steps in the life cycle of a product are included in the analysis, namely the extraction of raw materials from nature (soil, water and air), the production of materials and the final products (goods or services), their use, different kinds of end of life (recovery e.g. recycling and waste disposal) and transports between stages (Klöpffer (Ed.), 2014). LCA **results on component level** plus the operational energy demand and maintenance effort **can be scaled up to product or building level** and can be used for information purposes in B2B communication, for example, in form of **Environmental Product Declarations (EPD)** (Link to section 7.4.3 and see the *Communication* chapter).

Assignment 7.2 - Life cycle of a brick wall

Try to imagine a life cycle (cradle-to-grave, linear) of a brick wall and describe it. What raw materials do we need to extract? How does manufacturing and use phase look like? What general options do we have at the last stage of its life cycle? Define the process steps needed after the product goes end of life (collection, sorting, etc.) Compare your thoughts with material flow diagram on pg. 342: http://www.carlsterner.com/research/files/Life_Cycle_Assessment_of_a_Brick_Bearing_Wall_2010.pdf. Consider the challenges of reusing the bricks.

LCA Framework

Life cycle assessment delivers **decision support in the planning, development and implementation** phase and helps tracking changes and their following impacts. It is applicable for both design and redesign as well as for new and existing products, product-service systems and buildings.

LCA generally follows two international standards - ISO 14040:2006 and ISO 14044:2006. They provide general rules on how to conduct an LCA study and define the four phases for conducting such studies as shown in the diagram below.

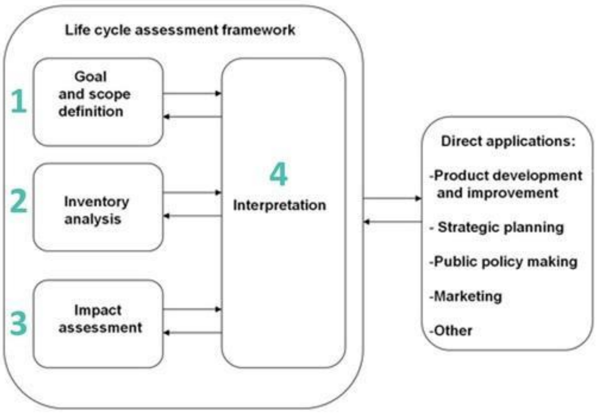


Figure 7.4 – Phases within the life cycle assessment framework (Life Cycle Assessment, s.a.).

LCA results are used, for instance, for:

- Planning: What to anticipate?
- Design: What to consider?
- Re-Design: What to change?
- Refurbishment: What to keep?
- Strategy: What to focus on?
- Policy: What to support/prevent?
- Information: How to communicate?

The four phases of an LCA will be introduced in the following.

Step I - Goal and scope definition

The goal and scope of the study must be stated explicitly, because it provides the context for the assessment and explains to whom and how the results are intended to be communicated and therefore, the level of detail required for the study. The **goal definition is decisive for all the other phases of the LCA. A clear, initial goal definition is hence essential for a correct later interpretation of the results**. Goals of the assessment could be the comparison of two similar products with the same functions e.g. two office chairs or the definition of Eco labelling criteria e.g. for kitchen furniture.

This step includes the detailing of technical information – such as defining the functional unit, the system boundaries, the assumptions and the limitations of the study, the impact categories and the methods that will be used to allocate environmental burdens in cases where there is more than one product or function.

Assignment 7.3 - Information needed

What information would you need to describe the case of an individual house? See pg. 351-352 of https://www.eebguide.eu/eebblog/wp-content/uploads/2012/07/LCA-report-new-buidings-simple-case-study.pdf

Function and functional unit

It is necessary to define the product **function** which presents the **result or purpose** of a product as well as the functional unit (FU). The **functional unit** is a **quantified reference unit for all data** in the LCA study. It quantifies the performance of a product system to which all the results are related and therefore, must **be clearly defined and measurable for a certain period**, e.g. 1 m^2 of installed textile floor covering in a house for a lifetime period of 10 years. This provides the necessary basis for the product system modelling and the comparison of alternatives. The function of the textile floor could be described as follows: Floor covering for an office building with specific requirements like noise protection, emissions and low maintenance.

Table 7.1 – Guidelines for the functional unit (Klöpffer & Grahl, 2009).

Guidelines for the functional unit	
1. The definition of the FU is crucial for the result of a LCA and its interpretation.	If you compare studies with different results for the LCA of the same product, take a look at the definitions of the FU. Maybe they are also different!
2. It is usually a good idea to define your FU right at the beginning of your LCA study.	If you have difficulties defining the FU…There might be a lack of understanding of your system. You might lack important data. An LCA might not be suitable for your evaluation or you might require an advanced method, e.g. product baskets.

Guidelines for the functional unit	
3. There are many possibilities to define your FU, but it needs to suit your objectives.	Ask yourself... Is the unit of the FU practical for your task? Is the interpretation of the functional unit clear?
4. The time frame in which your product fulfils its function should be included in the FU, especially if it has a longer life span.	Is the defined time frame of the FU practical? Is the assumed life span of the product realistic? How do the life spans of your compared products differ? How does the life span of your products depend on external factors, e.g. its utilization? It is often useful to take the life span of the most durable product of your comparison as a reference.

Assignment 7.4 - Definition of the functional unit

Think about three furniture or three construction products and define the functional unit of each.

Assignment 7.5 - Function and functional unit

a) Define the function and possible functional unit for insulation. One possible answer: 1m² of insulation with sufficient thickness to provide a thermal resistance value of 3 m²K/W, equivalent to approximately 100mm of insulation with a conductivity (k value) of 0.033 W/mK (source: https://www.bre.co.uk/greenguide/page.jsp?id=2086)
b) Define the function and possible functional unit for a piece of furniture.

System boundaries

The system boundary **defines which processes and stages will be included** in or excluded from the product system to be assessed. The system should be described by using a process flow diagram showing the processes and their relationships. **Cut-off criteria** are used to define the parts and materials included in and excluded from the product system. The figure 7.5 shows an exemplary system of harvested wood products including forestry, manufacturing of products, construction of building and installation and use & disposal. The reuse of products, recycling and recovery of materials lie outside the system boundary in this case; **D - Credit/debit: Environmental loads and benefits beyond a buildings life cycle** via reuse, recycling or energy recovery potentials.

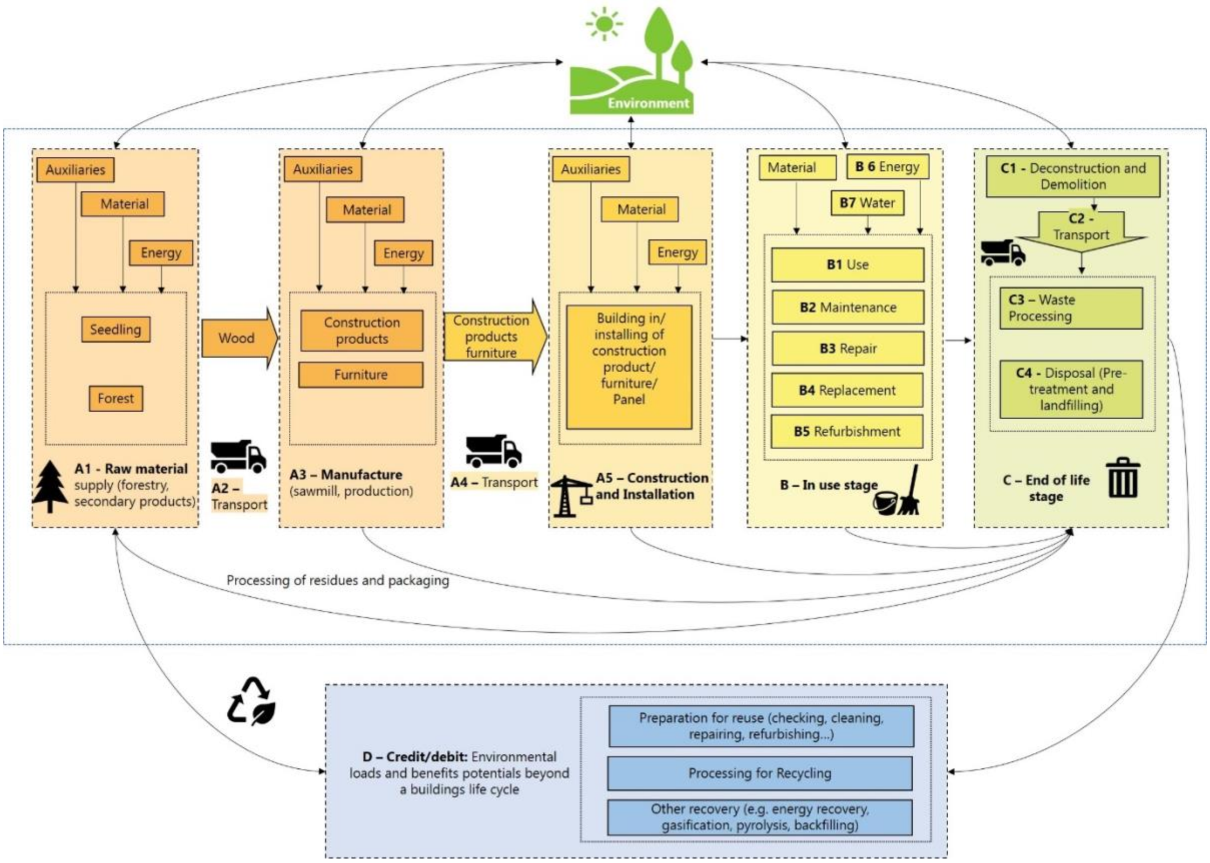


Figure 7.5 – Exemplary system boundary of harvested wood products including Life cycle information modules according to EN 15978 and EN 15804 (AIE, 2019).

Assignment 7.6 - System boundaries

Define a system and its boundaries for one of the previous assignment products. Draw a flow diagram of the life cycle for this selected product.

The following **life cycle information modules for the sustainability assessment of construction products** are defined in EN 15804 + A2: 2018 (Sustainability of construction works - Environmental product declarations - Core rules for the product category of construction products, draft under revision; standard in force EN 15804:2012+A1:2014). The assessment on product level is part of A1-A3 (Product stage or status, mandatory scope). As per 2019 some EPD cover the whole life cycle but most of them only show the product stage (modules A1-A3), also called "Cradle to gate" or including construction and use ("Cradle to gate with options" A1-B4). This will change in future times following updated standards where the modules A-D will be mandatory to declare.

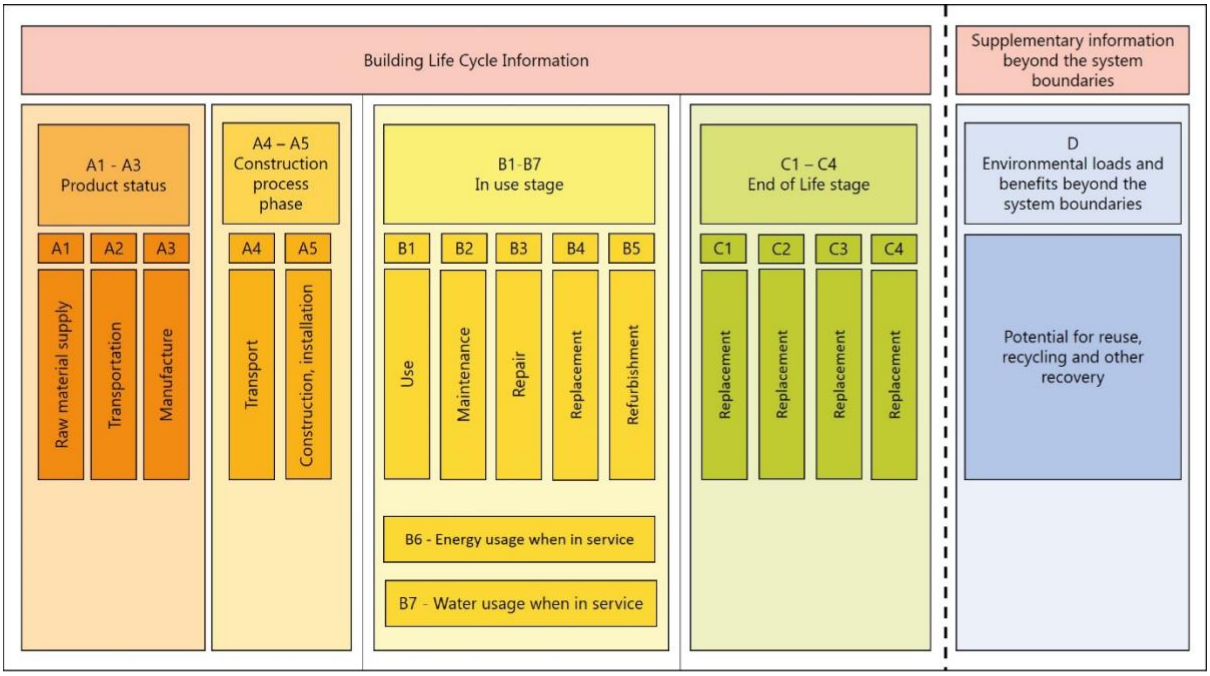


Figure 7.6 – Life cycle information modules (AIE 2019; according to EN 15978 and EN 15804).

Step II - Life cycle inventory analysis

In this second phase, **all resources extracted from the environment (inputs of material and energy) as well as emissions released into the environment (outputs) are collected along the product's life and grouped in an inventory.**

Life cycle inventory analysis (LCI) includes collecting and validating quantitative and qualitative data for every unit process in the system. Data can be based on research, measurement or assumption. The LCI is often presented as a table listing all the material and energy inputs and outputs per unit process and referring to the functional unit. The inventory starts with the collection of data (inputs and outputs) specific to companies and their value chain. These data may come from unitary processes or be aggregated, depending on the availability of the information and the objective of the study (i.e. the degree of detail). By means, generally, of databases associated with LCA software (e.g. GaBi, SimaPro, OpenLCA, etc.), the necessary resources to obtain these inputs and outputs are quantified. For example, using a data set for e.g. 1 kg of stainless steel, the database includes all the resources needed and all the emissions released to air, soil and water to produce this 1 kg of steel. Because of large data sets requirements, LCI is the most work intensive phase of an LCA.

The following table shows an exemplary inventory of the life cycle assessment of a porcelain stoneware tile and its material composition. The functional unit (FU) was defined as 1 m_2 of household floor surface covering with porcelain stoneware tile for 50 years.

Table 7.2 – Material and energy inventory of the ceramic tile along the life cycle relative to the functional unit, including glaze life cycle from cradle to gate (Ros-Dosdá et al., 2018).

	Product stage A1-A3	**Construction process stage** A4-A5	**Use stage** B1-B7	**End of life stage** C1-C4
INPUTS				
Body raw materials(1) (kg/m_2)	2.39E+01			
Glaze raw materials(1) (kg/m_2)	7.85E-01			
Auxiliary inputs (kg/m_2)		3.50E+00	4.94E-02	
Electric energy from the grid (MJ/m_2)	1.68E+01			negligible
Thermal energy from natural gas (MJ/m_2)	1.31E+02			
Groundwater (l/m_2)	1.55E+01			
Tap water (l/m_2)	2.36E+00	8.80E-01	2.60E+02	
Recycled water from other industries (l/m_2)	1.83E+00			
Packaging (kg/m_2)	8.13E-01			
OUTPUTS				
PST tile (kg/m_2)	2.15E+01			
Electric energy sold to the grid (MJ/m_2)	1.46E+01			
Air emissions of particulate matter(2) (mg/m_2)	6.00E+03			
Air emissions of NO_x from the process (mg/m_2)	3.36E+03			
Air emissions of SO_2 from the process (mg/m_2)	2.79E+03			
Air emissions of HF (mg/m_2)	1.36E+03			
Air emissions of HCl (mg/m_2)	1.43E+01			
Air emissions of heavy metals (mg/m_2)	1.88E+00			
Non-hazardous wastes (kg/m_2)	4.91E+00			2.50E+01
Hazardous wastes (kg/m_2)	1.54E-03	8.13E-01		
Wastewater discharge (l/m_2)	3.39E-01		2.60E+02	
NOTE: (1) Composition detailed in table 2 (2) Channelled and fugitive particle matter emissions into the air				

Step III - Life cycle impact assessment

Life cycle impact assessment (LCIA) is the third phase in an LCA where the **inputs and outputs** of elementary flows **are translated into potential environmental impacts** related to human health, natural environment and resource depletion. The inputs and outputs are first assigned to impact categories (classification) and their potential impacts quantified according to characterization factors (characterization).

In a classification step, the inputs and outputs defined in previous LCI stage are assigned to one or more impact categories according to expected effect, such as “climate change”, “human toxicity” etc. The next step includes so-called characterization, where all elementary flows assigned to impact categories are converted to a reference unit using a characterization factor, according to their polluting potential.

For example, the reference substance for the impact category “global warming potential” is the chemical compound CO_2 and the reference unit is defined as “kg CO_2-equivalent”. All emissions that contribute to global warming e.g. carbon monoxide (CO), Nitrous Oxide (N_2O) or methane (CH_4) are converted to kg CO_2-equivalents according with a specific characterization factor. Methane has a characterization factor of 25, meaning that methane contributes 25 times more than carbon dioxide to the global warming potential. Very complex environmental damage models allow for establishing this type of relationships, therefore, those stages of an LCA are generally performed with the support of specific software.

The figure below shows the relationship between sulphur dioxide (SO_2), nitrogen oxides (NO_x) and hydrochloric acid (HCl) and the **characterization factors** for the reference $SO_{2\text{-eq}}$ for the acidification potential AP. NO_x is also related to eutrophication (EP, characterized in $PO_{4\text{-eq}}$ with a different factor), i.e., the excessive growth of plants and algae in lakes and rivers, eventually leading to the death of water bodies.

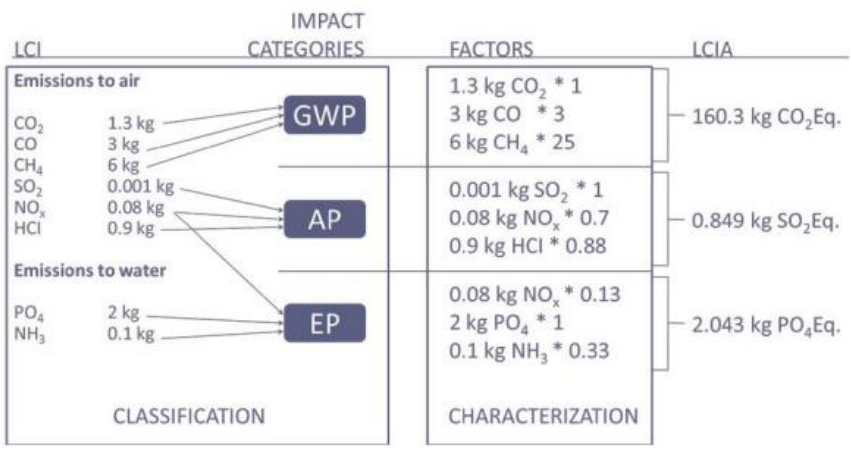


Figure 7.7 – Classification and characterization of impacts (University of Lublijana, 2018). [GWP: global warming potential, AP: acidification potential, EP: eutrophication potential]

Assignment 7.7 - Transformation of inventory data to impact categories

Explain the impact categories of an LCA and the transformation of the inventory to the impact categories.

Related to the inventory table presented in table 7.2 the life cycle impact assessment of a porcelain stoneware tile is shown in the table below (Ros-Dosdá et al., 2018).

Assignment 7.8 - Impact categories

Can you name several emissions to air and water? To what impact categories would you assign them? See figure 7.7.

Table 7.3 – Impact assessment results of LCIA of porcelain stoneware (Ros-Dosdá et al., 2018)

	ADP-elements kg Sb Eq.	**ADP-fossil** MJ	**AP** kg SO_2 Eq.	**EP** kg PO_{34}-Eq.	**GWP** kg CO_2 Eq.	**ODP** kg R11 Eq.	**POCP** kg C_2H_4 Eq.
A1	9.93E-05	2.82E+01	1.17E-02	1.87E-03	2.12E+00	2.23E-07	1.05E-03
A2	6.45E-09	4.19E+00	5.37E-03	6.94E-04	3.16E-01	5.93E-10	3.59E-04
A3	9.74E-07	8.90E+01	1.23E-02	1.44E-03	7.04E+00	4.22E-07	8.81E-04
A4	1.44E-08	8.79E+00	1.27E-02	1.38E-03	6.75E-01	1.24E-09	8.12E-04
A5	6.60E-05	4.05E+00	4.82E-04	2.00E-04	5.01E-01	1.06E-08	5.32E-05
B2	2.19E-07	1.32E+00	9.12E-04	1.57E-04	1.52E-01	5.36E-08	2.64E-04
C1	0	0	0	0	0	0	0
C2	4.23E-09	2.45E+00	9.11E-04	1.84E-04	1.79E-01	3.63E-10	1.01E-04
C3	0	0	0	0	0	0	0
C4	9.93E-10	1.13E+00	5.79E-04	8.50E-05	1.56E-01	1.38E-09	1.02E-04
D	2.37E-08	-1.70E+00	-1.24E-04	-3.87E-05	-1.78E-01	-1.72E-08	-1.61E-05

NOTE: Eq.: Equivalent
ADP: Abiotic (Resource) Depletion Potential, **AP**: Acidification Potential, **EP**: Eutrophication, **GWP**: Global Warming Potential, **ODP**: Ozone depletion, **POCP**: photochemical oxidant creation, **D** = Benefits and loads beyond the product system boundary

Step IV - Life cycle interpretation

The purpose of the interpretation phase is to **identify, quantify, check and evaluate information from the results of the LCI and/or the LCIA in accordance with the goal and scope of the study. This should generate a set of conclusions and recommendations**. Furthermore, it should identify significant environmental issues, an evaluation of the study (completeness, sensibility and consistency check) and limitations (the uncertainty of LCIA methods, the achieved LCI data quality and consistency). The results and conclusions of the LCI/LCA study shall be completely and accurately reported to the intended audience, e.g. B2B or end customers. The results of an LCA could be used for instance:

– information and marketing purposes
– the comparison of two alternatives

- redesign of products
- the integration in certification schemes and
- strategic planning purposes.

ISO 14040 and ISO 14044 standards prescribe a **critical review by independent experts** for LCAs where results present a comparative assertion to be disclosed to the public. In the following table, an example of the **main relative contributions (in %) of the in- and outputs to the environmental impact** categories are shown which can support in deciding which measures should be taken in order to reduce the environmental impact of the product assessed. Minor contributions are aggregated under "Rest of processes".

Table 7.4 – Main relative contributions (in %) of the inputs/outputs in the FU of the portrayed tile to the environmental impact categories studied (Ros-Dosdá et al., 2018).

Life cycle module	Input/output	ADP-elements	ADP-fossil	AP	EP	GWP	ODP	POCP
A1	Body raw materials		14.4	9.2	8.1	12.5	25.8	15.0
	Glazes (from cradle to gate)	59.6	6.1	16.8	23.2	6.8	6.2	14.2
A3 Granulate manufacture	Electricity sold to the grid		-28.3	-19.0	-9.0	-28.1	<-1.0	-25.8
	Electricity bought from the grid		6.3	6.0	3.0	6.7	23.3	6.7
	Thermal energy from natural gas		32.3	7.6	9.3	31.1	<1.0	11.8
A3 Tile manufacture	Thermal energy from natural gas		44.7	10.5	12.6	43.1		16.3
	Electricity bought from the grid		10.0	9.3	4.7	10.5	36.5	7.5
	Emissions from raw materials decomposition			12.8	2.6	1.1		4.6
A2	Transport			12.0	11.6	2.9	<1.0	10.0
A4	Transport		6.4	28.4	23.2	6.2	<1.0	22.5
A5	Adhesive	40.0						
B2	Detergent						7.1	6.3
D	Benefits and loads beyond the product system boundary						-2.5	
Rest of processes			≤3.0	<2.5	≤3.5	<3.0	<2.0	<3.0

NOTE:
Eq.: Equivalent
ADP: Abiotic (Resource) Depletion Potential, **AP**: Acidification Potential, **EP**: Eutrophication, **GWP**: Global Warming Potential, **ODP**: Ozone depletion, POCP: photochemical oxidant creation, **D** = Benefits and loads beyond the product system boundary

See section 7.4.4 for more reflections on LCA results and their limitations and comparability and section 7.4.5 for the discussion on circularity indicators and integration into LCA method and KATCH_e tools.

Assignment 7.9 - Limitations of Life Cycle Assessment

Think of what limitations Life Cycle Assessment could have. Try to name some difficulties while performing an LCA study.

A simplified and practical tool has been developed as part of the KATCH_e materials: CE Analyst including KATCHing Carbon: The CE Analyst quantifies the potential improvements of the environmental profile of a given linear product, when different circular scenarios (such as share, repair, and reuse) are applied. The results show the changing LCA profile after applying certain circular strategies. A basic environmental profile of a linear product over the five life cycles (raw materials, manufacturing, distribution, use, disposal) is needed which can be calculated using the KATCHing Carbon tool (see KATCHing Carbon and KATCH_e CE Analyst tools; see also section 4.5).

7.2.2 Life cycle costing

Life cycle costing analysis (LCCA) or shortly life cycle costing (LCC) is described as: **"a technique which enables comparative cost assessments to be made over a specified period of time, taking into account all relevant economic factors both in terms of initial costs and future operational costs**" (ISO 15686-5). LCC is an assessment technique for calculating the directly related costs along the entire life span a product, process or activity. Regarding LCC in the construction sector, the costs of two or more alternative designs are calculated and compared to determine which is most economical over the entire life span of a building or a facility.

LCC can be applied in the **construction of new buildings and refurbishing of existing ones**. LCC of buildings are regulated by a great number of various standards on national as well as international level and guidelines for LCC assessment. ISO 15686-5 "Building and constructed assets – Service-life planning – Life-cycle costing" provides an international code of practice for LCC in relation to the built environment.

Benefits of LCC:

- Delivers overall cost savings potential (use of energy, water and fuel; disposal costs; maintenance and replacement)
- Demonstrates payback periods and return on investment (ROI)
- Gives an overview of where the costs are allocated
- Preserves asset value
- Predicts future costs
- Facilitates budgeting and forward planning (Langdon, D., 2007), which is especially challenging when assessing the life cycle costs of a building.

Even though the **LCC methodology** is well developed and standardized by now, it is still facing numerous problems in the practice. The analysis is **based on the estimation and valuation of uncertain future events and outcomes**; hence, subjective factors are involved in the process and will affect the results.

Difficulty for planners at early design stage

- Lack of reliable data and benchmarks
- Lack of data accessibility (Kovacic & Zoller, 2015)
- Costs for long term products are hard to predict

Sustainable building certification and LCC

Applying LCC analysis in the built environment can be advantageous when it comes to sustainable building rating systems (see also section 4.2). Green building certification systems such as BREEAM (UK), LEED (US), VERDE (ES), DBNB (GE) or ÖGNB/klimaaktiv building standard (AT) increasingly reward the consideration of future cost categories.

LCC means considering all the costs that will be incurred during the lifetime of product or product-service. In general, LCC can be split into two main areas – the initial costs and the following costs (or follow-up costs). The following example focuses on the relevant costs categories for buildings because they are complex and have a very long lifespan, but the described approach is also applicable on furniture or construction products. **Initial costs** include e.g. cost of design and survey works, project cost, capital investment costs for land acquisition, construction costs, costs related to machines, equipment and inventory for operating a facility, running costs for preliminaries. The **following costs**, which are shown in the table below, can be divided in the categories: operation, maintenance and end-of-life costs. The Austrian standard ÖNORM B1801-4 describes costs as the discounted sum of all costs resulting from use and operation of a building together with the demolition and disposal costs.

Table 7.5 - Exemplary description of building related following costs (based on B1801-4).

Cost category	Cost subcategory	Content and boundaries
Operation cost	Administration	Administration and management Fees, taxes, duties and insurance
	Technical operation of building	Technical building management Inspections (general, warranty etc.) Servicing, minor repairs
	Supply and disposal	Energy supply with consideration of own generation Water and wastewater, Waste disposal
	Cleaning and cultivation	Maintenance cleaning (cost of interior cleaning) Window and glass surface cleaning (inside/outside) Façade cleaning and outdoor facilities cleaning Winter service (removal of snow and ice etc.) Gardening (lawn care, tree and shrub cutting etc.)
	Security and safety	Security and safety service e.g. guarding, concierge Fire protection service
	Building service	Information and Communication Technology Removals (internal transport etc.) Reception and internal office service Gastro service (e.g. canteen operation)
Maintenance cost	Repair and conversion	Major repairs (costs for renewal of components or facilities to extend their life span and functionality) Improvements and conversion (new usage features)
End-of-Life cost	Removal and demolition	Planning/organization for demolition and disposal) Demolition and disposal (cost of recycling materials or raw materials, liquidation costs, landscaping cost etc.)

Life cycle costs can also be categorized regarding the stakeholders to influence and bear them; the following figure shows a distinction between manufacturer and user related costs categories.

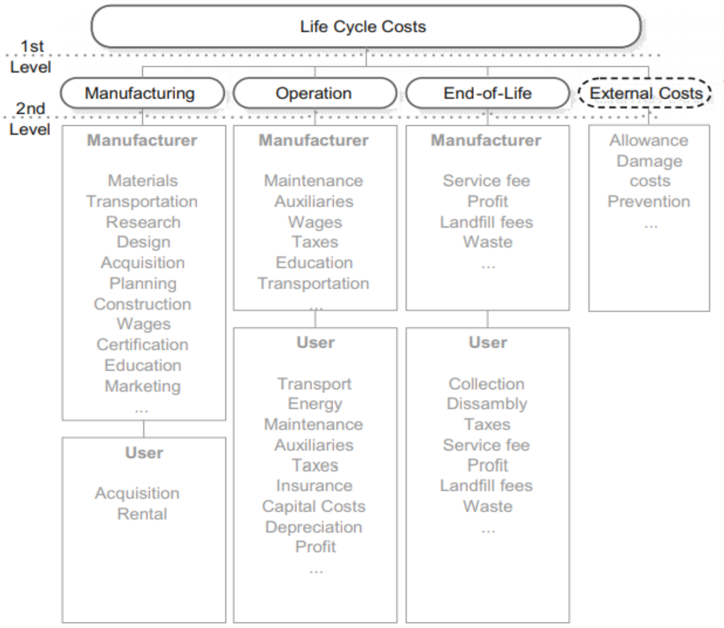


Figure 7.8 - Overview of cost categories distinguishes between aggregation levels and between manufacturer and user perspective (Hauschild et al., 2018).

Assignment 7.10 - Share of initial and following costs of buildings

Before reading the next paragraph, students could guess the percentage distribution of initial and following costs. They will be surely surprised.

- Initial costs: 20%, following costs: 80%
- Initial costs: 40%, following costs: 60%
- Initial costs: 50%, following costs: 50%
- Initial costs: 70%, following costs: 30%
- Initial costs: 90%, following costs: 10%

Also, new ways of motivating different stakeholders to save financial resources over the whole life cycle need to be defined, especially for investors in the building sector. The shifting of negative consequential costs from investors to users should be avoided by depicting the costs for different actors over the whole life span. The following figure shows an overview of different cost categories distinguished between aggregation levels and manufacturer and user perspective.

Relevance of life cycle costing analysis

The costs of planning and consultancy services represent a negligible portion of total life-cycle costs of a building (3%). At the same time, these early building design phases impose the greatest impact on the LCC. The possibility to affect following costs decreases with the project development from 100% to approximately 20% in the construction phase. It has been estimated that 80 to 90% of the operation, maintenance and renovation costs are determined at the design stage.

As it has been demonstrated in practice, the follow-up costs of a building can exceed the erection costs several times over. The next figure shows that in the first 70 years of a building lifespan, a user must bear building-induced following costs that represent up to 80% of total costs. The exact exceeding point as well as the proportion of purchase to operating costs depends on the quality of construction, the intensity of use and the type of building, as well as on the designated lifespan.

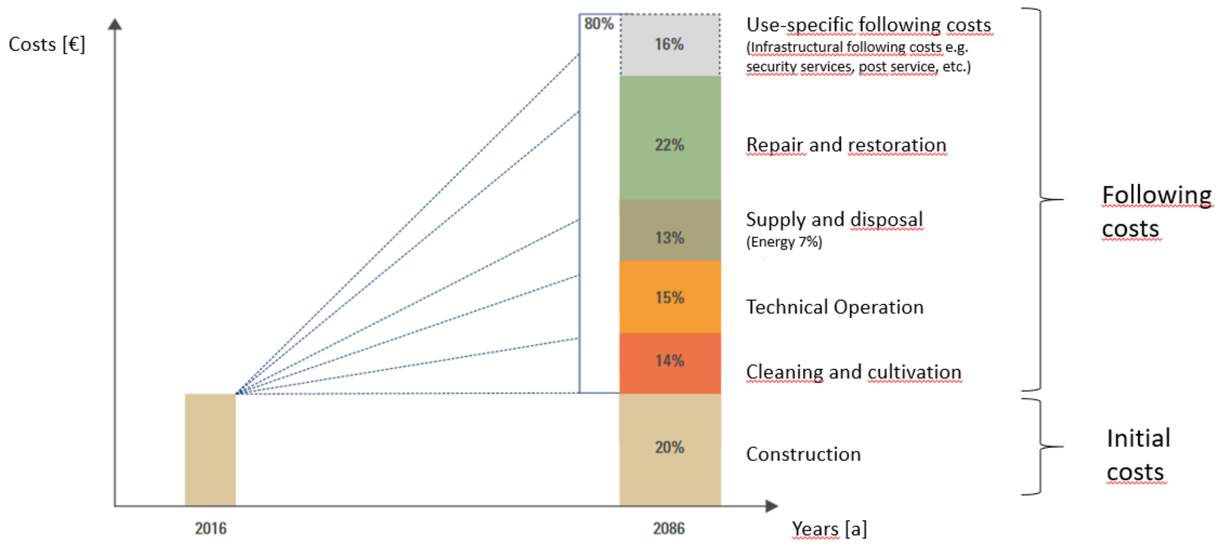


Figure 7.9 - The LCC of an office building during the 70 years after its construction (IG Lebenszyklus Bau, s.a.).

When implementing e.g. energy saving measures, the user of a building gains profit out of it. This is not yet the case when implementing resource saving measures e.g. during production or construction as the user does not necessarily gain benefit out of it. In a circular building practice this must be implemented in order to share the benefits over the life cycle and different stakeholders.

Methods for LCC in construction sector

LCC analysis distinguishes between static and dynamic methods. The static methods are not applicable because they refer only to a specific point in time or time-period without considering costs occurring over the course of time (Kovacic & Zoller, 2015). The most suitable and most commonly adopted practical approach in assessing the life cycle cost of buildings is the **Net Present Value (NPV)**. NPV or discounted cash flow method is defined as the value of a future investment at present time. Based on this, the standard approach focuses on the selection of the alternative with the lowest net present value which presents an orientation including risks and uncertainties as e.g. predicting interest rate levels is possible only to a certain extend.

Assignment 7.11 - Role of Net Present Value and LCC

Question: Why do we need to know the present value when calculating LCC?

The period of an LCC analysis is not fixed and may vary (from 10-100 years). LCC may be applied throughout the complete life cycle of a constructed asset (from its creation to final disposal/demolition) or for a selected limited period within it (Langdon, 2007).

Assignment 7.12 - Operation costs and allocation to stakeholders

Estimate/calculate various costs for the operation of a building/flats and their allocation to the different stakeholders. How does product/building design influence operational costs?

7.2.3 Social life cycle assessment

In environmental LCA, overall social wellbeing of a product or unit process is not in the focus. A **social and socio-economic Life Cycle Assessment (S-LCA)** intends to add critical indicators of human wellbeing that are influenced by processes or companies in supply chains, such as workers' rights, community development, consumer protections, and societal benefits (Benoit-Norris et al., 2012). The ultimate objective of a S-LCA is to promote **improvement of social conditions and of the overall socio-economic performance** of a product throughout its life cycle for all its stakeholders, meaning the individuals affected (UNEP/ SETAC Life Cycle Initiative, 2009).

What to consider

The S-LCA approach **can help to identify social hotspots** and opportunities for organisations along the production chain to improve their social performance (Siebert et al., 2016). Hotspots are production activities in the product life cycle that provide a higher opportunity to address issues of concern (e.g. human and worker rights, community well-being), as well as highlight potential risks of violations, damage to reputation, or issues that need to be considered when doing business in a specific sector and country.

Each life cycle stage can be associated with geographic locations, where one or more of these processes are carried out (mines, factories, roads, rails, harbours, shops, offices, recycling-firms, disposal-sites). At each of these geographic locations, social and **socio-economic impacts** may be observed **in five main stakeholder categories**:

- Workers/employees
- Local community
- Society (national and global)
- Consumers (end-consumers and consumers who are part of the supply chain)
- Value chain actors.

Additional stakeholders like NGOs, public authorities, suppliers, business partners etc. can be added (UNEP/SETAC Life Cycle Initiative, 2009).

Assignment 7.13 - Social impacts for workers along the life cycle

What stages of the life cycle have the greatest risk potential for workers? Describe a sector specific example.

Benefits and weaknesses

S-LCA is applicable when one wants to understand the social impacts related to a good or a service. When using S-LCA, the **focus should lie on the improvement potential** and **highlight life cycle stages where improvements are most crucial**. S-LCA could be used as a motive to favour enterprise locations where most social negative impacts are already low. However, it could be also used as a motive to favour process locations where investments procure a larger share of positive social impacts, e.g. in less developed countries.

S-LCA, just as E-LCA, is useful in highlighting trade-offs between different alternatives. One alternative may not be simply better than the other, but S-LCA will give an understanding on under what circumstances/ regarding which issues one of the alternatives is preferable (UNEP/ SETAC Life Cycle Initiative, 2009).

Similarities and differences regarding to LCA or LCC

The S-LCA follows the four phases of ISO 14040 (see section 7.2.1). A clear difference to LCA lies in the fact that **inventory data and impact assessment are specified in relation to different stakeholders** and stakeholder involvement/participation is also emphasized.
Function and functional unit: In contrast to LCA, S-LCA often works with information about attributes or characteristics of processes and/or their owning companies, which cannot be expressed per unit of process output. Regarding the **system boundaries**, in S-LCA it should be enough to include only those parts of the life cycle which can be directly influenced by the company.

Social life cycle inventory analysis (sLCI)

This phase is concerned with the development of the inventory: Here, a first identification of sub-categories is carried out. For example, the subcategory 'child labour' relates to the stakeholder category 'workers'. In this stage, inventory indicators are also developed for the subcategories (i.e. 'worker age' is an inventory indicator in the case of the subcategory 'child labour'). Compared to environmental issues, many social issues on which a performance measurement takes place are **difficult to quantify**. Data may be quantitative, semi-quantitative (yes/no rating scale responses), or qualitative (descriptive text) and due to the characteristics of the indicator required, the data are collected at the level of unit processes (i.e. energy power station), at the site specific level (facility), but also at an organizational (all production sites and administrative offices), national or global level.

Assignment 7.14 - Discuss stakeholder subcategories and indicators and social impacts

Before seeing the table below, students should guess stakeholder subcategories and indicators followed by a discussion

The **Social Hotspots Database** (SHDB) is a social indicator data repository that provides sector- and country-specific indicator data in five thematic areas:

- Labour Rights and Decent Work (indicators for e.g. child or forced labour etc.)
- Health and Safety (indicators for e.g. injuries, toxics and hazards)
- Human Rights (indicators for e.g. gender equity, high conflicts)
- Governance (indicators for e.g. legal system and corruption) and
- Community Infrastructure (indicators for access to hospital beds; drinking water and sanitation quality).

The following table lists exemplary subcategories according to stakeholder groups and examples of inventory indicators to every single subcategory and its measurement unit based on quantitative, semi-quantitative or qualitative data (UNEP/SETAC Life Cycle Initiative, 2013).

Table 7.6 - Selected S-LCA indicators (UNEP/SETAC Life Cycle Initiative, 2013).

Categories	Subcategories	Inventory indicator	Measurement
Worker	Freedom of Association & Collective Bargaining	Evidence of restriction to FoA and CB	semi-quantitative
	Child Labour	% of children working by country/sector, workers age	quantitative, semi-quantitative, qualitative
	Fair Salary	Minimum wage by country	quantitative
	Working Hours	Excessive hours of work	quantitative/semi-quantitative/qualitative
	Social Benefits/Social Security	Social security expenditure by country and branches e.g. healthcare	quantitative/semi-quantitative
Consumer	Health & Safety	Quality/number of information/signs on product health and safety	quantitative
	Consumer Privacy	Country ranking related to regulations on data-sharing	Semi-quantitative
	End of life responsibility	Strength of national legislation covering product disposal & recycling	Semi-quantitative
Local community	Access to material resources	Changes in land ownership	quantitative
	Safe & healthy living conditions	Pollution levels by country	quantitative
	Community engagement	Freedom of peaceful assembly and association	qualitative
Society	Public commitments to sustainability issues	Existence of (legal) obligation on public sustainability reporting	qualitative/semi-quantitative
	Prevention & mitigation of armed conflicts	Is the organization doing business in a region with ongoing conflicts?	qualitative/semi-quantitative
	Corruption	Risk of corruption in the country and/or sub-region	corruption index

Categories	Subcategories	Inventory indicator	Measurement
Value chain actors not including consumers	Fair competition	National law and regulation	qualitative/semi-quantitative
	Promoting social responsibility	Industry code of conduct in the sector	semi-quantitative
	Respect of intellectual property rights	General Intellectual Property Rights and related issues associated with the economic sector	qualitative/semi-quantitative

Social life cycle impact assessment (sLCIA)

In the impact assessment, the inventory data is 'translated' into impacts via models. Impact categories represents social issues of interest that will be expressed regarding the stakeholders affected and may cover health and safety, human rights, working conditions, socio-economic repercussions, cultural heritage and governance. For the impact assessment phase**, each case study combines different assessment methods or develops its own methodology** (as seen in the following case study of building materials).

S-LCA considers both positive and negative impacts of the product life cycle, because beneficial (positive) impacts are often of importance and to encourage performance beyond compliance (with laws, international agreements, certification standards, etc.).

Interpretation of results

Like an environmental LCA, a life cycle interpretation is carried out in the last phase. The case study *Social life cycle assessment for material selection: a case study of building materials* attempts to design a S-LCA for building material life cycle system in Iran (Hosseinijou S. A. et al, 2014). Two main building structures, i.e., steel and concrete, are compared in order to figure out which of these two alternatives is socially preferable overall.

7.3 The life cycle of products and discussing circular loops

7.3.1 Discussion on furniture and impacts of design decisions

In this section, the link from product and service design to implications on later life cycle phases and stakeholders is drawn and possibilities of creating circular loops with selected design strategies demonstrated.

The figure below depicts the simplified value chain of a generic furniture product. It illustrates the complexity related to the fact that furniture includes a broad range of products, materials and designs, and can be used in domestic and non-domestic applications (Cordella and Hidalgo, 2016).

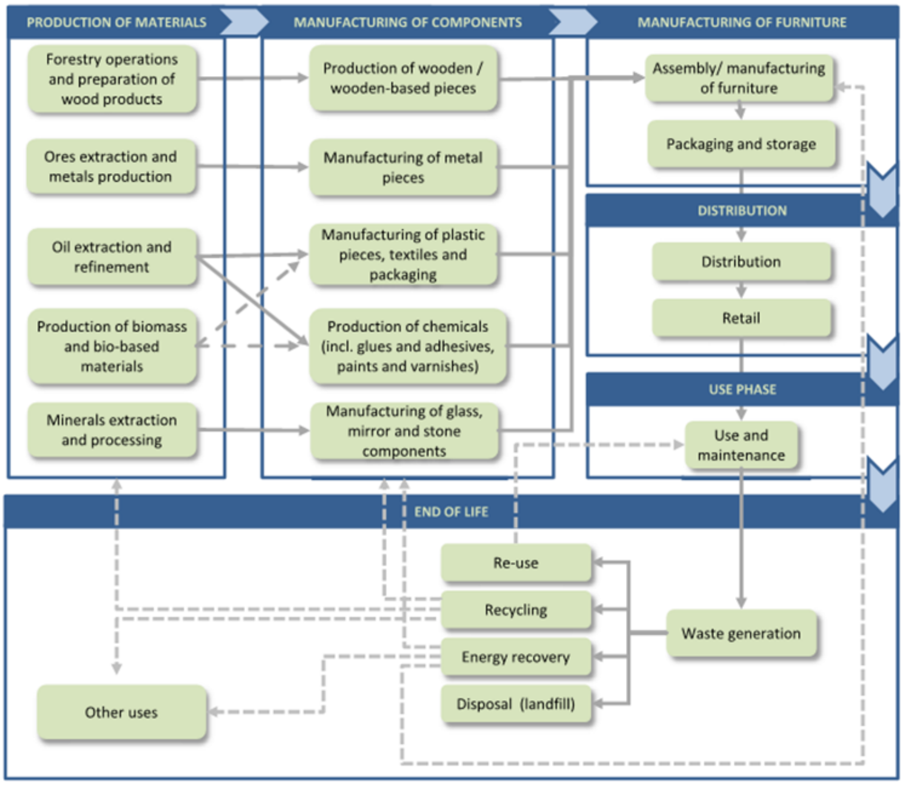


Figure 7.10 - Streamlined value chain of a generic furniture product (Cordella and Hidalgo, 2016).

Using a screening approach based on a literature review of environmental LCA studies, Cordella and Hidalgo (2016) have identified the **most critical environmental areas of the life cycle of furniture in five impact categories: Acidification, Climate Change, Eutrophication, Ozone Depletion and Photochemical Ozone Formation**. According to them, the **environmental profile of furniture is mainly determined by the materials**. Thus, carefully selecting materials, increasing efficiency in resources use and extending durability are promising strategies from an environmental point of view.

The **Dutch company Gispen**, a major producer of office furniture in The Netherlands, has **evaluated different circular business models and design options** and concluded that for business reasons, a pay per use scenario is not feasible; hence they tested a service of upgrade or remanufacture at clients' premises (revitalization) and compared it with the normal linear scenario. Figure 7.11 shows the results of the analysis for a desk with a steel top. On the left, the CO_{2eq}-emissions arising from a refurbished desk (assumed lifetime of 12 years) are compared to the CO_{2eq}-emissions from a linear scenario (assumed lifetime of 8 years). During its life, the refurbished desk causes on average 1,3 kg less CO_{2eq}-emissions per year than the linear product. As you can see, the emissions of the refurbished product are lower in all life cycle stages except for transportation.

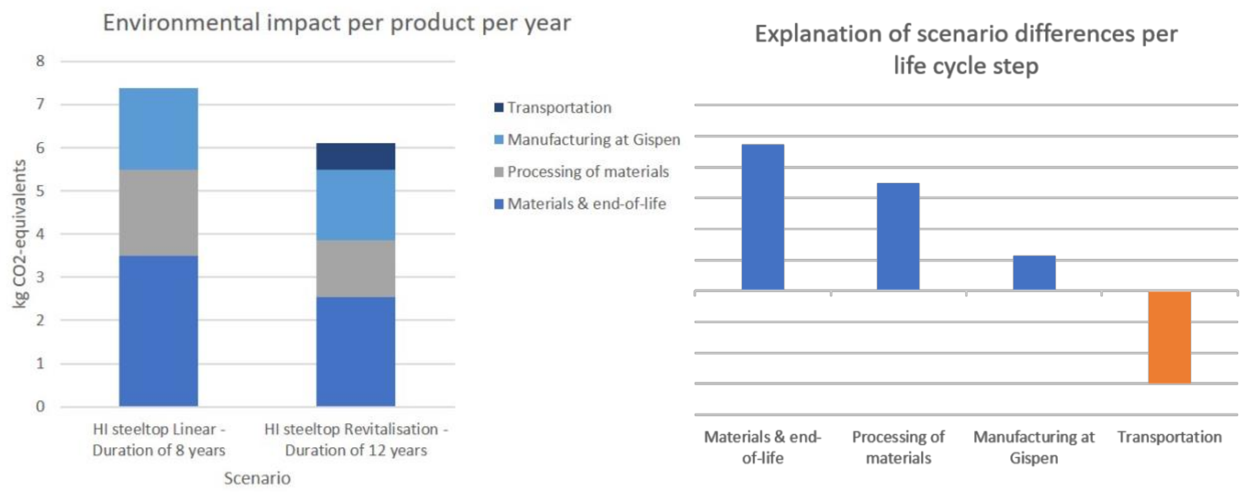


Figure 7.11 - Outcomes of the C-LCA calculations for a linear as well as a revitalization scenario (AIE, 2019; based on Bosch et al., 2017).

The choice of materials and product design has impacts on all following phases - economic ecologic and social ones. In the use phase materials, their quality and processing have big influence on the intensity of usage and customer satisfaction, repairability and life span of furniture. When the pieces of furniture come to their final stage, the material choices and connections facilitate reuse or recycling as the surface can be refurbished and the connections are still intact and easy to detach (see also the *Design and development* chapter and for material aspects and processes see the *Processes and materials* chapter).

In the following, we will take a closer look at a best-practice-example for hotel room furniture by investigating the role of Life Cycle Thinking and product/service design and by showing the consequences on later life cycle phases. The character of the chosen building has been kept by revealing elements of the woodwork and preserving the façade. The building has been erected in 1860 for the Basler Mission and is run as a hotel since 2001.

Figure 7.12 - Hotel Bildungszentrum 21, Basel (Hotel Bildungszentrum 21 Basel, s.a.)

Example: Furniture of hotel room

- high quality of materials,
- long-life products
- services for product-life extension

Bildungszentrum 21, Source: AIE

The following details refer to selected design criteria and potential implications on other phases in the life cycle of furniture.

Solid wood table: material sustainability

- Eliminate the use of toxic materials → health aspects in production and use phase, enables recycling, lower environmental impacts at End of Life
- Use of locally produced raw materials (European or Siberian oak) → less transport effort, local value creation in production
- Suppliers with good social responsibility practices

Bildungszentrum 21, Source: AIE

The bed consists of solid wood parts and the connections are made of stainless steel, which are easy to localize and standardized tools can be used to detach them.

Solid wood bed: long life product
High quality and durable material → less maintenance effort, long use, suitable for reuse Timeless and customized design → long use possible User friendliness → rounded edges, customer satisfaction, easy to handle for staff
Bildungszentrum 21, Source: AIE

The covering of the chair can be taken off for cleaning purposes or changed in case of damage.

Chair with upholstery: product-life extension
Easy replacement of components → easy to handle for staff, economic refurbishment Aesthetic and/or technical upgradeability → long use, customer satisfaction
Bildungszentrum 21, Source: AIE

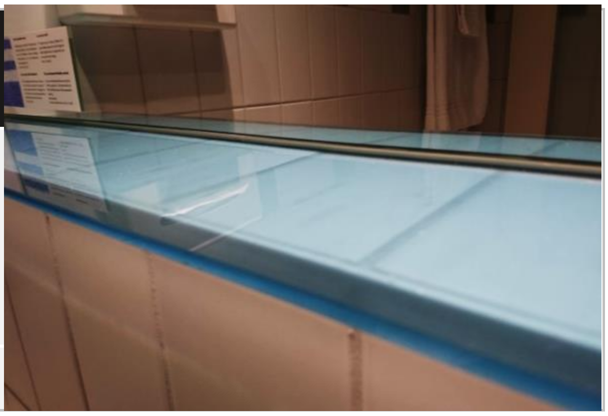
Lightning and bathroom facilities give also a high-quality and appealing impression.

Lightning: long life product
Timeless and customized design → long use Reliability → customer satisfaction, low maintenance effort, long use User friendliness → customer satisfaction
Bildungszentrum 21, Source: AIE

Bathroom facilities: long life product
Timeless and customized design → long use Reliability → customer satisfaction, low maintenance effort, long use User friendliness → customer satisfaction
Bildungszentrum 21, Source: AIE

Bathrooms are usually much more challenging in terms of renovation, e.g. changing or removing tiles. Adding or changing elements does not take much effort and it leads to nice visual and practical effects.

Tiles and boards: product life extension
Aesthetic and/or technical upgradeability → long use, economic refurbishment Durable and wear resistant materials and components → long use
Bildungszentrum 21, Source: AIE



The selection of materials and design decisions have impacts on all other life cycle phases:

- **Raw material:** Renewables; f.e. European or Siberian oak from certified origin
- **Production:** No toxic or harmful substances are used which prevents negative health effects for the workers and less environment impacts and the accumulation when recycled
- **Distribution:** Short distances, less material needed for protection of the product
- **Use:** User friendly with no sharp edges, pleasant when touching, feels smooth and warm; Solid wood is not only more durable and resistant to staining, scratching etc. but can also gain in character if the surface is aging and developing patina.
- **Waste Managment:** Potential for reuse, recycling, energy & other recovery or incineration

Circular loops along the life cycle can be fostered (or hampered) by product design:

- **Maintainance:** easy to clean, easy to apply surface treatment like natural oil
- **Product life extention:** durable surface, re-establishing the surface quality with f.e. grinding and applying natural surface treatments like oil.

- **Reuse/Redistribute:** High quality enables reuse for commercial or private use
- **Refurbish/Remanufacture:** harvesting of components or refurbish the whole product
- **Take back & Recycling of material:** use of material or in partical boards or in chemical industry

Creating circular loops involves cooperation and different actors along the value chain and opens opportunities for new bussiness fields and saving resources (see the *Value chains* chapter and the *Radical innovation and collaborative design processes* chapter). The initial actors along the product life cycle or new ones could be involved in offering services for prolonging the life span or taking back the products for refurbishment, reuse or recovery.

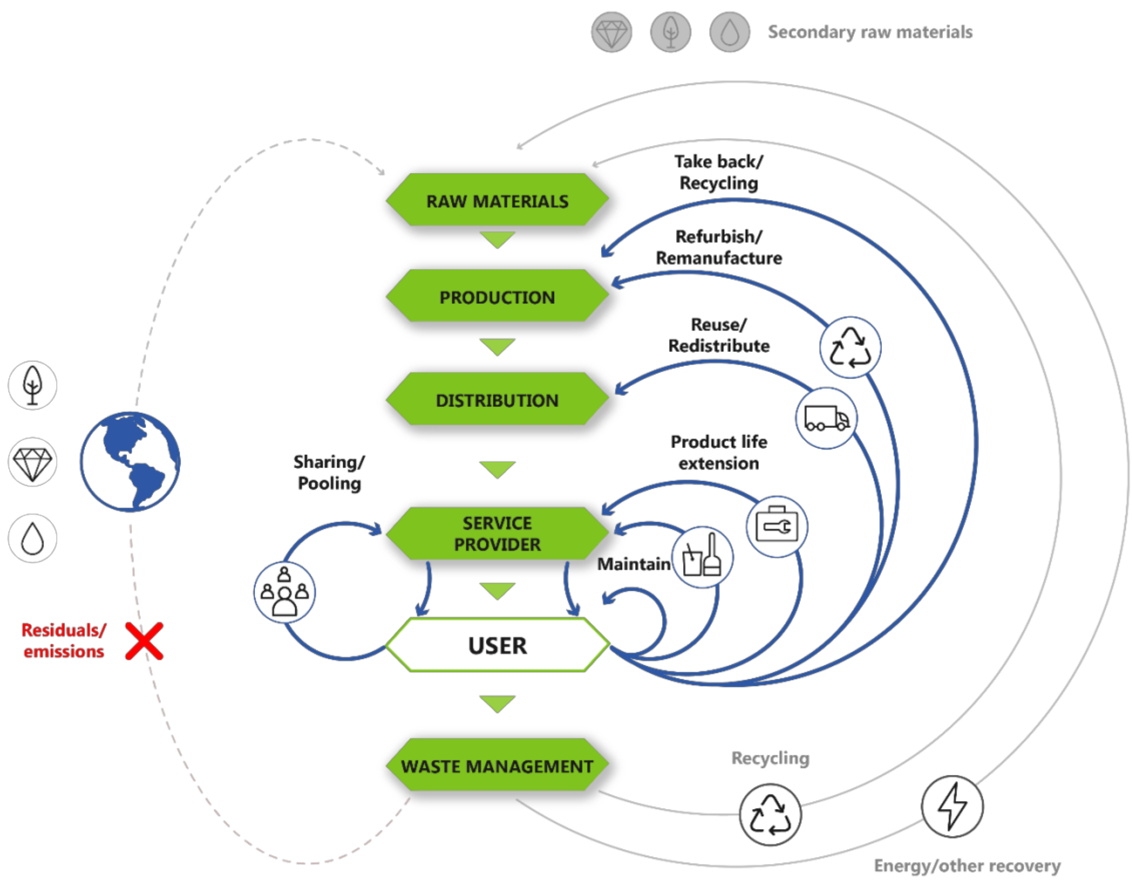


Figure 7.13 - Creating circular loops along a product's life cycle (AIE, 2019; after Ellen MacArthur Foundation, 2017).

Design and performance of the products allow and support services for the owner of the hotel as well as the manufacturer could benefit from, for instance:

- **Use-oriented services**: The ownership of the furniture is not transferred to the hotel; all life cycle costs stay with the provider so the manufacturer has a high interest in prolonging the life span as long as possible and make refurbishing as easy as possible.
- **Product-oriented services:** The hotel is the owner of the furniture and uses services for life extension like maintenance, repair, refurbishment and cleaning services.

Present situation at the end of life and reuse before dismantling of buildings: Furniture in commercial use is generally replaced in short time periods, e.g. 9-12 years (5-10 years in public buildings) due to aesthetic and corporate reasons, which means that the products are mainly in good shape, making them suitable for reuse and the second-hand market. Also, they are available in a high number of similar products and in many cases of high quality.

The clearing out of buildings is the first operational activity that occurs in the dismantling process. In general, the contracts for the clearing out are assigned to the contractor of the dismantling, who often incorporates subcontractors for that specific task. Consequently, the project developer is not able to overview the operational work done easily and the **potential for reuse or recycling of components and material remains locked in most cases**. Even reusable furniture often ends up as bulky waste.

reuse before dismantling: develop services that support the life extension
Selective dismantling → Check hazardous substances Localize potentials for reuse → on site visits Integrate clearing out in process → establish new cooperation, employment creation and good working conditions
Source: BauKarussell (2018)

Figure 7.14 - Furniture as bulky waste (tatwort Nachhaltige Projekte GmbH, s.a.; OÖ Landesabfallverband, s.a.).

From the lamp to the bed – main characteristics of the furniture and selected design criteria which support sustainable resource use and foster circular loops can be summarized as follows (for detailed information on circular design strategies see the *Design and development* chapter):

Table 7.7 - Product design approaches for the circular economy (KATCH_e, 2019).

Phase of the life cycle	Related strategies of design for a circular economy and criteria
Raw materials	**Design for materials sustainability** - Durability of material: choice for wooden furniture – oak - Mono materials: wood, metal - Preferably local wood from certified sources: social and environmental aspects - No toxic materials: no harm to environment and health and no accumulation during end-of-life treatment
Design & production	**Design for product-life extension** - Detachable connections: screws, sturdy metal plates for the bed - Easy replacement of components: head of bed, chair seat cover - Simplified product architecture - Minimize connecting elements: easy to find, detachable
Use & maintenance phase	**Design of long-life products** - Durable and wear resistant materials and components - Timeless and customized design - User-friendliness: smooth surfaces, no edges - no toxic materials **Design of product-oriented services** - Offering of maintenance, repair, refurbishment and cleaning services: employment creation and good working conditions, customer satisfaction **Design of use-oriented services:** ownership of the furniture is not transferred to the client (potential option); all life cycle costs stay with the provider so the manufacturer has high interest in prolonging the life span and make resource use as efficient as possible
Creating circular loops before reaching the End of Life	**Design of long-life products:** suitable for reuse, high quality **Design for product-life extension:** possible refurbishment, exchangeable parts
Creating circular loops after reaching end of life	**Design for recycling:** detachable connections, mono materials, no harmful substances **Design for remanufacturing:** simplified product architecture, minimized connection elements, easy to find, detachable; use of solid wood components for other purposes

7.3.2 Discussion on building components at their end of life

The construction sector is one of the most resource consuming sectors in Europe - it accounts for approximately half of all extracted materials, half of total energy consumption, one third of water consumption and one third of waste generation (European Commission, 2014).

Currently, the **biggest gap to realize circularity in the construction sector occurs at the end of life in the phase of dismantling**. Even though a lot of material is recycled in the construction sector, it is questionable if this happens in the best possible way regarding circularity. The following examples highlight actual behaviour when it comes to the dismantling of buildings in Austria. Options for actions in other phases of the life cycle that would allow closing loops and raising the potential for circularity will be addressed as well as the interdependency between the different phases of a life cycle mentioned.

Example 1: Parquet floor of high quality (oak, herringbone)

Present situation: Dismantling companies remove parquet floors manually or using small deconstruction machinery. Despite the high quality of the floor, it is rarely reused. The waste fraction "wood" is mostly used for material recycling, e.g. in particle boards or incinerated if it contains impurities which hamper recycling. This happens because wood is seen as a disturbing factor that hinders production of recycled construction material from e.g. reinforced concrete or bricks.

Options towards circularity: In the frame of the impurity and contaminant investigation (which is mandatory for dismantling of buildings in Austria from a distinctive threshold) of the building, the actual status of the parquet floor can be documented. In case it is still in good quality, the planner of the dismantling process can start to think on how a high value reuse can be achieved. Basically, the parquets can be grinded and sealed to enter a new use-phase. Related to product design and processes several **obstacles** can prevent the slowing, narrowing or closing of the resource flow:

- **Adhesives** used to connect the single parquets (not separable)
- **Parquets that are not solid enough to be grinded** (quality, durable materials)
- **Special dimensions or patterns that hinder compatibility**
- **Hazardous material -** what is below the parquet that could harm workers?
- **Legal constraints -** Were there any substances used, that must not be placed on the market nowadays (due to change in legislation)?

Figure 7.15 - Checking quality and reuse potential of parquet floor in building to be demolished (BauKarussell, 2018).

Steps towards closing loops:

- **Time frame before dismantling**: Define the time frame and a deadline regarding the material remaining (in the sense of storage) in the building.
- **Involve stakeholders**: Discuss with the project developer and the architect if the material can be reused at the respective construction site. That could replace other floor material and raise resource efficiency.
- **Supply and demand**: Try to find a purchaser that wants to reuse the material.
- **Information on the product/quality assurance**: Provide documents that define the product (e.g. product data sheet, technical/chemical expert reports), size of the top layer of the parquet floor.
- **Link to product design and mounting**: What method was used to fix the parquet floor (nails, screws, glue, click-system)?
- **Link to producer/value chain**: Who was the seller of the product and is there an option to cooperate to refurbish the parquets? This cooperation offers the chance for the producer to supply a new product for the rest of the construction project, so it can be a win-win-situation.

On the KATCH_e Knowledge Platform you find a case study on BauKarussell with design strategies and implementation ideas on the reuse and refurbishment for windows, doors and floor boards (see https://www.katche.eu/knowledge-platform/other-resources/case-studies/).

Example 2: Polystyrene boards for roof insulation

Present situation: Polystyrene hard boards used for roof insulation before the year 2000 contain with high probability Chlorofluorocarbons (CFC). It is essential to know if this is the case when deciding whether this product must be treated as hazardous waste or could be used in an alternative way. In the first case it must not be handled with machinery, but with special care. To avoid the release of CFCs into the atmosphere, the boards must not break during dismantling because the GHG effect of CFCs is about 1.000 times higher than CO_2. They must be stored carefully and finally treated in a proper waste incineration facility to ensure the elimination of the CFC.

Options towards circularity: The important decision of banning the production and use of CFC was made in the year 2000. Although the absolute mass of CFC used is low, it is ecologically critical because of its high GHG potential. Since the material is so light in weight, construction workers often fail to handle the boards with the necessary care (dropping, breaking, cutting…).

Steps towards closing loops:

- It should be tested if the boards contain CFC in the frame of an **impurity and contaminant investigation** before starting the dismantling process, primarily to estimate the costs for dismantling and secondarily to set the legal requirements for the dismantling company.
- **Information on the product**: To reuse boards without CFC, it is crucial to provide the technical data sheets and optional technical assessments of the specific material.
- **Warranty issues**: Set up an agreement that clarifies warranty and liability.

Since buildings are complex products with a very long life, the role of stakeholders and decision makers is also a more complex one. Solutions for a more circular construction business offers not only opportunities for demolishers and wholesalers, some more examples for **"winners and losers" of a more circular economy** can be described as follows (Van Sante, 2017):

- **Architects, contractors:** Can integrate easy dismantling and sustainable insulation materials. An alternative design process is required but the architects' role remains unchanged.
- **Building materials suppliers:** Can provide sustainable insulation materials (minimum environmental impact, materials passport, and maximum life span, suitable for reuse). Circularity might have an adverse effect because demand for new products would decrease and product-service systems are less suitable/likely for low-tech building components like insulation.
- **Wholesalers:** Can trade circular insulation materials. Circular insulations are an opportunity for them because they can establish a second-hand market.
- **Contractors:** Can use circular insulation where possible and are familiar with alternative insulation materials. They might have to adapt but their role in the value chain remains unchanged.
- **Project developers:** Have a leadership role, can enable their partners to show their innovation potential in tenders. Thus, they would have to adapt to circular standards.
- **Investors/owners:** Have to appreciate and understand the value of circular materials.
- **Tenant:** Can demand/request sustainability and circularity of residential objects.
- **Demolisher:** Can do demolishing aligned to a circular use of insulation, tradereusable insulation materials. In a circular model, they have an opportunity to contribute added value.

7.4 Assessment and communication on building and component level

7.4.1 European standards for the assessment in the construction sector

EN 15978:2011 **Sustainability of construction works - Assessment of environmental performance of buildings - Calculation method** specifies the calculation method, based on LCA and other quantified environmental information, to assess the environmental performance of a building, and gives the means for the reporting and communication of the outcome of the assessment. The standard is applicable to new and existing buildings and refurbishment projects, and after a revision process in 2019 a new section with other - non-LCA - qualitative and quantitative environmental indicators will be incorporated.

The approach of the assessment covers all stages of the building life cycle and is based on data obtained from Environmental Product Declarations (EPD), their "information modules" (EN 15804: 2018 **Sustainability of construction works - Environmental product declarations - Core rules for the product category of construction products**, draft under revision) and other information necessary and relevant for carrying out the assessment on product level. The assessment includes all building-related construction products, processes and services used over the life cycle of the building.

The standard EN 16309:2014 **Sustainability of construction works - Assessment of social performance of buildings – Methods** provides the specific methods and requirements for the assessment of the social performance of a building while considering the building's functionality and technical characteristics. This European Standard applies to all types of buildings, both new and existing. In this first version of the standard, the social dimension of sustainability concentrates on the assessment of aspects and impacts of the use stage of a building expressed by the following social performance categories (from EN 15643-3): accessibility, adaptability, health and comfort, impacts on the neighbourhood, maintenance, safety and security.

The purpose of the European Standard EN 16627:2015 **Sustainability of construction works - Assessment of economic performance of buildings - Calculation methods** is to provide calculation rules for the assessment of the economic performance of new and existing buildings as one part of an assessment of the sustainability of the building. This standard describes the methods and the rules for calculating the cash flows over the life cycle of buildings, with an emphasis on the field of life cycle costing. Principles developed in ISO 15686-5 are included but have been adapted for sustainability assessment in the EU context. This standard describes two approaches to the calculation of economic performance:

– **Life Cycle Costing:** Economic performance expressed in cost terms over the life cycle, taking into account negative costs related to energy exports and from reuse and recycling of parts of the building during its life cycle and at the end of life. Calculation of this indicator is mandatory for compliance with the standard.

– **Life cycle economic balance:** incooporates Life Cycle Costing and in addition incomes over the life cycle and at the end of life. Calculation of this additional indicator is optional.

7.4.2 Assessment and certification schemes on building level

Building certification schemes play a major role in urban development or real estate projects, as e.g. requirement within tendering or public funding programs. The performance of construction products contributes to the overall performance of a building and is thus an integrative part of the underlying assessment. **Circularity aspects are only partly included**. For instance, the share of recycling materials or renewables is displayed but is not in focus yet. The focus lies on legal compliance, avoidance of harmful substances and energy efficiency during the use phase. The relevant questions in this respect are: "How can product and product service design contribute to the reduction, slowdown and closing of resource flows in buildings? What product characteristics support the circularity of buildings? How to include the product requirements (criteria) in existing, well established certification schemes in order to put it into practice?"

The EC Joint Research Centre has developed a **common EU framework of core indicators for the sustainability assessment of office and residential buildings called Level(s**). Level(s) provides a set of indicators and common metrics for measuring the sustainability performance of buildings along their life cycle (European Commission, 2017a). In comparison to existing building certification schemes, the optimization of the building design and circular flows is part of the six macro-objectives addressed with the framework which should support **circularity in the construction sector** (European Commission, 2019). In the section Resource efficient and circular material life cycles, the **optimisation of the building design, engineering and form in order to support lean and circular flows, extend long-term material utility and reduced significant environmental impacts are explicitly mentioned**.

Sustainable building standards have been well established in the construction sector and stand for the optimization of the building in terms of energy consumption and environmental impact, quality of the interior and quality in operation. In common, criteria for the following categories are assessed:

– Energy
– Material
– Water
– Ground
– Inner space
– Operation and management

The differences between the certification schemes for buildings result from the aggregation of data and their weighting. The green buildings concept has been further developed towards Sustainable Buildings and some of the certification schemes also incorporate social or economic criteria. In the following, the most common third party verified building certification schemes are portrayed. Other well-established systems are HQE (France), Minergie and SNBS (Switzerland) or Itaca (Italy).

BREEAM (Building Research Establishment Environmental Assessment Methodology) was the first sustainability assessment method for buildings established in 1990. The BRE Group operates internationally and was found in the UK. BREEAM building assessment is available for different building types (e.g. In Use – commercial buildings, New Construction and Refurbishment – home and commercial buildings) and BREEAM International presents an internationally applicable assessment method used worldwide. The BREEAM ratings range from Acceptable (In-Use scheme only) to Pass, Good, Very Good, Excellent to Outstanding and are reflected in a series of stars on the BREEAM certificate. BREEAM measures sustainable value in nine categories, ranging from energy to wastewater. Each category is subdivided into a range of assessment issues, each with its own aim, target and benchmarks.

In the mid-1990s, on the initiative of Canadians Nils Larsson and Ray Cole, the **Green Building Challenge** was launched, a global platform for the further development of building rating systems based on the BREEAM pioneer system. From this platform (the now very numerous) national building rating systems emerged, including the US-American system LEED (Leadership in Energy and Environmental Design) which presents the most widely used certification scheme. LEED is hosted, further developed and distributed internationally by the U.S. GBC Green Building Council. The World Green Building Council is an international association of organizations that provide and drive national building rating systems. LEED applies to buildings that are being newly constructed or going through a major renovation (LEED, 2019).

Following the ÖGNB/ASBC method, the Austrian Sustainable Building Council developed **Total Quality Building**, an optimization instrument suitable in the design and planning phase, as well as for quality assurance during the construction and validation of the sustainability criteria/goals after handover. The certification results - documented in a planning or construction certificate - make the quality of a building visible and comparable. Currently, all buildings in one of the largest urban development areas in Europe - Seestadt Aspern in Vienna - are quality assured with the ÖGNB method. Some circularity aspects are depicted under the sub-criteria for Technical Quality & Resource efficiency, social under Location & Facilities plus Health & Comfort whereas economical ones aggregated under Economy (compare figure 7.16 and assignment 7.15).

	Demo-Project	1000	0
	GENERAL BUILDING INFORMATION		
A	LOCATION AND FACILITIES	200	0
B	ECONOMY AND TECHNICAL QUALITY	200	0
C	ENERGY AND SUPPLY	200	0
D	HEALTH AND COMFORT	200	0
E	RESOURCE EFFICIENCY	200	0
E.1	Avoidance of critical material	50	0
E.2	Regionality, recycling share, certified products	50	0
E.3	Eco-efficiency of entire building	60	0
E.4	Disposal	60	0

Figure 7.16 - Assessment Categories and Sub-Categories of Resource Efficiency (ÖGNB method s.a.).

Assignment 7.15 - Check an existing certification scheme on circularity aspects

Discuss the assessment criteria of an existing building certification scheme, check it in terms of circularity indicators and how to integrate new ones in order to foster circular design. Then, compare different buildings or parts of it with the criteria proposed by the scheme.

For instance, you can take a look at the demo version of the ÖGNB assessment tool under https://www.oegnb.net/en/zertifikat.htm?typ=hs&sop=6457,8455,6453.

Click through the categories and subcategories of **B Economy and Technical Quality** as well as **E Resource efficiency** and discuss the links between planning, product design, execution and the impacts created for the following life cycle phases and different actors along the value chain. If you insert various values or select possible answers, please make screenshots because in the demo version it is not possible to save results.
Note: If you want to save your projects and data, then you must register. The use of our system is free of charge. After successful registration you receive an access to the full version from TQB.

Table 7.8 - Overview of selected building certification schemes.

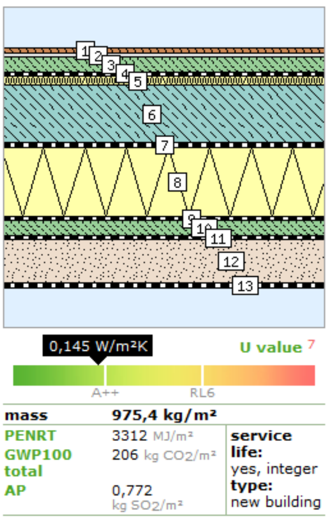
Name	Organisation	Application /country	Categories	Criteria on circularity/ weighing/comments
BRE Environmental Assessment Method	BRE - Building Research Establishment Limited 	Internat. UK BREEAM	Energy Health and Wellbeing Innovation Land Use Materials Management Pollution Transport Waste Water	Each category divided in sub assessment issues with own aim, target and benchmarks and different weighing result displayed via star rating
LEED Leadership in Energy and Environmental Design	U.S. GBC Green Building Council 	Internat. US	Innovation Indoor Environmental Quality Materials and Resources Location and Transportation Sustainable Sites Energy and Atmosphere Water Efficiency	Recycling content part of the criteria, but not weighted that much; for structural products established in the USA and also the Arabian world
ÖGNB/TQB Total Quality Building	Austrian Sustainable Building Council 	AT	Location and Facilities Economy and Technical Quality Energy and Supply Health and Comfort Resource Efficiency Life Span =100 years	1000 credits: 200/category Economy + Technical 200 cr Energy + Supply 200 cr Resource Efficiency 200 cr Disposal indicator; https://www.oegnb.net/en/zertifikat.htm?typ=hs TQB is fully compatible with TC350, EN 15805 and ISO 14025
klimaaktiv	Klimaaktiv, Austrian national initiative on climate change	AT	Location and Quality Assurance Energy and Supply Resource Efficiency Health and Comfort Life Span =100 years	1000 credits: Focus an energy efficiency and climate change (500 credits); circularity aspects to be integrated in revised version; klimaaktiv and ÖGNB/TQB are harmonized
DGNB	Deutsche Gesellschaft für Nachhaltiges Bauen	GE / Int.	Ecological Quality (22,5%) Economic Quality (22,5%) Social Quality (22,5%) Technical Quality (15%) Process Quality (12,5%)	Environmental aspects are addressed by 22,5 %; Newly introduced circular-economy-boni for measures supporting circularity in 2018 version;

Name	Organisation	Application /country	Categories	Criteria on circularity/ weighing/comments
	DGNB		Quality of site (5%)	90 % of buildings certified in German speaking countries, rest international
LIDERA	Instituto Superior Técnico, Lisboa LIDERA	PT	Site and Integration, Efficiency of Resources Environmental Loadings Environmental Comfort Socioeconomic experience Sustainable Use	A+++ to E level. E represents usual practice and A has a 50% better performance than E. Level A+ corresponds to a factor 4 (or 75%), level A++ to a factor 10 (or 90%) and level A+++ to a regenerative factor.

Note: Certification schemes are under revision periodically, where criteria and thresholds are changed or updated. Please check the web pages for developments regarding the integration of circular economy aspects into the certification schemes.

For the **LCA of building components and buildings there are several online tools available** e.g. Eco2Soft (https://www.baubook.info/eco2soft/?SW=27&lng=2). In the test version you can see various results for demo buildings in Austria. Figure 7.17 shows the results for an exemplary floor construction; figure 7.18 the results for a whole building. With the **OI3 index** the environmental quality of building materials in terms of the Global warming potential (GWP, kg CO_{2eq}), acidification potential (AP, kg SO_{2eq}) and non-renewable primary energy demand (PENRT in MJ) (IBO, 2018) is displayed. The higher the number of the aggregated result (in points, here: ΔOI3 = 248 Pkt/m² floor), the higher the negative impact of the construction element or of the building on the environment.

EFu01_a

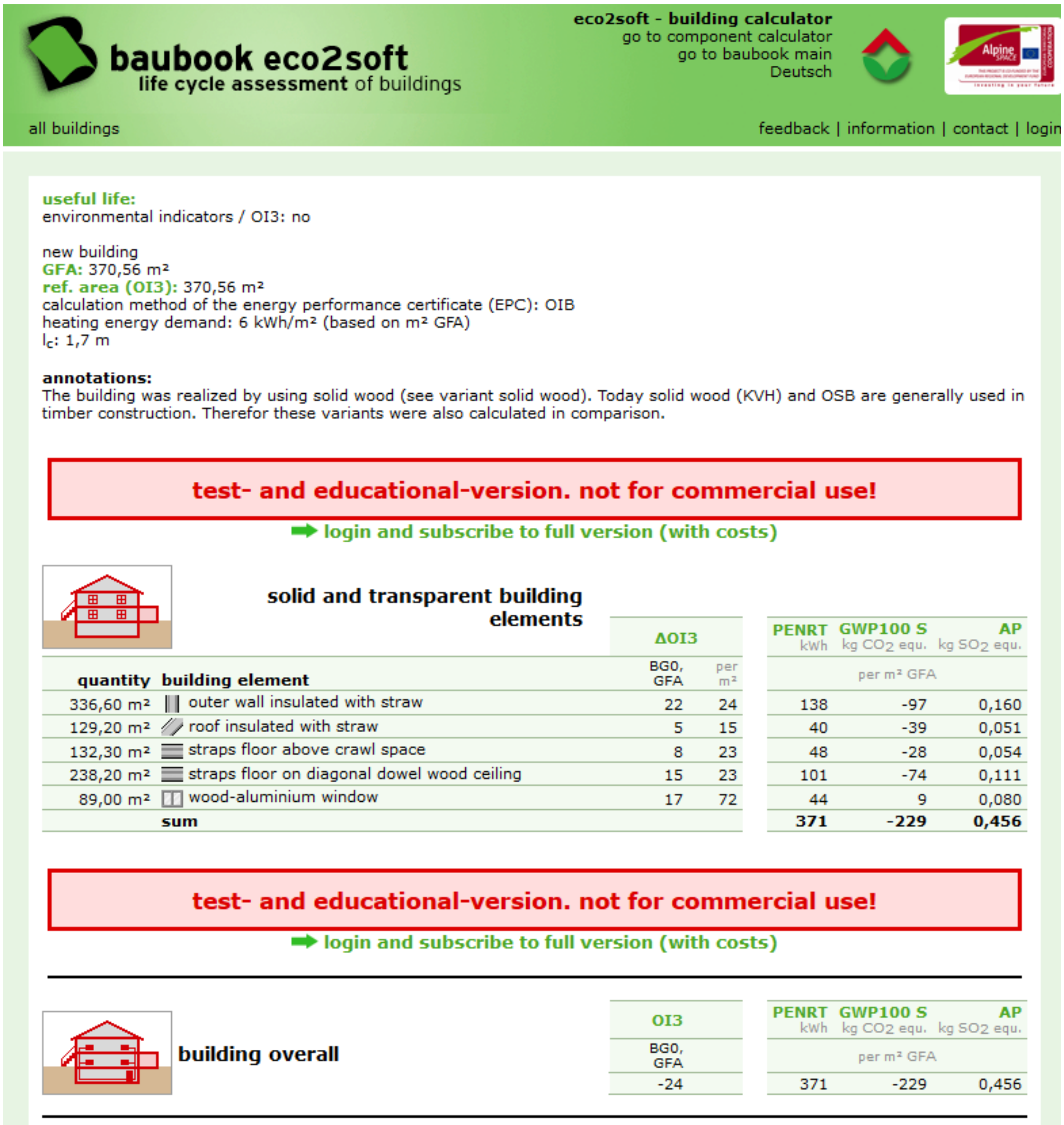


Floor: in contact with ground – heat flow descending (BG6)

no.	type layer	d cm	λ W/mK	R m²K/W	ΔOI3 pts/m²
1	Solid parquet	1,00	0,160	0,06	[2] 41
2	Parkettklebstoff	0,06	0,900	0,00	[2] 7
3	Zementestrich	5,00	1,700	0,03	18
4	Building paper	0,03	0,170	0,00	0
5	Holzfaser-Dämmplatte (100 < roh <= 160 kg/m³)	3,00	0,048	0,63	10
6	Waterproof concrete with 160 kg/m³ reinforcing steel (2 vol. %)	20,00	2,500	0,08	70
7	Polyethylene (PE) sealing sheeting	0,04	0,500	0,00	[2] 1
8	Schaumglasplatte (roh <= 105 kg/m³)	24,00	0,041	5,85	75
9	Polymer bitumen sealing sheeting	0,78	0,230	0,03	[2] 19
10	Magerbeton / Schütt- und Stampfbeton / Aufbeton	5,00	1,330	0,04	4
11	Building paper	0,03	0,170	0,00	0
12	Sand, Kies jeweils feucht 20%	15,00	[6]	[6]	2
13	PP fleece	0,02	0,220	0,00	1
	R_{si} / R_{se} =		0,170 / 0,000		
	R' / R'' (max. relative error: 0,0%) =		6,898 / 6,898		
	building element	**73,966**		**6,898**	**248**

Figure 7.17 - LCA results on component level, example parquet floor (baubook eco2soft s.a.).

The following figure shows exemplary LCA results for the selected environmental impact categories for a whole solid wood building.


baubook eco2soft
life cycle assessment of buildings

eco2soft - building calculator
go to component calculator
go to baubook main
Deutsch

all buildings

feedback | information | contact | login

useful life:
environmental indicators / OI3: no

new building
GFA: 370,56 m²
ref. area (OI3): 370,56 m²
calculation method of the energy performance certificate (EPC): OIB
heating energy demand: 6 kWh/m² (based on m² GFA)
l_c: 1,7 m

annotations:
The building was realized by using solid wood (see variant solid wood). Today solid wood (KVH) and OSB are generally used in timber construction. Therefor these variants were also calculated in comparison.

test- and educational-version. not for commercial use!
login and subscribe to full version (with costs)

solid and transparent building elements

quantity	building element	ΔOI3 BG0, GFA	ΔOI3 per m²	PENRT kWh per m² GFA	GWP100 S kg CO_2 equ. per m² GFA	AP kg SO_2 equ. per m² GFA
336,60 m²	outer wall insulated with straw	22	24	138	-97	0,160
129,20 m²	roof insulated with straw	5	15	40	-39	0,051
132,30 m²	straps floor above crawl space	8	23	48	-28	0,054
238,20 m²	straps floor on diagonal dowel wood ceiling	15	23	101	-74	0,111
89,00 m²	wood-aluminium window	17	72	44	9	0,080
	sum			**371**	**-229**	**0,456**

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building overall

OI3 BG0, GFA	PENRT kWh per m² GFA	GWP100 S kg CO_2 equ. per m² GFA	AP kg SO_2 equ. per m² GFA
-24	371	-229	0,456

Figure 7.18 - LCA results on building level (baubook eco2soft s.a).

The **EI10 disposal indicator** takes after life scenarios like recycling, thermal recovery or disposal into account in order to calculate, compare and optimize **after life properties** of components and materials at building level. So far, alternative scenarios like reuse or long lifetime are not considered in this semi-quantitative indicator (rating from 1-best to 5-worst option) which is integral part of assessment schemes in Austria (IBO, s.a.). The higher the expenditure for dismantling and recycling and the more negative the effects of disposal are on the environment, the worse the classification at building material level (like a five-part grading scale).

7.4.3 Assessment and communication on product level

The ISO committee has classified ecolabels and declarations into three types: type I or certified ecolabels; type II or self-declarations of environmental products; and type III or environmental declarations of products (ISO 14020, 2000).

The environmental impact of products can be communicated via an **EPD – Environmental Product Declaration** (type III), which summarises verified, and transparent information based on the results of an LCA (see also the *Communication* chapter). EPD do not award products performing better than alternatives like Environmental labels (type I) but display third party verified information on the environmental impacts along the life cycle. EPD are based on **ISO 14040** and **ISO 14025**. Additionally, product category rules set specific requirements along the products life cycle for a specific product group ("category").

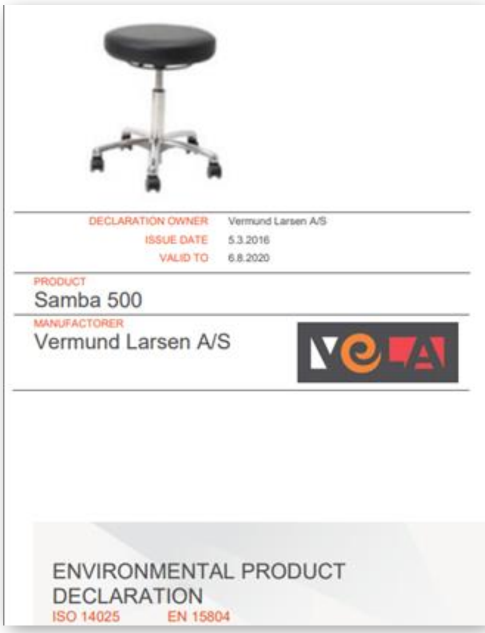

Figure 7.19 - Exemplary EPD of a cushioned classic stool (Vermund Larsen Sverige AB, 2016).

Product category rules (PCR) define the rules and requirements to conduct the associated LCA and to communicate their results through an EPD of a certain product group (category). The PCRs enable transparency, consistency, harmonization and comparability between EPD. In the construction sector, the European standard EN 15804 offers basic rules for construction products, which must be supplemented by specific rules for each product category (stand-alone construction products and construction products and services). For furniture there is a PCR Basic Module (nr. 381) which can be used as guidance document or template when developing PCRs but does not constitute a PCR document in itself. In case no PCR for the requested product is available, expert committees can establish one in case there is an interested community of e.g. planners, building contractors, builders, associations using it.

The figure below shows the procedure and necessary steps prior to issuing an EPD.

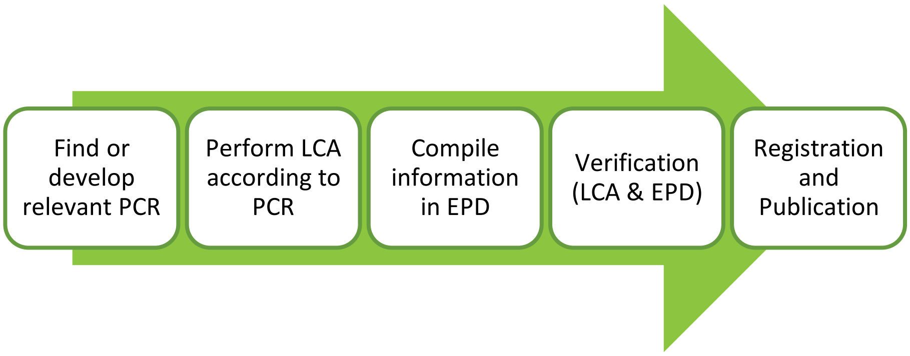

Figure 7.20 - Steps to create an EPD (EPD International AB, s.a.).

There are several companies performing, verifying and managing EPD. Ecoplatform (https://www.eco-platform.org/the-eco-epd-programs.html) is the European platform that hosts the largest number of national and international EPD programmes.

For labelling outstanding **single or multi criteria aspects,** there are reliable **third party verified environmental labels** (type I) e.g. like the Nordic Swan for furniture and fitments. Furniture and fitments labelled with the Nordic Swan have the lowest environmentally impact in their category. The requirements are based on a life cycle assessment of the product and requirements are imposed on production, use and waste. The requirements promote the use of certified wood raw materials and recycled plastics and metals and use of fewer substances that are harmful to health and environment, a high degree of durability and recyclability. Also, the Nordic Ecolabel provides criteria for construction specific products (like 010 Construction and facade panels, 096 Indoor paints and varnishes or 102 Renovation). For some building certification schemes, the use of environmentally labelled products is part of the assessment criteria.

In contrast to Environmental Product Declarations, environmental labelling type I aims at distinguishing products which have a better environmental performance in comparison to average products of the same kind and should support B2B as well as end consumer decisions.

7.4.4 Limitations of comparability of different assessment and labelling approaches

There are some limitations when comparing LCA, LCC and SCLA study results, since **the portrayed systems (boundaries, functions, calculation modes, reference units etc.) can be different**. The same is true when comparing EPD.

When architects, designers, building engineers or building planners are using EPD as a source of environmental information in decision-making, he or she must understand their content, limitations and know how to use them in order to interpret them in a correct manner.

In the case of **construction materials**, there is a standard defined at European level that establishes common rules for the category of construction products (EN 15804 **Sustainability of construction works - Environmental product declarations - Core rules for the product category of construction products**); European type III labelling programs take these general rules and adapt them to the different categories of construction products. The same does not apply to the **furniture sector; there is no common general rule**.

When comparing EPD of construction products, the **comparison should be based on the contribution that they make to the environmental performance of the building** (whole building or sub-building level), hence the comparison of EPD information shall be based on the product use in and its impacts on the building and shall **consider the complete life cycle**. Similarly, comparisons of EPD of furniture should be based on the use of the product.

In order to avoid wrong conclusions or misleading interpretation, in the comparison it shall be assured that products or systems portrayed in the EPD…

- have the same functional unit
- accomplish the same functionality
- have equivalent system boundaries;
- identical criteria for the inclusion of inputs and outputs (based on same PCR documents) and
- same or equivalent environmental impact assessment method have been used (based on same PCR documents).

Third-party verification by a program operator as per ISO 14025 also guarantees comparability and liability of the EPD results. Further information on EPD comparability can be found in ISO 14025:2006 (all sectors) and EN 15804 (for construction products).

What to consider when comparing LCA results?

1. The purpose of the LCA should be clear – Why is the LCA performed? To whom and how should the results be communicated?
2. Are the results third party verified and checked for completeness & relevancy of information and consistency of assumptions, methods & data? Has a critical review of the study been carried out?
3. Covered life cycle phases – What exactly is looked at?
4. The functional unit has to be presise and clear – What is the reference unit?
5. The origin of data should be quality assured: Where do data come from? Real data if available and most recent data are best. What database has been used?

7.4.5 Circularity indicators and KATCH_e tools

For the assessment of circularity there are different approaches developed by several institutions and researchers addressing **macro-level** (city, province region or country), **meso-level** (inter-firm), **micro-level** (single-company or consumer) and **nano-level** (products, components) (Saidani et al. 2017, WBCSD, 2018). Analyses show that 19% of interviewed companies measure the circularity of their products or services at Nano level (WBCSD, 2018). At product or component level, several indicators or methods are discussed in the following and matched to the approach developed within the KATCH_e project (see the *Processes and materials* and *Communication* chapters).

A short tool description, characteristics and operating mode of the three portrayed circularity indicators is given in the table below, accomplished by Life Cycle Assessment. Note: LCA is not a tool focusing on circularity; it assesses the potential environmental impacts along the life cycle. As circularity became a big issue in industry, LCA consulting companies react with e.g. the integration of circularity indicators like the MCI into GaBi or SimaPro Software (http://www.gabi-software.com/international/software/gabi-software/gabi-circularity-toolkit/, https://simapro.com/2017/7-steps-to-a-combined-circular-economy-lca-study-in-simapro/).

Table 7.9 - Circularity tools and criteria in comparison, based on Saidani et al (2017), [LCA: Life Cycle Assessment; CET: Circular Economy Toolkit (Circular Economy Toolkit, 2013), MCI: Material Circularity Indicator (Ellen MacArthur Foundation and Granta Design, 2015), CEIP: Circular Economy Indicator Prototype (WBCSD, 2018), MCDA: Multi Criteria Decision Analysis (Niero & Kalbar,2019)].

	LCA	CET	MCI	CEIP	MCDA
Description	Assesses potential environmental impacts of a product system along its life cycle (from raw material extraction to end of use)	Identifies and assesses potential improvement of products' circularity. Provides recommendations of improvement on each step of the life cycle	Methodology for the estimation of the circularity of products and services. Allows comparison of performance with industry´s averages	Evaluates a products circularity performance in the context of Circular Economy	Integrates different indicators by means of a Multi Criteria Decision Analysis, e.g. for circularity of materials like the MCI plus lifecycle-based ones like LCA.
Support	Commercial calculation tools like GaBi, SimaPro, databases like ecoinvent	Dynamic webpage	Excel spreadsheet	Excel spreadsheet	
Inputs needed	Material and energy inputs, Processes for each step of product system,	Answers to 33 questions with 7 sub-categories related to life cycle stages	Different percentages (reused, recycled, virgin) about material origin, utility	15 weighted questions divided into five lifecycle stages.	Depends on the integrated indicators. Combines several

	LCA	CET	MCI	CEIP	MCDA
	Waste for each step	from design to recycling	during usage (usage, intensity, durability, repair, maintenance) and after use (landfill, energy recovery, recycling, reuse). Efficiency of recycling processes for inputs/outputs.		indicators e.g. MCI and LCA based indicators like (kg CO_2-eq) or Acidification potential (AP).
Resulting outputs	Impact assessment, risk categories	Qualitative: improvement potential at 3 levels (high, medium, low) for the 7 sub-categories	Quantitative: the MCI, single score, gives a value between 0 and 1 where higher values indicate a higher circularity.	Quantitative: CEIP score (%) and a radar diagram showing aggregated score for each lifecycle stage.	Quantitative and qualitative, depending on the integrated indicators.
Information	ISO 14040:2006 ISO 14044:2006	circulareconomy toolkit.org	Ellen McArthur Foundation and Granta Design, 2015	WBCSD, 2018	Niero et Kalbar, 2019

KATCH_e tools **CE Analyst including KATCHing Carbon** follow a combined approach**:** The **CE Analyst** quantifies the potential improvement of the environmental profile of a given linear product, when different circular scenarios (such as share, repair, and reuse) are applied. The results show the changing LCA profile after applying certain circular strategies. A basic environmental profile of a linear product over the five life cycle phases (raw materials, manufacturing, distribution, use, disposal) is needed which can be calculated using the **KATCHing Carbon** tool. The benefit of this approach is that one is not left with the result but gets supported in improving the environmental profile with selected circularity strategies. Were and what to change is suggested.

On the KATCH_e Knowledge Platform you find case studies on various products where the tools have been applied for the development of innovative product-service concepts and accustomed business strategies (https://www.katche.eu/knowledge-platform/other-resources/case-studies/).

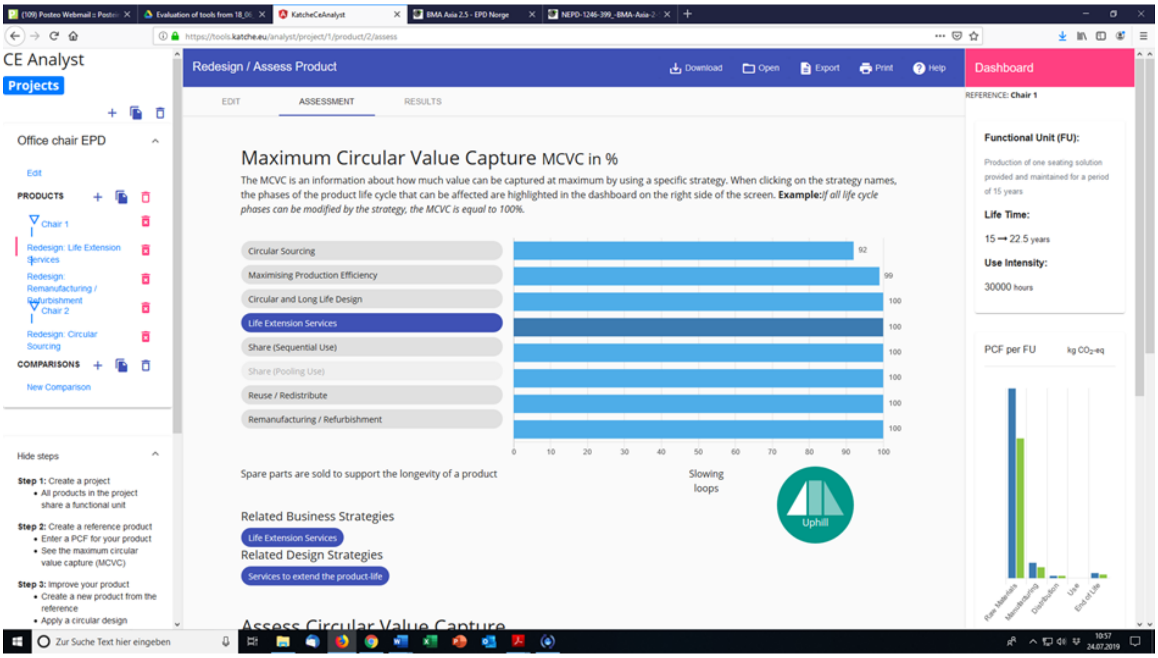

Figure 7.21 - Maximum Circular Value Capture with the CE Analyst tool (KATCH_e, 2019).

The CE Analyst tool support in getting an idea, which design, and business strategies could be relevant from environmental perspective for the improvement of the circularity performance. **Strategies** having a very **high Maximum Value Capture Potential** are highlighted and should be considered for further **product improvement.**

The Material Circular Indicator, MCI, allows the quick assessment of a product's circularity. Further developments would allow the assessment for each product part in a quantitative way. Input would be needed on the weight and type of raw materials used, after use scenarios, which parts are repaired, lifetime, functional unit and transport at local, national or international level.

Assignment 7.16 - Application of KATCH_e tools

Select a furniture or construction product and try out the applicability of the KATCH_e tools. Compare the results and discuss.

Assignment 7.17 - Check of existing certification schemes/eco labels

Are you familiar with a specific building certification scheme or eco label for furniture/construction products? Compare the criteria of the scheme/eco label and check the adaptability concerning circularity indicators (product or building level).

Input for assignment 7.17: The following table shows the exemplary comparison of two Austrian building certification schemes and their coverage of environmental indicators and impacts from construction products in the life cycle according to ÖN EN15804 Building Product LCA Standard. This table is also relevant for the assessment of the whole building, including hundreds auf construction products and technologies. The comparison shows a **partly coverage of circularity aspects in the existing assessment schemes**, e.g. the percentage of secondary raw materials or the potential for reuse or recycling and thus the **limitations for the assessment of building technologies or product characteristics in terms of circularity**.

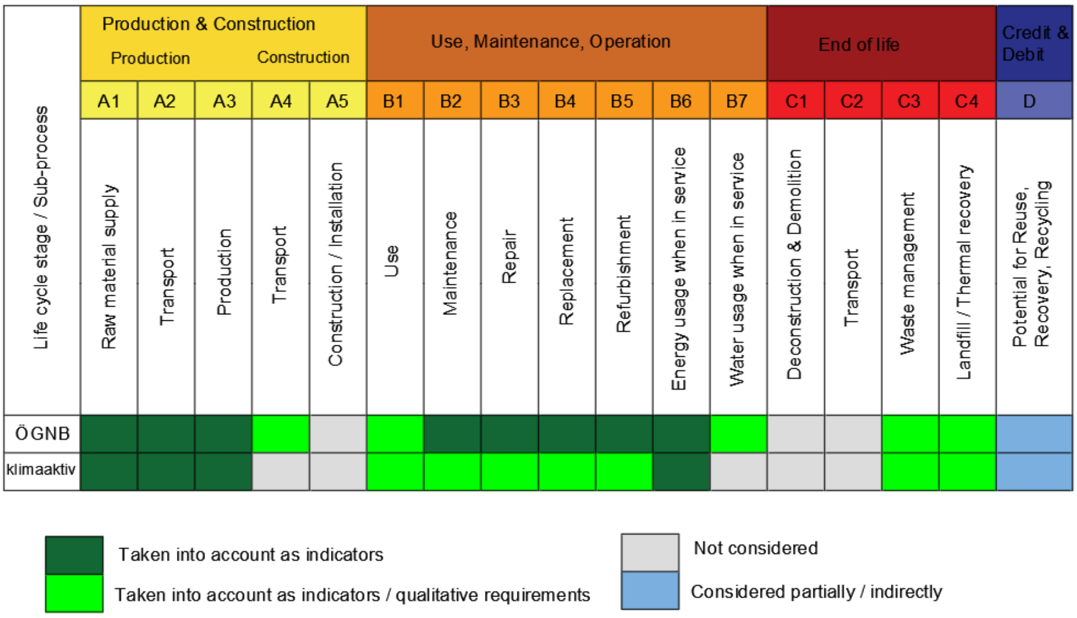

Figure 7.22 - Coverage of environmental indicators and impacts from construction products in the life cycle according to ÖN EN15804 (ÖGNB, 2018).

The Circular Economy Toolkit: The figure below shows the potential improvement results for a parquet floor with generic data using the Circular Economy Toolkit. After answering several qualitative questions along the life cycle of the parquet floor the improvement potential has been classified as high.

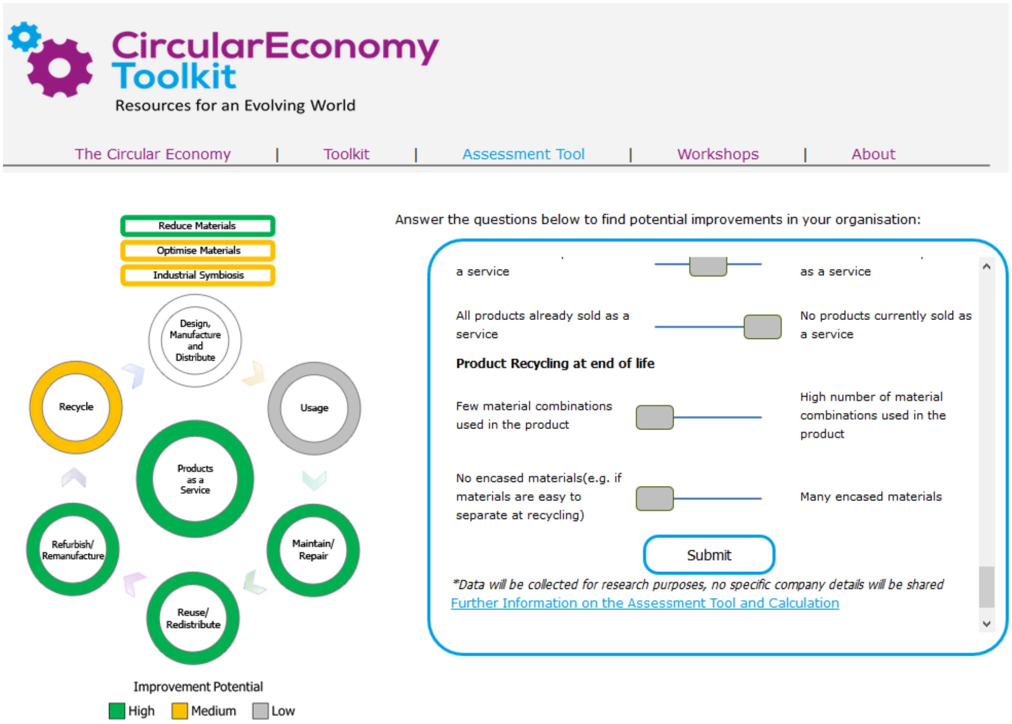

Figure 7.23 - Improvement potential for parquet floor (assumptions) (Circular Economy Toolkit, 2013).

Assignment 7.18 - Application of selected methods

Apply the CET and MCI for the reference product parquet floor and compare, analyse and discuss the results.
CET: http://www.circulareconomytoolkit.org/
MCI: https://www.ellenmacarthurfoundation.org/resources/apply/circularity-indicators

Summary of characteristics to be included when assessing the circularity of products or buildings

The key influencing factors on the circularity of products and buildings are considered

- Life span
- Material use and
- Construction principles

which are discussed in detail in the *Design and development* chapter.

Life span: The life span of buildings, components and construction materials plays a key role in defining the circularity potential. Building components that last twice as long as alternative products could be manufactured at greater expense and still lead to a better performance in the overall consideration. The working life of a construction material commences with the incorporation of the construction material into the building in question and ends with the disassembly. The life span of products is also very relevant when assessing and improving the circularity of – especially raw material intensive – products.

Note: Basis for calculating the life span is the **technical lifespan**. The technical lifespan is defined as the period from the construction of a building or part (or production of a product) up to the time where it no longer meets functional or aesthetical requirements. Not only the **inherent material properties**, but also other factors influence the technical lifespan, such as environmental influences, user behaviour or planning and implementation errors.
The **working life** of material and products includes not only the technical lifespan but also economic, aesthetic, comfort-related and hygiene-related factors. These demands imposed may mean that components have to be replaced earlier than would otherwise be the case based on their technical lifespan. The technical lifespan can thus be considered the maximum attainable working life. Declaring the end of the working life of a material layer may also involve disassembling and destroying other material layers that still have plenty of working life remaining - earlier than desired or necessary.

Besides the inherent material properties (see also the *Processes and materials* chapter) and options for slowing and narrowing resource loops via using secondary raw materials or reuse products, the **design and construction principles** have major influence on the circularity of products.

Application of indicators and discussion on selected EPD

Assignment 7.19 - Use of EPD data as input for the application of selected indicators

1. Choose an EDP with scope cradle to grave, for instance from https://www.environdec.com/ or http://www.bau-epd.at.
2. State the important technical information of the EPD, if given in the text (system boundaries, functional unit…). Note: as per 2019 not many EPD cover the whole life cycle, most of them only show the production stage (modules A1-A3). This will change in future times following updated standards (modules A-D mandatory to declare).
3. Apply the KATCHing Carbon tool to your selected product based on EPD data, analyse the results and discuss the difficulties you had with the tools and their benefits.
4. Compare your product to the list of Critical Raw Materials (European Commission, 2017b) – which of the listed critical materials are used in your product?

Illustrate the life cycle of your product.

In the following two possible assignments are suggested for the application of different indicators and analysing their applicability on basis of given EPD results.

Assignment 7.20 - Application of indicators based on EPD and comparison of options

1. Choose two EPD of similar/comparable products, for instance from https://www.environdec.com/ or http://www.bau-epd.at.
2. State the important technical information of the EPD, if given in the text (system boundaries, functional unit…). Note: as per 2019 some EPD cover the whole life cycle (cradle to grave), most of them only show the production stage (moduless A1-A3).
3. Illustrate the life cycle of your products.
4. Discuss the differences of the two chosen products, analyse possible limitations of their comparability (check on PCR documents followed if any) and explain which one is more circular in your opinion.

7.5 Examples

Long-life products for a hotel

Description	With the example of hotel room furniture, the role of Life Cycle Thinking and link to product and service design has been shown and consequences on later life cycle phases discussed (see section 7.3 of this chapter and also the MOOC). As reference example serves a Swiss hotel, where the reduction of resource consumption and waste production is of major concern. Product design decisions and their related consequences on different stakeholders have been demonstrated.
Organization and country	Bildungszentrum21, CH
Sources	Own visit, pictures and reflections by Austrian Institute of Ecology
Images	  Hotel room and detail of bed, Bildungszentrum 21 Basel, https://bz21.ch/
Summarizing aspects along the life cycle	- Raw materials – durability, quality, certified sources, no harmful substances - Production – simplified product architecture, easy replacement of components - Use – timeless and customized design, user-friendliness, no toxic materials - End of life – suitable for re-use, possible refurbishment, exchangeable parts
Sector	Furniture
Circularity approach(es)	Slowing loops

Reuse of construction components – example window, by BauKarussell

Description	Clearing out of buildings is the first operational activity that occurs in the dismantling process. Project developer often cannot overview the operational work done easily and the potential for reuse or recycling of components and material remains locked in most cases. BauKarussell, a Viennese start-up, offers services for the development of a dismantling concept for buildings including risk analysis, assessment for the reuse potential of components and operational implementation. On the Knowledge Platform there is a case study on BauKarussell where design strategies and implementation ideas have been elaborated for Design for Reuse and Remanufacturing.
Hints for overcoming obstacles for reuse	- Prepare construction details to train workers for proper disassembly - Technical indicators allow reuse according to the national construction legislation - Analyse if the design of the product system allows refurbishment, e.g. aluminium front layer and wooden corpus - Clarify who is responsible for linking the planning process of dismantling and the process of planning the new building? Window provider might be willing to take back the used windows and refurbish them for the new one. - Plan the reverse logistic system. Where is intermediate storage possible?
Organization and country	AT BauKarussell Beschäftigung & Kreislaufwirtschaft
Sources	https://www.baukarussell.at/
Images	 
Sector	Construction
Circularity approach(es)	Slowing, narrowing, closing loops
Additional information	On the Knowledge Platform you find a case study on BauKarussell with design strategies on the reuse and refurbishment for windows, doors and floor boards.

Environmental profiles of products, by Wiesner Hager Möbel GmbH

Description	The main environmental impacts of furniture refer from the materials used. With carefully selecting materials, increasing efficiency in resource use and extending durability the environmental impact can be reduced. The environmental impacts of products based on Life Cycle Assessment are more and more communicated via Environmental Product Declaration (EPD) in industry. But does an EPD give information on the circularity of products? What are promising strategies concerning circularity?
Organization and country	Wiesner Hager Möbel GmbH, AT
Sources	https://www.wiesner-hager.com/de/produkte/stuehle/macao-stuhl-230
Images	  Which of the chairs for commercial uses has the better environmental profile? What would be the suitable functional unit? 1 piece of furniture lasting 15 years or 1 person sitting for 15 years? What makes the difference?
Summarizing aspects along the life cycle	- Raw materials – Durability, quality - Production - Simplified product architecture, easy replacement of components - Use - timeless and customized design, user-friendliness, no toxic materials - End of Life - suitable for re-use, possible refurbishment, exchangeable parts
Sector	Furniture
Circularity approach(es)	Slowing, narrowing loops
Additional information	See section 7.3 in the MOOC for more discussion on the comparability of LCA results and EPD.

Modular and versatile buildings by LukaLang

Description	Lukas Lang building technologies offers modular construction systems that make buildings flexible so one can adapt them to spatial requirements at any time. Lukas Lang builds turnkey wooden houses but also raises construction to a new industrial dimension with the modular construction system. VALUE RETENTION and sustainability are core characteristic of their business model: - Due to detachable connections the size and floor plans of the buildings can be adapted at any time to new life or work circumstances or a different use. - Maximum life-time-value of the components is guaranteed — they can be assembled, disassembled and used somewhere else while retaining their value - Service/Business model approach: Take back guarantee once the building reaches it (first) end of life and possibilities for remanufacturing or recycling
Organization and country	LUKAS LANG Building Technologies GmbH, Austria
Sources	Company Website: https://www.lukaslang.com/en/home/
Images	 
Sector	Construction
Circularity approach(es)	Slowing, narrowing loops
Design Strategies	Design for long-life products, Design for product-life extension, design for materials sustainability, design for dis- and reassembly, design for remanufacturing, design for reverse logistics services
Additional information	See company webpage for further information https://www.lukaslang.com/en/philosophy/value-preservation/ https://www.lukaslang.com/en/building-diversity/family-house/

Ceramic Sustainable Urban Drainage System by Life Cersuds

Description	In the CERSUDS project, funded by European LIFE program, a sustainable urban drainage system (SUDS) that uses ceramic tiles used are of low commercial value or have no market value (considered as waste by the companies) as a flooring filter system has been developed. This has been done by designing and implementing a sustainable urban drainage system (SuDS) demonstrator. The demonstrator consists of a permeable surface (picture left) whose skin is constituted by an innovative system of low environmental impact based on the use of ceramic tiles of low commercial value and wastes in stock (picture right) transforming it into an aesthetically positive product with a high drainage capacity.
Organization and country	LIFE CERSUDS, Ceramic Sustainable Urban Drainage System, ES
Sources	LIFE CERDUS Project http://www.lifecersuds.eu/en
Images	 
Sector	Construction
Circularity approach(es)	Closing, narrowing loops
Design Strategies	Design for recycling, Design for materials sustainability, Design for energy sustainability
Additional information	On the Knowledge Platform you find two case studies for further information on the environmental profile of different material options - Case study CERDUS KATCHing Carbon and on options for the improvement of the environmental profile - Case study CERDUS CE Analyst and CE Designer.

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08

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Communication

Contents

Executive summary 407

8.1 Introduction to communicating circularity 408

8.2 Guidelines and techniques for communicating circularity....... 414

8.2.1 Creative narration: storytelling and storyboard 414

8.2.2 Educational messages 418

8.2.3 Calls to action....... 419

8.2.4 Cognitive dissonance....... 420

8.2.5 Circular Economy Communication Canvas....... 421

8.2.6 Information representation....... 422

8.3 CE specific communication tools 429

8.3.1 Cradle to Cradle (C2C) design certification and communication tool 429

8.3.2 The Circle Assessment Tool....... 431

8.3.3 Material Circularity Indicator (MCI)....... 431

8.3.4. Circularity Indicator (CI) – adaptation from MCI....... 433

8.3.5 Sector specific communication tools....... 436

Furniture specific communication tools....... 436

Building specific communication tools 436

8.4 Environmental labelling and Product Declarations and its relation with CE....... 438

8.4.1. ISO labels and Product Declarations 438

8.4.2 Lifespan labelling 440

8.5 Examples of circularity communication....... 441

Bibliography 446

Executive summary

8.1 Introduction to communicating circularity

Reflects on why communication of circular products and services is important. It aims to demonstrate the practical application of circular economy (CE), to increase awareness and to change perceptions. Communication also plays a role during co-creation of CE solutions and models, inspiring and encouraging knowledge sharing. Designers have to think about the product/service and about how to communicate it during the design process. For an effective communication, companies need to apply the communication strategies both internally and externally considering their supply chain and stakeholders. It explains the British Standard 8001:2017 part on developing a marketing approach for CE in organisations and some communication strategies for CE.

8.2 Guidelines and techniques for communicating circularity

This is the most extensive section. It describes the main general techniques for communicating circularity: Creative narration through storytelling and storyboards, educational messages, calls to action, cognitive dissonance and Circular Economy Communication Canvas. Every technique contains at least one example. Then, it shows some recommendations for effective information representation, such as the use of statistics and numerical data, infographics, icons and butterfly diagrams.

8.3 CE Specific circular communication tools

Firstly, 8.3 describes the Cradle to Cradle (C2C) design certification communication tool and the C2C Communication Strategy Tool to help identifying the value priorities within the C2C vision. Then, the section presents the Circle Assessment Tool, the Material Circularity Indicator and an adapted Circularity Indicator. The next section describes sector specific communication tools, as the Green Furniture Mark. The section finishes with a short presentation of assessment tools for buildings that communicate environmental issues related to circularity, as BREAM, LEED, or EGB.

8.4 Environmental labelling and product declarations and their relation to CE

It presents labels and product declarations somehow related to Circular Economy. It describes type I, II and III labels. The section depicts how the Nordic Swan Ecolabel considers circular economy. Finally, it presents a lifespan labelling proposal to communicate lifetime of products.

8.5 Examples of circularity communication

This section provides examples of circularity communication in the furniture and construction sectors are provided.

8.1 Introduction to communicating circularity

Circular economy (CE) is a relatively new concept and there are still many linear products in the market to compete with. So, communication and marketing are very important for CE, since ensuring that new products and services succeed in the market implies that they should be appealing to customers (BSI, 2017. BS 8001:2017). Product **reuse**, **refurbishment** and **remanufacturing** and moving **from products to services** are solutions aligned with circularity that may face resistance from the customers' side, as they may require a new mind-set, a new way of analysing the cost structure and new routines. The success in the implementation of circular economy depends on the ability to trigger a different behaviour in customers. The main objectives of CE communication are, according to Perella (2015):

- To demonstrate practical application of CE.
- To increase awareness of the agenda.
- To change perceptions.

Other objectives are to involve and co-create the CE solutions and models, encouraging knowledge sharing and introducing and inspiring creation of new models to the market. Many stakeholders are involved in communicating circularity. Companies that have adopted CE communication strategies are applying them both internally and externally to their supply chain and stakeholders. Strong communication to engage all stakeholders is crucial for the success of CE (WBCSD, 2016). It is agreed that for an effective CE strategy it is critical to demonstrate practical application of CE. It is a priority to include real life examples, emphasized with data and facts. To reach a broader impact, creative storytelling, educational messages and calls to action are also needed (see next subsections). The whole organization should be involved: from the CEO to the different departments. Thus, defining the communication strategy is also addressed during the design process. Designers have to think about the product/service and about how communicating it. Communication strategies should involve showing **leasing, sharing, no waste options** in fashion magazines, health magazines, influencers' blogs, etc. (Stahel, 2016). This will raise awareness about all stakeholders' responsibility about the products and services lives.

The British Standards Institute has developed a practical framework and guidance document, the British Standard 8001:2017: 'Framework for implementing the principles of the Circular Economy in organizations – Guide', 2017. (BS 8001:2017 from now on). The BS 8001:2017 states that marketing has to be relevant at three customer decision stages:

- (1) Acquisition of a product: whole, in parts or pre-used;
- (2) Adoption of a service model;
- (3) Choice of end of use collection scheme.

The Standard highlights the following aspects for organizations that are developing a marketing approach for CE, summarised in Table 8.1:

Table 8.1 - What to do? Tips for CE marketing. Own elaboration based on "BSI, 2017. BS 8001:2017. Framework for implementing the principles of the circular economy in organizations - Guide," 2017

What to do? Tips for CE marketing	
Perceived economic value	Make sure that the perceived value equals or exceeds the real cost. EXAMPLES: - Re-used products: Reinforce communication, provide good guarantees. - Service instead of selling products (**leasing** or **renting**): Communicate effectively that service costs are lower than ownership
Convenience	Make sure that the product/service fits well in customers' routine and lifestyle. If it is less convenient, (more effort for the end-user/stakeholder), compensate it (saving bonus, returning or discounting money,etc.) EXAMPLES: - Collection Schemes. - **Renting**. (requires the user to access the renting points)
Value-driven factors	Make sure that it reinforces customers' identity drivers: trends, fashions, values, etc.
Claims & declarations	Ensure that the product/service is marketed and communicated in a responsible manner. All claims and declarations must be legal, fair, honest, transparent and sensitive to stakeholders needs, trustful and verifiable (the company has to be able to support claims)
Sales processes	Incentive and train sales people, to prioritize circular products and services

For instance, concerning the convenience, some supermarkets provide machines to collect empty cans and bottles. To motivate end users, these receive discount bonus in return. In Denmark retailers are obliged to take the bottles back (figure 8.1). People get money back for each returned bottle, and the return rate is well above 90%.

Replenish, Smart Refill©, sells bottles and concentrates to use one and again the bottles for cleaning, using water from home. This option may convince users to change from buying cleaning products packaged and shipped in disposable plastic bottles that are used once and thrown away (figure 8.2).

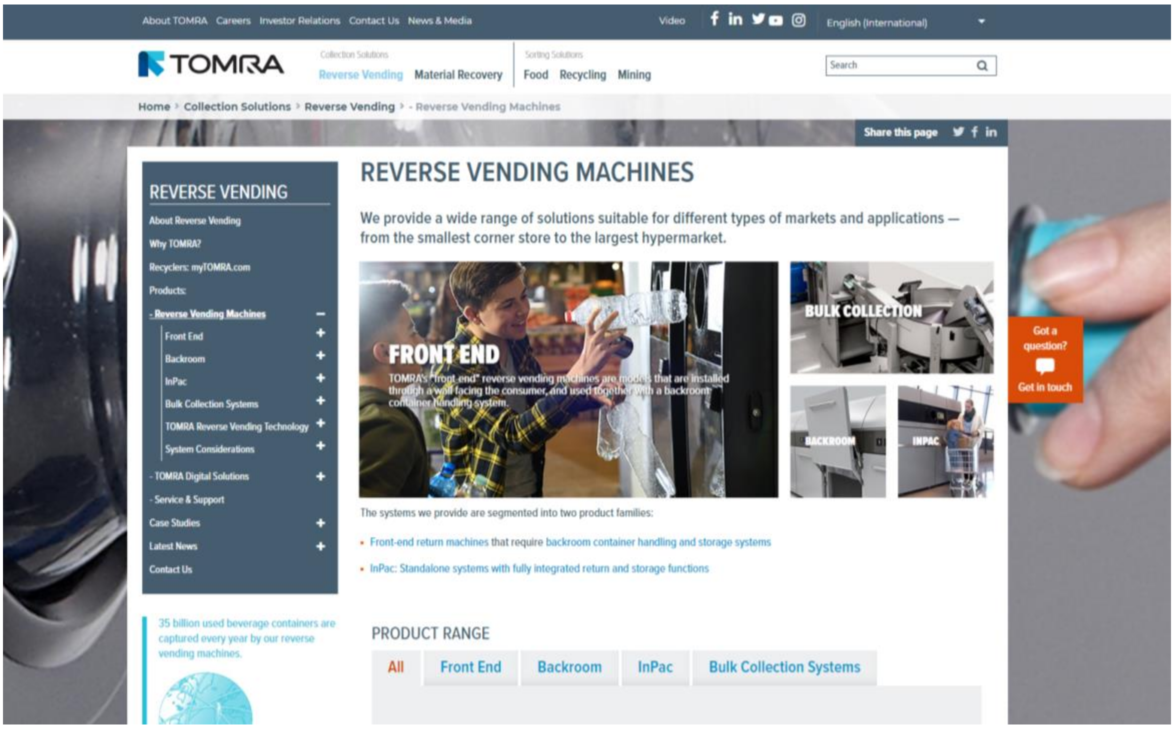


Figure 8.1 - Screen capture of reverse vending machine provider's website:

https://www.tomra.com/en/collection/reverse-vending/reverse-vending-machines

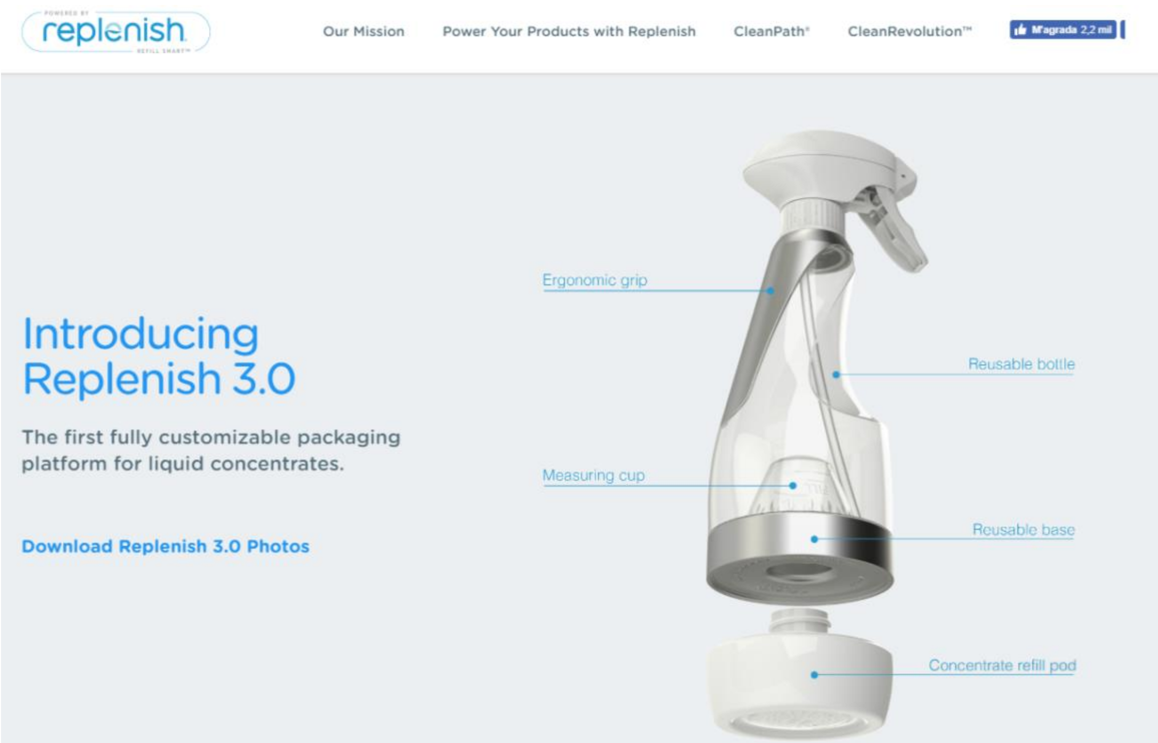


Figure 8.2 - Screen capture of Replenish, Smart Refill© system website's screen capture.

http://www.myreplenish.com/

The consumer perspective in CE is still a new area. A literature review has explored the marketing practice of four clothing companies aligned with CE. As an initial result, they have come up with a list of communication strategies and examples to address each of the consumer factors that they had previously identified as the most relevant for CE. Table 8.2 shows communication ideas particularized for the furniture and construction sectors. Suggested ideas come from exploration of companies' websites as inspired from Chamberlein and Bocks, (2018).

Assignment 8.1

The "Sell your Furniture" IKEA's service consists in (2018, Spain):

1. Fill-in an online form with your personal data, furniture data, pictures and the store where you wish to deliver the furniture.
2. Wait until IKEA gives you an answer and a purchasing prize proposal.
3. Bring your furniture to the store. You have to assemble the furniture. If you need tools to do it, IKEA will provide you those.
4. An expert from IKEA will check that the furniture coincides with the pictures you sent. If so, you will receive an IKEA card with the agreed value.
5. Finally, IKEA puts your furniture to sale in the second chances area for the same amount you have received.

Identify a list of advantages and inconveniences of this process from the user's point of view.

Table 8.2 - Suggestion of communication strategies matching consumer concerns in a CE (Based on Chamberlin & Bocks, 2018).

Consumer factor for CE	Communication design strategies	Examples of communication strategies
Contamination / disgust / newness	Importance, playfulness, rephrasing and renaming, emotional engagement, empathy, personality, framing, choice editing	Reduce the importance of not new. Playful phrases to rename as "better than new". Give personality "heroic, rescued materials". Disinfecting processes of used materials. Each item is unique (non-uniform waste materials are reframed as one-off exclusive pieces). Use of anthropomorphic phrases: compare materials to people, give them a story and reassure customers of their durability. Hand crafted materials. Limited edition products.
Convenience / availability	Encouragement, direction, simplicity, assuaging guilt, worry resolution	Free shipping/Easy return/Trade it in a store near you. Next day delivery (is it sustainable?) Simple steps to follow to rent / acquire the product / service You choose: Standard dimensions or design it yourself in five steps.
Ownership	Meaning, anchoring	Furniture rental. Option to buy it.
Cost / financial incentive / tangible value	Encouragement, rewards, importance, first one free, scarcity, framing	It saves money per use. 20% off in first purchase. 10€ welcome gift to spend in next order. Customers are encouraged to see their waste as valuable. High cost of product implies its status. Financing option available.
Environmental impact	Transparency, simplicity, empathy, obtrusiveness, meaning, framing, emotional engagement, importance, assuaging guilt, direction	Campaign against planned obsolescence. Keep material in motion and avoid landfill. Re-engineer and use for a different purpose.
Brand image / design / intangible value	Meaning, storytelling, empathy, mood, colour associations, importance, emotional engagement, scarcity, prominence, obtrusiveness, expert choice, social proof.	Media and Public Relations endorsement. Creator's personality and lifestyle. Use of social media. Good logo and images in website and ads. Partnership with other well-known companies.

Consumer factor for CE	Communication design strategies	Examples of communication strategies
		Value-based emphasis on repair, reuse and quality. Rescue materials and donate profits as values. Highlight purpose beyond profitmaking. Sustainable luxury.
Quality / performance	provoke empathy, meaning, storytelling, personality, importance, scarcity, expert choice, direction, emotional engagement, worry resolution	Durable at an affordable price. Made in...(a place nearby) → Locally manufactured. High quality assured that last for years → Consideration of the customer's time and money. Timeless designs.
Customer service / supportive relationships	Encouragement, tailoring, transparency, emotional engagement, metaphors, provoke empathy, assuage guilt, reciprocation, importance	5-year guarantee → Free repairing service during that time. Free advisor service. Personalization service available. Local professionals. 'Repair and care' program, 'design to endure' policy. Catchy names. Mailing list, social media and direct mail contact provided. Genuine care for the customer experience. Communication seems transparent and authentic in terms of material sources and manufacture processes.
Warranty	reciprocation, assuaging guilt, worry resolution, obtrusiveness, metaphor, importance	No risk policy. "Our" guarantee offers replacement or refund.
Peer testimonials / reviews	social proof, storytelling, provoke empathy, expert choice, importance, worry resolution	Quotes from global media. Celebrities' endorsement. Customer ratings, reviews and photos. Mass media presence

Assignment 8.2

For the "Sell your Furniture" IKEA's service of the assignment 1, find out a way to communicate that the benefits are higher than the costs or a better way to compensate it.
You can apply and combine the strategies described in Table 2.

8.2 Guidelines and techniques for communicating circularity

Most instruments that can be used for communication are still under development or adaptation. Successful companies use website, blogs, social media and mass media to make visible their mission, their purpose, what they want to achieve, what is the expected impact as well as labels and recognitions. Next subsections explain techniques, resources and tools to communicate circularity and how to apply them.

8.2.1 Creative narration: storytelling and storyboard

Creating CE business opportunities implies the understanding of stakeholders' needs and limitations; flows of materials and product and services logistics. Circular products/services must satisfy the end user while creating value for all stakeholders and reducing negative impact for the environment.

Creating stories during the design process is a way to represent future, non-existing scenarios in a visual, simple and quick manner (Gascá & Zaragozá, 2014). These future proposed scenarios associated to the new ideas about circular products/services can be tested with all stakeholders through as many iterations as needed. Storytelling can also be used at the end of the design process to launch the product/service to market.

Narration consists of telling a story by means of words and images that connect and emphasize with the receivers. It is an ancient technique very applied nowadays. The aim is that the information has a significant effect on the users.

Narration does not need to tell the users how circular a product or service is, but how good the experience would be, emphasizing on the different advantages. A good narration may even make users question their values and actual decisions. The next tips to elaborate a storytelling are based on the following websites: https://www.circulardesignguide.com/post/narrative and on https://medium.com/ideo-stories/how-to-tell-stories-that-influence-people-and-inspire-action-bd1db98d1a01:

- Think about the emotional qualities you want to evoke for users/stakeholders. Which is the main idea you want them to retain at the end?
- Learn about your audience.
    - Are they sceptical about environment and sustainability? Are they concerned? Are they wishing to change the world? If you want to persuade them with a new idea, you will need to help them imagine how good that would be for the world.
    - What is important for your audience? What do they wish/like? What do they fear? Take notice of this, empathise with their emotions and think about how to stimulate and reveal those emotions in the story.

- Create the storyboard **characters** and **setting**.
    - If there are characters: who they are? How many characters are needed? How is their routine and lifestyle?
    - In which context is the challenge or need happening? (place, moment).

- Create the storyboard plot.
    - Does it start with a big challenge? With a common situation in a person's life?
    - Which are the consequences of this unsolved challenge/need? What would the audience like to happen? Which is the reason of that wish? Which are the barriers to get it?
    - What is our innovation? Why is important? What insights brought you to this solution? How will this change your users' lives in some way? How will they feel with this new product/service? Which emotions should be highlighted?

- Construct the story creating a 'through-line' to it and placing all the components.
    - Think carefully about which words to use.
    - Use specific, simple and emphatic language.
    - Be original.
    - If possible, add humour.
    - Choose scenarios and define details that help the audience to identify themselves with the story.
    - Use numbers. Which are the most important numbers to depict the economic, environmental and social impacts of this product/service? If you do not have this data, it is a good idea to estimate them (saving energy, tons of raw material saved, tons of waste recovered, number of Jobs created, saving space, saving time, etc.). The book by Berners-Lee (2011) is a good example of using numbers for simple and effective communication.
    - Think about the images that will go with the story and create a draft storyboard.
    - It can include a call to action (see later).

- Test it. **Prototyping** and **testing** is very important and several iterations are needed. Draft your story in different ways and show them to different people. Then, get their feedback and use it

- Implement and disseminate it.

Figures 8.3 and 8.4 are taken from two storytelling examples related to CE:

Veolia:

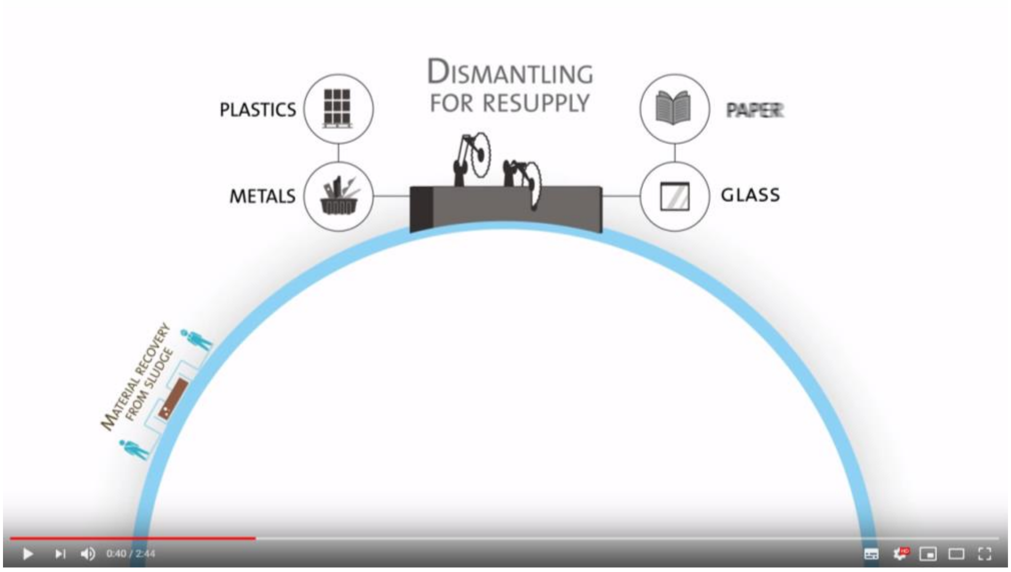


Figure 8.3 - Snapshot of Veolia's video on CE - https://www.youtube.com/watch?v=30MOeH3CGsQ

Ikea:

Figure 8.4 - Snapshot of IKEA's video 'Give your furniture a second chance'.

https://www.youtube.com/watch?v=WNHyJWR27yg

Figure 8.5 depicts a storyboard created to show the advantages of an adaptive stroller:

		
Hi, everyone! I'd like to tell you the story of Pablo.	His parents have been planning for his arrival for some time now, and they are very excited because he is going to be born soon.	Among the different arrangements to be made, they need to choose a stroller. It is not always easy, as there seem to be many aspects to consider.
 		
They ended up deciding on a very versatile model.	At last, the big day comes – look how comfortable Pablo is in his stroller! It seems they made the right choice.	Some time later, everything changes… Pablo's little brother, Alex, is joining the family soon.
	 	
Thanks to the stroller they chose, all they need to buy is	That is how the parents avoided buying a second	Now, Pablo has grown up and he prefers to walk. His parents

as coupling mechanism to carry both children at the same time.	individual stroller or a twin stroller.	return to an individual stroller for Alex by removing the coupling mechanism.
		
In sum, they didn't need to buy a second stroller. They have spent less money and their storage room is not so full. Furthermore, they have made better use of the planet's resources, with the ensuing savings in raw materials.	Counting up all the children that are born before their elder sister or brother is two years old, by using a convertible stroller, it would be possible to save up to 250 tonnes of strollers a year Spain alone!	Hence, if we prolong the use of the products we have, we are benefitting ourselves and looking after the environment.

Figure 8.5 - Storyboard to show the advantages of an adaptive stroller.

https://vimeo.com/129596346 (Royo González, 2016)

Assignment 8.3

Gispen is a furniture company in the Netherlands involved in Circular Economy.
Look at the "Cabinet becomes sofa" or other repurpose-remade example in their Website: https://www.gispen.com/en/.

1. Think of a creative story following proposed steps in subsection 2.1 creative narration.
2. Draft a storyboard of 8 scenes. You can use the template at the Annex.

8.2.2 Educational messages

For an effective change to CE it is needed that, not only do designers, architects and business people get knowledge and training about it; the whole society needs to understand that CE is an alternative sustainable way. Educational messages have to use a simple terminology and communicate the benefits related to business, environment and society. Myths that might be anchored in people's mind, as "taking care of environment is against economy" must be erased. Changing behaviour is essential.

COTEC, a Spanish Agency for Innovation launched an informative video explaining Circular Economy in March 2017. This video has gained more than half a million visits in a year, arriving to more than a 1.5 million visualizations and more than 6000 comments in May of 2019 (figure 8.6). It is very visual, dynamic, and uses data to emphasize the relevance of CE (COTEC, 2017) retrieved from https://www.youtube.com/watch?v=Lc4-2cVKxp0.

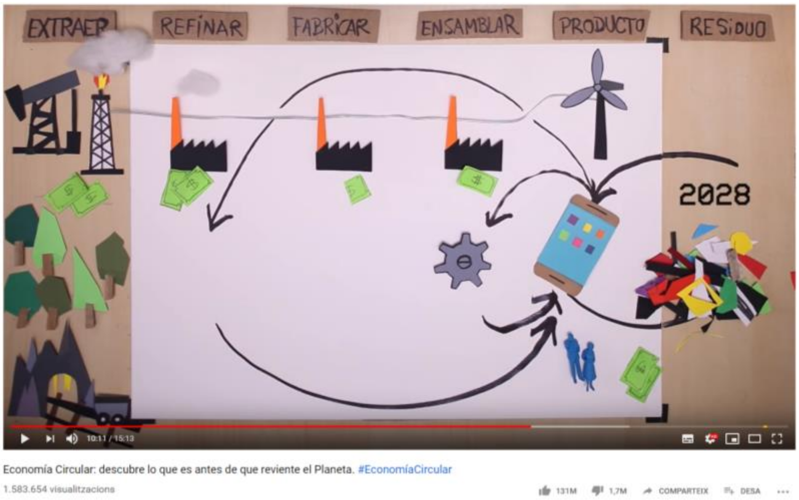


Figure 8.6 - Snapshots of COTEC video about Circular Economy. https://www.youtube.com/watch?v=Lc4-2cVKxp0

8.2.3 Calls to action

Calls to action search a massive support and a kind of answer by people. Answers can be in form of signing a request, making a donation, reproducing a symbolic act, etc. Calls to action can be addressed to governments, institutions and companies. Platforms as Change.org are an easy way to spread calls to action.

At the end of 2013, Dave Hackens from PhoneBlocks (figure 8.7), launched a call to action to persuade industry to invest in a modular Smart phone. This phone should be able to be updated and adapted during the whole life of the user. The campaign has been seen up to 22 million times and it called the attention from investors. It also sensitized the consumers, making them think about using a phone for longer.

Figure 8.7 - Phonebloks' video explaining the advantages of a modular smart phone. https://www.youtube.com/watch?v=oDAw7vW7H0c

Other example is Tristam Stuart's Stop food waste in Europe campaign in Change.org. (figure 8.8).

Figure 8.8 - Call to action to ask the European Parliament to stop wasting food. https://www.change.org/p/frans-timmermans-stop-food-waste-in-europe-stopfoodwaste

8.2.4 Cognitive dissonance

One of the limitations of persuading by means of arguments to change attitudes is that their effect is often temporal. It lasts until the person thinks or hears about a stronger argument to take a different position.

For instance, one may believe that he/she is responsible for the environment, and at the same time he/she consumes and wastes more than needed. A negative feeling may arise, that disappears the moment he/she sees a commercial of the newest version of a laptop at a very good price.

Cognitive dissonance is the discomfort we feel when we are aware that our behaviour is incongruous with our values and believes. This is what makes cognitive dissonance more powerful to produce changes, since it is a challenge to a person's self-concept. To reduce dissonance, one needs to rethink his/her actions or to justify them (DICKERSON, Thibodeau, Aronson, & Miller, 1992).

To address cognitive dissonance in the context of CE, the next steps could be followed:

- Identifying believes that go in line with CE.
- Identify behaviours dissonant with those believes.
- Show alternatives that would reduce that dissonance and at same time approach to the CE paradigm.

Figure 8.9 shows an example of cognitive dissonance.

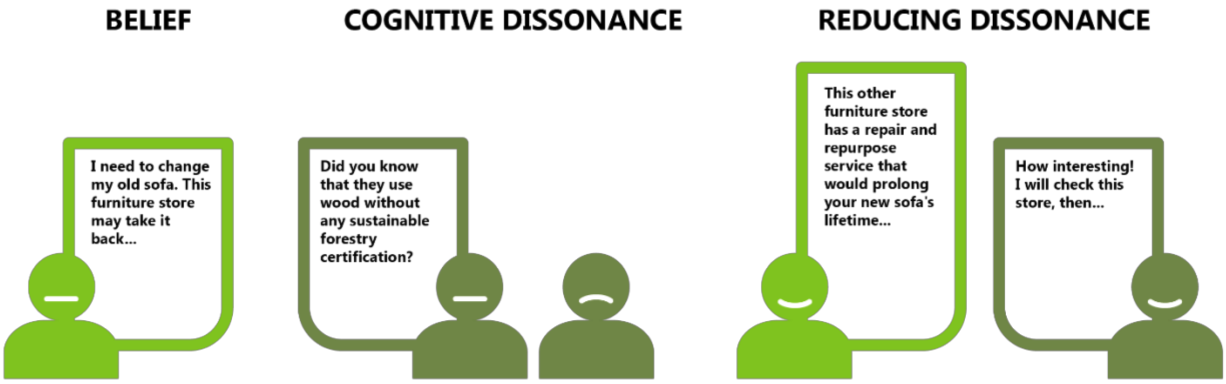


Figure 8.9 – Cognitive dissonance example.

Assignment 8.4 (suggested for working in groups or pairs)

Imagine a user that needs to change his/her kitchen.

1. Identify believes that would go in line with CE.
2. Identify behaviours dissonant with those believes.

Think of alternatives that would reduce that dissonance and at same time approach to the CE paradigm.

8.2.5 Circular Economy Communication Canvas

A study identifies eight key elements for effective CE communication in the fashion sector (Han, Henninger, Blanco-Velo, Apeagyei & Tyler, 2017). The representation of these elements follows the traditional Canvas model format, widely used in business models, adapted to the development of communication strategies. The final aim is to facilitate decision making of all stakeholders.

Table 8.3 shows the eight elements to build the Communication Canvas.

Table 8.3 - Circular Economy Communication Canvas components. Adapted from Han et al, 2017

Circular economy communication canvas	
Market research Trends, competitor analysis, current issues in industry.	Target audience Clear final user profile: income, interests, motivations, lifestyle choices.
Coherence values Clear communication of core values and followed through the supply chain.	Visually engaging Use of creative, short, unique text, images and symbols.

Circular economy communication canvas	
Clear message Why is important what the company is doing? Why users' should stand for this? Communicate with transparency and authenticity how the supply chain follows stands for it	Multichannel Combine online and offline channels to reach a wide audience. Survey research to know preferences.
Compelling products Attractive products that compete with the style, design and prices of linear ones.	Feedback loops Creating feedback loops, collecting recommendations from all stakeholders across the supply chain.

Canvas template represents in an easier way all the elements that take part in the CE communication. Each section in the Canvas template can include drawings, icons and other kind of symbols. All the stakeholders are encouraged to participate and propose new ideas, which will be laid in a visual way in order to understand them easily.

Assignment 8.5

For the case presented in Assignment 8.3 "Cabinet becomes sofa", fill in a Communication Canvas. You can use the template at the Annex.

8.2.6 Information representation

It is very important to pay attention on how information is represented when a communication strategy is implemented. During the design process, it will be necessary to collect the data that demonstrate the advantages and impact of the circular product/service solutions. It will be needed to think and elaborate attractive, original and direct ways to show the information so that the message communicates better. In this sense, next subsections show some examples of ways to represent synthesized and key data related to circularity.

Statistics

Statistics synthesizes numerical data that can be broad and difficult in a simple way. The strength of statistics is that they are easy to remember and have the power to draw a situation with objectivity. As mentioned, Berners-Lee's book (2011) provides many examples of using numbers from calculations for a meaningful communication to the end user.

For instance, for the Replenish company that provides customizable packaging for concentrated liquids, next figure summarizes an example of how this company shows data and statistics, in order to make the costumer aware of the huge amount of plastic that is disposed of every year (figure 8.10).

Figure 8.10 - Data and statistics to communicate concentrates and refilling bottles (Replenish. Smart Refill).

It is usual to combine statistics with visual information, to use together more than one communication channel (figures 8.11 and 8.12). For instance, a mandatory policy package to implant CE in the furniture sector could have an impact of around 156,000 jobs in the EU (EEB, 2017).

Figure 8.11 - Numerical data combined with visual simple draws.

Figure 8.12 - Numerical data combined with picture.

Assignment 8.6

Think of a company that dismantles doors from old buildings that are going to be reformed. Then the company mount these doors in other spaces, like social houses, association venues, etc.

1. Compare this circular against the linear landfill alternative
2. Search or estimate numerical data to reflect the differences. (You may hypothesize about the company size and workload).
3. Think about the simplest and the most direct way to show numerically the advantages of the circular alternative.
4. Show the numerical data like in the previous examples (figures 8.10, 8.11 and 8.12) or in a different way.

Infographics

Communication in an infographics is achieved by a combination of very explicative images that synthesize complex information, and text. It is a more imaginative and non-obvious representation that really informs what it matters.

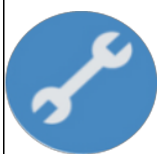
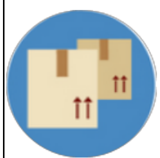
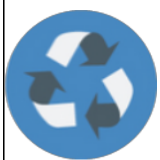
For instance, Fairphone provides an infographic representation of costs (figure 8.13):

Figure 8.13 - FairPhone cost breakdown Infography (FairPhone.com)
https://www.fairphone.com/en/2013/09/12/costbreakdown/

CE related icons

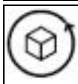
The use of specific icons facilitates the communication and therefore it is a good idea to incorporate them when applying the communication techniques described in this section. Among the proposed icons to express CE are those of the butterfly diagram by Ellen MacArthur (table 8.4).

Table 8.4 - CE icons in Ellen MacArthur Butterfly Diagram

Maintenance	Reuse/redistribute	Refurbish/remanufacture	Recycle
			

A study identified the five most representative design requirements that a circular product should meet: update, disassembly, extension of useful life, repair and reuse. The study provides the following icons (table 8.5) as representative of those requirements with a percentage of correct association between the 85.5% and the 91.5% of the respondents.

Table 5 - Globally selected icons for five CE requirements (Bovea et al., 2018)

Upgrade	Disassembly	Lifetime extension	Reparability	Reuse
				

Assignment 8.7

Insert some of these icons in the storyboard created in the assignments 8.3 or 8.5 with the purpose to make them more communicative.

Butterfly diagram

The Butterfly diagram is a graphical representation, which illustrates the continuous flow of technical and biological materials through the 'value circle'. The *Introduction* section, shows a picture of the circular economy biological and technical loops butterfly diagram published by the Ellen MacArthur Foundation website, https://www.ellenmacarthurfoundation.org/circular-economy/interactive-diagram.

Butterfly diagram can be adapted to show the stakeholders the different loops a particular product/service system reaches.

For instance, a circular system to provide windows for buildings may consist of:

- Parts manufacturers that transform materials into parts;
- Window manufacturer that transform parts into windows;
- Service providers that install the windows in the buildings, repair and collect to reuse and redistribute;
- User, in charge of basic maintenance.

Figure 8.14 depicts these loops following the butterfly diagram technical scheme adapted to this particular case:

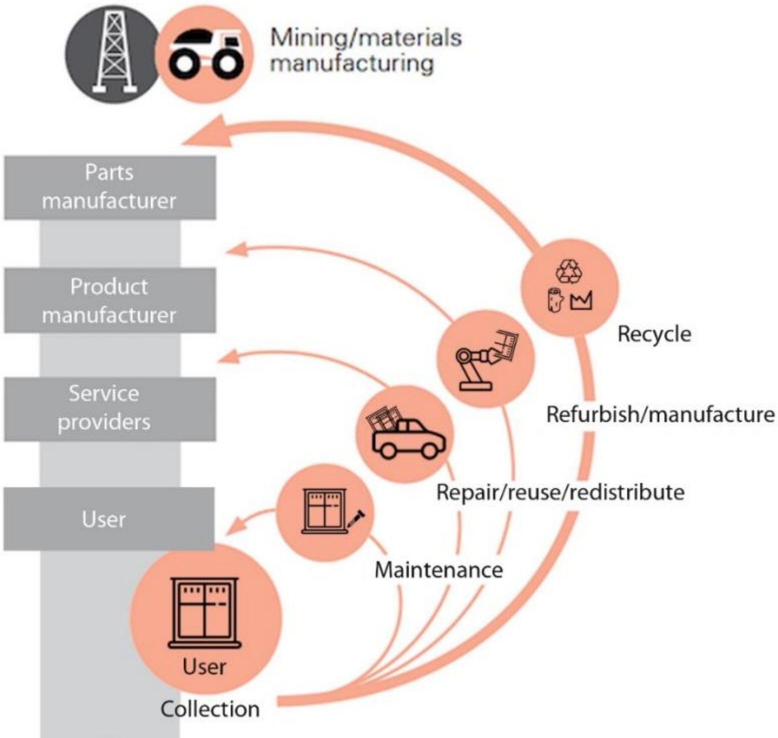


Figure 8.14 - Example of butterfly diagram for a PSS for circular windows.

Other graphics

There are many possibilities to create original graphics or visual presentation, with no more limits than imagination.

Some companies provide visual information about a product economic cost for the user in the following lives after the first owner, as the depiction of subsequent lives of a product that can be resold once again (figure 8.15).

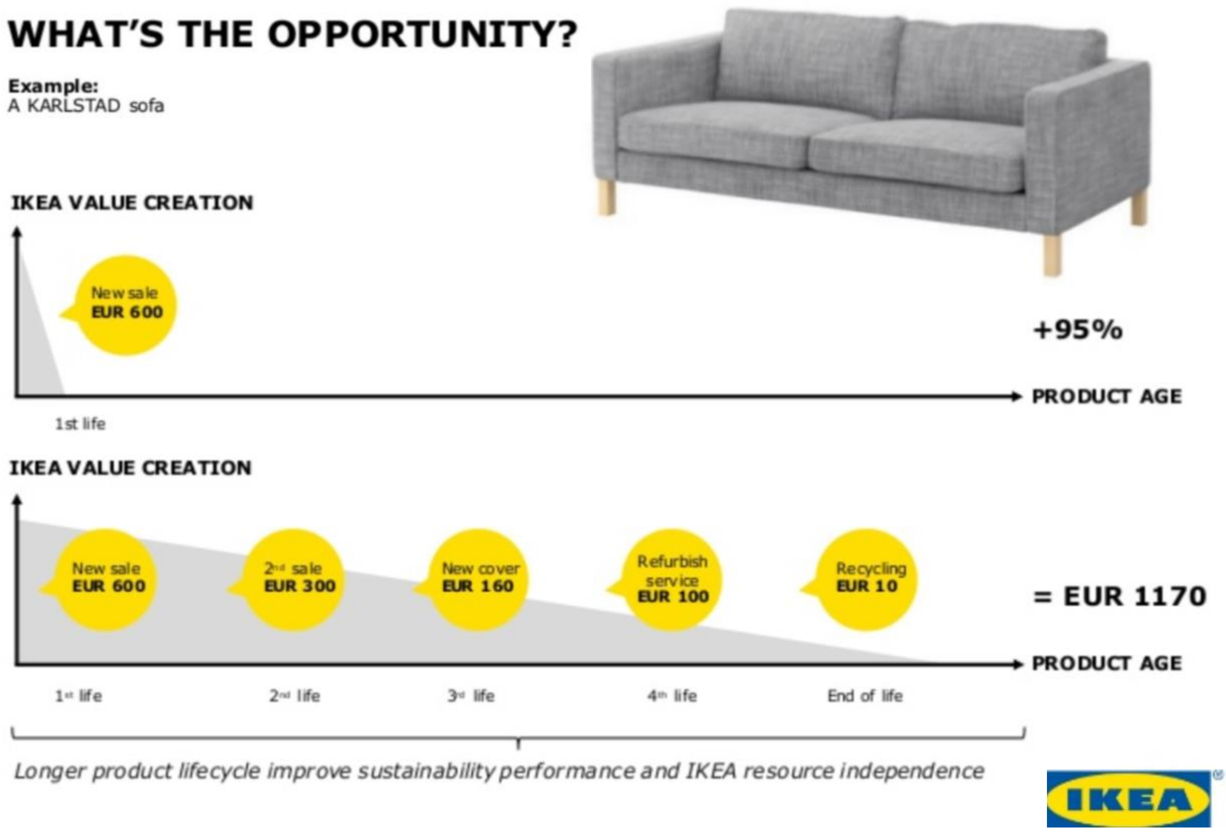


Figure 8.15 - Many lives graphic (Ikea).

Companies that recover raw material for subsequent lives, usually represent the circular flow of the main materials. Figure 8.16 is an example of this in a cork company.

Figure 8.16 - Circular flow of the main raw material (Amorim).

8.3 CE specific communication tools

8.3.1 Cradle to Cradle (C2C) design certification and communication tool

The Cradle to Cradle Certified™ Product Standard (MBDC, 2015) guides designers and manufacturers through a continual improvement process through five categories:

- Material health: Knowing the chemical ingredients of every material in a product, and optimizing towards safer materials.
- Material reutilization: Designing products made with materials that come from and can safely return to nature or industry.
- Renewable energy and carbon management: Envisioning a future in which all manufacturing is powered by 100% clean renewable energy.
- Water stewardship: Manage clean water as a precious resource and an essential human right.
- Social fairness: Design operations to honour all people and natural systems affected by the creation, use, disposal or reuse of a product.

A product receives an achievement level in each category. There are five levels: Basic, Bronze, Silver, Gold or Platinum. Each level corresponds to a specific requirement. The lowest achievement level represents the product's overall mark. Next figure depicts an example product C2C certification scorecard (figure 8.17). A new C2C certification version (C2C 4.0) is expected for 2019.

Figure 8.17 - Cradle to Cradle product certification example.

There is also a C2C Communication Strategy Tool that helps diagnose the dominant value priorities and interests of business stakeholders and suggests the value propositions within the C2C vision that best align with the needs of the stakeholders.

This tool is implemented in an Excel sheet (http://www.c2c-centre.com/tools/communication-tool). To apply it, the company has to fill in a questionnaire about five organizational aspects: character, leadership, cohesion, emphasis and rewards. For each category, there are four statements about organizational preferences. The tool asks to divide 10 points between the four statements to indicate how closely the organization resembles each of these. According to the points assigned, the tool calculates four values corresponding to four organization cultures and depicts them in a spider map. As a result, the tool provides which the organizational value priorities are and how C2C will help (figure 8.18).

Q1 Organisational Character (Please distribute 10 points)	
Organisation A is a very personal place. It is like an extended family. People seem to share a lot of themselves	5
Organisation B is a very dynamic entrepreneurial place. People are willing to stick their necks out and take risks.	1
Organisation C is very results oriented. A major concern is with getting the job done. People are very competitive and achievement oriented.	1
Organisation D is a very controlled and structured place. Formal procedures generally govern what people do	3

Q2 Organizational Leadership (Please distribute 10 points)	
Managers in **Organisation A** are warm and caring. They seek to develop employees' full potential and act as their mentors and guides.	6
Managers in **Organisation B** are risk-takers. They encourage employees to take risks and be innovative.	2
Managers in **Organisation C** are coordinators and organisers. They help employees meet organisations goals and objectives.	1
Managers in **Organisation D** are rule-enforcers. They expect employees to follow established rules, policies and procedures.	1

Organisational Value Priorities

COLLABORATE by promoting human development and seeking long-term goals. This organisation focuses on internal process and knowledge acquisition.

Communication Strategies - What C2C offers you

C2C will provide your organisation a platform for collaboration amongst staff and offer an inspiring and comfortable work environment. C2C offers your business:
Buildings and facilities that love people/People-loving development
Collaborative working
Positive influence on supply chain, clients and other businesses
Increase in quality of working environment
Positive impact on health of people
Attraction and retention of high quality employees

Q3 Organisational Cohesion (Please distribute 10 points)	
The glue that holds **Organisation A** together is loyalty and mutual trust. Commitment to this organization runs high.	2
The glue that holds **Organisation B** together is commitment to innovation and development. There is an emphasis on being on the cutting edge.	3
The glue that holds **Organisation C** together is the emphasis on achievement and goal accomplishment. Aggressiveness and winning are common themes.	2
The glue that holds **Organisation D** together is formal rules and policies. Maintaining a smooth-running organization is important.	3

Q4 Organisational Emphasis (Please distribute 10 points)	
Organization A emphasizes human development. High cohesion and morale in the organisation are important.	5
Organization B emphasizes creating new challenges and acquiring new resources. Trying new things and prospecting for opportunities are valued.	1
Organization C emphasizes competitive actions and achievement. Hitting stretch targets and winning in the marketplace are dominant.	1
Organization D emphasizes permanence and stability. Efficiency, control and smooth operations are important.	3

Q5 Organisational Rewards (Please distribute 10 points)	
Organization A distributes its rewards fairly equally among its members. It's important that everyone from top to bottom be treated as equally as possible.	2
Organization B distributes its rewards based on individual initiatives. Those with innovative ideas and actions are most rewarded.	2
Organization C distributes its rewards based on achievement of objectives. Individuals who contribute to attaining the organisations goals are rewarded.	3
Organization D distributes rewards based on rank. The higher you are, the more you get.	3

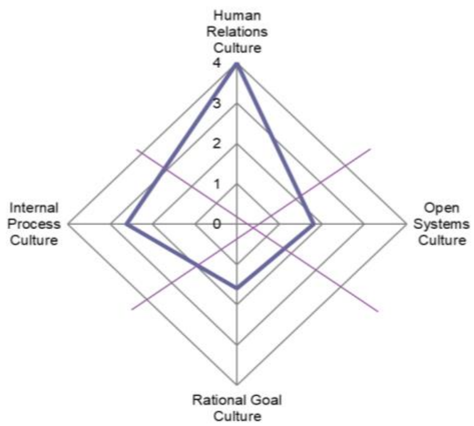


Figure 8.18 - Example of C2C Communication tool (http://www.c2c-centre.com/tools/communication-tool)

8.3.2 The Circle Assessment Tool

The Circle Assessment Tool evaluates the circularity in a company. It is a self-assessment tool that consists of an online survey. The tool provides to what extent the company is implementing circularity in six categories: Collaborate, Innovate, Reduce, Cycle, Lead and Extend (C.I.R.C.L.E). Each category receives a punctuation from 0 to 100 and a total score (0-100) is provided (figure 8.19).

Figure 8.19 - Sample results (https://es.slideshare.net/circleeconomy/circularity-assessment-for-companies)

The results are used for internal and external communication and help to improve, attract investors and define new strategies. For instance; in the case where performance is 79% (category extend), the company might decide to improve warranties or apply refurbishment, etc.

8.3.3 Material Circularity Indicator (MCI)

The Material Circularity Indicator (MCI) is an indicator developed by Ellen MacArthur Foundation and Granta Design (Ellen MacArthur Foundation, Granta Design, 2015). It assesses a product's circularity rating it between 0 and 1. Since it provides a number to assess the product circularity, it is directly useful to communicate how much circular the product is. For the end user and other stakeholders, a number is an easy data to understand and to compare with other similar products. This number can consequently help users to decide which product/PSS choose.

The MCI evaluates the material flow and the lifespan of the product's materials, parts or subassemblies comparing them with other similar products according to the weight of the components, the portion of mass from recycled/reused sources and the portion of mass to be recycled/reused at the end of life of the product. The indicator calculates the result computing the virgin feedstock material, the unrecoverable waste, the Linear Flow Index and the utility factor. The Linear Flow Index measures the fraction of material flowing in a "linear" way. The utility factor takes into account the lifetime and functional unit of the product (Janik & Ryszko, 2017).

As a limitation of the tool, we find that the calculation must be made with a complete product, without taking into account that it can be made up of several components of different materials. It does not cover this particular case and there is no option to enter the different component's data separately. It would be necessary to calculate an average previously in order to enter a single input of each variable that encompasses the entire product. The fact that the components cannot be taken into account separately, could vary the circularity of the product and complicates the interaction of the user with the tool, since it does not differentiate between different materials and components.

In the image (figure 8.20), you can see the different parameters with which the tool works and how they relate to each other to compute the final result. Table 6 summarizes the input data required. *Life Cycle Perspective* section describes the MCI tool to assess circularity. An adaptation of this tool for the furniture and building sectors is available in the Katch_e Resource Centre.

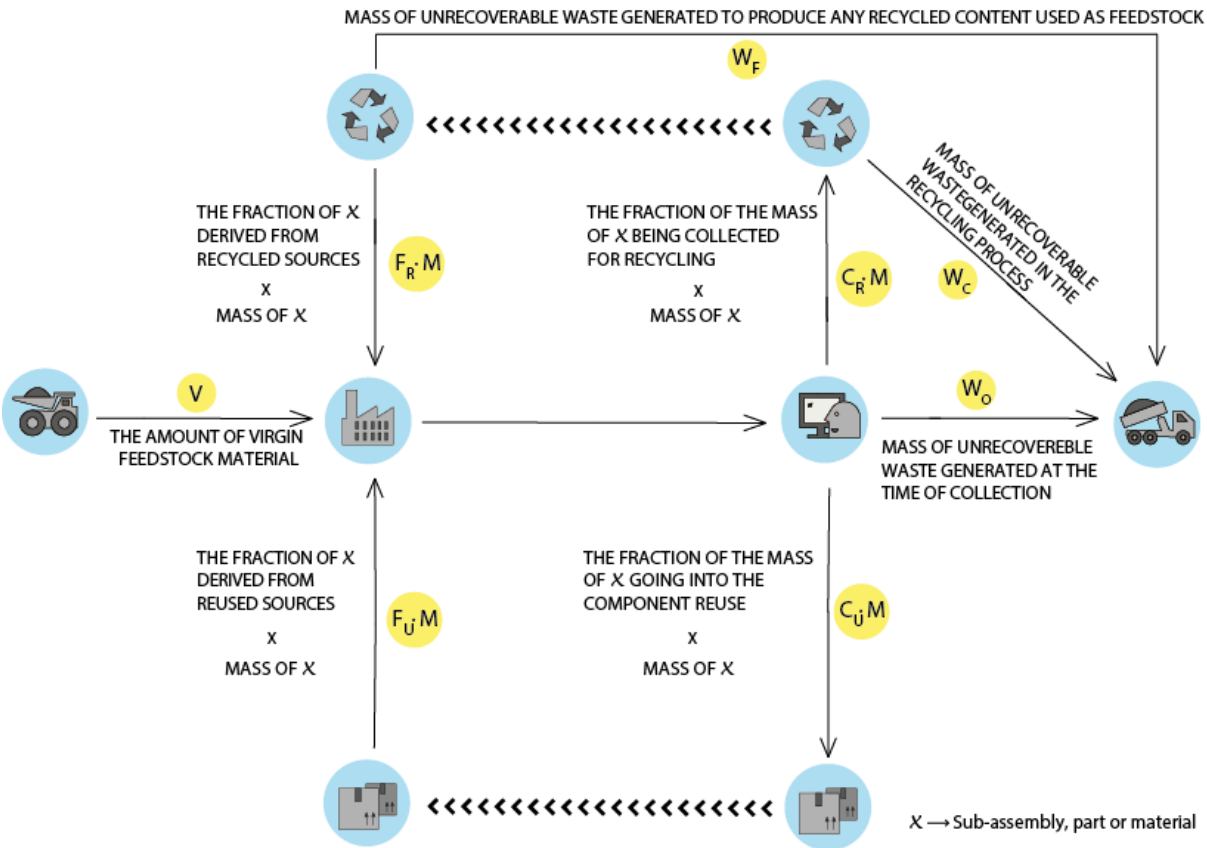


Figure 8.20 - Diagrammatic representation of material flows in MCI. Adapted from Ellen McArthur and Granta (2105).

Table 8.6 - Inputs and units in MCI tool

Inputs and units in MCI tool	
Feedstock reused/recycled	%
Recycling efficiency (feedstock)	%
Destination after use reused/recycled	%
Recycling efficiency (destination after use)	%
Lifespan of the product/lifespan of a reference product	
Functional unit of the product / Functional unit of a reference product	

8.3.4. Circularity indicator (CI) – adaptation from MCI

The Circularity Indicator (CI) is an adaptation of the MCI, carried out under the KATCH_e project context. The result that the indicator provides is also a number between 0 and 1 (being 1 the more circular result).

It works at the component level, which means that each of the components of the product under study is computed separately, taking into account the different materials that each of the parts may have, as well as their origin and destination, and the possibility or not of repairing. In addition, by means of an environmental impact coefficient for each of the materials that the tool takes into account, the result is corrected according to the material of the component that is being evaluated. You can enter up to five components, being able to work with subassemblies (of equal material) if the product has more parts.

The tool considers more parameters than the MCI. In this case, the "recover" and "repair" loops are taken into account, as well as the possibility that the material goes to the landfill at the end of its life. Besides, a transport correction has been added, changing the value of the result according to the starting material or depending on the material destination at the end of its useful life, be it local, national or international. Table 8.7 and figure 8.21 show the CI parameters.

Table 8.7 - Inputs and units in CI tool

Inputs, abbreviation and units in CI tool		
Average life time of product to value	Lp	Years
Average life time of industry product	Lav	Years
Functional unit of product to value	Up	Uses
Functional unit of industry product	Uav	Uses
Material	-	Selected from a list
Mass	M	Kg
If part's raw material is reused / recovered / recycled	Fu, Fp or Fr	Fraction of material (0-1)
Transport of raw material	Ti	Local, national or international
If at the end of life, the part is reused / recovered / recycled / landfill	Cu, Cp, Cr or Cd	Fraction of material (0-1)
Transport of end of life material	Ti	Local, national or international
Reparation	R	Yes - No

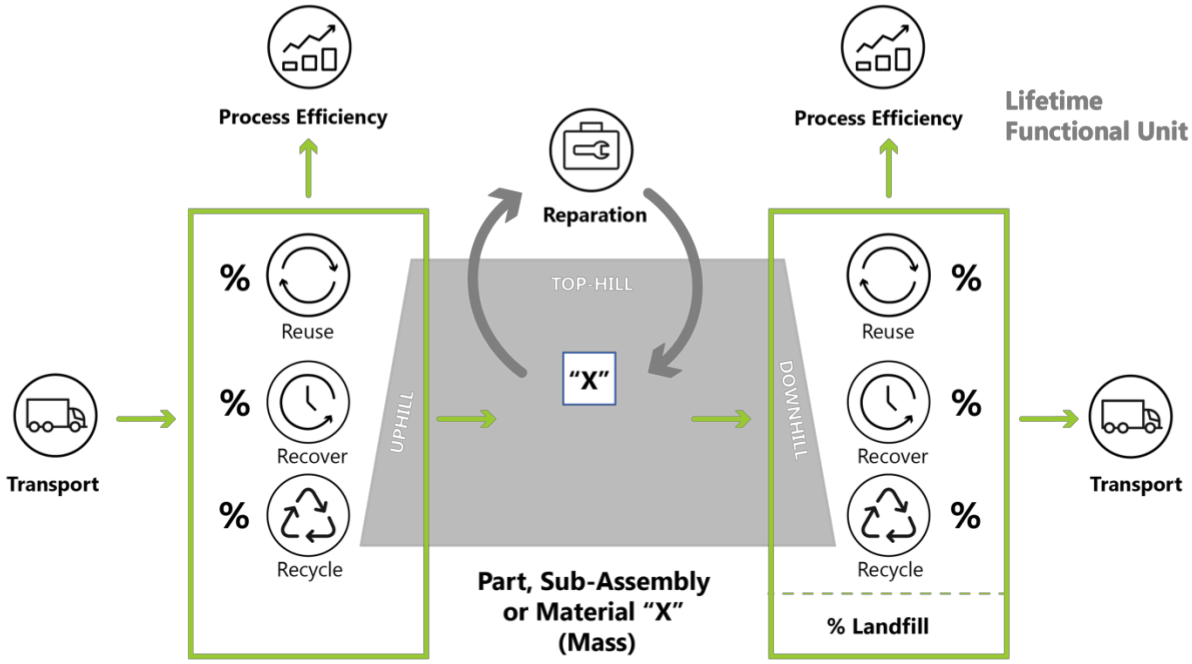


Figure 8.21 - CI parameters summary

Assignment 8.8

Evaluate the product in assignment 8.3 "Cabinet becomes sofa" using the following communication tools:

- Circle Assessment Tool (www.circle-economy.com)
- Material Circularity Indicator (MCI) (https://www.ellenmacarthurfoundation.org/resources/apply/circularity-indicators)

Summarise the results of the three tools in an A3 size sheet of paper.

8.3.5 Sector specific communication tools

Furniture specific communication tools

In the report 'Circular Economy opportunities in the furniture sector', (EEB, 2017), EEB, The European Environmental Bureau, (https://eeb.org/) highlights the importance of defining a Green Furniture Mark (GFM) – a new A to G rating instrument similar to the EU energy label, with the intention of providing consumers and procurement professionals with clearer information on the environmental and circularity features of furniture products.

Building specific communication tools

Several assessment tools also serve as a communication on how sustainable a building is in a simple way. For instance, certification systems like BREEAM, LEED, etc.

BREEAM, (https://www.breeam.com/) measures sustainable value in nine categories, ranging from energy to waste water. Each category is subdivided into a range of assessment issues, each with its own aim, target and benchmarks. The BREEAM ratings range from Acceptable (In-Use scheme only) to Pass, Good, Very Good, Excellent to Outstanding and are reflected in a series of stars on the BREEAM certificate.

Many national building rating systems, including the US-American system (Leadership in Energy and Environmental Design) which presents the most widely used certification scheme derive from the BREEAM system.

LEED, (https://new.usgbc.org/leed), is hosted, developed and distributed internationally by the U.S. GBC Green Building Council. LEED applies to buildings that are being newly constructed or going through a major renovation. Buildings are rated according to seven categories. Recycled content for structural products is used, but with low weight.

Level(s), (http://ec.europa.eu/environment/eussd/buildings.htm), is a voluntary reporting framework to improve the sustainability of buildings. Using existing standards, Level(s) provides an EU-wide approach to assessing environmental performance in the built environment. It encourages life cycle thinking for the whole building by offering a step by step approach to life cycle assessment.

Level(s) can be used by assessment and certification schemes to make sure that their criteria reflect the most important priorities for circular economy at a European level, and to enable the comparability of data and results across different building performance rating systems.

Level(s) has created a series of indicators and tools which at the moment are being thoroughly tested by building professionals across Europe. The feedback from the testing phase will inform the final version of the Level(s) framework – to be launched around summer 2020.

Another way to collect and report CE characteristics of products is BAMP project's Materials Passports (MP). (https://www.bamb2020.eu/topics/materials-passports/) BAMB project is working on MPs focused in the building sector with the purpose of creating ways to increase the value of building materials (Luscuere and Mulhall, 2019). MP databases contain data about compositions of products and components, modularity of a product, prefabrication versus assembly on site, etc. Reports in BAMB would improve the CE decision-making during building adaptations.

At national level, there Austrian certifications as TQB (https://www.oegnb.net/en/zertifikat.htm?typ=hs), Klimaaktiv (https://www.klimaaktiv.at/), agpb (www.agpb.at).

In Portugal: LiderA (http://www.lidera.info/?p=index&RegionId=3&Culture=en) and in Germany: DGNB (https://www.dgnb.de/en/index.php). *KATCH_e Life Cycle Perspective* section describes in more detail these certification schemes.

8.4 Environmental labelling and product declarations and its relation with CE

8.4.1. ISO labels and product declarations

The ISO 14020 series of standards (ISO, 2000, 2006, 2016, 2018) contains principles and guidelines for environmental claims and declarations which are useful in this context.

Environmental labelling or eco-labels of products and services give consumers the guarantee that these products and services comply with environmental quality requirements beyond what the law establishes. They are important tools that companies can use on their path to the circular economy. Indeed, the European Commission emphasizes in its Action Plan for the Circular Economy the importance of providing the consumer with clear and homogeneous information on the environmental aspects of products and services, avoiding confusing information.

There are multiple ecolabels that communicate environmental information of products both to consumers and/or to businesses.

There are three types of environmental labels, according to this ISO 14020 series.

- Type I labels (ISO 14024): "third party" labels that indicate voluntary conformance to pre-determined, multi-attribute criteria that identify environmentally preferable products within a particular product category, based upon life cycle considerations. Examples include: European Ecolabel , Blauer Engel or Nordic Swan Ecolabel
- Type II labels (ISO 14021): self-declared claims made by manufacturers, importers, distributors, retailers, etc., focusing on environmental improvement of some specific aspect of their products, such as energy consumption, compostable, degradable indoor air quality, or recycled content. Examples include: Energy Star, WaterSense or Greenguard.
- Type III labels (ISO 14020 and 14025): These labels present comprehensive product information based on quantitative validated Life Cycle Assessment (LCA) studies and often referred to as Environmental Product Declarations (EPD). Examples include: BAU EPD, ENVIRONDEC, AENOR GLOBAL EPD, Institut Bauen und Umwelt e.V. (IBU), ASTM-EPD or DAP Habitat.

Even if none of these environmental labels refers exclusively to the Circular Economy concept, many of these labels include requirements very closely related to the approach of closing the loop.

Box 1 includes an example of how the Nordic Swan Ecolabel (Type I) stimulates circular economy.

Box 1. Some examples of how the Nordic Swan Ecolabel stimulates circular economy.

- *Requirements for renewable, recycled and sustainable raw materials*: For building panels and construction it is a requirement that at least 70% of the wood is certified sustainable wood.

- *Strict chemical requirements*: For construction, there are chemical requirements so that the choice of raw materials ensures clean materials that can be reused.

- *Reduced use of resources and energy*: For construction, there are requirements concerning low energy consumption in the use stage.

- *Quality requirements and lifetime*: For furniture there are requirements concerning strength and durability.

- *Requirements for product design, dismantling and reparability*: For furniture there are requirements for metal and plastics to be easily dismantle and thus reusable.

- *Requirements for optimum waste handling*: for ecolabelled houses and flats, there is a requirement that waste can be sorted in a minimum of four fractions.

Additionally, there are specific environmental labelling programs related to the content of recycled materials of products, as seen in figure 8.22.

Figure 8.22 - Ecolabel programs related to the content of recycled materials of products.

8.4.2 Lifespan labelling

New initiatives and discussions are arising in relation to product labelling and circular economy, as for instance, the proposal of the French Government about supporting a voluntary product "lifetime" label - to be implemented by 1st January 2020 -, with the aim of reducing the obsolescence of products. This label would measure the reparability, sturdiness, and durability level of products. This initiative aligns with the already created Austrian label that grades the durability and reparability of appliances.

The European Economic and Social Committee launched a study in 2016 to set out how the consumption patterns would change if the users would be informed about the lifespan (European Economic and Social Committee, 2016). The study was done with several products and labels and almost 3.000 people participated.

The results show that products labelled as long-lasting would see an increment in sales. The study shows that the more that users are prepared to spend, the more value they place on product lifetime.

Labelling types matter, being the most effective format, the ranking from A to G (figure 8.23).

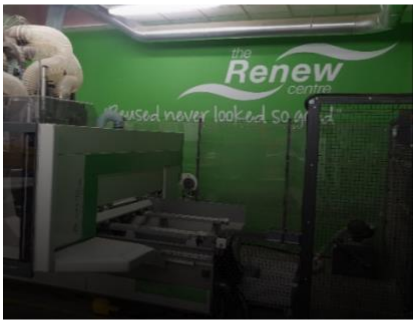
Figure 8.23 - Three different lifespan labels (EESC, 2016).

8.5 Examples of circularity communication

The Cradle to Cradle centre website and publications like (MDBC, 2013), provide examples of certified products and projects. Some of the examples in the furniture and construction sectors are:

- Premier Workplace Services – Office furniture remanufacturing. Dedicated to remanufacturing, refurbishing and repairing desks, chairs and other office furniture. Their motto is: "Re-used never looked so good". They communicate about sanitization and cleaning.
- Lubelska reclaims, cleans and up-cycles various oak, brick and terracotta products. They reasure the quality and durability and the absence of chemicals or detergents for cleaning.
- Biobased PU Resilient Flooring, PRODUCED BY Shaw Industries Group, Inc. This flooring is designed with biobased materials to provide a natural solution that does not require wax and top coats.
- High density Polyethylene Outdoor Chair, by Loll Designs. They use recycled polyethylene.

Premier Workplace Services – Office furniture remanufacturing, by Premier

Description	Premier Sustain's office furniture remanufacturing services help their clients make the most of their existing furniture assets, returning these items to an 'as good as new' condition and remanufacturing them to meet new working requirements. Their award-winning Renew Centre is solely dedicated to remanufacturing, refurbishing and repairing desks, chairs and other office furniture. Their motto is: "Re-used never looked so good". As well as remanufacturing the client existing furniture, they can provide items from their extensive stock of ready to remanufacture resources, delivering significant cost savings and reducing waste.
Organization and country	Premier Workplace Services, UK
Sources	Company Website: https://www.premierworkplaceservices.co.uk/services/office-furniture-remanufacturing/
Images	  
Images' source or credits	https://www.premierworkplaceservices.co.uk/wp-content/uploads/2016/09/remanufacturing-general-2.jpg https://www.premierworkplaceservices.co.uk/wp-content/uploads/2016/12/chair3-story-768x286.png
Sector	Furniture
Circularity approach(es)	Closing and Slowing loops.
Additional information	This company uses communication strategies in its website to tackle the concerns about contamination, disgust or not newness that the customer may have. Their office furniture pieces are cleaned, sanitized and in full working order. They offer options to remanufacture and remodel all type of furniture to transform them into unique items.

Reclaimed oak, brick and terracotta tiles, by Lubelska

Description	Lubelska reclaims, cleans and up-cycles various oak, brick and terracotta products at their re-cycling centre. They use eco-friendly methods for the cleaning and preparing of their floorings, without the use of chemicals or detergents. They try to reduce their impact on the environment at all stages. Their reclaimed flooring has been recovered mainly from old farm buildings, detected for metal and either engineered for mordern underfloor heating of left as is.
Organization and country	Lubelska – United Kingdom
Sources	Company Website: https://lubelska.co.uk/
Images	  
Images' source or credits	https://lubelska.co.uk/wp-content/uploads/2019/07/U.-Hall-1-1024x1524_c.jpg https://lubelska.co.uk/wp-content/uploads/2019/07/KY4.104-1-1-1024x1524_bl.jpg https://lubelska.co.uk/wp-content/uploads/2019/07/LBSR.103-e1564481605702-1024x1524_br.jpg
Sector	Building
Circularity approach(es)	Closing loops
Additional information	This company uses communication strategies in its website to tackle the concerns about contamination, disgust or not newness that the customer may have. Their materials are cleaned using eco-friendly methods without the use of chemicals or detergents. The customer is reassured about the durability of the product and quality. They claim that their floors will last a lifetime and increase the capital value of a building.

Biobased PU Resilient Flooring, by Shaw Contact

Description	Shaw's biobased PU resilient flooring is inspired by nature, with healthy chemistry & high design. It provides resilient flooring solutions where ease of maintenance, durability, and sustainable design are required. This flooring system is available in tile, sheet and plank configurations that do not require transitions between sheet & tile flooring options. Designed with biobased materials to provide a natural solution that does not require wax and top coats, it provides inherent stain and scuff resistant finishes. With beautiful wood and abstract visuals, the product can self-cove and heat-weld at seams to achieve a truly aseptic floor.	
Organization and country	Shaw Industries, USA	shaw contract®
Sources	Company Website: https://www.shawcontract.com/en-us/about/press-center/shaw-contract-introduces-new-bio-based-flooring	
Images		
Images' source or credits	http://www.c2c-centre.com/sites/default/files/styles/v2-single-page/public/IMG_WEB_Shaw_PU_Flooring_System.jpg?itok=qJuyFQyR	https://www.shawcontract.com/SCGDEV/media/IMG/Images-Logos/Products/Collections/biobasedslider3.jpg?ext=.jpg
Sector	Construction	
Circularity approach(es)	Narrowing and slowing loops	

High Density Polyethylene Outdoor Chairs, by IOLL

Description	Loll designs and manufactures durable, all-weather outdoor furniture made from 100% recycled plastic – mostly from single-use milk jugs.	
Organization and country	Loll Designs, USA	
Sources	Company Website: https://lolldesigns.com/ http://www.c2c-centre.com/product/interior-design-furniture/outdoor-furniture	
Images		
Images' source or credits	https://lolldesigns.com/wp-content/uploads/home-intro-3.jpg	https://lolldesigns.com/wp-content/uploads/about1.jpg
Sector	Furniture	
Circularity approach(es)	Closing loops	

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