

# Circular Design Research in The Netherlands




Marcel den Hollander  
Marijke Idema  
Peter Joore





# Circular Design Research in The Netherlands



**Marcel den Hollander**  
**Marijke Idema**  
**Peter Joore**

## Title

Circular Design Research in The Netherlands

## Authors

Dr Ir Marcel den Hollander, Circular Design Consultant and Professor Circular Design & Manufacturing <sup>1</sup>

Ir Marijke Idema, Research Fellow and Design Coach <sup>2, 4</sup>

Dr Ir Peter Joore, Professor Open Innovation <sup>3, 4</sup>

## Scientific Advisory Board

Dr Ir Inge Oskam, Professor Circular Design & Business <sup>2</sup>

Dr Ir Marcel Crul, Associate Professor Circular Design <sup>3</sup>

Prof Ir Daan van Eijk, Professor Industrial Design Engineering <sup>4</sup>

Ir Siem Haffmans, Strategic Consultant Circular Economy <sup>5</sup>

<sup>1)</sup> Rotterdam University of Applied Sciences

<sup>2)</sup> Amsterdam University of Applied Sciences

<sup>3)</sup> NHL Stenden University of Applied Sciences

<sup>4)</sup> Delft University of Technology

<sup>5)</sup> Partners for Innovation

## English text correction

Roger Staats

## Design and Layout

Studio RATATA.nl

## Illustrations

Kalle Wolters

## Publisher

Network Applied Design Research (NADR)

## Date

1 December 2023

## ISBN

9789491589270

## DOI

10.48544/ce845da3-5ba4-4047-ac07-e106eff00167

## Support

This publication is made possible with the financial support of CLICKNL and Taskforce for Applied Research SIA, part of the Netherlands Organisation for Scientific Research (NWO)

## License

This work is licensed under CC BY-NC-ND 4.0 (Attribution-NonCommercial-NoDerivatives 4.0 International).

---

## Network Applied Design Research

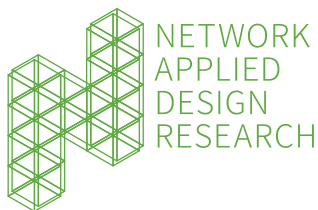
The Network Applied Design Research (NADR) is the Dutch national platform for researchers focused on applied design research. Unifying theme is the methodological approach of combining design and research, in any possible variation. NADR researchers deploy applied design research to tackle issues in healthcare, architecture, energy, food and agriculture, retail, hospitality, and fashion. Unique about NADR is that researchers with very different application areas collaborate, allowing them to integrate knowledge and insights from different sectors.

## Disclaimer

Reasonable efforts have been made to publish reliable data and information, but the author and publisher cannot assume responsibility for the validity of all materials or the consequences of their use. The authors and publishers have attempted to trace the copyright holders of all material reproduced in this publication and apologize to copyright holders if permission to publish in this form has not been obtained. If any copyright material has not been acknowledged please write and let us know so we may rectify in any future reprint.

## Trademark notice

Product or corporate names may be trademarks or registered trademarks and are used only for identification and explanation without intent to infringe.



**CreativeNL**





# Content

Preface	6
1. Circular Design Research in The Netherlands	9
2. Looped Systems	15
3. Extending Useful Product Lifetime	21
4. Servitisation	27
5. New Materials and Production Techniques	33
6. Information Technology and Digitisation	41
7. Creating Public and Industry Awareness	49
8. Suggestions for Further Research	53
Case index	59

# Preface

In 2023, the Netherlands is strategic partner of the Business of Design Week in Hong Kong, with Circular Design as the central theme. The initiators of this partnership, CreativeNL and CLICKNL, together with the Netherlands Consulate General in Hong Kong and Macao, and the Netherlands Innovation Network, have set the goal of promoting long-term international cooperation as a result of this cooperation. These collaborations can range from practical partnerships between companies and designers, to research collaborations between universities and other knowledge institutions.

My enthusiasm as chair of the Network Applied Design Research (NADR) was raised when I heard about this initiative. After all, one of NADR's core ambitions is to promote international cooperation, and what topic lends itself better to this than sustainability and circularity? These crucial topics know no sectoral or national boundaries, and if we really want to achieve positive societal and environmental impact, international cooperation is indispensable.

As a first step towards developing mutual future cooperation, we initiated a project to map the current state-of-the-art in Circular Design Research in the Netherlands. This publication is



---

the result of this project. It provides an accessible overview of current developments in the Netherlands related to Circular Design Research, including inspiring best practices.

The main author of this publication is Dr Ir Marcel den Hollander, circular design consultant, professor Circular Design & Manufacturing, and co-author of the book 'Products That Last'. Together with research fellow and design coach Ir Marijke Idema, relevant cases related to circular design were collected. This process was supported by a scientific advisory board, consisting of experts Dr Ir Inge Oskam, professor of Circular Design & Business, Dr Marcel Crul, associate professor of Circular Design, Ir Siem Haffmans, Circular Design expert and author of the book 'Products that Flow', and Prof Ir Daan van Eijk of Delft University of Technology as the link to the trajectory in Hong Kong.

We hope this publication will serve as a starting point for fruitful discussions between designers, entrepreneurs, and researchers, with the underlying aim of initiating promising collaborative projects between Dutch organisations and their counterparts in Hong Kong. After all, only if we really work together intensively can we contribute to the development of a sustainable, circular, and habitable world.

**Peter Joore,**

Chair Network Applied Design Research





---

# 1. Circular Design Research in The Netherlands

## 1.1 Introduction

The transformation of our linear economy into a circular economy poses a formidable challenge. This NADR (Network for Applied Design Research) publication 'Circular Design Research in The Netherlands' offers a concise overview of six potential 'gateways to circularity'. 'Gateways', as each of them can provide a starting point or entrance for research and educational institutions and businesses alike to actively take part in the transformation to a circular economy by leveraging their particular expertise, be it design, engineering, material sciences, information technology, business theory or the arts. Each chapter is illustrated with a selection of cases of circular design research projects and pioneering business ventures in the Netherlands. In the preparation of this publication, we came across so many ongoing research business initiatives that we cannot possibly claim our current selection to be comprehensive. All these research initiatives

## Case: Stroncq by Omlab

Stroncq is a research project led by Omlab in collaboration with Aquaminerals and designer Lilian van Daal, aimed at discovering ways to reinforce slopes in an environmentally friendly way. They developed an ecological material with the strength of gypsum concrete, composed 98% of residual flows from sewage and drinking water treatment. Inspired by nature's efficient root network, 3D-printed biodegradable tiles with integrated plant seeds naturally reinforce slopes and dikes as the plants' roots grow into the tiles. This natural material strengthens earthen walls and promotes biodiversity while counteracting effects of soil acidification, offering a sustainable alternative to synthetic slope reinforcement.



[omlab.nl](https://omlab.nl)

and business ventures are doing their best to catch up with and hopefully overtake over two centuries of linear economy thinking, knowledge and experience, in only a few decades. As can be expected with such a steep learning curve, few, if any, of the examples shown are perfect from a circularity perspective. We are well aware of that, but our intention with this publication is not to present picture perfect 'colour-by-numbers' templates for circular products or business models. Rather, we want to show you that circular design in the Netherlands is extremely diverse and very much alive. In addition, the examples of products, processes and projects presented here are intended to challenge and inspire. Some of the products shown are already out there and real, whilst others are just creative sparks, experiments or prototypes that still need a lot of commitment, dedication and funding to come to fruition. Our aim is to inspire you to partake in the circular transformation and to help push the circular design envelope closer to perfection.

## 1.2 Examples of Circular Design Research

The research for this publication started by collecting examples of applied circular design research in the Netherlands. We asked people in our own and the wider network of Dutch universities of applied sciences to bring in examples of circular design research and innovative circular business cases they either knew of or had participated in. Our call resulted in a long-list of over two-hundred cases that were then screened by the members of our scientific advisory board and the authors. From this long-list, we removed cases that were either insufficiently documented or not considered relevant from a circular design perspective. Next, the remaining cases were analysed in search of

an ordering principle deemed suitable for this publication. At the time of our initial call for cases, we expected that clustering them by domain, for example ‘fashion’, ‘everyday products’, or ‘architecture’, would provide a functional ordering principle suited to our purpose. However, after closer examination of and a number of discussions on the wide range of cases we received, other common factors emerged. We found that cases across different domains ran into similar problems and found solutions to their circular challenge in similar themes. Almost every case, in one way or another, tries to keep materials and products ‘in the loop’, i.e. prevent them from disappearing as waste. In fashion as well as with everyday products, for example, finding new, more circular materials or processes is essential. Alternative modes of providing products to customers such as rental or lease instead of selling them, are found in fashion, in everyday products, as well as in lighting. Digital technologies are not only used to keep track of the whereabouts of products but also in new manufacturing techniques such as 3D printing or robotic production that can be used to make spare parts that extend product lifetimes or to create new products from recycled materials. Lastly, we recognised the important role of some of the more experimental cases, such as creating publicity and raising awareness around social, environmental and circular issues. As such, we have organised this book in the following chapters, based on each of the six common themes that run through the cases: Chapter 2: Looped Systems, chapter 3: Extension of Useful Lifetime, chapter 4: Servitisation, chapter 5: New Materials and Production Techniques, chapter 6: Information Technology and Digitisation and chapter 7: Creating Public and Industry Awareness.

## Case: Auping Revive

In Europe, approximately 35 million mattresses are discarded every year, significantly contributing to landfill waste due to their complex composition of glued materials. Hotel mattresses form a substantial part of this waste stream. Auping, in collaboration with Niaga®, developed a novel hotel mattress that contains no conventional foam or adhesives enabling it to be recycled into high-quality new mattresses. The material sourcing is transparent, as all materials are documented in a product passport with a scannable label. Using a smartphone scan, the label identifies the composition and origin of all materials used in the mattress.



[auping.com](https://auping.com)

## Case: Festival Living Labs

As temporary mini-societies, festivals offer real-life contexts with similarities to the real world, providing ideal locations to experiment with sustainable innovations in a safe, fun and laid-back atmosphere. In the European Innoquarter project, over 20 partners from across Europe joined forces to facilitate sustainable innovations taking place at festivals varying from Welcome to the Village in the Netherlands, Into the Woods in Sweden, and Northside in Denmark. The lessons learned from these events have been published in a Festival Experimentation Guide; a collection of learnings and tools explaining how festivals can be used as places for sustainable and circular experimentation.



[innoquarter.eu/feg](http://innoquarter.eu/feg)

## 1.3 Future Research

We believe that the common themes in which the many different cases have found solutions to their circular challenges can serve as good starting points for others. We have made our final selection of examples for this publication with the intention to cover this full spectrum of themes or 'gateways' as best we could. In addition, we chose to only include cases that are public and for which more information can be found online for a more in-depth review by those interested to learn more. For researchers, these examples can provide context for promising new research projects. Entrepreneurs can consider them as inspiring pointers towards potential solutions to their own circular challenges, or to opportunities for creating products or services that help solve those of others. As mentioned above, few, if any, of the cases we received and the examples we present in this publication are finished and perfect from a circularity point of view. Even regarding those solutions that already function well, adjustments and improvements will inevitably be needed to make their large-scale implementation possible and perhaps even mandatory. In chapter 8: Suggestions for Further Research, we have therefore tried to distil topics from the cases that need to be researched further and in more depth. Our hope is that some of these suggestions will be picked up, elaborated on, and worked into successful research projects with practical outcomes that will bring us closer to a functioning circular economy.

---

## Case: Swapshop

The Swapshop offers a sustainable solution for good condition, no longer worn clothing items. Customers bring up to five items (clothing, shoes, or accessories) per visit, receiving Swaps on their account for each item, with higher quality items earning more Swaps. These Swaps can be used to purchase other items in the shop, providing €1 discount per Swap, with a maximum of 50% off per item. Swaps are perpetually valid and can be used at The Swapshop events and their online store. Even clothing items that are outmoded or worn to be offered to customers are given a new lease on life: They are processed and made into The Swapshop's very own padded designer laptop sleeves. Currently, there are Swapshops in Rotterdam and in Amsterdam, with more to come.



[the-swapshop.com](https://the-swapshop.com)





---

# 2. Looped Systems

## 2.1 Introduction

In a perfectly circular economic system, the left-overs from one set of processes form valuable inputs for the next set, over and over again, similar to the workings of our Earth's ecosystem, albeit on different timescales. As such, it will come as no surprise that looped systems are at the heart of the concept of a circular economy. In fact, they are considered so essential that the circle, as the most elementary representation of a perfectly closed loop with no discernible beginning or end, has been chosen to lend its name to the concept. The basic idea underlying the importance of looped systems to the circular economy concept is that what is not lost, does not have to be replenished nor cleaned up at increasingly higher ecologic and economic costs.

## Case: Loop.a Life

Loop.a Life is focused on combating textile waste, making the textile industry circular by transforming discarded clothing into high-quality fashion and interior products. The process begins by collecting post-consumer clothing, averting it from incineration and reducing the textile waste burden. Innovative sorting technology simplifies material separation. Volunteers remove accessories and the cleaned textiles are mechanically recycled, restoring them to raw materials without using chemicals or water. By blending fibres, they create new colours without dyes, permitting knitting in sustainable 3D design. The resulting timeless, detail-oriented designs embody the principles of circular fashion and sustainability.



[loopalife.com](https://loopalife.com)

## 2.2 Separate Loops for Biological and Technical Materials

As with all things, however, everyday practice is often more unruly than theory. Creating perfect closed loops in an economic system made up of millions of products and thousands and thousands of, sometimes harmful, substances, is no small feat. In Nature, all living beings and inanimate objects share the same, limited number of basic building blocks. There, the chances are high that what is no longer needed by one creature will sooner or later be useful to another organism. But what need would an organic farmer in our economic system, for example, have for the materials contained in discarded smartphones? The circular economy concept has found an elegant way around this problem by starting out with two main closed loop systems. One of these is for biological materials that can be broken down and harmlessly assimilated by natural, organic processes at atmospheric pressure and relatively low temperatures in our ecosystem. The second is for technical, man-made materials which cannot be broken down and assimilated safely by natural, organic processes but require contained industrial processes, pressures and temperatures in order to be reprocessed safely. As such, the technical materials loop should be kept strictly separate from the biological materials loop, including our natural environment. Everything will be fine as long as the latter rule is followed strictly. However, as we all know, in practice this unfortunately is not the case.

Although it may not be easy and require fundamental changes in the way we select materials and design our products, it is certainly possible to keep materials within their respective loops, as is illustrated by the following examples. The ongoing research project [Stroncq](#),

demonstrates that it is possible to exclusively use materials from the biosphere in man-made engineering applications, in this instance to reinforce slopes. [Auping](#) has introduced Revive, a mattress that uses Niaga® instead of permanent adhesives, allowing the technical materials to be cleanly separated and recycled. To allow eco-entrepreneurs to get a better feel for what works and what doesn't when attempting to build looped systems, [Festival Living Labs](#) may be a promising testing grounds because of their real-world similarities. The festivals themselves already are an interesting special case scenario of looped systems, as their logistics often involve temporary and highly localised closed loop systems, for example for drinking cups.

## 2.3 Open Loop and Closed Loop Systems

In addition to the distinction between biological and technical loops, a further practical distinction is required. In the context of a circular economy, both biological and technical looped systems can be divided into closed and open loop systems.

In closed loop systems, products or materials are kept in their own particular loop. After these products or materials leave their respective manufacturing or growing processes, their whereabouts remain known to -and sometimes even controlled by- their respective manufacturers or growers throughout their entire lifecycle. After they have reached the end of their useful lifetimes, these products or materials are collected and returned to their respective manufacturers or growers in order to be prepared for their next useful lifetime. Often these products, parts or materials re-enter the production processes that created them in the first place.

### Case: Superlocal Circular Estate

The Superlocal circular urban development in Parkstad Limburg aims to repurpose materials from two vacant high-rise buildings to create around 130 new homes and enhance public spaces. With Parkstad's population expected to decline by 27% in the next 30 years, preventing vacant properties due to depopulation has become a priority. Rather than demolishing both buildings, they have been partially repurposed and renovated, preserving qualities like spaciousness and strong social connections among neighbours. Materials are carefully separated by type and reused, serving as the foundation for new, more circular homes. This approach leads to significant reductions in CO<sub>2</sub> emissions compared to the construction of new buildings.



[superlocal.eu](https://superlocal.eu)

### Case: Collective Ecosystem Boschgaard

Collective Ecosystem Boschgaard is a former community centre in Den Bosch that has been transformed into 19 residential units with collective living and neighbourhood functions. Designed by Superuse, this development prioritises circular construction by utilising residual materials harvested from the project site and its surroundings, eliminating the need for new materials. In contrast to a national average of 8%, 84% of the materials used are secondary resulting in significant cost savings and reduced CO2 emissions compared to conventional building standards. Residents actively participate in material harvesting and construction, helping to keep the project within social housing budgets.



[superuse-studios.com](https://superuse-studios.com)

In open loop systems, it is perfectly natural for products or materials from different manufacturers to end up in one and the same loop. The exact whereabouts of products or materials is less well known, or even unknown, to their original manufacturers as open loop systems generally are not controlled by a single manufacturer. Because of this open character, the products or materials in such a loop do, at the end of their useful lifetimes, not necessarily end up with their original manufacturers. As a consequence, collected products are of little to no value at the product or part level in an open loop system.

A noteworthy exception to this rule of thumb is provided by the [Swapshop](#) initiative. Here, entire products are exchanged in what can be considered an open loop system. More often than not, however, open loop systems are used to facilitate the recycling of materials that end up either in similar or in entirely different products and production processes than those they originated from. [Loop.a Live](#), for example, collects post-consumer clothing waste and reduces it to fibres that are then transformed into high-quality fashion and interior products. On a more local scale, the [Superlocal Circular Estate](#) in Parkstad Limburg aims to repurpose materials from two vacant high-rise buildings to create new homes and public spaces. In a similar vein, the [Collective Ecosystem Boschgaard](#) in Den Bosch designed by Superuse Studios, harvests residual materials from the project site and its surroundings to reduce or even eliminate the need for new materials. The [Circular Footwear Alliance](#) is an example of an open loop system where discarded (safety) shoes are collected and disassembled so the recovered secondary materials can be used as inputs for the manufacturing process of new products.

For the time being, and perhaps forever in specific industries and scenarios, both looping systems have their own place in a circular economy. They both serve to prevent products and materials from escaping the economic system as non-recoverable waste. The open loop system, mostly operating at material level, perhaps more closely resembles the natural order of things in the Earth's ecosystem. Materials are more universally interchangeable than products and components. As a consequence, open loop systems are often less complex and, from a (return)logistics point of view, tend to reduce eco-impacts related to transport. In circular practice, however, the closed loop variety offers more economic promise, as it can operate on product, part and material level and thus provides more opportunities for preserving perceived added value in a business context.

## Case: Circular Footwear Alliance

The Circular Footwear Alliance was established by Allshoes Safety Footwear and EMMA Safety Footwear to encourage organisations to invest in designing recyclable work and safety footwear for a circular system. Companies registering with the alliance receive designated collection boxes for collecting used work and safety footwear. Once collection boxes are full, the footwear is taken to a central sorting location. The footwear is disassembled using existing and new recycling technologies, reclaiming valuable raw materials which are then used to produce new products. The ultimate objective is to develop a fully circular safety shoe.



[cfalliance.eu](https://cfalliance.eu)



---

# 3. Extending Useful Product Lifetime

## 3.1 Introduction

In an ideal - as opposed to a real-world - circular economy, the concept of waste no longer exists. Because of the clear end-goal of zero waste, the circular economy concept is considered an absolute approach to sustainability, as opposed to other, more relative approaches. The latter are aimed at reducing waste and harmful emissions by making existing local situations or specific products less environmentally damaging. The circular economy concept, instead, is aimed at eliminating waste and harmful emissions altogether by transforming the way we do things at a systemic level. This distinction may be subtle or even feel artificial to some, but is important to keep in mind as it has profound consequences for how we look at tangible products and their business contexts in a circular economy.



## Case: Roetz-Life E-bike

Roetz factory introduces the Roetz-Life E-bike, designed to extend the typical 6 to 7-year lifespan of electric bikes. The bike can be adapted to suit diverse mobility needs, for example use as a cargo bike or for transporting children. Prioritising easy servicing and maintenance, key components like the battery, lights, brakes, and the rear wheel are designed for quick replacement, enhancing longevity of the bicycle as a whole. The frame minimises components, reducing the need for material recycling and making repairs simpler. The bike can be leased or bought. In the latter scenario, Roetz buys back the frame post-use. Sensor monitoring extends part lifespan, with preventive maintenance notifications sent to users and home servicing offered by Roetz.



roetz.life

In an economic system where waste is allowed, industry tends to recover and recycle only those products, components and materials that can be recovered and recycled profitably. In a perfect circular economy, where waste is no longer an option, every single piece of a product must be recovered and recycled at the end of its useful lifetime, no matter how costly or difficult. It may, of course, be clear that in practice this is impossible, however performing this mental exercise helps us to better understand why, in a circular economy, the order in which we apply recovery interventions to products and systems is so important. For if we know we ‘must’ process even the most difficult bits of our products at end-of-life at potentially high cost, it then makes perfect sense to strive to both postpone and reduce the number of end-of-life events as much as possible and preserve and capture as much of the added economic value we painstakingly added when manufacturing those products. When we, for example, shred a product prematurely and only recover the economic value of the embedded materials, we destroy much of the added value. This value could have been captured as business revenue should the useful lifetime of the product as a whole have been extended first, for example by reuse, repair or remanufacturing.

## 3.2 Design Approaches for Extending Useful Product Lifetime

In principle, there are three main design approaches to achieving a long or extended useful product lifetime in a circular economy. The first is to design a product that is so robust, well-made and loved that people can and will use it for as long as they can. The second is to design a product in such a way that it can be easily maintained, repaired and upgraded, should



need be, so that it can fulfil the needs of its user for a long time. The third and final approach is to design a product optimally suited for use by another user, either 'as is' or after refurbishing or remanufacturing.

These different design approaches can be used separately, but can also be used in conjunction, as, for example, achieved by bicycle manufacturer Roetz in the design and engineering of their [Roetz-Life E-bike](#). With a durable stainless steel frame and an overall design that prioritizes easy servicing and maintenance, the E-bike is built to last. In another example, [Billenboetiek](#), combine the first two approaches in their offer. They specialise in sustainable cloth diapers that, with regular washing, can be reused again and again. The smartphone producer [Fairphone](#) has chosen a particularly interesting focus on the second approach by designing and engineering their products in such a way that all repairs and upgrades can be carried out by the phone owners themselves, thus significantly lowering the cost and (logistic) complexity of repair and upgrade procedures. The mattress manufacturer [Ubed](#) has developed innovative modular mattresses so parts can easily be replaced, allowing personal tuning, but more importantly, increasing the mattress lifetime to double the industry average of 10 years. Architectural firm Cepezed, together with Du Pre architects, designed and built a [Temporary Courthouse](#) in Amsterdam that after its pre-planned 5 year use as a courthouse can be cleanly disassembled and reconfigured into a new building with a different function in a new location.

Coming from a linear economy, many of our current products are not designed and engineered with lifetime extension in mind. Still, many of the interventions, such as maintenance, repair, refurbishing and recontextualising (i.e. use of a

## Case: Billenboetiek

Billenboetiek is a Dutch online retailer offering a range of cloth diapering solutions, making it easier for parents to choose an eco-friendly and cost-effective alternative to disposable diapers. The company offers comprehensive cloth diaper packages enabling parents to get started with cloth diapering without the complexity of selecting individual components. Billenboetiek prioritises the sale of new, high-quality washable cloth diapers to maintain product hygiene and quality standards. In addition, Billenboetiek provides educational resources and consultations to make cloth diapering a practical and environmentally friendly choice for parents.



[billenboetiek.nl](http://billenboetiek.nl)

## Case: Fairphone

Fairphone, founded in 2013 by Bas van Abel, is a Dutch smartphone manufacturer dedicated to making ethical and sustainable practices the standard in the electronics industry. Fairphone creates smartphones that prioritise environmental impact reduction, social responsibility, and product longevity. At the core of their products is a modular design approach. This means that all components, including camera, battery, and screen, are easily replaceable or upgradable by the user, in order to extend the device's lifespan and reduce electronic waste. Fairphone places a strong emphasis on sourcing minerals like tin, tungsten, and gold from conflict-free regions. The company collaborates with manufacturers that support fair wages, safe working conditions, and labour rights, reducing exploitation often associated with electronics production.



[fairphone.com](https://www.fairphone.com)

product by another user or in a different role than it was originally designed for) can be applied to products originally designed and engineered for use in a linear economy, albeit in many instances not as efficiently or cost-effectively. The United Repair Centre, for example, aims to save one million kilograms of textile waste annually, and encourages other brands to join their denim repair centre initiative. Cooloo combines two circular approaches: first, they take materials such as leather and cork from waste streams to create high-end coatings. Next, they use these coatings to refurbish used furniture, thereby granting these pieces a second life. The 'Repurpose Driven Design' project explores how discarded products, parts and materials not designed with lifetime extension in mind can be given a second life while retaining as much of their functional and emotional value as possible.

What approach works best in practice for a particular product or organisation depends on many factors such as type of product, company size and strategy, location etc., and needs to be thoroughly examined on a case-to-case basis.

A useful rule of thumb regarding the preferred order of possible interventions for extending useful product lifetime in a circular economy was laid down by Walter Stahel, founder of the Product Life Institute, in what he called the 'Inertia Principle'. Every intervention for extending useful product lifetime comes with its own economic cost and environmental impact, as it involves transport, exchanging parts etc.. The Inertia Principle therefore recommends limiting our interventions to replacing or changing only the smallest part required to restore the economic value of a product or system. So, as Stahel puts

it, don't repair a product that's not broken, don't remanufacture a product that can be repaired, and don't recycle a product that can be remanufactured.

As such, in a circular economy it pays from both an economic and an environmental perspective, to carefully consider and even plan the different interventions and use cycles of a product over its entire useful lifetime, preferably at the design stage of a new product. An important reason for doing this as early as possible is that application of the Inertia Principle not only affects the design of the actual tangible product, but more often than not it also puts specific requirements on the business context(s) that product is embedded in over its lifetime. Manufacturing and selling a brand-new product is challenging enough, but how do you market products that need their use cycles to be carefully managed along their total lifetime in order to achieve the lifetime potential they were designed for? One of the most promising answers to that question is a concept called 'servitisation', a subject we will discuss in more detail in chapter 4.

## Case: Ubed

Every year, millions of mattresses end up as non-recyclable waste; in the Netherlands over 1.6 million mattresses are discarded annually. Ubed, a Dutch bedding manufacturer, has developed modular mattresses with 100% interchangeable and recyclable components, doubling the mattress's lifespan while reducing waste. Ubed's mattresses use 3D Polyester, a material that excels in ventilation, ease of cleaning, and durability, ensuring a comfortable, fresh sleep experience. This innovative approach not only contributes to a cleaner environment, but it also benefits sleep quality.



[ubed.com](https://ubed.com)



---

# 4. Servitisation

## 4.1 Introduction

At present, the vast majority of businesses built around durable consumer goods, i.e. physical products intended for more than single use, create their revenue by selling as many products as they can within a given timeframe. In mature economies, the majority of these transactions are what are called ‘replacement purchases’. In these cases, we buy newer versions of products that we already own which, in most cases, are still fully functional. The older product gets discarded not because it is worn or broken, but because we are tempted by one of the heavily promoted new models with more functions, in a seemingly never-ending stream of new product introductions. It should come as no surprise that circular interventions aimed at reducing the number of these replacement purchases, for example by extending the useful lifetime of products, are often perceived by industry as a threat to profitability. The concept of servitisation is important in a circular economy as it offers a way to resolve the apparent paradox of reducing the number of products traded whilst preserving revenue, or in circular economy terms ‘limiting the inflow of non-renewable resources into our economic system whilst preserving its capacity to generate wealth and well-being’.

## Case: Temporary Courthouse

The Central Government Real Estate Agency asked Du Pre architects and Cepezed developers to design and build a temporary, sustainable building for the courthouse in Amsterdam. The courthouse had to demonstrate circular characteristics like preventing waste and maximising residual value. Knowing its use as a courthouse would last for 5 years only, it was designed to be highly adaptable, permitting various uses by different occupants in different locations after its initial use. The removal and reuse of components are contractually mandated. To enhance adaptability and circularity, the building was designed as a 'kit of parts', easily assembled, disassembled, and reassembled, while retaining the same level of quality, functionality, and representativeness of a permanent facility.



cepezed.nl  
(photo by Leon van  
Woerkom)

Servitisation begins with two important realisations. The first is that people generally want products for what these products can do for them, i.e. how these products help increase their perceived quality of their life. From buying the latest smartphone model because it helps them stand out from their peers to buying a washing machine because they value clean clothes and bed linen, few people buy a durable consumer good just because they want to own the bundle of materials the product is made of.

The second realisation is that no value proposition is created on the basis of either 100% tangible product or 100% intangible service. Every value proposition is supported by a mix of the two: physical products come with service, and services are provided with the help of tangible products. By rethinking and (re)positioning their value proposition as a combination of a physical product and a service, positioned somewhere on the scale between 100% product and 100% service, businesses can create opportunities for retaining or even increasing their profits with fewer tangible products.

## 4.2 Forms of Servitisation

These new, more circular value propositions come in many different flavours.

One closest to the current situation would be to provide customers with an affordable repair service or upgrade paths to support their current products, so they can use them longer (See the [Fairphone](#) example). Another option is to change the nature of the commercial transaction. Instead of merely transferring ownership of relatively short-lived physical products in a single sales transaction accompanied by a limited warranty, renting or leasing products that last with lifelong support could prove a more profitable alternative;

many people with busy lives would gladly trade some of their cash for a hassle-free experience. Others with less buying power can gain access to long-life (higher grade) products and appliances that are otherwise beyond their reach by 'paying as they go', instead of having to come up with the full sum needed for a one-time purchase. A small price premium could remove a great deal of inconvenience, risk and stress for consumers. Bicycle subscription service [Swapfiets](#) does just that by offering customers a convenient and sustainable way to get around. Similar options can be found in the field of clothing and fashion. For example, [MUD jeans](#) offers a concept where customers can lease their jeans instead of buying them, and returning them for recycling when worn out – an example of a closed loop system (chapter 2). [Palanta Designer Clothes Rental](#) offers customers access to a curated collection of high-quality and well-maintained garments without the commitment of ownership.

An altogether different approach is that of selling performance instead of materials or physical products. The concept of a 'performance economy', perhaps the ultimate form of servitisation, was proposed by Walter Stahel. Instead of buying the actual physical product, customers pay for the result generated with the help of the physical product, the performance. In these cases, customers don't even operate the actual products that create the results, for example in the age-old laundromat service, where customers bring in dirty clothes only to pick them up cleaned and ironed a little while later, without ever having to go near washing machine, dryer or ironing board.

## Case: United Repair Centre

The goal of United Repair Centre, a collaboration between Makers Unite and Patagonia, is to transform clothing repair. The aim is to save one million kilograms of textile waste by carrying out 300.000 high-quality repairs annually. Brands are encouraged to embed these repair services into their business models. New textile repair professionals are trained at the United Repair Centre Academy, a joint initiative with House of Denim. Customers send their clothes that are in need of repair to the specific brands, which in turn forward them to the repair centre. The brand then returns the refurbished item to the customer, increasing the product's lifespan and supporting the growing demand for extended responsibility.



[unitedrepaircentre.com](https://unitedrepaircentre.com)



## Case: Cooloo

Cooloo transforms waste streams into high-end coatings for furniture, interior projects and design applications. For instance waste streams such as concrete, leather, jeans or even shredded banknotes are turned into upholstery, acoustic materials or complete interior make-overs. These flexible coatings are a sustainable alternative to upholstery. Cooloo's vision is that art, design, and industrial solutions can be created within a sustainable and circular economy. Therefore Cooloo develops aesthetic and ecological coating solutions that can be applied flexibly and create high-end design products. The Cooloo techniques are shared worldwide with licensing partners so that everyone can increase their sustainable impact.



cooloo.nl

## 4.3 Benefits of Servitisation

From a circular economy as well as a business perspective, servitisation has many advantages. By shifting some, or all, of the burden of generating revenue from the physical component to the service component supporting the value proposition, it becomes possible to create multiple propositions tailored specifically to the wants, needs and purchasing power of different customer segments. These are then perceived as being more valuable, while based on essentially the same physical product. In addition, the service component can be customised to 'pick up the slack' resulting from the fact that the physical product component supporting the value proposition remains the same or has deteriorated somewhat with time, to still create an overall offer that is valued by customers. Telecom provider KPN, for example, offers subscription plans that include refurbished, second hand smartphones. The 2-year warranty and difference in price (service components) make up for the fact that the smartphone (physical component) is not brand new.

More advanced servitisation solutions, i.e. those where the actual physical products are no longer sold to the customer but offered as part of a service, have even greater benefits. The 'Pay-per-lux' proposition of lighting company Signify (formerly 'Philips') is a working example of a performance-based solution. Customers pay for the amount of dynamic lighting tailored to their working conditions that is delivered; Signify provides, and retains ownership of, the physical lighting fixtures and picks up the energy bill. In these servitisation models, the ownership of the products and the often valuable resources embedded in them typically remains with the company that markets and manufactures them.



During the use phase, companies instigate proper and timely maintenance and repairs, substantially increasing the longevity of their products. For well-designed and engineered products, i.e. products that can be easily disassembled into components and clean material fractions, retaining ownership means that a wealth of secondary resources remains available to the original manufacturers, limiting the need for the use of virgin materials and reducing future supply chain risks.

## Case: Repurpose Driven Design

The Repurpose Driven Design project focuses on utilising the added value of used products, discouraging the use of virgin materials, and promoting value retention. This project, led by the Circular Design & Business professorship at Amsterdam University of Applied Sciences, explores how discarded products, parts, and materials can be given a second life while retaining their functional and emotional value. Current examples are the re-use of discarded chairs from the Johan Crujff ArenA stadium in Amsterdam and sliding doors from office cupboards. The project's three main strategies involve using materials in new contexts, creating new products from old components, or using old materials as the basis for new products.



[hva.nl/repurpose](https://hva.nl/repurpose)



---

# 5. New Materials and Production Techniques

## 5.1 Introduction

So far, we have highlighted a number of different approaches that can, either separately or combined, act as a gateway to circularity for an organisation. At first glance, they may seem an eclectic mix of interventions in both the tangible and intangible aspects of an organisation. However, at their core, they share the common aim of reducing the net eco-impact of materials and energy used by organisations and their extended economic systems. Most of the interventions presented in earlier chapters constitute ways of reducing the amounts of environmentally harmful or economically scarce materials that enter our economic system to compensate for those materials that escape along the entire value chain as non-recoverable waste. The illustrative cases show that these interventions often involve complex business

## Case: Swapfiets

Swapfiets is a bicycle subscription service offering customers a convenient and sustainable way to get around, providing a hassle-free solution to urban mobility. Customers subscribe to Swapfiets for a fixed monthly fee which covers the use of a bicycle and its maintenance and repairs. The distinctive Swapfiets green front tire make Swapfiets bicycles easily recognizable and act as a theft deterrent. In addition, when worn, the blue tires are returned to their original manufacturer to be turned into new blue tires. Swapfiets simplifies cycling for city residents by eliminating the need to worry about maintenance or unexpected repair costs. Following its introduction in the Netherlands in 2014, Swapfiets has now extended its services to users in many European cities.



[swapfiets.nl](https://www.swapfiets.nl)

model and logistics adjustments, whether extending the useful lifetime of products, providing products as a service, or collecting products after their useful lifetime has ended.

In this chapter, we review a different, though highly complementary, approach, asking, ‘what if the materials and processes used to manufacture our products would inherently be less environmentally damaging or economically scarce to begin with?’ Then, for example, non-toxic materials could be recovered successfully by parties other than the original manufacturer, reducing the need for maintaining ownership or for return logistics. They could more easily find secondary uses as they no longer pose a danger to the ecosystem or to human health. Should they accidentally end up in the environment, they could perhaps disintegrate in a way that seamlessly matches natural and organic processes. But even in conjunction with many conventional technical materials, that most certainly must not end up in the environment, the use of alternative manufacturing processes could prove beneficial. New processes, for example, that do not require mixing one type of material with another in ways that would prevent reuse or recycling or that can connect components in a manner that makes it possible to take them apart cleanly and easily, could greatly help to reduce the overall eco-impact of materials used.

When assessing new materials and production techniques for a circular economy, we discovered three variations are theoretically and practically possible: new materials in conventional production processes, conventional materials in new production processes, and new materials in new production processes. We discuss each of these options, provide some promising examples,

and look at aspects that need to be carefully considered when aiming to introduce new materials and processes to increase circularity in an organisation.

## 5.2 New materials with conventional production techniques

The application of new materials in conventional, industrial scale production processes often involves the use of plant-based fibres or of thermoplastic bio-based and/or bio-degradable plastics that can be processed with conventional production techniques such as spinning, twining, weaving, pressing, extrusion, blow-moulding or injection moulding. The Rietgoed project, for example, transforms seagrass, more specifically, the fibres of reed mace plants, into sustainable textiles, as well as modifying extraction techniques to improve the quality of the resulting yarns.

Paperfoam provides another example of the application of bio-based materials to form a recyclable and compostable alternative to traditional plastic and foam packaging. Seepje develops effective natural clothes-cleaning products made from soap berries rich in saponin, working closely with communities in Nepal and India to help their personal and economic development.

Bio-based plastics are made from renewable biological sources like plants, algae or trees. There are a number of important aspects when considering the use of bio-based plastics. First, from a sustainability perspective, it is preferable to use bio-based resources such as agricultural cutoffs, that do not compete with those used for human or animal food production. Peelpioneers, for example, has specialised in drawing valuable ingredients from food waste like orange and lemon peel and vegetables that would otherwise

### Case: MUD Jeans

MUD Jeans is a Dutch denim brand offering customers a circular fashion approach: leasing instead of purchasing. This not only reduces the overall number of jeans produced but also encourages customers to return their old pairs when they're done with them. Returned jeans are then recycled into new ones, creating a closed-loop system. The brand uses organic and recycled materials for their jeans, minimises water usage, and encourages ethical labour practices. MUD Jeans' transparent approach allows customers to track their jeans' entire journey, from sourcing materials to production and recycling.



[mudjeans.nl](https://mudjeans.nl)

## Case: Palanta Designer Clothes Rental

Palanta is a clothing rental business that promotes the idea of 'slow fashion', encouraging people to choose quality over quantity. Through their subscription service, customers access a curated collection of designer clothing, for rental rather than purchase. The service offers a wide range of clothing styles, brands, and sizes, offering subscribers a more diverse wardrobe without the commitment of ownership. With Palanta handling the cleaning and maintenance, the rental process is hassle-free and ensures subscribers receive clothing items in good condition.



[palanta.co](https://palanta.co)

be discarded. Secondly, the fact that plastics are bio-based does not automatically mean they are also bio-degradable. Many currently produced bio-based plastics, like (partly) bio-based PE, PP or PET, are virtually indistinguishable from their fossil-based varieties, and, like their fossil-based varieties, they are non-biodegradable. Thirdly, it is now possible to create bioplastics that are both recyclable and completely biodegradable, for example PLA and PHA, which can be broken down completely and safely by microorganisms into water, carbon dioxide, natural mineral salts and new biomass within a defined period of time.

Which option is best and eventually will result in the smallest overall environmental footprint for an organisation depends on the specific situation. What should be avoided at any cost is the use of so-called oxo-degradable plastics. These are fossil-based plastics that disintegrate into minuscule fragments under the influence of oxygen and heat. These microscopically small pieces of plastic contaminate the environment, with nano particles ending up in living organisms, including the human bloodstream.

## 5.3 Conventional materials with new production techniques

The use of conventional materials in new production processes encourages the use of materials in applications and ways that previously were not deemed feasible. Advanced production techniques like additive manufacturing (as in 3D printing) and robotic production not only help increase the level of precision, repeatability, geometric freedom and control, they also allow for a high level of customisation as they are software based and computer-controlled. In the 'Circular Wood for the Neighbourhood' research project, wooden elements such as door frames

and beams are recovered locally from renovation or demolition sites. In the subsequent digital production process, new wooden parts are carved from what was once considered as waste. **Impacd Boat** uses 3D printing to build their electric-powered recreational boats from recycled PET bottles and household plastic waste. A 6.8 meter long boat can be printed in 72 hours. **ByBorre**, an Amsterdam based textile innovation studio, uses digital technologies to manufacture and design their fabrics, allowing for creative freedom in yarn and fabric production.

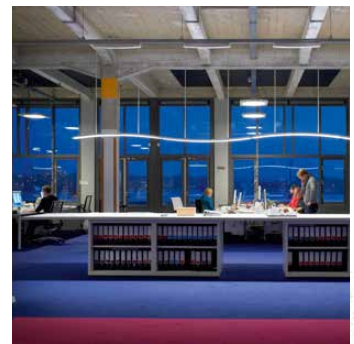
One of the main environmental advantages of additive manufacturing is that less material is needed compared to conventional processes, as excess material does not have to be removed. Instead, the correct amount of material is exclusively deposited there where it contributes the most from a functional perspective. Because mechanical and aesthetic product properties are determined to a substantial degree by the processes used in their manufacture, the resulting products from these novel combinations of materials and production techniques often sport a look that is 'different yet familiar'. Depending on the type of product and customer, this can be either an advantage or a disadvantage for an organisation that wants to employ these new combinations.

## 5.4 New materials with new production techniques

For this third variation, we are referring to biological materials that are coaxed to grow into specific shapes, or to bio-based materials that are shaped into products with the help of additive manufacturing techniques. An example of this is **Urban Reef**, which creates bio-based algorithms to control 3D printers. Printing with bio-based

### Case: Pay-Per-Lux

In 2011, Philips (now Signify), prompted by architect Thomas Rau, introduced 'Pay per Lux' or 'Light as a Service'. Users pay for the actual amount of light used, rather than owning the lighting fixtures. Consumption is measured based on performance, specifically the quantity of lux (light units) used. Signify acts as the primary contractor, handling both lighting installation and energy costs while retaining product ownership, allowing users to benefit from energy-saving innovations. After the contracted period, Signify takes back the lighting products for reuse or recycling, reducing waste and optimising resource use.



[signify.com](http://signify.com)



## Case: Rietgoed

RietGoed is a project developed by designer Iris Veentjer of Studio i Focus, focused on transforming cattail, a tall reedy marsh plant, into eco-friendly textiles. The project's first tangible product, a kitchen towel, is crafted from reed mace fibres. RietGoed's textiles respond to the unique challenges of large-scale farming in the Netherlands, by emphasising the natural benefits of wet cultivation methods. By championing wet fibre crop cultivation, the project combats land subsidence and reduces CO2 emissions, while raising consumer awareness. The project extends beyond making reed-based textiles; it also aims to improve the extraction techniques, facilitating the production of superior yarns.

and even living materials, these printers in turn produce objects that serve as a habitat to living organisms which can regulate environmental moisture and temperature without use of additional technology. Another example of a new production technique was explored in the [3D Concrete Printing on Sand](#) project, in which moulds are created using robotically formed sand formwork, avoiding the need for wooden scaffolding, plastic or foam-based formwork for pouring concrete.

At the current level of development, one of the main obstacles to industrial scale production with these techniques is the speed at which many of these processes take place. Another potential obstacle, shared with many bio-based solutions, is that material properties, such as for example resistance to moisture, mechanical strength and scent, tend to differ from those of more familiar conventional, technical materials.



[rietgoed.nl](http://rietgoed.nl)



---

## Case: 3D Concrete Printing on Sand

'3DCP on Sand: Filigree Freeform Facades' is a research project exploring innovative patterns and ornaments in architecture using 3D Concrete Printing (3DCP). Executed by prof. Juliette Bekkering, in collaboration with Neutelings Riedijk Architects, TU Eindhoven's Department of Architecture and Engineering, and Vertico, the project focuses on exploring aesthetical and technical feasibility of double-curved facades with filigree infill. By combining designer skills with technical skills, a unique visual language was developed. The research addresses the issues of circular construction and reduction of raw-material usage in concrete formwork, by using sand as reusable moulds, robotically shaped into various non-standard geometries, offering flexibility and sustainability in architectural design.



[bekkeringarchitects.nl](http://bekkeringarchitects.nl)



---

# 6. Information Technology and Digitisation

## 6.1 Introduction

In our current linear system, there are a number of reasons why products and their embedded materials manage to escape from the multitude of interconnected supply chains that make up our economy. Perhaps the most important of these is the industry tendency to sell, or better: 'permanently transfer ownership of', products and their constituent materials to customers. From the late 18th century, the sale of products has been the primary mechanism for capitalising on value added during production and distribution. To this day, most manufacturers do not know whether, when and in what condition they will get their products back after they have been discarded, either prematurely or at the true end of their useful lifetime. And, from a circular perspective, things are even worse. Many manufacturers don't even want their products back, as they have no idea what to do with them. The vast majority of products are sold in one-way transactions, and striving for the lowest manufacturing cost is still

## Case: Paperfoam

PaperFoam is an eco-friendly alternative to traditional plastic and foam packaging. It is made primarily from renewable and biodegradable materials, including natural fibres and industrial starch. This makes it lightweight, sturdy, and fully compostable. It provides excellent protection for a variety of products such as electronics, cosmetics, and food items, without contributing to plastic waste or environmental pollution. PaperFoam's production processes consume less energy and generate fewer greenhouse gases compared to those of conventional packaging materials. Additionally, PaperFoam can be easily recycled or composted, contributing to a circular economy and reducing the strain on landfills.



[paperfoam.com](http://paperfoam.com)

the name of the game in most linear economy industries. Thus, many products are put together in ways that make it virtually impossible to repair, refurbish or remanufacture them or even recover intact components or uncontaminated materials. Products are discarded prematurely and precious, non-renewable resources are lost as often only small fractions can be recovered at materials level from discarded products and packaging. As a result, a constant inflow of energy and virgin material resources is required to keep the economic system going.

In previous chapters, we present several approaches to preserve added value, energy and materials in order to help curb the inflow of resources into our economic system. What all of these approaches, ranging from looped systems (chapter 2), extension of useful product lifetime (chapter 3), servitisation (chapter 4) to new materials and production techniques (chapter 5), have in common, is that information technology and digitisation are key enablers for their successful implementation. Although digital technology has its own ecological drawbacks, some of which are addressed in this chapter, and therefore must be implemented with care, there is little doubt that information technology and digitisation are essential when moving towards a more circular economic system.

## 6.2 The Role of Information Technology and Digitisation in Support of Looped systems

Looped systems prevent valuable resources escaping from our economic system or from ending up being contaminated beyond economically and ecologically viable recovery.

The success of looped systems in general, and closed loop systems in particular, largely depends on how well actors throughout the supply chain are able to keep track of the momentary whereabouts of products and embedded resources in the wider economic system. The Madaster platform, for example, keeps records of building components used in real estate and infrastructure objects. Their database and materials passports help simplify the dismantling process for potential reuse. ByBorre, for example not only uses digital technologies to manufacture and design their fabrics, but also maintains a textile library containing material passports that show where their materials and product are and have come from. Scanning equipment and information technology is used to identify and help sort products and materials in deposit systems and waste collection streams alike. CurvCode by FiliGrade Sustainable Watermarks is an example of a digital watermark technology used in packaging that was designed specifically to aid mechanical waste sorting.

Information technology is used to monitor and process the information many modern day electronic products, such as computers, microwave ovens and fridges, transmit when connected to a digital network like the Internet of Things. Without these crucial information systems, the flows of product and materials would become more difficult to manage and predict, let alone control. Especially in closed loop systems, once control is lost, the resources have, for all practical intents and purposes, disappeared from the economic system. Any opportunity for original equipment manufacturers to capitalise on value added earlier disappears with them.

When hazardous technical materials get lost in the biosphere, what was an economic problem becomes an even greater problem, as this crossing of technical and biological loops has a

## Case: Seepje

Seepje creates eco-friendly laundry and household cleaning products. Seepje's laundry detergent, their flagship product, is made from natural soap berries (*Sapindus Mukorossi*) rich in saponin, a natural soap, which effectively cleans clothes without the need for harsh chemicals. Moreover, the colour of the Seepje containers has been chosen so that they can be made from recycled conventional plastics and the paper labels can be attached without the use of glue to ensure both the containers and the labels can be recycled again after use. The company works closely with communities in Nepal and India, empowering these communities and ensuring sustainable soap berry harvesting practices.



[seepje.nl](http://seepje.nl)

## Case: Peelpioneers

PeelPioneers is specialised in tackling food waste by focusing on the innovative use of, often-overlooked, fruit and vegetable peel. PeelPioneers has developed techniques to transform these discarded peels into valuable ingredients and products, promoting a waste-to-value approach. For example, citrus peel oil, extracted from discarded orange and lemon peels has many applications in food, cosmetics, and cleaning products, offering a natural alternative to conventional ingredients. By repurposing peel that would typically be discarded, PeelPioneers contributes to reducing food waste and its environmental impact. This aligns with the growing demand for eco-friendly and ethical sourcing in the food and cosmetic industries.



[peelpioneers.nl](https://peelpioneers.nl)

detrimental effect on both human health and the living environment. In the context of looped systems, digital technologies allow companies to uniquely mark and subsequently detect, track and trace their products and materials along the entire supply chain. Technologies like Blockchain help to increase trust and transparency, as the data are virtually incorruptible and accessible for all users and supply chain partners involved. Accurate data on the how, where and what of products and resources are at the basis of circular asset and resource management and control in (closed) looped systems. The data help prevent resources from disappearing, or being intentionally disappeared as illegal waste, from the wider economic system. When combined with artificial intelligence, these digital technologies can become an even more powerful aid in managing open and closed looped systems. They can, for example, enhance the accuracy and speed of material recognition and sorting, or support advanced forecasting of the (reverse) logistics required to run economically viable open or closed loop systems.

## 6.3 The Role of Information Technology and Digitisation in Support of Extending Useful Product Lifetime

In addition to keeping track of the whereabouts of materials and products in looped systems, digital technologies play an important role in extending the useful lifetime of products by ensuring timely maintenance and repair of assets in a circular economy. For example, digital twins and (remote) monitoring system can provide insights into the current condition of products, equipment and processes. Based on this information, adjustments, preventive maintenance and repair

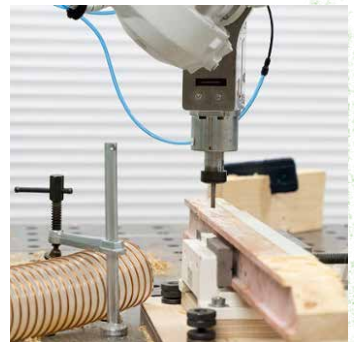
can be executed before products, processes or production lines grind to a costly, and sometimes even dangerous, halt. Bicycle manufacturer Roetz, for example, uses sensors and digital technology to timely inform the user about needed service or repairs. In conjunction with new materials and production techniques, digital technologies can help ensure that spare parts for many products become available around the world and remain available over time, as digital libraries of part geometries together with distributed manufacturing technologies, such as 3D printing and robotic production, eliminate the need for costly warehousing and extensive shipping of parts.

## 6.4 The Role of Information Technology and Digitisation in Support of Servitisation

In addition to the two roles outlined above, digital technologies can be used to support servitisation (chapter 4). In short, servitisation aims to increase the importance of the service component of a value proposition in order to reduce the number of physical products required to run an economically viable business. Different modes of making physical products available to customers, often in conjunction with dedicated services, offer manufacturers alternatives to permanently transferring product ownership and allow them to retain control of their products and embedded material resources. Instead of being sold, products can, for example, be made available to users for shorter or longer periods of time through rental or lease or used to deliver a desired result to customers. In support of such ‘pay-per-use’ or ‘pay-for-performance’ product-service systems, digital technologies can, for example, be used to

### Case: Circular Wood for the Neighbourhood

Research by Amsterdam University of Applied Sciences revealed the need for standardised processes to salvage waste wood from renovation projects. The Circular Wood for the Neighbourhood project addresses current inefficiencies of processing discarded wood. Advanced technology using computational design and industrial robots breathe new life into pieces of waste wood from renovation projects that would otherwise have been discarded. Using digital scanning, their geometries, including the location of foreign elements like screws and nails, are logged. The software then determines how specific new wooden parts can best be created, using robotics for ultimate flexibility. Typically consigned to incineration or other low-value applications, waste wood from housing renovations is now given a second chances.



[cw4n.nl](http://cw4n.nl)



## Case: Impactd Boats

Impactd Boats was inspired by the sight of numerous abandoned boats in Friesland, Netherlands, a popular water sports province in the Netherlands. Impact boats are 3D printed from recycled PET bottles and household plastic waste, customizable with various textures and colours. The process takes 72 hours to print a 6.80-meter boat. These boats are powered by electric motors, eco-friendly and fully recyclable. Impactd collaborates with Delft University of Technology for sustainability assessments. The company seeks to automate production and enhance sustainability further, producing CE-certified boats. Their focus lies in creating high-quality, eco-friendly boats with minimal environmental impact, promoting a greener future for water sports.



[impactdboats.com](http://impactdboats.com)

grant temporary access, accurately monitor and log the actual use and location of the products involved, and provide a means of secure payment for services rendered.

## 6.5 Information Technology and Digitisation to Replace Physical Products and Interactions

Lastly, information technologies and digitisation have the potential to actually replace physical products and interactions. A striking example are our current smartphones and tablets. In the span of ten to fifteen years since their introduction, their rapid technological advancement has virtually eliminated the need for many separate analogue and digital devices in all but the most demanding professional applications. Media players, diaries, address books, digital cameras, GPS navigation, audio recorders, maps, weather stations, clocks, measuring equipment and portable gaming consoles are just a few of the products they have replaced by taking over and improving on their functionalities. Moreover, security and encryption facilities on portable and wearable devices such as tablets, smartphones and smartwatches have reached levels that they can be used for payment and identification purposes and safe (local) storage of confidential (medical) information, potentially eliminating the need for cash, plastic credit cards, and paper files. Video conferencing and the option of working remotely have changed our attitudes towards physical travel and work, reducing the need for office facilities and transportation. Taken to its (current) extreme, entire spaces and environments can be (re)created or augmented by means of virtual reality, potentially reducing the need for tangible physical artefacts even further.



---

## 6.6 Digitise with care

From the above, it may be clear that digital technologies harbour a huge potential for enabling and speeding up the transition to a circular economy. However, this is not to say that information technologies and digitisation should be embraced without questions or limits. Many of the chips and passive antennas used, for example, in tracking and in retail theft prevention systems are single use. They are sewn into clothing as labels or stuck onto the inside of packaging. Before the newly acquired products are used, these labels are cut out of newly bought garments and, sharing their fate with packaging, thrown into waste bins. Active devices, scanning devices and the computing equipment used to run software applications contain even more electronics and rare earth metals and minerals that are too valuable to discard or lose. As things are now, digital systems and information technologies like AI or Blockchain, that without doubt can play an important role in both managing looped systems, servitisation and product lifetime extension, are forecast to consume ever larger amounts of energy in the coming years. Unfortunately, this energy is still mainly derived from non-renewable resources. Because of this, the environmental impact of resources and energy consumed by information technologies and digitisation should always be carefully weighed against the economic and ecologic benefits that their deployment in service of circular economy tasks is expected to bring.

As such, there is an interesting form of reciprocity between the circular approaches noted in previous chapters and information technology and digitisation: the principles of looped systems, product lifetime extension and servitisation should all be applied to digital technologies so that, in turn, digital technologies can be put to use responsibly, i.e. with a net positive eco-effect.

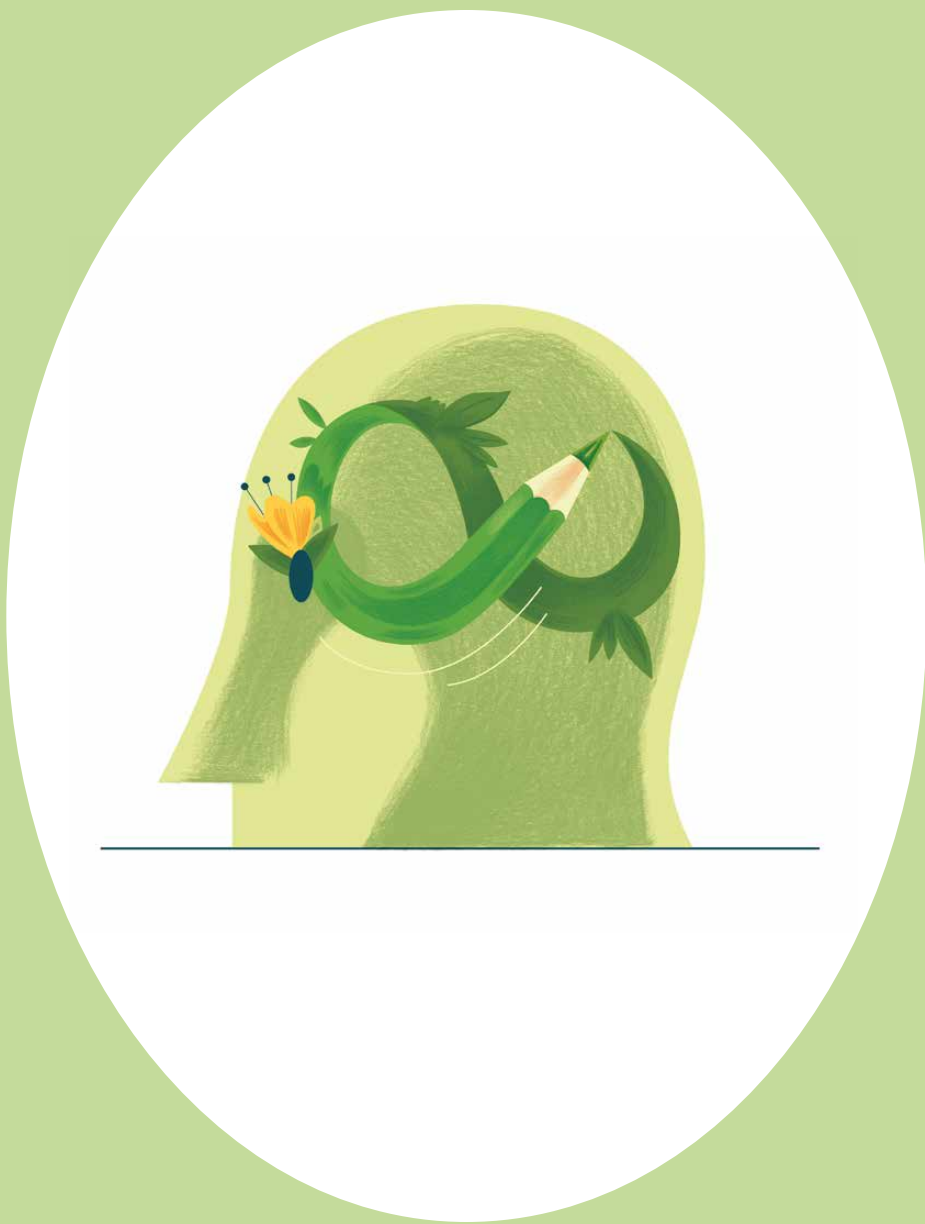
---

### Case: Byborre

Byborre, an Amsterdam-based textile innovation studio started by designer Borre Akkersdijk, specialises in high-quality knits created through advanced technology, emphasising material development, functionality, and aesthetics. Byborre's approach involves hand-rendered techniques that provide creative freedom to experiment with patterns, colours, and textures. By designing from the yarn up, Byborre redefines the relationship between material and machine. The studio houses a knitting and innovation lab, an atelier, a team of experts, and a library of unique fabrics. In addition to fabrics based on customer designs, in the Byborre Textile Library<sup>TM</sup> the products' textile passports show where the yarns come from, how the textiles are produced, and all the steps in between.



[byborre.com](http://byborre.com)



---

# 7. Creating Public and Industry Awareness

## 7.1 Introduction

The previous chapters show examples of how organisations and businesses can move towards a more circular way of working. In some of these examples, the nature of the changes implemented is unmistakable to the customer, as demonstrated by substituting a digital solution for what used to be a physical product, or changing from lacquered wood to 3D printed recycled plastic.

In other examples, changes take place behind the scenes and out of view of customers or even competitors. Sometimes this can be intentional, as change is not always appreciated by consumers. For example, as a stubborn remnant from the early days of eco-design, so-called 'green' products are still often thought to be of inferior quality, or more expensive, than their 'regular' counterparts.

## Case: Urban Reef

Urban Reef is a young Dutch company located in the Rotterdam Innovation Dock. Urban Reef create special habitats in cities to help a greater variety of living grow and live together. They create bio-based algorithms to control 3D printers, using bio-based and living materials to print natural, organically grown looking objects. These so-called 'Reefs' serve as a habitat for living organisms. When placed in urban environments these inhabited structures help regulate moisture and temperature without the need for additional technology.



[urbanreef.nl](http://urbanreef.nl)

With regard to quality, in many cases this prejudice no longer makes sense, as materials and production techniques have improved significantly. Cost and price, however, can still pose a problem as many alternative production processes are not fully matured, and the use of new materials is not yet sufficiently widespread to benefit from economies of scale.

## 7.2 Achieving Critical Mass for Change

To kick-start and speed up the transformation to a circular economy, it is paramount to quickly achieve the critical mass of customers and businesses that fully embrace and support the concept. In addition to making changes to the actual products and processes of operational businesses as suggested in previous chapters, it is therefore equally important to try and promote changes in the minds of business leaders and users alike. The following projects aim to achieve just that. The [Exploded View](#) project by Pascal Leboucq is a showcase for the huge potential for material reclamation and repurposing in the building industry. [Trashure](#) focuses on raising awareness amongst Generation Z about textile consumption and the re-valuation of textile waste, creating a commercially viable line of products that uses textile waste as its primary resource. Another example from the domain of fashion is the ['Keeping it Local'](#) project which functions as a living lab where researchers, designers and companies research the intersection of co-creation, local production and sustainable consumer behaviour, taking local fashion heritage as a starting point to bring about behavioural change.

---

Examples like these help create and increase public and industry awareness, both of the mounting ecological, economic and social problems we face and of potential solutions. This is essential as awareness is the first step on the road to (behavioural) change.

---

## Case: Madaster

The Madaster platform serves as an online registry for materials and products used in buildings and infrastructure. It facilitates the transition to a circular economy by providing comprehensive insights into the materials' properties such as recyclability, embodied carbon, and toxicity. By keeping records of building components used in real estate and infrastructure objects, Madaster creates a material passport and a digital twin for a building project, thereby simplifying the dismantling process for potential reuse. Since its introduction in 2017, the platform has grown into a tool that supports construction and real estate circularity by promoting efficient resource management and circular construction practices.



[madaster.nl](https://madaster.nl)



---

# 8. Suggestions for Further Research

## 8.1 Introduction

The cases presented in the earlier chapters show us examples of the steps that can be taken to move towards a circular economy. What is clear from the examples and themes discussed in the various chapters, is that (a higher level of) circularity cannot be achieved in isolation. Circular solutions require close cooperation along value chains and across industry domains and business disciplines. Materials, products, services, the business models in which they are embedded and the technologies used in their manufacturing, distribution and management have to be developed in conjunction. In an ideal scenario, each of those entities should be specifically tailored to fit all of the others. This brings new degrees of complexity to circular economic systems and solutions that conventional linear thinking and knowledge are often unable to address.

## Case: Curvcode by FiliGrade

FiliGrade Sustainable Watermarks is an advocate of digital watermark technology in packaging, designed specifically to enhance mechanical waste sorting. CurvCode, their European brand of digital watermarks, has three distinct advantages. First, it is tailored exclusively for efficient plastic and fibre-based waste sorting without storing sensitive brand-owner data. Second, the implementation costs are lower in comparison to alternative technologies. Third, it employs a robust ICT framework with standard components like monochrome cameras and LED lighting, ensuring reliable operation under challenging waste-handling and sorting conditions. FiliGrade collaborates in many European projects and local initiatives aimed at achieving circularity in plastic food packaging, including Coalition 2.0 Food2Food.



[curvcode.com](http://curvcode.com)

Although the pioneering research projects and businesses presented in the preceding chapters have come a long way already, a lot of work still needs to be done before our economic system can truly be called circular.

In this final chapter, we present some suggestions for further research in aid of this transition. These suggestions are based on obstacles encountered by the cases and selected examples and on the experience of the professionals and researchers we met when researching this publication. We share them here, as we believe that the outcomes of research along these lines, running across the boundaries of the six main themes, will provide valuable and much needed knowledge and insights that will bring us closer to a functioning circular economy faster.

## 8.2. Suggestions for Future Research Lines

The seven suggested research lines presented below do not neatly follow the boundaries of the separate chapter themes or ‘gateways’. Rather, they pertain to common challenges, essential connections that need to be made, and new contexts and conditions to be created in order to enable a successful transition to a circular economy:

- **Circular design and engineering:** What (manufacturing) processes, systems, products and materials can we design and engineer that are tailored to circular business model archetypes, enable the extension of useful product lifetime in line with Stahel’s Inertia Principle, reduce energy consumption and facilitate effective resource recovery?



- **Development of heuristic frameworks:** How can we predict which combinations of industry sectors, sets of conditions, sequence of circular business model archetypes and interventions for lifetime extension can be expected to be the most successful in specific scenarios?;
- **Forms and levels of collaboration:** What (type of) collaborations do we need to support specific circular interventions? (e.g.: across business disciplines, cross-sectoral, local, national, international, public-private, small-large scale enterprises etc.);
- **Development of true valuation systems:** What generally accepted, quantitative valuation systems that accurately reflect true economic and ecologic benefits and costs can we develop to help us decide whether or not a particular intervention is a valid option for increasing the level of circularity of a system, product or material in a specific situation?
- **Circular incentives:** What can we do to promote and instigate change? Many circular interventions such as looped systems, servitisation models, or product lifetime extension, require (economic) incentives or active removal of barriers to support their introduction and acceptance on the business as well as the customer side. These incentives can, for example, take on the form of awareness campaigns, smart value propositions, innovative circular business models, emerging economies of scale or laws, regulations and standards;
- **Resource efficient information technologies:** How can we make information technologies and digitisation more energy and material efficient? For example through use of bio-based or low-energy computing, long-lived hardware, bio-based sensors and markers, efficient programming to reduce hardware requirements.

## Case: Exploded View

The Exploded View project by Pascal Leboucq is an example of circular design advocacy in The Netherlands. Through meticulous deconstruction, it showcases the potential for material reclamation and repurposing, emphasising resource efficiency. What distinguishes this initiative is its extensive collaboration with a diverse array of designers and companies, reflecting a cross-sectoral commitment to circular principles. This collective engagement enhances the project's outreach and influence, contributing to a broader dissemination of sustainable practices. With a multi-stakeholder approach, Leboucq's project fosters a deeper understanding of circularity, driving tangible impact and paving the way for a more environmentally conscious future in The Netherlands.



[theexplodedview.com](http://theexplodedview.com)

## Case: Trashure

Trashure is a collaboration between The Hague University of Applied Sciences, haute couture designer Ronald van der Kemp, social enterprise i-did, and textile collector Sympane. The project explores innovative and sustainable business models to engage mainstream audiences with textile waste products. Trashure investigates how to make recycled textiles appealing and profitable by exploring innovative business models for mainstream appeal, particularly among Generation Z. Using recycled felt, fashion items have been created with a 'from trash to treasure' ethos. In this way, Trashure aims to establish a circular textile fashion business model by using recycled materials to create fabrics with a wide consumer appeal.



[thuas.com](https://thuas.com)

- **Transition strategies:** How can we enable and facilitate transitions from one process, system, product, material or business model to another?

## 8.3. Closing remarks

We hope our overview of circular initiatives and gateways has inspired you to take action. Whether you are a researcher, entrepreneur or consumer, the examples and suggested research lines show there are many opportunities to contribute to the transition from a linear to a circular economy. In part, the above research lines will of course involve fundamental, theoretical research. But to a large extent, much of the knowledge that needs to be gained will also come from hands-on applied design research, where knowledge institutions from different domains work closely together with designers and businesses. As NADR (Network Applied Design Research), our mission is to see to it that outcomes of fundamental research get translated into practical applications that help improve the quality of life in the everyday world. We invite you to work with us to make that happen!

---

## Case: Keeping it Local

Keeping it Local is a collaborative research project between Amsterdam University of Applied Sciences, Amsterdam University of the Arts, and Dutch knitwear companies. It promotes co-creation, local production, and sustainable consumption, drawing inspiration from traditional Dutch fishermen's sweaters. These represent local communities and use traditional and computer-generated patterns for 3D-knitted, personalised, and on-demand production to reduce waste. The project tracks post-purchase interactions to develop a circular research and design approach. By encouraging participation, co-creation, and monitoring, the project explores the potential for transforming clothing behaviour, serving as a sustainable model for resilient strategies that promote long-term circularity.



[amsterdamuas.com](http://amsterdamuas.com)



# Case index

• Auping Revive	11
• Billenboetiek	23
• Byborre	47
• Circular Footwear Alliance	19
• Circular Wood for the Neighbourhood	45
• Collective Ecosystem Boschgaard	18
• Cooloo	30
• Curvcode by FiliGrade	54
• Exploded View	55
• Fairphone	24
• Festival Living Labs	12
• Impactd Boat	46
• Keeping it Local	57
• Loop.a Life	16
• Madaster	51
• MUD Jeans	35
• Palanta Designer Clothes Rental	36
• Paperfoam	42
• Peelpioneers	44
• Pay-per-Lux	37
• Rietgoed	38
• Repurpose Driven Design	31
• Roetz-Life E-Bike	22
• Seepje	43
• Stroncq by Omlab	10
• Superlocal Circular Estate	17
• Swapfiets	34
• Swapshop	13
• Temporary Courthouse	28
• Trashure	56
• Ubed	25
• United Repair Centre	29
• Urban Reef	50
• 3D Concrete Printing on Sand	39





## **Circular Design Research in The Netherlands**

In 2023, the Netherlands is strategic partner of the Business of Design Week held in Hong Kong, with Circular Design as the central theme. One of the objectives of this partnership is to foster enduring international cooperation. As an initial step towards future collaborative efforts, the Network Applied Design Research (NADR) made an inventory of the current state of Circular Design Research in the Netherlands. This publication represents the results of this effort. Inside, readers will find a summary of six promising 'gateways to circularity' that may serve as entry points for future research initiatives. These six gateways are: Looped Systems; Extension of Useful Lifetime; Servitisation; New Materials and Production Techniques; Information Technology and Digitization; and Creating Public and Industry Awareness. The final chapter offers an outlook into topics that require more profound examination. Our hope is that this publication will serve as a starting point for discussions among designers, entrepreneurs, and researchers, with the goal of initiating future collaborative projects between Dutch knowledge organizations and their counterparts in Hong Kong. It is our belief that only through intensive international cooperation, we can contribute to the realization of a sustainable, circular, and habitable world.

