Circularity and Biobased Materials in Architecture and Design

Evaluation of the Status Quo and Defining Future Perspectives

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C+Bb 4TUe

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I would like to express my gratitude to the following people, without whom this book would not have been possible. First of all I would like to thank Daan van Eijk, for asking me to lead the research on Circularity and Biobased Buildings for Design United, the 4TU research centre for design. The development of this book was stimulated and supported by him and Marijke Idema, both as representatives of Design United. I would like to thank everybody who helped to collect information, assemble and produce this book. And last but not least, I am also deeply indebted to all of the researchers and practitioners who inspired this book though conversations and through sharing their work within the field of circularity and biobased building.

Juliette Bekkering

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INTRODUCTION

Why This Research?

Circularity and biobased buildings are currently a pressing and key topic in the design sector and the building industry. The global challenges we are facing due to climate change and the depletion of natural resources is forcing us to radically change the way we shape our built environment and to take a critical and new look at how we design and construct. The building sector plays a central role in all industrial sectors, as it currently is responsible for a large share of resource consumption, energy use, CO2 emissions and waste generation. The Dutch government's goal is to make the building industry completely circular by 2050:

> 'This means that we will develop our buildings and infrastructure in such a way that all materials and raw materials are reusable or biobased and we will no longer use fossil energy sources. The emphasis is on achieving (higher-) quality reuse (including dismantlable construction) and the implementation of biobased materials in all submarkets of the construction industry.'
> (De Bouwagenda, 2018)

This is an ambitious plan and requires a radical change in how the building sector designs and builds, but also in how we view our buildings and interact with the built environment. This paradigm shift lies at the core of the architecture profession and will not only affect the execution of buildings, but will in fact require a radically new design attitude.

Being that sustainability has been a centre-stage topic for the last decade, covered by numerous publications, reports and opinion pieces, it may be surprising to learn that 'our world is only 9% circular'. We, as a global community, are still at the very start of a long path towards achieving the goal of circularity. This realization should not demoralize, but incentivize us. In the light of numerous global challenges, the world seems determined to embark on a journey towards circularity (and ultimately zero waste) and to address the challenges that lie ahead. In this research, executed for Design United, we made an inventory of ongoing research and initiatives in the field of circularity and biobased buildings in the Netherlands. Design United is the 4TU Research Centre for design research and is the podium for the creative industry in academia.

We collected knowledge questions from both academia and the professional field and used these to identify the most pressing knowledge gaps. In addition, we made a report of a selection of projects and in a series of interviews and questionnaires we challenged academics and designers to formulate their most pressing research questions. Our overview does not strive for completeness, but its ambition is to expose a range of exciting initiatives and to put together a challenging agenda that explores, shifts and thunders through boundaries. Our aim is to offer a simplified yet systematized direction for action in the complex realities surrounding circularity.

The topic of circularity is far too complex and multi-layered to be contained in chapters, by lists and tables. As we find ourselves in a transition phase from a linear to a circular economy, we strive for a unified and systematized direction that can point us towards a shared vision of circularity in the built environment and beyond.

Juliette Bekkering + Cristina Nan

Research Setup

For research into circularity and biobased buildings, we made a quick scan of ongoing research spread across all four Universities of Technology (TUs), universities of applied sciences, the embassies, research institutes and design offices. Much research takes place within a broad research field and does not exclusively fall under the heading of circularity and biobased buildings, but places itself in a broader setting of sustainability and innovation.

The research carried out at the four TUs and universities of applied sciences involves various alliances and often involves collaborations with governments, industries and clients.

The majority of the research is confined to a delineated research field, which limits implementation in pilot projects or in practice. Ongoing studies cover the field of exploration of biobased materials, designing with reused waste materials, designing with reusable building components, 3D printing with waste, recycling from waste material to whole buildings and developing techniques for making building materials reusable. In addition, processes investigating how to open up and make accessible the wide spread of available used materials by developing databases for used materials (material Passports) and for designing buildings as material banks are also being explored.

Besides the research in academia, we also want to show innovations in the professional field. The example projects from the professional field, the *built* practice-based exemplary projects, have a large focus on circularity. Neutelings Riedijk's Gare Maritime, for instance, is the largest CLT project in Europe, where the use of CLT as a biobased material is one of the features that makes the project so innovative, but it also scores high on reduced energy consumption, the reuse of existing structures, low water consumption and is labelled BREEAM Excellent. This ambition to focus on different areas at the same time can be seen in several projects, since the high ambitions of clients often lead to simultaneous exploration of the sustainable aspects on different levels. This can also be seen in the projects of Superuse and Popma Ter Steege, where high efforts have been made, not only in the field of circularity and the reuse of materials, but also in proposing solutions for social sustainability and reduced energy consumption, just to name a few.

The practice-based projects are not fully circular, as it is hardly possible in practice to perform optimally on all levels, but their pioneering role is vital to showcase the necessary paradigm shift that is slowly unfolding in our built environment.

JB

Overview of Institutional Networks and Relevant Actors

This book is inspired by the conversations about circularity and biobased building that we had with the following persons and/or their publications:

4TU: DESIGN UNITED

Delft University of Technology
Prof. Dr. Ing. Tillmann Klein
Prof Dr. Ir. Vincent Gruis
Ir. Bas Janssen

Eindhoven University of Technology
Dr. Ir. Faas Moonen
Ir. Tom Veeger
Dr. Ir. Rijk Blok
Ir. Jan Schevers
Prof. Dr. Ir. Jos Brouwers

University of Twente
Dr. Ir. Marc van den Berg

Wageningen University and Research
Dr. Daan van Es

World design embassy circular and biobased building

Curator: New Heroes: Diana van Bokhoven, Lucas De Man

Universities of applied sciences

Avans Hogeschool and HZ University of Applied Science
Dr. Ir. Perica Savanović

Other organizations, names

Primum
Ir. Max Drath

Greenport West-Holland
Willem Kemmers

Superuse Studios
Ir. Jan Jongert

Neutelings Riedijk Architects
Ir. Michiel Riedijk

Popma Ter Steege Architecten
Josse Popma


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CONTEXT

Global Challenges

The culture of unlimited economic growth has come to an end. Fifty years ago *The Limits to Growth* (Meadows, Meadows, Randers, & Behrens III, 1972) already forecast that our planetary boundaries cannot support unlimited economic and population growth. More recently, in 2015, global leaders at the Paris UNFCC conference COP21 realized with alarm that their respective development plans were at odds with the carrying capacity of our planet. Consequentially, the Paris Agreement was adopted by 196 Parties as a legally binding international treaty to combat climate change.

The force with which humans became major actors on the global stage – a force previously associated with the geotechnical violence of volcanism, ice ages or similar – is a recent phenomenon. The magnitude, spatial scale and pace is unprecedented, and has therefore been named the 'Anthropocene', a new geologic epoch, in which humankind has in just a few hundred years emerged as an unprecedented significant force capable of transforming the face of the planet.

We are faced with multiple crises: climate change, loss of biodiversity and depletion of resources. We are in a pivotal decade, characterized by interconnectedness of challenges, irreversibilities and tipping points. We have to act now, but without a profound change of sociotechnical systems, we cannot tackle these challenges. Climate change has been identified as the most pressing challenge of our times.
To cope with this governments have launched ambitious policies. The EU Green Deal (2019) aims for 55 per cent GHG emission reductions by 2030 (compared with 1990 levels). The Netherlands Climate Act (2019) aims at 49 per cent GHG emission reduction by 2030 (compared with 1990 levels).

Building Challenges

In this context the building sector is playing a crucial role. In the Netherlands, compared with all sectors, the construction industry is responsible for 50 per cent of raw material consumption, 40 per cent of energy consumption, 35 per cent of CO_2 emissions, 30 per cent of water consumption, and 40 per cent of construction and demolition waste (Ministry of Infrastructure and the Environment & Ministry of Economic Affairs, 2016). Further challenges might be the scarcity of finite resources and the availability of renewable materials.

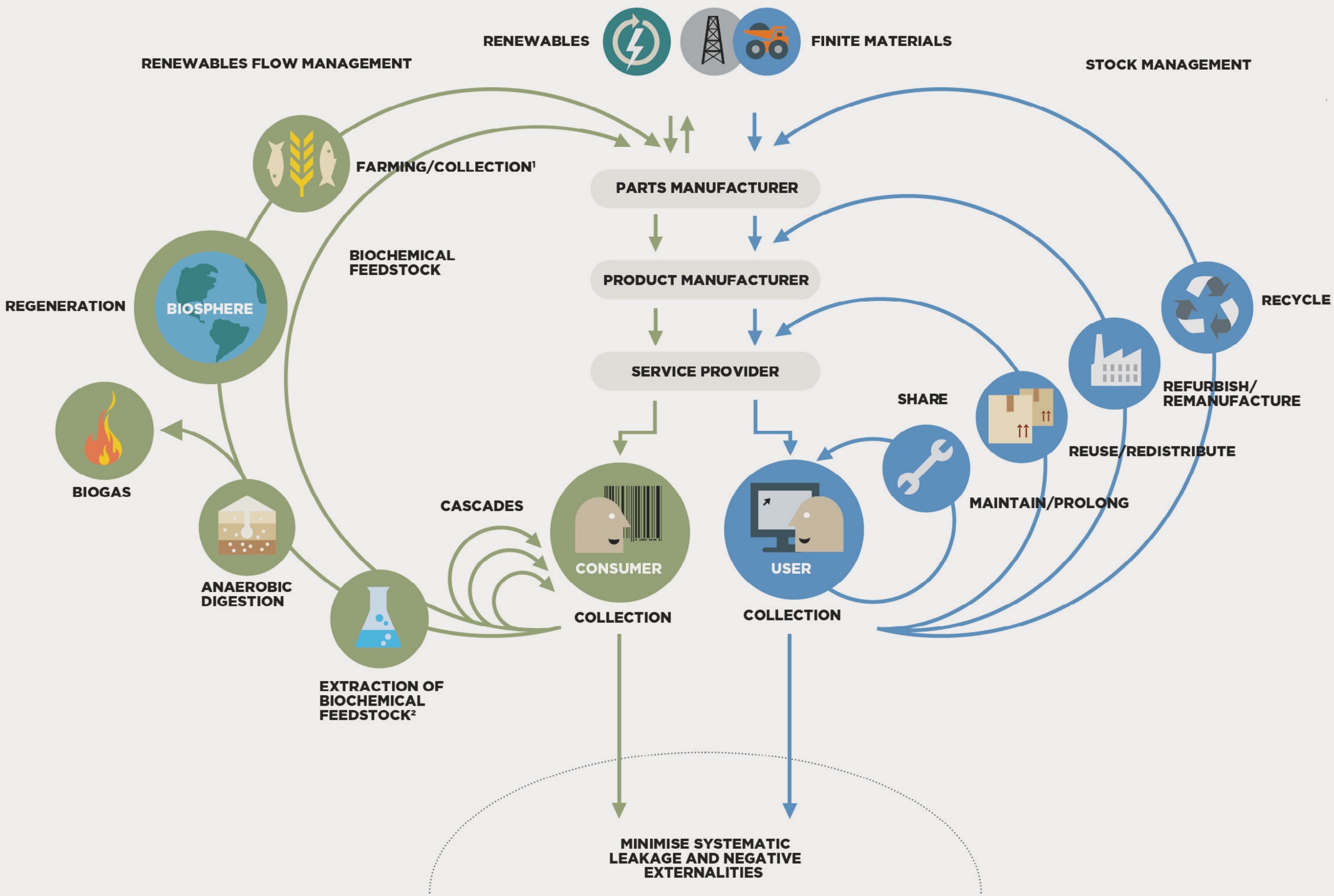
For a long time, the focus has been on operational energy consumption of buildings and related CO_2 emissions. With the objective to achieve nearly zero-energy buildings (NZEB), the material dimension of buildings has moved to centre stage.

Radical Transformation

The Netherlands is at the start of an ambitious agenda: to make the building industry fully circular by 2050 (Rijksoverheid, 2018). But what does circularity actually imply? The concept began to emerge in the 1970s. By now the concept has received widespread attention. The popularity of the circular economy concept has led to many different interpretations. One frequent interpretation is the following:

> 'A circular economy is 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 impair 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, p. 7)

The meaning of the concept of the circular economy remains contested (Kirchherr, Reike, & Hekkert, 2017). Interpretations draw on different principles. Many are based on reducing, reusing and recycling (the 3R framework), others draw on more differentiated approaches, for instance the 10R framework. Many interpretations emphasize the systems perspective, as well as the relation to sustainable development, although this relation is not usually made explicit.



There are also differences regarding the prioritization of either economic prosperity or environmental integrity, while questions of social integrity are largely neglected. Crucially, the transition to a circular economy requires systemic change.

While there is a huge buzz around circular economy in the building sector, on the ground (in practice) there are many open questions and contradictions about how to actually implement the ambitious agenda of the circularity transformation. This ambition requires a fundamental rethinking and restructuring of the entire building industry in three key areas: first, policies, laws and regulations, procurement processes and the production chain; second, circular business models, circular design, production and construction processes and the development of circular materials; and third, the development of methods to measure the impact of circularity and a new generation of lifecycle assessment methods (Kruithof et al., 2020). This transformation also affects the organization of the building design process itself, which needs to become interrelated with the stages of material supply chains and building lifecycle assessment. The tasks for the architect do not end with 'building completion' or 'handover', but new opportunities and roles emerge in the continued stages of a building's 'use', 'maintenance', 'reparations', 'refurbishment', and 'deconstruction' (Gruis et al., 2021).

This radical transformation will fundamentally change the how buildings are designed, how they are constructed and how materials are chosen and used. As featured in this report, many innovative approaches have already been developed. But current challenges are a lack of circularity tools, guidelines, measurement systems and data availability for materials, components and buildings.

10R Model

Refuse	prevent raw materials use
Reduce	decrease raw materials use
Renew	redesign product in view of circularity
Re-use	use product again (2nd hand)
Repair	maintain and repair product
Refurbish	revive product
Remanufacture	make new product from 2nd hand
Re-purpose	re-use product but with other function
Recycle	salvage material streams with highest possible value
Recover	incinerate waste with energy recovery

The 10R framework (Cramer, 2017): Refuse, Reduce, Renew, Reuse, Repair, Refurbish, Remanufacture, Repurpose, Recycle and Recover, presents an nuanced waste hierarchy framework. Particularly the dimension of 'Refuse' often seems to be neglected. 'Recycling' has received a lot of attention, but it is crucial to be aware that the meaning of recycling is vague and often implies downcycling.

The 10R framework originates mostly from the field of product design. As a framework the 10R model cannot be built, but crucially relies on transformation and adaption in design practice. Thus, for building design a crucial question is how to translate this framework into building design practices. Many design strategies have been developed: for instance, design with reuse, design with biodegradables, design for reuse, design waste out, design in layers, design for disassembly, design for repair, design for adaptability, design for longevity, and more. While these strategies can serve as a compass, more guidance is needed in how to choose between them, as some might also contradict each other. Crucially, translation requires all stakeholders to agree on a shared goal. This goal needs to be well defined and stakeholders are required to work together towards this goal. Defining the design goals and related challenges is vital, as they shape design targets, design strategies and the materializing artefact. Different stakeholders are involved in different ways in the building process, and thus have different interests and values, making negotiation, agreement and collaboration essential to successful design development. In the end, circular buildings will be evaluated by how far they have managed to address key challenges of circularity, but also by whether they are of high design quality: Has a building taken shape that is accepted, liked or even loved?

Torsten Schröder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MATERIALS COMPONENTS PROCESS

Three Main Categories of Investigation

In each design, consideration is given to how materials can be brought together to constitute a coherent whole. Materials form spaces – high versus low, wide versus narrow – in one fluid composition and the concatenation of spaces determines the use of the building. In every design, decisions must be made regarding the distinct materials, the merging of materials into components, the parts that make up the whole, and finally why and how they are assembled over time.

In our search for various studies and research on circularity and biobased buildings, we wanted to focus specifically on the design sector and how the ambitions regarding a circular economy are affecting the design profession. The designer works in a context of buildings, individual materials, building components and eventually techniques to realize the design.

If one wants to design in a circular and biobased way, first the search for materials starts: Which materials are circular or biobased, how can they be applied, how can they be recycled? The architectural profession has a long tradition in which the performance of proven materials and processing techniques plays a major role. Legislation and certification ensure that quality and performance are closely monitored. The new condition of the availability of new materials in construction that have not been tested before and that have not withstood the ravages of time, the recycling of materials not specifically developed for construction or the emergence of biobased materials, puts enormous pressure on the capacity to innovate in construction. Never before have so many new materials or application techniques come onto the market. It is therefore not surprising that all these materials, from biobased materials such as mycelium, hemp and recycled materials such as crushed concrete, textile remnants, PET bottles and other plastics, have to be studied extensively before they can be applied in buildings that have to withstand the test of time in terms of lifespan, comfort and safety.

The same applies to components: here, too, there is a challenge to find ways of recycling and reusing building components by + upgrading + remanufacturing + upcycling, whose properties, dimensions and appearance form all the colours of the rainbow. The challenge lies in incorporating them into the design in such a way that the entire spectrum of variations can be accommodated, and systems must be devised to ensure that the quality and safety requirements demanded in the construction industry can be met.

This leads to the last point: the process. By using new techniques of production, collaboration and manufacturing of both the basic materials themselves and the various components and finally the assembly of the entire building, the objective of using materials more efficiently, more purposefully and more economically can be achieved. At the same time, the entire process will have to be organized differently, from design to transport, from management to processing, from storage to assembly, from building to disassembly. These new techniques will herald a time of new possibilities. Ultimately, this trinity: material, component, process, will be the adage of architectural design in an age of complete circularity.

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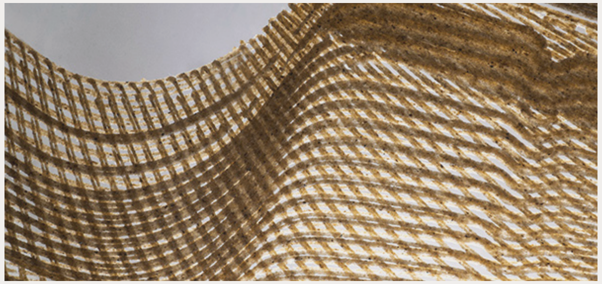
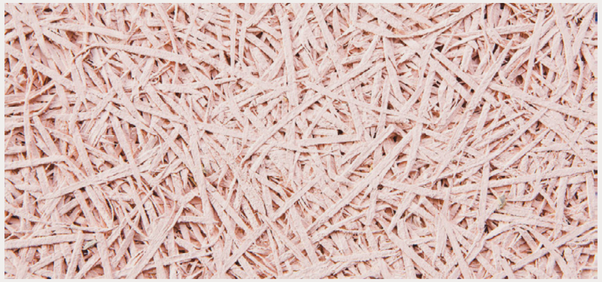
MATERIALS

From Recycled to Biobased and Composites

The palette of commercially available materials is on a continuous path of extension, as are the opportunities for reuse, recycling and repurposing – from sawdust, timber, clay and brick to mycelium and kelp. One inspiring example is the studio Emerging Objects. Moving across different scales, from printing teapots to printing entire self-standing structures in the desert, this practice explores innovative new recipes for 3D printing, including materials such as coffee grounds, salt, tea and even rubber (Rael & San Fratello, 2018). Opting for materials with a high potential for circularity is an important step in facilitating a circular design economy, simply by insuring the material's reusability. Sourcing of the materials, the production method and their lifecycle are relevant parameters to be taken into consideration to assure circular qualities. One material group at the centre of current discussions are biobased materials.

Currently, the EU defines biobased materials as 'materials derived from biomass' (European Committee for Standardization, 2014) offering a broad framework under which to operate. It is relevant to note, however, that biobased does not automatically translate to biodegradable, nor does it ensure that the product is part of an extended circular lifecycle (Kawashima, Yagi, & Kojima, 2019; Prieto, 2016). Similarly, it does not refer to a fixed mixing ratio for composite materials. Therefore an agreed upon definition when embarking on this topic is needed as a baseline to clarify and manage expectations. Biobased materials do offer significant benefits, one of the most often cited in the wake of our climate and environmental crisis is their renewable sourcing (Jones & Brischke, 2017). When referring to circularity in design and architecture, material choices represent a first stepping stone. Various platforms offer support and guidance when it comes to better understanding material implications and the right choice. The *Circular Design Guide* (Circular Design Guide, 2021) offers an abundance of information as does the *Ellen MacArthur Foundation* (2016), where one can access a *Smart Material Choices Worksheet*. The Danish webpage *Material Pyramid* even offers a calculator to make an estimate of the CO2 footprint of selected construction materials (Materialepyramiden, 2021). Although it is desirable to extend and encourage the use of biobased materials, there are several challenges to be faced. While the exposure of procurable materials should be increased, availability on a large scale is one obsta-





cle to be overcome, as are questions of long-term durability, maintenance for both interiors and exteriors, and regulatory requirements. Another relevant aspect is the use of non-biobased coatings or fillers as surface treatment to increase the performance of biobased materials, which leads to a paradoxical contradiction. As to experimental biobased materials developed in academic research labs, one of the most common challenges is the jump to industrial standards and scaled-up production. With the gradual broadening of commercially available materials and through an early involvement of suppliers, informed material choices can be made, thus overcoming current challenges.

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COMPONENTS

Reuse of Components

Circularity in the domain of construction implies by necessity the maintenance and reuse of components, themselves biobased or not. In order to facilitate and establish this practice as modus operandi for the industry, the offer of available components for reuse needs to be signalled, communicated and made available to a wide audience of professionals as well as clients. The latter, often reluctant, may be easier persuaded to incorporate reused items when charmed by the presented material character of salvaged components. Setting up such databanks and the correlated physical storage, digital twins and conveying material qualities via digital means represents serious challenges to be tackled. Additionally, uniqueness of the individual components, material heterogeneity and quality variations are inherent to component reuse and need to be assessed for each specific case. One of the façades of the new headquarters of the EU in Brussels is made out of 3,750 reused window frames from across Europe. This gesture sets the tone and the direction in which to move, both for communities but also for the design and construction disciplines. The repurposing of components that are not obvious candidates for architecture can lead to extraordinary and unpredictable material expressions. The architecture firm CHYBIK + KRISTOF used 900 black plastic seats for one of their built designs.

Another noteworthy approach to components is a reverse-engineered strategy where buildings are designed from the very start as material banks. The projected demolition of a building is accounted for in the design process, reinterpreting built designs as future sources for components. This strategy entails the oversizing of to-be-reused components, thus amplifying their suitability for future reuse. Maximizing the adaptive potential of components, approaching buildings as material depositories and developing the necessary logistical infrastructure to support component reuse necessitates new and enhanced operational systems as well as design strategies.

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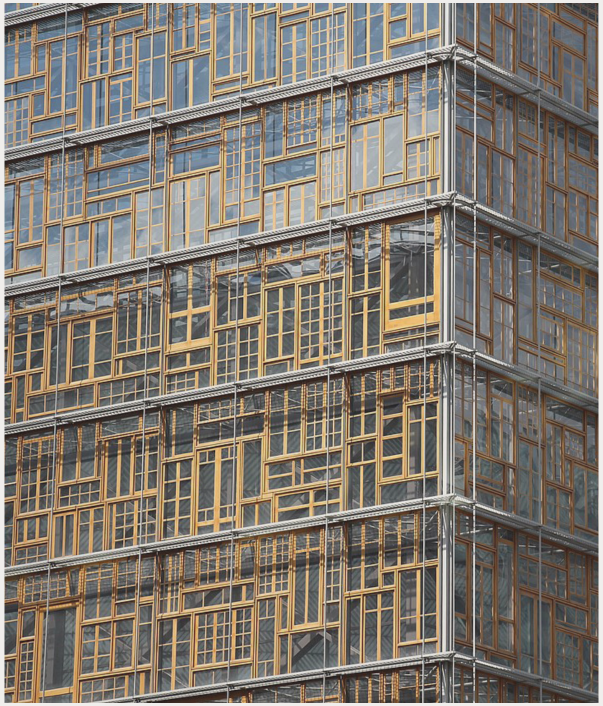

PROCESS

Implementing circularity as an integral part of our design practice, through the use of biobased materials, the adaptive reuse of components or by setting up buildings as material banks, to name just a few possible strategies, requires a shift in thinking: extending design thinking to system thinking, including considerations of lifecycle and cyclical material-component flows.

Process is key, particularly process that is not driven through the lens of style. Process is about determining the right relationship between material, components, design qualities and fabrication. In order to optimize the circularity potential of any project, design or manufacture, materials and component use have to be correlated (Eberhardt, Birgisdottir, & Birkved, 2020). Different aspects may be prioritized, but through process design these are treated in a unified, holistic manner.

Computation and digital fabrication can be valuable assets and key parameters in the processes correlated to circularity and adaptive reuse, making increased optimization of efficiency, production and performance possible. Advanced digital tools for design and manufacture can reduce material use by minimizing production waste such as offcuts, simultaneously offering the designers the opportunity to actively design CNC-based production workflows. Designer, tradesmen and manufacturers will have to grow to the challenge of emerging technologies, managing increased logistics, labour and time – overall higher complexities. By necessity this results in an expansion of networks and collaboration, making up in the future for the present-day insufficient number of contact points and established large-scale networks. Another aspect that needs to be acknowledged is that designing for disassembly may require more input, time and labour (Kanters, 2020). These realities and their implications will have to be acknowledged by the industry, professionals and clients.

But this equation can only work if clients are targeted long before the commissioning of specific projects (van den Berg, Voordijk, & Adriaanse, 2019). They may at first be reluctant to agree to a certain extent of managed ‘unpredictability’ of materials or components, but their commitment is quintessential to facilitating and navigating these processes in a successful and productive manner.

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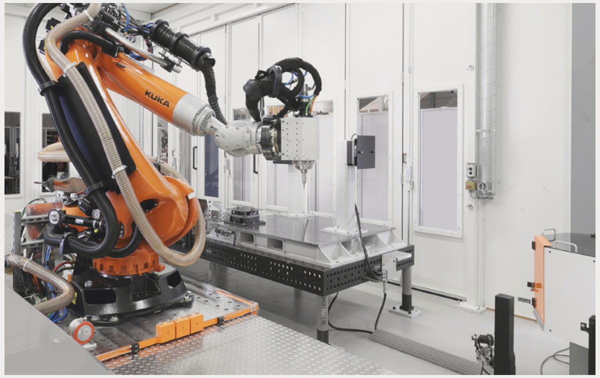

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AGENDA FOR THE FUTURE

Research Questions for the Future

The fields of circularity and biobased materials are broad and to be tackled efficiently they rely on cross- and interdisciplinary collaborations. To achieve circular economy standards, one must go beyond one-step actions such as simple material selection, recycling or reuse of items. A variety of definitions of what a circular economy is exist in specialized literature, increasing the difficulty of formulating a unified action plan and agenda. Therefor it is important for the design-related disciplines, the involved professionals and research institutes to understand the relevant key challenges – immediate and projected – that need to be overcome as well as to identify the clustered research gaps and correlated research questions.

Advancing circularity within architecture and design requires an extended palette of prototypes and pilot testing to showcase materials, components and strategies of integration. These should be visible, widely published and broadly discussed. The more case studies and pilots that are run, the better we can understand material behaviour, monitor performance, test ageing, and advertise circularity to clients and the larger community. Strategies will have to be thought of and put in place to push for prototyping and pilot testing. Trial and error, both exhibited and made accessible over extended periods of time, lead to a steepening of the learning curve related to materiality, but also to innovation in the area of process. In order to facilitate this, a formalized infrastructure for practice, academia and industry to collaborate on meaningful applied care studies will have to be developed. Exhibiting successful collaborations will further incentivize fruitful partnerships, but needs interorganizational sustainability management (Korhonen, Honkasalo, & Seppälä, 2018).

Productively orchestrated collaborative efforts between industry and academia may prove quintessential to solving the challenge of how to scale up experimental material production from the test samples developed in laboratories to commercially available large-scale quantities. Additionally, formalized tracks, schemes and methods will be needed to increase the overall availability of certified biobased materials and circular components designated for adaptive reuse.

Research and investigation in the area of process and legislation will have to follow suit. As circularity and biobased materials demand a new expertise from architects, designers, manufacturers and builders, it also opens up the opportunity for design-related practitioners to be actively involved in not only building design but the design of process – processes of making. New roles for architects and designers may emerge, outside of the established boundaries. Particularly through the means of computation and digital tools (from robotic sawing to laser cutting, robotic assembly and smart factories). This democratization of fabrication technology through digital means, meaning the commonplace availability of 3D printers, industrial robot arms and the like, offers divers lines of research on how to deal with material heterogeneity and self-similar yet not identical components. The previously mentioned research directions will be of little relevance and can only have a limited impact on everyday business if the design community does not explore ways in which challenges in legislation, building codes and certification can be overcome. This undertaking should not be left to the legislator, but designers can lead the way and engage in the development of legislative fast-tracks.

Another aspect that needs to be acknowledged is the fact that 'the scientific and research basis of the CE approach seems to be only in its infancy' (Korhonen et al., 2018). The design community has to follow the latest research outputs of other disciplines such as ecological economics and behavioural psychology and let itself be guided by scientific findings in these fields.

Beyond the technical and logistical aspects of circularity, as design professionals we also have to engage in a sustained preoccupation with an ambitious design language of circularity that makes use of an extended architectural vocabulary and reflects the underlying technological complexity and systems thinking. How can such a language or languages be developed? How will a new type of systems thinking be reflected in design – from object level to built environment? Design-related research can help formulate answers that go beyond personal styles. More importantly, how will the design community communicate this emerging vocabulary to clients and stakeholders? If meaningful impact is aimed for, then the disciplinary self-absorption and preoccupation will need to be overcome and serious research will need to be undertaken into how to develop meaningful and measurable outreach and awareness programmes.

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A look into the future of building with biomaterials, Tij Observatory, RAU architects

BOOSTING CIRCULARITY

The Paradigm Shift from Linear to Circular Design

Increase Fair Pricing

From a Linear to a Circulair Lifecycle

Today, the building industry is highly automated and prefabricated elements are frequently used, it therefore has a linear lifecycle based on new products and the current low prices of materials. Costs are calculated for investment processes that run until completion and rarely include maintenance and recycling costs incurred during and at the end of the building's lifecycle. This creates a distorted picture of the finances. In order to promote fair pricing of circular construction, the costs of recycling materials and components should be included. Furthermore, circular building is labour-intensive when it comes to the reuse of materials and components, with labour costs highly taxed while materials are cheap and taxed at a lower rate, raising the building costs of circular buildings disproportionally compared with linear lifecycle buildings. If circular building is to be promoted, taxes on labour must be lowered and materials must be taxed at a higher rate, taking into account recycling costs and environmental impact over the building's entire lifecycle.

Increase Awareness

Make Circular Designs and Materials Visible and Available to a Broad Audience

Thinking in terms of circular designs requires a turnaround in the mindset of designers, clients, builders and users. To make the transition to circular building possible, it is of vital importance to make all stakeholders involved aware of the possibilities that exist and to make them accessible and visible by means of exemplary projects, exhibitions, symposia and pilot projects.

Increase Visibility

Build Prototypes, Pilot Projects and Experiments!

Although a lot of progress has been made, examples remain scarce. In order to test materials, techniques and applications, these need to be applied in pilot projects so that they can serve as examples and testing grounds. Academia can take the initiative to build pilot projects and experimental applications together with professional and societal stakeholders to increase the visibility of circular building and biobased materials in building design.

Increase Applicability

Design for Large-Scale Applications, Collaborating with Designers, Academia, Building Industry and Suppliers

The experimentation and research into circular design and biobased buildings often takes place in small-scale applications. In order to make applicability possible on a large scale, cooperation is needed with various stakeholders to facilitate this transition in the building industry.

Increase Certification & Legislation

Introduce Control Mechanisms, Legal Assesments and Quality Assurance

An unprecedented number of new materials are coming onto the market and being processed in the building industry that were not previously used for this purpose: recycled materials, reused components, but also biobased materials and biobased components and their processing methods. In addition, recycling has led to an unprecedented use in construction of elements whose properties (strength, fire safety, durability, toxicity, lifecycle, etcetera) are highly uncertain. New evaluation methods and tools, certificates and quality assurance systems are required to test, certify and develop methods to ensure that these materials and components meet legal and quality requirements. Furthermore, these properties must be translated into guidelines for designers so that these materials and components can be applied in design.

Increase Availability

Develop Databanks and Develop Systems to Make Circular Products Available on a Large Scale

The building sector is the biggest producer of waste in the Netherlands, but also reuses the most waste. However, the use of waste often comprises the downcycling of reused materials. In order to improve recycling, products have to above all become findable, by creating databases where materials and components can be found and purchased. The material passport is an initiative to make materials available by providing each of them with an 'identity', so that the characteristics are known and can serve as the keywords in the search engine. By creating the passport of a material now, it becomes possible for a building to be easily dismantled in the future, giving its parts a new life elsewhere: the building as a material bank. Databanks should be improved: from building components to buildings as a whole, where designers, contractors and other stakeholders can purchase their products (CBS, 2019).

Increase the Network

Create a National Circularity Platform and Expand Academic Networks and Research Projects

There are many initiatives in the Netherlands and there is a great willingness to invest in circular buildings. It is therefore crucial to bring all these initiatives together on national platforms where the design field/academia/clients and governments can work together on the circularity issue and where information can be obtained on circular construction.

Design for the Future

(According to the 10R Model) Design and Develop New Design Tools and Design Vocabulary With New Materials and Components

The design of circular buildings requires a reworking of existing design principles. Moving from a linear to a circular design process means that intermediate design phases must be integrated and the recycled elements/materials must be evaluated in relation to the design. The programme of requirements (POR) is steered from the inside and materials add a new layer of complexity to the POR.

Additional complexity might consist of the performance of novel materials, the specific properties of materials, the properties of components: reusing components as objets trouvés, where found objects can give a specific character and looks to the design and have to be fitted consequently.

Another challenge is to look for inspiration in old techniques in which biobased materials and recycling techniques were applied and to translate these techniques into future-oriented applications (for instance clay constructions, hemp constructions, building with straw, wood constructions but also reusing brick, stone materials, and so forth).

Design & Develop

New Design Strategies for Buildings as Material Banks

Lifecycle thinking means that buildings should be seen as material banks rather than as static constructions of materials. Designing buildings as material banks means thinking of the design process in a different way, acknowledging aspects as how different parts are going to be put together, so that they can be taken apart again without damage, how parts can be catalogued in anticipation of a possible disassembly and how parts can be stored. Mounting principles, construction and production principles as well as material applications will have to be rethought and redesigned. This strategy was applied in Japanese traditional constructions, but can also be seen in the Netherlands on the coast, where structures are put up in the summer and taken down in the winter.

Design & Develop

Designs that Handle the Newly Arrising Technical Challenges

All the technical challenges that circular construction and biobased materials will present us with cannot be brought under one denominator. In each case, the designer will have to consider how to respond most adequately to the question and come up with a suitable solution. New materials require new production technologies, construction methods and sustainability techniques. How do we make biobased materials fire resistant? How can we make them sufficiently strong, resistant to weather and wind? How do we make these materials sustainable, what is the performance of the composites, but also what is the performance of recycled components and how do we make these in accordance with applicable standards and regulations?

Design & Develop

New Technologies to Enable Optimized Material Use and Novel Production Methods

New (digital) techniques can lead to more efficient use of materials and minimization of waste. These techniques can be implemented in the production of materials, the production of components, the assembly in the factory, the assembly on site or the disassembly at the end of the building's lifecycle.

JB

COUNTER-POINTS, THOUGHTS, PROVO-CATIONS

Circularity – A Widely Explored Topic. An Exciting, Multi-layered Conversation

Through literature research, conversations with design professionals on collaborative projects, talks with researchers and through our own work experiences, we have uncovered parts of the conversation that relates to ongoing collaborations and projects, key challenges, trends and relevant research areas of the present and future. Beyond this as a final note, we, the authors of this publication, would like to address a few more aspects of this complex circularity conversation. These are aspects that sparked our interest, additional thoughts that we find are worth mentioning, maybe even some provocative notions.

Therefore, in this final part of our report we will change to a more 'personal' writing style, to reflect the suggestive nature of these afterthoughts. Below you will encounter a wilfully unsystematized array of provocative propositions.

We've Always Been Circular. Recently, We've Just Been out of Touch.

We've always been circular — it's part of architecture's DNA, a reappearing red line in its historical development. The tradition of adaptive reuse, repurposing and recycling is deeply embedded in architecture, across geography and time. Industrialization, mass production and legislation have put a temporary halt on circularity in architecture and construction. The tide is turning and we are uncovering old practices.

Necessity and Informality

Necessity often leads to innovative practices. Informal settlements as circularity incubators. They have a lot to teach us.

Start-ups, Business Models and the Sharing Economy

New circular business models as industrial disruptors. What would the circular, sustainable version of Uber look like?

The Social Aspect

Democratization of technology. Power to the people in terms of materials and design. Can we put communities in control of circularity? How can we amplify the social factor?

Circularity = Sustainability

The focus on the material dimensions must not suppress the ties to the social and ethical. Circularity without sustainability will result in a throwback.

3D Printing

Surely not a universal panacea, but an opportunity worth exploring nonetheless. If you can crush it, you can print it. What materials can be reused by being processed and made fit for 3D printing? Reducing waste and resource use is right up its alley. How about 3D printing with biobased materials, such as meat? Now there's a thought!

L'Objet Trouvé

Get inspired by lost and found objects. See where the road of design will take you, when encountering the unexpected and placing it in new contexts. Material necessity can become creative inspiration.

Blockchain Technology

Can blockchain technology support the circular economy, by recording all transactions related to a specific product, making all information about it transparent and available?

Biobased vs Mineral Resources: a Double-Edged Sword

Discriminating against mineral resources. Circularity is a complex matter with a thousand answers. Quit using slogans. Balanced views are what is needed.

Fast Fashion and Circularity in Architecture and Construction

Let's point the moralist finger at Fast Fashion. The Fast Fashion industry is a major polluter and a black hole of resources. How can architecture and design relate to throwaway clothing? Can unlikely partners turn into prolific collaborators?

Architectural Complicity

Pay for thoughts, not just for bricks. For a long time architects have supported and lived well on the linear design. If a lot of the designers' efforts start going into not building/not materializing, we need to reinvent fees for architectural services.

Hacking Nature: Algae, Kelp, Mycelium and More

Nature's default position is zero waste. Her strategies have always served as inspiration and blueprints for design, architecture, construction. Combining biomimicry with hacking natural systems may result in exciting opportunities and an increase in resilience.

Circular Education

What is the makeup of a cross-disciplinary circular education implemented already in school?

Space Waste

How about not polluting space and recovering our space waste? Next challenge: outer planetary circularity?

A Rich Man's Game

Show me the money!
Put more effort into making circularity affordable for all.

Inclusiveness

Circularity as a non-elitist mindset.
No ideology.
Make it relatable to everyone.

Post-Circularity: Zero Waste

Not generating waste in the first place.
What a vision!

JB + CN


5

INSIGHTS

Introduction

In order to refine our understanding of the opportunities and challenges that lie ahead of circularity and the extended use of biobased materials in architecture and design, we reached out to practitioners and researchers to share their experiences and thoughts on these topics. All of the included contributors received the same questionnaire with relevant questions on circularity, challenges, opportunities and proposed focus areas for research.

Certification of new biobased materials, case-specific technical detailing for reused components, refining material lifecycles, truly experimental practices beyond implementing well-established 'solutions' have proven to be reoccurring hurdles to be faced. Higher investment costs in the incipient project phase and required long-term thinking on the part of investors and clients are important challenges that should not be underestimated. There also seems to be agreement that the key to the solution is meaningful, in-depth inter- and cross-disciplinary collaboration.

Shedding light on perceived knowledge gaps, difficulties of implementation and long-term benefits offers a more complete picture of the current situation. More importantly, these insights offer indications of the direction we need to move in, both as individual practitioners and as a discipline, to achieve future scenarios of circularity, resilience and sustainability in our built environment and beyond.

CN

Dieter de Vos
Rijk Blok
Perica Savanovic
Bas Wouterszoon Jansen
Tom Veeger
Pascal Leboucq
Marc van den Berg
Vincent Gruis

Dieter de Vos

Architect,
Neutelings Riedijk Architects

Neutelings Riedijk Architects is a leading international architectural practice based in Rotterdam, The Netherlands. They offer a strong commitment to design excellence: realizing high quality architecture through the development of powerful and innovative concepts into clear built form.

www.neutelings-riedijk.com

What are your current areas of research or ongoing projects in relation to circularity and the built environment?

We have just completed our project Gare Maritime in Brussels.

A reconversion of a former early 20th century freight station into a complex comprising retail, public functions, offices, and covered public areas. The key elements of the design consist of a respectful restoration of the large existing steel column and roof structure and the integration of 12 freestanding new built volumes (with a loadbearing structure in CLT). As many original elements as possible have been kept or have been re-used.

What do you perceive as the biggest challenges with regards to circularity and biobased building design?

Being fairly new building materials, the required certifications and attestations for use in buildings are not always available and require specific testing. This is at the moment a challenge to have these materials widely used; only larger scale projects can absorb the extra costs of testing etc. For example, the Belgian regulations and attestations are conceived for steel and concrete applications, and not for wood. It is more expensive at the moment than traditional materials.

AAs circular building materials only make sense when dismantling of these buildings and materials are possible, technical detailing is to be conceived differently. On the one hand that may require some additional financial means, on the other hand a common sense mentality that is not to be disregarded to build buildings that are and can be futureproof.

Typical contractors may not always have the technical expertise of execution of these detailing principles.

What do you perceive as the biggest opportunities?

To move forward towards making buildings that are inherently sustainable, beyond 20th century or early 21st century notions of how a building should perform over time; taking into account different required life time spans of the different building elements; for example longer longevity for the loadbearing structure with perhaps a higher carbon footprint at time of construction and neutral carbon footprint for furnishings in relation to social sustainability of the built environment.

How do you assess the difficulty and/or ease of implementing circularity in research or practice? What are the biggest challenges when it comes to academia and industry?

The main difficulty consists in the measuring methods actually used based on databases, that may not always take into account common sense of longevity beyond the spreadsheet information. Hence there being a risk of missing opportunities to making buildings better overall that will last better through time with a reduced carbon footprint by complying blindly with the spreadsheet. I.e. certain materials may get a bad score in the spreadsheet, but may prove to be much more durable when in place for a century or more or do not degrade when re-used.

If given the opportunity, how would you allocate a funding of 4 million euros for research in the field of circularity and biobased materials in building design?

Research that looks beyond the typical life time cycle of typical materials and challenges 20th century notions of the lifetime span of contemporary buildings. What is needed to make buildings that last a century, what elements in a building need to have which lifespan. Research that look into the proper circularity of materials; certain materials and products may prove to be circular, but in actual fact degrade when re-used.

Rijk Blok

Assistant professor of Innovative Structural Design, Eindhoven University of Technology

Rijk Blok is an Assistant Professor in the Department of the Built Environment at Eindhoven University of Technology (TU/e) in the chair of ISD: Innovative Structural Design. His key areas of expertise include structural design and analysis, service life and sustainability of (circular) building and bridge structures, bio-based structures, construction engineering and project management. As a Structural Designer and Researcher, Rijk is not only interested in solving challenging structural problems but also realizing these innovative (structural) solutions within the context of (a sustainable) society.

www.tue.nl/en/research/researchers/rijk-blok
www.nweurope.eu/smartcircularbridge
www.stimulus.nl/opzuid/avada_portfolio/living-lab-structural-health-in-biobased-constructions

What are your current areas of research or ongoing projects in relation to circularity and the built environment?

I'm currently involved in projects looking at resource-efficient and circular structures: the reuse of prefabricated concrete elements in new buildings. This will involve four demonstration projects across Europe. Use of biobased (flax and hemp) composites in load-bearing structures: roof and bridge structures. The Interreg NWE (TU/e project leader) Smart Circular Bridge project will build three bridges in Europe using structural health monitoring and artificial intelligence. With Clemson University (USA) we are looking at the effects on the service life of building structures in the decision-making process of renovation versus demolition. With the German DGNB, we are also looking at the impacts of demolition and ways to arrive at circular reuse versus demolition. With Dienst Huisvesting TU/e we will develop a circular safety-region building

What do you perceive as the biggest challenges with regards to circularity and biobased building design? Shortly elaborate why.

The biggest challenges are:
—Reducing fossil material use to improve theoretical solutions for circular-

ity in terms of overcoming obstacles to the market. This involves many stakeholders: government/authorities have to provide clear policies to accelerate impacts such as CO2 reduction and the construction Industry needs to develop solutions that can be widely applied and demonstrate sufficient long-term performance.
—Making clear what the drivers behind elongating the circles of use in circularity are. Not only end-of-life circularity solutions, but also solutions for effective safe and economic use in the longer term are important.
—Closing the loops: circular end-of-life solutions for buildings, building elements and building materials are needed.
—A non-fixed, open methodology for evaluating all circularity effects in a useful way, from the level of science to the level of implementation in the construction industry.

<u>What do you perceive as the biggest opportunities?</u>

Longer use, the renovation of buildings also designed for reuse is a good opportunity, reuse of structural elements is a promising direction minimizing material impacts. Differentiation of material use depending on the service life of components, for example internal partition walls have a shorter service life and therefore using bio materials here could be very effective.

<u>How do you assess the difficulty and/or ease of implementing circularity in research or practice? What are the biggest challenges when it comes to academia and industry?</u>

Not only technical solutions are needed but all stakeholders should be convinced. Demonstration projects are therefore needed. Academia cannot develop solutions on its own. (See also question 2)

<u>If given the opportunity, how would you allocate a funding of 4 million euros for research in the field of circularity and biobased materials in building design?</u>

—1 million for reserach on bio-composite material use as an alternative for fossil materials
—1 million for the reuse of existing building and structure elements
—1 million for drivers, decision-making process and building properties on the decision of demolition versus renovation
—1 million for assessment methodology and roadmap development towards circularity and circular building

<u>What do you perceive as the largest knowledge gaps when it comes to circularity and biobased materials in building design?</u>

We do not know what the drivers are on how long a building and each of the building systems, façades, installations, etcetera will be used. Buildings have a relatively long service life, meaning that the buildings we build now that are perceived as very sustainable could for as yet unknown reasons be perceived as unheathy, unneeded, or uncomfortable in 10 to 20 years’ time. That means that a holistic approach is necessary. This is somewhat contradictory to an academic approach that sometimes focusses on a limited scope.

Perica Savanović

Applied Research Professor Built Environment, Avans University of Applied Sciences

Perica savanovic has been a lecturer in the built environment lectorate at the expertisecentrum technical inovation (ETI) of Avans University of Applied Sciences. Perica studied architecture at Delft University of Technology and then worked for the architectural firm Van den Broek en Bakema. Perica obtained his docorate on the subject of integral design at Eindhoven University of Technology (TU/e). In additon to his research, his attention is focused on education and lifelong learning. In Addition to working with students, Percia also provided workshops on intergrated design and construction for several years. These workshops are held in the context of continuous proffessional education of the industry association for Dutch architectural firms BNA and NL ingenieurs.

www.interreg2seas.eu

What are your current areas of research or ongoing projects in relation to circularity and the built environment?

My research focuses primarily on participative co-creation, regarding and embracing the complexity of societal challenges, by using a design and design research approach to open systems advances towards a sustainable built environment.

An example research project: Circular Bio-based Construction Industry, 2 Mers Seas Zeeën

What do you perceive as the biggest challenges in regard to circularity and biobased materials in building design?

The first and most important challenge is to stop approaching them as only technical problems and from the perspective of 'closed systems'. Secondly, biobased materials are always incorporated into bigger building products/blocks/elements, the focus therefore needs to be on the characteristics of these complex configurations instead of on biobased materials only. Additionally, seeing circularity only through the perspective of biobased materials tends to enhance the technical, closed systems view, which doesn't help to achieve the goal of circularity in a multifaceted practice and complex open systems.

What are the biggest opportunities?

New regional economies. Combined with a growing awareness that we are dealing with complex issues, and therefore the readiness to at least listen to different views and approaches. Everybody is searching for new ways and solutions, the task is to channel this search towards joint development instead of fast general consensuses.

How do you assess the difficulty/ease of implementing circularity in research or practice?

The difficulty is the dominant call for more 'mass' and an instant impact (on a bigger scale). Coupled with this, it remains difficult to find real-life projects that are more than only 'implementation possibilities for tested and proven solutions'. Even when the responsible parties are willing to experiment in practice, the goals usually remain quick 'validations' and bigger scale replications.

The ease remains to be the competences and flexibility of the involved and engaged practitioners and researchers to keep looking for opportunities, both in and outside their own primary fields of expertise. Luckily, the term 'built environment' is both 'specific and vague' enough to be accepted as a relevant issue and partner (through a variety of disciplines) for new initiatives. This characteristic of the built environment should be cherished!

How would you administer / what would you do with a grant of 4 million euros?

A very interesting and intriguing question! Ultimately, I would choose to use it to develop a monitoring approach from the perspective of ever changing 'benchmarks' regarding design-driven innovation in the built environment – the relative speed of this change, combined with 'designerly metrics' for capturing and presenting these changes, would indicate the role of design research in knowledge development and the added value of design in directly utilizing new knowledge for the sustainable adaptation of our built environment. The developed monitoring would hopefully also help to better understand the relation between design research and design in built environment, for both education and practice.

Bas Jansen

PhD Researcher
Delft University of Technology

Bas (Wouterszoon) Jansen studied Architecture at Eindhoven University of Technology. He worked at architecture firms at home and abroad with a focus on sustainable residential building. He currently promotes the development of circular building components, in which he leads the 'The Circular Kitchen' research project. He also works as an independent designer at Atelier Wouterszoon.

www.tudelft.nl/thecircularkitchen

What are your current areas of research or ongoing projects in relation to circularity and the built environment?

My current area of research is the development of circular building components. Specifically, I lead a project called The Circular Kitchen (CIK) and collaborate on the REHAB project, led by Anne van Stijn.

The CIK project was initiated by Delft University of Technology, AMS (Amsterdam Institute for Advanced Metropolitan Solutions), Bribus Keukens as the kitchen producer, Dirkzwager Groep as the contractor and housing associations Eigen Haard (Amsterdam) and Waterweg Wonen (Vlaardingen) as clients. In 2018, housing associations Ymere, Woonbedrijf, investor Syntrus Achmea and appliances supplier ATAG joined the project. This research project is part of a larger research project in cooperation with Chalmers University of Technology Gothenburg. Parallel to this research, a circular kitchen is being developed in Sweden with project partners Vedum (kitchen producer), HSB (housing association) and ASKO (appliances supplier).

What do you perceive as the biggest challenges in regard to circularity and biobased building design?

First, one of the main challenges of implementing circularity in the build-

ing sector, and more specifically in the production of building components, such as façades, roofs and kitchens, is that in general 'circular' building components entail higher initial investment costs. Although we have seen that these components usually cost less over longer periods of time (>30 years), the uncertainty that accompanies these long periods and the circular loops that have to take place can make clients unwilling to invest.

Second, the implementation of the aforementioned circular loops will in many cases call for a change in the building industry from project based, to product based (that is, building with standardized prefab products on a larger scale), and will require radical changes and new collaborations in the supply chain. In the building industry, which is quite conservative, these changes could cause resistance and might take long to implement.

What do you perceive as the biggest opportunities?

The main opportunities in the development of circular building components, is that in order to successfully develop these components, new collaborations have to be formed. Supply chain partners will have to come to an understanding of their needs and capabilities and collaboratively become the 'owners' of the product they develop. This could bring forward products that function better, and have greater support than products that are not developed in such a collaboration.

How do you assess the difficulty and/or ease of implementing circularity in research or practice? What are the biggest challenges when it comes to academia and industry?

In our research, we constantly communicate with our project partners. Making them an integral part of the research project gives new insights and mitigates the risk of implementing products that do not live up to standards. In this way, academia plays a role not only in research, but as a facilitator as well. However, academic research is often slower and comes with more uncertainties than industry partners would like. Occasionally this leads to a discrepancy between the expectations of industry partners and the substantiation that the academic parties can actually deliver.

If given the opportunity, how would you allocate a funding of 4 million euros for research in the field of circularity and biobased materials in building design?

Personally, I see big possibilities in extending the scope of mass-customizable (standardized, but customizable) building components for larger building projects to encompass all components in a standardized way. Up to now, research is generally done per component due to the limited scope of projects and the high complexity of researching just one circular building component. However, a larger system of interlocking building components could prevent even more waste, emissions and resource use. This would require a much larger consortium of parties, but could build on current studies such as the CIK or REHAB projects.

What do you perceive as the largest knowledge gaps when it comes to circularity and biobased materials in building design?

The largest knowledge gap would be the discrepancy between academic research into the circular economy (CE), and the implementation and interpretation of it in practice. The interpretation of the CE by practice, if they are not part of a research project, is quite often limited. For example, in practice the CE is often interpreted as using waste materials in products, or as focusing on recycling. Only rarely is it applied in the holistic sense in which it is often portrayed in academia.

Tom Veeger

Architect and Tutor Faculty of the Built Environment, Eindhoven University of Technology

Tom Veeger is working on projects in the field of Architecture, Art and Light (atelier Veeger) and combines it with teaching at the Faculty of the Built Environment (chair of Architectural Design and Engineering) at the TU/e. He worked in the past 20 years in different large architectural studios as an all-round senior architect and at the moment in his own studio. He has been designing projects like hospitals, schools, office buildings, large scale housing projects and urban plans. In this period he won different prices with his architectural projects. Besides his architectural work he alwayshas been working on projects outside of the architectural boundaries in the field of art, stage and lighting design. He carried out projects in art spaces, museums, festivals, theatres and galleries in the Netherlands and abroad.

www.stimulus.nl/opzuid/avada_portfolio/living-lab-structural-health-in-biobased-constructions/
www.myceliumlab.nl

What are your current areas of research or ongoing projects in relation to circularity and the built environment?

—Living Lab: Structural Health in BioBased Constructions
—My Celium Lab: Research into new materials like mycelium (the project funding has ended)
—Collaboration in the Summerlab project with partners outside the faculty on the topic of sustainability in various fields.

What do you perceive as the biggest challenges in regard to circularity and biobased building design?

Biobased materials are still in development and are faced with a construction industry that is conservative and does not like to switch to new 'materials' and this is not without reason. Many of the products currently applied are certified and have a long history and there is no need to be afraid of possible unexpected 'teething problems'. Problems in construction with materials often only become apparent after a longer period of time, but then have a large financial impact in the form of damage claims and huge repair costs. This is something I have experienced several times as a project architect. We need to do more intensive research into these biobased materials before we will be able to introduce them into our discipline.

What do you perceive as the biggest opportunities?

Biobased materials are part of the answer to the climate problems we currently face. In addition to further focus on intelligent reuse of buildings and materials.

If given the opportunity, how would you allocate a funding of 4 million euros for research in the field of circularity and biobased materials in building design?

Practice-based research, use the available funds to set up a few concrete pilot projects (housing or, for example, an educational building) as a living lab and design these buildings first and then monitor them for a longer period of time.

Pascal Leboucq

Designer, Biobased Creations

Pascal is a designer and scenographer. He was classically trained at the royal academy of fine arts in Antwerp and specialized in Public Space at the Design Academy in Eindhoven. Besides his work for New Heroes Pascal develops his own projects and works as a freelance scenographer for different theatre companies. At New Heroes Pascal creates urban art installations and cross-discipline scenographies.

www.companynewheroes.com
(Growing Pavilion, The Exploded View)

What are your current areas of research or ongoing projects in relation to circularity and the built environment?

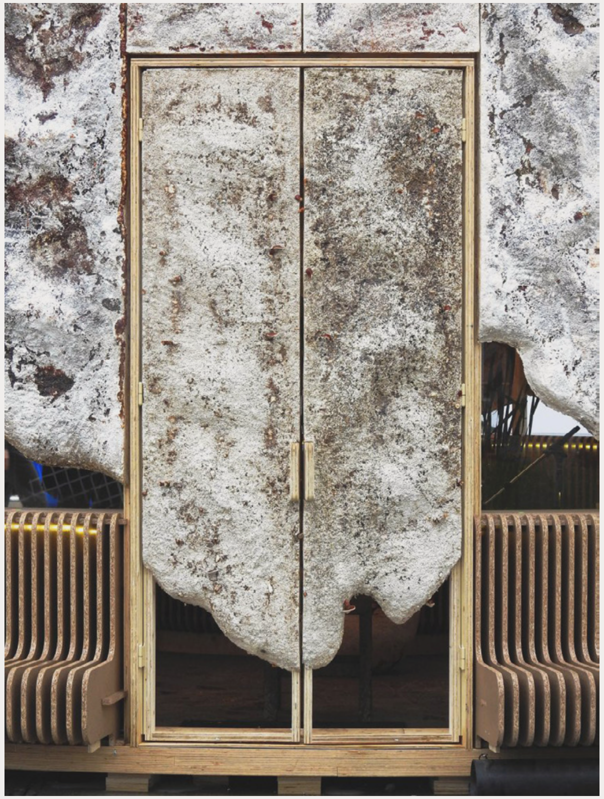
As a designer I am active in the theatre and museum world, developing pavilions and installations. These are often temporary projects that make extensive use of waste flows.

My design focus is on the mapping and upscaling of biobased materials and innovations in collaboration with other (material) designers.

The aim is to create a much wider range of material options to use in (cultural) commissions. I not only focus on the sustainability aspect of these materials but also on ways to use the unique aesthetics of these natural materials to create high-quality design on a larger architectural scale. As head designer of Biobased Creations I have, together with our team, translated this research into concrete projects in which we use imagination, design and storytelling to show the potential of sustainable building to a wide and diverse audience.

What do you perceive as the biggest challenges in regard to circularity and biobased building design?

Besides the technological problems, one of the biggest challenges is to create the awareness (broad social support) that this transition is not a



movement or a style, but a necessity. It's a transition that has to take place in the very near future, before the climate crisis catches up with us all and we find ourselves in an irreversible situation. Sustainable dwelling and living practices are not only feasible for the upper classes, but for society as a whole.

If not, this transition will be of very little consequence.

What do you perceive as the biggest opportunities?

The prospect of once again being able to live in a healthier environment indoors as well as outdoors. Seeing that housing and nature increasingly merge even in the urban context. The possibility of always being connected to natural aesthetics gives me hope and peace of mind.

I think this is the greater good for which we are all working every day.

How do you assess the difficulty and/or ease of implementing circularity in research or practice? What are the biggest challenges when it comes to academia and industry?

A lot of the research and development that takes place at universities and in industries is still only entrusted to paper or of too small a scale. Developing detachable building elements that are separate from main structures creates the flexibility to implement new innovations and to test them on a proper scale and in the right context. This is the only way to gain the experience and knowledge we need to eventually create a fully-fledged product.

The responsibility for such a development trajectory not only lies with the material producer but also with architects, contractors/processors and users, and is therefore a shared responsibility. Today, material producers often shoulder the full responsibility. As a result, many potential innovations never leave the sample cabinet.

If given the opportunity, how would you allocate a funding of 4 million euros for research in the field of circularity and biobased materials in building design?

To create ‘fab labs’ equipped with advanced pressing machines and industrial-scale 3D printers. In these labs both designers and start-ups can upscale their innovations for a small fee without existing production processes in companies having to shut down. The latter is often an important reason why companies cannot or will not support new innovations. I would like these labs to be connected to industries and universities rather than be autonomous organizations. This will create cross-fertilization and allow the necessary innovations to be organically integrated in or to replace existing production processes.

What do you perceive as the largest knowledge gaps when it comes to circularity and biobased materials in building design?

There are all kinds of possibilities to produce completely biobased building materials, but there are not enough suitable biobased coatings to guarantee the lifespan (water resistance, UV protection and fire resistance) of these products.

Due to the use of less sustainable coatings, we see building materials that have been developed in a sustainable way, but are difficult or impossible to compost nevertheless. Another major hurdle is that innovative material producers/designers often have to organize the entire chain, from raw material to end product, themselves to be able to market it, which is a very time-consuming process.

The reason for this is that many biobased raw materials are still often only available in very small, limited quantities and that there is insufficient collaboration between the agricultural sector and the manufacturing sector.

Marc van den Berg

Assistant Professor, Construction Management and Engineering, University of Twente

Marc van den Berg studies and teaches new methods to enable circular buildings and infrastructures. His award-winning PhD thesis, entitled 'Managing Circular Building Projects', is one of the first worldwide to focus on understanding the application of the circular economy concept to the construction industry. He currently works on integrating circularity thinking into the Systems Engineering methodology.

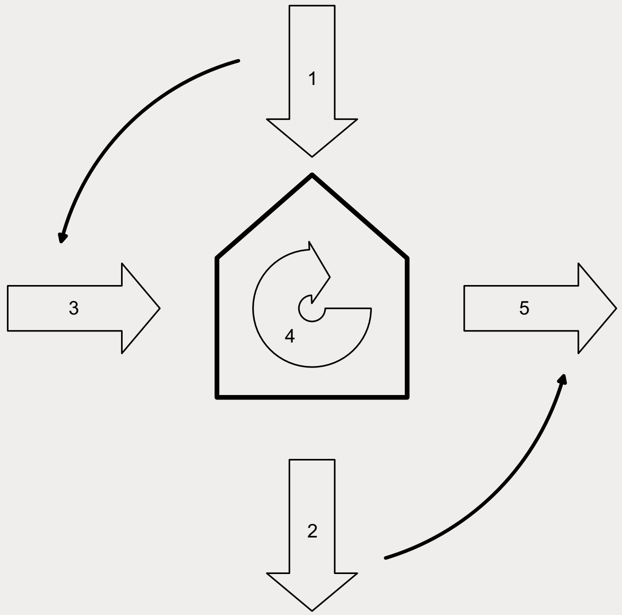
www.mcvandenberg.com

What are your current areas of research or ongoing projects in relation to circularity?

My research focuses on new approaches to designing circular civil engineering systems. I want to develop tools and methods to integrate circularity in the Systems Engineering methodology. As such, I'm working on a BIM-based circularity assessment tool that can be used during different design phases. I'm currently also collecting and comparing experiences of frontrunners in circular design projects to better understand how those professionals deal with the complexities and uncertainties associated with circularity. Furthermore, I am chairing a Platform CB'23 working group on roles and collaborations in circular design.

What do you see as biggest challenges in regard to circularity and biobased materials in building design?

One of the biggest challenges in regard to circularity is the need to rethink the value of buildings and infrastructures. No longer seeing salvaged building materials as waste, but as commodities that should be kept in the loop, has far-reaching implications for the entire construction ecosystem. The system needs to change: construction parties need new methods to understand and reap the potential benefits of any circularity investments.



Circular Project Model with large arrows representing material flows around a construction project and small arrows indicating a 'transition' from linear to circular practice: 1 new materials, 2 waste , 3 reuse of recovered materials (from an old building), 4 recovery and reuse (from and in the same building), 5 recovery of materials for reuse (in another building)

What are the biggest opportunities?

There is currently a lot of interest and enthusiasm in the industry. It is good to see that more and more construction companies realize that we must change traditional working practices. There is simply no alternative. Another opportunity concerns the clear ambition of the Dutch national government to realize a fully circular economy by 2050. Finally, thanks to increased digitization, construction firms are having more possibilities available to store, process and transmit digital asset information – with which they can work towards circularity.

How do you assess the difficulty/ease of implementing circularity in research or practice?

It is still very difficult to implement circularity in any project, given the diverging views on what the concept entails (and what it does not). This is quite problematic as it prevents independent assessments and may also lead to greenwashing: deceptively branding a product as circular or environmentally friendly. The transition is also hampered by parties that have a stake in traditional, resource-intensive and polluting construction practices. Persuading such parties to change will be extremely difficult.

How would you administer / what would you do with a grant of 4 million euros?

I would develop a toolbox with circular design strategies: field-tested solution concepts that different construction parties can embed and contextualize in their own practices. Those solution concepts will consist of both high-tech and human-touch components: they balance, for example, the potentials of the latest digital technologies with processual or managerial views on circularity. The solution concepts will be tested in real-world projects and the lessons learned will be made widely available.

Vincent Gruis

Professor Housing Management,
Delft University of Technology

Vincent Gruis is professor of Housing Management at Delft University of Technology. His research addresses the question of how landlords, developers, investors, governments and tenants can adapt their housing to societal challenges. He currently focusses on how to implement principles of a circular economy in the management and redevelopment of the housing stock. After a (necessary) emphasis on increasing the energy efficiency to reduce carbon emissions, creating a circular built environment is the next sustainability challenge.

www.tudelft.nl/bk/onderzoek/onderzoeksthemas/circular-built-environment
www.tudelft.nl/thecircularkitchen
www.tudelft.nl/bk/onderzoek/onderzoeksthemas/circular-built-environment/projects/rehab
www.nweurope.eu/projects/project-search/charm-circular-housing-asset-renovation-management/

What is your current area of research or ongoing projects in relation to circularity and the built environment?

My research addresses the question of how to implement principles of a circular economy in the built environment. I focus in particular on strategies to make housing more circular in a gradual way by adding 'circularity' as a criterion for carrying out maintenance, renovation and construction activities. As part of this, our group is developing the exemplary case of a circular kitchen as well as other building components for circular housing renovation. Moreover, we are working with social housing organizations in North West Europe to develop methods and tools for incorporating circularity in their asset management, including circular procurement guidelines and concepts for material exchange platforms.

What do you perceive as the biggest challenges with regards to circularity and bio-based building design?

I perceive several challenges for implementing technical 're-loops' in the maintenance, renovation and construction of buildings, including:

—Lack of knowledge throughout the whole construction sector;
—Lack of suitable (proven) products and business models;
—Finance based on Total Cost of Ownership models instead of initial purchase price/costs does not fit very well within our current system for finance, valuation (appraisal) and accountancy;
—(Perceived) competing priorities amongst housing providers, such as the huge housing shortage and need for energy efficiency.

For implementing bio-based (non-toxic) building approaches, I think the lack of tradition in the supply chain as well as amongst clients is one of the major barriers. As a simple example we can refer to timber-frame housing; we're just not used to it in The Netherlands, although the quality can be good and the environmental benefits substantial.

What do you perceive as the biggest opportunities?

The current challenge to make our buildings more energy efficient provides an excellent opportunity for also implementing building components that are designed according to principles of a circular economy. The same goes for the shortage of 1 million homes. In principle, this provides a scale that is large enough for feasible implementation of circular construction methods and the necessary innovation in chains of supply and demand. Moreover, although the current state of play is mainly focused on knowledge exchange and pilot projects, there is a vast and increasing interest in circularity amongst all stakeholders in the built environment. If we are somehow able to combine and channel that energy into upscaling of promising approaches, we could create a wave that is big enough to ride.

How do you assess the difficulty and/or ease of implementing circularity in research or practice? What are the biggest challenges when it comes to academia and industry?

I believe that innovation can be sped up by research and development (R&D) projects in which academics and industry partners jointly work towards marketable products. Some of the examples in my research group show that this can be done by applying what we call 'action research through design'. These projects are in particular interesting for early career academics, who can then combine research with working with industry towards something tangible and meaningful. The main difficulty lies in scaling up such joint R&D projects, amongst others due to lack of capacity within academia. Setting up teams of clients, suppliers and academics, even around a singular building component, takes quite a bit of time and effort.

If given the opportunity, how would you allocate a funding of 4 million Euros for research in the field of circularity and bio-based materials in building design?

I would set up a portfolio of joint R&D projects around roughly eight to ten most common building components. 'Common' here refers to building components that are or will be most frequently replaced and cause most (toxic) waste and depletion of scarce resources. In these R&D projects, I would not only look at the design and materialization of the products, but also at the supporting business models (value proposition, supply chain partners and roles, finance, marketing, logistics etc.). Furthermore, I would look into which smart combinations of 'technical' and 'bio-based' design solutions are likely to perform best in environmental and economic terms (including social acceptance).

What do you perceive as the largest knowledge gaps when it comes to circularity and bio-based materials in building design?

I think the largest knowledge gap is that we do not know which solutions are likely to perform best in environmental and economic terms. Currently, circular life cycle analysis and total costs of ownership models are being produced that can generate some relevant knowledge about this. Nevertheless, the input for these models has to depend on a lot of assumptions about how circular buildings and their components will 'behave' in the future. How many times will components be re-used? What value will they have at the end of subsequent use cycles? Such questions arise in particular for solutions that are designed to facilitate technical re-loops and can also lead to the perception of such solutions as a 'risky business'. It could consequently be argued that bio-based (non-toxic) solutions might fit better within our system. For bio-based solutions, nevertheless, I also believe there is a lack of knowledge and therefore also trust in the long term performance regarding building quality and economic value.


6

CASE STUDIES

Introduction

The listed case studies are made up of research-led explorations as well as built examples, illustrating varied approaches to circularity and biobased materials in architecture and design. As many of the projects demonstrate through their list of involved partners and collaborators, the successful implementation of circularity and/or biobased materials in applied projects depends on the involvement of multiple actors, from research institutes to municipalities. Evidently, this list does not strive in any manner for completeness. It is a reduced reflection of a far broader spectrum, containing varying building typologies, material palettes, and applied processes of manufacturing and fabrication.

Each case study naturally highlights different aspects of circularity, materiality, and the correlated processes of fabrication or assembly. The described projects showcase in a contextualized manner several of the observations mentioned in the 'Insights' chapter. The faced challenges remain mostly the same, despite varying project scales. What this collection of case studies manages to illustrate is the multifaceted high-quality outcomes that can emerge through collaboration, persuasion and insistence.

CN

BlueCity Offices

Project BlueCity Offices
Practice Superuse Studios
Location, Year Rotterdam, 2017
Collaborators Coup-Group, Workspot, Lennard Mooyman en Hans Overdevest, BIKbouw, OKKE HOUT meubelmaker, KEES ontwerpatelier, Floris Zegenswaard, Jaap Verheul, Hugo Lammerink en Fred Schurink, Climatic Design Consult, Engie, Municipality Rotterdam

www.bluecity.nl

Companies that Accelerate the Circular Economy

With the office wing, BlueCity wants to offer circular companies representative space and thus encourage more cooperation and innovation. Among the companies currently located in the building are circular design and project agencies Verdraaid Goed, Masters that Matter, architect and design agency Superuse Studios, Better Future Factory and the ifund foundation. The offices and workplaces complement the production areas and the BlueCity lab that are also being realised in the building. Several biobased designers who also work in the lab have their offices here. The first part of the transformation from swimming pool to model city is 90% circular. The first 1.300 square metres of the total 10.500 square metres have been completed.

From Throw-aAway Culture to Innovative Lego

Circular building is like Lego: right from the start, you think about how you can put together parts of a building – preferably existing ones – so that you can take them apart again at the end of the journey. To reuse them or give them back to nature. And not to burn them on landfill, as is the case in linear construction.

Actually, circular building is about a life cycle approach. Materials are already used, renewable or recycled and non-toxic. Because you keep reusing materials, not only does the impact of raw material extraction decrease, the amount of waste released during construction, renovation and demolition also drops drastically. A win-win situation – at least on paper.

Practice, however, is more difficult: it is full of unexpected situations, dilemmas and answers that mainly raise new questions. Where do you get the used, renewable, non-toxic material from? And how do you deal with something as complex as repurposing? As in any innovation process, it comes down to a mix of knowledge gathering, cooperation, transparency and, above all, a good dose of courage. Especially when you convert a dance club into a workplace.

From Run-Down Disco to Innovative Workplace

Converting an empty disco into workplaces for innovative companies took a lot of hard work. The greatest challenge lay in the conversion: how do you convert a building that was built as a disco, and thus optimised for intensive night-time use by frenzied dancing people, into an office wing where people work and sit still during the day?

'In order to make that happen, the municipality prefers to see a well thought-out and sealed plan for the entire building in advance,' says Yvette Govaart, project coordinator for transformation. We are building an ecosystem here and it must grow organically. We need freedom to innovate. Fortunately, the municipality is very active in helping us, and we were able to separate the development of the former disco into BlueOffices from the formal decision-making process about the reuse of the entire building.

Built with 90% Recycled Materials

The construction process itself is also very different. 'Raw materials are our leitmotif,' says Govaart, 'and that affects the entire process. As a contractor, you have to be able to cope with that.' In the transformation of BlueCity, the question of people with whom the construction team works is therefore different from usual. 'Normally you make a design that meets the requirements, you negotiate the price and then you can start,' explains Govaart. 'With the transformation of BlueCity, there is no point in working out plans in detail, because we are working with reused materials and you are dependent on their availability. Details, some design solutions and construction logistics can therefore only be finalised later in the process.'

The circular renovation of BlueCity always looks at what materials are available on the market, and how can we use them in this space? The properties of the material are guiding principles in the design process. Govaart: 'You embrace the material and start from there, not from a standardised floor plan based on elements from the new product catalogues.' This working method not only requires a lot of flexibility, but also a lot of craftsmanship on the part of the implementers. Investing in the local circular economy As well as saving a dilapidated building from demolition, circular building (re) construction delivers environmental gains in several areas. Firstly, of course, in working with recycled materials. These are also locally sourced, which means that there are environmental gains in terms of transport. Finally, local labour is used, especially craftsmen. This also boosts the circular economy in real estate. 'And then of course there is the ripple effect,' says Govaart. 'People who have worked with us now also look at the use of reused materials differently.'

Gare Maritime

<u>Project</u> Gare Maritime
<u>Practice</u> Neutelings Riedijk Architects
<u>Location, Year</u> Brussels, 2020
<u>Collaborators</u> Extensa Group (client), Bureau Bouwtechniek (architecturalengineering), Ney & Partners BXL (civil and structural engineering renovation), Ney & Partners WOW (civil and structural engineering pavilions), MEP – Boydens engineering Brugge, OMGEVING Antwerpen (landscape architect)

www.neutelings-riedijk.com/gare-maritime

Project Description

The monumental Gare Maritime on the Tour & Taxis site in Brussels has been transformed into a new city district by Neutelings Riedijk Architects in cooperation with Bureau Bouwtechniek, commissioned by Extensa. Once Europe's largest railway station for goods, Gare Maritime is now turned into an inspiring place for companies, ranging from start-ups to renowned brands. Together they surround an impressive indoor public space for all kind of events; 'A city where it never rains'.

As Neutelings Riedijk Architects designed this covered city entirely in wood, Gare Maritime is an excellent example of a sustainable development. Moreover it is the largest CLT-project in Europe.

Gare Maritime dates from the beginning of the twentieth century. The enormous building is no less than 280 meters long and 140 meters wide. It exists of three larger and four smaller halls, that now have been made accessible to the public again. Under the existing roofs of the side aisles, twelve new building volumes are added to accommodate the new program of 45.000 m2.

Design Strategy

The central space in the heart of the building has been kept open for public events. It has a pleasant climate which follows the changing of the seasons. Inspired by the 'Ramblas', on both sides of the event space a green walking boulevard is created. The 16 meters wide pedestrian routes give enough room for spacious inner gardens, with a hundred large trees. The gardens are planned by landscape architects OMGEVING. They designed a total of ten gardens based on four themes: the woodland garden, the flower garden, the grass garden and the fragrance garden. The choice of plants has been adapted to the specific growing conditions, which are comparable to a Mediterranean climate. For the little squares, Brussels visual artist Henri Jacobs designed eight mosaics.

Together with Ney & Partners and Bureau Bouwtechniek, the construction of the new built-in volumes has been realized in Cross Laminated Timber (CLT) with façade finishings in oak (FSC). With an enormous reduction in the amount of cement as a result: In concrete, the building would have been five times heavier. The choice for wood also had a favorable effect on the construction process: thanks to prefabrication and the dry constructing method, the construction time was considerably shorter than when using traditional construction methods. Circularity was also a main design starting point. That resulted in the design of demountable connections and modular wooden building elements.

Gare Maritime is entirely energy neutral and fossil free. The glass facades on Picardstreet are provided with solar cells. On the roofs a total area of 17,000 m2 of solar panels has been installed. At all levels - construction, climate, circularity, biodiversity, health - far-reaching sustainability measures have been implemented. Use of geothermal energy and reuse of rainwater for watering the gardens are a few of the measurements taken.

In the first phase, the existing historic building was carefully restored by Jan de Moffarts Architects, Bureau Bouwtechniek, Ney & Partners and Boydens. The supporting structure, consisting of riveted lattice girders and characteristic three-hinge trusses, has been sustainably renovated and reinforced where necessary. An extensive analysis with various scenarios led to the sustainable renewal of the original "skin".

As for the offices, the key focus was to create a healthy working environment with light, open and inspiring workplaces. The pavilions are composed of a ground floor, first and second floor with an additional mezzanine under the ridge. Large oak windows on the ground floor also serve as balconies for the offices above. The pavilions are interconnected by sculptural oak "staircases" above the inner streets.

Based on a modular system, various functions can easily be accommodated, such as offices, workshops, shops and showrooms. Because the twelve separate pavilions all have their own address, the huge project still has a human scale.

Biopartner 5

Project Biopartner 5
Practice Popma ter Steege Architecten (PTSA)
Location, Year Leiden, 2021
Collaborators Biopartner Center Leiden (Client), IMd Raadgevende Ingenieurs (Construction), Deerns Nederland (MEP + Building Physics), Stone 22 (Projectmanagement) , IGG bouweconomie (Construction), Lodewijk Baljon (Landscape design), De Vries en Verburg (Contractor), Vic Obdam (Steel builder), Beelen Next (Supply donormaterial), Leiden University (Donorbuilding steel)

www.ptsa.nl/incubator-biopartner-5
www.bouwwereld.nl/bouwkennis/duurzaamheid
www.architectenweb.nl/nieuws/artikel.aspx?ID=47972

Project Description
Biopartner is a successful incubator organization based at the Leiden Bio Science Park (LBSP). It is closely tied in with the growth of the park and developed its fifth building as a meeting place for the new section of the Oegstgeest campus. This makes Biopartner 5 a quartermaster for campus development; it has the ambition to set the tone for the sustainable development of the area.

Biopartner 5 is a layered laboratory building measuring approximately 7,000 m2 in which high-tech and low-tech come together. The building is firmly anchored in its immediate surroundings. The architectural design, landscape design, materialization and programming all aim to facilitate contact and interaction between the users of the building. The result is an inspiring working environment in which the collaborative culture of the Leiden Bio Science Park is paramount.

Design Strategy

More than anything else the creation of an actual campus building with a high-tech and efficient character as well as an open and informal side has informed the design choices made during the development trajectory. We believe that bringing together these seemingly opposing worlds creates good tension that allows quality to emerge – in architecture as well as in daily use. High-tech and low-tech need each other just like concentration needs relaxation.

This idea has been leading, from initiative to execution: from the struggle to realize the required parking spaces off-site and to keep the ground level free for interaction, to the use of 'lost and found' paving materials to create a continuous public carpet that transforms the building into a public interior.

The reuse of building materials contributed considerably to the formation of this creative tension. We use existing building materials in the same way Ray and Charles Eames, who found freedom in the use of standard industrial building elements from a catalogue, once did. We use the existing stock of building materials for our catalogue; its limitations give us the freedom to reflect on ways to best apply materials and, conversely, on what we need to achieve the best possible building.

Circularity Strategy and/or Bio-Based Materiality

For the PTSA, the design trajectory was an investigation into the possible significance of circularity to current building practices. This search resulted in a commercial, 7,000-m2 laboratory building in which radical building materials were nevertheless applied on a large scale. The design process strategy was to examine, per building element, how its environmental impact could be limited, on the basis of market research, common sense and above all design ideas. We left out what could be left out and used biobased materials where possible; our starting point was to create detachable elements and we used secondary materials where possible or available. Afterwards, the NIBE calculated that this reduced the building's CO_2 emission to below the new DGBC Paris-Proof threshold.

The circular strategy/interventions

- The reuse of the steel main support structure of a nearby demolished university building. > High impact, because support structures of buildings have a high mass and high shadow costs.
- The use of a detachable main support structure: a steel structure with concrete hollow core slab floors without a compression layer. > Fit for future reuse or adaptation.
- The use of a lightweight building envelope; timber frame elements finished with technical textiles. > Because of the high demands made on the façade, the focus should be on biobased, low mass and minimal use of materials. Materials and window frames are detachable.
- The reuse of debris from the donor building in the low-tech green façade on the ground-floor level. > The indigenous planting found on the grounds continues in the façade to connect the building and its surroundings and to enhance biodiversity. Calcareous rubble and spaces between the stones also contribute to biodiversity. Plants are irrigated with collected rainwater which, through a cascade of mirror ponds, brings quality to the courtyard garden.
- Reuse in the interior and décor. > This includes used interior walls, stone floor finishing, paving, sanitary facilities and rejected carpeting. This theme is also continued in built-in and freestanding furnishings, which include reclaimed wood. The décor is composed using second-hand design classics collected by the architects.
- Using biobased materials in finishing and interior (less vulnerable than in façade). > Includes biobased insulation in all interior walls, wooden finishing on walls and floors, linoleum and natural paint.
- Involving local like-minded partners to strengthen regional circular ambitions. > From collaborating with Leiden University for the 'harvesting' of steel, rubble and stone to collaborating with the local recycling shop to reclaim furniture wood for the interior.

- Being energy neutral for building-related energy. > Including limiting energy demand by avoiding oversized and overheated entrance areas (winter garden), limiting artificial lighting by ensuring ample daylight incidence and by generating energy by means of air heat pumps and solar panels.
- Creation of a landscape for people and urban nature using rainwater collection.

Reflection – Challenges and Opportunities of Circularity and/or Biobased Materials

The desire to seriously reduce the environmental impact of building requires dedicated design and implementation. Standard solutions need to be reconsidered, new solutions need to be designed and numerous stakeholders must be involved in and convinced of the plans. This offers architects the opportunity to play a central part in a layered process. Architects are in an excellent position to play a connecting role throughout the stages and scales of the project. In the Biopartner 5 project, we succeeded in assuming such a central role. The trust of both the client and among the team members was essential for its success.

Practical challenges

- Flexibility. The process and the team need to be sufficiently adaptable to be able to cope with the uncertainties involved in the extraction, procurement and application of secondary materials. Exact qualities, quantities, finishing levels and so on are sometimes different than expected. A development team has to have problem-solving capacities. Designers have to stay committed throughout the entire process and continue to design until the implementation stage. This also requires a flexible and confident method of specifying the details of a commission.
- Organization. The logistics of reuse are a well-known bottleneck. Available materials are not always usable and sought-after materials are not always available at the right time. The focus on reusing building materials as a basis or as resources for new products therefore makes a lot of sense. From an environmental point of view, however, 1:1 reuse is also desirable and possible. It is up to architects to play a part in the organization of the materials they use to build.
- Greenwashing. People speak of circularity too lightly too often. Too few promises are kept. It is important that impact is perceptible and measurable and that the environmental impact of materials is well known and calculated.

Town Hall Brummen

Project Town Hall Brummen
Practice RAU Architects, Turntoo
Location, Year Brummen, 2013
Collaborators Brakel Atmos (Glass cover), Mostert de Winter (Greenroof), Van Brakel interieur (Interior), GLC (Wood construction), Oskomera (Facade), BAM Techniek (Installations)

www.rau.eu/portfolio/gemeentehuis-brummen

Shared Responsibility

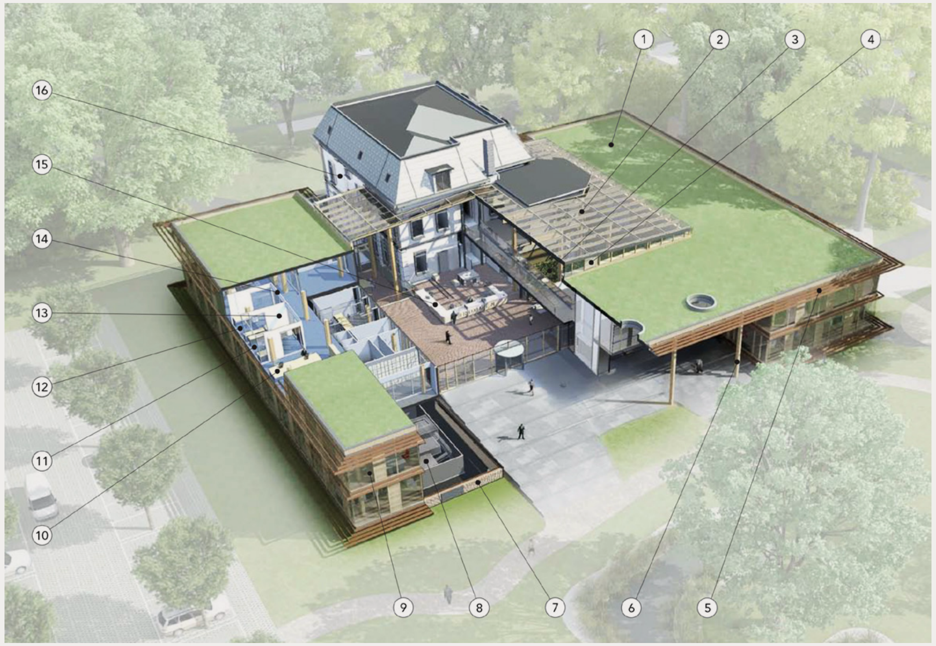
Given the number of contradictory reports on the environmental effects of human activity, there seems to be a struggle between experts who take turns to warn or reassure the public. Our current consumer society results in an assault on raw materials. While ingenious climate concepts to save energy are commonplace in architecture, concepts for responsible use of materials are now also making their appearance. The reason for this is often the pressure on our supply of raw materials, but also the reduction of CO_2 emissions in the production of those materials. Thomas Rau advocates a circular economy. Together with business economist Sabine Oberhuber, he has translated this concept into his own business model, called Turntoo.

Turntoo strives not only for the reuse and retention of the value of materials, but also for cross-sectoral chain cooperation. The fact that producers remain responsible for and owners of the raw materials makes them indispensable in the chain. In a circular economy, this increases their economic, ecological and social value. Customers only pay for the use of the products, not for the products themselves. In Turntoo, the products remain the property of the producer, and after use the producer takes back his own product. And because producers get their own raw materials back, they are challenged to make high-quality products whose raw materials last as long as possible. In this way, they can be reused almost endlessly. At Turntoo, products or building elements are seen as a raw material depot, just like buildings. Raw materials are temporarily in a particular form, and after their useful life or lifespan, can be reprocessed in a different form. For the products used, a passport is compiled that lists which raw materials have been used, who owns them and how they can be dismantled. Turntoo combines two cycles in its services: a raw materials cycle and a use cycle. This means that parallel to recording the manufacture and recycling of the product, customer service and contracting is coordinated. In this way, total quality control remains under one banner.

The vast majority of companies are enthusiastic about the business model because they too recognise that they are facing a ‘raw materials tornado’, says Rau. A change in thinking in terms of total cycles could provide an economic impulse. A research report by McKinsey shows that in the European Union, 380 billion could be saved each year by switching to a circular economy. It should be noted that environmental pollution does not only come from waste, but also from production pollution due to energy consumption and transport. Furthermore, a possible negative aspect of a circular economy is the risk that comes with companies in case of a long period of use. The raw materials are a kind of capital deposit that a company cannot simply dispose of. In the case of a light fitting with a five-year life span, this is certainly easier than with a building that has been standing for forty years.

Building as Raw Materials Depot

Thomas Rau sees that, despite the advantages of a circular economy, the government is not eager to implement policies on it. The question is whether we should rely on the government at all. Initiatives from the business community can also transform practice, as the recently completed town hall in Brummen shows. Here, RAU architects designed a semi-permanent extension around an existing monumental villa which



1 Moss sedum roof
2 Maximum daylight access
3 Green wall
4 Natural ventilation via the hall
5 Passive solar design external shading
6 Dismountable wooden construction (fsc)
7 Gabions with stone from old building
8 Installations are underneath the building
9 Three-layer glass
10 Open workplaces
11 Silent workplaces / closed consultation
12 C2C flooring
13 Presence detection / led lighting
14 Flexible wall arrangement
15 Cardboard counter
16 Repurposed monumental villa

can be dismantled in twenty years' time. The Turntoo principle was applied to the interior and the structural components. The U-shaped main mass of the extension embraces the villa and is held apart from it by an atrium. In this way, the villa stands stately in the new complex and the impact of the new construction on the monument remains limited. After the extension has been disassembled, the villa can continue on its own. The temporariness desired by the municipality has thus led to a self-evident architecture, characterized by clarity and simplicity. Construction and building elements have been designed and executed in such a way that the predominantly wooden prefabricated parts can be easily disassembled and returned to the manufacturer. The wood supplier has given a discount on the beams, with a guarantee that they will be returned after twenty years. All elements are slightly oversized, increasing the possibilities for reuse. If specific dimensions had been applied to this project, it would have undermined the Turntoo principle. This applies especially to wood, since wood as a raw material cannot be transformed like steel or aluminium. Shredding wood would be a form of degradation. For that matter, steel or aluminium could just as well be used at Turntoo. Nevertheless, a wooden main structure and floorboards were chosen because of their natural appearance. According to the architect, it fits in with the green surroundings. In the further choice of materials, their life expectancy/usability was taken into account. The architect foresees changes in the interior in the next 20 years and therefore used cardboard for the walls and the reception desk. Both the contractor and the manufacturers have adhered to the Turntoo principle in the realization of the town hall. Thomas Rau says that this is a prerequisite for it to work properly. The building team was complete as early as the tender stage, and the design process was integrated. In addition to quality control, Turntoo results in cost reduction, because individual links in the chain are less able to drive up prices. In a linear development process, the inadequate knowledge of other parties regarding products is sometimes used. In fact, we can only really judge the success of the Turntoo principle in relation to construction once the town hall has been dismantled. It will then become clear whether the parties involved are fulfilling their responsibilities and whether Turntoo is financially attractive in a possible new economic climate. Given the urgency of the raw materials issue, however, we do not have the time to wait, according to Rau: we are already twenty years too late in thinking sustainably. The town hall is a solid step forward.

The Exploded View

Project The Exploded View
Practice Company New Heroes
Location, Year Eindhoven, 2020
Collaborators Dutch Design Foundation
(The Embassy of circular and biobased buildings)

www.theexplodedview.com

Project Description

The Exploded View is ¼ scale model of a particular house. It stands for a radical new look at how a home is realized: pulling apart and dissecting the endless number of applications found in a house and rebuilding them with circular methods and biobased materials. It showcases the endless potential material streams that are available but not yet being used in the construction world: food, textile, sewage or even things from our own living environment. How can we keep the circle as small as possible? Each room in the house has is own material group or circular methods. The kitchen, for example, is made from food waste and the toilet is printed of sewage. In this live research installation we show everything we've discovered as well as what is still missing; we discuss both the qualities and the weak points, inviting everyone to think and act along with us.

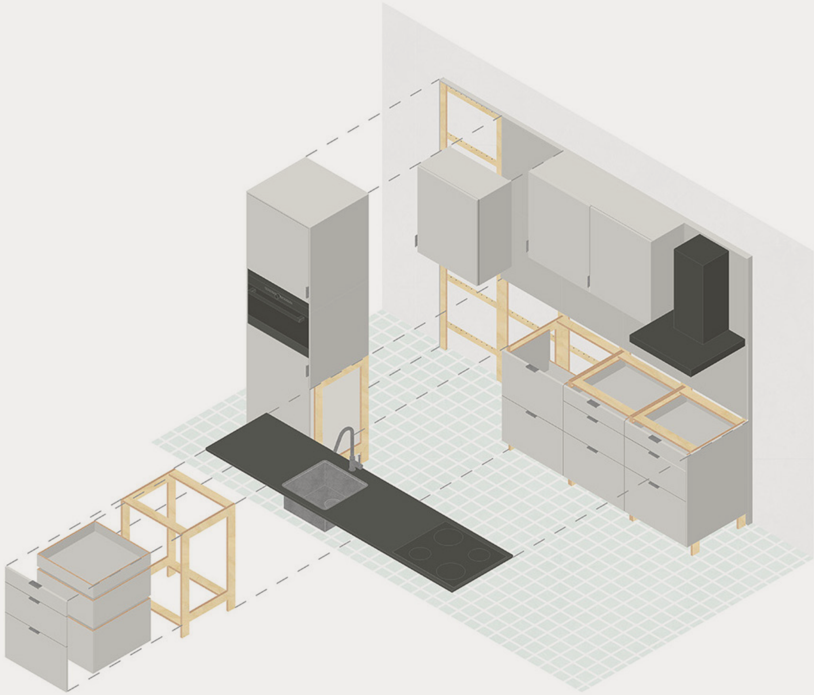
Design Strategy

The best strategy is to make the fact that we can build and live in a biobased and circular house visible and tangible for professional and private clients. And to show what the unique aesthetic and appeal of a sustainable home can be. It is especially important to demonstrate the great diversity of possibilities, which makes it possible to respond flexibly to the local economy and personal wishes of the user. There is not one ideal construction method, but the diversity and flexible use prevents the creation of new (centralized) mono-construction systems.

By linking and displaying all these different material producers/designers, contractors, knowledge partners in the Exploded View project, we show the endless possibilities, but above all there is a cross-pollination between the different participants. As a result knowledge is shared and valuable collaborations arise. Connecting through a project is an essential working method to create a strong chain.

Circularity Strategy and/or Biobased Materiality

I our case is this a collection of 60 different circular methods and materials.



Circular Kitchen

Project The Circular Kitchen (prototype)
Location, Year Amsterdam, 2020
Collaborators Delft University of Technology, Bribus, EIT Climate KIC, AMS Insitute for Advanced Metropolitan Solutions, Eigen Haard, Portaal, Waterweg Wonen, Woonbedrijf, Ymere, Syntrus Achmea, ATAG, Topline, Dirkzwager, Chalmers University of Technology, Vedum, HSB Living Lab

www.tudelft.nl/en/thecircularkitchen

Project Description

Compared with other building components like roofs and façades, kitchens are replaced frequently because their functional lifespan (how long they meet the user's – aesthetic – requirements) and technical lifespan (how long they function as intended) are generally much shorter. On the one hand, the frequent replacement of kitchens leads to waste, carbon emissions and the depletion of resources. On the other, if we could design them in a circular way they could be an ideal pioneer in the transition to a circular built environment, precisely because they are replaced so often. The circular kitchen project aims to do this and the second prototype was recently placed in housing association dwellings to be tested in real-life situations.

Design Strategy

The circular kitchen is developed in co-creation with kitchen supplier Bribus, several clients (mainly housing associations) and academics. The process follows what we call 'action research through design'. Through joint development and testing, the design is continuously refined and, at the same time, several knowledge questions arise during the process, which are addressed through scientific research. In addition to the technical design, we are also working on the supporting business model, addressing the supply chain logistics and contractual arrangements for delivery, maintenance and take back of kitchens and their components.

Circularity Strategy and/or Biobased Materiality

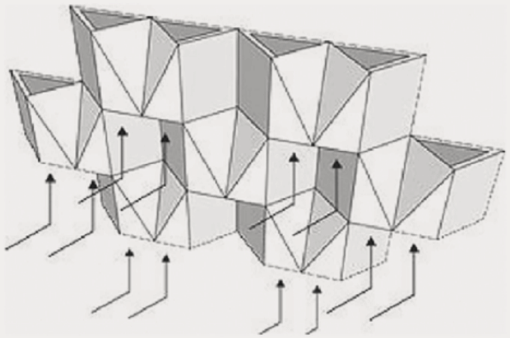
The circular kitchen consists of modules with easily replaceable parts. So, after 20 years, instead of buying a whole new kitchen, you can simply buy or lease a new style package. The functional components only need to be replaced after 40 years and the frame on which everything is installed lasts a lifetime – up to 80 years. The main emphasis is therefore on making a kitchen that enables ‘technical’ re-loops of materials and components. The technical design is optimized by using materials that have a relatively low negative impact on the environment, while having a good functional performance (in terms of, for example, water and heat resistance).

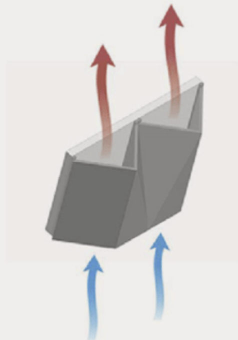
Reflection: Challenges and Opportunities of Circularity and/or Biobased Materials

Two main challenges can be derived from the circular kitchen project so far. First, although the total cost of ownership (TCO) is lower, the initial cost price is higher. This will provide a challenge for marketing the kitchen, in particular for the non-social housing market. Perhaps paradoxically, for Dutch housing associations it is relatively (but still not) easy to prioritize TCO over initial cost price, due to their finance structure. For homeowners and real estate investors, a different financial model might be necessary to make the circular kitchen attractive and affordable. Second, during placement of the prototype we encountered some situation-specific circumstances that were not anticipated in the design. In one case, this led to on-site adjustments that might hamper the future reusability of that kitchen. This stresses the importance of testing prototypes in real life before starting mass production and marketing.

This circular kitchen project was made possible by

eit Climate-KIC





The following text is composed of excerpts from: Pujadas-Gispert, E., Alsailani, M., van Dijk (Koen), K. C. A., Rozema (Annine), A. D. K., ten Hoope (Puck), J. P., Korevaar (Carmen), C. C., & Moonen (Faas), S. P. G. (2020). Design, construction, and thermal performance evaluation of an innovative bio-based ventilated façade. Frontiers of Architectural Research, 9(3), 681–696.

Biobased Facade, LINQ

Project Biobased Facade, LINQ
Team virTUe, University of Technology Eindhoven
Location, Year Dubai & Eindhoven, 2018
Collaborators NPSP (Willem Böttger), University of Technology Eindhoven, Equipment prototype center (EPC TUe), Stam + de Koning

www.teamvirtue.nl/linq
www.sciencedirect.com/science/article/pii/S2095263520300170
www.doi.org/10.1016/j.foar.2020.02.003

LINQ, connected to improve
LINQ is an apartment complex that lets smart technologies complement and strengthen each other, stimulating people to learn from these technologies and creating a social environment in which people interact with each other. On the Solar Decathlon Middle East 2018, Team VIRTUe portrayed this vision by building one of the apartments of LINQ.

LINQ is a small, human scale apartment complex with many shared spaces for its inhabitants and the rest of the neighbourhood. Minimum energy loss is determined by the shape of the building. The roof and south façade are tilted 15 degrees to provide for roofed PV panel efficiency and to create a shadowed south façade in the summer months. All floors of LINQ are connected by the curved green atrium, which serves as a meeting place and vertical garden for the inhabitants. All functions are connected to this atrium.

Temperatures tend to be very high during summertime in Dubai where the climate is generally hot and dry. The passive energy strategies used in the LINQ apartment consists of double-glazed windows with metallic coatings, highly insulated walls (bio-foam), a pale reflective grey colour on the exterior cladding, the south wall is inclined outwards at 15 degrees from the vertical plane to reduce its solar exposure, with the south and west walls as ventilated facades, and a north wall with a green facade. The green façades provide natural cooling and insulation, while improving air quality by removing toxins and other harmful substances, thus generating a positive effect on people's health and well-being.

Ventilated Facade

The concept behind the ventilated facade is that air will freely flow between the plywood backing boards and the exterior cladding and thus extract heat from the buildings surface. The exterior facade will absorb the incident direct solar radiation the heat will then be distributed through convection in the ventilated cavities and air buoyancies will be generated between the plywood boards and the exterior cladding, given the temperature difference, which will push warm air out and draw cooler air in, thereby providing a natural airstream in between the two.

Temperature and the air velocity measurements recorded on the façade in Dubai showed that the façade had contributed to cool temperatures within the apartment, particularly during the hottest hours of the day. The façade is a promising option for climates with hot summers and mild winters as it contributes to reducing energy consumption and the environmental impact of building materials.

Biobased composite tile: Shape

Form finding for the tiles included several parameters most importantly: allowing air to flow behind the panels, easy assembly and disassembly, differentiated design while using a maximum of two moulds, lightweight and durable. In the end two symmetrical tiles that repeated a pattern over the facade were developed. The tile designs were first created through hand-drawn sketches and then modelled with 3D drawing software. The designs were modified following production related feedback from the manufacturer. For instance, the tile corners were curved with smooth surfaces, so that none of the mouldable material could stick to the corners of the mould. Moreover, the tile sizes could not be larger than 30 x 30 x 30 cm. Once the tile designs were prepared for production, a sample was printed on a 3D printer for final verification.

Material

The bio composite material Nabasco® 8010 (created by NPSP) that forms the basis for the facade tile consist of, grass, recycled toilet paper, reclaimed textiles, waste cane, flax, calcium carbonate and a biobased resin.

The calcium carbonate is residual material from the softening process of drinking water and the biobased resin is based on residues from the biodiesel production. The fibre containing materials are shredded so that only the individual fibres remain. Mixed to gather with calcium carbonate and resin, a malleable 'dough' is created. The dough can at this stage take any shape. With this particular mix of materials pressure and heat is required to harden the material and create the familiar tile shape. Though this process only takes a few minutes the specific temperature, pressure, mould shape and time under pressure are very important for the creation of a success full tile.

The Nabasco composite, is tested for fire safety according to EN 13501-1 and it achieved class B-s1,d0. It can therefore be used on a large scale in the construction industry. Maintenance is a very high priority due to the use of the chosen combination of raw materials and the high pressure with which they are pressed.

The development of the bio composite façade panel is a close collaboration between Students from TU Eindhoven, NPSP, Avans Hogeschool and HZ University of Applied Sciences and companies AkzoNobel, KNN Cellulose and NewFoss. The result of the development process is a visually attractive, high-quality and durable facade panel that is strong, retains its shape and has a long lifespan. At the end of its lifespan, the material can be ground up and reused as a basic raw material in the same process, the so-called Circular Economy.

Circular Skin

<u>Project</u> Circular Skin (prototypes)
<u>Location, Year</u> Rotterdam, 2019
<u>Collaborators</u> Delft University of Technology, AMS Institute for Advanced Metropolitan Solutions, Dura Vermeer, Ymere

www.tudelft.nl/en/architecture-and-the-built-environment/research/research-themes/circular-built-environment/projects/rehab
www.tudelft.nl/en/2020/bk/circular-energy-retrofitting
www.duravermeer.nl/nieuws/studenten-hogeschool-testen-ideeen-circulaire-schil

<u>Project Description</u>
The transition to a circular economy in the built environment is one of the major challenges of our time. The aim of a circular economy is to use less material, to use components for longer and to close the loop for materials. Buildings are made up of different components, such as façades, kitchens and bathrooms. By replacing these with circular components during maintenance and renovation, we can make the housing stock circular step by step. In the 'REHAB' project we develop circular building components for housing renovation, including a 'Circular Skin'. Many homes in the Netherlands need to be made more energy efficient. This is often achieved by insulating the façade using a 'second skin', thus requiring additional materials. We aim to connect the energy transition and circularity by developing a Circular Skin.

<u>Design Strategy</u>
The Circular Skin is developed in co-creation with a contractor, suppliers, architects, (circular) experts, clients (housing associations) and academics in workshops and pressure cookers. The pressure cookers were thematic, focusing on topics such as modularity, standard-sizing, circular materials or joints. Next to developing the 'technical design', a supporting supply chain and business model is also explored.

In the collaboration, designing and research are closely intertwined. Through joint development and testing, the design is continuously refined. Simultaneously, the design(ing) provided opportunities to generate knowledge about key questions.

Circularity Strategy and/or Biobased Materiality

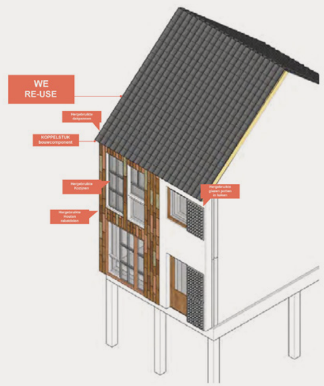
We found that different pathways could be followed to integrate circularity into the Skin. Subsequently, we developed different designs variants, including:

— THE RECLAIM SKIN applying local, reused or recycled materials.
— THE BIO SKIN made with renewable and biodegradable materials.
— THE PRODUCT2PRODUCT SKIN applying high-quality building products, easy to diss- and reassemble, making the products easy to reuse in the future.
— THE PLUG-AND-PLAY SKIN a modular façade, made out of building blocks, making the façade easy to adapt and reuse in the future.

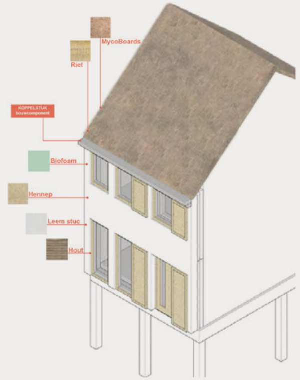
For each design variant prototypes have been realized and tested by the students of the Rotterdam University of Applied Sciences. The tests ranged from evaluating building physical properties, the ease of diss- and reassembly, or mapping the source of secondary materials. Additionally, the environmental performance was assessed by the researchers. The project team chose to combine design principles of different prototypes in the further development of the Circular Skin. By combining principles strategically, resource loops can both be 'narrowed' now, and 'slowed' and 'closed' in the future. The team is currently working towards a first demonstration home.

Reflection: Challenges and Opportunities of Circularity and/or Biobased Materials

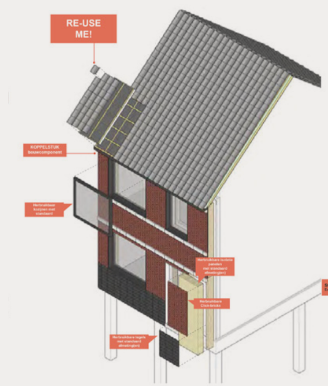
We can facilitate possibilities for future reuse, updates and recycling in the design of circular building components. But to optimally slow and close loops, one needs to look multiple cycles into the future. This means looking beyond the scope of a typical (renovation) project. Therefore, we need to explore different ways of collaborating on the development and realization of components as well as setting up long-term collaborations for future value-retention processes.



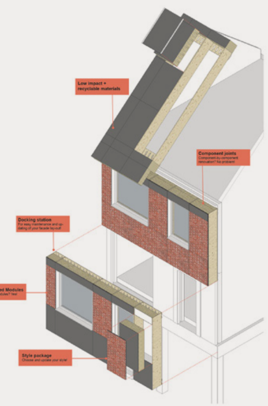
RECLAIM SKIN



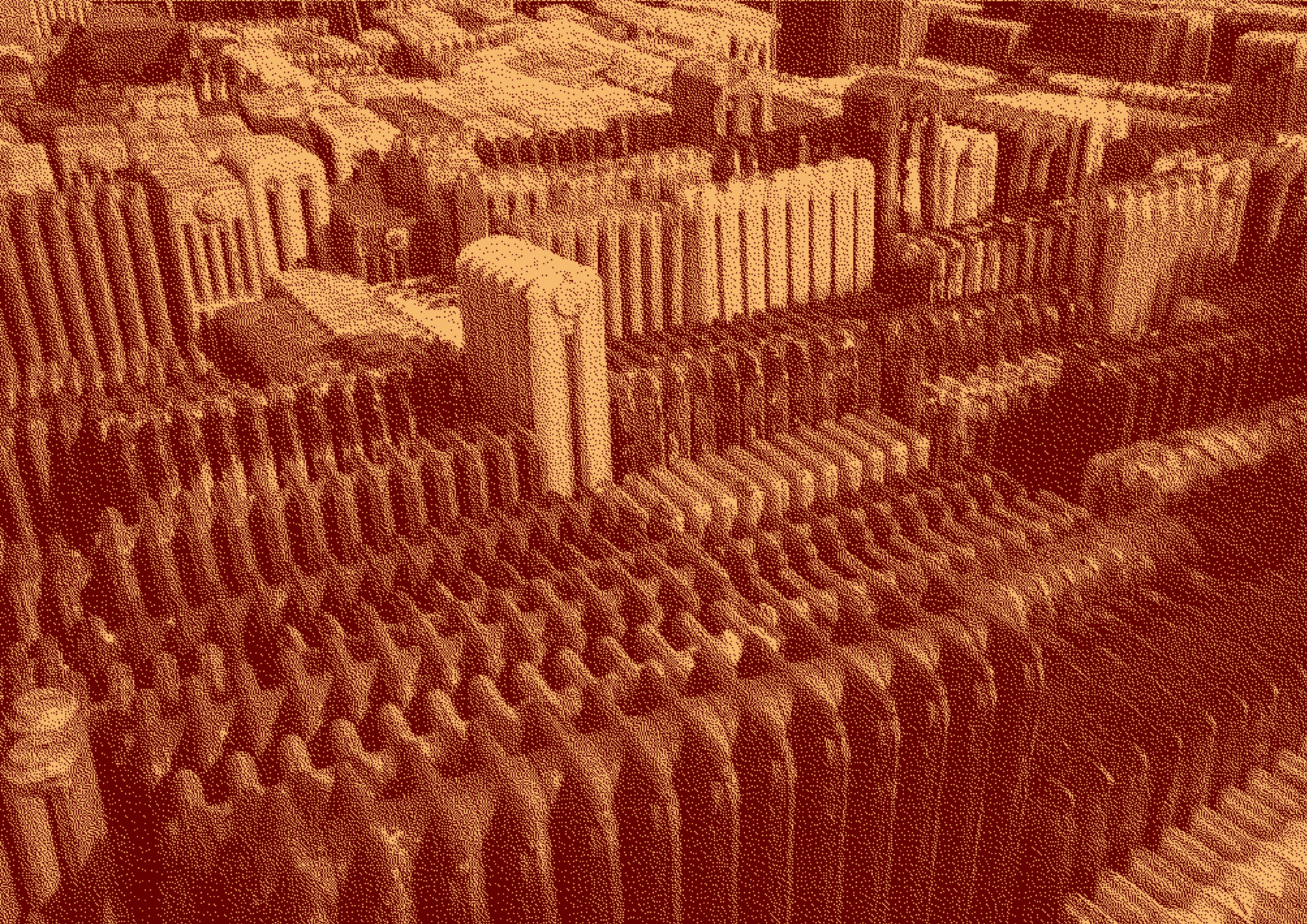
BIO SKIN



PRODUCT 2 PRODUCT SKIN



PLUG AND PLAY SKIN



Biographies

Juliette Bekkering

Juliette Bekkering is a full professor at Eindhoven University of Technology (TU/e), head of the chair of Architectural Design and Engineering. Her focus is on strong innovative architectural concepts and she leads the research and education of the chair, which has sustainability, shifting typologies and emerging technologies as its main themes. She is engaged in ongoing research with GGzEindhoven and 3D concrete printing, as well as in exploring future-oriented urban developments for various stakeholders. She founded the research lab of her chair: ArchiLab. For Design United she is currently directing the research on circularity and biobased buildings. With a strong dedication to excellence in architecture, the natural environment and sustainability, her work has included conducting Summer Schools on the Galapagos Islands, a UN heritage site. She combines her work at the TU/e with her own practice: Juliette Bekkering Architects, with a portfolio ranging from urban designs to public and infrastructural buildings. Currently she is collaborating with Neutelings Riedijk Architects on a range of complex projects. Juliette Bekkering graduated in architecture from Delft University of Technology and finalized a post-graduate degree in urbanism at the Laboratori d'Urbanisme in Barcelona (ETSAB). Previously she was a visiting professor of Architecture at the Czech Technical University in Prague. She is a member of the Supervisory Board of Het Nieuwe Instituut (the Dutch institute of Architecture, Design and Digital Culture) and a member of the Expert Team of the University of Hasselt and the think-tank Het Groene Brein.

Cristina Nan

Cristina Nan is an assistant professor in the Unit of Architectural Design and Engineering (ADE) of the Department of the Built Environment at Eindhoven University of Technology (TU/e). In her research, Cristina focuses on emerging technologies relating to computational design and digital fabrication, such as additive manufacturing, automation, architectural robotics and material experimentation. She studied architecture at the Technical University Munich (Germany) and University of Bath (UK) and received her PhD with honours (magna cum laude) from the HafenCity University in Hamburg (Germany) in 2015. From 2015 to 2020, Cristina Nan was assistant professor of Digital Fabrication and Design at the Edinburgh School of Architecture and Landscape Architecture at the University of Edinburgh (UK). She also held the position of international director of the Edinburgh College of Art at the University of Edinburgh. Cristina is co-founder of FFTT – Future Fields Think Tank, launched in 2019. She was part of the research team that developed the Minibuilders at the Institute of Advanced Architecture of Catalonia in Barcelona (Spain), which was internationally widely published. Her work was exhibited at the National Museum of Scotland, the Festival of Architecture Montpellier 2019, the London Design Fair, ArcInTex Edinburgh and the Concrete Construction Centre part of Futurebuild 2019 at ExCel London.

Torsten Schröder

Torsten Schröder is an architect, researcher and design innovation strategist. Currently he is assistant professor of Sustainability in Architectural Design at Eindhoven University of Technology (TU/e). His research focuses on translating the concepts of sustainability and circularity into architectural and urban design practices in more innovative, meaningful and effective ways through the lens of Science and Technology Studies (STS). Schröder co-founded the ArchiLab, a university-based architectural and urban think-tank dedicated to exploring, creating and developing concepts and scenarios for sustainable futures. Recently he co-initiated the 'Radical Architecture Practice for Sustainability' project (rapsresearch.com) and co-led the knowledge and innovation programme 'Circular Design' for BTIC (btic.nu). He obtained his PhD in the Cities Programme at the London School of Economics and Political Science, winning the RIBA PhD research award in 2015. Torsten Schröder has participated in and led diverse research projects on national and European scale. He has more than ten years of experience in designing and realizing a wide range of architectural projects for leading design practices, among others for Rem Koolhaas / Office for Metropolitan Architecture as architect and project leader on projects in the USA, Germany, South Korea and China.

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