CBCI
Circular Bio-based Construction Industry

Interreg
EUROPEAN UNION
2 Seas Mers Zeeën
European Regional Development Fund

White paper

Five essentials for successful circular bio-based construction initiatives

How real estate professionals, (public) property owners and developers put circular bio-based principles into practice

Colophon

Contributing partners	See page 35
Link with project	White paper 1 of 3
Date	30-9-2020
Status of the document	Final
Language	English (French & Dutch are available)
Annexes	2

Circular Bio-based Construction Industry (CBCI) is an Interreg 2 Seas 2014-2020 project. Interreg 2 Seas is a European Territorial Cooperation programme. This project has received funding from the Interreg 2 Seas programme 2014-2020 co-funded by the European Regional Development Fund under subsidy contract No 2S05-036 CBCI.
Visit our website: www.CBCI.eu

CITATION

When citing from this publication, use the following reference:
Koster, M., Schrotenboer, I., Van der Burgh, F., Dams, B., Jacobs, L., Versele, A. & Verdoodt, S. (2020). White Paper: Five essentials for successful circular bio-based construction initiatives. Circular Bio-based Construction Industry (CBCI).

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COPY & DESIGN

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Acknowledgements

We are very grateful for the organizations and people that let us interview them. Their knowledge and contributions were invaluable to the creation of this White Paper:

Adnams Distribution Center, United Kingdom
Andy Wood (CEO at Adnams PLC)
City Office Venlo, The Netherlands
Bas van de Westerlo (Circular building procurement at C2C Expolab)
Emergis, The Netherlands
René Brugman (Project leader at Emergis),
Carola Helmendach-Nieuwenhuize (Project manager at Impuls Zeeland) &
Taco Tuinhof (Architect & director at Rothuizen)
Enterprise Center UEA, United Kingdom
John French (Professor & project CEO, UEA) &
Iris Anderson (Consultant and ex-civil servant)
Mundo A & Mundo Madou, Belgium
Frédéric Ancion (Director at Ethical Property Europe)
Réhafutur, France
Frederic Laroche (Head of the Sustainable Building division at
Centre de Développement des Eco-Entreprises (CD2E)) &
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Science Museum Group, United Kingdom
Marta Leskard (Care and Collections Manager, Science Museum)
Streekhuis Dijleland, Belgium
Willy Verbeke (Project manager at Natuurinvest) &
Wim Aertsen (Project manager at Regionaal Landschap Dijleland)
SVGG Eindhoven, The Netherlands
Joyce Vercoelen (Projectmanager at Gemeente Eindhoven (SVGG)) &
Jeroen van de Water (Brink)
The Greenhouse, The Netherlands
Rogier Joosten (Circular developer at Studio R)
Tijdelijke Rechtbank, The Netherlands
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Triodos Office, The Netherlands
Sander Kok (Project leader buildings at JP van Eesteren)
Wiegelied, Belgium
Cindy Debeen (Administrative Expert, dept. KJOS, Stad Oostende) &
Sarah Colpaert (Administrative Expert, dept. childcare) &
Maarten van der Linden (Architect, Bast architects & engineers)

We want to thank the contributing observer partners Izhar van Eenennaam (Jeras), Barbara Govaert (Stad Gent) and Mieke Vandenbroucke (VIBE) for their feedback on the White Paper while it was still work in progress.

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How real estate professionals, (public) property owners and developers put circular bio-based principles into practice

Introduction

The circular economy is increasingly becoming part of our lives. Reuse and recycling of materials is gaining popularity in many sectors including the construction sector, who is currently responsible for about a third of waste volumes in Europe[1]. The shift towards circularity is driven by intrinsic motivation as well as by increased emphasis on material and energy efficiency on European, national and local levels. In this White Paper you will read about the experience of thirteen organizations from the United Kingdom, Belgium, The Netherlands and France who are already proud owners and users of circular bio-based constructions.

In contrast to conventional construction, a circular construction does not follow a linear path of make, use and demolish. Instead, elements, products and materials are meant to remain cycling instead of becoming waste. In the construction sector circularity means continuous reuse of non-renewable resources such as metals, sand and stones, and of renewable materials, like wood and crop-based insulation. Yet, how to put this into practice within construction projects? We noticed that leaders and other people involved in construction initiatives, still have many questions and doubts such as: What are common challenges and how to face them? What are the keys to success? How to select the right parties to collaborate with? How to make and keep constructions affordable as well as functional?

This white paper is of interest for those involved in the initiation phase of construction projects before the actual production and construction begins. The five essentials and exemplary projects are of interest for those in search of guidance as well inspiration. We particularly aim at real-estate professionals, (public) property owners as well as developers who recently did or soon will embark on a circular construction project, including renovations as well as building extensions. Even though other players in the construction sector, such as architects and constructors, are not the main audience, for them this white paper could still be worth reading.

1 Kozlovská, M., & Spišáková, M. (2013). Construction waste generation across construction project life-cycle. Organization, technology & management in construction: an international journal, 5(1), 687-695.

This document came about as follows. Firstly, desk research was done on topics of funding mechanisms, cooperation models and stakeholder needs. Subsequently, interviews were held with the initiators and key-partners of thirteen exemplary circular construction projects, referred to as case studies and cases. Eight of these cases were selected for their unique characteristics such as a combination of circularity and application of bio-based materials. They were analyzed in further detail (see Annex A). The paper will refer to certain insight using numbers, i.e. 1.2. Please check Annex A for an overview of the insights these numbers refer to. We hope the practical insights of the interviewees will inspire you (20.7); just like the interviewees were inspired by others by watching movies, visiting projects or attending topical lectures (1.2).

We start out by briefly sketching the main general challenges of circular bio-based construction at the moment of writing. Next, each of the following essentials, extracted from interviews, has a dedicated chapter:

1. **Affordable** cost-effective & inclusive reuse
2. **Flexible** prepare for future functions
3. **Passive** stay cool & healthy with bio-based materials
4. **Integral** continuously reflect on circular bio-based benefits
5. **Traditional Ownership** keep it, simple

CBCI Project: Learning while doing

Without claiming to be complete, we share our learnings from the interviews and literature study. Rather than theorizing, our main endeavour is to provide practical insights and readily applicable solutions. The Circular Bio-based Construction Industry project is structured in a way that allows for continuous learning. We will put the gathered insights into practice during the realization of three construction projects that are living labs within this applied research project.

This is the first publication in the context of the CBCI project and will be followed by (white) papers on procurement, rules and regulations as well as technical feasibility of bio-based and circular materials. If you like to receive updates from CBCI you can sign up here.

Challenges of circular bio-based construction

In this section we take you through the main challenges for circularity. Moreover, we reflect on the position of bio-based materials in the framework of circularity of the European Environmental Agency, shown in the table (1) below. This framework neatly summarizes the main challenges for circularity in the construction and demolition industry[2].

In the interviews we found that challenges, specific for the construction industry, are; small profit margins in combination with business interest of past production facility investments. Low margin and past investments hold back innovation and contribute to risk aversity (30.3). Another challenge is that cost minimizing requirements typically dominate the decision-making process of construction projects. They regularly overrule environmental ambitions (3.2).

What?	Why?	Potential
Price competition with virgin alternatives	Stakeholders tend to favour cheaper and credible solutions, and virgin ([a]) minerals are in many cases cheaper than secondary materials due to the latter's processing costs	A competitive secondary materials market would create demand for both quantity and quality of waste material, thus directly increasing circularity
Confidence in quality and structural properties of secondary materials (traceability)	Stakeholders tend to choose virgin materials that are quality assured through warranties and standards	Engaging in the development of standards for secondary raw materials would increase the trust in their properties and quality
Hazardous substances content	Polluted materials are not suitable for recycling, and removal of the hazardous content is costly	Develop technology for efficient removal of hazardous substances and eliminate use of hazardous materials in new construction
Lack of sufficient and reliable data on (historical) buildings	The composition of material streams from demolition activities cannot always be predicted	Pre-demolition audits and, in the future, materials passports help register the type and volume of materials in the existing building stock
Time delay	The time delay between implementing a circular action and its benefits due to the long life spans of buildings may discourage stakeholders	Not applicable
([a]) Virgin materials are raw materials that originate from nature as opposed to secondary materials originating from waste processing.		

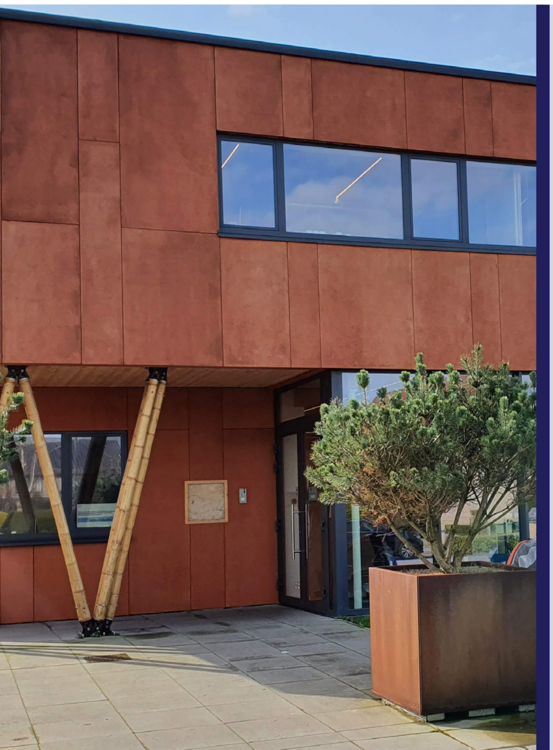
Table 1: Circular adoption challenges identified by the European Environmental Agency[2]

2 European Environment Agency. (2020). Construction and demolition waste: challenges and opportunities in a circular economy. https://www.eea.europa.eu/publications/construction-and-demolition-waste-challenges.

Bio-based construction placed in the framework

Bio-bases materials have multiple roles in the future of construction. Being part of the technical as well as the biological cycle, bio-based resources take a special position within circularity. They may be reused and recycled in a technical way, yet bio-based materials can also return to the biological cycle by composting, and, if in the right composition and conditions, degrade and become a source for nature again. Bio-based materials also take a special position because of their potential ofreduction of CO_2 emissions. For example, when applied in construction projects, bio-based materials store their embedded CO_2 for relatively long timescales.

Despite this special position bio-based materials are not included in the table of challenges composed by the European Environmental Agency. We, however, think that bio-based materials can play a pivotal role in the transition towards circular construction. Moreover, in the interviews conducted for this white paper, we found strong indications that the challenges of bio-based materials are fairly similar to the challenges for circularity in general.



Wiegelied

Oostende, Belgium

Initiator: Wiegelied
Main function: Childcare center
Architect: Bast Architects & Engineers (Gent)
Main contractor: Furnibo (Veurne) with PUUR Bouwen (Baaigem)
Year of completion: 2018
Unique: Working with bio-based materials was new to the team and many challenges were resolved within a tight budget.

“It was mainly financial technical matters, without losing sight of the purpose of an ecological building. In terms of budget and planning, the project was rather tight… we had to take a number of decisions up front. For example, we came up with an integrated solution for the plinth, which allowed the main contractor to use prefab elements. We have completely changed the starting point for the roof composition, for example we have optimized supporting beams in function of load capacity and cost”.
● **Maarten van der Linden, Architect at BAST architects & engineers**

Essentials put into practice in this case: Affordable Reuse | Flexible | Passive | Integral | Traditional Ownership

With bio-based as well as circular materials, there are challenges related to price competitiveness relative to virgin materials. There are also challenges related to confidence in quality. In the example of Wiegelied we show how combining functionality helped staying within budget using bio-based materials. Currently, costs and quality-related challenges mainly stem from lack of production scale, especially for new bio-based products.

As an example, for the UK cases we identified that bio-based construction seemed to become more difficult to realize over the last years due to a decreasing number of suppliers present in this market (30.7). This is different from when the UK cases, presented later on in this White Paper, were realized.

‘Currently, costs and quality-related challenges mainly stem from lack of production scale’

Interviewees shared in several cases that initiators, users and legislators indicated concerns related to bio-based materials. However, after they did research, the challenges related to the construction quality, fire safety, allergies and insect risks of bio-based materials were overcome or appeared irrelevant on closer inspection (10.1). This indicates that for circularity to take up, the attitude towards bio-based and reuse is relevant, as is the willingness of the construction team to do research.

'For newly created circular and bio-based materials it is often difficult to get certified'

For newly created circular and bio-based materials it is often difficult to get certified. It is hard to prove the quality of the material, especially if it cannot be implemented in practice and at scale without this proof.

In those cases where testing and certifying is possible, it can still be relatively expensive. Because reused materials(circular) are certified on a case by case basis, it is more costly compared to virgin materials. Also, for bio-based materials we saw that standards/norms differ or are not available compared to their conventional equivalents.

The above makes clear there are several challenges for construction projects that aim to apply reused and bio-based materials. These challenges come on top of all other challenges that tend to characterise construction projects. We aim to contribute to the success of future circular and bio-based construction projects with practical insights and readily applicable solutions in the essentials that follow.

1 AFFORDABLE

cost-effective & inclusive reuse

When focussing on technical reuse, recurring questions during the initiative phase of a construction project include: How to incorporate what is already out there? What (construction) elements, products and materials are available for a second life in our construction? Yet, when considering reuse, one may face the challenge of doing this in an affordable way. How can this be tackled? Inthis first essential you will learn more.

Elements, products and materials may be present on your own premises, for example in a construction that needs to be replaced or a construction elsewhere that needs to be dismantled. Such constructions may then serve as a so-called donor building that can be saved from being demolished. In addition, there are resellers and platforms active that reclaim and refurbish construction materials and products. Here larger quantities as well as good quality materials are available. As such, they facilitate circularity in the construction sector. See for example the platform websites opalis.eu (France), salvoweb.com (UK), insert.nl (NL) and oogstkaart.nl (NL).

Through reuse, redistribution and refurbishment, the demand for virgin materials decreases. Moreover, if don in an energy efficient manner, the environmental impact of a construction with reused materials is generally lower compared to all-new/virgin materials. However, because the current stock of constructions is mostly not restorative by design, reuse can be very time, energy and labour intensive, resulting in higher costs of reuse.

Still, we recommend not to push the idea of reuse, redistribution and refurbishment aside too soon, despite pressure of tight budgets and fixed deadlines in construction projects. During interviews we were shown that there are ways to make reuse affordable. The Emergis case in the Netherlands provides an inspiring example.

Emergis Clinic

Kloetinge, The Netherlands

Initiator: Emergis
Main function: Mental health facility
Architect: Rothuizen Architecten (Middelburg)
Main contractor: Bouwmeester Pro (Middelburg)
Year of completion: 2019
Unique: Flexible building built with materials, including bio-based materials, harvested from a donor building. This was a former office of Rijkswaterstaat. Logistics and refurbishment were done by social labour at De Ambachten (also from Emergis).

"Finding a new destination cannot be done easily for the services/installations. Here we ask installers to apply it immediately and keep track of what they reused. We didn't make a good estimation at the start [of the project]. Luminaires are almost never reusable. Emergency exit signs and cable ducts are. Wiring again isn't and neither are switch boxes. Many air treatment pipes are easily recyclable as well, so it doesn't make sense to reuse it since the [needed] sizes are different."
● **Taco Tuinhof, Architect at Rothuizen**

Essentials put into practice in this case | **Affordable Reuse** | Flexible | Passive | Integral | Traditional Ownership

Indeed, in the set of cases analysed for this paper, the most frequently recurring priority and selection criterium is price related to the budget. This is reflected by fixed budgets and other cost constraints. This priority was followed by time, i.e. fixed deadlines. Interestingly, in the cases of Emergis, Réhafutur and Wiegelied, the exact allocation of the budget cost items was kept flexible during the project. They reasoned as follows: With reuse, just as in demolition, it is hard to predict the material quality at the outset and hence, how and to what extent it could be applied. Therefore, the potential of reuse was repeatedly considered at every phase of the construction process by the architect as well as the (sub) contractors. The flexible budget (cost items) approach seemed to be helpful in optimizing material reuse throughout the project.

> *'The most frequently recurring priority and selection criterium is price related to the budget'*

There are limits to reuse though. For heating, ventilation, and air conditioning (HVAC) and other installations such as water, affordable reuse seems to be more challenging (also see essential 4). In the Emergis project, the contractor initially budgeted for a larger portion of reused installations (HVAC) than could eventually be realized, because affordable reuse appeared to be too complicated here.

The problem of labour intensity and costliness of making use of a donor building for reusable materials, was tackled as follows in the case of the Emergis Clinic. In particular, the reuse of timber (small tiles) appeared time consuming and hence costly. Therefore, a (internal) social labour organization was approached to help. Compared to conventional labour, costs of this form of labour are lower. The choice of engaging this social labour organization also had non-financial benefits. The people of this organization, put to work on the construction project, really enjoyed it, even more so because they knew they contributed to an important facility for the region. In addition to labour, this organization also provided storage space needed after demolishing/disassembly and during the building phase. Supervision and management of social labour requires special skills, as well as a different take on planning pressures. Overall, the collaboration contributed to more inclusive and enjoyable work for people (previously) distanced from the labour market. This case shows that circular construction provides an opportunity to let reuse and inclusive labour go hand in hand.

'Circular construction provides an opportunity to let reuse and inclusive labour go hand in hand'

The example above shows that some flexibility is needed to integrate reused materials in a construction, particularly as long as reuse is not industrialized.

A learning by doing approach was necessary to deal with reused materials and unknown/unpredictable aspects of the quality in some of the observed cases (20.6). For successful construction with this approach, it is important that the selected building partners reflect this mindset.

Finally, we want to address labour required for reuse of your new construction at the end of its lifetime. In order to make reuse of elements, products and materials affordable at a future moment in time, it is wise to anticipate it and seek for solutions that are not labour intensive. This aspect is addressed in the list of practical considerations below and further elaborated in essential 2 (prepare for future functions) and essential 4 (continuously reflect on circular bio-based benefits).

Tijdelijke Rechtbank

Amsterdam, The Netherlands

Initiator: Rijksvastgoedbedrijf, Den Haag, public
Main function: Courthouse
Architect: Architectenbureau cepezed, Delft
Main contractor: Cepezedprojects & Du Prie Bouw en Ontwikkeling
Year of completion: 2016
Unique: Courthouse built to be removed after 4-6 years, 'Kit of Parts', Design, Build, Maintain & Remove (DBMR) contract.

"The problem is that standard units do not fit the specific functions of the court. Only 10-15 of the 60 units could be standard. Other units required special glass, stronger insulation or had a very specific function, such as public stands and cell blocks. Building systems often fail on such unique conditions. This made the other [industrial prefab] suppliers more expensive."

Menno Rubbens, director of project developer cepezedprojects

Essentials put into practice in this case | Affordable Reuse | Flexible | Passive | Integral | Traditional Ownership

Practical considerations

To make reuse, redistribution and refurbishment affordable, the following practical considerations can help you to take preparatory actions for decision making with your team and for actual reuse. Though listed here in order, in practice this is an iterative process since many actions are interrelated.

Reuse at your own premises

- Refuse to demolish/deconstruct (parts of) an existing construction. Prefer renovation over newly build if viable.
- Make an inventory of elements, products and materials with reuse potential. There are parties in the market that can do this inventory for you.
- Assess the residual value of elements, products and materials with reuse potential.
- Asses labour needs for parts with reuse potential, redistribution and refurbishment as well as logistical- and storage costs.
- Consider sourcing inclusive labour.
- Assess or request quotes at demolishers to determine the residual value/costs of materials that can only be recycled.
- Select (internal) parties for which the materials are most valuable (initiator, producer, contractor, demolisher, etc.) and sell or give it to them in order to maximize reuse value or lower costs.
- Detach (or cut loose) reusable parts, describe dimensions, quantities, weight etc. and do not forget to label and digitize unique items with location or relative constraints.
- Offer unused/remaining elements, products and materials to parties that can create affordable materials for others or to resellers in 2nd hand market. Prefer reuse above down/recycling.

Design with reused materials & construction elements

- Investigate how to incorporate elements, products and materials identified above in the design, taking into account the logistics in the planning.
- Source reclaimed and refurbished elements, products and materials from donor buildings or through second-hand material marketplaces in your region or country.
- Explore sourcing inclusive labour for the labour associated with redistribution and refurbishment of elements, products and materials from donor buildings and or market places.
- Source from refurbishers, for example if you are limited by the available quantities or logistics.
- Consider (local) sources of bio-based leftovers that can be tapped into for insulation or composites.

Design for affordable future reusability

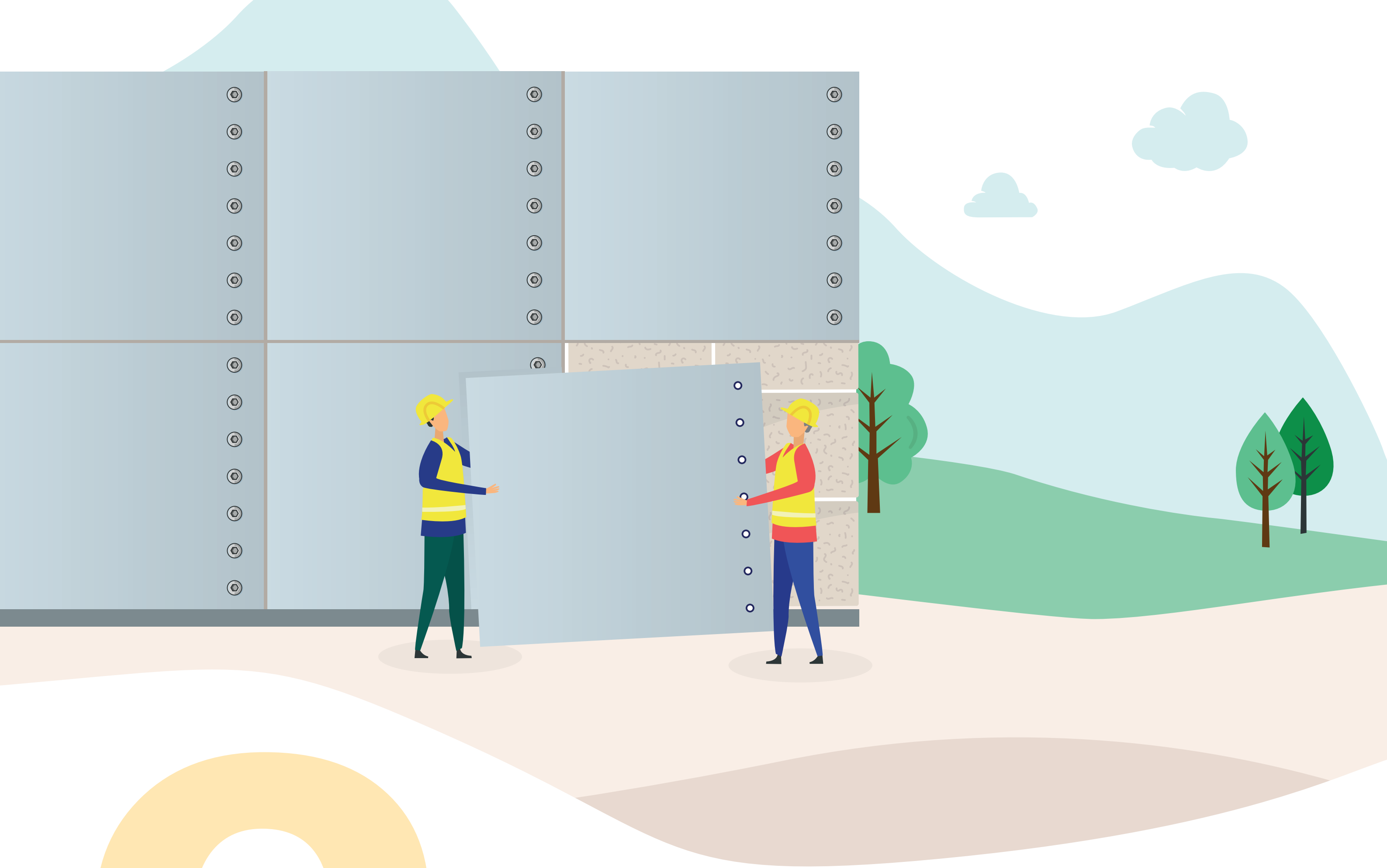
- Include prefab/standardized elements for cost reduction, consistent build quality, maintenance and demountability (20.1). This aspect was mentioned in over half of the interviews as promising.
- Decrease future deconstruction and material costs by designing demountable structures with non-toxic and pure materials (Cradle 2 Cradle is often used to define these materials).
- Use digital construction tools (BIM) to ease future reuse and maintenance during the lifetime.

Let's conclude this first essential, by answering the question: Why walk this extra mile? In Europe the construction sector is responsible for up to 33% of total waste streams. On average only half of this volume is recycled, the rest is put into landfills or incinerated[3]. Next to the visible materials, embedded energy as well as labour is wasted.

With 40% being recycled, the UK deconstruction waste has a recycling percentage close to the EU average. The other countries in the 2-Seas area; Belgium, The Netherlands (+-60%) and France (+-70%) do better[3]. In Belgium, which has the highest recycling rate of the three, 90% of the recycled construction waste is used as subbase and base layers in road construction, which means the materials are downcycled[4]. This shows us that there is much room for improvement when it comes to circular reuse of materials.

Circularity could reduce overall virgin material use by 50%, reduce energy consumption by approximately 40% and reduce CO_2 emissions by 35%[5]. Research shows that the predicted number of residential construction projects, in the Dutch context, will outnumber demolition projects by a factor of two in 2030. For non-residential construction projects, the number of newly built projects outnumbers demolitions with a factor of nearly three[6]. While the Netherlands has ambitions to be 50% circular by 2030 and 100% by 2050, our findings indicate that there is a gap of over 66-75% that cannot be closed with circular materials. Application of bio-based materials as renewable source in constructions has the potential of playing a key role to close this gap and meet the circular ambitions.

3 Kozlovská, M., & Spišáková, M. (2013). Construction waste generation across construction project life-cycle. Organization, technology & management in construction: an international journal, 5(1), 687-695.
4 Vyncke, J., & Vrijders, J. (2010). Recycling of C&D waste in Belgium: State-of-the-art and opportunities for technology transfer. In Second International Conference on Sustainable Construction Materials and Technologies, Universita Politecnica delle Marche. Ancona, Italy (p. 11).
5 Herczeg, M., McKinnon, D., Milios, L., Bakas, I., Klaassens, E., Svatikova, K., & Widerberg, O. (2014). Resource Efficiency in the Building Sector Final Report. Client: DG Environment.
6 Arnoldussen, J. (EIB), Roemers, G. (Metabolic), Errami, S. (EIB), Blok, M. (Metabolic), Semenov, R. (EIB) Kamps, M. (Metabolic), Faes, K. (SGS Search). (2020). Materiaalstromen, milieu-impact en energieverbruik in de woning- en utiliteitsbouw, Stichting Economisch Instituut voor de Bouw en Metabolic, januari 2020.



2 FLEXIBLE

prepare for future functions

Construction projects often stem from specific requirements that were relevant at the time of development. Yet needs may – and likely will – change over time, and so will the function of a construction during its lifespan. To minimise waste and demand for new materials when functions change, we argue that successful implementation of circular construction requires circularity and function change/adaptability by design. This is what the second essential is about.

Changes in functions and users may require modifications of the buildings' interior, exterior or perhaps even relocation of the construction. In the Netherlands, people move on average once every 10 years[7], while organisations move about once every 25 years, which is 4% of organisations per year[8]. To follow up on this changing demand over the lifespan of a building, flexible design with so-called separate building layers facilitates adaptations and replacements of elements. This makes changes and also renovation easier, reduces the impact upon the existing building and increases the total lifespan.

7 CBS. (2018). https://www.cbs.nl/nl-nl/nieuws/2019/09/minder-verhuizingen-in-2018.
8 Van Oort, F., Ponds, R., Vliet, J. V., Amsterdam, H. V., Declerck, S., Knoben, J., ... & Weltevreden, J. (2008). Verhuizingen van bedrijven en groei van werkgelegenheid.

Thinking in terms of future scenarios helps to prepare for building changes that are likely and/or impactful and help you to develop a concept that can change functions with minimal waste of materials, resources and energy in the future. Keeping flexibility and adaptability in mind will also contribute to future cost savings and unnecessary needs for new materials. To benefit from circular/adaptable design it is important to administer the design, and changes throughout the construction's lifetime properly. This can be done using a BIM model or by other digital means.

Keeping layers separate & demountable

In many of the interviews, the separation of building layers (see figure 1), was an important aspect of the design (20.4). Several reasons for this were given. Firstly, separation of layers allows the building to be disassembled more easily compared to integrated layers. Secondly, because lifespans of layers differ (see figure 1), independent refurbishment and maintenance per layer help to keep the construction relevant for a longer period. For example, if you decide to integrate the services layer of a building, which has a lifetime of approximately 30 years, and the structural layer, which has a lifetime of 100 years, the effective lifetime of both layers can become that of the layer with the shortest lifetime, in this case 30 years.

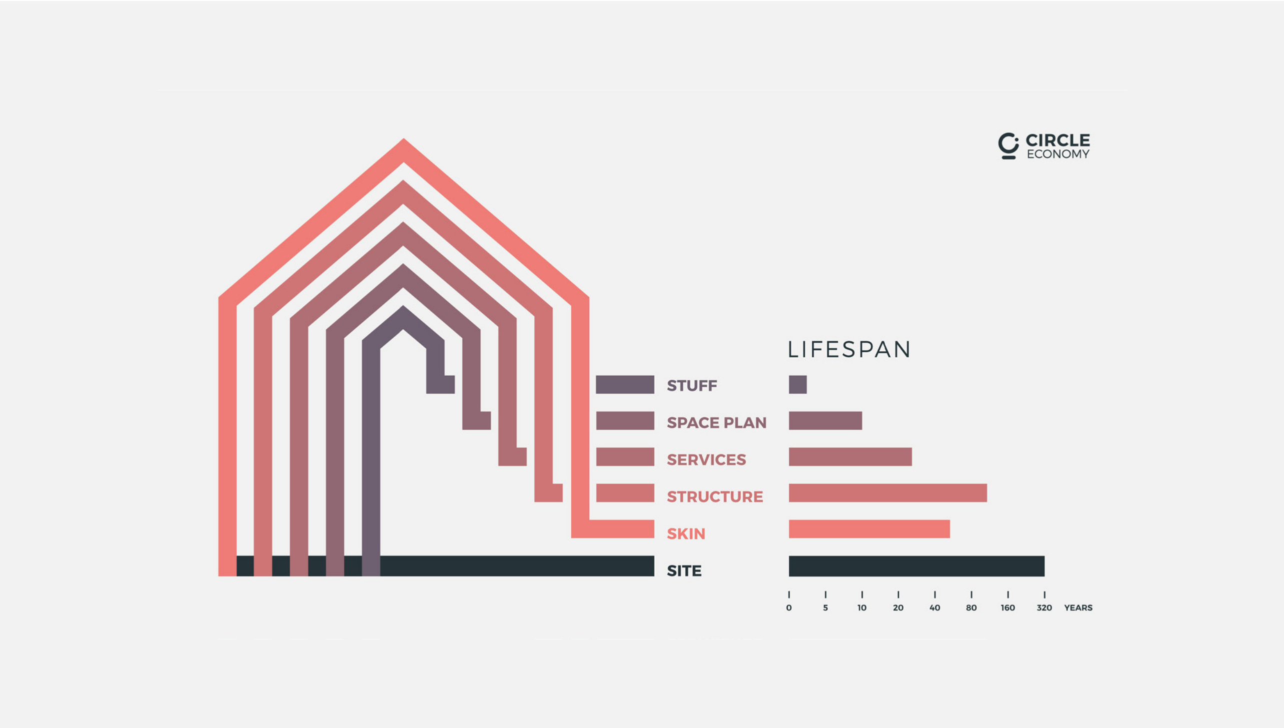


Figure 1: Six Building Layers, based on work of Stewart Brand[9]

9 Brand, S. (1995). How buildings learn: What happens after they're built. Penguin.

Science Museum Group

Wroughton, Wiltshire, United Kingdom

Main function: Archival storage space
Architect: Emission Zero Engineering Architecture Ltd.
Main contractor: Lime Technology (Abingdon) and Hempcrete Projects (Chesterfield)
Year of completion: 2012
Unique: With hemp-lime very stable levels of relative humidity are achieved, important to ensure the preservation of significant heritage collections. The material properties are effective at reducing energy usage and decrease reliance on heating services.

"With reusing it in mind, it is modular so it could be disassembled. The hempcrete panels are just hung on to the steel frame with bolts, nothing is plastered in place or anything like that, you could remove them. There is a rat mesh on the wood fiber board, because everybody was very concerned that rats would chew the hempcrete, despite the fact that it's supposed to be pest-proof! But you could take that off and you could take the wood fiber board off, it's just cladding. So you could disassemble that building and reuse it elsewhere."

Marta Leskard, Care and Collections Manager at Science Museum at Wroughton

Essentials put into practice in this case	Affordable Reuse	Flexible	Passive	Integral	Traditional Ownership

Demountability does not only apply to building layers, but also materials, products, components or spaces. This means the layers and sub structures can be disassembled/ separated whenever the need arises during the use phase, as well as at the end of their respective lifetimes. Observed practical ways to achieve this include; connecting materials with screws, dowels, hooks, click connections and bolts instead of glue and nails. Moreover, the reusable hempcrete panels of the Science Museum (see box) show that circularity and application of bio-based materials can go hand in hand.

Flexible capacity

What to prepare for? In half of the analysed cases designs took into account; different developed scenario's, future use-options, future capacity changes or upcoming changes in policies. For the Adnams brewery, for example, floor plans and entries were designed in such a way that they allow to double the building capacity if the company grows. If so, the design will be re-used for the construction of an extension, which will then be connected to existing building via an already present door.

'For projects with long realization periods it seems even more relevant to create a load-bearing foundation ready for future growth. '

Anticipating future changes in functions and capacity requires special attention to the foundation and load bearing structure. It is important to create these in a way that they can support different loads, functions and related technical requirements over time, possibly about 100 years. This aspect of adaptability creates a longer effective use potential and therefor a higher value of the building. For projects with long realization periods (such as infrastructure projects) it seems even more relevant to create a load-bearing foundation ready for future growth. The reason is that it is likely that estimations concerning usage/ capacity already changes during the construction phase.

Flexible usage / functionality

The space plan (see figure 1) or floorplan, is also an important building layer to consider when designing a future proof circular construction. The Emergis clinic is an interesting example in that regard. At Emergis, they developed scenarios of how their environment might change in terms of demand for mental health care, for example in number of clients or in rules and regulations regarding health care, and tried to envision how that would impact their building design. Subsequently, several floorplan options were developed that can be realized with a single unit. At Emergis, they created isolated units, connected by doors to facilitate different types of care to be given in the departments over time. These units can also be so that the space per room is enlarged, which could be useful for certain forms of healthcare. Next to this, by design, the units can easily be converted from consultation rooms to small private apartments for long-stay care, if need be. The units were designed and constructed in such a way that changes do not require major construction works. This means, on top of adhering to circular principles, that clients and staff will experience only limited inconvenience during the actual adaptions.

'Flexibility by design is also desired to anticipate changes in rules and regulations.'

Flexible for changing rules and regulations

Flexibility by design is also desired to anticipate changes in rules and regulations. In the Dutch healthcare sector, for example, regulations change quite often. With their flexible and convertible units, Emergis anticipated this in the design of their circular clinic. Emphasis lies on demountability and re-arrangement, created by smart choices of connectors and of dimensions of elements.

Potential changes in rules and regulations can also be taken into account in the detailing of a design. In the Tijdelijke Rechtbank, they anticipated on window glass upgrades, which could be required when the building is scheduled to be moved in a few years from now. Extra room in the window frames was intentionally made for glass that requires more space, such as triple glazing and potentially also glass with integrated solar panels (3.4).

Final remarks on flexibility

In addition to envisioning what might change, it is helpful to estimate how often those changes might occur. This will help you to set specific criteria, for example in terms of time and number of people required for changing a unit from one function to another. Will it be every quarter or just once in ten or fifteen years? In the latter case you will probably accept more time for function change than in the former. It is a matter of finding a circular solution with a suitable balance of flexibility, time and costs. Most importantly it is worthwhile to spend time reflecting on flexibility before you start building (also see essential 4).

PASSIVE

stay cool & healthy with bio-based materials

The third essential is about what a building can do for you in terms of staying cool, warm and healthy. From the cases, we learned that making a building passive by using bio-based materials is recommendable, not only to reduce the building's ecological footprint and the contribution to an organizations' decarbonization ambitions, but also because it has the potential of creating health benefits and delivering operational cost savings.

With regard to a building's ecological footprint and CO_2 emission, the selection of heating, cooling and ventilation services (HVAC) form an important part. These services provide thermal comfort and make the indoor air quality acceptable. Yet, these benefits can also be achieved with application of bio-based materials. The properties of bio-based materials to regulate the internal environment can be put to good use. In so-called passive buildings, installations are kept to a minimum, and energy is saved throughout the entire use phase. If done well, the additional investment (if any) to make a building passive, can be earned back (also see essential 4). In this chapter we take passivity broader than the common reference to energy usage. For us, passivity is all the benefits materials offer without active, energy consuming elements such as climate services.

A stable indoor environment with minimal fluctuation helps maintain the thermal comfort of the building's users. The natural properties of bio-based materials can provide internal environmental stability, with reduced fluctuations in temperature and relative humidity - a characteristic conventionally associated with thermally massive buildings such as stone or concrete[10]. Hygroscopic bio-based building materials passively regulate internal air humidity due to their ability to adsorb and desorb moisture, a property known as 'moisture buffering'[11]. This can improve internal environments in the following ways:

- **Thermal comfort and stability;** moisture buffering promotes the comfort of building users by minimising internal temperature change due to ventilation and infiltration. This reduces the demand for heating or cooling systems (HVAC) to regulate internal temperature, thus reducing energy consumption in buildings[12].
- **A reduced need for energy consumption in winter heating** due to the material generating latent heat the energy use in winters is reduced[13].
- **Lowering internal relative humidity levels in summer**[14].

Adnams Brewery

Reydon, Suffolk, United Kingdom

Initiator: Adnams Southwold
Main function: Brewery Distribution centre
Architect: Aukett Fitzroy Robinson (London)
Main contractor: Haymills (London)
Year of completion: 2006
Unique: Hempcrete building blocks made with locally sourced hemp (hempcrete) which provides a cooling advantage for the distribution center. The largest green roof in the UK, by the time of building.

"[when we first brought the temperature] down to 13°C, we closed everything, and we have been successful in maintaining an ambient temperature of between 13°C – 16°C since that day. When it starts to warm up too much, we chill the beer coming out of the brewery more extensively, so we'll take that down another one, or one and a half degrees, and that acts just as though you'd put a block of ice in a cool bag. It acts to cool the whole warehouse. That's a technique that we have discovered since we've been operating the building. It absolutely is performing as we hoped it would perform."

● **Andy Wood, CEO at Adnams plc.**

Essentials put into practice in this case | Affordable Reuse | Flexible | Passive | Integral | Traditional Ownership

10 Shea, A., Lawrence, M., & Walker, P. (2012). Hygrothermal performance of an experimental hemp–lime building. Construction and Building Materials, 36, 270-275.
11 Cascione, V., Maskell, D., Shea, A., & Walker, P. (2019). A review of moisture buffering capacity: From laboratory testing to full-scale measurement. Construction and Building Materials, 200, 333-343.
12 Zhang, M., Qin, M., Rode, C., & Chen, Z. (2017). Moisture buffering phenomenon and its impact on building energy consumption. Applied Thermal Engineering, 124, 337-345.
13 Kraniotis, D., Nore, K., Brückner, C., & Nyrud, A. Q. (2016). Thermography measurements and latent heat documentation of Norwegian spruce (Picea abies) exposed to dynamic indoor climate. Journal of Wood Science, 62(2), 203-209.
14 Osanyintola, O. F., & Simonson, C. J. (2006). Moisture buffering capacity of hygroscopic building materials: Experimental facilities and energy impact. Energy and Buildings, 38(10), 1270-1282.

Energy benefits

In the majority of the explored cases, the advantages of bio-based materials used in their projects were studied in the design phase (1.1). The Adnams Brewery is a prime example of energy related savings achieved by implementation of bio-based materials. For the brewery, hemp-lime insulation was used. This (largely) bio-based insulation material has good thermal as well as hygroscopic properties. The materials helps regulate and stabilize the internal temperatures of the brewery on the required levels. It became possible to reduce the investment in climate services. For the Adnams Brewery, a smart concept was implemented to lower the need for cooling services by making use of a lowered temperature of the incoming beer kegs.

Hemp-lime products, also known as hempcrete, were used in the Adnams Distribution Centre and Science Museum store. In this section they get some extra attention. Hemp-lime is a composite material which consists of the shives from the woody core of hemp plant stems mixed with a lime binder[15]. Hemp is an annual bast fibre plant with a woody core and an internal central space. Hemp is suitable for insulation purposes as the porous structure of fibres captures air (including the moisture it contains). Hemp-lime is at its most effective as a moisture buffer when the hemp-lime is internally exposed, or covered in a lime render[16].

Hemp insulation can offer the following advantages:

- Hemp insulation has been shown to be less sensitive to humidity variation than other bio-based material such as wool and wood fibres[17].
- Temperatures maintained in hemp houses are consistently one or two degrees higher than in brick houses for the same amount of heat input[18].
- Hemp-lime building reduces the effects that changes in the external environment have upon the internal environment, helping maintain comfortable internal conditions during summer and reducing energy use in winter due to Passivhaus-standard air permeability levels[19].
- Hemp sequesters/captures carbon, this product has a negative carbon footprint[20].

Much has already been achieved in passivity. The Réhafutur project for example, shows that renovation of old buildings to a passive house level is possible with bio-based materials. For the Science Museum in the United Kingdom, reusable (using screws) bio-based panels were used, to store valuable artefacts where temperature and humidity have to stay strictly within certain boundaries.

Passive health benefits

For the city council of Venlo, the positive effect the new building had on the employees' health was rather unexpected. In the first year since the new building was taken into use, sick leave of the staff fell by 2%. This resulted in cost savings which were about five times higher than the cost already saved on energy use (see box). Yet, although promising, there is still uncertainty about the real cause of this reduction in sick leave. It is likely that other factors than material usage also contributed to the health of the employees. Aspects such as the floor plan, incoming sunlight, CO_2 levels and perhaps the joy of a fresh start could have all contributed to a reduction in sick leave.

In the first year since the new building was taken into use, sick leave of the staff fell by 2%

The health benefits that can be realized using healthy materials are seen by us as a passive advantage. In the context of the CBCI project, we aim to explore and demonstrate the relative health, energy, environmental and cost benefits of bio-based materials. When assessing passive benefits, we will take the context of the building into account, because floorplans, materials used, geographical position and climate all have impact. The health benefits are not yet sufficiently underpinned by independent demonstration and monitoring. This shows that building owners and facility managers can contribute to this research by monitoring and sharing energy use and health data.

15 Kinnane, O., McGranaghan, G., Walker, R., Pavia, S., Byrne, G., & Robinson, A. (2015, November). Experimental investigation of thermal inertia properties in hemp-lime concrete walls. In Proceedings of the 10th conference on advanced building skins (pp. 942-949). Bern: Author.

16 Latif, E., Lawrence, M., Shea, A., & Walker, P. (2015). Moisture buffer potential of experimental wall assemblies incorporating formulated hemp-lime. Building and Environment, 93, 199-209.

17 Korjenic, A., Zach, J., & Hroudová, J. (2016). The use of insulating materials based on natural fibers in combination with plant facades in building constructions. Energy and Buildings, 116, 45-58.

18 Yates, T. (2002). Final report on the construction of the hemp houses at Haverhill, Suffolk. Building Research Establishment, Watford, report, 209-717.

19 Shea, A., Lawrence, M., & Walker, P. (2012). Hygrothermal performance of an experimental hemp–lime building. Construction and Building Materials, 36, 270-275.

20 Lawrence, M., Fodde, E., Paine, K., & Walker, P. (2012). Hygrothermal performance of an experimental hemp-lime building. In Key Engineering Materials (Vol. 517, pp. 413-421). Trans Tech Publications Ltd.

Municipality of Venlo

Venlo, The Netherlands

Main function: City Hall (offices and meeting rooms)
Architect: Kraaijvanger Architects
Main contractor: BBN Houten/ Laudy bouw en ontwikkeling, Sittard
Year of completion: 2016
Unique: Built according Cradle2Cradle principals, design and construction ready for reuse, interior with focus on health of the users, solar chimney with natural ventilation, green façade as part of the inner climate regulation, deposit for furniture & energy neutral.

"We have chosen to apply the Total Cost of Ownership - TCO - based on 40 years. 1% energy saving yields 16.9 million over 40 years. With a payback period of around 15 years it was initially rejected by the city council. We added a Cash flow calculation and brought it back to the Council once more. The saving after 1 year (energy / water) turned out to be greater than the interest charge of 3.4 million. This was – looking back - a key moment in the project. Unanimously the Council agreed ... that everything that is build needs to have a cash flow calculation."

Bas van de Westerlo, Advisor Circular Building & Public Procurement at C2C ExpoLAB

Essentials put into practice in this case: Affordable Reuse | Flexible | Passive | Integral | Traditional Ownership

For people's health, insulation materials appear to be of particular importance. Poor indoor air quality is mostly caused by the type of insulation materials, for reasons of moisture and release of hazardous substances (Volatile Organic Compounds), according to research conducted by Wageningen University in the Netherlands. In addition to the health of the people who will use the building, the potential health risks to the people applying the materials, or those who are active in demolition, should also be considered when choosing insulation materials.

Maintenance

While bio-based materials have several benefits for the users and owners of a building, in over half of the analysed cases, their application also brought some concerns. Particularly

'For people's health, insulation materials appear to be of particular importance.'

maintenance was mentioned as an important concern. It appeared that in this regard, bio-based materials could be less 'passive', so to speak, and could require more maintenance work compared to other materials. For lime surfaces as well as some woods, for example, maintainability is an important additional challenge in bio-based construction. These surfaces must be treated/painted more frequently and with the right products, to ensure a long lifetime. Bio-composites seem promising materials that could reduce maintenance needs because surface treatments are not, or less frequently, needed (8.3). Finally, some surfaces with course textures are not suitable for all audience, like children or care clients.

INTEGRAL

continuously reflect on circular bio-based benefits

After exploring the opportunities for maximizing re-use (essential 1), looking ahead to prepare for future functions (essential 2), and considering the potential of passivity (essential 3) it is time for the fourth essential for successful circular bio-based construction. Its goal is to approach financial and organizational aspects of the construction project in an integral manner.

Despite its advantages, a fully integral approach is not common in the construction sector. By putting the focus on collaboration and sharing learnings, it becomes easier to work in an integral way. An advantage of an integral approach is that it enables one to look beyond budgets and towards other, generally long-term benefits, addressing multiple stakeholders.

There are several options for working in an integral manner. In this chapter, we provide examples, present an overview of benefits of circular bio-based constructions, show you ways to mitigate risks and improve collaboration as well as methods for integral decision-making such as looking at Cash Flows, Life Cycle Analysis (LCA) and using certifications.

Overview of benefits

In order to help initiators to understand the benefits of circular and bio- constructions, we list them below. In about three quarters of the interviews benefits and related business cases played a role during the initiative phase (4.5). Canvasses, like the Business Model Canvas, were far less frequently used then we expected beforehand. Yet, they can be helpful. Therefore, we put information on canvasses in Annex B.

Identified benefits of circular bio-based construction include:

> *'Using materials with low production carbon emissions also helps reducing the footprint.'*

Health

The Venlo case shows health benefits to users of a building in which bio-based materials are applied. The sick-leave of the employees fell with 2%, reflecting positive impact on mental and physical health. Looking at costs related to sick-leave, the cost reduction was even about five times higher than reductions on energy and water that were also realized with the new building. Moreover, working with natural and non-toxic materials can also have health advantages to those working directly with these materials in the construction sector.

Lowering carbon footprint & energy use

Three cases show how the use of bio-based materials substantially decreases the energy consumption of buildings and hence contributes to decarbonization. For the Adnams brewery, the use of bio-based hempcrete as insulator resulted in cooling-energy savings of over a hundred thousand British Pounds per year. It is good to note that this can also be achieved with conventional insulation materials. With bio-based insulation materials, the need for cooling services was significantly reduced, lowering emissions, the investment and operational costs. The Science Museum storage space, for which bio-based hempcrete insulation materials are applied as well, uses 2/3 less energy than conventional storage spaces. For the City Council Venlo, energy savings were realized by green facades, i.e. with a type of vertical garden. Using materials with low production carbon emissions also helps reducing the footprint.

Flexibility

Flexibility is not just a characteristic of circular building (see essential 2 on preparing for future functions), but is also an inherent benefit. Flexibility keeps the use value of a building high throughout its lifetime. Furthermore, flexibility is likely to yield cost savings for renovations, maintenance and adaptations. Moreover, it makes a building more interesting for new owners or users at the time of sale, which positively contributes to the residual value. And in case of dismantling, a flexible building potentially produces less waste and as it generally has better reusability opportunities.

Increased end of life value

By designing with reuse in mind, the value of the construction at the end of life can be increased. For over half the observed cases the value at the end of life was taken into account. However, except for de Tijdelijke Rechtbank and Triodos Bank (where materials are kept in a material passport), no attempt was done on calculating the residual value. For those projects where the goal of circularity and value retention at the end of life was relevant, digitization of the building became a priority. More will be learned when the Tijdelijke Rechtbank will be disassembled in a few years (9.1). There are still many uncertainties in this area, for example when it comes to valuation and value on the balance sheet. Research of this area is not a priority for CBCI since there are already good sources available such as the Dutch Report of the C8 with Deloitte[21].

Promotional value

Because circular bio-based construction is not common yet, for now, owners and users of circular bio-based constructions, as well as (sub)contractors and other parties involved, can distinguish themselves from others. For construction initiators who want to be known as frontrunners in sustainable development, like Triodos Bank, the promotional and exemplary value was a relevant project objective of their build. For the majority of the other observed cases, to the initiators this was a side effect. However, the (sub)contractors involved strongly in these cases highly appreciated the promotional value (8.2). For example, the attention attracted by the Adnams Brewery brought the involved contractor into contact with a new client, leading to significant business value (20.15). Likewise, the Réhafutur project inspired local and regional businesses and social housing agencies to work with bio-based materials in their (renovation) projects.

21 Rau, Thomas. Van Bergen, Thomas. Driever, Desie. Mouseer, Ian. Havenga, Danique. Manschot, Dingeman. Menger, Olga & Verbaan, Jan, 2017. C8 | Van Vastgoed naar Losgoed: Nieuwe financiële baten van circulariteit voor vastgoedeigenaren

While the observed cases already indicated the benefits of circular bio-based construction listed above, we will investigate them in more detail in one of our Living Lab projects.

'We will further investigate social and societal impact of circular bio-based construction'

In addition, we will further investigate social and societal impact of circular bio-based construction, including inclusive labor and social cohesion. Moreover, we'll develop practical recommendations and tools to achieve these benefits.

Selecting partners

Construction is a collaborative effort, so partners need to be selected. But which partners to select for successful circular bio-based construction projects through an integral approach? The interviews hint at the following criteria:

- Entrepreneurial – being able to deal with unknowns
- Learning mindset, what did they learn from previous projects? – innovative projects require the ability to learn along the way
- Expertise on fields other than yours – cooperation should add value
- Not being afraid of reuse or bio-based materials (20.13)
- Willingness to understand other partners' interests (initiators, users, producers, contractors etc.)
- Reliability - Check with references whether they do what they say they'll do

Réhafutur

Loos-en-Gohelle, France

Initiator: Maison et Cites, social housing corporation
Main function: Office building and Expo Centre
Architect: GIE Arietur
Main contractor: Cluster EKWATION
Year of completion: 2015
Unique: Renovation of a building (1920) with bio-based and reused materials on passive house level. Pilot for the regional building industry (equipped with a monitoring system).

"Training-sessions (by manufacturer) for the workers. Airtightness was an important subject to train on. This was then still a quite unknown subject to most constructors. Also mixing building teams. We asked for experience: bio-based building, energy efficient." " Everybody enjoyed the adventure, good energy. Made it in less than 1 year. It became Everybody's project, not just from cd2e, proud of the project".
Frederic Laroche, Head of the Sustainable Building division at CD2E

Essentials put into practice in this case: Affordable Reuse | Flexible | Passive | Integral | Traditional Ownership

Risk mitigation in collaboration

In most analysed cases, except for one, risk mitigation played an important role in the process. Common risks are delays, misunderstanding, everyone working in their own silo, a sub optimal design and budget overruns. The following attention points can help initiators lower the occurrence of these risks and improve collaboration:

- Let the initiator be represented in the building team
- Maintain direct contact between directors/decision makers
- Start early with collaboration of all building partners (including producers)
- Plan for knowledge exchange and joint ambition setting
- Specify decision moments and process steps beforehand; e.g. a session for early involvement of users and process/decisions split up per building layer
- Plan moments of continuous dialogue and feedback between architect, building owners, manufactures, (deconstruction) contractors, builders and other stakeholders. From one of the interviews it became clear, by amazement of the builders, that asking feedback to them is uncommon in the Dutch construction sector (20.11).
- Keeping budget cost items flexible in order to iteratively optimize for material reuse (20.6).
- Involving users in the design process. This came by in the interviews only twice, for these cases it was very useful (20.11). Beforehand, we expected user consultation to occur more frequently than it did.
- Ambition driven leadership. Without it, it is hard to realize circular and bio-based ambitions. This aspect was present in all of the observed cases (20.2).
- Incentivise based on performance of the building partners. This was used to mitigate the risk of misalignment. In several cases it was used to improve transparency and taking of responsibility. We observed: sharing of the project profits/reduced costs amongst building partners (Emergis with Bouwmeester PRO method), initiators paying for material research if the material is selected (Venlo: C2C quick scan) and sharing of the residual value of a building (Tijdelijke Rechtbank (4.3).

'Visualization of cash flows in timelines showing annual and non-annual cash flows may be very revealing.'

Integral decision making

In order to make informed decisions, there are many helpful methods. In the interviews, we identified three methods: calculating cash flows, doing Life Cycle Analysis (LCA) of materials, and using certifications. We illustrate them below.

Calculating cash flows

Cash flow simulations are very useful for informed decision making, particularly if done to compare several options. For integral decision making, the cash flow simulations should cover the entire lifecycle of each building layer and include upfront costs as well as residual value, direct costs for use and maintenance, and also indirect costs and benefits that go beyond the direct costs related to the use of the construction. It is also important to distinguish cash flows for operating activities, like energy bills, investing activities, i.e. capital expenditures, and financing activities, like interest payments. If you do this for several options under consideration, you can put costs and benefits in perspective and make well-informed decisions. Visualization of cash flows in timelines showing annual and non-annual cash flows may also be very revealing.

For City Hall Venlo, cashflow calculations were decisive to allow for larger investments in health improvement, energy- and water reduction (4.4). From the calculations and projections, they learned that the future cost savings that could be realized with the proposed circular bio-based construction outweighed the additional investment and associated interest payments. Moreover, presentation of the calculations helped to convince internal stakeholders to increase the upfront investment, because the calculations showed how quickly it could be earned back. So, creating full overview in cash flows can help to make sound financial decisions and even increase the degree of resource efficiency of a construction.

Life Cycle Analysis (LCA)

With Life Cycle Analyses (LCAs), materials and products can be compared and linked to the overall ambition of the project (2.2). In the cases of Triodos Bank and the Tijdelijke Rechtbank, LCA information was used for the selection of materials. This LCA/EPD (Environmental Product Declaration) information is considered as a good and neutral information source about the overall environmental impact of materials. With a good LCA, aspects which otherwise may not have been taken into account, like the energy use of production, reuse and recycling (at the end of life) are now part of the decision. However, data is not yet available for all bio-based materials; this requires further research.

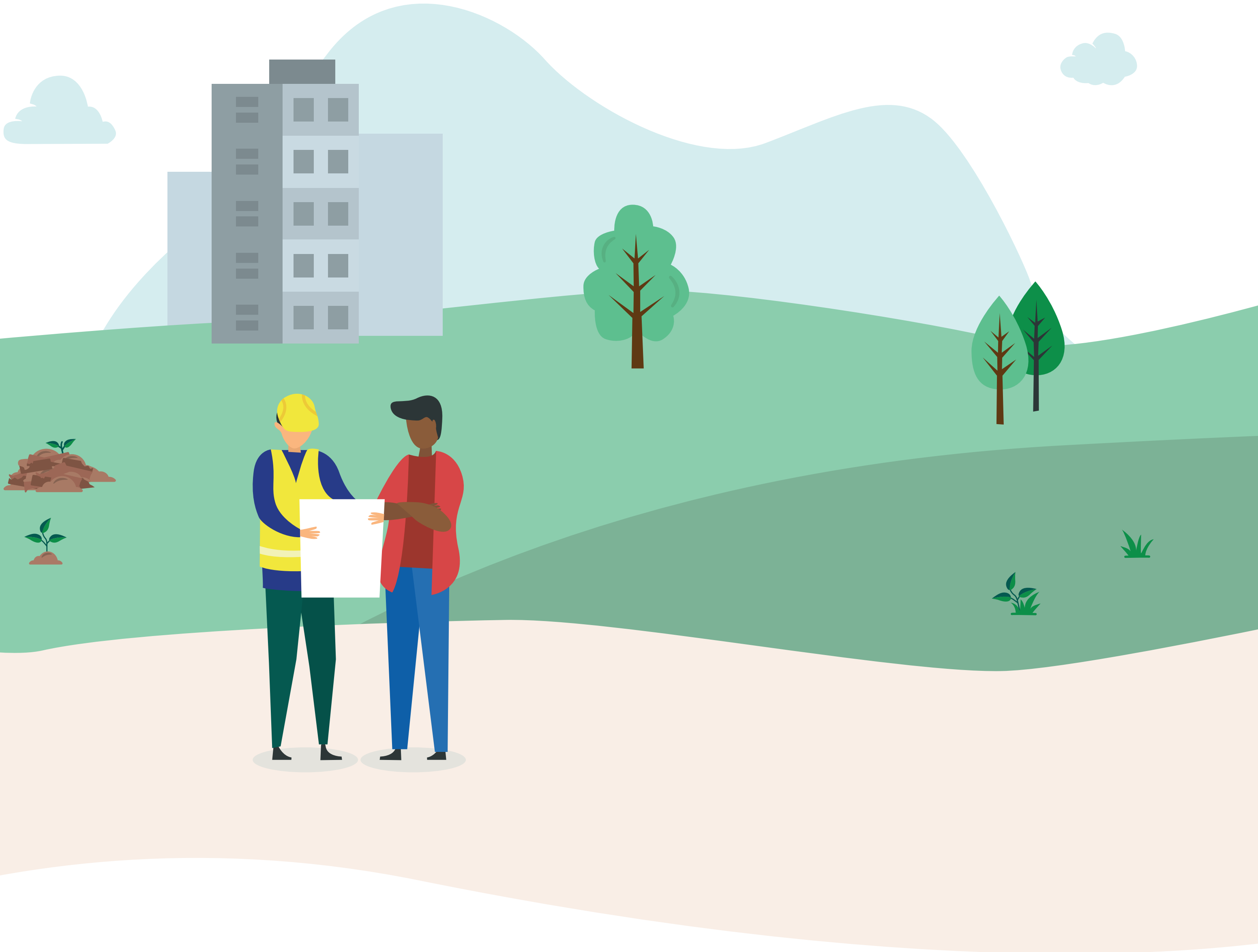
When selecting materials, it is also important to make sure they are in line with the overall reusability of the construction. It also impacts energy usage at the end of a construction's life. To find the optimal balance a trade-off between material use, availability, budgets, energy consumption and

'Certifications can be useful as guiding principles for the construction process.'

environmental impact has to be made. Based on Life Cycle Analysis (LCA) these decisions become easier.

Certifications

Certifications can be useful as guiding principles for the construction process. After having decided upon a particular certification, you'll have guidance in the decision making throughout the project, because you follow a certain standard. Only in two of the interviewed cases a certification and specifically BREAAM[22] was considered or implemented as a circularity standard in the construction process. In order to save money that was put into the building itself one of the two cases indicated that they used BREAAM as the standard, but did not apply for the certificate (8.1 / 30.2). In this case they did not have the intention of selling their building to institutional investors, who frequently favour such certifications.



22 BREEAM - Building Research Establishment Environmental Assessment Method is the world's longest established method of assessing, rating, and certifying the sustainability of buildings (since 1990).

5

TRADITIONAL OWNERSHIP

keep it, simple

While in the previous chapters we encourage you to be creative and innovative in finding solutions, in this chapter, we argue that it is essential to keep it simple when it comes to ownership of a construction. Even if the project contains the most innovative circular and bio-based materials and contraction methods, its ownership and related financing do not need to go with the latest trends. With two cases, we illustrate that traditional ownership can be the most adequate way for projects otherwise very innovative on a circular bio-based level.

Traditionally, the initiator of a construction project, i.e. the client, becomes the owner once the construction is finished; not the designer, the contractor, neither the suppliers, manufacturers nor element/prefab producers. Alternatives to this traditional transaction-type model include lease, rent, product-as-a-service, or pay-per-use. With those alternatives, the initiator does not become the owner of the construction it uses in its entirety, or of part of the construction (think of the layers here). Instead, in such alternative models, ownership lies elsewhere in the supply chain. One could argue that ownership towards the producer in the supply chain provides a stronger incentive for circularity than a sale to the user; ownership gives the producer or supplier a long-term stake and responsibility in the cycle. What makes this unattractive, though, is that in the construction sector a lot of value is added in the form of labour during the construction phase relative to the value of the construction materials. The same may apply for labour costs of a disassembly or refurbishment process. Another drawback relates to the often-long time horizon of constructions in comparison to the lifespan of businesses. This time gap is also mentioned in the framework of the European Environmental Agency referred to in table 1. For developing viable business models, solutions to ownership challenges are not widely accepted.

A recent approach in the area of ownership is the CESCO (Circular Economy Service Company), in which coalition partners remain the owners of what they physically supply to the client, take it back at the end-of-life, and bear the responsibility and task to ensure reuse. The coalition partners of a CESCO may jointly take steps towards financial institutes to finance the activities. More or less similar to this option is smart contracting and a dedicated consortium responsible for the design, construction and maintenance of the construction for a given time period.

Triodos Bank

Driebergen-Rijsenburg, The Netherlands

Initiator: Triodos Bank
Main function: Office building of Financial organisation
Architect: Rau Architecten
Main contractor: J.P. van Eesteren
Year of completion: 2019
Unique: BREEAM-NL Outstanding, remountable, modular design, use of Madaster as a digital material passport, Wooden beams for the construction as well as green roofs.

"Starting point was to make use of the service as a product approach. Pay per service. After calculations e.g. elevator, facade, lightning, the choice was made to keep the building elements in ownership of Triodos. The reason was that the future use and value of the elements was unsure, because technical developments in the future (elevator, facades, etc.) ... The prices for the contracts for the service were too high to make it profitable. It was economical more interesting to buy the elements and work as in the current practice with depreciation."

● **Sander Kok, Project Leader at Triodos**

Essentials put into practice in this case
Affordable Reuse | Flexible | Passive | Integral | Traditional Ownership

Question is whether these alternative models yield affordable circular bio-based constructions for the initiators and users. For the time-being, the answer seems to be no. Almost all cases we analysed for this white paper chose traditional ownership and financing with mortgages (4.6). Triodos Bank and Tijdelijke Rechtbank were particularly clear about their motivations. After due consideration, they both concluded that traditional ownership of the construction in its entirety is financially more attractive than the alternatives. They both indicated that the reason for this lies in the relative high lease or usage fees with external ownership compared to the costs of financing in a traditional way.

These higher costs are the result of a risk premium taken by contractors for the uncertainty of the future value as well as higher financing costs for these other parties if they would remain owners. Predictions of the residual value of the elements, products and materials at the end of the lifetime of a construction, which generally lasts long, are very uncertain. Moreover, contracts between the owner(s) of the building (layers) and the users can get rather complicated. Specifying liability for any damage or wear, for example, is still in its infancy. It is very uncertain whether risks are properly and completely overcome via contracts, because there aren’t many examples to learn from.

Another reason in favour of traditional ownership lies in the low interest rates for financing activities. Nowadays, having the ownership of the building allows you to get a mortgage at a low interest rate and this is therefore, generally speaking, the most affordable way of financing a building. Because of unfamiliarity with new business models and the associated risks, financing institutes may charge higher interest rates for construction partners that own parts of the construction. In turn these partners will include the costs in the fees, rents, and lease terms to be paid by the user.

‘We encourage you to keep your feet on the ground when it comes to ownership and related financing.’

With regard to ownership, the Tijdelijke Rechtbank makes an interesting case. It is a temporary build. Throughout the use phase, which is expected to be four to six years, it is owned by the Dutch governmental real estate agency. Subsequently, ownership will be transferred to an entity formed by cepezedprojects and Du Prie, respectively project developer and the contractor of the Tijdelijke Rechtbank. It was agreed that this will be a ‘gift’, in exchange for a discount on the initial tender offer.

By the time of transfer of ownership, the entity of cepezedprojects and Du Prie will search for ways to ensure reuse. While taking this responsibility upon them, they did not choose to enter a buy-back contract with the suppliers or producers, even though it is already known that clearing out and disassembly will take place in the foreseeable future. Instead, they made the pragmatic decision to simply sell everything including its furniture at, or near, the end of life, ’maybe just via an online platform, like Marktplaats’. The motivation was to keep things simple and reasonable, because external parties, to which materials are sold in advance, will likely take a relatively large compensation for risk/uncertainty that is disproportionate to the residual value (4.4).

This example of the Tijdelijke Rechtbank shows how traditional ownership does not necessarily interfere with circularity. Most important seems to be the mindset, that turns corporate responsibility with regard to our common future into action. Therefore, we encourage you to keep your feet on the ground when it comes to ownership and related financing. Just keep it simple.

Concluding summary

If enthusiasm, policies, rules and regulations continue to favour sustainability, circular bio-based construction is likely to be embraced more and more over time. Currently this way of construction is still in its early stages of development and several challenges remain. In this paper we demonstrated that there is already a solid foundation to build on: the pioneering work that preceded new circular bio-based construction projects.

In this white paper we showed you how circular and bio-based principles are complementary to each other. Prejudice around circular and bio-based materials often merely reflects fear and lack of knowledge on the subject and may not be related to actual risks. Based on exemplary cases, we gave you five essentials to consider in the initiative phase. With these essentials we aim to help you to confidently rise to the challenge of circular bio-based construction and thus benefit from the inherent advantages.

The initiation phase is a very important phase for the degree of circularity of a construction and for the extent to which bio-based materials are applied. Therefore, we propose to use the essentials as a guideline in the initiative phase, especially before taking irreversible decisions. The essentials can be summarized in brief by the following questions:

1. **Affordable** Did we search for cost-effective & inclusive reuse?
2. **Flexible** Did we look beyond the current needs and prepare for future functions and users?
3. **Passive** Did we search for passive ways to stay cool & healthy with bio-based materials?
4. **Integral** Did we broaden our perspective and continuously reflect on the financial and non-financial benefits of circular bio-based construction?
5. **Traditional Ownership** Did we keep ownership as simple as functional?

We hope the cases in this white paper and the five essentials inspire you and help you to realise affordable and feasible circular bio-based constructions. By focussing on the essentials, you will prevent valuable resources (including energy) going to waste, today and in the future. The exemplary cases show that it is possible. We have to admit it does require leadership, perseverance and isn't always easy. Yet, perhaps that is why, without exception, the initiators are proud of what they achieved (10.2). So, like the director of cepezedprojects said "[circular construction] isn't rocket science, if you're willing to, you can do it" (10.1). We gave you guidance. Now, it is up to you.

Keep learning with us
If you like to keep learning about circular bio-based construction together with us, click here and sign up to the CBCI newsletter We will further explore topics such as bio-based benefits, business cases, (public)procurement, certificates, rules and regulations.

Annexes

Annex A:
Analysed Cases

8 observed cases resulting in this table: Wiegelied (BE), Emergis (NL), Tijdelijke Rechtbank (NL), City Counil Venlo (NL), Triodos Office (NL), Adnams brewery (UK), Science Museum (UK) and Rehafutur (FR). For detailed interview findings contact the CBCI team.

	ID	Summarizing statement	Occurs*
Preparation & Design	1.1	Initiators want to learn about the benefits of bio-based circular solutions	100%
	1.2	Initiators want to get inspired by realized projects and information that can be used as an example	50%
	2.1	Initiators want to know which parties are available to realize their ambitions	50%
	2.2	Initiators want to make decisions that help them to most optimally reach their ambition	88%
	3.1	Initiators want to select parties they trust to overcome challenges and to meet the requirements	88%
	3.2	Initiators need to have a clear set of requirements in order to facilitate the construction process well	88%
	3.3	Initiators want the preliminary design and tender to express their needs well in order not to run the risk of getting something inadequate	88%
	3.4	Allowing for a possibility to adopt the building towards changing/growing usage needs in the future	63%
	4.1	Initiators want to develop an overall plan within a set budget or set of requirements	100%
	4.3	Using performance based revenue models/agreements	38%
	4.4	Circular and bio-based constructions can lead to interesting benefits or business cases. Cash flows help to make better decisions	75%
	4.5	Organizations use business model canvases to get overview in their project and align with different stakeholders	0%
	4.6	Alternatives of financing by mortage are considered but not selected. Financing traditionally is most affordable.	100%
Execute	5.1	Initiators want their project to be finished within the set of requirements when it comes to price, time, information and quality.	75%
	5.2	Circular/sustainable ambitions change over time	50%
	5.3	Initiators want to be represented in the building team	75%
Use	8.1	Initiators want to measure environmental ambitions	38%
	8.2	Initiators want to learn and be known as front-runner.	75%
	8.3	Initiators prefer maintainable buildings	63%

*Occurs = percentage of cases in which the aspect is observed.

	ID	Summarizing statement	Occurs*
End Life	9.1	Keeping value at the end of life	38%
Emotional	10.1	Perception: worries about bio-based and circular principles, because of unfamiliarity. With longer term experience and research we see it is unfounded.	63%
	10.2	Taking pride and motivation from being an example/inspirator to other projects	63%
Success	20.1	Prefab/standardized elements for cost reduction, consistent build quality and demountability	63%
	20.2	Strong leadership (groups) that are motivated to the ambitions as well as bio-based and circular construction	100%
	20.3	Offering customized solutions are preferred (this doesn't have to conflict with prefab)	25%
	20.4	Consciously keeping building layers separate	13%
	20.5	Having tight and pre-planned deadlines helps making decisions	13%
	20.6	Learning by doing approach was needed to deal with reusing materials and unknown/ unpredictable aspects of the quality	38%
	20.7	Enthusiasm turned (building) partners into evangelists	50%
	20.9	Taking rules and regulations and potential changes into account as much as possible	38%
	20.10	Labelling of parts and getting enough time to allow for reuse	13%
	20.11	Educating and asking feedback to the building team and users	38%
	20.12	Local productions helped with the environment, supply security and better labour conditions	38%
	20.13	The need for (sub)contractors that are not afraid to take a risk when it comes to material reuse and new approaches	38%
	20.14	A long-term view, family business as well as board members that stay for a long time are helpful for successful circular bio-based construction	25%
	20.15	The attention the building got promoted the organization and led to business opportunities	13%
Failure	30.1	Elements that cannot be reused (cost effectively) in design or as input streams (TENSION WITH 20.13)	50%
	30.2	Certificates might be too expensive for initiators that do not resell the buildings commercially. The amount concerned can also be used to make the buildings better.	13%
	30.3	Small margins in the building sector as well as investments made in the past hold back on risk taking and innovation	13%
	30.4	LCA data for bio-based materials is/was not always available	13%
	30.5	LCAs depend on predictions which can be impossible to know as of yet	25%
	30.6	Regretted not looking broader into business models/taking a stake into innovation that was enabled by the initiator	13%
	30.7	Bio-based construction seems to get harder to arrange in the UK over the last years due to a lack of suppliers in this field.	25%

*Occurs = percentage of cases in which the aspect is observed.

Annex B:

Business model canvasses and considerations

Canvasses are practical tools for developing new business models as well as refining existing business model. By explicating a business' value plus main components and objectives in such canvasses, it becomes easier to share key information of the value creation process with stakeholders. Developing and refining canvasses also helps to align thoughts, ideas and beliefs. Moreover, they encourage and facilitate discussions in groups.

The following canvas models can be used in collective sessions:

- **Business Model Canvas:** often used, it works well for the financial and commercial economic aspects. However, it does not fit well with social or sustainable aspects that are important parts of circular and bio-based principles.
- **Triple-layer business model:** incorporates multiple value aspects, including social and ecological components and is quite practical in use. This is currently the most practical and applicable for circular and bio-based construction identified.
- **The Cloverleaf model:** defines the various values that will be created, and adds sections for guiding principles and the modes of cooperation with stakeholders. The potential effects realized through such models, become visible only when multiple businesses incorporated it together. It is rather generic, so more study is needed on the applicability of this model.

The service models developed by Circle Economy & ABN AMRO provide a good overview of business models that you can choose. Additionally, data-driven business models, for example where building data is gathered to determine reuse value, are also promising according to the CBCI team. Approaches to consider for integrating circularity into business models are shown in figure 2 [23] [24]:

Figure 2: From A Future-Proof Built Environment - Putting circular economy into practice. Circle Economy & ABN AMRO [25]

23 Thelen, D. et al. (2018). Scaling the Circular Built Environment – pathways for business and government. Circle Economy & WBCSD.

24 Kubbinga, B. et al. (2017). A Future-Proof Built Environment - Putting circular economy into practice. Circle Economy & ABN AMRO.

25 Kubbinga, B. et al. (2017). A Future-Proof Built Environment - Putting circular economy into practice. Circle Economy & ABN AMRO.

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