# D3.1

# User requirements for decision-support framework

*Lead beneficiary:* VITO

Due date: 31.01.2021 (M9)

Type of deliverable: R

| ***Dissemination level*** | | |
|---|---|---|
| PU | Public | X |
| PP | Restricted to other programme participants | |
| RE | Restricted to a group specified by the consortium | |
| CO | Confidential, only for members of the consortium | |

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| *History of changes* | | | |
|---|---|---|---|
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## Executive Summary

This deliverable is the first of Work Package (WP) 3 of the ICEBERG project. WP3 is called “Innovative circular building products”. The first task of WP3, Task 3.1, is called “User requirement analysis”. The objective of Task 3.1 and its deliverable D3.1 “User requirements for decision-support framework” is to gather detailed and up-to-date information on circular building products, building elements and buildings. The specific information consists of user requirements and current barriers experienced by the different stakeholders within the construction sector.

This report describes the results of the desk research and workshops held within the framework of Task 3.1. The collected information will be used to the define the basic structure of the decision-support framework that will be developed in the second task of WP3.

## Acronyms

| | |
|---|---|
| CE | Circular Economy |
| EOL | End-Of-Life |
| ICEBERG | Innovative Circular Economy Based solutions demonstrating the Efficient recovery of valuable material Resources from the Generation of representative end-of-life building materials |
| PAAS | Product As A Service |
| WP | Work package |

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# 1. Introduction

## 1.1. General

The ICEBERG project aims to design, develop, demonstrate and validate advanced technologies for the production of high-purity secondary raw materials. In addition, it aims to make significant advances in the uptake of circular economy across the entire construction value chain: from end-of-life building materials to new building products prepared for circularity and resource-efficiency. This will be demonstrated in six circular case studies across Europe covering multiple building materials that account for more than 85% of the building materials used in the European built environment. Which will result in 28 innovations regarding smart services and software, advanced sorting/recycling technologies, and new circular building products.

The name of the third work package (WP) of the ICEBERG project is “Innovative circular building products” and consist of eight tasks. Five of the eight tasks within WP3 deal with the adjustment of formulations and pre-industrial prototypes of new circular building materials related to the case studies. The other three tasks deal with the formulation of circular design guidelines for buildings and building elements that promote the transition towards a circular built environment, i.e.:

- Task 3.1: user requirement analysis.
- Task 3.2: circular design of building elements.
- Task 3.8: practical catalogue for building professionals.

This report (D3.1) presents the results of Task 3.1 of the ICEBERG project.

## 1.2. Purpose and content of this deliverable

The objective of this deliverable “User requirements for decision-support framework” is to gather detailed and up-to-date information on circular building products, building elements and buildings. The specific information consists of user requirements and current barriers experienced by the different stakeholders within the construction sector. The collected information will be used to the define the basic structure of the decision-support framework that will be developed in the subsequent tasks of WP3.

After this subsection, the content of this report is structured as follows:

- Subsection 1.3 describes the approach applied to collect the required information.
- Section 2 presents the results consisting of:
  - Subsection 2.1: general conclusions taken from the three workshops were organised as part of the execution of Task 3.1.
  - Section 2.2: barriers to implement circular economy in the built environment that were collected from the workshops.
  - Section 2.3 user requirements for circular design that can be considered in the further development of the decision-support framework.
- Section 3 concludes the report of Task 3.1.

- The minutes of the three workshops held within Task 3.1 are included as annex of this report.

## 1.3. Applied approach

**General approach**

As a first step in collecting the necessary information, a desk research has been performed considering previous research done by VITO and EPEA, and additional literature found online such as research projects and papers. These results were used as input for the workshops that were organised within the scope of this task.

Three interactive workshops have been organised using online whiteboard tools:

- One on circular product design, targeted on manufacturers of building products, and moderated by EPEA;
- One on circular building design, targeted on all stakeholders, and moderated by VITO;
- And one during the general assembly of the ICEBERG project on circular product as well as building design, with all project partners, and moderated by EPEA and VITO.

With the results from the workshops, the user requirements based on the desk research have been refined and extended. In addition, an inventory was made on experienced barriers to implement circular design in products and/or buildings.

**Approach to collect information on barriers**

In workshop 1 on product design, attendees were asked the following questions related to barriers:

- What barriers do you face in optimizing your product in material health?
- What challenges do you face in improving the disassembly of your product?
- What would you need to expand the life span of your product?
- What would you need to be able to bring as much of your product back into a cycle?
- What would you need to be able to take your product back into your production?

In workshop 2 on building design and workshop 3 during the general assembly, attendees were asked the following questions related to barriers:

- What kind of barriers did you experienced?
- How did you overcome those barriers?
- What could have prevented those barriers? (Are there certain needs?)
- Which stakeholder(s) should be involved? (to fulfil the needs)

The answers of all three workshops regarding barriers have been processed and ordered based on the number of times a barrier was mentioned by an attendee. These results are presented in subsection 2.2.

### Approach to collect user requirements

A first overview of possible user requirements was drafted based on the desk research. Within the desk research a search was done on circular design qualities, concepts, strategies, requirements, etc. to come to a longlist of possible user requirements. To group the possible requirements, three main approaches were applied (see Figure 1): (1) narrowing the loops, (2) closing loops, and (3) slowing loops. A few requirements, e.g. design for disassembly, can be grouped in two approaches.

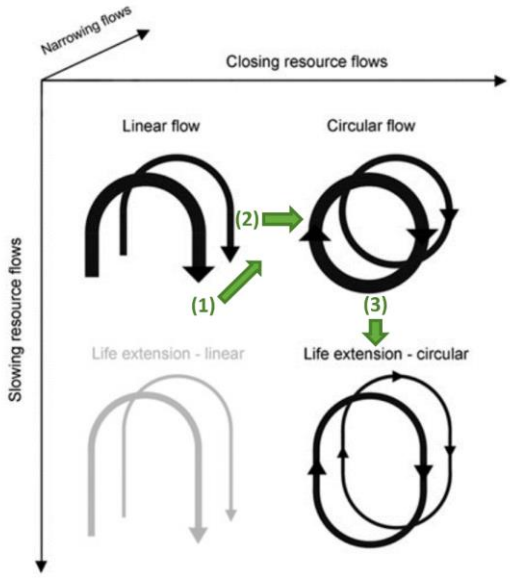



Figure 1. The main approach applied to group the user requirements (adopted from Bocken *et al.*, 2016).

The found requirements were presented in workshop 2 on building design and workshop 3 during the general assembly. The attendees were asked to vote per group of requirements their most and least important requirement. Attendes were also asked to add any missing requirements.

In workshop 1 on product design, attendees were asked to rate and/or explain the importance of material health, design for disassembly, distribution & use phase, recycling, and circular business models/take back systems.

The prioritisation/ratings by and feedback from the attendees are used to draft the final list of requirements which are presented in subsection 2.3.

# 2. Results

## 2.1. General conclusions from the workshops

The full minutes with screenshots of the online whiteboards and all findings of the three workshops are include as annex of this report. This section summarises important take-aways based on the three workshops. The collected information on barriers to implement circular design and user requirements is reported in section 2.2 and 2.3 respectively.

There is a need for an unambiguous definition, at least on European level, of what is seen as recycling. Making it possible to interpret the numbers on recycled waste fraction per country in a same way.

Within the user requirements and decision-support framework, a distinction needs to be made between products with a long lifespan and products with a short lifespan. For products with a shorter lifespan, ease of recycling is a more important requirement than for products that have a long lifespan. For products with a long lifespan, ease of disassembly for reuse is more important.

The social purpose of buildings should also be reflected in the user requirements for circular buildings (and spaces). The term *placemaking*, could be used to cover social requirements by trying to translate the term into more technical (measurable) characteristics.

There is a need for a clear definition of the requirements and guidelines on how to fulfil each requirement. During the desk research variants and differences in interpretations of terms related to circular user requirements were already noticed. This lack of clarity was confirmed at the workshops. A clear definition is an important point to keep in consideration when developing the user requirements decision-support framework in Task 3.2 and catalogue in Task 3.8.

Based on the workshops, it can be concluded that circular business models or Product As A Service (PAAS) concepts are not a priority for circular design. Optimising the materialisation of a design is the first step that needs to be addressed prior to setting up e.g. take back systems. In addition, supporting infrastructure and logistics are still lacking and a European market for secondary construction materials still needs to mature. Therefore, circular business models/PAAS concepts is left out of scope as a user requirement in the decision-support framework.

## 2.2. Barriers to implement circular economy in the built environment

Based on the three workshops, the following data mapping regarding barriers could be made (Figure 2). On the left side the mentioned barriers are grouped. In the middle the solutions that attendees applied to overcome certain barriers are indicated with a green colour, and the solutions that could have prevented certain barriers but are not yet set in place are indicated with a blue colour and a dashed line. The involvement of certain stakeholders is shown on the right side of the mapping. The frequency of how much a certain barrier or solution was mentioned is indicated by the intensity of the shading of the boxes. The more mentioned, the more intense the shading.

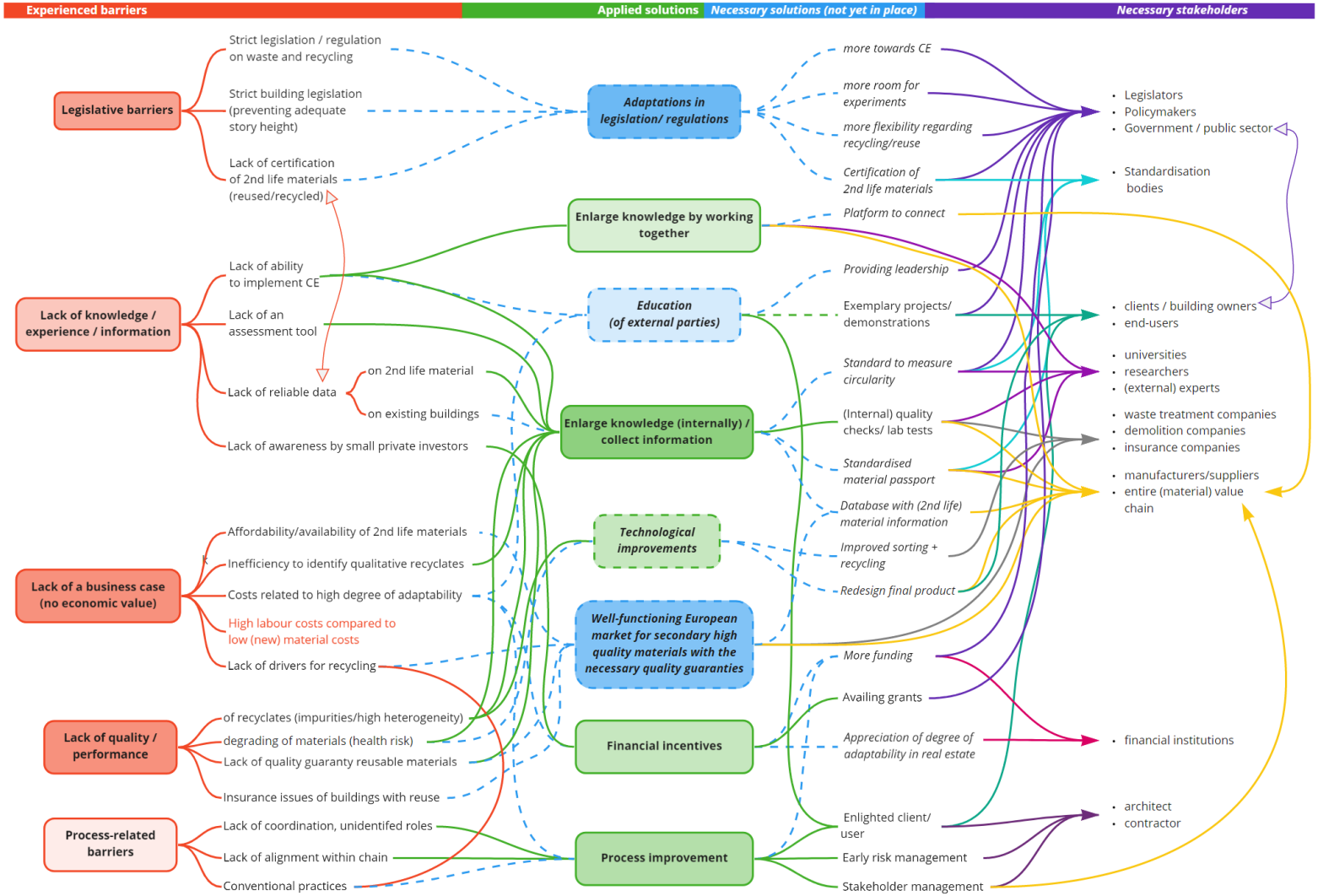



Figure 2. The mapped experienced barriers to implement CE in the built environment, possible solutions and necessary stakeholders to overcome those barriers.

## 2.3. User requirements on circular product and building design

The collected user requirements are given per group in individual tables (Table 1 - Table 3). In each group, the requirements are ordered from most to less important based on the voting by the attendees of the workshop, i.e. in workshop 1 based on the judgement of importance and in workshop 2 and 3 based on the number of green and red post-its. The requirements that received in the two last workshops relatively more red post-its than green post-its within their group of requirements are put in a grey text colour and are suggested to be excluded in the development of the decision-support framework in Task 3.2. If needed, requirements are made specific for product design and building design. After each requirement, the affected stakeholder(s) is(/are) added between brackets and in *italic* text. The references of the requirements found in literature are indicated by numbers in the last column. The numbers corresponds as follows: [1] Bocken *et al.* (2016), [2] Malmqvist *et al.* (2020), [3] EU-JRC (2020), [4] ARUP (2016), [5] Acharya *et al.* (2018), [6] Cambier *et al.* (2019), and [7] OVAM (no date).

Table 1. Requirements for narrowing loops.

| ***Requirements for narrowing loops*** | | |
|---|---|---|
| *Product design* | *Building design* | *Sources* |
| Optimising the environmental performance of the total life cycle *(all stakeholders within value chain)* | | 3 |
| Optimising total life cycle cost and value *(all stakeholders within value chain)* | | 3 |
| Optimizing the material health *(manufacturers, waste treatment companies, raw material suppliers)* | Designing healthy and comfortable spaces, designing out pollution *(architects, engineers, manufacturers)* | 3, 5, 6 |
| 3D printing of constructions, industrialising construction process, using solutions with advanced technology *(manufacturers, engineers, contractors, research bodies)* | | 2,4 |
| Optimising compatibility of components, designing for kit-of-parts *(manufacturers, engineers, architects, research bodies)* | | 6 |
| Designing lightweight product systems *(manufacturers, engineers)* | Designing lightweight constructions *(engineers, architects, research bodies)* | 2 |
| Applying regenerative design/biomimicry *(manufacturers, engineers, architects, research bodies)* | | workshop |
| Displacing resource use with virtual use, using virtual services/locations, remote service delivery *(manufacturers, engineers, research bodies)* | | 4 |
| - | Designing shared (multi-purpose) spaces *(architects, engineers)* | 2, 6, 7 |
| Optimising energy use during production stage *(manufacturers, engineers, research bodies)* | Optimising energy use during use stage *(engineers, architects, research bodies)* | 2 |
| Optimising water use during production stage *(manufacturers, engineers, research bodies)* | Optimising water use during use stage *(engineers, architects, research bodies)* | 3 |
| - | Optimising usable floor area *(architects, engineers)* | 2 |
| Optimising product form *(manufacturers, engineers)* | Optimising construction form *(engineers, architects)* | 2 |
| Virtualising the design process *(architects, engineers, research bodies)* | | 2, 4 |

Table 2. Requirements for closing loops.

| ***Requirements for closing loops*** | | |
|---|---|---|
| *Product design* | *Building design* | *Sources* |
| Design for a technological cycle/remanufacturing, using recycled and reused materials/components *(all stakeholders within value chain)* | | 1, 4, 6 |
| Design for disassembly, design in layers *(manufacturers, engineers, architects)* | | 1, 2, 6, 7 |
| Ensuring purity of materials and components during production stage *(manufacturers, waste treatment companies, raw material suppliers)* | Ensuring purity of materials and components during construction stage *(contractors, architects, engineers)* | 2, 6 |
| Documenting materials and components / applying material passports / building logbook *(all stakeholders within value chain)* | | 2 |
| Addressing both sides of the life cycle together: rethinking the production stage while considering the end-of-life stage *(manufacturers, engineers, architects)* | | workshop |
| Design for a biological cycle, using biobased materials *(manufacturers, engineers, architects)* | | 1, 2, 4, 6 |

Table 3. Requirements for slowing loops.

| ***Requirements for slowing loops*** | | |
|---|---|---|
| *Product design* | *Building design* | *Sources* |
| Design for reliability and durability / service life extension *(manufacturers, engineers, architects)* | | 1, 3, 7 |
| Design for ease of maintenance and repair (and disassembly) *(manufacturers, engineers, architects, contractors)* | | 1, 2, 7 |
| Design for standardization and compatibility *(manufacturers, engineers, architects, legislators)* | | 1 |
| Design for upgradability and adaptability, for future needs *(manufacturers, engineers, architects)* | | 1, 6 |
| Design for disassembly, design in layers *(manufacturers, engineers, architects)* | | 1, 2, 6, 7 |
| Optimizing the material health[1] *(manufacturers, waste treatment companies, raw material suppliers)* | Designing healthy and comfortable spaces, designing out pollution *(architects, engineers, manufacturers)* | 3, 5, 6 |
| Integrate knowledge of user/real usage by user in product design *(manufacturers, engineers, end-users)* | Design for social attachment and trust (context-specific) / placemaking *(architects, engineers, end-users)* | 1, 2, 6 |

[1] While this requirement was voted with relatively more red post-its than green post-its within workshop 2 and 3 within the group of “slowing requirements”, this requirement was indicated as very important in workshop 1 regarding product design and voted with relatively more green post-its than red post-its in workshop 2 and 3 within the group of “narrowing requirements”.

## 3. Conclusions

With the three workshops we were able to identify several barriers that have been encountered when trying to implement circular design. Possible solutions and necessary changes to overcome those barriers were also collected. In addition, user requirements for circular design found in literature were further refined for products and buildings. We were able to prioritise the requirements with the input of the attendees of the workshops. The information within this report can be used to the define the basic structure of the decision-support framework in Task 3.2.

It is important to give clear definitions of the requirements in the further definition of the decision-support framework. Also, a distinction between products with a short and a long lifetime needs to be made when developing the framework. For the readability of the decision-support framework, we suggest to draft guidelines per stakeholder.

# **Annex.** Minutes of the workshops

## Workshop 1 – Circular product design

Date and time: 14 January 2021, 10:00-11:30 CET

Venue: online

**Participants**

Organisers

| | |
|---|---|
| EPEA | Pascal Keppler |
| EPEA | Melanie Merz |
| VITO | Steven Claes |
| VITO | Wai Chung Lam |

Attendees

| | |
|---|---|
| Beşe Insaat | Tulay Ozlu |
| BPIE | Zsolt Toth |
| CIMSA | Ecem Çelik |
| CIMSA | Özge Gökçe |
| CSTB | Mona Nasseredine |
| EBC | Ann-Cathrin Roensch |
| ECI | Angela Vessey |
| EcoWise | Piers Larkman |
| EcoWise | Rembrandt Koppelaar |
| ECSPA | Laura Espadas Murillo |
| Hacettepe University | Emircan Özçelikci |
| Leiden University | Marc van der Meide |
| Leiden University | Mingming Hu |
| Metals For Buildings | Christian Leroy |
| Orbix | Peter Van Mierloo |
| PU Europe | Ainar Urionabarrenetxea |
| Reynaers | Marijke Rymenants |
| Tepe Betopan | Ceren Serap Akin |
| Tepe Betopan | Sibel Hacioglu |
| Vandersanden | JP Wuytack |
| Viuda de Sainz | Uxue Arteagabeitia |

| | |
|---|---|
| VUB | Marzieh Shafiei |
| Wienerberger | Andreas Jäger |
| Wienerberger | Anita Ory |
| Wienerberger | Nadine Sampl |

**Agenda**

| | |
|---|---|
| Welcome & brief introduction to the ICEBERG project | 5 mins |
| EPEA inspiration: definition of circular products | 30 mins |
| Interactive session on circular products – Mural | 35 mins |
| Discussion & outlook | 15 mins |

**Minutes**

Welcome & brief introduction to the ICEBERG project

Pascal Keppler (EPEA) welcomes all participants. Melanie Merz (EPEA) introduces the ICEBERG project. Pascal highlights the goal of the workshop by asking the attendees for input on any missing requirements that are important for transforming products into circular products as within this project we will be developing circular solutions.

EPEA inspiration: definition of circular products

Melanie Merz (EPEA) gives a presentation on their view on key aspects on defining a circular product. A summary of the main points of the presentation:

- Zoom in on the smallest scale → knowledge on the ingredients of the products maybe key to develop circular products
- Cradle to cradle approach → butterfly diagram
  - Division between biosphere and technosphere
- Focus on 3 topics:
  - Material health
  - Design for circularity
  - Positive impact
  - Example: Heavy metals in PVC holds its back for reuse → focus on ingredients
- Material ID plays a key role
  - Material banks
  - BIM tools
  - Details of products are important → determines the reuse potential
- Solutions for design for disassembly
  - Focus on new connections
  - Increase functionality
- Use phase
  - Offer new services such as replacement

    - Influence of logistics → how can the product be taken back?
- Recycling
    - Knowledge of the product composition is key
    - Producer has the best knowledge and can take advantage of it → higher recycle potentials achieved
- New business models
    - Lease products → manufacture remains owner → responsible for maintenance
    - Binds the client to the manufacture → positive impact on the business model of the producer

*Q&A*

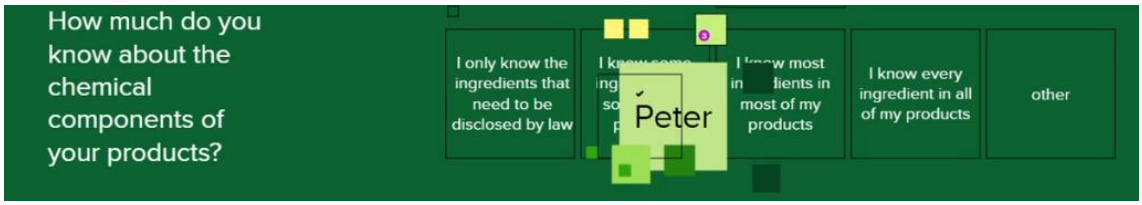
- JP Wuytack (Vandersanden): a first goal of circularity is to save natural resources. I am a brick producer and the clay resource is abundant, but the costs of recycling is much higher, is there still a need for circularity in my case?
    - Pascal: connections with other materials need to be circular. Design for disassembly becomes important in this case.
- Andreas Jäger (Wienerberger): on one of the first slides you showed that up to 40% of the solid waste is from the construction sector. The European waste directive says that 70% of construction materials needs to be recycled by 2020. Do you know what the current status is in Europe? Are the numbers presented worldwide numbers?
    - Pascal: I think they are worldwide, we can look it up. The many different views on classifying what is waste and what is recycling or use of the materials makes this a difficult topic. E.g. products that get backfilled in Germany are also seen as recycling: if ground is excavated from one place and used in earthworks on other place, it is classified as recycling. That is also why the official number in Germany on recycling is about 95% mainly due to the masses of the gaining of ground from one place to another. The differences in classification makes the numbers difficult to follow.
    - Andreas: Is there an European-wide definition for recycling?
    - Pascal: it is an very open definition. If I remember correctly, it is: the material has to provide a functional use. Which can be interpreted very differently.
      → There is a need for a clearer definition of recycling.
    - Marc van der Meide (Leiden University) in the Teams meeting chat: according to this 2019 publication numbers differ substantially in different countries in the EU. There is a link to Eurostat in the paper, but unfortunately the link is broken. Hope this helps in finding the data you are looking for!
      https://www.sciencedirect.com/science/article/pii/S0921344919302848

<u>Interactive session on circular products – Mural</u>

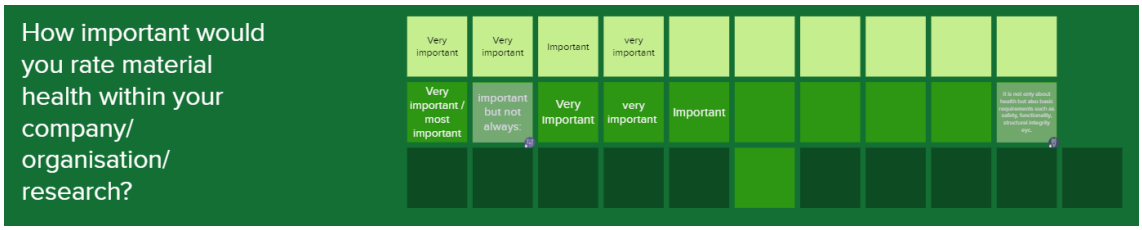
Pascal and Melanie moderate the interactive session via an online whiteboard on Mural. The whiteboard contains five sections with questions regarding topics presented in the previous part i.e.: material health, design for disassembly,

distribution & use phase, recycling, and circular business models/take back systems. Below are some screenshots from the filled in Mural grouped per topic. Attending manufactures (group 1) are asked to use the light-green-coloured post-its, (group 2) researchers/designers/engineers/consultants the green-coloured post-its, and (group 3) representors from sector federation the dark-green-coloured post-its. The key remarks and conclusions based on the interactive Mural are included below.

*Material heath – Do you know what's in your product?*




- The majority of the attendees know some of the ingredients in some of their products, not only the ingredients that need to be disclosed by law and not all of the ingredients.

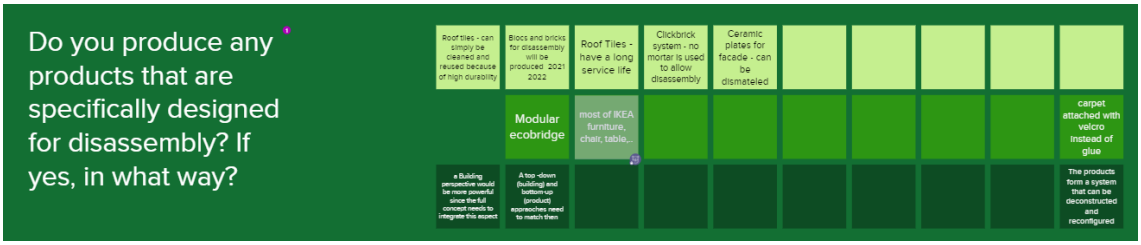



- All attendees rate material health within their company/research/sector as very important.

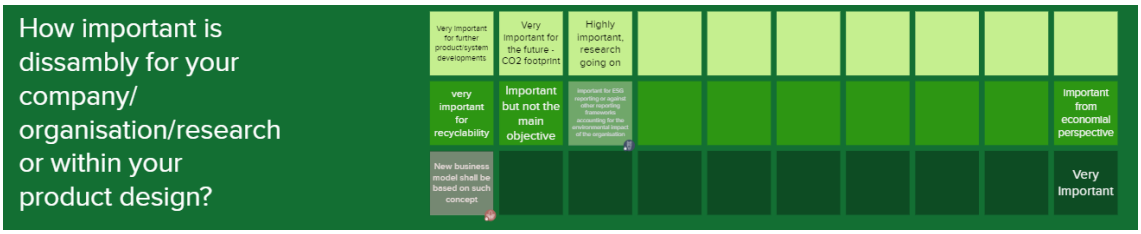

Based on the input received from the participants, it can be concluded that regarding material health:

- Most of the attendees know some or most of the chemical components in their products. The familiarity with these ingredients plays an important role for them. However, to optimize their products in material health group 1 and 2 face the barrier of having to meet quality, performance, and safety standards as well as cost limits.
- The to-be-developed decision-support framework will need to include a compilation of substances one has to consider when analysing a product on material health aspects. It needs to show which material groups require special attention and give examples of products that were successfully optimized including the steps that were taken to do so.

*Design for disassembly – How easy is it to remove your product from the building?*




- On building level this requirement is even more powerful and is linked with the afternoon workshop session.



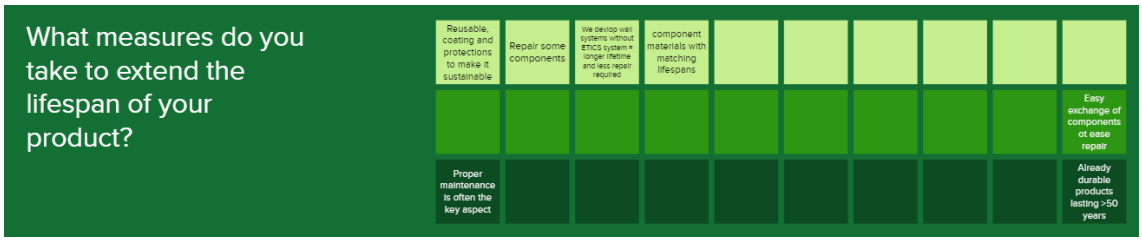

- In attendee group 1 and 3 disassembly is considered as very important within their company/research/sector or product design. In group 2 it is considered as important from different perspectives.


- Pascal mentions that regarding disassembly, waterproofing remains a large challenge. At the moment there are no proper mechanical waterproofing solutions available yet.
- Some important remarks regarding challenges included by the attendees on the board are:
  - Products are part of a system and surrounded by other products. It is a system that needs to perform the function.
  - There are little incentives at the moment to design for disassembly: no support from the government from an economic perspective.

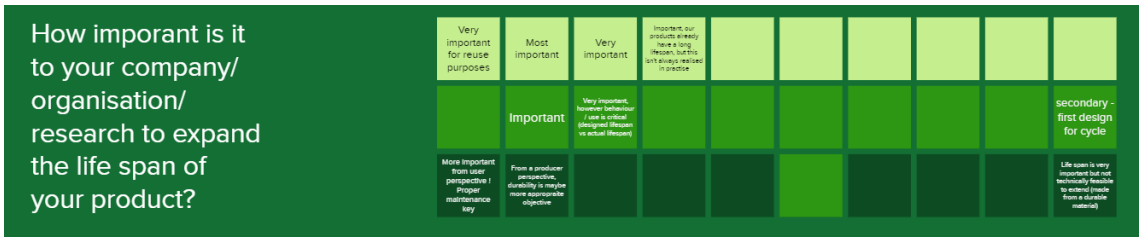
Based on the input received from the participants, it can be concluded that regarding design for disassembly:

- Disassembly is an aspect that plays an important role for all attendees and is largely integrated within their product design. Difficulties are the combination with other products or technical and safety legislations such as waterproofing.
- Different options of connections and joints need to be explained in the decision-support framework with user requirements and must be supported with examples to outline the variety of options that can be considered in designing for disassembly.

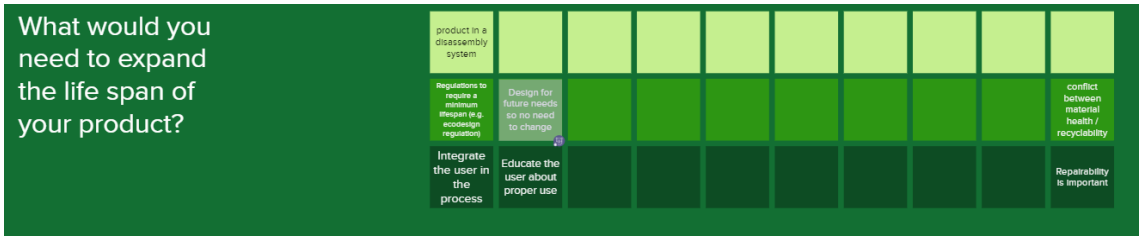
*Distribution & use phase – Is your product meant to last?*




- Measures listed by the attendees concern: reusability or repairability of some components, ease of or less need for repairs, proper maintenance, quality and durability.




- Pascal sees extension of the life span as a secondary requirement, as when a product is designed in such way it can be taken back into a cycle of the butterfly diagram optimising a product within a cycle would be more beneficial.
- Andreas Jäger (Wienerberger) comments on this that for products with a very long lifetime, such as bricks, increasing the lifetime can be one of the biggest sustainable impact that can be made for a building.
- Pascal agrees with Andreas for such products. However also adds that currently the experience is that buildings have a much shorter lifespan and reduced to 50 years. So, products with a long lifespan will also be deconstructed from buildings and therefore designing products for a cycle can also be important.



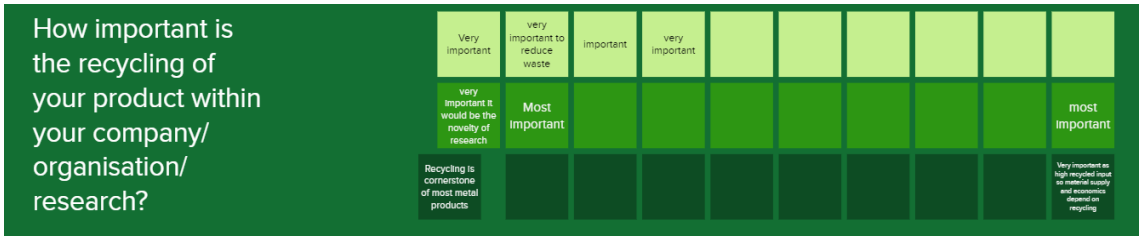

- Pascal mentions that the question above can also be interpreted as which challenges are faced when the lifespan of a product needs to be expanded. One challenge Pascal experiences is the conflict between increasing the lifespan and worsening the material health. For example, the use of composites or applying glue or more bonds, this is often good for increasing the lifespan of a product but on the other hand contra productive for material health and recyclability.
- A good point made by one of the attendees is to integrate the user in the design process to gain knowledge on how the products are really used.

Based on the input received from the participants, it can be concluded that regarding distribution and use phase:

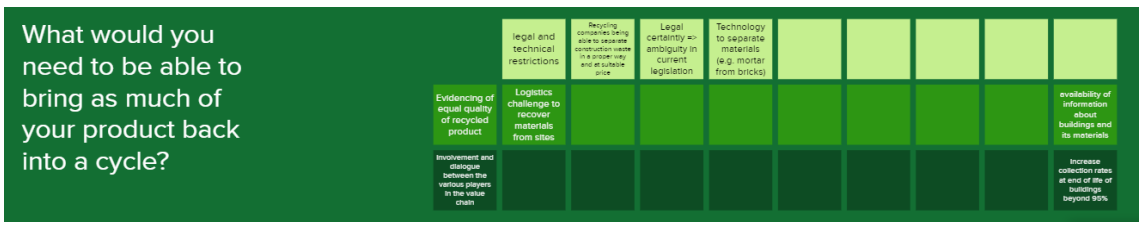
- Most attendees already pay attention to the lifespan of their product. However, there are some aspects that are hard to control by them as a manufacturer, researcher, engineer etc… This includes e.g. the user behaviour. What is also needed the most is regulations regarding the lifespan of products in general.
- The overall opinion seems that this is more of a topic for the future when there are more circular products on the market. It is also a very case-specific topic, meaning that general guidelines for now will be hard to give.
- Therefore this topic is judged as of secondary relevance and will not focus on educating on it in the to-be-developed decision-support framework. Also because educating the user on the use of their products lies with the manufacturers.

*Recycling*


- Some products are specifically designed for recycling. Ceramic products can be reused or crushed and partly be recycled into new products. Metal-based products are recyclable and already recycled today.




- Pascal mentions that, when designing the product, it is important to keep in mind how it can be recycled in the end.
- The majority of attendees rates recyclability within their company/research/sector as very important. A few even as most important, e.g. for most metal products it is the cornerstone.



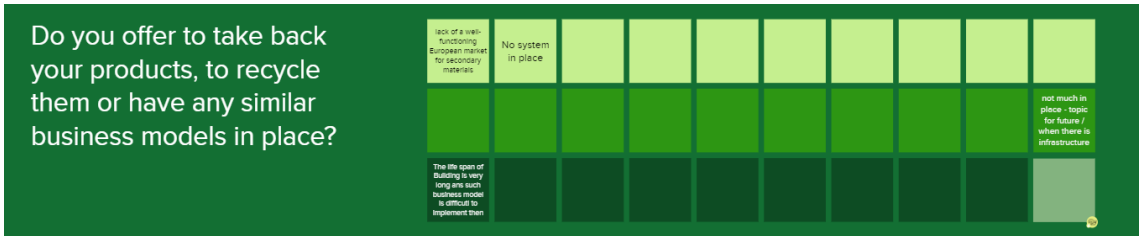

- A big challenge that Pascal sees in here is the information availability when dismounting a building. At the moment there is practically no information known. Product information on how to dismount would be beneficial for the recycling.
- Some important remarks made by attendees regarding challenges faced around recycling:

- The evidencing of equal quality of recycled products. Pascal's experience is that a system exists but it is difficult as it has to be proven that the recycled material remains its quality, while recycled materials are not by definition of less quality. The view on recycled materials being less qualitative needs to be corrected.
- Legal issues are mentioned often as an experienced barrier for recycling.

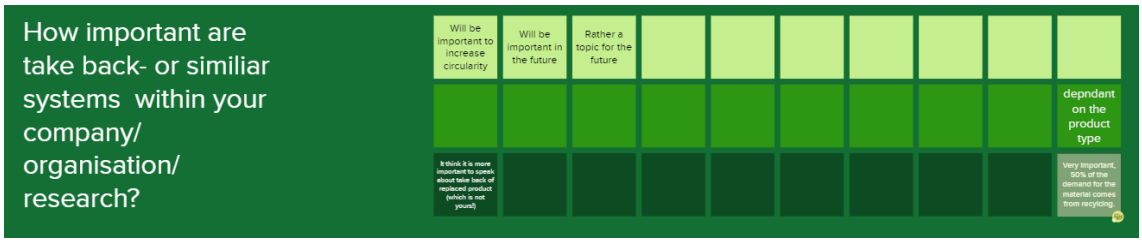
Based on the input received from the participants, it can be concluded that regarding recycling:

- As lots of attendees are involved in the manufacturing or design of products such as brick or metal-based products, there is already an established recycling process existing. The challenge is to guarantee the separation from other materials at the end of the lifespan. The involvement of multiple parties within the value chain is required. In addition, legal and technical restrictions are the most mentioned barrier to ensure the recycling of a product.
- The to-be-developed decision-support framework should outline the different existing exploitation processes and provide positive examples of a high quality recycling.

*Circular business models/take back systems – Are you taking back your products?*




- Pascal sees this more as something for the future, as products needs to be designed first in way that can support such take-back systems and there is a lack of infrastructure for take-back systems.




- Pascal mentions that for some products the lever exists to go to a circular business model, but for many products it does not makes sense to set up take back systems.
- Based on the input received from the attendees, the importance of take-back systems depends on the product type. In case of products that relies on recycling of materials, such systems are very important.


- A big issue pointed out by one of the attendees on the board is the long building lifespan making it difficult to implement a working circular business model. This also experienced by EPEA.

Based on the input received from the participants, it can be concluded that regarding circular business models:

- Most attendees state that circular business models are not part of their design yet. It is rather a topic that will need to be addressed in the future. Important conditions for circular business models are that the infrastructure and logistics for such systems get extended and that the European market for secondary material needs to mature.
- As developing a circular business model is considered a second step, after optimising a product itself, take-back systems will not be addressed within the to-be-developed decision-support framework in detail.

Closing remarks

- Tulay Ozlu (Beşe Insaat) want to give a remark on the third topic regarding lifespan extension of products. I would suggest using the term qualitative lifespan rather than just lifespan, as the quality of a lifespan is important. Pascal and Melanie agree with the suggestion: indeed, if the lifespan of a product is extended but with loss of quality a user would probably replace the product even sooner.
- Anita Ory (Wienerberg) asks if the questions can be made available, as it is also interesting to use it for an exercise within our company with colleagues working on circularity. Pascal confirms that it will be shared together with a summary of all the results in a report and that the participants will be notified when it is available.

Pascal and Melanie thank all attendees for their input and participation.

## Workshop 2 – Circular building design

Date and time: 14 January 2021, 14:00-16:00 CET

Venue: online

**Participants**

Organisers

| | |
|---|---|
| VITO | Wai Chung Lam |
| VITO | Steven Claes |
| EPEA | Pascal Keppler |
| EPEA | Melanie Merz |

Attendees

| | |
|---|---|
| ACE | Selma Harrington |
| Archipelago | Joost Declercq |
| Beşe Insaat | Tulay Ozlu |
| EBC | Ann-Cathrin Roensch |
| ECI | Angela Vessey |
| EcoWise | Piers Larkman |
| ECSPA | Laura Espadas Murillo |
| EPEA | Julius Oldehaver |
| Hacettepe University | Emircan Özçelikci |
| Leiden University | Marc van der Meide |
| Leiden University | Xining Yang |
| Luca School of Arts | Simen Vrancken |
| Metals For Buildings | Christian Leroy |
| SECO | Sye Nam Heirbaut |
| University of Twente | Silu Bhochhibhoya |
| Viuda de Sainz | Uxue Arteagabeitia |
| Wienerberger | Andreas Jäger |
| Wienerberger | Nadine Sampl |
| WKO Austria | Roland Zipfel |
| - | Çağatay Alp Arslan |

**Agenda**

| | |
|---|---|
| Short introduction to ICEBERG | +- 5 min |
| Warm up with two polls (and to get familiar with Miro) | +-10 min |
| Presentation desk research existing circular design qualities and concepts | +- 10 min |
| Interactive part 1: prioritising user requirements | +- 30 min |
| Inspiration from existing circular building project examples<br>Building a better future today!<br>– Jona Michiels, process manager innovation, Van Roey | +- 10 min |
| Interactive part 2: design barriers from your practice | +- 30 min |
| Closure of this workshop | +- 10 min |

**Minutes**

Short introduction to ICEBERG

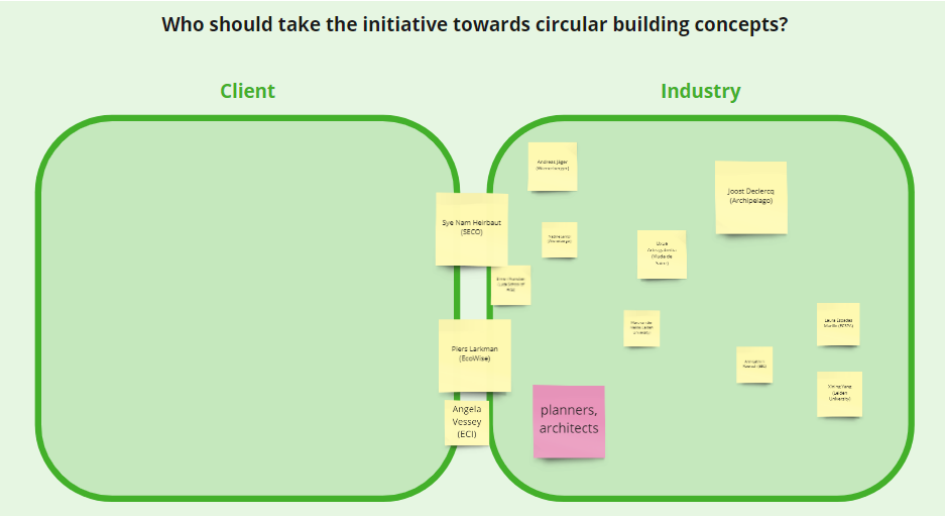
Steven Claes (VITO) welcomes all participants and introduces the ICEBERG project.

Selma Harrington (ACE) asks if the term “donating” buildings used in the introduction of ICEBERG can be clarified. Wai Chung Lam (VITO) explains that the project also includes some demolition projects and some of the materials resulting from the demolition will be used as resources for some of the new product developments done within the project.

Warm up with two polls (and to get familiar with Miro)

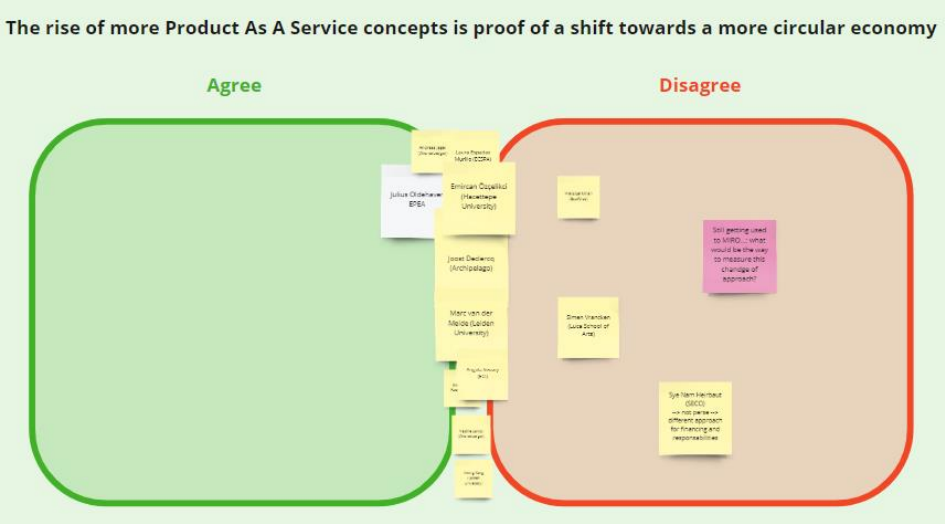
Wai Chung moderates the remaining part of the workshop and asks all participants to go to the online Miro whiteboard. Two polls were set up as a warm-up.

*Poll 1*



Based on the first poll, the majority of the attendees thinks that the initiative towards circular building concepts needs to be taken by the industry. A few attendees thinks the initiative needs to be taken by the client as well as the industry. One of the few is Piers Larkman (EcoWise) and is asked to elaborate on his view. Piers mentions that circular economy ideas are important for everybody to be aware off, to be involved so they are up for it.

*Poll 2*



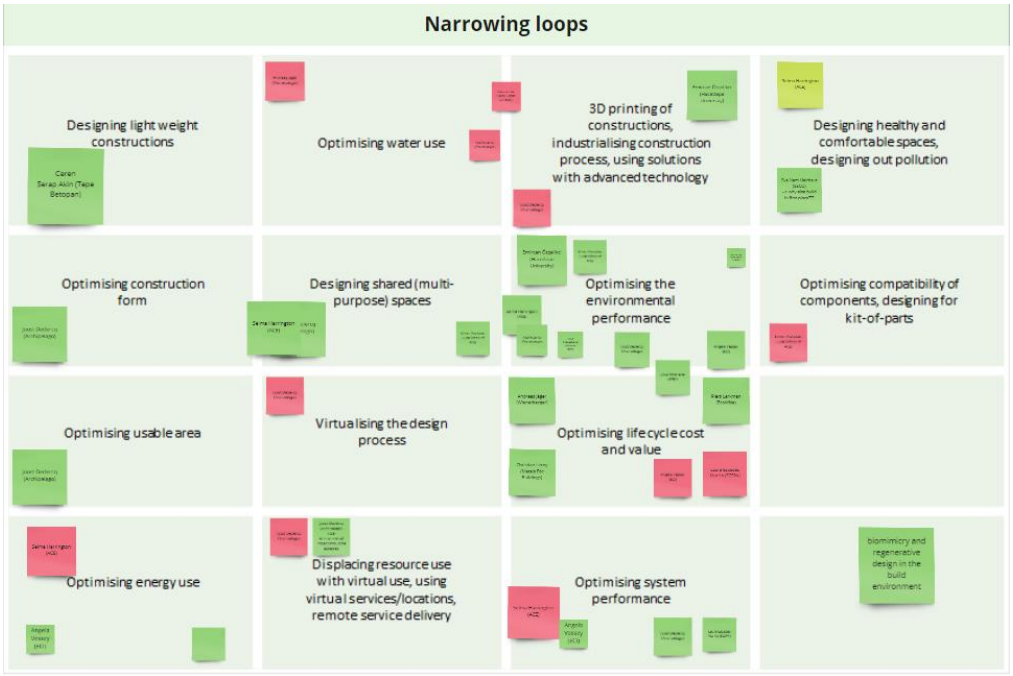

On the second poll the majority of the attendees neither agrees nor disagrees with the statement. Three attendees disagrees, of which Simen Vrancken (Luca School of Arts) is asked to explain his view. Simen would agree if Product As A Service (PAAS) would lead to dematerialisation, however that is not the case and for a circular economy (CE) we should dematerialise products. In addition, Joost Declercq (Archipelago) gives his remarks on PAAS and why he thinks that the majority neither agrees nor disagrees: the concept of PAAS can be helpful as an incentive to move toward a circular built environment, however in the current market the concept is often misapplied as a disguised leasing contract. Also, it is just one part of the CE while it is often used as the main idea and implemented first because it is the easiest to implement. On the Miro board Sye Nam Heirbaut (SECO) elaborated on why he thinks that PAAS is not per se a proof that we are shifting towards a more CE, as it is a different approach for financing and responsibilities. An additional comment that was added on the board by an attendee is the question how to measure this change of approach.

<u>Presentation desk research existing circular design qualities and concepts</u>

As an introduction to the first interactive part of the workshop, Wai Chung presents briefly the main results from the desk research on existing qualities, concepts or requirements that could be adopted in a circular building or products design. There is a big diversity in nomenclature found in the consulted literature. A long list of possible requirements to address circularity in a design was drafted. To group the possible requirements, three main approaches were applied: (1) narrowing the loops, (2) closing loops, and (3) slowing loops. A few requirements, e.g. design for disassembly, can be grouped in two approaches.

Interactive part 1: prioritising user requirements

The goal of the interactive part following the presentation was to prioritise the found user requirements to get a view on the most and least important requirements for the different stakeholders. Attendees were asked to use a green and a red post-it per group to indicate their most and least important requirement respectively per group of requirements. The key remarks and conclusions based on the first interactive part on the Miro board are included below. Important remark: a requirement indicated as least important does not equal as found unimportant.



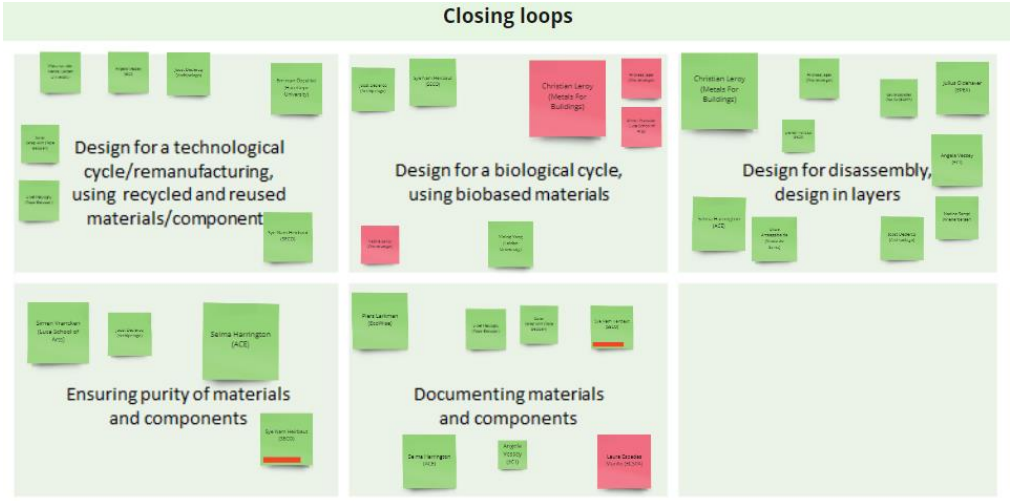

Based on the above screenshot of the prioritisation of possible design requirements to narrow loops, the requirements are ordered from most to less important as follows:

- Optimising the environmental performance
    - Joost Declercq (Archipelago) added the remark that the total environmental impact should be assessed
- Designing shared (multi-purpose) spaces
- Designing healthy and comfortable spaces
    - Sye Nam Heirbaut (SECO) added the remark: why else build in the first place
- Optimising construction form
- Designing lightweight constructions
- Optimising usable area
- Optimising system performance
- Optimising energy use
- Displacing resource use with virtual use, using virtual services/locations remote service delivery
- Optimising life cycle cost and value
- Optimising compatibility of components, designing for kit-of-parts

- Virtualising the design process
- 3D printing of constructions, industrialising construction process, using solutions with advanced technology
- Optimising water use

Attendees could also add requirements that they missed on the whiteboard. The following was suggested for narrowing the loop:

- Biomimicry and regenerative design in the build environment

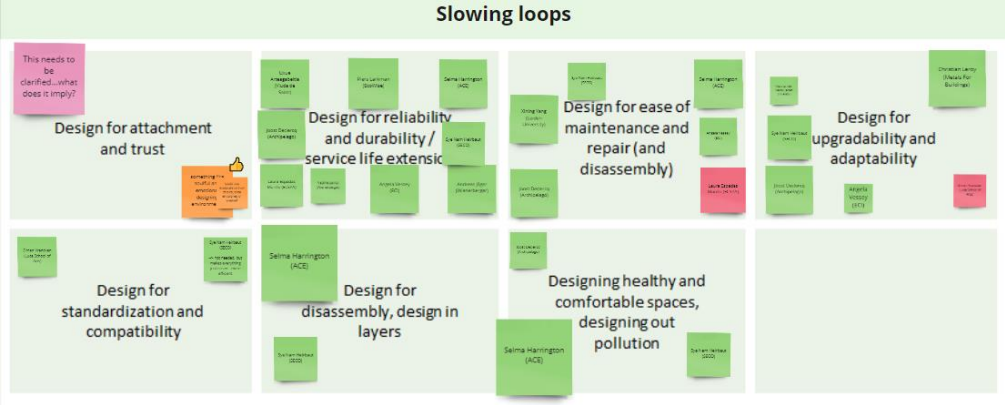



The five possible requirements found in the literature to close loops were prioritised by the attendees as follows (ordered from most to less important):

- Design for disassembly, design in layers
- Design for a technological cycle/remanufacturing, using recycled and reused materials/component
- Ensuring purity of materials and components
    - Sye Nam Heirbaut (SECO) added the remark that the term purity needs to be defined in terms of criteria
- Documenting materials and components
    - Sye Nam added the remark that it should be defined what needs to be documented
- Design for a biological cycle, using biobased materials

Attendees could also add requirements that they missed on the whiteboard. The following was suggested for closing the loop:

- Both sides need to be addressed together: input/production and end-of life stages




Based on the above the screenshot, the possible requirements to slow loops were prioritised as follows (ordered from most to less important):

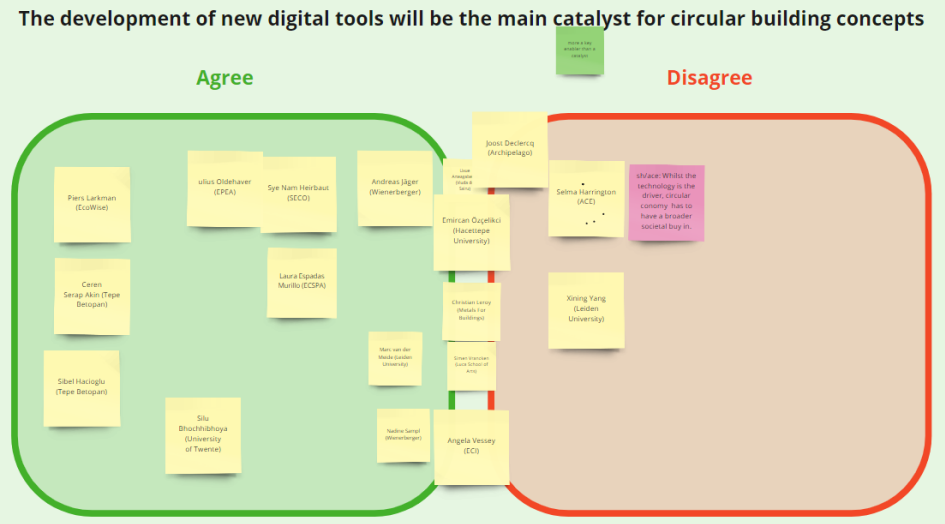
- Design for reliability and durability / service life extension
- Designing healthy and comfortable spaces, designing out pollution
- Design for standardization and compatibility
- Design for disassembly, design in layers
    - An attendee mentioned on the whiteboard that it is not easy to know the difference between disassembly/flexibility
- Design for attachment and trust
    - Attendees made the remark that this requirement needs to be clarified how this could be created. An attendee suggested: something like a soulful and emotional designed environment.
- Design for ease of maintenance and repair (and disassembly)
- Design for upgradability and adaptability

For slowing loops no additional requirements were added by attendees.

→ The prioritisation exercise shows that there is a need for a clear definition of all requirements and guidelines on how to fulfil the requirements, which will be an important issue when the user requirements decision-support framework is being developed.

In addition to the prioritisation of requirements, two additional polls were held among the attendees.

*Poll 3*

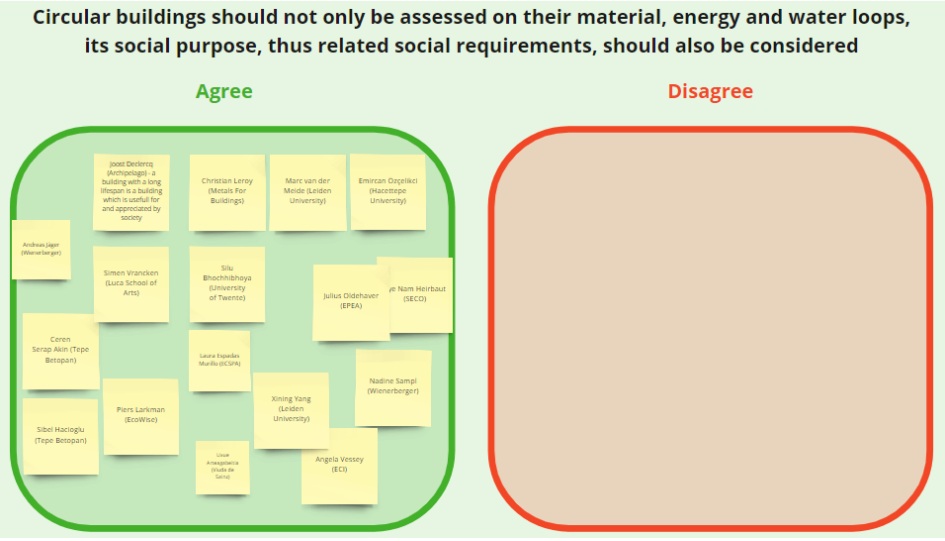



The development of new digital tools is one of the objectives within the ICEBERG project.

- Christian Leroy (Metals For Buildings) gives his view on the formulation of the polling question that by using the term *catalyst* it is difficult to fully agree with the statement, as *catalyst* would describe more the initiation of a process and suggest to use the term *key enabler* instead.
- Selma Harrington (ACE) commented on the Miro board that: whilst the technology is the driver, circular economy has to have a broader societal buy in. In addition, she also explains her view orally: she disagrees with the statement as there is more than tools; the driver is economic and a climatic consciousness of a more broader participation of stakeholders. Technology is a tool and can be pushing and enabling, so in that sense it could be a catalyst. The given statement is a leading question.

Based on the poll and the related discussion, it can be concluded that the majority of the attendees agree with the statement that new digital tools are important, but see tools rather as a key enabler than a main catalyst.

*Poll 4*



All attendees agrees with the last poll that social requirements should be considered. Some attendees elaborated on their view:

- Joost Declercq (Archipelago) added on the whiteboard: a building with a long lifespan is a building which is useful for and appreciated by society.
- Selma Harrington (ACE): if you go back to poorer societies, the awareness of recycling or the value of materials and their reuse at the end of the life cycle, is very well observed and present. So the poorer societies and economies have more innate awareness, they don not always have the technologies or the resources. Therefore it is more important to build on the mechanistic approach of CE and circular buildings, and adding the societal value is of utmost importance. Because without that buy-in there is no CE. The current operating economic model has stimulated consumerism and disposability for decades. The change of view on personal ownership is changing with the awareness of climate. Therefore the social component is much broader than the technical components and has to be the overarching theme in these discussions.
    - Wai Chung: indeed, but we have also noticed that social requirements are difficult to measure.
    - Selma: yes, the question is what makes ownership, but not in a direct sense, by the community of their built environment? This is also related to one of the mentioned requirement on attachment. In heritage it is sometimes more clearer: there is a sense of ownership and belonging. In the urban planning literature, there is the term *placemaking* which sort of explains this immeasurable value. I agree, it is not easy to measure what makes something being accepted or belonging by the society on a specific place. So placemaking might be the term that should be added and then explained in a more technical perspective, like aspects of heritage and aiming to make a building that belongs to that place allowing the community to “own” it with the sense of belonging.
    - Wai Chung: The idea of placemaking exist already for some time. Have we lost the idea of placemaking?
    - Selma: Speaking from my architectural background, it is still very alive, you will find the term in the planning guidelines of local authorities, for example in Scotland or Ireland, used by the government for looking after development and maintenance of built space. To my knowledge most architects advocate placemaking as a term, a concept, and a goal as a feature within their developments of space. It might be worthwhile that your team look into that and tries to give it more technical characteristics.
    - Joost: fully agrees with miss Harrington. Through history, we see that buildings that get a long lifespan are useful for the society and are appreciated by the society. So they are good made places and buildings. Focussing only on a good energy performance and material performance, but designed badly with no spatial quality that people do not like to use will not make a building last long. We often have projects with buildings that are just 20-30 years old and of which the client just wants to demolish them because they do

not fit, are not good made places. Circular building design just starts with a “good design” in the broadest sense.

Inspiration from existing circular building project examples

Jona Michiels (innovation manager at Van Roey) was invited to give a presentation on their practical experiences with circular building. Van Roey is one of the biggest construction group within Belgian providing total solutions. A summary of the main points of Jona’s presentation “Building a better future today!”:

- The presentation includes some the experiments Van Roey has done and the barriers they have faced within those experiments.
- One of the reasons of Van Roey’s to focus on using circular materials is the results of a life cycle assessment of their 33 pprox.. 5-year old headquarters that showed that the strategy of designing and developing a nearly-zero energy building paid off with a low environmental impact due to operational energy use. However the replacement of certain materials during the use stage of 60 years shows a higher impact. During the design process the environmental impact of material use was not a focus and in hindsight it is something that should be done too.
- Some of the experiments of Van Roey:
    - BAMB Circular Retrofit Lab → use case on circular design methods and solutions of different level
    - ProReMat = procurement of reused and recycled materials → economic driver → inventory due to a search for information
    - De Hoorn Leuven → use case of façade in recovered masonry, almost 2000 m2 → experienced barriers:
        - Large quantities of materials are hard to find
        - A need for quality control (instead of what you see is what you get)
        - Reservation system is not in place at vendors of reused materials → missed some lots due to internal approval process of purchasing lots
        - Process regarding quality checks and certificates of reused materials is different → higher risks, higher costs for checks and risks, link with other aspects e.g. insurance
        - Due to time shortage normal cement mortar was used, preventing a 3rd life of the reused bricks. There are alternative mortars on the market ensuring a 3rd life.
    - Facadeclick, a start-up with circular potential → cost effective for large facades without windows → many wall openings and deviations in bricks are an issue
    - MaakLeerPlek Leuven, pilot focussing on reversible design → example making a canopy from a façade system

*Q&A*

- Joost Declercq (Archipelago): 3D printing and automation is often seen as a potential way of reducing material. What is your feedback based on your experiences? What are the problems?
    - Jona: They have a potential if used in the right way e.g. if there is no need for reinforcing steel in construction, material use can be reduced compared to a normal concrete wall. However, a problem is that the concrete materials nowadays use a lot of cement which has no positive impact on an LCA. So, the material itself has to be considered. Using 3D printing as prefabrication of components and in combination with installing the printed components on site with reversible connections has the biggest potential towards a circular construction. Just printing a whole non-reversible building, like we have done in our test case, not.
- Christian Leroy (Metals For Buildings): Reversibility, adaptability, flexibility… it is not always easy to understand the differences. It was nice to see your example of a reversible design that shows that metal structural elements are already well standardised, making it easy to reuse it in other purpose. Did you have a methodology to assess reversibility and reusability of buildings?
    - Jona: Short answer is no. It is interesting though. I often hear questions on developing an assessment tool for circular buildings, but it is such a complex and holistic approach that I think it cannot be quantified in a single score. For me, a circular design is more a philosophy and something that is not meant to just collect scores with like with many other tools. We are still figuring out what a circular building is – there is no 100% circular building. Also assessing reversibility is not figured out yet, because you have to think in different scenarios. It is rather a circular “potential” and you hope that the market will adopt the reuse scenario rather than just demolishing it after its first life.
    - Wai Chung: I agree with Jona, there are still a lot of questions on quantitative assessments of circularity. We don’t want to make wrong comparisons.
    - Christian: Indeed, I am aware of the challenges. But if we want to promote circular buildings, we need to at some point be able to measure circularity.
    - Jona: In my opinion, the biggest challenge is to make the economy part of a circular economy into a reality. The reuse market needs to mature. If demolished materials have a residual value, because somebody wants to pay for it than it will come through.
- Selma Harrington (ACE): At what stage are the decisions made? Which of course depends on the character within the project. As a main contractor, when are you consulted? Does it depends on the set-up of the design team?
    - Jona: At what stage: as soon as possible. Design and build is what we primarily do. In a traditional way of procurement: architect does the design, contractor does the prising, facility manager does the maintenance, everything is a separated part of the process.

Building today, specifically when thinking of a circular economy, the red line in circular business models is the total cost of ownership. Right now building is becoming too complex. You need a holistic approach and by that you need a consortium with all the necessary knowledge and important partners of the whole life cycle of the building to be involved in the project as early as possible. If you have everyone around the table when receiving an output-driven tender from the owner of a building, then circular innovation will be possible.

- Selma: It is interesting to hear. In Ireland there is a mixed view on design and build. In some way architects feel somewhat threatened by the concept of a design and build contract, as sometimes they are invited very late in already advanced process. Also an enlightened client is needed who shares the same vision. Are it mostly public buildings? Is it the public sector who is driven this, or a private investor who wants it property not only to perform but also to belong?
- Jona: In Belgium we have the same discussions that some architects also feel threatened by the concept of design of build. The architect still has an important necessary role but a different role than the classical role we know.
  The kickstarting of the question for circular buildings in Belgium comes from the public sector due to their exemplary role. The biggest innovations today are coming from the public sector. Also because they are willing to pay for it. We are noticing that private investors are becoming aware of this new trend. What we see is like with BREEAM, every public investor wants a BREEAM certificate as it adds value. As renters are also asking for a sustainable building. This is also happing with the requests for circularity.

Thank you Jona for the interesting presentation!

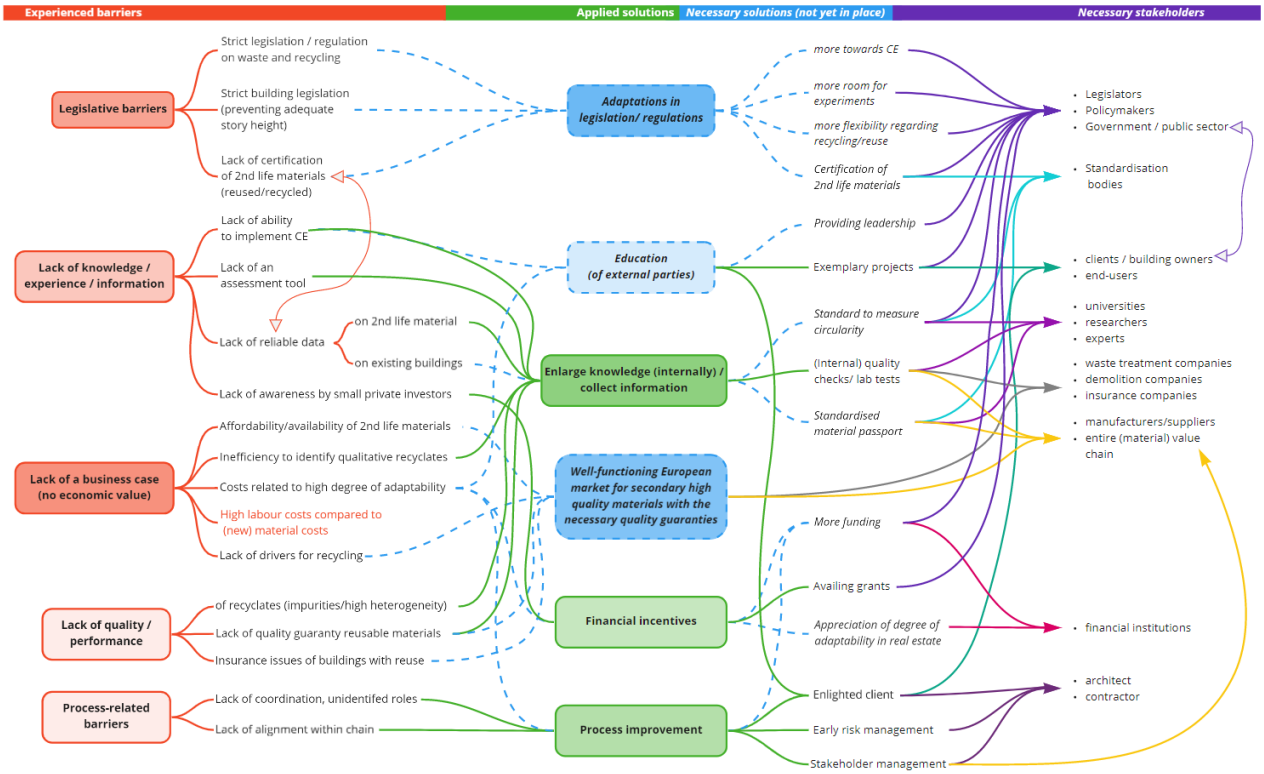
<u>Interactive part 2: design barriers from your practice</u>

The goal of the last interactive part was to collect the experiences of the attendees regarding barriers they have encountered. For each attendee a column of post-its was set up to answer the following:

- Your experienced barrier(s)
- How did you overcome that(/those) barrier(s)?
- What could have prevented that(/those) barrier(s)? (certain needs)
- Which stakeholder(s) should be involved? (to fulfil the needs)

Based on the post-its, the following data mapping regarding barriers could be extracted. On the left side the mentioned barriers are grouped. In the middle the solutions that attendees applied to overcome certain barriers are indicated with a green colour, and the solutions that could have prevented certain barriers but are not yet set in place are indicated with a blue colour and a dashed line. The involvement of certain stakeholders are shown on the right side of the mapping.

The frequency of how much a certain barrier or solution was mentioned is indicated by the intensity of the shading of the boxes. The more mentioned, the more intense the shading.




## Closure of this workshop

Wai Chung thanks all attendees for their contributions.

## Workshop 3 – internal workshop during general assembly

Date and time: 19 January 2021, 9:40-11:00 CET

Venue: online during the general assembly

**Participants**

Organisers

| | |
|---|---|
| VITO | Wai Chung Lam |
| VITO | Steven Claes |
| EPEA | Pascal Keppler |
| EPEA | Melanie Merz |

Attendees

Project partners of the ICEBERG project that attended the second day of the general assembly

**Agenda**

| | |
|---|---|
| EPEA inspiration: definition of circular products | +- 15 min |
| Interactive part 1: requirements for circular products | +- 20 min |
| VITO presentation: desk research existing circular building requirements | +- 5 min |
| Interactive part 2: requirements for circular buildings | +- 25 min |
| Discussion/ closure of this workshop | +- 10 min |

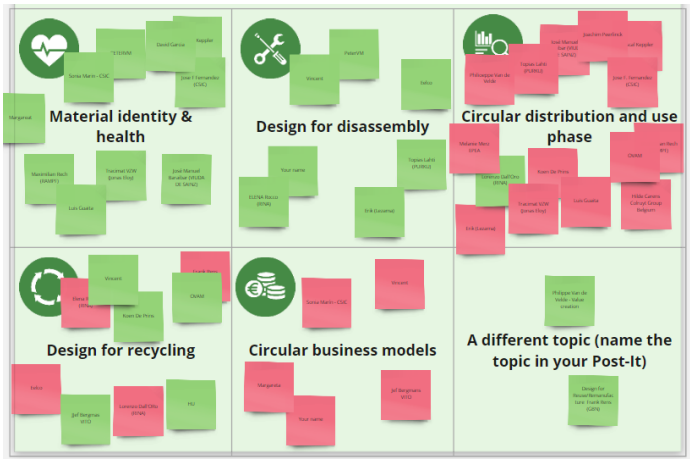
**Minutes**

EPEA inspiration: definition of circular products

As an introduction to the first interactive part, Melanie Merz (EPEA) gives a shorter version of the presentation given in Workshop 1.

Interactive part 1: requirements for circular products

Pascal Keppler (EPEA) moderates the first interactive session via an online whiteboard on Miro. This first interactive part existed of two parts. In the first parts, the attending project partners were asked to prioritise the five circular product design topics. They were asked to use a green post-it to indicate their most important topic and a red post-it for their least important topic.



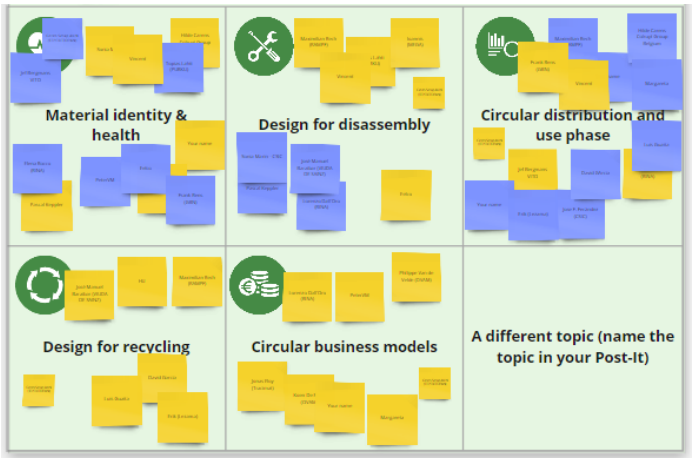

Based on the above screenshot of the prioritisation of circular product design topics, the topics were ordered from most to less important as follows:

- Material identity & health
- Design for disassembly
- Design for recycling
- Circular business models
- Circular distribution and use phase

Attendees could also suggest a topic. The following two topics were suggested:

- Design for reuse/remanufacture
- Value creation
    - Philip Van de Velde (OVAM) was asked to elaborate on his suggestion: with circular design we need to make sure that value is added. Therefore new business models need to be developed. E.g. by assigning material value to buildings.

In the second part of the first interactive part of the workshop the attendees were asked to identify the most challenging topics by sticking a yellow post-it on the most challenging topic and a blue post-it on the least challenging post-it.




The circular product design topics were ordered by the attending project partners as follows in order of most challenging to least challenging:

- Circular business models
- Design for recycling

- Design for disassembly
- Material identity & health
- Circular distribution and use phase

During the first interactive part the following comments were given:

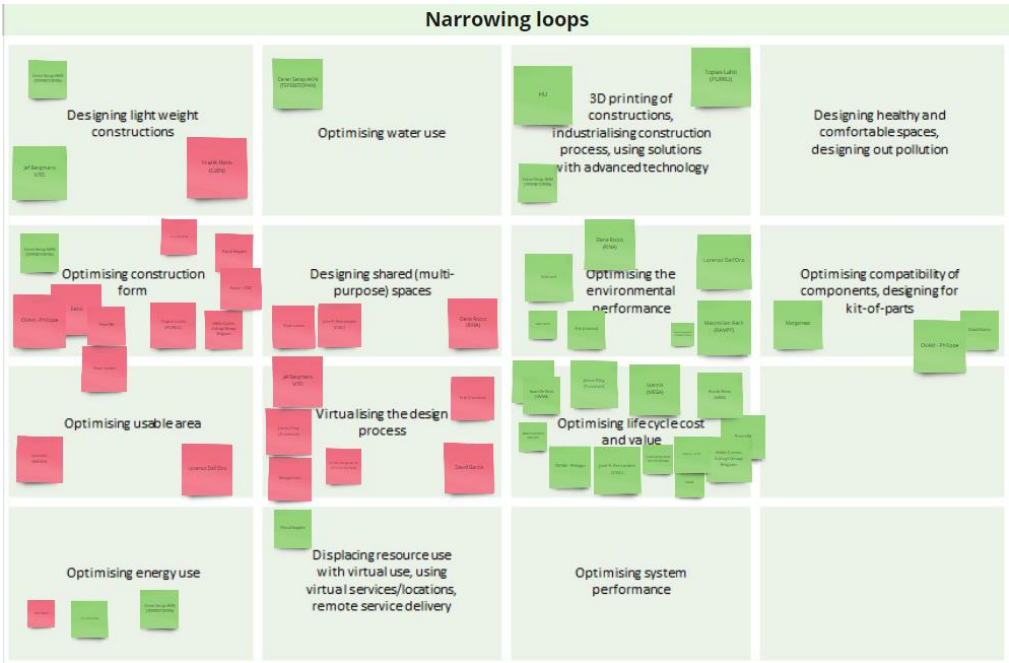
- The difference between disassembly and recycling = how do you get the material out of the building versus how do you separate the materials of a component.
- Focus on material passports.
- The costs for society needs to considered. Redistribute the costs if no positive net results are achievable.
- Mohamed Osmani (Loughborough University): regarding business models, break it down to the component level.
- Hilde Carens (Colruyt Group): we lack information about our buildings, especially of our older buildings. A learning curve is needed and we need to think what we can do with those materials. However, retaining information requires a lot of money and time.

VITO presentation: desk research existing circular building requirements

As an introduction to the second interactive part, Wai Chung Lam (VITO) gives the same presentation as given in workshop 2 on the main results from the desk research on existing qualities, concepts or requirements that could be adopted in a circular building or products.

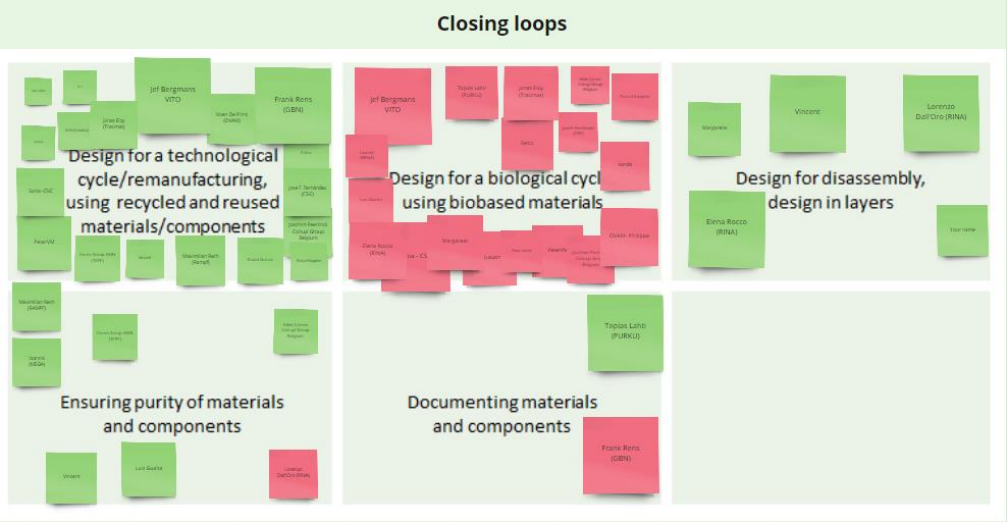
Interactive part 2: requirements for circular buildings

Similar to workshop 2, the attendees were first asked to prioritise the most (green post-it) and least (red post-it) important requirements per group of requirements. Second, the attending project partners were asked to share their experienced barriers, how they did overcome them, what could have prevented the barriers, and which stakeholder(s) should be involved to prevent the barriers.




The attending project partners prioritised the possible requirements found in literature for narrowing loops as follows (ordered from most to less important):

- Optimising life cycle cost and value
- Optimising the environmental performance
- Optimising compatibility of components, designing for kit-of-parts
- 3D printing of constructions, industrialising construction process, using solutions with advanced technology
- Displacing resource use with virtual use, using virtual services/locations remote service delivery
- Optimising water use
- Designing light weight constructions
- Designing healthy and comfortable spaces
- Optimising system performance
- Optimising energy use
- Designing shared (multi-purpose) spaces
- Optimising usable area
- Virtualising the design process
- Optimising construction form

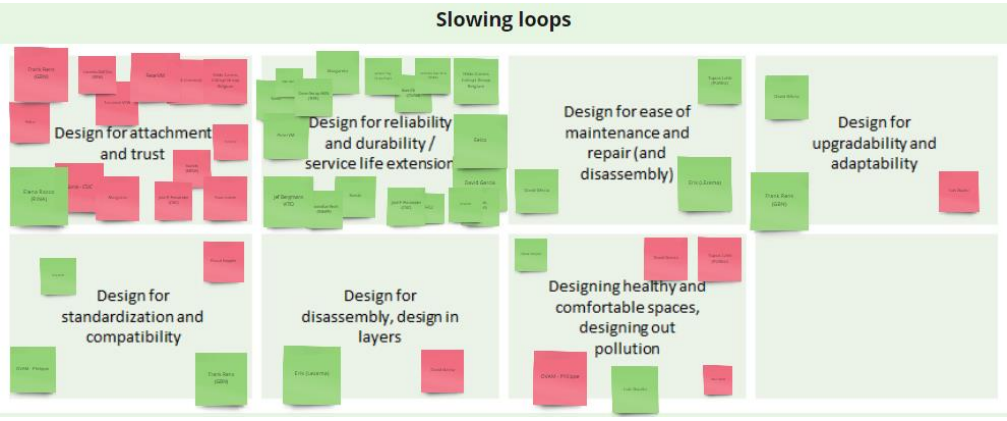



The possible requirements found in literature for closing loops were prioritised by the attending project partners as follows (ordered from most to less important):

- Design for a technological cycle/remanufacturing, using recycled and reused materials/component
- Design for disassembly, design in layers
- Ensuring purity of materials and components
- Documenting materials and components
- Design for a biological cycle, using biobased materials

Regarding the requirement on using biobased materials which was voted as least important, the following comments were given during the workshop at the general assembly:

- The biological cycle is less applicable in the building sector compared to the technical cycle.
- Of biological materials, the impact on land use needs to be kept in mind.
- Hilde Carens (Colruyt Group): least important does not mean it is not important. There are less opportunities for biobased materials.



The attending project partners ordered the possible requirements found in literature to slow loops as follows (ordered from most to less important):

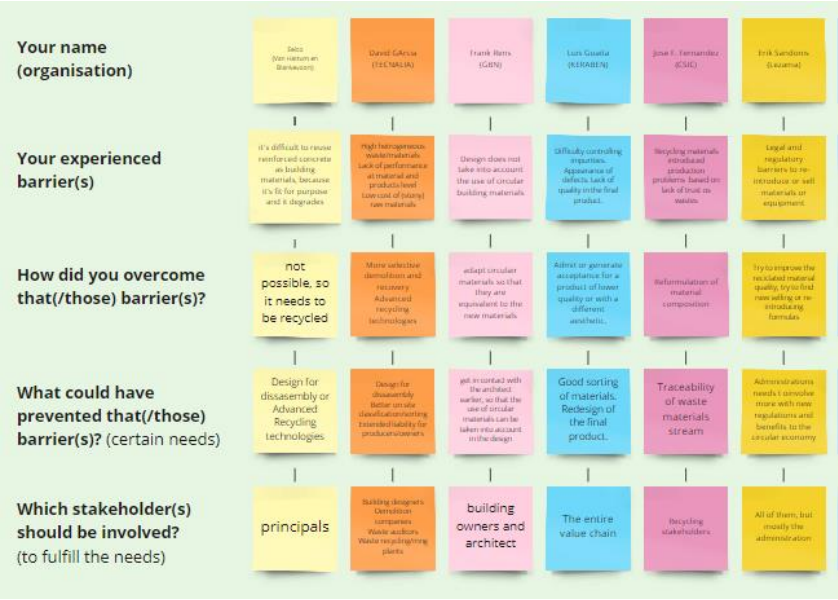
- Design for reliability and durability / service life extension
- Design for ease of maintenance and repair (and disassembly)
- Design for standardization and compatibility
- Design for upgradability and adaptability
- Design for disassembly, design in layers
- Designing healthy and comfortable spaces, designing out pollution
- Design for attachment and trust

The following remarks were given during the workshop regarding the requirement on designing for attachment and trust:

- Wai Chung Lam (VITO): it is remarkable that in this workshop, this requirement was indicated so many times as least important while in the previous workshop we had a discussion on the importance of this requirement. Elena is the only attendee who voted it as most important.
- Elena Rocco (RINA): if there is more attachment to a building, it will be better maintained.
- Vincent Barraud (Soprema): if a client is buying a product, is the trust not already there?

→ also this workshop shows that there is a need for clear definitions of the requirements.

Like in workshop 2, attendees were asked in the last part of the workshop to fill in their experiences of regarding barriers they have encountered.




The following contributions regarding barriers were given by attending project partners:

| Your name (organisation) | Your experienced barrier(s) | How did you overcome that(/those) barrier(s)? | What could have prevented that(/those) barrier(s)? (certain needs) | Which stakeholder(s) should be involved? (to fulfil the needs) |
|---|---|---|---|---|
| Carens, Hilde (Colruyt Group Belgium) | 1) knowing the possibilities of what we can do with our materials and elements | by working together with material suppliers, legislation and external experts | a central point / database of material information or an open platform to connect with others in one place instead of searching the internet for a fraction of the necessary items | 1) legislation 2) material suppliers 3) owners 4) construction workers 5) experts / study bureaus 6) universities |
| | 2) legislation around recycled content | | | |
| | 3) the economic value of reused or recycled content | | | |
| Jose F. Fernandez (CSIC) | Recycling materials introduced production problems based on lack of trust of wastes | Reformulation of material composition | Traceability of waste materials stream | Recycling stakeholders |
| Luis Guaita (KERABEN) | Difficulty controlling impurities. Appearance of defects. Lack of quality in the final product. | Admit or generate acceptance for a product of lower quality or with a different aesthetic. | Good sorting of materials. Redesign of the final product. | The entire value chain |
| Frank Rens (GBN) | Design does not take into account the use of circular building materials | adapt circular materials so that they are equivalent to the new materials | get in contact with the architect earlier, so that the use of circular materials can be taken into account in the design | building owners and architect |
| Eelco (Van Hattum en Blankevoort) | it's difficult to reuse reinforced concrete as building materials, because it's fit for purpose and it degrades | not possible, so it needs to be recycled | Design for disassembly or Advanced Recycling technologies | principals |
| David Garcia (TECNALIA) | High heterogeneous waste/materials Lack of performance at material and products level Low cost of (stony) raw materials | More selective demolition and recovery Advanced recycling technologies | Design for disassembly Better on site classification/sorting Extended liability for producers/owners | Building designers Demolition companies Waste auditors Waste recycling/mng plants |
| Erik Sandonis (Lezama) | Legal and regulatory barriers to re-introduce or sell materials or equipment | Try to improve the recirculated material quality, try to find new selling or re-introducing formulas | Administrations needs t involve more with new regulations and benefits to the circular economy | All of them, but mostly the administration |
| Kanda Philippe (KEEY) | Lack of experience in construction materials and design | | | |
| Maximilian Rech (RAMPF) | 1.) Creating usable recycled product for reusage in existing production lines while matching the needed specifications, therefore finding possible options for degrading the materials without hindering the following production of the final product. | Lab scale analysation, experiments, know-how, generated over the years | separation, clean cutting (without materials like metal chips), using non-toxic materials in production line | Producer End-User Demolisher |
| | 2.) Impurities, that hinder the recycling process or causing conflicts with new product from recycled material | | | |
| | 3.) Health risk through degrading | | | |
| Margareta (VTT) | Currently downcycling favorized, economic aspects, lack of proof in many case, lack of demonstrations | public works demonstrating (should be required by public constructors to introduce new solutions, also education or all stakeholders along the value chain | lack of knowledge, trust for that solution reliable (especially meet the technical requirements) | the end-user and the constructor and also in case of demolition (the building owner) |
| ORBIX NX | Certification, legislation | Performance and tests Proof benefits | No flexibility in legislation for new products | Government |
| Topias Lahti (PURKU) | Legislation on waste and recycling (reusing recycled concrete in new buildings) | renewing the legislation | Laws that back up circular economy | Authorities and legislators |
| Joachim Peerlinck (Colruyt Group) Belgium | How materials/elements can be reused and recycled | searching the internet at many places... | a website/place where you can easily share elements to others to reuse + a list where for all materials is given how it is recycled(or not) and which are possible reuse applications | '-study bureaus -construction company -demolisher' |
| Pascal Keppler (EPEA) | Legislation or usual practices do not permit innovation for circularity | We try to influence policymakers to be open for innovation and prove feasibility | Laws that benefit circular construction not slow it | All stakeholders of the construction industry need to be involved |
| Soprema | The raw material used in the past. No solution for the insulation thermosetting board | Analyze the initial product Lab scale Analyze the raw material Lab test | Clean the input product | Demolisher Procurer |
| Tiihonen | Building material requirements regulate reuse and new innovative structures | Idea for more free experimental building structures | | |
| Sonia (CSIC) | knowing the real percentage of type of demolition material that we have to work with | | design for disassembly and pre-sorting/storing | |

During the last part of the workshop, the following explanations or remarks were given:

- Topias Lahti (Purkupiha): legislations on waste and recycling makes everything harder, e.g. concrete recycling. Using recycled concrete in new buildings is not allowed in Finland. New legislation should be adopted that would allow possibilities of using recycled materials.
- Tulay Ozlu (Beşe Insaat): there is a need for a certification process, European legislation, and a clear policy vision on a product level.
- Kanda Philippe (Keey Aerogel): it would be helpful to know how the material is used in a building, like how the end user would integrate it in their design.

- Francesco: I did not hear the word "quality". I think that the assessment of the material quality and the performances related to those quality, should play an important role

Closure of the workshop

Melanie, Pascal, and Wai Chung thank the attending project partners for their useful inputs and active contribution.

## References

Acharya, D., Boyd, R. and Finch, O. (2018) *From principles to practices: first steps towards a circular built environment*.

ARUP (2016) *The Circular Economy in the Built Environment*, *Callifornia Academy of Sciences, San Francisco, USA*.

Bocken, N. M. P. *et al.* (2016) 'Product design and business model strategies for a circular economy', *Journal of Industrial and Production Engineering*, 33(5), pp. 308–320. doi: 10.1080/21681015.2016.1172124.

Cambier, C. *et al.* (2019) 'Building a Circular Economy. Buildings, a Dynamic Environmente', *V. A. E. Vrije Universiteit Brussel, Ed. Brussels*.

EU-JRC (2020) *Level(s) common framework*. Available at: https://susproc.jrc.ec.europa.eu/product-bureau/product-groups/412/documents.

Malmqvist, T. *et al.* (2020) 'Circularity in the built environment: a call for a paradigm shift', in *Handbook of the Circular Economy*, pp. 425–438. doi: 10.4337/9781788972727.00042.

OVAM (no date) *24 Ontwerprichtlijnen veranderingsgericht bouwen*.