Deliverable 4.2

Intermediate report: demonstration of technological solutions fostering circular economy

Work package number: WP4

Lead beneficiary: GBN Groep B.V.

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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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Executive Summary

ICEBERG solutions developed in WP1, WP2 and WP3 are demonstrated in WP4 through 6 circular case studies (CSS) across different locations in Europe, representing common European building typologies (residential and non-residential), execution practices and multiple building materials accounting for more than 85% by weight of the European built environment.

These CCS follow a common approach, including the following activities:

1) Pre-demolition audit
2) Execution of selective refurbishment/demolition
3) EBM processing: industrial application of new sorting and processing technologies
4) Resource-efficient production of new circular building products
5) Installation and use in representative building spaces
6) Demonstration of the new digital EBM traceability service
7) Simulation of easy disassembly of the new building products in mock-ups.

The building companies will extend the durability monitoring of the installed circular building products beyond ICEBERG duration, thus contributing to the social and market confidence on the new solutions.

This document reports the first activities, describing and illustrating the intermediate advances for each CCS, with a focus on pre-demolition activities and smart demolition works.

Acronyms

ADR: Advanced Dry Recovery

BAU: Business As Usual

BIM: Building Information Modelling

BIM4DW: BIM-aided Smart Pre-Demolition tool

BS: British Standard

C2CA: Advanced Technologies to produce Cement and Clean Aggregates from Construction and Demolition Waste (*Concrete 2 Cement and Aggregates*)

CCS: Circular Case Study

CDW: Construction and Demolition Waste

CTP: Cloud Traceability Platform

EA: Environmental Agency

EBM: End-of-Life Building Materials

EOL: End-of-Life

GA: General Assembly

GYPS: British Gypsum

HAS: Heating air and classification system

ICEBERG: Innovative Circular Economy Based solutions demonstrating the Efficient recovery of valuable material Resources from the Generation of representative end-of-life building materials

LCA: Life Cycle Analysis

LCC: Life Cycle Costing

LIBS: Laser-Induced Breakdown Spectroscopy

LU: Loughborough University

QR: Quick Response

RFID: Radio Frequency Identification

SC: Steering Committee

URL: Uniform Resource Locator

WP: Work Package

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1 Introduction

Construction, renovation, and demolition waste (CDW) is one of the heaviest and most voluminous waste streams generated in the EU (350 Mt/year, excluding excavation waste). Proper management of CDW and recycled materials can have major benefits in terms of sustainability and the quality of life. It also can provide major benefits for the EU construction and recycling industry, as it boosts demand for recycled building materials.

As part of a continuous effort towards a sustainable economy, the European Council (EC) adopted in 2015 a new Circular Economy Package with measures prioritizing End of Life Building materials among others. The ICEBERG[1] project, funded under H2020-EU.3.5.3, will make significant advances in the uptake of the circular economy in the building industry through the development of innovative circular reverse logistics' tools and high-value secondary raw materials production technologies to establish market confidence and acceptability of recycled End-of-Life building materials (EBM).

Therefore, ICEBERG aims to develop and demonstrate novel cost-effective circular smart solutions for an upgraded recovery of secondary building raw materials along the entire circular value chain: from EBM to new building products prepared for circularity, resource-efficiency and containing 30wt% to 100wt% of high-purity (>92%) recycled content.

Solutions will be demonstrated through 6 circular case studies (CSS) across different locations in Europe, representing common European building typologies (residential and non-residential), execution practices and multiple building materials accounting for more than 85% by weight of the European built environment. Figure 1 shows the locations and building materials of the 6 circular case studies conducted in work package 4.

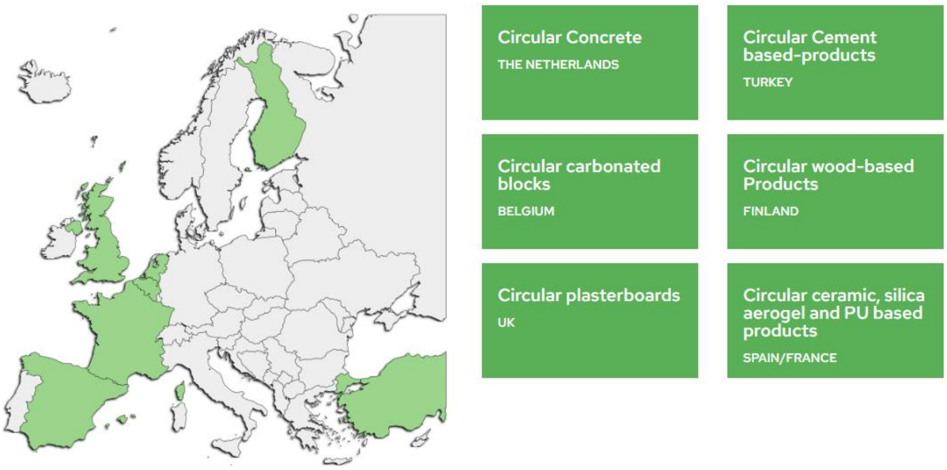


Figure 1. Circular case studies across different locations in Europe, representing common European building typologies, execution practices and multiple building materials

[1] Innovative Circular Economy Based solutions demonstrating the Efficient recovery of valuable material Resources from the Generation of representative End-of-Life building materials. More information about ICEBERG can be found on: https://iceberg-project.eu/

2 Description of WP4

2.1 Objectives of WP4

The objective of work package 4 is to demonstrate (at TRL7) the feasibility and cost-effectiveness of smart circular building solutions through 6 case studies across different locations in Europe representing common European building typologies (residential and non-residential), execution practices and multiple EBMs accounting for more than 85% of the European built environment. Additionally, the objective of work package 4 is to identify, quantify and evaluate the energy and water efficiency of each ICEBERG circular solution through the measurement of energy and water consumption across the supply chain and comparison with existing commercial solutions.

2.1.1 Circular case studies (CCS)

The circular case studies (CSS) conducted in Work Package 4 are shown in Table 1. In the next paragraphs, the objective of each CCS is described.

Table 1. Overview of circular case studies (CCS) and tasks.

Nr.	Title	Task	Location
	Circular design of the CCS	4.1	
CCS1	Case study demonstrating circular concrete	4.2	The Netherlands
CCS2	Case study demonstrating circular cement-based products	4.3	Turkey
CCS3	Case study demonstrating circular carbonated blocks	4.4	Belgium
CCS4	Case study demonstrating circular wood-based products	4.5	Finland
CCS5	Case study demonstrating circular plasterboards	4.6	United Kingdom
CCS6	Case study demonstrating circular ceramic, silica aerogel and PU based products	4.7	Spain/ France

2.1.2 Objective of CCS1 – Case study demonstrating circular concrete (task 4.2)

Leader: GBN; Participants: KEEY, TUD, VW[2], TECN, SERI

Objective: To demonstrate smart circular building solutions for upgraded recovery of EoL concrete used in new structural ready-mix concrete structures (>75 wt%) and concrete building block system with U<0.21 W/m2K.

Description:

[2] Due to the withdraw of VW (VolkerInfra), task 4.2 has changed. A new partner (Roosens) has joined the project to produce 30 m3 concrete blocks, 5 m3 concrete slabs and 500 m3 ready mix concrete.

1) Selection and pre-demolition audit of a non-residential building of around 1500 m2 in The Netherlands (GBN, SERI).
2) Collect and separate EBM concrete fraction for further processing (GBN).
3) Treat >1000 ton of concrete waste to produce coarse recycled aggregates (>4 mm) (C2CA), high quality recycled concrete sands (0.25-4mm) and dry cementitious material (<0.1 mm), which will be characterized in real-time by the LIBS-based quality assurance system (TUD).
3.1) Produce (KEEY) silica granular aerogel.
3.2) Produce new structural ready-mix concrete (500 m3) and precast building blocks (100 m2) using concrete fractions recycled on-site (>75 wt%).
4) Construct new non-residential building (demo surface of nearly 200 m2) with recycled concrete and precast building blocks with circular silica granular aerogels for external and internal walls (VW) with U<0.23 W/m^{2}K.
5) Validate the CTP adopted for the traceability of circular concrete products through RFID-based tags and collect information for WP5 (TUD).
6) Characterise building products and assess materials, energy, and water efficiency (TECN, TUD, GBN, VW).

2.1.3 Objective of CCS2 – Case study demonstrating circular cement-based products (task 4.3)

Leader: BESE; Participants: HU, TEPE, CIMS, KEEY, SERI

Objective: To demonstrate smart circular building solutions for enhanced recovery of concrete, ceramic, glass, gypsum, and wood fractions through i) Novel Eco-Hybrid Cement (35 wt% of RBM), ii) Ultra-lightweight non-structural concrete wall elements and green woodchip concrete panels (100 wt% of RBM) and iii) Prefabricated recycled concrete structural elements (>75 wt% of recycled concrete and U< 0.26 W/m2K).

Description:

1) Perform the pre-demolition audit of 1 or 2 EoL residential building with 4 to 6 floors of about 1500m² (BESE, SERI).
2) Identify useful EBMs and perform selective demolition, on-site sorting, transfer, and storage of concrete (900-1300 ton), bricks (40-50 ton), ceramics (35-45 ton), gypsum (20-50 ton), glass (5-7 ton) and wood (8-20 ton) (BESE).
3) Process EBMs for the production of intermediate products: 3.1) Pre-treat Concrete (180 ton), brick/ceramic (30 ton), glass (3 ton) and gypsum (3 ton) waste to produce Novel Eco-Hybrid Cement (CIMS); 3.2). Modify wood waste with alkali-treatment to obtain improved wood fibres (3-4 ton) (TEPE); 3.3) Treat EoL concrete to obtain recycled coarse aggregates (150 ton) and recycled fine aggregates (30 ton) (BESE).
4) Transform intermediate products into final products (TEPE): 4.1) 1x3x0.02 m green woodchip concrete panels (330 m2 in total) employing all recycled green material (novel eco-hybrid cement, recycled concrete aggregates, alkali-treated recycled woodchips);4.2) 0.5x0.5x0.15 m ultra-lightweight non-structural concrete wall elements (130 m2 in total) enhanced by incorporating SICLA aerogels (KEEY); 4.4) Precast structural elements (30-35 m3) composed of 12 columns (0.4x0.6 m) and 17beams (0.4x0.6 m).
5) Design and construct (BESE) 1-storey residential building with nearly 200 m2 and 3 m of height (U value <0.25 W/m2K) using a fully demountable structure.
6) Validate the CTP adapted to the traceability of circular cement-based products (HU).
7) Characterize building products and assess their materials, energy, and water efficiency (HU, BESE, TEPE, CIMSA).

2.1.4 Objective of CCS3 – Case study demonstrating circular carbonated blocks (task 4.4)

Leader: COLR; Participants: OVAM, ORBI, TRAC, VITO, SERI

Objective: To demonstrate smart circular building solutions for enhanced recovery of EoL concrete by carbonation of coarse recycled concrete aggregates and subsequent production of structural concrete and new demountable building blocks by the carbonation of recycled concrete fines (>60 wt%, U<0.22 W/m2K)

Description:

1) Pre-demolition audit of an outdated department store building in Flanders with about 1500 m² surface (COLR, SERI).

2) Perform selective demolition (COLR), building decontamination and production of pure concrete waste fraction (>12 ton) including a high-grade concrete fraction and selective collection of other EBM fractions for which an economically viable recycling route exists in Flanders (e.g., PVC recycling by Deceuninck, LoI in section 4).
3) Pre-treat and carbonate coarse concrete aggregates (12 ton) (ORBI).
4) 4.1) Produce structural concrete (15 m3) using coarse recycled aggregates enhanced through carbonation. 4.2) Produce pre-cast demountable building hollow blocks using carbonated aggregates to reduce the water absorption (<5%) (ORBI).
5) Construct inner wall structures (estimated surface: 25 m2 and U<0.22 W/m2K) using the hollow block system including insulation in a new supermarket with nearly 400 m² surface and cast foundation with concrete containing improved coarse concrete aggregates to replace natural aggregates (>50 wt%) (COLR).
6) Validate the CTP adapted to the traceability of circular carbonated blocks (TRAC).
7) Characterize carbonated products and assess the resource efficiency (COLR, ORBI, VITO). The design solutions will be applicable to other constructions of COLR and other buildings in Flanders (OVAM).

2.1.5 Objective of CCS4 – Case study demonstrating circular wood-based products (task 4.5)

Leader: PURKU; Participants: SOPR, VTT, TIIHO, MEGA, SERI

Objective: To demonstrate smart circular building solutions for enhanced recovery of EoL wood in novel wooden insulation panels (U<0.17 W/m2K) with 50-95 wt% recovered wood fibres and 2.5 wt% bio phenolic resin obtained through the fast pyrolysis and purification process.

Description:

1) Perform the pre-demolition audit of an EoL building containing high amount of wood in structure, partitions, and envelope (VTT and PURKU remotely supported by SERI) in Finland, guaranteeing 20 tons of wood waste for the processing step and at least 5-10 construction wooden products for reuse.
2) Conduct selective demolition activities, sorting, and separation of wooden reusable products, high-quality (pure) wood waste free of impurities and mixed wood waste containing impurities (PURKU).
3) 3.1) Undertake reuse operations of the construction products (TIIHO). 3.2) Mechanically process wood waste through the novel integrated crushing and sorting system to produce at least 10 ton of recycled wood fibres (for panels) from the pure wood waste and 7 ton of wood particles from the mixed wood waste (for pyrolysis). (TIIHO) 3.3) Produce at least 100 kg of bio-oil for pretesting of purification (fractioning of pyrolysis oil) and other 250 kg for the synthesis of biophenolic-resins (VTT). 3.4) Convert bio-oil into a biophenolic-resin through the optimization of the formula and the synthesis parameters (reaching a 50% phenol replacement level) and pilot-scale production of 500 kg of biophenolic-resins (MEGA).
4) Produce 10.5 ton of insulation panels using 10ton of wood fibres and 500 kg of biophenolic-resins (SOPR).
5) Install panels and reused wooden products at least in the walls and roof of a technical room (8x8x4 m, with 128 m2 of walls and 64 m2 of roof and floor) in an industrial construction of 500 m2. The estimated thickness of the insulation is 25.0 mm for the walls and 47.0 mm for the roof to meet the requirements of the regulations in Finland (U<0.17 W/m2K for the walls and U<0.09 W/m2K for the roof).
6) Validate the CTP adapted to the traceability of circular wooden products through RFID-based tags (VTT).
7) Characterize the building wooden products and assess their easy-disassembly and materials, energy, and water efficiency (VTT, TIIHO, SOPR, MEGA).

2.1.6 Objective of CCS5 – Case study demonstrating circular plasterboards (task 4.6)

Leader: GYPS; Participants: LENZ, ENVA, LU, KEEY

Objective: To demonstrate the application of the novel circular plasterboard (U<0.28 W/m2K) using 35 wt% recycled gypsum in two refurbishment projects (B1 and B2) on the LU site.

Description:

1) Perform pre-demolition audit of 2 buildings located at LU campus (dismantle, collect and tag approximately 720m2 EoL plasterboard from building B1 and install the new circular products in refurbishment of building B2).
2) Undertake dismantling process, transport to the recycling plant and sort EoL gypsum from post-consumer plasterboards and synthetic gypsum by-products (citrogypsum and phosphogypsum) (ENVA).
3) Execute HSI processing of large impurities, paper-gypsum powder separation and hydrocyclone treatment of resulting gypsum powder combined with acid purification to separate minor impurities (LENZ, ENVA, LU).
4) Transport treated gypsum powder to GYPS and manufacture 1000 m2 of ICEBERG plasterboards with 35 wt% treated gypsum powder and silica aerogels (KEEY) to enhance their thermal performance.
5) Install ICEBERG plasterboard in the refurbishment (B2with 1500 m2) guaranteeing a U<0.28 W/m2K.
6) Validate the CTP adapted to the traceability of circular plasterboards products through RFID-based tags (LU).
7) Characterize circular plasterboards and assess their easy-disassembly and material, energy, and water efficiency (GYP, LU, ENVA).

2.1.7 Objective of CCS6 – Case study demonstrating circular ceramic, silica aerogel and PU based products (task 4.7)

Leader: VDA; Participants: TECN, LEZA, GAIK, KEEY, KERA, LENZ, RAMP, SOPR, SERI

Objective: To demonstrate smart circular building solutions for enhanced recovery of EoL ceramic, concrete, PU/ PIR foams and glass/silica containing fraction used (>50 wt%) as purified raw material in i) novel ceramic tile floors; ii) new circular PU panels (15-50 wt% recycled polyols); and iii) PU panels containing PU aerogels (U< 0.19 W/m2K).

Description:

1) Undertake the pre-demolition audit of an EoL industrial building (approximately 2000 m2) in the Spanish province of Biscay (LEZA, SERI).
2) Apply smart demolition process and selective sorting (LEZA) of the stony fraction (containing a mixture of concrete, red ceramic rubble and impurities (the stony fraction (concrete and ceramic) will be jointly demolished and on-site stocked in order to guarantee economic feasibility at the demolition stage), glass, PU/ PIR, and others (other EBM materials can arise, without constituting the target area for this case study. They will be managed following feasible available options).
3) Perform crushing and sieving (LEZA, VDA) of mixed stony fraction (> 25ton) and use HSI mobile system programmed to increase the sorting efficiency of ceramic fraction, concrete fraction, and post-consumer mixed PU/PIR foams (GAIK, LENZ). Collect Glass waste using traditional selective demolition processes (LEZA).
4) 4.1) Manufacture 250 m2 of novel circular designed ceramic tile floors (KERA) using at least 3 ton of purified red ceramic granular material, 1 ton of purified concrete, 0.8 ton of clean glass and 0.5 ton of green waterglass (KEEY). 4.2) Produce 25 m3 of circular silica granular aerogels using purified glass fraction (>2.5 tons) (KEEY).4.3) Subject the sorted PU/PIR fractions to the optimized solvolysis and filtration routes (RAMP) to produce recycled polyols (>2 tons), which will be incorporated (15%-50 wt%) in new circular PU panels (67-85 units of 1.2x3x0.1m3) and PU panels containing circular PU aerogels (25units) (SOPR).
5) Install building products (VDA) in flooring, insulating interior façades (U<0.19 W/m2K), and partition walling of a renovated office building space (200 m2) in Biscay.
6) Validate the CTP adapted to the traceability of circular ceramic, silica aerogel and PU-based products through ID tags (SERI, TECN).
7) Characterize building products and assess their easy-disassembly and material, energy, and water efficiency (All).

2.2 Activities of WP4

The findings of the 6 circular case studies (CSS) conducted in WP4 are described in the following paragraphs, as shown in Table 2.

Table 2. Overview of circular case studies (CCS), tasks and paragraphs

Nr.	Title	Task	Location	Paragraph
CCS1	Case study demonstrating circular concrete	4.2	The Netherlands	3.1
CCS2	Case study demonstrating circular cement-based products	4.3	Turkey	3.2
CCS3	Case study demonstrating circular carbonated blocks	4.4	Belgium	3.3
CCS4	Case study demonstrating circular wood-based products	4.5	Finland	3.4
CCS5	Case study demonstrating circular plasterboards	4.6	United Kingdom	3.5
CCS6	Case study demonstrating circular ceramic, silica aerogel and PU based products	4.7	Spain/ France	3.6

Each case study follows a novel common circular procedure encompassing the following shared paragraphs[3]:

- Perform pre-demolition audit on chosen buildings with BIM4DW;
- Execution of selective refurbishment/demolition with built surfaces larger than 500 m^2;
- EBM processing: industrial application of new sorting and processing technologies;
- Resource-efficient production of new circular building products optimized in WP3;
- Installation and use in representative building spaces (>200 m^2) and application of circular design;
- Demonstration of the new digital EBM traceability service through the CTP, comparing with traditional services in terms of time and cost consumption, functionality, interaction between stakeholders and global performance.
- Simulation of easy disassembly (in T4.8) of the new building products in mock-ups constructed in previously projects with a final assessment of materials, energy, and water consumption over the circular chain. The building companies will extend the durability monitoring of the installed circular building products beyond ICEBERG duration, thus contributing to the social and market confidence on the new solutions.

[3] Partners have made a preliminary design in the proposal phase of detailed scope including minimum quantities in each stage of the value chain.

2.3 Deliverables of WP4

As described in the Grant Agreement (GA) for ICEBERG, the title of deliverable 4.2 (D4.2) is "Intermediate report: demonstration of technological solutions fostering circular economy" which "describes and illustrates the intermediate advances for each CCS in Tasks 4.2 to 4.7, including the pre-demolition audit and smart demolition works".

As described in the Grant Agreement (GA) for ICEBERG, the title of deliverable 4.3 (D4.3) is "Final report: demonstration of technological solutions fostering circular economy" which "describes and illustrates the final results obtained for each CCS in Task 4.2 to 4.7, including the processing of EBM, manufacturing of new products, installation and traceability."

3 CCS1: Case study demonstrating circular concrete (task 4.2)

The objective of CCS1, led by GBN, is to demonstrate smart circular building solutions for upgraded recovery of EoL concrete used in new structural ready-mix concrete structures (>75 wt%) and concrete building block system with U<0.21 W/m^{2}K.

CCS1 includes the following stages:

1) Selection and pre-demolition audit of a non-residential building of around 1500 m2 in The Netherlands (GBN, SERI).
2) Collect and separate EBM concrete fraction for further processing (GBN).
3) Treat >1000 ton of concrete waste to produce coarse recycled aggregates (>4 mm) (C2CA), high quality recycled concrete sands (0.25-4mm) and dry cementitious material (<0.1 mm), which will be characterized in real-time by the LIBS-based quality assurance system (TUD).
   3.1) Produce (KEEY) silica granular aerogel.
   3.2) Produce new structural ready-mix concrete (500 m3) and precast building blocks (100 m2) using concrete fractions recycled on-site (>75 wt%).
4) Construct new non-residential building (demo surface of nearly 200 m2) with recycled concrete and precast building blocks with circular silica granular aerogels for external and internal walls (VW) with U<0.23 W/m2K.
5) Validate the CTP adopted for the traceability of circular concrete products through RFID-based tags and collect information for WP5 (TUD).
6) Characterise building products and assess materials, energy and water efficiency (TECN, TUD, GBN, VW).

CCS1 demonstrates innovative methods and tools for the selective demolition of EOL building, and the production of new concrete from the processing of aggregates that formulate the CCS1 scenario. The goal is to assess the feasibility and cost-effectiveness of the methods and tools derived from WP2 in a real demolition project in the Netherlands.

There are some remarks to the activities originally planned of CCS1:

- The case study is a former juvenile detention center, next to a monumental building with unique characteristics. The detention center is not designed to be (easily) disassembled and has an increased difficulty in detaching components, which can result in additional costs and/or man hours. Therefore, it can be argued that in this case study less material can be selectively removed than in an average building.
- The treatment of 1000 tons of concrete waste into coarse and fine aggregates (by the C2CA technology and LIBS) does not reflect the real potential for concrete that could be derived and processed. The total amount of EOL concrete in this case study is around 10000 ton, of which 20% (2000 ton) was mixed with other stony waste due to non-separate

removal. The remaining 80% of EOL concrete (8000 ton) is clean. In addition, the owner of Eikenstein wanted 9000 ton of crushed concrete for (new) foundation material on the demolition site. Therefore, 9000 ton of concrete is crushed together with the mixed stony waste into road base aggregates. The remaining concrete, only 1000 ton of clean EOL concrete, is available for this task.

3.1 Description of circular case study in the Netherlands

A best-practice selective demolition, targeting on the highest recycling goals, was implemented on a non-residential building at Utrechtseweg in Zeist, the Netherlands (called Eikenstein). The building consists of two parts; a monumental section that will be renovated and a former juvenile detention center, which was demolished. The building and area will be redeveloped into a residential area[4]. For the redevelopment of Eikenstein, the front part of the building (a monumental part) will be transformed, the rear part of the building will be removed (as shown in Figure 2).

Figure 2. The Eikenstein detention center in Zeist, Netherlands. The grey area is the non-monumental part that is deconstructed (within the scope of ICEBERG).

In December 2022, the monumental part and surroundings are emptied. In the period till June 2023 the detention center (grey area) is demolished. During the demolition, circularity played a major role. GBN carried out the planning and supervised the selective demolition, including the process of circular waste management.

[4] More information about the redevelopment can be found at https://www.eikensteinzeist.nl/

Process of circular waste management

The process of circular waste management considers three different phases, which are shown in Figure 3. The three phases of the process of the circular demolition, which are considered in the next paragraphs, are:

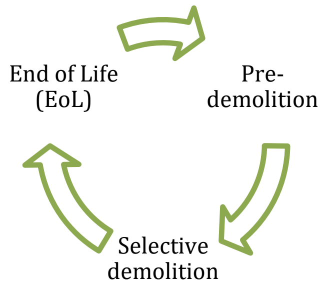


Figure 3. Phases of the process of circular waste management

- Pre-demolition

At the start of the demolition, a waste management plan of a non-residential building in the Netherlands is developed by GBN that represents the current best practice (BAU). This entails a form of selective demolition aiming to identify hazardous substances and a limited quantity of materials for recycling.

Before the demolition project commenced, a BIM-supported pre-demolition audit by TECNALIA was performed. The purpose was to identify and quantify the available materials that could potentially be harvested from the building and assess their processing method (e.g., reuse, recycle, energy recovery). Considering that the demolished building was previously a detention centre, an increased difficulty in dismantling materials and detaching components for reuse and recycling was anticipated

- Selective demolition

A selective demolition was performed before diverting materials to reuse and recycling in nearby facilities. The demolition is considered selective, with the purpose to reuse materials as much as possible.

- End of Life (EOL) – reusing and recycling

After the demolition, the End-of-life concrete removed from the building was crushed, sieved, and used as input for the ADR and HAS plant to produce coarse and fine aggregates, which then underwent the quality assurance process by LIBS. The next step is to produce new pre-mix concrete and prefabricated elements by substituting natural with recycled aggregates, which will be used in a new building.

Circularity strategies in the Netherlands

In the Netherlands, the degree of circularity is often related to the R-ladder[5] of the Government-wide Circular Economy Program (PBL.nl). The higher a strategy is on this ladder of circularity strategies, the more circular the strategy is. For this case-study, the following terms and definitions of the R-ladder are applied (from high to low):

- **Re-use**: products are reused in the same function (one-to-one), whether after processing.

[5] RVO.nl | Rijksdienst | R-ladder - strategies of circularity (website in Dutch)

- **Recycle**: secondary (raw) materials from discarded products are converted into new products or materials. Recycle is subdivided into:
  - Upcycle: recycle into new products or materials of the same or a higher value than the original product/ material. An example is the processing of end-of-life concrete into new concrete or the processing of green waste into compost.
  - Downcycle: recycle into new products or materials of lower quality, reduced functionality and/or lower value than the original product/ material. An example is to contaminate and/or mix of materials to make road foundations from end-of-life concrete.
- **Incineration**: energy is recovered from secondary (raw) materials that would otherwise have been waste. Another non-circular strategy is **landfill**: waste is disposed and layered with dirt and other absorbing materials to prevent contamination of the surrounding land or water.

3.2 Pre-demolition audit/ preparatory activities

Before the start of the demolition, GBN preformed a pre-demolition audit to inventories the different materials within the building and the potential for reuse or recycling of those materials. Next to the 'manual' pre-demolition audit, Tecnalia used the BIM-aided-Smart Pre-Demolition tool (BIM4DW) to perform a pre-demolition audit. In the next paragraphs, the two different ways of performing the pre-demolition are described.

3.2.1 Manual audit / scan

GBN performed a pre-demolition audit to prepare an inventory with information on materials quality, quantity, and location. At the same time, an additional objective of the pre-audit was the identification of components and appropriate waste management options, as well as locating potential local markets for reuse.

The manual audit scan is performed by two employees of GBN and took about 8 hours. After the overall scan, some additional visits to the demolition site were made together with the partners of GBN to determine the reuse potential of some specific object/materials.

During the pre-demolition audit we also collected information about the type of building, available space to operate the machinery and store materials, possible logistics route to take the material outside the building, time available and necessary to remove and reuse materials, possible costs, and revenues. Based on this information the most optimal way of demolition is determined.

We used a camera and notebook during the audit, and the results were collected in a excel sheet. In some cases, it is necessary to take a sample to determine if a material can be recycled (example roofing felt / carpet).

3.2.2 Results of pre-demolition audit

The materials which are defined during the pre-demolition audit (executed by GBN) to be recycled and to be reused can be found in respectively Table 3 and Table 4.

Table 3. Number of materials to be recycled (results of pre-demolition audit, executed by GBN)

Material	Amount (tonnage)	Destination
Debris	9.500	Downcycling
Debris (concrete for C2CA Technology)	1.000	Upcycling (C2CA)
Construction and Demolition Waste (CDW)	126	Recycling (after waste separation)
Wood	52.5	Recycling (in chipboard)
Glass	20	Recycling
Roof waste (bitumen)	105	Energy recovery
Ferrous waste	83	Recycling
Non-ferrous waste	234	Recycling
Carpet waste (linoleum)	1	Recycling
Insulation waste	5	Recycling
Total	**11120.5**	

Table 4. Number of materials to be reused (results of pre-demolition audit, executed by GBN)

Material	Amount	Weight (total)	Destination
Gratings of air space	60 pieces	1800 kg	Reuse
Gratings of AHU (roof)	More than 2 pieces	150 kg	Reuse
Facade mesh (courtyard)	51 pieces	1500 kg	Reuse
Facade mesh (courtyard)	650 m2	5000 kg	Reuse
Checker plates	500 m1	25000 kg	Reuse
Ceiling panels	600 m2	5000 kg	Reuse
Wooden storage cabinets and desks from cells (small variant)	100 pieces	500 kg	Reuse
Doors (hardwood)	60 pieces	2500 kg	Reuse
Hinges and locks (at hardwood doors)	60 pieces	60 kg	Reuse
Door closers	83 pieces	200 kg	Reuse
Mirrors	30 pieces	150 kg	Reuse
Hatch	1 piece	5 kg	Reuse
Toilets (stainless steel)	15 pieces	150 kg	Reuse
Small staircase of AHU (3 steps)	2 pieces	100 kg	Reuse
Staircase in workspaces (wood and steel)	2 pieces	1000 kg	Reuse
Shelves at floor in workspaces	40 m1	400 kg	Reuse
Handrails of staircase	38 pieces	40 kg	Reuse

Material	Amount	Weight (total)	Destination
Benches (gym)	13 pieces	300 kg	Reuse
Set of ropes	1 piece	20 kg	Reuse
Climbing frame	2 pieces	500 kg	Reuse
Climbing holds (gym)	20 pieces	10 kg	Reuse
Control boxes and individual machines	3 pieces	20 kg	Reuse
Central heating boilers	6 pieces	30 kg	Reuse
Heaters (electrical)	5 pieces	25 kg	Reuse
Bicycle shed at back yard (wood and steel)	1 piece	2000 kg	Reuse
Bicycle shed (Construction and Demolition waste)	1 ton	1000 kg	Reuse
Bicycle shed (Wood)	1 ton	1000 kg	Reuse
Bicycle shed (Concrete)	5 ton	5000 kg	Reuse
Pavements	1500 m2	2700 ton	Reuse
Total (approximately)		**3000 ton**	**Reuse**

3.2.3 BIM4DW

An additional pre-demolition audit is carried out using the BIM-aided-Smart Pre-Demolition tool (Figure 4). For this process, two experts from TECNALIA visited the demolition site and performed an audit of the entirety of the building in 8 hours. The audit deliverables include a detailed inventory of the quality, quantity, and location of materials, an optimized plan for potential reuse and recycling of 100% of materials and components, and three-dimensional drawings provided to the demolition company.

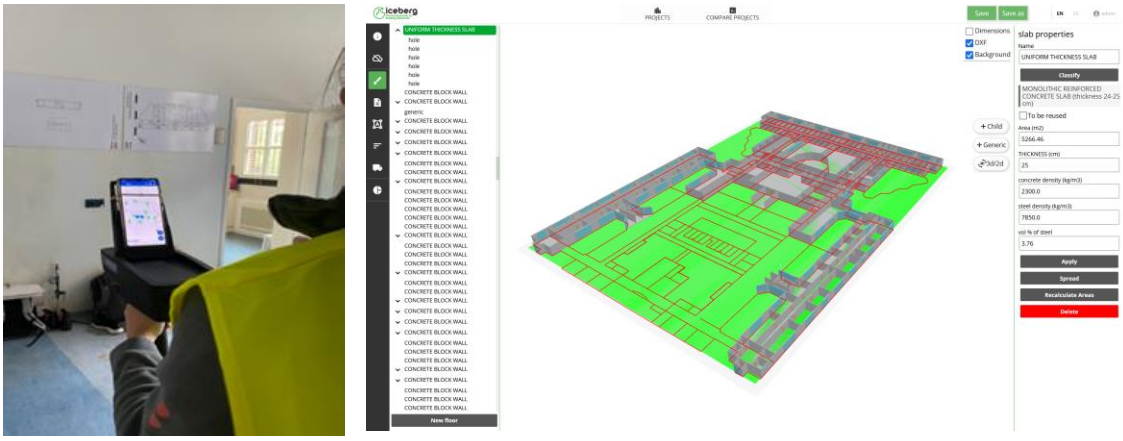


Figure 4. BIM-aided-Smart Pre-Demolition equipment used on-site during the demolition of the Eikenstein detention center in May 2022

The major elements (slabs, walls and other structural elements) have already been modelled and the amount of 11,171 tonnes of concrete (17 01 01) has been obtained. This quantity is in line with the manual audit results (10,500t).

Concrete represents by far the largest amount of the total Construction and Demolition Waste (CDW), with the weight of other types of waste being much lower than that of concrete.

3.3 Execution of selective refurbishment/ demolition

After the pre-demolition and before the selective demolition, an asbestos inventory has to be done by a certified (SC540) company. This is reported in a separate asbestos inventory report. Figure 5 shows an example of this asbestos inventory. After all the asbestos is removed by a specialised and certified company, the building is marked free of asbestos which means the selective demolition can safely start.

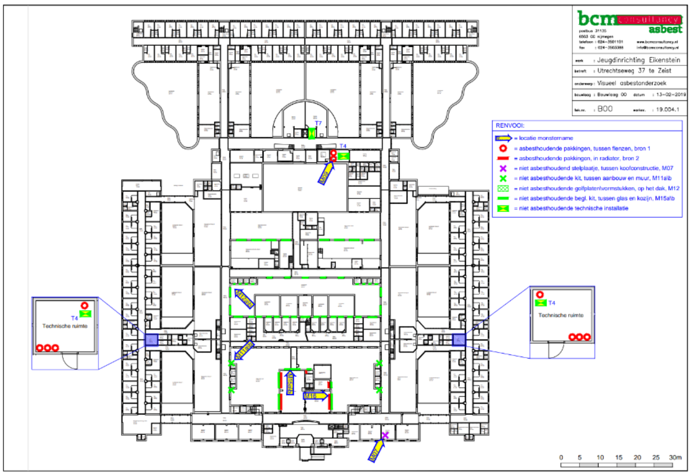


Figure 5. Drawing out of asbestos inventory report with location of asbestos

Following the results of the pre-demolition audit and based on the optimized planning, the sequence of activities for the selective demolition is decided. During the pre-demolition audit, several reusable materials and waste streams are selected, including Construction and Demolition Waste (CDW), wood, glass, ferrous and non-ferrous, linoleum, cable trays, fire extinguishers, and others are removed using scaffolding and hand tools, as shown in Figure 6.

Figure 6. Hand tools used for pre-demolition

The first step in the selective demolition is to remove all the reusable materials, based on the results of the pre-demolition audit. Approximately 30 different objects / materials were selected for reuse. GBN has a broad network of different partners for the recycling and reuse of materials from demolition projects. Based on the experience and the knowledge of this network we now before the start of the demolition which materials can be reused, in most cases the partners also remove the materials themselves. Because of this method it is not necessary to store the reusable materials. To follow this method, it is necessary to have enough time before the actual start of the demolition to plan these visits and to make appointments with the partners about when and how to remove these materials. The total time needed for dismantling the reusable materials was about 6 weeks (approx. 600 working hours).

Figure 7. Collection of reusable ceiling plates (photographed by Frank Rens and Bente Kamp, GBN)

Figure 8. Collection of reusable doors (photographed by Frank Rens and Bente Kamp, GBN)

After all the reusable materials were removed the second step of the pre-demolitions started, the removal of al obstructive and recyclable non stony materials. The removal of those materials was done with the same scaffolding and hand tools. Al the different waste streams are collected in 40 m3 containers outside the building. For easy logistics some windows are removed, or parts of the outside walls are removed.

The removal of the outer area, including the fencing, gates, light poles, and pavements, is performed with a demolition crane. In total, the man hours dedicated to the ICEBERG pre-demolition and demolition were double compared to the BAU scenario. The total amount of the generated CDW from the ICEBERG pre-demolition and selective demolition is approximately 35% less than the BAU demolition.

Figure 9. Collection of insulation materials (photographed by Frank Rens and Bente Kamp, GBN)

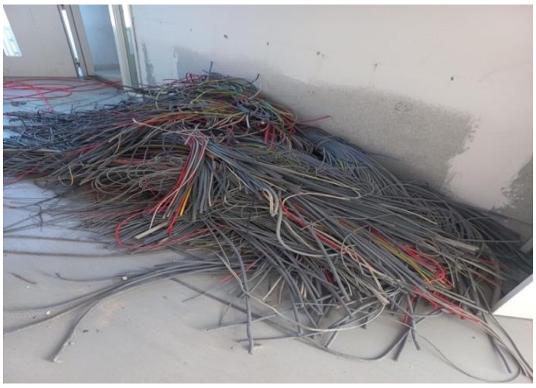


Figure 10. Collection of cables (photographed by Frank Rens and Bente Kamp, GBN)

Figure 11. Stripped area, collection of doors and cable trays (photographed by Frank Rens and Bente Kamp, GBN)

Figure 12. Collection of carpet (photographed by Frank Rens and Bente Kamp, GBN)

After the pre-demolition the selective demolition started, this means all the non-stony materials which are still in the construction of the building are removed by a demolition crane and collected in several 40 m3 containers. During this event waste is separated in concrete, mixed stony material, wood, glass, ferro, non-ferro, isolation material, roofing (bitumen) and CDW.

3.3.1 Collect and separate EBM concrete fraction

After all the non-stony materials were removed, we started to demolish the concrete structure of the building. The demolition was done with two demolition cranes in 360 hours. The generated waste included CDW, wood and ferrous waste streams, and stony material. For the EOL concrete, a demolition crane is used for a total of 320 working hours. From this process, 14500 tons of stony material and 1000 ton clean EOL were generated.

During this step also two containers of clean ceramic bricks were collected separately. These bricks will be recycled into new bricks by crushing it and blend it with new virgin clay in the production process.

Figure 13. Collection of bricks (photographed by Frank Rens and Bente Kamp, GBN)

Figure 14. Demolition crane on site (photographed by Frank Rens and Bente Kamp, GBN)

Figure 15. Stony waste on site (photographed by Frank Rens and Bente Kamp, GBN)

Figure 16. Mixed waste before separation on site (photographed by Frank Rens and Bente Kamp, GBN)

During this step 1000 ton of Clean EOL concrete was selected and kept separately, the remaining 14500 ton stony materials was demolished, reduced in size (<50x50x50cm) and as much as possible iron and other contaminations were removed.

Figure 17. Removal of iron rebar (photographed by Frank Rens and Bente Kamp, GBN)

Figure 18. Clean concrete before it was reduced in size to make it small enough for crushing

3.3.2 Impact of selective demolition (compared to BAU)

The selective demolition results in the removal of approximately **16.187,4 tons of recycled materials**, which can be found in Table 5. This total consists of 95,2% of debris (15.522,8 ton). The chart in Figure 19 shows the percentages of the materials in tons, with the secondary pie chart indicating the material in addition to debris. The corresponding weight and processing method per material can be found in Table 5.

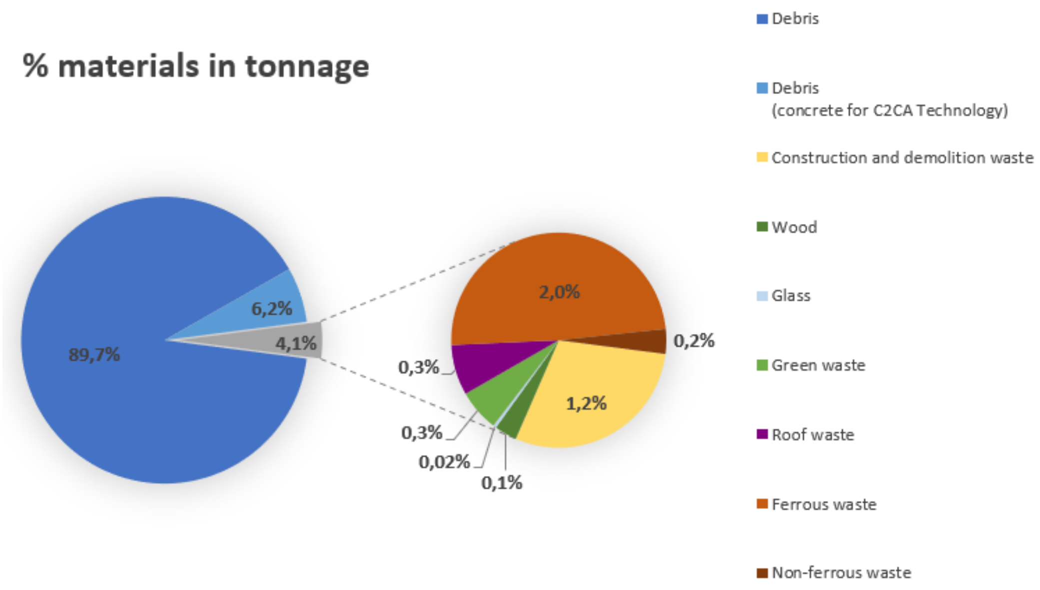


Figure 19. Pie chart with materials in tonnage (%)

Table 5. Number of recycled materials (results of selective demolition)

Material	Amount (tonnes)	Percentage	Processing method
Debris	14.522.8	89,7%	Downcycle
Debris (concrete for C2CA Technology)	1.000.0	6,2%	Upcycle
Construction and demolition waste (CDW)	196.1	1,2%	Whereas approximately 55% upcycle, 20% downcycle and 25% incinerate
Wood	22.5	0,1%	Upcycle
Glass	3.1	0,02%	Upcycle
Green waste	41.8	0,3%	Upcycle
Roof waste	50.4	0,3%	Upcycle
Ferrous waste	325.9	2,0%	Upcycle
Non-ferrous waste	24.8	0,2%	Upcycle
Total	**16187.4**	**100%**	

Besides the recycled materials, all the materials to be reused of the pre-demolition (as shown in Table 4) found a new destination, mostly in the surroundings of the case-study. This means the selective demolition results in the removal of approximately **3000 tons of reused materials**.

To conclude, many materials from the Eikenstein project have been used in a circular manner. In total, **99.8%** of the materials have been reused or recycled (upcycle/ downcycle). Table 6 shows the percentages of the circular processing methods in tons. Figure 20 shows the corresponding chart, with the secondary pie chart indicating the processing method of materials other than downcycle.

Table 6. Amount of recycled and reused materials (results of selective demolition)

Processing method	Amount (tonnes)	Percentage
Re-use	3000,0	15,6%
Upcycle	1577,9	8,2%
Downcycle	14563,4	75,9%
Landfill	0,0	0,00%
Energy recovery	46,1	0,2%
Total	**19187,4**	**100,0%**

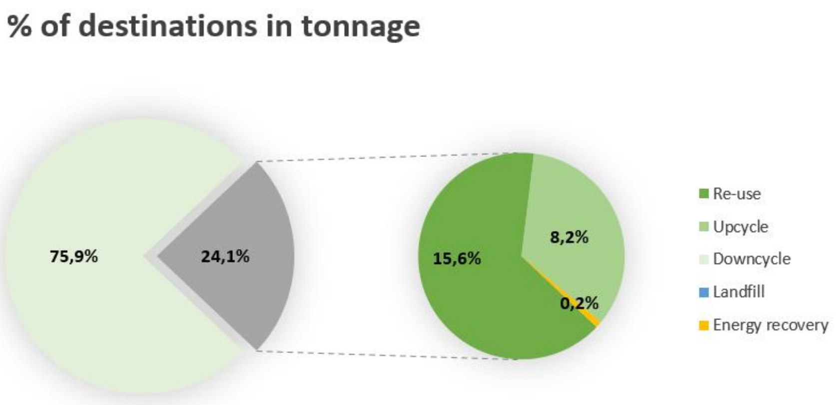


Figure 20. Pie chart with destinations of materials in tonnage (%)

3.4 EBM processing (concrete recycling by C2CA)

During the demolition of the concrete structure, 15500 tons of stony material and concrete waste were generated. But because of the demand of road base aggregate from our client only 1000 ton was crushed in to 0-16 mm EOL concrete aggregates and the other 14500 ton was crushed into road base aggregate. The 1000 ton 0-16 mm was transported to the recycling site of GBN in Hoorn the Netherlands and became the input for C2CA Technology to produce coarse and fine aggregates for new concrete production. In September 2022, the HAS was not ready yet, so the crushed EOL was stored on the recycling site in Hoorn.

Figure 21. Crushing the EOL concrete with a mobile crusher

The process for recycling the EOL concrete with the C2CA technology is showed in Figure 22. After crushing, the material will go to the ADR and HAS and the quality of the products will be determined by the LIBS

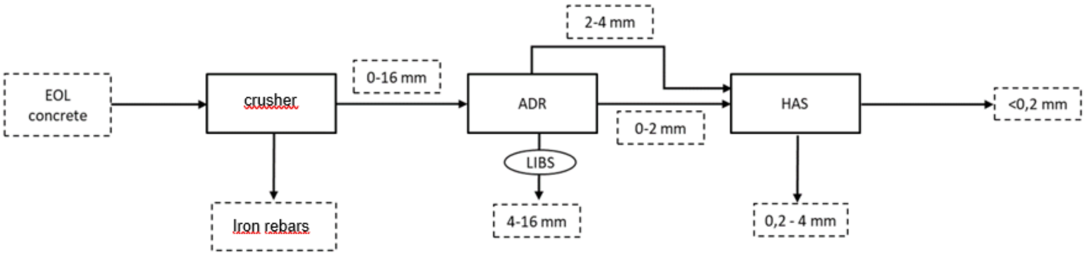


Figure 22. C2CA process

The pre-crushed 0-16 mm concrete is processed with the ADR. The moister content in the input material was higher than average because there was a couple of months between crushing and processing the materials, during this period the crushed aggregate became more wet because of the rain. The moist conditions are no problem for the ADR, since this is especially designed to separate moist and hard to sieve material. But after processing the moist material is concentrated in the fine particle which leads to a higher energy demand of the HAS.

The ADR separates the coarse and fine aggregates based on density. The ADR will separate the concrete in three different fractions. The rotor fraction is 0-1 mm, the air-knife is 0-2 mm and the coarse fraction 2-16 mm. The mass balance of the ADR is as follows:

- 70% coarse fraction 4-16 mm
- 30% fine fraction < 4 mm

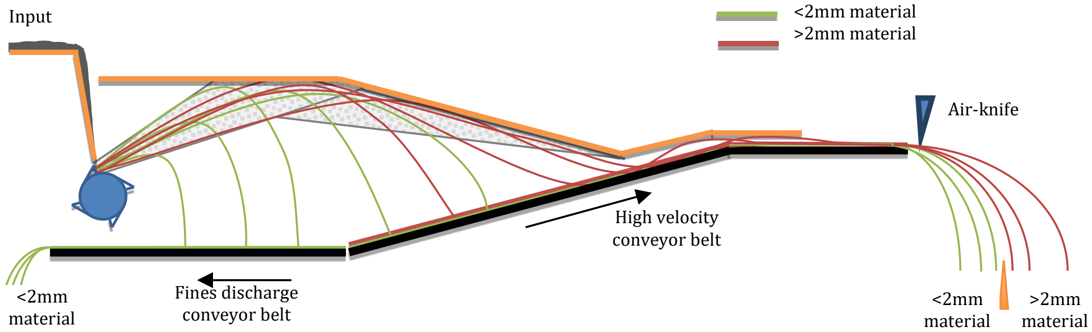


Figure 23. Working principle of the ADR

Based on the 1000 ton crushes EOL concrete, about 700 ton coarse aggregate is produced. The production capacity of the ADR was around 40 tons/hour. During the production we had several hours of down-time to clean the machine and to replace a broken drive belt. The coarse aggregates are stored on site and are ready to be shipped to the ICEBERG partner Roosens in Belgium.

Figure 24. Coarse material stored before shipped to Roosens

During the production of the coarse material several samples are taken. From this samples, the particle size distribution (PSD) was analysed. In Figure 25, the PSD of the different samples is shown. The line in red (max) and green (min) show the limits where the PSD must be within. As can be seen, the average PSD of the new produced coarse aggregates is within the limits. However, the PSD changes during the production. The reason for this change is the accumulation of material on the splitter of the Air-knife, as shown in Figure 26. Additionally, the water absorption of the coarse materials was determined. This is around 3,5 – 4 % m/m after 24 hours.

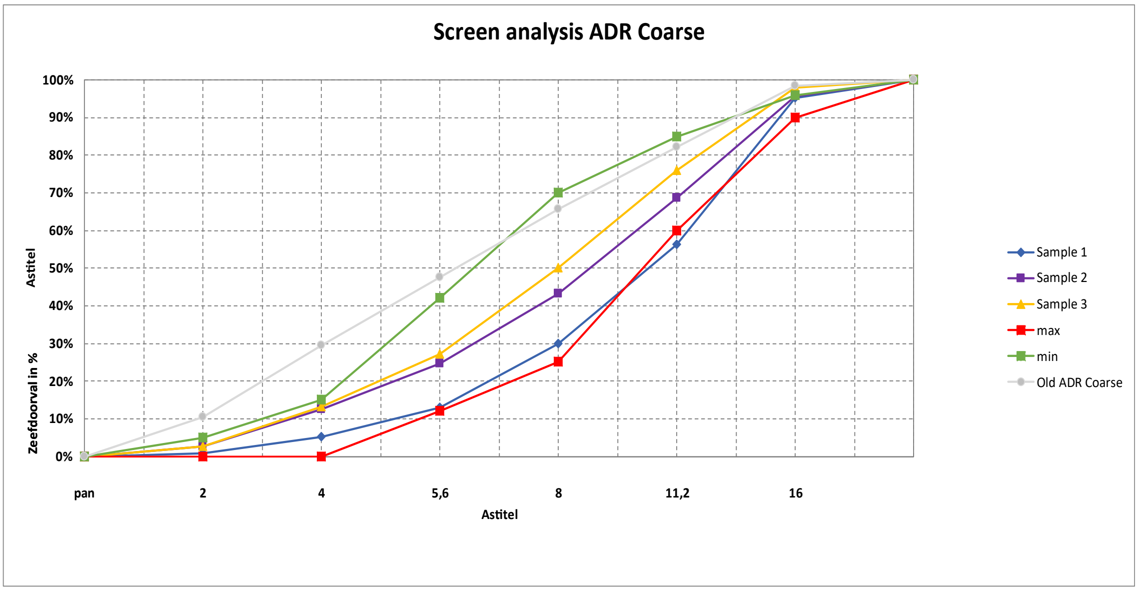


Figure 25. PSD of the coarse aggregates produced with the ADR

Figure 26. Accumulation of material on the splitter of the ADR

Figure 27. Fines produced with the ADR

The fine aggregates out of the ADR still contain a lot of fine hardened cement paste attached to the sand particles. To further separate the sand and cement stone, this fraction is processed by the HAS. Around 100 ton of fines are processed by the HAS. The HAS uses hot air to liberate and separate the ultra-fine cement paste particles and the sand. The working principle of the HAS is shown in Figure 29. The mass balance of the HAS is as follows:

- 74% fines (sand) 0,250 – 4 mm
- 16% ultra-fines (cement paste) < 0,250 mm
- 10% moisture (water vapor)

Figure 28. Processing of material with HAS for case study

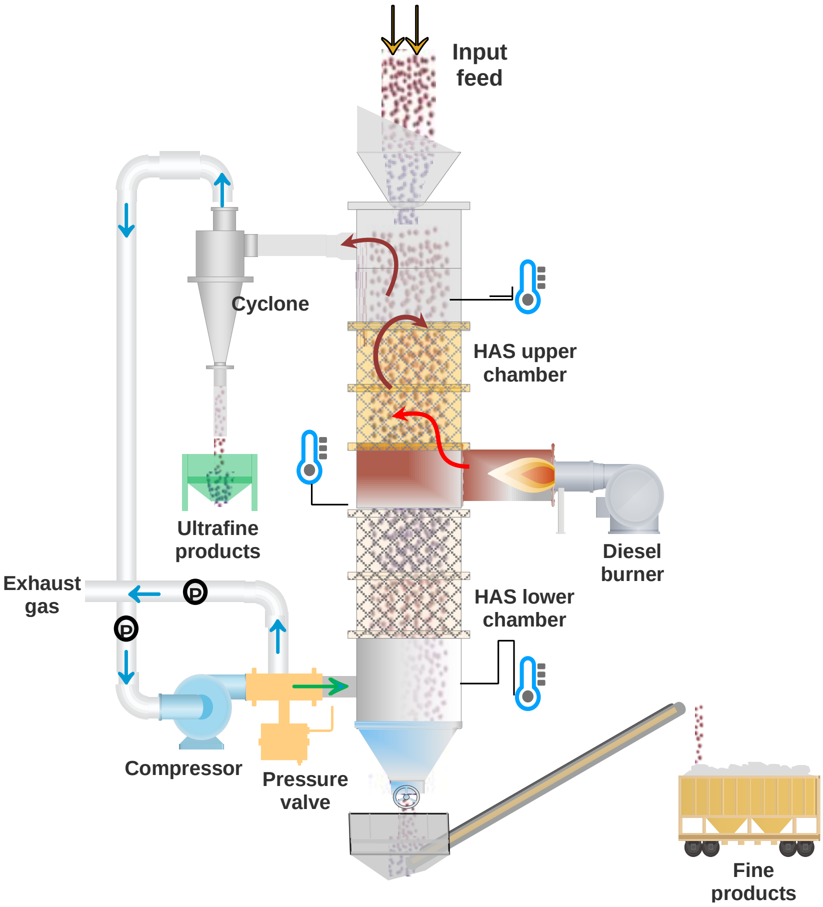


Figure 29. Working principle of the HAS

During the production with the HAS a sample of the fines was taken and the particle size distribution (PSD) was analysed, as shown in Figure 30. The line in red (max) and green (min) show the limits where the PSD must be within. As can be seen, the particle size of the fines is within the limits. In addition, the PSD of the old pilot version of the HAS is compared to new pilot. The pilots resulted in similar particle sizes. Additionally, the water absorption of the fine materials was determined. This is around 6 – 7 % m/m after 24 hours.

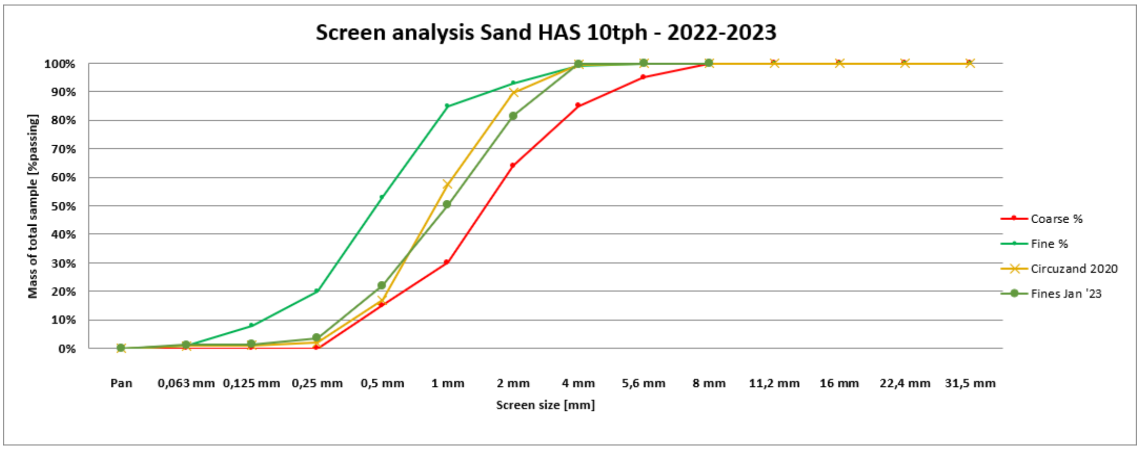


Figure 30. PSD of the fines (sand) produced with the HAS

During processing a sample of the input material of the HAS was taken and weighed before and after drying, based on this the moister content was around 13,8%. This is higher than average because the time between crushing and processing was a couple of months, during this period the crushed aggregate became more wet because of the rain and was concentrated in the fines after the ADR. The capacity of the HAS is determined based on the energy that is need for drying and separating the material. The new improved HAS system has control logics to control the true put and energy use in the system. Based on different temperature sensors the speed of the feeding screw is adapted based to keep the temperature at the top of the system between 150 and 200 degrees Celsius. The capacity of the burners is modulating to keep the temperature in the cascades between 500 and 600 degrees Celsius.

The capacity of the HAS during the production lay around the 8 ton/hour per module. With dryer material or more heat recovery this can go up to 10 ton/hour. Based on this information we need 3 cascade modules to reach the desired production capacity of 30/ton an hour so the HAS can be put in line with the crusher and HAS. During the production, all the data generated by the system is stored and displayed in a dashboard. This is shown in Figure 32.

Figure 31. Control logic of the HAS

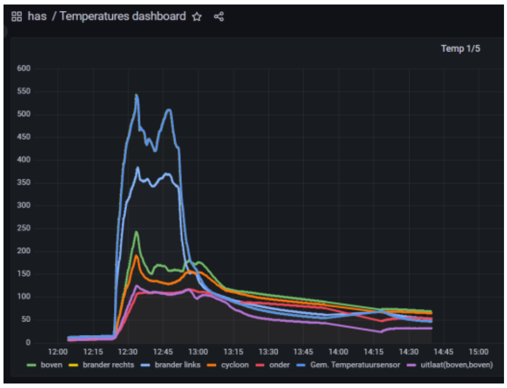


Figure 32. Data collection dashboard of the HAS

The moist material also gave some problems with feeding it into the HAS system. This resulted in material accumulating in the inside of the screw feeding. The resistance within the screw became higher and caused the thermal protection of the engine to stop the machine. The moist material also partially blocked the material splitter on the top of the HAS. Both problems are shown in Figure 33.

Figure 33. Accumulation of material in the screw feeding and on top of the HAS

The total mass balance of the whole C2CA process is as follows:

- 70% coarse 4-16 mm
- 22.2% fines (sand) 0,250 – 4 mm
- 4.8% ultra-fines (cement paste) < 0,250 mm
- 3% moisture (water vapor)

Based on the 1000 ton EOL concrete, the following materials are produced:

- 700 ton coarse aggregate 4-16 mm
- 75 ton fine aggregate 0,250 – 4 mm
- 16 ton ultra-fines < 0,250

3.5 Circular design

[This is an intermediate report. This paragraph will be added in the final report (deliverable number: D4.3).] - Input: EPEA / Roosens

3.6 Manufacturing of new circular building products

The End-of-life concrete is used to produce the following products (which are described in the next paragraphs):

- New pre-mix concrete and prefabricated elements by substituting natural with recycled aggregates, which will be used in a new building;
- Silica aerogel.

3.6.1 Production ready-mix concrete and precast building blocks

[This is an intermediate report. This paragraph will be added in the final report (deliverable number: D4.3).] - Input: Roosens

3.6.2 Production of silica aerogel

The process of silica aerogel production consists of three main steps as follows:

1. Silica precursor preparation from EBM;
2. Silica aerogel synthesis;
3. Drying process.

<u>1. Silica precursor preparation from EBM</u>

In general, waterglass or sodium silicate (Na_2SiO_3) is used as silica precursor for silica aerogel manufacturing. The commercial waterglass is usually produced by reacting quartz sand with sodium hydroxide (NaOH) solution at elevated temperature and pressure. In Iceberg project, the quartz sand was replaced with EBM to obtain low-cost waterglass for aerogel synthesis. The different EBM in this study is presented in Figure 34.

Glass waste **C&DW (SC1)** **C&DW (SC2)**

Figure 34. Photos of the glass waste and C&DW samples SC1 and SC2

This study was realized in task 2.7 resulted in the selection of EBM as optimized raw materials for the precursor preparation.
Table 7 shows the results of silica extraction obtained from the different EBM samples.

Table 7. Waterglass solutions obtained from the different EBM samples.

Sample treated	Silica extraction yield (%) in the waterglass	Molar ratio SiO2/Na2O in the waterglass
GW	60	1.35
SC1	32	1.68
SC2	63	2.07

The highest silica extraction yield at 63% was obtained with SC2 sample, then SC2 was selected for silica aerogel production.

1m^3 of SC2 as shown in Figure 35 (a) was received from GBN for silica aerogel production. SC2 was firstly pre-crushed with an impact (rotary crusher) to a 0-16 mm aggregate then fed into Advanced Dry Recovery (ADR). The ADR separated the coarse and the fine aggregates. The fines aggregates 0-4 mm went to the heating air classification system (HAS). The ultrafine particles (<0.2 mm was removed and the fine particles (0.2 – 4 mm.) were used in this work.

For the silica extraction process, SC2 sample was hydrothermally treated with a basic solution under high temperature and pressure during a specific time. The reaction was performed in 30 L reactor as shown in Figure 35 (b).

Figure 35. (a) 1m^3 of SC2 from GBN (b) 30 L reactor for Hydrothermal process

Figure 36 shows the appearance of the products prior to filtration. The obtained products were filtrated to separate liquid solution and solid residues. The obtained waterglass was brownish due to the remained Fe2O3 in the solution.

The properties of WG-SC2 are presented as follows:

- Density (g/cm^3): 1.21
- SiO2 (wt.%): 12.61

- Na_2O (wt.%): 6.98
- SiO_2/Na_2O ratio: 1.87

Figure 36. The appearance of the products prior to filtration and solid residue.

2. Silica aerogel synthesis

The filtrated waterglass solution was diluted to desire concentration and treated with cation-exchange resin to eliminate the sodium ion. The used resins were regenerated with diluted hydrochloric acid. The optimized resin/ WG ratio at 0.64 was used for the process. The obtained sol, silicic acid, was used to form a hydrogel in silica aerogel synthesis reactor as shown in Figure 37. Ammonium hydroxide (NH_4OH) was added as a catalyst into silica solution to create nanostructured silica particles.

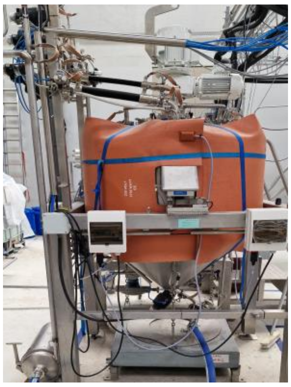


Figure 37. Silica aerogel synthesis reactor

The ethanol washing/solvent exchange process was carried out to produce silica aerogel based on aqueous solution such as waterglass, since water is poorly miscible with CO_2 during supercritical drying process. The pure ethanol was replaced the aqueous solution within the hydrogel porous to a minimum of 98vol%. The washed ethanol was reserved and recycled by using a pervaporation ethanol recovery unit.

3. Drying process

The prepared silica aerogel particles were dried using Low temperature supercritical Drying process (LTSCD) with Carbon Dioxide as solvent. This process was carried out at homogeneous conditions of supercritical carbon dioxide and ethanol.

The first batch of silica aerogel 120L will be supplied to Project partner in the beginning of May 2023

3.7 Installation and use in representative building spaces

[This is an intermediate report. This paragraph will be added in the final report (deliverable number: D4.3).] - Input: Roosens / GBN

3.8 Demonstration of the new digital EBM traceability service

[This is an intermediate report. This paragraph will be added in the final report (deliverable number: D4.3).] - Input: TU Delft (RFID tags)

3.9 Simulation of easy disassembly of the new building products

[This is an intermediate report. This paragraph will be added in the final report (deliverable number: D4.3).] - Input: Roosens / GBN

4 CCS2: Case study demonstrating cement-based products (task 4.3)

In the first step of Work Package 4 of the project, it has been decided to selectively demolish an 11-story, approximately 3850 m2, 50+ years old risky building located in Ankara, Turkey to obtain the necessary EBMs for the serial production of the recipes developed in Work Package 3. The architectural drawings of the building have been provided to TECN and GBN partners for the application of BIM4DW as part of the pre-demolition audits. Visuals related to the selected building are presented in Figure 38.

Figure 38. Images of selected building to be demolished

Also, interior visuals of the building planned to be demolished are presented in Figure 39.

Figure 39. Interior visuals of the building to be demolished

4.1 Pre-demolition audit/ preparatory activities

The first stage of the study was the pre-demolition audit of 1 EoL residential building with 11 floors of about 3850 m² and carry out the demolition of this building with selective demolition.

As this build had updated drawings, they were used as supportive layers for the later modelling with BIM4DW, so in this case it was not necessary to scan the building geometry. The definition of building elements and materials was done through emails.

Once the digital model was completed (Figure 40), the results in terms of total materials in the building was validated before start planning the demolition process.

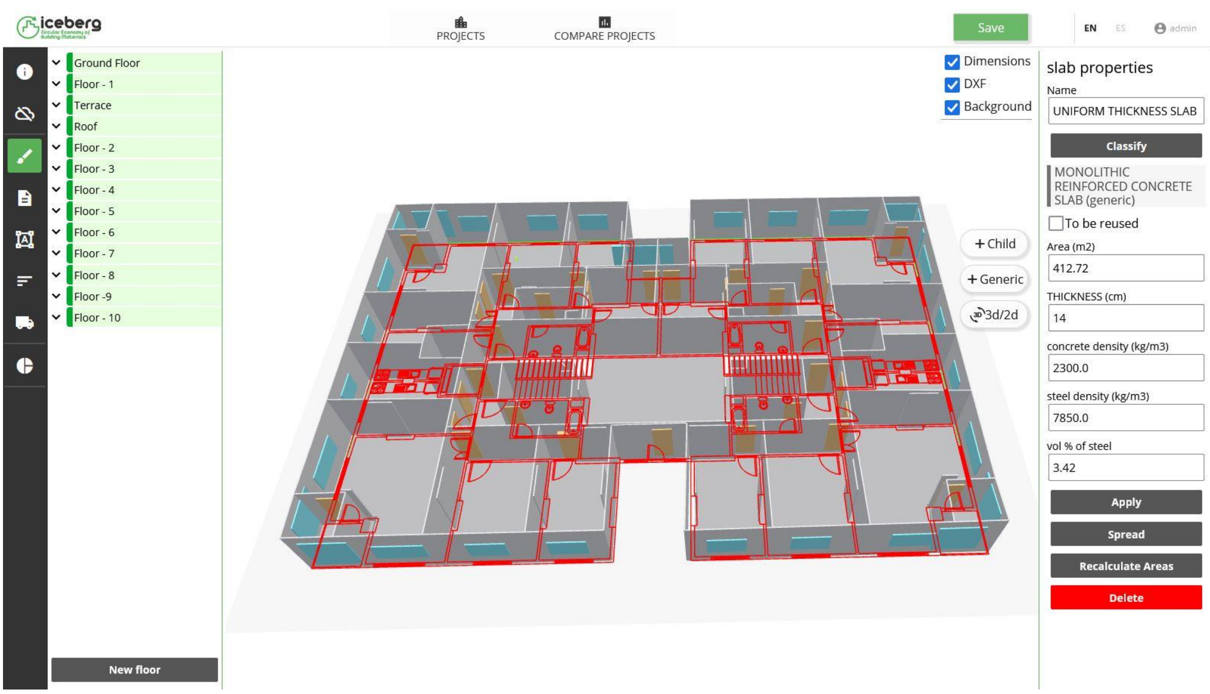


Figure 40. 3D view of one floor of the digital model of CCS2 building.

During the modelling of the building, the tool inventoried the materials and elements (Table 8 and Table 9). The summary of the materials shows what materials form the building with their EWC codes, what number of elements contains each material, their weight in tons and volume in cubic meters. While the summary of the elements shows the elements that and the quantity of them that compose the building.

Table 8. Summary of the materials of CCS2 building.

EWC Code	Name	Quantity	Weight (T)	Volume (m^3)
17 01 02	Brick	996	799.994	842.118
17 01 01	Concrete	1591	2029.611	892.916
17 08 02	Gypsum plaster	1244	157.739	68.02
17 02 03	Plastic	333	116.988	84.408
17 04 07	Metals	609	7.279	0.836
17 02 02	Glass	241	0.297	0.176
17 09 04	Other	241	0	0
17 02 01	Wood	277	26.292	40.343
17 04 05	Steel	369	212.615	28.962

Table 9. Summary of the elements of CCS2 building.

Name	Quantity
Wall: Hollow brick wall, no insulation, cement mortar, gypsum plaster	996
Door: PVC door and frame	92
Window: PVC-framed window, double glazing, unknown/other material blind	220
Door: Simple panel door	276
Door: Steel door	44
Wall: Reinforced concrete wall, no insulation, cement mortar, gypsum plaster	248
Slab: Monolithic reinforced concrete slab	77
Generic	22
Window: PVC-framed window, single glazing, unknown/other material blind	21
Slab: Wooden roof with wooden shingles	1

The building elements have been grouped into work items based on their main materials, dismantling methods, and location (Figure 41).

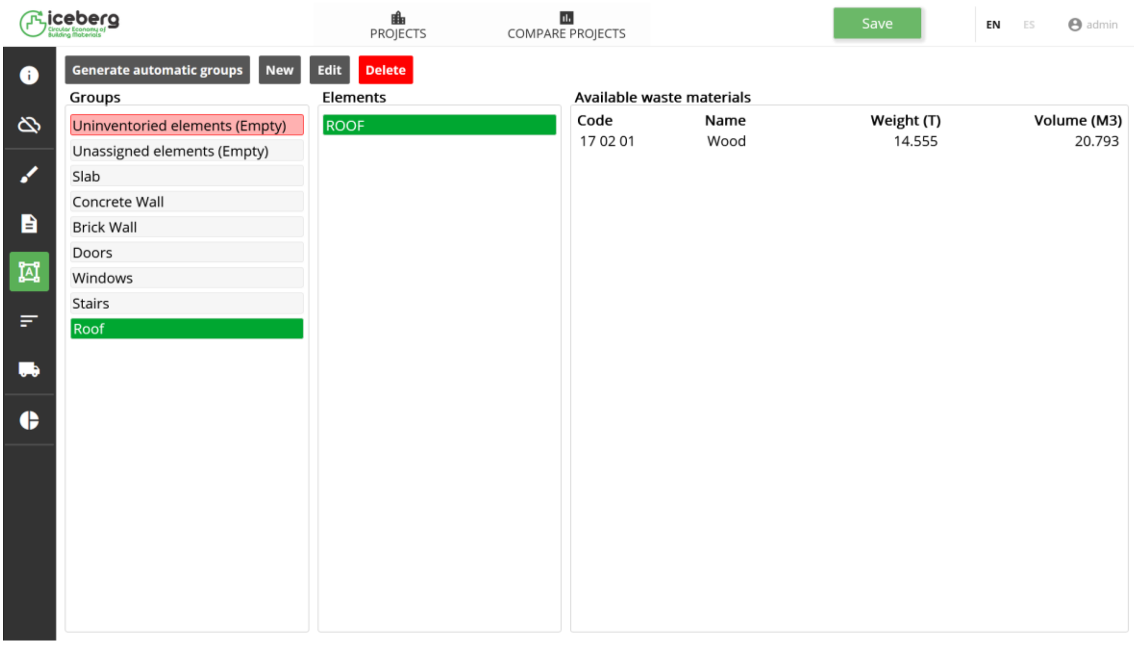


Figure 41. Groups of elements that form the CCS2 building.

Once the groups have been defined, the materials of the groups will be related to a suitable waste stream for further treatment by selecting the EWC code. The chosen dismantling method is directly related to the waste stream. BIM4DW provides a quantification of the resulting waste streams that has been compared with the resulting amount (Table 10).

Table 10. Resulting CDW quantities of the CCS2 building demolition by BIM4DW.

EWC Code	Name	Weight (T)	Volume (m^3)
17 01 01	Concrete	1724.738	750.313
17 04 05	Steel	212.615	28.962
17 09 04	Mixed construction and demolition waste, other than those mentioned in 17 09 01, 17 09 02 and 17 09 03	1262.606	1052.741
17 02 03	Plastic	116.988	84.408
17 04 07	Mixed Metals	7.279	0.836
17 02 02	Glass	0.297	0.176
17 02 01	Wood	26.292	40.343

4.2 Execution of selective refurbishment/ demolition

In the selective demolition stage, the vehicle and equipment control has been fully ensured in the demolition works. Therefore, care has been taken to ensure that the vehicles are operated by trained and competent personnel. Regarding hand tools, manufacturer instructions have been followed. The use of devices with damaged or broken parts has been prevented by checking their condition and ensuring that only fully functional devices are used. Before the implementation of the demolition works, the following have been meticulously fulfilled:

- Job description, work constraints and requirements,
- Requirements of the contract and contractor qualifications and competency,
- Details of the structure to be demolished,
- Details of asbestos and other hazardous materials,
- Details of current service and usage facilities,
- Details of previous use of the building and surroundings, and details of the demolition site and its surroundings.

Furthermore, before starting the selective demolition application in the building, experts from an authorized organization on hazardous waste have conducted necessary inspections in the demolition area. Locations of hazardous or suspected waste have been identified. Asbestos-containing materials detected in the buildings to be demolished have been carefully removed/disposed of in accordance with the appropriate techniques and procedures.

4.2.1 Selective Demolition and Waste Management

Selective demolition method can be defined as the selective and systematic dismantling of a building that has been decided to be demolished to reduce waste production, provide high-quality building materials/components suitable for reuse and recycling. With the selective demolition techniques to be implemented in the building to be demolished, different types of waste can be classified more easily, and demolition waste management can be carried out more effectively. During the selective demolition process, the dismantling process was carried out in reverse order to the construction process followed during the construction. In non-structural dismantling, different dismantling practices were carried out simultaneously.

A preliminary assessment was conducted on site prior to the selective demolition, taking all necessary safety precautions and disposing of hazardous materials. During this assessment, a recovery plan for demolition waste was developed, ensuring that all critical factors were included in the plan. An interdisciplinary team consisting of an engineer, a demolition contractor, control officials, and an academic was assembled to determine which materials would be removed from the structure and estimate their quantities. The same team also decided on the number of human resources required for these activities and which equipment would be used. The storage location and method for the demolition waste and extracted materials on site were also determined before the demolition. The number of containers required for storing demolition waste during the activity and their locations were identified at this stage. Prior to the start of the demolition, a work distribution program was developed among the project workers to determine who would maintain the necessary records and how, such as the amount of waste generated, the quantity of obtained material, and the amount of material sent for recycling. This made it easier to keep statistics on the waste generated, the obtained material, and the amount of material sent for recycling.

Prior to demolition, individuals with market experience in the recycling and evaluation of waste materials have shared their knowledge and expectations regarding the materials that can be obtained from the demolition waste. This approach allows for a cost-benefit analysis to be approximately estimated, based on which materials have commercial value, which ones can be recycled for a fee, and which ones can be disposed of without any cost. In order to successfully carry out selective demolition, personnel have been provided with the necessary training on the subject. This enables the optimal utilization of demolition waste and ensures the safe removal of reusable materials.

In summary, the following results were achieved through the selective demolition activities carried out:

- Harmful materials to human health and the environment were identified by experts as a priority and were dismantled using the correct methods.
- The demolition was carried out with the highest possible recycling rate.
- An inventory of all building materials, architectural fixtures, mechanical-electrical equipment and components, and all other materials that had not yet lost their economic value was maintained. These materials were stored and evaluated using the correct methods.
- The records of waste generated from the demolition, excavation soil, and other waste materials were effectively kept. The quantities were clearly identified for each type of waste.
- Since the demolition was carried out in the city center, maximum efforts were made to minimize the damage to the environment during the implementation (such as the structure collapsing due to incorrect demolition methods, causing damage to neighbouring buildings, material falling/flying from the structure causing harm to nearby people and buildings, and excessive vibration from machinery causing damage to neighbouring buildings, etc.).

Prior to the actual demolition process, wooden household materials such as cabinets, parquet flooring, kitchen cabinets, and tables that were present in the building to be demolished were collected and transported separately to second-hand sales warehouses. Usable items among these materials will be evaluated and the rest will be evaluated by scrap dealers. The extracted wooden household materials consist of processed and unprocessed timber, natural lumber, wooden frames, façade cladding, interior connection, and cladding elements, MDF, wood fiber board, plywood, framing timber, boards, logs, pallets, and packaging products. The dismantling of doors and windows has been completed without damaging their frames. The value of these materials may vary depending on factors such as the material they are made of, their level of wear and tear, and any damage they may have sustained during transportation or dismantling. The ones that are in good condition can be evaluated as second-hand, while those that are worn out can be evaluated as scrap. Figure 42 shows the doors and windows removed from the building.

Figure 42. The dismantling of elements such as doors and windows

The electrical, fuse, internet and telephone equipment, cables and channels have been dismantled appropriately and stacked for reuse or recycling according to their method of acquisition. At this stage, it is important to identify the type of cable that is being produced. For example, it has been determined that copper cables that emerge are more valuable as scrap. This made it easier to find buyers. Figure 43 shows these materials separated before demolition.

Figure 43. The cables and other components removed without damage before demolition

Selective demolition has been successfully carried out for the dismantling of all materials such as doors, windows, wood, PVC, kitchen and bathroom elements, and they have been stacked separately for transportation to the waste treatment site (Figure 44 and Figure 45).

Figure 44. The wooden materials collected from the demolished building

Figure 45. The steel, wooden, PVC doors, and PVC windows removed from the demolished building

The demolition of the building was carried out using the top-down floor-by-floor method, using both manual and mechanical demolition techniques (mini machines and long-reach machines). During the demolition, care was taken to ensure that the waste generated from walls and structural elements did not mix with each other as much as possible, within the limits of the safety measures. Accordingly, the emptying of each type of waste from the demolished floors was carried out through a gutter system installed in the building and elevator shafts. The structural steel obtained from the reinforced concrete elements will also be separated on the floors and stacked in a way that will not mix with other waste in the field. As it is a very expensive and valuable material, it is possible to easily market the waste steel obtained from the building (Figure 46).

Figure 46. The selective demolition of structural elements

The waste materials that will be sent to excavation sites or regulated landfills have not been stored in the field. They have been continuously directed to the relevant sites/ centers with transportation vehicles that comply with the relevant regulations. These waste materials have not been burned and have not been disposed of in inappropriate ways in the field (Figure 47).

Figure 47. Transportation of all materials obtained from building

The list of materials resulting from the dismantling of removable elements in the selective demolition process are presented in Table 11.

Table 11. Removable element list

Name	Quantity
Steel doors	36
Wooden doors	216
PVC doors	72
Toilets	36
Taps	108
Plug sockets	1080
Electric heater	252
PVC windows	216

The data comparing the BIM4DW model with the actual selective demolition material list is presented in Table 12. At this stage, the exact number of materials resulting from the demolition is not precisely determined and the data provided are estimated values. The final quantities will be calculated after the EBM processing stage is completed.

Table 12. Material list after BIM4DW and actual demolition

EWC Code	Name	BIM4DW	Actual
17 01 01	Concrete	1724.738	1800-2100
17 01 02	Brick	N/A	300-350
17 01 03	Tile	N/A	14-16
17 04 05	Steel	212.615	150-200
17 09 04	Mixed construction and demolition waste, other than those mentioned in 17 09 01, 17 09 02 and 17 09 03	1262.606	N/A
17 02 03	Plastic	116.988	N/A
17 04 07	Mixed Metals	7.279	N/A
17 02 02	Glass	0.297	1.5-2
17 02 01	Wood	26.292	N/A

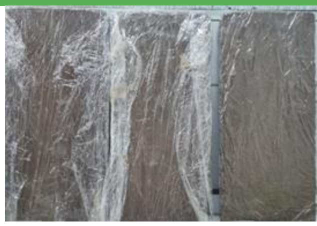
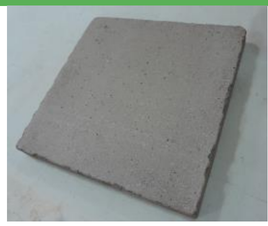
4.3 EBM processing

Figure 48. End-of-life building material processing

4.4 Circular design

Within the scope of Circular Design, the recipes to produce elements such as columns, beams, slabs, walls, and roofs of the building to be constructed in CCS2 have been successfully developed under WP3 in previous phases of the project. The eco-hybrid cement, structural green concrete, green woodchip concrete panel, and ultra-lightweight concrete panel recipes, which form the main binding form of structural elements, are presented in Table 13. The manufacturing of the new circular building products will begin after the completion of EMB processing.

Table 13. Circular design

Eco-hybrid cement	Structural green concrete	Woodchip panel	Ultra-lightweight panel
			
INGREDIENTS			
• Portland cement • EBMs (brick, concrete, gypsum) • CSA	• Eco-hybrid cement • Recycled aggregate • Water • SP	• Eco-hybrid cement • Alkali-treated wood fiber • Recycled aggregate • Chemicals • Water	• Eco-hybrid cement • Recycled aggregate • Silica-aerogel • Foaming agent • Water

4.5 Manufacturing of the new circular building products

[This is an intermediate report. This paragraph will be added in the final report (deliverable number: D4.3).]

4.6 Installation and use in representative building spaces

[This is an intermediate report. This paragraph will be added in the final report (deliverable number: D4.3).]

4.7 Demonstration of the new digital EBM traceability service

[This is an intermediate report. This paragraph will be added in the final report (deliverable number: D4.3).]

4.8 Simulation of easy disassembly of the new building products

[This is an intermediate report. This paragraph will be added in the final report (deliverable number: D4.3).]

5 CCS3: Case study demonstrating circular carbonated blocks (task 4.4)

The demolished building (Figure 49) is a supermarket building with a built surface of 2834 m² and a volume of 16104 m³, furthermore the demolition lot contained 5627 m² of asphalt and 525 m² of concrete parking space (Figure 50).

Figure 49. The demolition case study (the petrol station in the front is not part of the demolition works) (address: Gampelaeredreef 1, 9800 Deinze, Belgium).

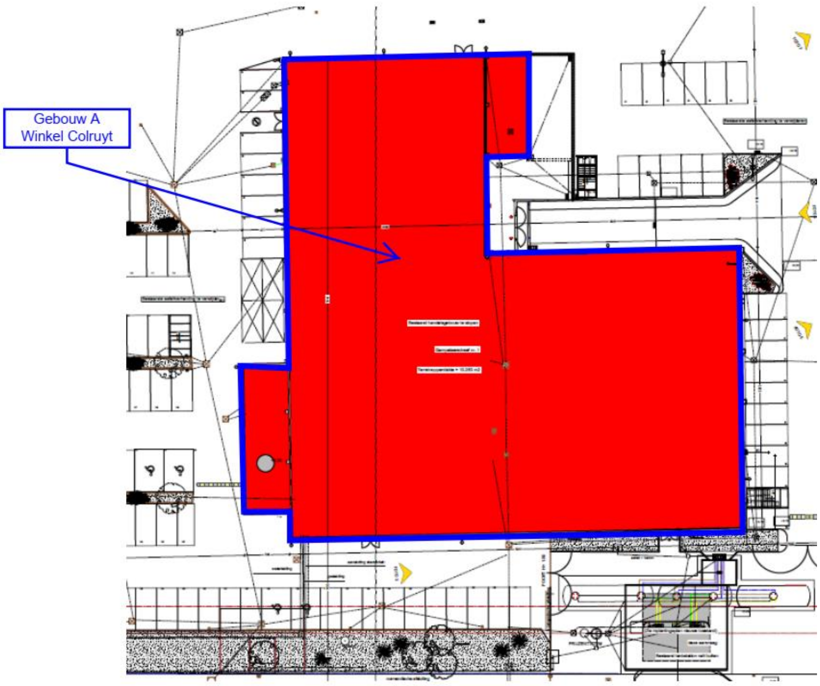


Figure 50. Plan of the demolition case in the pre-demolition inventory.

5.1 Pre-demolition audit/ preparatory activities

The pre-demolition audit was performed according to the procedures of the demolition management organisation Tracimat and received a declaration of conformity from Tracimat. This means the pre-demolition audit is complete, includes the necessary analyses, an overview of the materials present, and a complete classification of suspected asbestos applications, including some advice for their correct removal.

Several suspected asbestos applications were detected, sampled, and analysed: coatings, putty between the façade concrete panels, and the bituminous roofing (Figure 51). No asbestos was detected. A core sample of the asphalt concrete was sampled and analysed (analysis of PAH16), it did not contain tar. The bituminous roofing was not sampled during the pre-demolition audit (since the building was still in use). This was tested afterwards by Derbigum for an assessment of its recycling potential. For all hazardous materials, pictures are included in the pre-demolition audit.

Figure 51. Two applications tested for asbestos (left: coating, right: putty between concrete panels.

The audit indicated the presence of the following hazardous materials:

Table 14. Hazardous materials in the demolition case study.

<table>
<tr><th colspan="2">Application</th><th>Mass (ton)</th><th>Amount</th><th>Surface (m²)</th></tr>
<tr><td colspan="2">Smoke detectors</td><td></td><td>15</td><td></td></tr>
<tr><td colspan="2">Airconditioning system</td><td>0.08</td><td>1</td><td></td></tr>
<tr><td colspan="2">Cooling installations</td><td>0.20</td><td>2</td><td></td></tr>
<tr><td colspan="2">Fire extinguishers</td><td>0.23</td><td>15</td><td></td></tr>
<tr><td colspan="2">Bituminous roofing, potentially containing tar</td><td>51.40</td><td></td><td>2570</td></tr>
<tr><td rowspan="4">Lighting</td><td>Emergency lighting</td><td>0.03</td><td>34</td><td></td></tr>
<tr><td>Fluorescent lights</td><td>0.13</td><td>423</td><td></td></tr>
<tr><td>Light fittings</td><td>0.40</td><td>397</td><td></td></tr>
<tr><td>Other lights</td><td>0.01</td><td>21</td><td></td></tr>
</table>

The following non-hazardous materials were detected:

Application	Mass (ton)	Amount	Surface (m^2)	Volume (m^3)
Other stony materials – 17 01 07	**3386**			**1846**
Foundation material	3322			1846
Floor screed	64.44		358	
Clay bricks and roof tiles – 17 01 02	**289**			**165**
Outer walls	289			165
Concrete – 17 01 01				
Construction above ground	**898**			**408**
Outer walls	155			70.50
Roof structure	79.20			36.00
Columns	65.47			29.76
Beams	477			217
Stair	7.90			3.50
Mezzanine floor	113			51
Foundation & flooring	**1802**			**819**
Outdoor pavement	**127**			**57.76**
Asphalt concrete – 17 03 02	**776**			**338**
Autoclaved aerated concrete – 17 08 02	**663**			**947**
Inner walls	11.76			16.80
Outer walls	233			333
Roof structure	418			598
Ceramic tiles – 17 01 03	**4.49**		**224**	
Floors	3.80		190	
Wall covering	0.69		34.32	
Porcelain	**0.14**			
Toilets	0.08	4		
Sinks	0.06	4		
Mixed C&DW – 17 09 04	**0.23**		**77.00**	
Epoxy flooring	0.23		77.00	
Window glass – 17 02 02	**1.70**		**117**	
Gypsum – 17 08 02	**2.23**		**92.80**	

Application	Mass (ton)	Amount	Surface (m²)	Volume (m³)
Wall plaster	2.23		92.80	
Wood – 17 02 01	**9.65**		**499**	
Inner walls	1.53		69.50	
Cabinetwork	0.03		4.68	
Doors	0.17	11		
Ceilings	0.54		36.00	
Furniture	1.55	2		
Flooring	1.17		78.00	
Wall covering	4.67		311	
Inorganic insulation material – 17 06 04	**0.23**		**56.70**	
Wall covering	0.23		56.70	
Organic insulation material – 17 06 04	**11.97**		**2993**	
Ceilings	0.03		14.85	
Roof insulation	10.28		2570	
Gate	0.12		24.00	
Wall covering	1.54		385	
Plastics: PVC – 17 02 03	**0.09**		**6.9**	
Roof covering	0.07		6.9	
Door	0.02	1		
Metals: aluminium – 17 04 02	**6.26**		**1004**	
Metalwork	0.37		123	
Ceilings	2.43		243	
Gate	0.38		24.00	
Wall covering	3.07		614	
Metals: iron and steel – 17 04 05	**3.75**			
Doors	0.22	6		
Beams	2.94		103	
Stairs	0.15			
Heating elements	0.44	11		

The audit report also includes recommendations for the demolition works, like:

- A maximal separate removal of the inner elements (store shelves, cash registers, lighting, …)
- A maximal separate removal of non-stony materials
- Attention (visual inspection) for the potential presence of hazardous materials (e.g., pieces of asbestos) in the soil or foundation layers.

5.2 Execution of selective refurbishment/ demolition

The demolition process of the supermarket was carried out in two phases. At first, the back part of the store was demolished while the front part was kept open as a supermarket. After construction of a new supermarket on and around the location of the back part, the front part was demolished. This chapter describes the demolition process of the back part of the supermarket.

The demolition process started with a decontamination step. In this step, all hazardous materials (Table 14) were removed. Furthermore, all Colruyt equipment furniture/equipment (cash registers, store shelves, alarm system) were removed for reuse in other supermarkets (Figure 52). After this step, Tracimat performed a control visit to confirm the removal of the hazardous materials.

Figure 52. Some elements that were selectively removed for reuse.

During the demolition, the following non-stony materials were collected separately for recycling: wood, autoclaved aerated concrete (AAC), metals, bituminous roofing (Table 15).

Insulation materials and PVC were selectively removed. However, due to a lack of economically interesting recycling routes and/or limited amounts of the materials, they were brought in the same container to a sorting plant.

Afterwards, the structural part of the building was demolished, and a stony fraction was produced for recycling. Concrete beams and columns were collected separately for use in the ICEBERG project.

5.3 EBM processing

Most non-stony materials were recycled (Table 15). Part of the AAC was collected separately to investigate its recycling potential in new AAC in another research project ("Hoogwaardig recyclageproces van cellenbeton optimaliseren", received VLAIO-funding in the framework of the Flemish Resilience recovery plan). However, it was found that the bituminous coating of the steel rebars in the AAC hampered this recycling route. The rest of the ACC was recycled according to the current state-of-the-art recycling route in Flanders (sand replacement in screeds).

Table 15. Recycling routes for the selectively removed non-stony materials.

Material	Recycled into
Wood	Fibreboard
Metals	New metals
Bituminous roofing	New bituminous roofing
Autoclaved aerated concrete	Sand for screeds

The stony fraction was pre-crushed to remove the steel reinforcement and afterwards treated by a mobile crushing plant to use the material onsite as aggregates (0-40 mm) in the foundation layer of the new supermarket building and the new parking lot. Concrete beams and columns were kept separately, pre-crushed to remove steel reinforcements (Figure 53) and transported to a stationary crushing plant where the material was crushed and sieved into recycled fine (0-4 mm) and coarse (4-20 mm) concrete aggregates for further use in the project. This crushing plant is certified to produce high-grade recycled concrete aggregates (type A+, NBN EN 12620). Concrete beams and columns were selected because they are composed of high-quality concrete.

Figure 53. Pre-crushing of selected concrete beams.

5.4 Manufacturing of the new circular building products

5.4.1 Carbonation of the coarse recycled concrete aggregates

Four big bags of the coarse recycled concrete aggregates were carbonated at the Orbix carbonation pilot facilities in Farciennes, Belgium (Figure 54). Carbonation took place under 30% CO_2 (atmospheric pressure) and 60 °C for 18 hours in an autoclave. After carbonation, the water absorption of the recycled aggregates decreased, and their density increased (EN 1097-6) (Table 16). A longer carbonation time did not result in a further decrease in water absorption (tested by carbonating the aggregates further in lab conditions). The low water absorption of the recycled aggregates before carbonation indicates the high quality of the selected concrete for processing (beams and columns).

Table 16. Characteristics of the recycled coarse concrete aggregates before and after carbonation.

Parameter	Before carbonation	After carbonation
Water absorption after soaking for 24 hours (in %)	4.0	3.2
Oven-dried particle density (in kg/dm³)	2.38	2.43
Porosity (in %)	10.6	8.5

Currently, concrete samples (C30/37, 340 kg/m³ cement, w/c = 0.55, environment classes XC3 & XF1) with the use of these carbonated aggregates (replacement rates: 30%, 50%, 70%, 100%) are being tested for lot certification.

Figure 54. Orbix carbonation pilot facilities.

5.4.2 Production of carbonated blocks

The industrial production test took place at the Masterbloc production plant, since this is the only plant in Belgium that has the facilities (mixers, vibration press, carbonation curing chamber) for the industrial production of carbonated masonry blocks. Masterbloc is currently producing carbonated masonry blocks according to the Carbstone process, patented by Orbix and VITO. Currently, these carbonated blocks don't contain any recycled concrete material.

Carbonated masonry blocks were produced by mixing 25% of Carbinox® with 75% of recycled concrete sand (0-4 mm), and water (11% water content) in a silo. The water content is an important parameter, since too much water can impede the transfer of CO2 in the blocks, while too little water leads to a suboptimal packing during the vibration pressing, causing small cracks in the masonry blocks. Carbinox® is a fine material that is produced during the crushing and washing process of stainless-steel slags by Orbix. Carbinox® is an easily carbonatable material.

Subsequently, the material mixed is pressed into blocks by a vibrational press (Figure 55), and cured in a carbonation chamber (70% CO_2, atmospheric pressure, 24 hours) (Figure 56).

Phenolphthalein colouring of the cross sections of carbonated masonry blocks confirmed complete carbonation. An average compressive strength of 5.6 MPa was obtained for the produced blocks. The total carbon content of the carbonated blocks is 3.0%, which means the blocks stored 34 kg CO_2 per ton of blocks during the carbonation process. Currently, a subsample of the carbonated blocks is being tested for lot certification.

Figure 55. Produced blocks right after vibration pressing.

Figure 56. Carbonation chamber (left) and carbonated blocks (right).

5.5 Installation and use in representative building spaces

The produced carbonated blocks will be used in the construction of an inner partition wall. The carbonated aggregates will used in the production of foundation concrete with recycled aggregates. The installation and use of the produced materials will be described further in D4.3.

5.6 Demonstration of the new digital EBM traceability service

The demonstration of traceability will be described in D4.3.

5.7 Simulation of easy disassembly of the new building products

The simulation of easy disassembly will be described in D4.3.

6 CCS4: Case study demonstrating circular wood-based products (task 4.5)

6.1 Pre-demolition audit/ preparatory activities

The pre-demolition audit was done in two different demolition sites: Suonsivunkatu 11, Tampere and Puijonkatu 22, Kuopio. Audit in Tampere was done by using a tool made by the Finnish Ministry of Environment. The demolition in Tampere was not business-as-usual, therefore the audit was done with more precise evaluation tool, with what the re-usable construction parts could be specified more accurate. In Tampere the object was to dismantle all the reusable construction parts of a wooden storage building (Figure 57). Demolition site in Kuopio was business-as-usual, so the audit was done with traditional estimation based on on-site review and information that was got from the customer. From Kuopio demolition site the objective was to conduct at least 20 tons of high-quality (pure) wood waste free of impurities and mixed wood waste containing impurities, which was executed successfully.

Figure 57. The wooden storage building in Tampere.

6.2 Execution of selective refurbishment/ demolition

The demolition in Tampere was done with hand tools and HIAB truck. Usually, a wooden storage building like that would be torn down with excavators, but in this case the wooden and metal construction parts were dismantled whole without wrecking. The dismantling was done successfully, and construction parts were delivered to Ismo Tiihonen intact (Figure 58).

Figure 58. The dismantled wooden and metal construction parts waiting to be reassembled.

In Kuopio the demolition was executed with selective demolition (as usual), and the wooden demolition waste was delivered to Ismo Tiihonen (Figure 59).

Figure 59. Mixed wood waste.

6.3 EBM processing

The mixed wood waste was sorted by Ismo Tiihonen manually with a crapple crane into three different classes: clean wood, coated/clued/painted wood and building boards. Wood wastes were mechanically processed with hammermill to smaller wood fibers. For pyrolysis the wood waste was crushed to particle size between 0,25-3 mm and dried, to get the water content between 10-12 %. For insulation panel manufacturing the wood will be crushed to a 40 mm particle size (Figure 60) and metals will be removed with magnetic separator. Light non-wood materials will be removed from fibers with wind separator and finally the fine dust will be sieved from it with a drum sieve.

Figure 60. The 40 mm wood fibers for insulation panel manufacturing.

The bio-oil production and lignin separation were done successfully by VTT. Lignin was sent to Megara Resins, and they were able to make the optimization of resin synthesis protocol with the aim to reach 50 % replacement of phenol with pyrolysis lignin. The resin was tested by Soprema in insulation panel manufacturing. Unfortunately, they had to conclude that it is not compatible in the process, so the final conclusion is, that the bio-phenolic resin can't be used in this task.

6.4 Circular design

The lab scale test trials are still on going by Soprema. Some of the tests have been done and the obtained flexible panel prototypes with wood fibers from demolition wood waste get good sight (Figure 61). Concerning the values, some comparison says they are:

- good for tensile strength (comparing to standard flex products done on pilot line)
- a little bit more dusty
- more difficult to get a good fire behaviour with the same amount of fire retardant, so the industrial production will surely need to use more RF than the standard version of Pavaflex products. The thermal conductivity will be tested soon.

Figure 61. Insulation panel sample obtained from wooden demolition waste

6.5 Manufacturing of the new circular building products

Once the last lab-scale tests have been done and test results have been approved, Soprema will manufacture the flexible insulation panels. This will be done in the near future. The insulation panels will be made from 40 mm wood fibers and using “regular” resin.

6.6 Installation and use in representative building spaces

The installation and use in representative building spaces will be carried out in summer 2023. Ismo Tiihonen will start to build the foundation of the new building at early stage of summer 2023, in which he will use the re-usable wooden construction parts and the insulation panels, once they will be ready. The installation of the panels must be done carefully, to keep ventilation between external wood cladding skin and outer face of flexible insulation.

6.7 Demonstration of the new digital EBM traceability service

RFID tags were attached to wooden and metal construction parts at the demolition site in Tampere (Figure 62). The validation of the traceability service will be done at later stage.

Figure 62. RFID tag attached to wooden construction part.

6.8 Simulation of easy disassembly of the new building products

The assessment of easy disassembly of the wooden products will be done at later stage.

7 CCS5: Case study demonstrating circular plasterboards (task 4.6)

The objective of CCS5 is to demonstrate the application of the ICEBERG circular plasterboard) containing 35 wt% recycled gypsum in two refurbishment projects (building 1 and building 2) on the LU site. Building 1 will be used to source EoL plasterboard and building 2 will be used to install the ICEBERG plasterboard.

CCS5 includes the following stages:

1) Perform pre-demolition audit of LU building 1, followed by dismantling and collection of approximately 720 m^2 EoL plasterboard.
2) Transport EoL plasterboard to ENVA's recycling plant to recycle it based on the ICEBERG gypsum purification process that was developed in WP2.
3) Transport the purified gypsum to GYPS and manufacture 1000 m^2 of ICEBERG plasterboards with 35 wt% recycled gypsum and silica aerogels (KEEY) to enhance their thermal performance.
4) Tag and install ICEBERG plasterboards in the refurbishment (LU building 2 with 1500 m^2).
5) Validate the CTP adapted to the traceability of circular plasterboards products through RFID-based tags.
6) Characterize circular plasterboards and assess their easy-disassembly and material, energy, and water efficiency.

There are some modifications to the activities originally planned during stage 1 (demolition), stage 2 (recycling) and stage 3 (manufacturing) of CCS5:

Stage 1. GYPS needs **35 tons** of recycled gypsum to produce the minimum requirement of 100 tons (11850 m^2) of ICEBERG circular plasterboard at their manufacturing site. ENVA envisages that up to **5 tons** of gypsum could be lost along the recycling treatments of the ICEBERG gypsum purification process. The estimated amount of EoL plasterboard in building 1 at LU site is **2.5 tons** (300 m^2). Therefore, ENVA will source the remaining **37.5 tons** of EoL plasterboard from a customer.

Stage 2. The HSI system developed by LENZ in T2.1 will not be used to separate large impurities (mortar, wood, plastics, etc.) from EoL plasterboard fragments at the EoL plasterboard recycling stage because the HSI system requires particles between 50-80 mm that must be obtained through crushing. Plasterboard crushing generates vast amounts of **gypsum dust that cannot be classified by the HSI system**. Also, the blowing of plasterboard fragments in the HSI system will release significant amounts of dust in the air, which represents a **health hazard for operators of the recycling site** and could cause **site contamination**. The lab-scale HSI system developed by GAIKER in T2.1 showed that the efficiency of this system is comparable to that of manual segregation. For all these reasons, manual segregation will be implemented in CCS5.

Stage 3. The recycled gypsum in ICEBERG plasterboards produced in CCS5 will not contain ICEBERG purified phosphogypsum obtained after acid leaching (T2.5), because this material still contained **heavy metals above the levels demanded by plasterboard manufacturers**. Also, the ICEBERG plasterboards produced in CCS5 will not contain the silica aerogel developed by KEEY (ST2.7.2) because it was **not possible to produce homogeneous blends of gypsum and silica aerogel** (T3.6), which is a requirement of plasterboard manufacturers.

Demolition of LU building 1 will commence on 9th May 2023. Therefore, work carried out in the reporting period focused on pre-demolition activities of stage 1.

7.1 Pre-demolition audit/ preparatory activities

This activity commenced in June 2022 and was completed in April 2023. LU building 1 is an office building with three levels located at the LU campus in Loughborough (UK). The latitude and longitude coordinates of this building are respectively 52.76503969499 and -1.2304111312276. Digital plans of the building were obtained from LU Estates.

The pre-demolition audit activities performed in the current research period were:

1. Measurements, videos, and photos of LU building 1.
2. BIM model and modelling with new ICEBERG's BIM4DW tool.
3. Production of EoL plasterboard dismantling, segregation, and storage protocol.

7.1.1 Measurements, videos, and photos of LU building 1

LU building 1 was visited on 25/08/22, 10/11/22 and 01/12/22 to take measurements of plasterboard, record its location in walls and ceilings, make videos and take photos. Measurements were performed with a tape measure and a Bosch GLM 120 C digital laser measurer. Plasterboard was located in walls and ceilings of some rooms and corridors. Videos were recorded with a Canon XA10 video recorder, and photos were taken with a 13 MP digital camera (Figure 63).

The recorded measurements from LU building 1 were used to create an Excel spreadsheet (Figure 64) and calculate the total area in square meters of plasterboard in each room and floor. It was assumed that the plasterboard in walls and ceilings had a thickness of 12.5 mm to calculate the volume of plasterboard. A density of 8.44 kg/m^2 was used to convert square meters into kilograms. The recorded measurements amounted to 300 m^2 of plasterboard in LU building 1, which equates to around 2.5 tons.

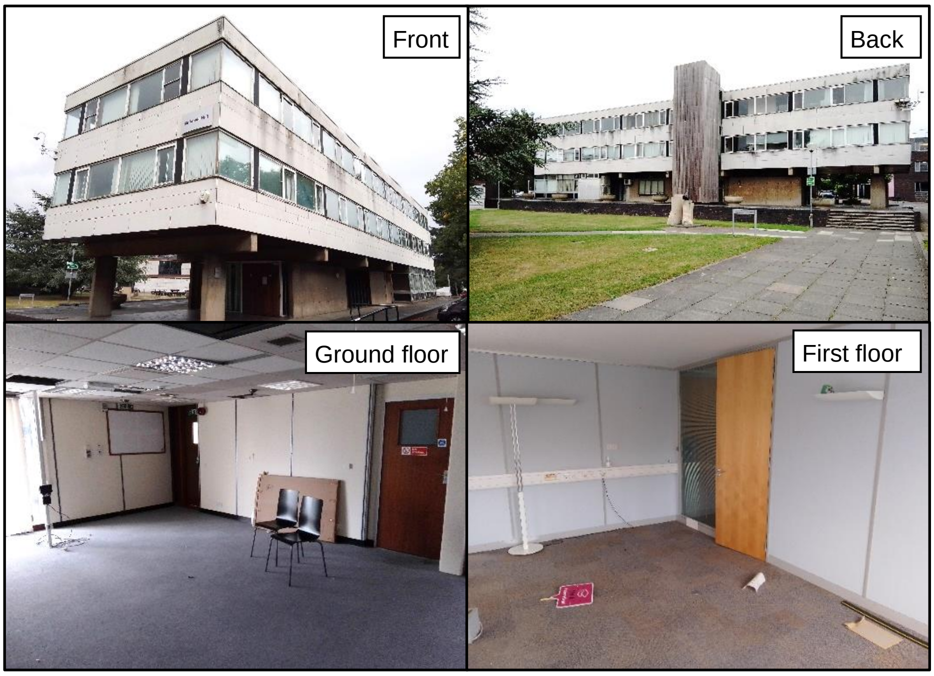


Figure 63. Outside of LU building 1 (top) and rooms with plasterboard in walls (bottom).

		Wall-Exterior concrete with wood cover			Wall-Exterior Plasterboard-concrete			Wall-Interior brick with wood cover both			Wall-Interior brick with plaster finish			Wall-Plaster board			Wall-Glass			Wall- Exterior concrete with wood cover			Basic wall-other materials			Ceiling
		m2	m3		m2	m3		m2	m3		m2	m3		m2	m3		m2	m3		m2	m3		m2	m3		m2	m3
Ground floor	A1	15.4	4.3	B1	4.3	1.2	C1	1.5	0.2	D1	6.5	0.9	EE1	7.9	1	F1	9.5	1.2	G1	5.8	1.6						
	A2	15	4.2	B2	17.7	4.9	C2	8.1	1.2	D2	1.7	0.2	E2	3.2	0.4	F2	2.5	0.3	G2	8.1	2.2						
	A3	12.8	3.5	B3	11.7	3.2	C3	4.2	0.6	D3	1.6	0.2	E3	1.4	0.18	F3	10.1	1.26	G3	6.5	1.8						
	A4	27	7.5	B4	7.1	2	C4	12.1	1.8	D4	11.5	1.7	EE4	11.1	1.4	F4	18.1	2.2									
	A5	17	4.7	B5	1.1	0.3	C5	3.3	0.5	D5	2.6	0.4	E5	2.6	0.3	F5	5.5	0.7									
							C6	17.6	2.6	D6	3.2	0.4	E6	9	1.1	F6	4.8	0.6									
							C7	12.05	1.8	D7	5.2	0.7	E7	3.5	0.4	F7	3.6	0.4									
										D8	2.9	0.4	E8	4.3	0.5	F8	5.9	0.7									
		87.2	24.2		41.9	11.6		58.85	8.7		35.2	4.9		43	5.28		60	7.36		20.4	5.6						
First floor				1B1	11	3				1D1	25.1	3.7	1EE1	4.6	0.5	1F1	7.08	0.8	1G1	9.7	2.7	1H1	2.3	0.2	1ce1	174	69
				1B2	15.2	4.2				1D2	7.7	1.2	1EE2	2.5	0.3				1G2	8.1	2.2	1H2	1.2	0.1			
				1B3	28.3	8				1D3	4.4	0.6	1EE3	4.8	0.6				1G3	11.5	3.2	1H3	6.1	0.7			
				1B4	10.9	3				1D4	6.2	0.9	1EE4	1.5	0.2												
				1B5	57.1	16				1D5	12.8	1.9	1EE5	1.5	0.2												
										1D6	7.8	1.1	1EE6	3.3	0.4												
										1D7	2.1	0.3	1 E7	1	0.13												
										1D8	51.4	7.7	1 E8	0.7	0.09												
										1D9	6.3	0.9	1 E9	9.3	1.17												
										1D10	6.3	0.9	1 E10	13.9	1.7												
										1D11	4.4	0.6															
										1D12	4.4	0.6															
										1D13	3.6	0.5															
										1D14	11.03	1.6															
										1D15	7	1															
										1D16	9.1	1.3															
										1D17	10.9	1.6															
										1D18	0.8	0.12															
										1D19	12.9	1.9															
										1D20	13.7	2.06															
										1D21	6.2	0.9															
					122.5	34.2		0	0		214.13	31.38		43.1	5.29		7.08	0.8		29.3	8.1		9.6	1		174	69
Second floor				2B1	14.2	4				2D1	11.1	1.6	2EE1	1.5	0.2				2G1	9.8	2.7	2H1	0.6	0.07			
				2B2	21.7	6.1				2D2	1.1	0.1	2EE2	1.5	0.2				2G2	8.1	2.2	2H2	6.1	0.7			
				2B3	39	11				2D3	3.2	0.5	2EE3	8.4	1.05				2G3	10.3	2.9						
				2B4	14	3.9				2D4	6.2	0.9	2EE4	2.9	0.3												
				2B5	62.6	17.4				2D5	19.2	2.9	2EE5	2.02	0.2												
										2D6	11.4	1.7	2EE6	3.3	0.4												
										2D7	10.2	1.5	2EE7	2.9	0.3												
										2D8	30.9	4.6															
										2D9	8.1	1.2															
										2D10	8.1	1.2															
										2D11	9.8	1.4															
										2D12	9.8	1.4															
										2D13	9.3	1.4															
										2D14	0.7	0.1															
										2D15	4.6	0.7															
										2D16	6.3	0.9															
										2D17	4.6	0.7															
										2D18	6.3	0.9															
										2D19	4.9	0.7															
										2D20	9.6	1.4															
										2D21	3.9	0.6															
										2D22	4.6	0.7															
										2D23	10	1.5															
										2D24	28.1	4.2															
					151.5	42.4		0	0		222	32.8		22.52	2.65		0	0		28.2	7.8		6.7	0.77			

Figure 64. Spreadsheet of plasterboard inventory in LU building 1.

7.1.2 BIM model and modelling with new ICEBERG's BIM4DW tool

The recorded measurements were used to construct a BIM model that locates the plasterboard in the different floors (Figure 65).

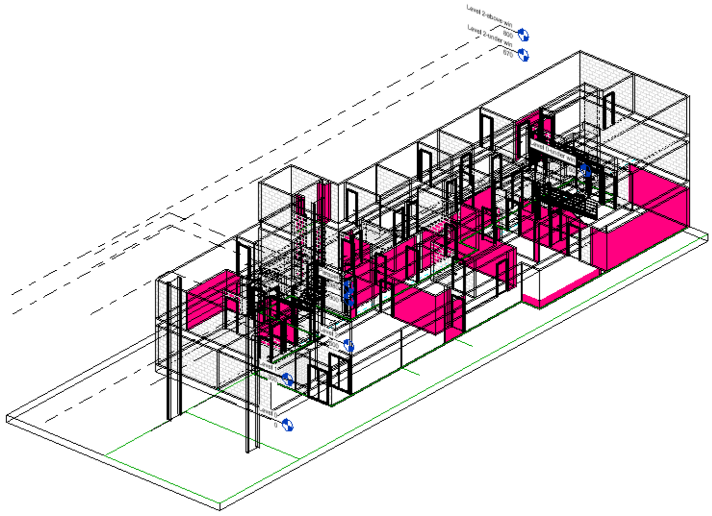


Figure 65. BIM model of LU building 1 showing in magenta the plasterboard located in walls.

The recorded measurements of all elements and plasterboard in LU building 1 were also uploaded to the BIM4DW tool. Modelling of each floor of LU building 1 is still a work in progress due to compatibility issues with the BIM4DW software. As an example, Figure 66 shows the model of the first floor of LU building 1 with the dimensions of walls.

Figure 66. BIM4DW modelling of the first floor of LU building 1.

7.1.3 Production of EoL plasterboard dismantling, segregation, and storage protocol

An EoL plasterboard dismantling, segregation and storage protocol was produced in consultation with the demolition contractor of LU building 1. This protocol prioritizes the dismantling of EoL plasterboard before any other demolition activities commence and introduces onsite segregation and storage of EoL plasterboard to prevent cross-contamination. This protocol is as follows:

1. Operatives to comply with Health and Safety requirements.
2. Clear area in room to place plasterboard waste.
3. Remove EoL plasterboards from walls and ceilings by hand (pulling) or with the use of tools when necessary to minimize formation of gypsum dust and small plasterboard fragments. Common tools for plasterboard dismantling and their recommendation are presented in Table 17.

Table 17. Tools for plasterboard dismantling and their recommendation.

Tools for EoL plasterboard dismantling	Recommendation
Shovel	Preferred
Spade	Preferred
Pickaxe	Preferred
Screwdriver	Preferred
Crowbar	Optional
Cutting chisel	Optional
Saber saw	Optional
Sledgehammer	Not recommended

4. If possible, remove any metal frame, insulator, fire switch, etc., in the plasterboard.
5. Collect and place the segregated EoL plasterboard in skip provided by ENVA (one 6 yard or 8 yard skip should be sufficient to collect all EoL plasterboard).

7.2 Execution of selective refurbishment/ demolition

This activity will be performed in May 2023. A demolition contractor was appointed at the beginning of 2023 for the demolition of LU building 1. An initial meeting between LU Facilities Management and the demolition contractor was held on 20/03/2023 to

- Introduce ICEBERG's CCS5 objectives and requirements,

- Discuss the ICEBERG's plasterboard dismantling, segregation, and storage protocol,
- Schedule the delivery of a skip provided by ENVA (plasterboard recycler) that will be used to store and transport the EoL plasterboard to the recycling site,
- Plan site visits by LU members to take photos, record videos and collect LCA and LCC data during EoL plasterboard dismantling, segregation, and storage, and
- Identify potential barriers envisaged by the demolition contractor for the successful completion of the EoL plasterboard activities.

7.3 EBM processing

This activity will commence in May 2023 and will be completed in September 2023. The schedule of this activity has already been defined by ENVA. In May-June 2023, EoL plasterboard from LU building 1 (2.5 tons) and from an ENVA's customer (37.5 tons) will be transported to ENVA recycling site in Nottingham (England) to be processed (Figure 67).

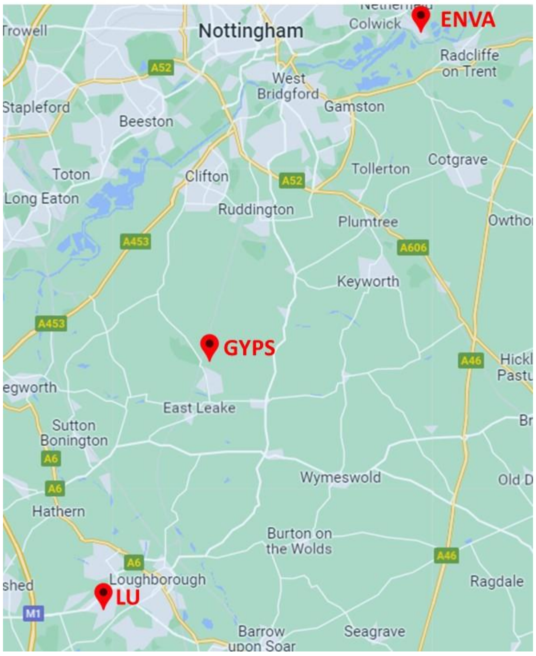


Figure 67. Location of LU, ENVA (Nottingham) and GYPS sites.

In June 2023, the recycled gypsum will be transported to MidUK (external plasterboard recycler) to be crushed to particle sizes less than 8 mm. In June-July 2023, the crushed gypsum will be transported to ENVA recycling site in Paisley (Scotland) for acid leaching purification, which will be completed in September 2023. Quality control of each batch of the ICEBERG purified gypsum product will be carried out to ensure that it fulfils the requirements of GYPS (plasterboard manufacturer).

7.4 Circular design

This activity will be performed in September 2023

7.5 Manufacturing of the new circular building products

This activity will commence in September 2023 and will be completed in November 2023. ICEBERG plasterboard manufacturing will take place within GYPS production facility at Sherburn in Elmet (Figure 68).

Figure 68. Location and imagery of GYPS production facility at Sherburn in Elmet (England).

Planning for the trials have identified that these trials will require the plant to be closed to normal commercial activities for a period of 48 to 72 hours. During the planning phase, the processes for receiving, handling, and processing the purified gypsum have been mapped, subject to further planning and manufacturing requirements.

Although gypsum is classified as a non-hazardous material, it requires Environmental Agency (EA) permits for the legal handling of the material. To ensure compliance with local EA requirements, all permits have been reviewed to ensure that it is permissible to manage the purified gypsum on the site.

Following the manufacturing process, the ICEBERG plasterboards will be subject to testing to the British Standard EN 520[6]. This testing will be completed by the end of November 2023.

7.6 Installation and use in representative building spaces

This activity will commence in November 2023 and will be completed in December 2023. Initial discussions with LU Facilities Management have been carried out to identify LU building 2 to commence the installation of ICEBERG plasterboards in late November or early December 2023.

[6] British Standard EN 520:2004+A1:2009. Gypsum plasterboards – Definitions, requirements, and test methods.

7.7 Demonstration of the new digital EBM traceability service

This activity will commence in December 2023 and will be completed in January 2024. A review of the existing trials for product identification using QR code has been undertaken to access the suitability of use for traceability. The result of the review is that, although there is the capability to produce ICEBERG plasterboards with the necessary QR code, it is not feasible to use the QR code for traceability. The reasons for the decision are:

a) If the QR code is printed on the back of the board (Figure 69), there will be no access to the QR code once the ICEBERG plasterboard has been installed.

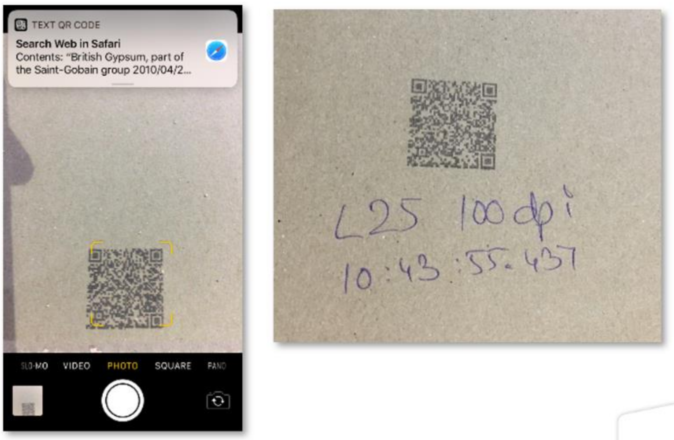


Figure 69. Example of using a QR code on the back of the plasterboard.

b) If the QR code is printed on the front of the ICEBERG plasterboard, it will most surely be covered with paint, ceramics tiles or many other forms of finishing products such as skimmed plaster, which will prevent access for scanning the QR code.

To provide traceability, an RFID label (Figure 70) will be adhered to the back of each ICEBERG plasterboard. The label will be encoded to provide the data relating to the product website URL, along with information that can be used to provide an inventory listing of the quantity of material installed.

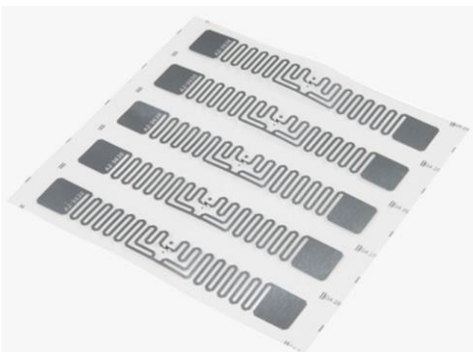


Figure 70. Example of RFID label.

At this stage, no final decision has been taken on the exact RFID label that will be used in ICEBERG plasterboards.

7.8 Simulation of easy disassembly of the new building products

This activity will commence in December 2023 and will be completed in January 2024.

8 CCS6: Case study demonstrating circular ceramic, silica aerogel and PU based products (task 4.7)

8.1 Pre-demolition audit/ preparatory activities

A building of the Litoral Thermal Power Plant, which is being dismantled by LEZA, is chosen to carry out case study 4.7. The site is located in the town of Carboneras, in the region of Andalusia, Spain.

Figure 71. Litoral Thermal Power Plant and the location of the electrical building

The building is the former electrical maintenance building of the power station. It has 2 floors, concrete structure, masonry enclosure and exterior sheet metal. Flat roof with concrete slab. It has a floor area of 11.50 x 17.50 m^2 and is 8 m high. The ground floor is on a concrete floor.

Figure 72. Main facade of the electrical building which was demolished.

On 21 February 2023, TECN, with the support of LEZA's personnel on site, carried out the pre-demolition audit of the electrical maintenance building. On the one hand, several constructive characteristics of the building were noted, including some tasting to visualise the structure and composition of some areas (raised floors, false ceilings, manholes, etc...); as well as consulting with site personnel on the planned demolition procedure (order of execution, planned resources, identified materials to be segregated, possible difficulties identified, etc...).

Figure 73. Scanning process by TECN.

On the other hand, the building was scanned using the scanner 2D of Faro Scanplan. The data obtained were downloaded to a device and verified that the data were correct and well collected.

Figure 74. Scanning process by TECN.

The following images show floors 1 and 2 modelled in the BIM4DW programme.

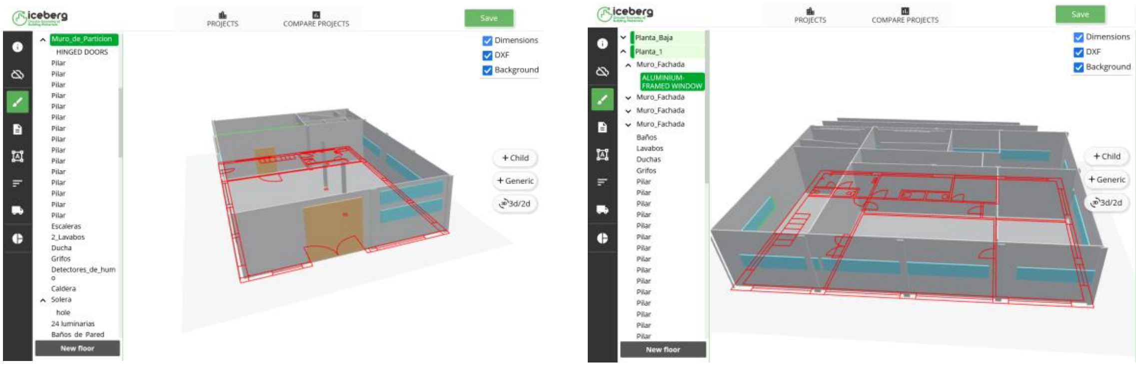


Figure 75. Modelling of the building using BIM4DW programme.

The following table shows the results of the residues obtained with the BIM4DW software.

Table 18. Waste from BIM4DW.

EWC CODE	WASTE DESCRIPTION	BIM4DW (t)
17 01 01	Concrete	287,212
17 01 07	Stony mixture	185,336
17 01 03	Ceramics	0,619
17 04 02	Aluminium	5,656
17 04 05	Iron and Steel	41,403
17 04 07	Mixed metals	0,126
16 06 16	Components removed from discarded equipment	0,08
17 02 02	Glass	0,851
17 02 01	Wood	1,532
17 08 02	Gypsum	4,58
17 02 03	Plastic	0,113
20 01 21*	Fluorescents	0,151 (168 uni)
17 04 11	Cables	
17 04 01	Bronze	

8.2 Execution of selective refurbishment/ demolition

Once the pre-demolition audit has been carried out and with the expected waste obtained, selective demolition is carried out, following the steps below:

1) Previous cleaning (pick up off furniture, rubbish, etc.):

This activity was previously done, before doing the pre-demolition audit, so there are no photos, and the waste that was generated in this previous cleaning has not been accounted.

2) Internal demolition:

In this activity, an internal demolition of the building is carried out manually, in order to segregate the waste found in the building so that it is not mixed when the demolition of the building structure is carried out by machinery. Therefore, these materials were removed:

a. Raised flooring – Wood, plastic, and steel.

Figure 76. Raised flooring dismantling process.

b. Suspended ceiling – Aluminium and gypsum

Figure 77. Suspended ceiling dismantling process.

c. Windows – Aluminium and glass

Figure 78. Small windows of the building

d. Doors – Wood

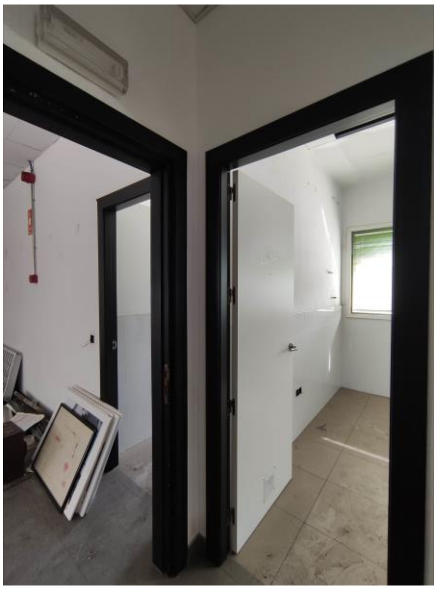


Figure 79. Removal of the doors.

e. Stairs – Plastic

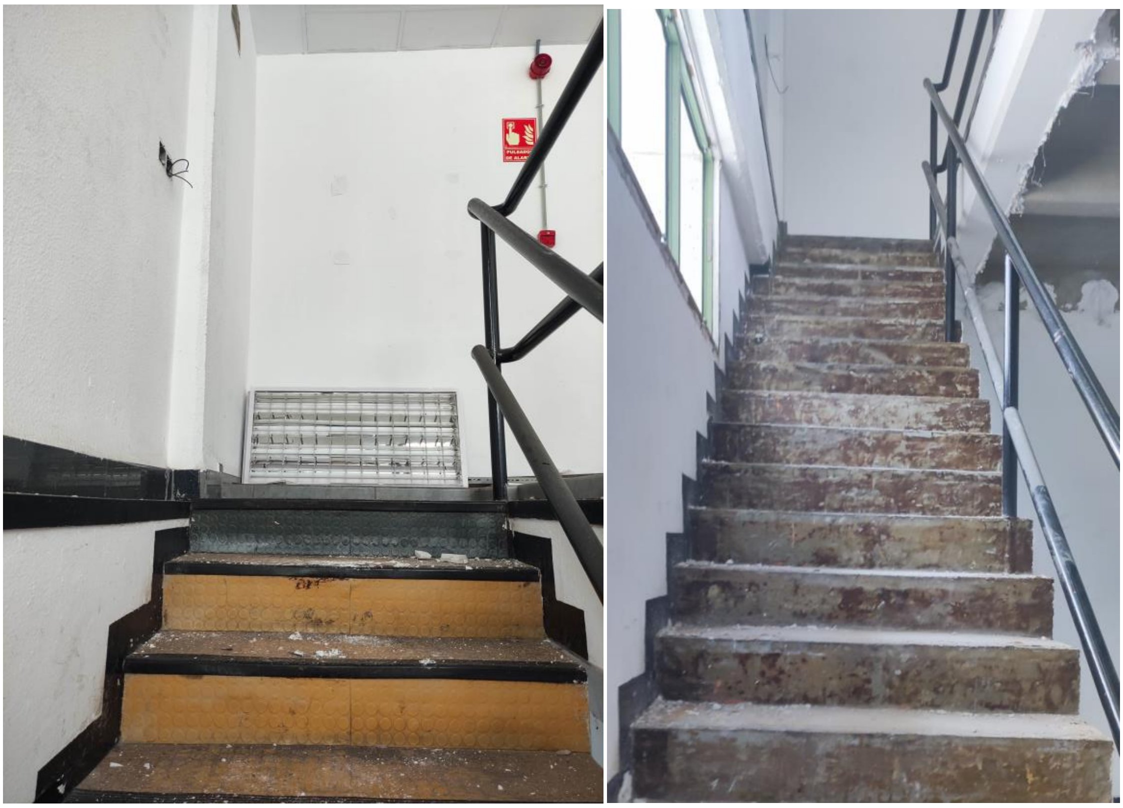


Figure 80. Manual dismantling process for the stairs.

f. Fluorescents

This equipment was removed individually and following the instruction for a special hazardous waste. There are no photos of the fluorescents removal as it was done on a previous.

g. Toilets – Ceramics

The ceramics from the different services like toilets or sinks were removed manually and segregated as a different stream.

Figure 81. Bathroom of the building.

h. Electrical wires

All the wires from the building are removed previously in order of recycling all the metals that are inside the wire.

Figure 82. Wires in the building.

Following images show the different waste streams segregated properly:

Figure 83. Waste streams segregated during the internal demolition process.

3) Demolition with machinery:

Finally, the structure was demolished using machinery. First of all, the aluminium sheeting was removed.

Figure 84. Dismantling of the covering of the building.

Then, the structure of the building could be demolished, generating a big stream of concrete.

Figure 85. Machinery demolition of the structure.

Once the demolition process is finished, the materials are weighed in situ and in the next table, the comparison of the reality versus the programme is shown.

Table 19. Comparison of the reality and BIM4DW.

EWC CODE	WASTE DESCRIPTION	BIM4DW (t)	FWMR (t)
17 01 01	Concrete	287,212	208,72
17 01 07	Stony mixture	185,336	266,36
17 01 03	Ceramics	0,619	0,14
17 04 02	Aluminium	5,656	2,1
17 04 05	Iron and Steel	41,403	30,77
17 04 07	Mixed metals	0,126	
16 06 16	Components removed from discarded equipment	0,08	0,18
17 02 02	Glass	0,851	0,85
17 02 01	Wood	1,532	1,72
17 08 02	Gypsum	4,58	5,15
17 02 03	Plastic	0,113	0,22
20 01 21*	Fluorescents	0,151 (168 uni)	0,01
17 04 11	Cables		0,2
17 04 01	Bronze		0,02

A deviation can be observed for the wastes catalogued as 17 01 01 (Concrete), 17 01 07 (Stony mixture) and 17 01 03 (Ceramics). But grouping them all together as Total stony fractions, the results are more balanced, as it is shown in the table below.

Table 20.Comparison of the total stony fraction.

	BIM4DW (t)	FWMR (t)
Total stony fractions	457,392	475,22

8.3 EBM processing

As mentioned above, the building is demolished using a smart demolition process. Therefore, all material streams are separated at source in order to manage each stream efficiently. However, the stone fraction and the structural concrete are kept as a whole, generating a multi-material phase that is currently being recovered.

Thus, once the interior demolition has been carried out, the aluminium of the cladding of the building is separated by heavy machinery equipped with hydraulic shears, generating the first metallic stream. Then, the demolition of the concrete structure can begin, generating two new streams: the CDW and the steel contained in the reinforcement of the structure.

After the primary demolition, the segregation of the structural metals and the CDW contained in the structure can begin. Thanks to the use of a secondary demolisher, these two streams are separated on the ground, and it is possible, on the one hand, to send the ferrous material for recovery and, on the other hand, to crush the CDW to generate a fraction with a reduced size (0-200 mm). In this way, 3 main fractions are obtained:

- **Aluminium:** it is managed independently and without the possibility of being contaminated by another waste stream.
- **CDW:** is separated from structural steel and a multi-material stream of concrete and different types of ceramic materials is obtained.
- **Steel:** from the rebar contained in the concrete. Once separated, it is managed for recycling.

Ultimately, the last step to be taken is to be able to separate the fraction of CDW containing concrete and ceramic materials. Therefore, samples of these mixed streams will be sent so that they can be separated using the advanced HSI system from LENZ and so that further tests of their data with real materials can be developed.

Even so, the use of materials other than those proposed at the beginning is considered, in order to be able to carry out the learning of the HSI system with materials new to the algorithm, such as wood or fragments of rock wool or glass wool insulation in conjunction with concrete.

8.4 Circular design

Designing materials using waste within the circular economy is an innovative and sustainable approach that seeks to harness available resources to minimize environmental impact. Instead of disposing of waste, it is given a second life as a raw material for creating new products, thus reducing the amount of waste generated and avoiding the exploitation of non-renewable natural resources. Additionally, the use of waste as materials can help reduce production costs and improve energy efficiency, which in turn can improve the profitability of businesses.

The circular economy is a key strategy for transitioning to a more sustainable and just economic model, and designing materials using waste is an essential part of this strategy. By reusing waste as a raw material, the production cycle is closed, and resource waste is avoided, which can contribute to the reduction of greenhouse gas emissions and the conservation of biodiversity. Furthermore, designing materials using waste can encourage innovation and collaboration among companies, which can drive the creation of new sustainable products and services and improve competitiveness in the market. In summary, designing materials using waste is an important and necessary practice for moving towards a more sustainable and equitable future.

In the context of the ICEBERG Project, in the case study described in this section, circularity criteria have been used both in the manufacturing of ceramic tiles and in the PU insulation panels. The detailed description of the pre-industrial formulations of the ceramic tiles is developed in task T3.4. The corresponding one for the PU insulation panels is developed in task T3.7.

8.5 Manufacturing of the new circular building products

Regarding the circular ceramic tiles, the pre-industrial scale production is currently in progress. The formulation for pre-industrial scale production has been developed in task T.3.4 of the ICEBERG Project, and the final tests are pending, which will include even a higher percentage than initially expected of ceramic aggregates recovered from debris.

In relation to the PU insulation panels, the description of pre-industrial formulations is included in task T3.7 of the ICEBERG Project. SOPREMA has sent 725 m^2 of EFIMUR type panels and 215 m^2 of TMS type panels to their place of use in December 2022. It is worth noting that the characteristics of the manufactured products even comply with the CE marking that SOPREMA has for this type of products.

Figure 86. PU insulation panels sent by SOPREMA to VIUDA DE SAINZ in December 2022

8.6 Installation and use in representative building spaces

The circular products developed are going to be installed in the renovation of an office space belonging to the construction company VIUDA DE SAINZ in its facilities in Mungia, located in the province of Bizkaia (Spain). At the time of writing this intermediate deliverable, the installation work of the pre-industrial prototypes described in the previous section is in progress.

The tiles manufactured by KERABEN using circularity criteria are expected to arrive at the site in the coming weeks.

The insulation panels have already been received by SOPREMA and some first installation tests have been carried out.

Figure 87. Reception on site of insulating material sent by SOPREMA and test installation on the ground.

The complete renovation of the office is planned for the following weeks.

8.7 Demonstration of the new digital EBM traceability service

This activity will be reported in D4.3.

8.8 Simulation of easy disassembly of the new building products

This activity will be reported in D4.3.

9 Next steps

This is an intermediate report.

The CCS will continue until the end of 2023. The timing of each CCS will be internally adjusted to the running activities and materials processing, products manufacturing and new construction needs.

The feedback from these demonstrations will be shared with technologies and products developers. The data for the later LCA/LCC assessment will continue being collected.

The results and final conclusions will be added in the final report (deliverable number: D4.3).