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Circular Economy of Building Materials

Innovative Circular Economy Based solutions demonstrating the Efficient recovery of valuable material Resources from the Generation of representative End-of-Life building materials

28	6	35	10	15,6
Innovations	Circular case studies	Partners	Countries	Million of euros

May 2020 – April 2024

Six years ago…

CE-SC5-07-2018-2019-2020 - Raw materials innovation for the circular economy: sustainable processing, reuse, recycling and recovery schemes

Raw materials innovation for the circular economy: sustainable processing, reuse, recycling and recovery schemes.

Actions should develop and demonstrate innovative pilots for the clean and sustainable production of non-energy, non-agricultural raw materials in the EU from primary and/or secondary sources finishing at Technology Readiness Levels (TRL) 6-7.

…actions should facilitate the market uptake of solutions developed through industrially- and user-driven multidisciplinary consortia…

…pilot demonstrations in different locations within the EU…

Subtopic: **Recycling of raw materials from buildings**

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Understanding the problem

Construction, renovation and demolition waste (CDW) is one of the heaviest and most voluminous waste streams generated in the EU28 (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 EC adopted in 2015 a new Circular Economy Package with measures prioritizing End of Life Building materials among others.

CDW includes a wide variety of materials such as concrete, bricks, wood, glass, metals and plastic. Some components of CDW have a high resource value, while others may have a lower value, but could still be easily reprocessed into new products or materials.

Based on volume, CDW is the largest waste stream in the EU (25-30%)

ICEBERG consortium

TIIHONE
N ISMO

ICEBERG project

This project 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 end-of-life building materials (EBM) to new building products prepared for circularity, resource-efficiency and containing 30wt% to 100wt% of high-purity (>92%) recycled content.

This will be undertaken through 6 pilot **circular case studies**, covering building materials accounting for more than 85% by weight of the European built environment.

ICEBERG will also contribute to raising **building circularity awareness** among the stakeholder communities (local authorities, professionals, students and final building users).

ICEBERG project: technologies

SMART SERVICES AND SOFTWARE

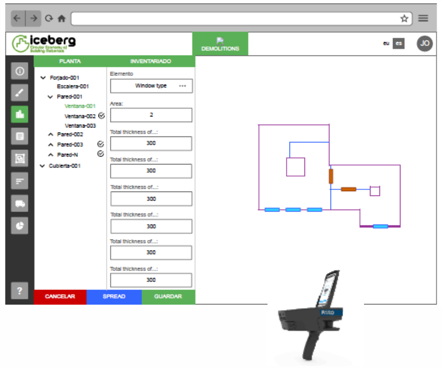
Sensors, artificial intelligence and blockchain to ensure greater information capture, process optimization and traceability to guarantee greater confidence in terms of quality throughout the value chain of resources and products for building.

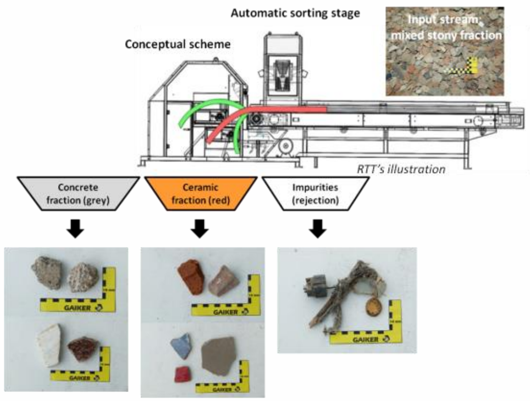
ADVANCED SORTING/ RECYCLING TECHNOLOGIES

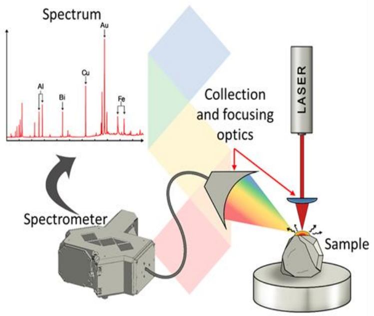
Advanced technologies for the classification and purification of resources from the end of life of construction products.

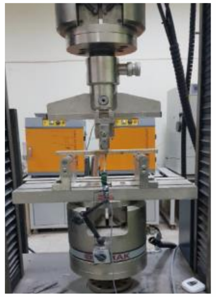
NEW CIRCULAR BUILDING PRODUCTS

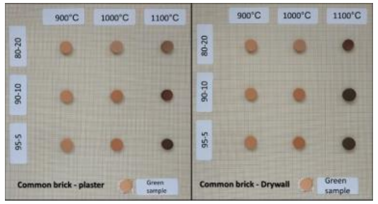
Eco-design of new products and systems for building to incorporate the new criteria of circularity in the industrial manufacturing processes of the target products.











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ICEBERG project: case studies

ICEBERG solutions will be demonstrated (at TRL7) through **6 case studies** across different locations in Europe (Finland, The Netherlands, Belgium, UK, Spain/France and Turkey) representing most common European building typologies (residential and non-residential), execution practices and multiple building materials.

- Pre-demolition audit
- Selective refurbishment/demolition.
- Waste processing
- Production of new circular building products.
- Installation and use in representative building spaces.
- Demonstration of the new digital building materials traceability service.
- Simulation of easy-disassembly of the new building products in mock-ups
- Assessment of materials, energy and water consumption

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ICEBERG project: more than technology

Health, environmental and economic assessment from life cycle perspective
Health assessment and mitigation of occupational risks related to the ICEBERG recycling technologies.
Evaluate the performance of the ICEBERG solutions in the 6 case studies regarding circularity, the environmental impact and financial cost.

Policy and standard recommendations
- Regulatory and legislative framework (waste management and landfill fees)
- Social attitudes
- Market confidence and acceptance of the recovered building materials and new building products designed for disassembly
- Business models
- Standards and European Technical Approvals.

Training and social awareness

Spreading the results

Scientific papers (>25)

Conferences

PhD thesis

Press conference

Corporate video summary and videos with short interviews

Press releases

5 KER

Patents

High TRL solutions

Web in operation and updated

Social networks
Twitter, Instagram, Linkedin, Youtube

8 newsletters

E-brochure
(review 2024)
Videos

ICEBERG Final Workshop: agenda

9:00 - 9:30 Welcome & Introduction to ICEBERG Project

9:30 - 10:00 Smart Services and Software for Demolition Planning and Traceability

10:00 - 10:45 Advanced Sorting & Recycling Technologies for High-Purity Secondary Materials

10:45 - 11:30 Innovative Circular Building Products

11:30 - 12:00 Circular Case Studies in ICEBERG

12:00 - 12:30 Policy Recommendations

12:30 - 13:30 Questions & Answers

13:30 Closure & Lunch

Open questions

- What are the biggest challenges hindering the adoption of circular practices in construction, and how can we overcome them?
- How can we incentivize stakeholders across the construction value chain to embrace circular practices?
- What are other successful examples of circular construction projects, and what lessons can we learn from them?
- What solutions and strategies could be also suitable in emerging countries?
- What other technologies should be considered for circularity improvement in construction sector?

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This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 869336

Smart services and software for demolition planning and traceability

Final workshop 19 April 2024

Verónica García Cortés (TECNALIA), David García Estévez (TECNALIA)

Cheng Chang (TUD)

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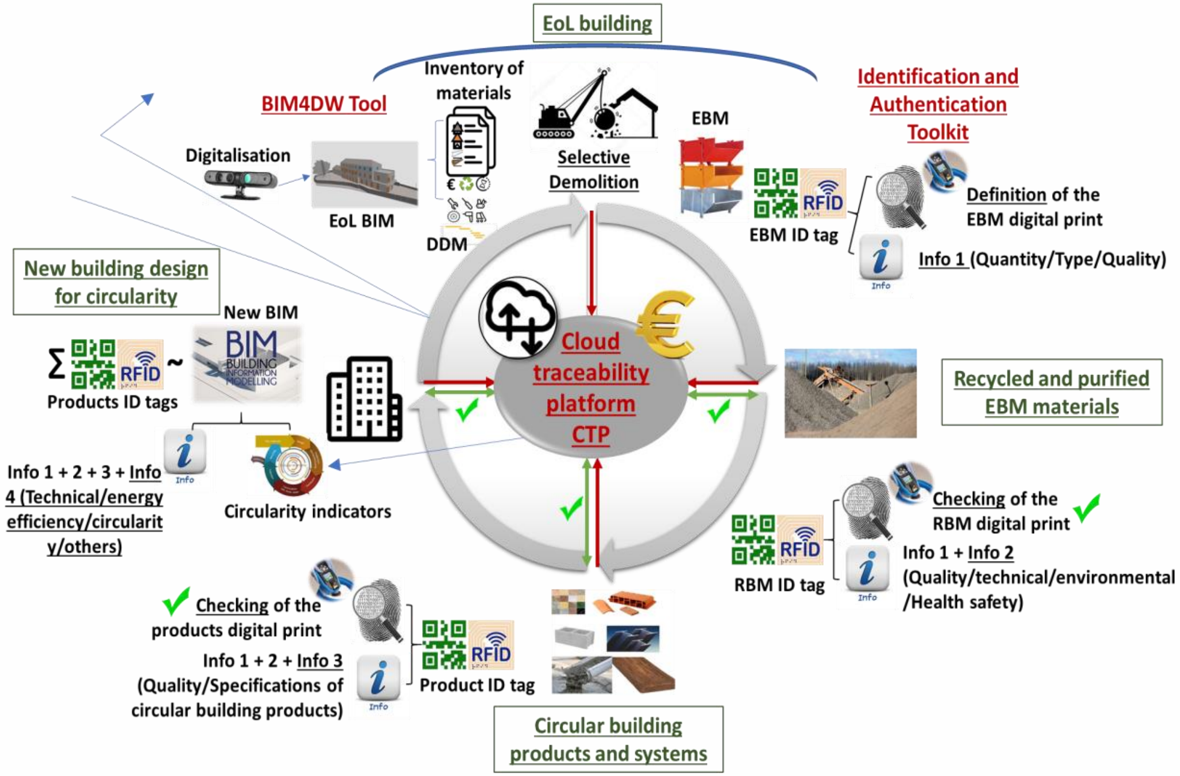
Smart tools for refurbishment / demolition planning and digital traceability

Objective: to **develop and validate a suite of smart solutions** to enable cost-effective, reliable management and traceability of EBM



- Define **requirements** for the digital EBM **traceability service**
- Develop and validate the **BIM4DW tool**
- Develop and validate the automated **Identification and Authentication Toolkit (IAT)**
- Develop and validate the **Cloud Traceability Platform (CTP)**

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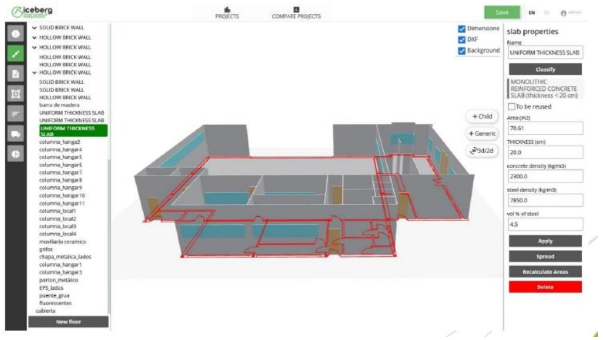
Smart services and software for demolition planning and traceability

The traceability system is composed by three independent tools

BIM4DW tool

a **web-based tool** to support pre-demolition activities



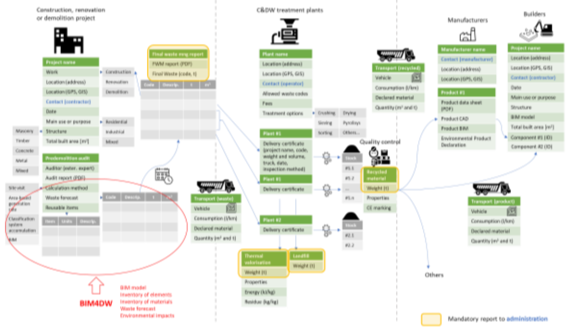
Obtain an **accurate quantification of the CDW streams,** estimate **environmental and economic impacts.**

Automated Identification and Authentication Toolkit (IAT)

A suite of tagging solution to be implemented in certain materials and products **to ensure their identification**

Cloud traceability platform (CTP)

which using a Blockchain network, **ensures the registered transactions and changes in the value-chain assets** (waste, materials and products).



BIM4DW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PROJECTS
COMPARE PROJECTS
Save
EN
SOLID BRICK WALL
HOLLOW BRICK WALL
HOLLOW BRICK WALL
HOLLOW BRICK WALL
HOLLOW BRICK WALL
HOLLOW BRICK WALL
SOLID BRICK WALL
SOLID BRICK WALL
HOLLOW BRICK WALL
barra de madera
UNIFORM THICKNESS SLAB
UNIFORM THICKNESS SLAB
UNIFORM THICKNESS SLAB
columna_hanga2
columna_hangar4
columna_hangar5
columna_hangar6
columna_hangar7
columna_hangar8
columna_hangar9
columna_hangar10
columna_hangar11
columna_local1
columna_local2
columna_local3
columna_local4
mobiliario ceramico
grifos
chapa_metalica_lados
columna_hangar1
columna_hangar3
porton_metálico
EPS_lados
puente_grua
fluorescentes
cubierta
New floor
Dimensions
DXF
Background
+ Child
+ Generic
3d/2d
slab properties
Name
UNIFORM THICKNESS SLAB
Classify
MONOLITHIC REINFORCED CONCRETE SLAB (thickness < 20 cm)
To be reused
Area (m2)
70.61
THICKNESS (cm)
20.0
concrete density (kg/m3)
2300.0
steel density (kg/m3)
7850.0
vol % of steel
4.5
Apply
Spread
Recalculate Areas
Delete

BIM4DW

Problem

- Construction and demolition waste (CDW) is the main waste stream stream in terms of volume
- The quantification of CDW in demolition works is imprecise, due to the **lack of reliable information in old buildings**. **Its collection is slow and costly**.
- Existing Building Information Modeling (BIM) tools are oriented to the design, construction and maintenance phases. The absence of BIM tools for pre-demolition activities exacerbates the problem.
- Prior tool developed in HISER project had a main drawback:

Requires a IFC file (BIM model), which takes too much time (and cost)

LIDAR scanning → point clouds management → BIM model
On-site manual survey → 2D-3D drawings → BIM model

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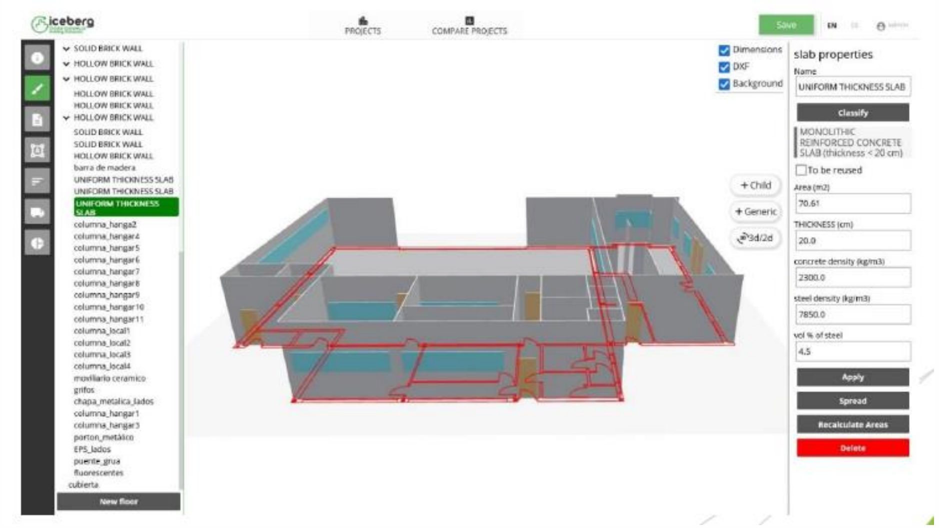
BIM4DW

BIM4DW addresses these challenges by providing assistance with pre-demolition activities.

BIM4DW is a web-based tool software for **modelling**, **inventory**, **planning the demolition and quantifying the main waste streams** and estimated costs and environmental impacts.



BIM4DW Register number:TX 9-285-839

- Fast and cost-effective digital modeling of the building (<2 €/m2 of floor area).
- Accurate and fast quantification of demolition waste (deviation less than 20%).
- Demolition planning driven by circular economy criteria.
- Reliable and visual presentation of the demolition option to customers.
- Optimization of demolition and CDW management

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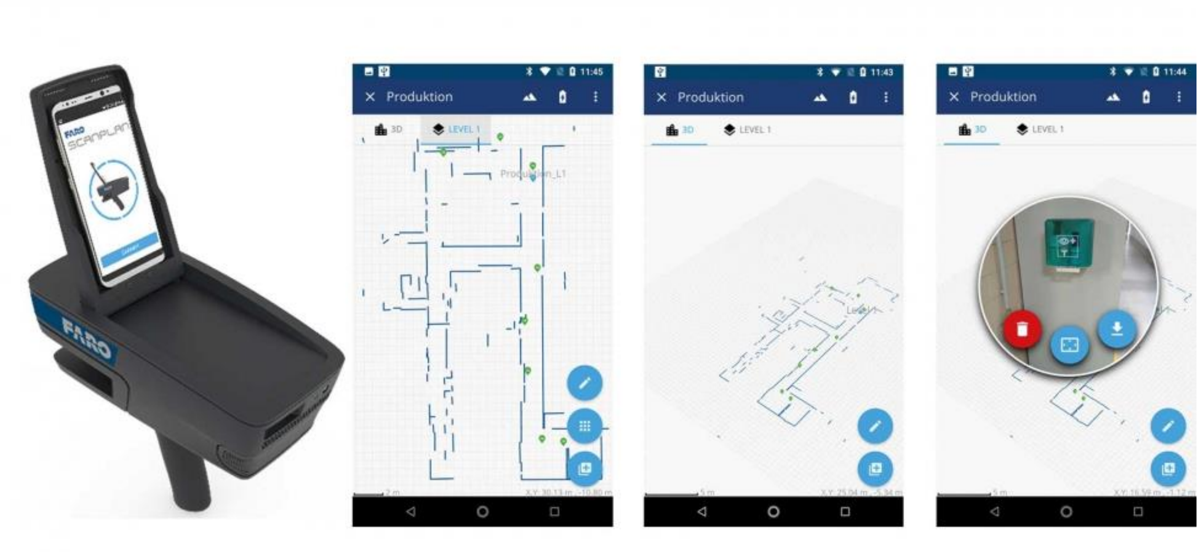
BIM4DW. Geometric adquisition

FARO ScanPlan



200m^2/ 60”

- Generates a “project” with the 2D mapped walls
- Real time view on the smartphone
- Quick export to DXF (ASCII based) or PDF

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BIM4DW steps

1. Modelling
2. Inventory
3. Creation of groups
4. Definition of demolition techniques
5. Allocation of time, human resources and equipment
6. Calculation of waste streams
7. Definition of final treatments
8. Environmental and cost assessment: physical demolition + transport + treatment
9. Reporting, dashboard and export of results

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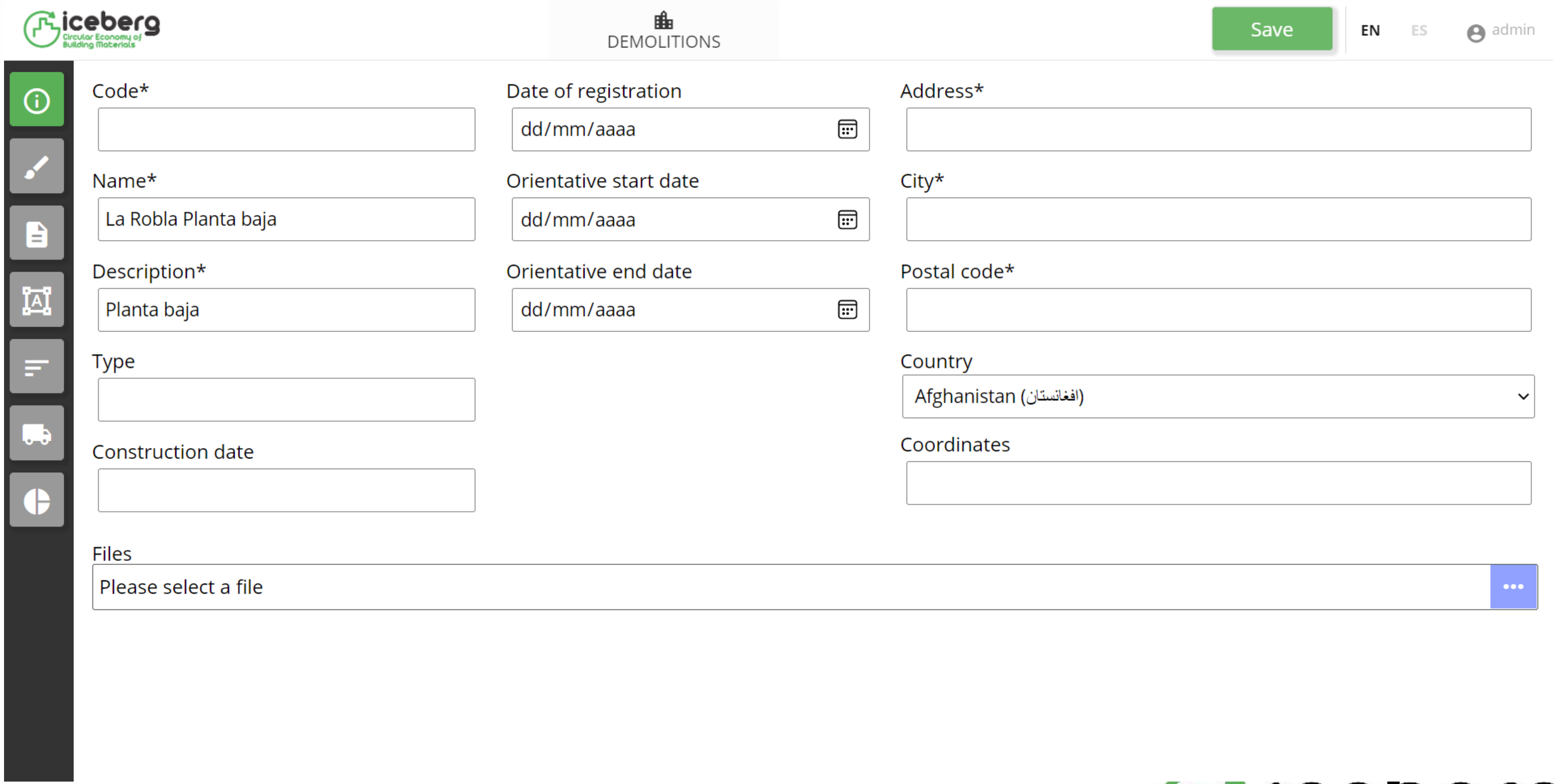
BIM4DW

Project information



BIM4DW

Modelling configurator: The configurator is a canvas created with the Threejs library for 2D/3D view modelling **from zero, DXF or PNG files.**

Draw vertical construction elements (walls, doors and windows and horizontal elements (floors, openings)

BIM4DW Register number:TX 9-285-839

Each modeled element can be categorized hierarchically in four levels.
Parameters are defined from the geometry of the odel, using average market values or data entered by the user

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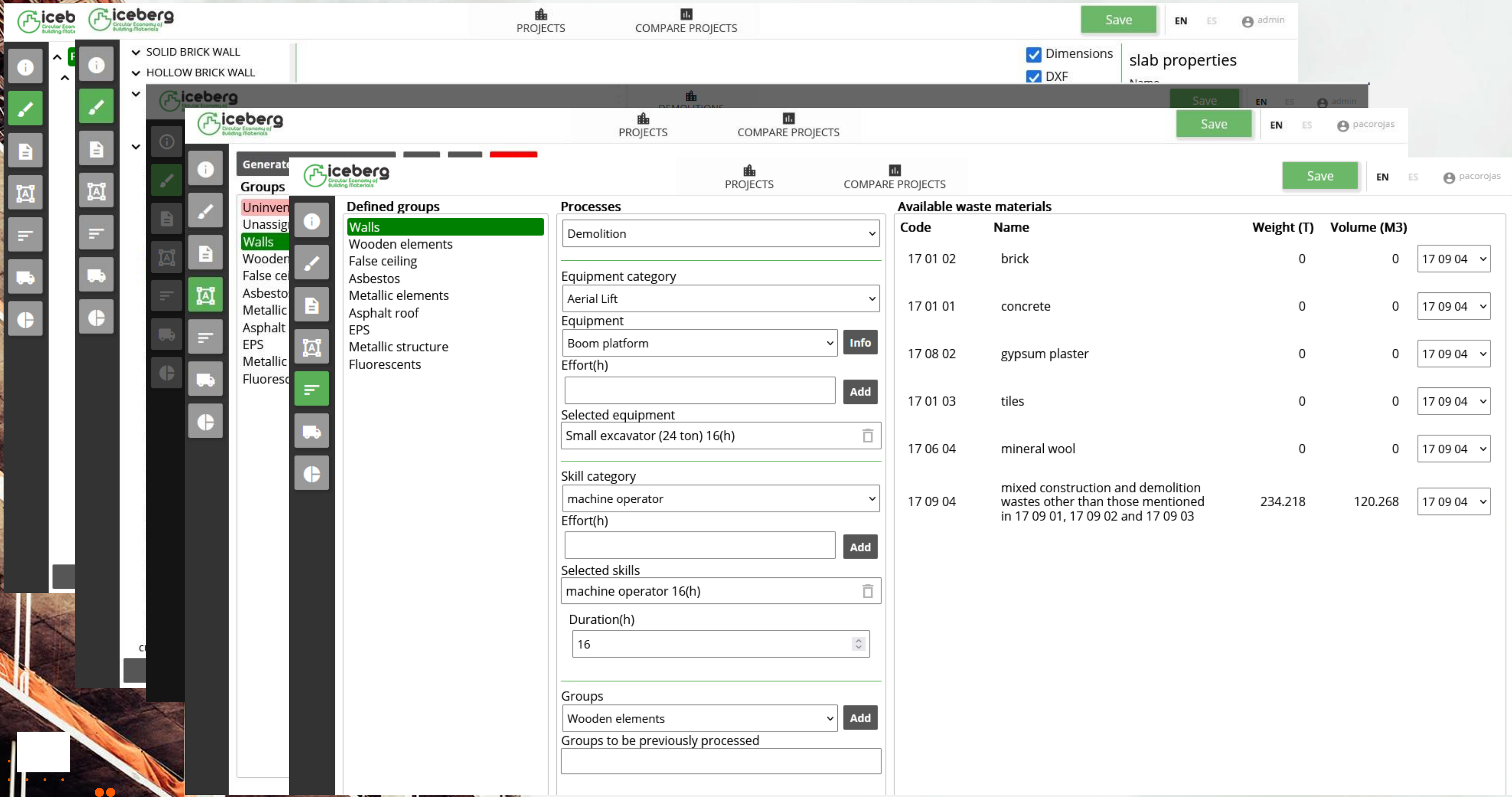
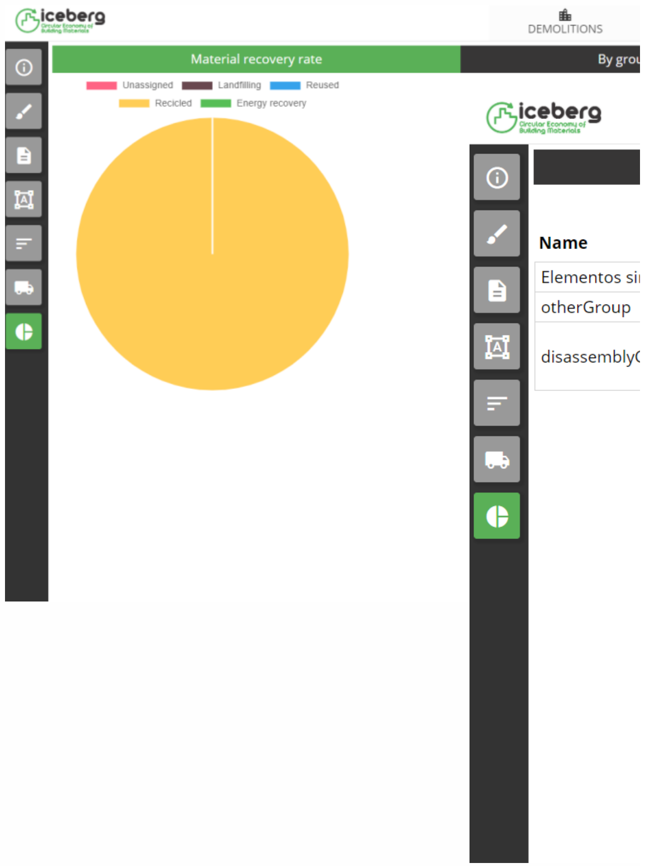
MEMBER OF BASQUE RESEARCH & TECHNOLOGY ALLIANCE

BIM4DW: demostration

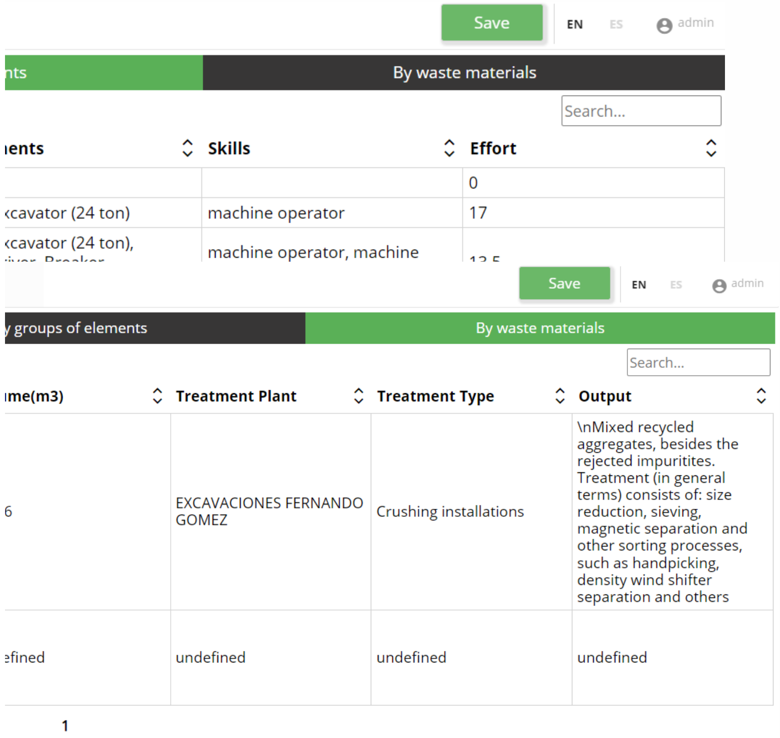


BIM4DW – planning and DDM

Results

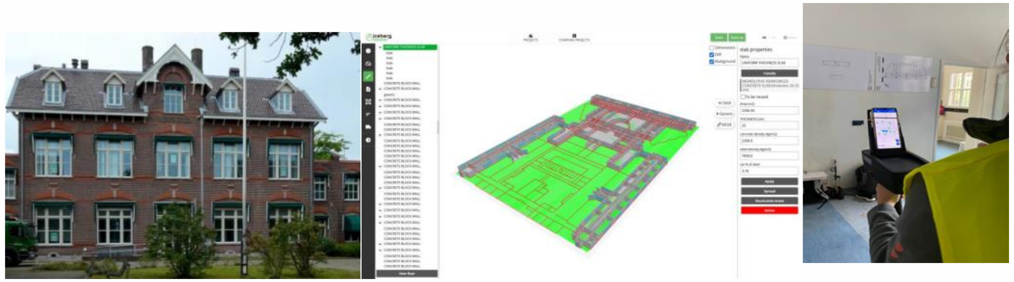


EWC CODE	WASTE DESCRIPTION	BIM4DW (t)
17 01 01	Concrete	287,212
17 01 07	Stony mixture	185,336
17 01 03	Ceramics	0,619
17 04 02	Aluminium	5,656
17 04 05	Iron and Steel	41,403
17 04 07	Mixed metals	0,126
16 06 16	Components removed from discarded equipment	0,08
17 02 02	Glass	0,851
17 02 01	Wood	1,532
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	

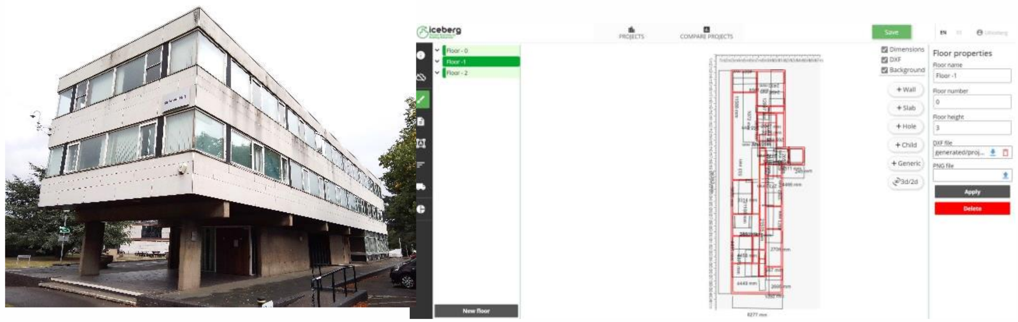


BIM4DW

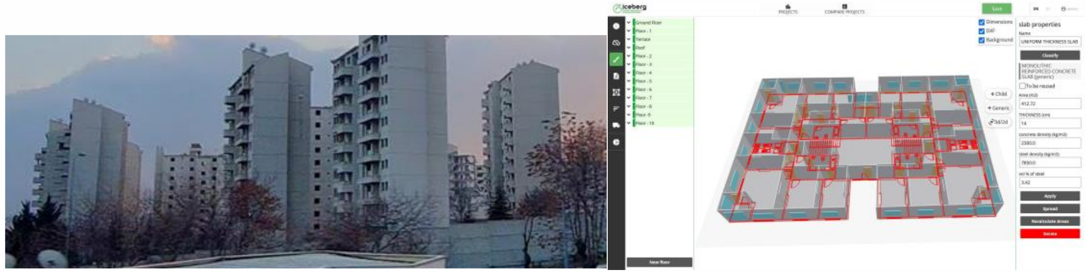
BIM4DW was tested on 5 case studies



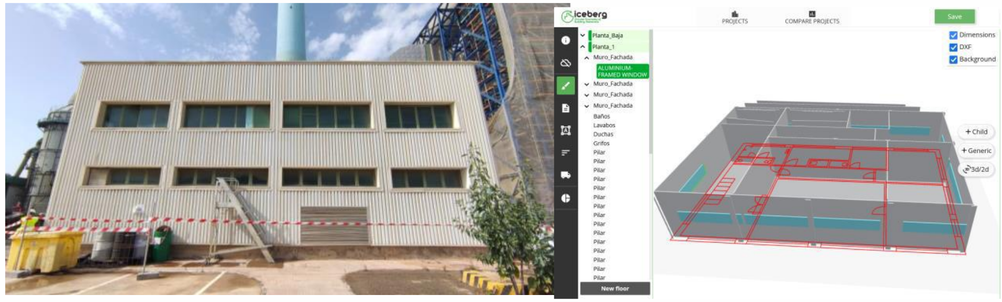
The Netherlands. **1500 m²**



LU building.



Turkey. Residential building



Carboneras, Spain

BIM4DW provided relatively **accurate estimates of waste weights. Deviations were ranging from 1% to 20%**

Time needed was **less than 2 working days** (1 for on-site survey and scanning, 1 for BIM4DW)

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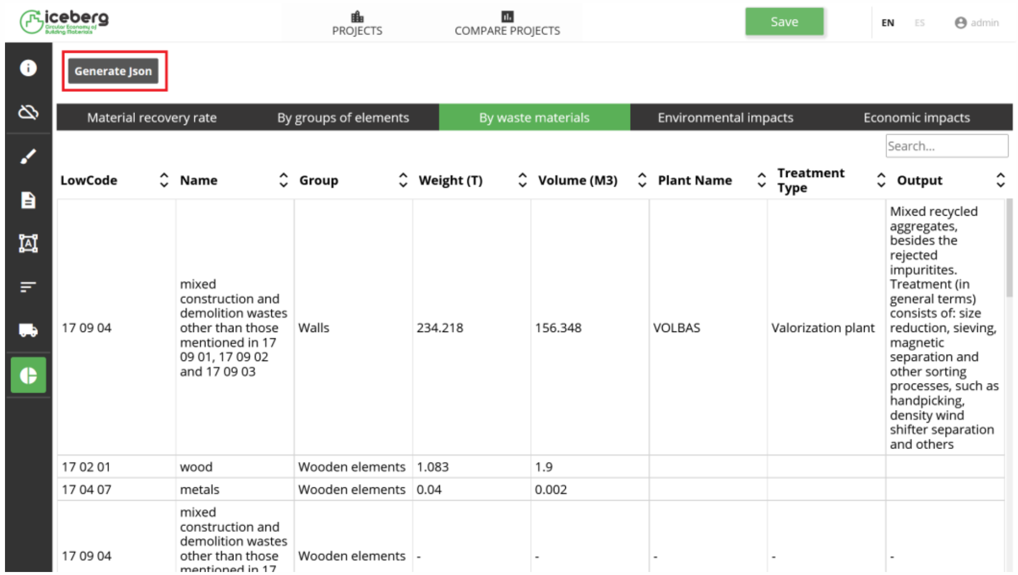
BIM4DW integration with the CTP:

BIM4DW and CTP were integrated by an exportation-importation process through a JSON file

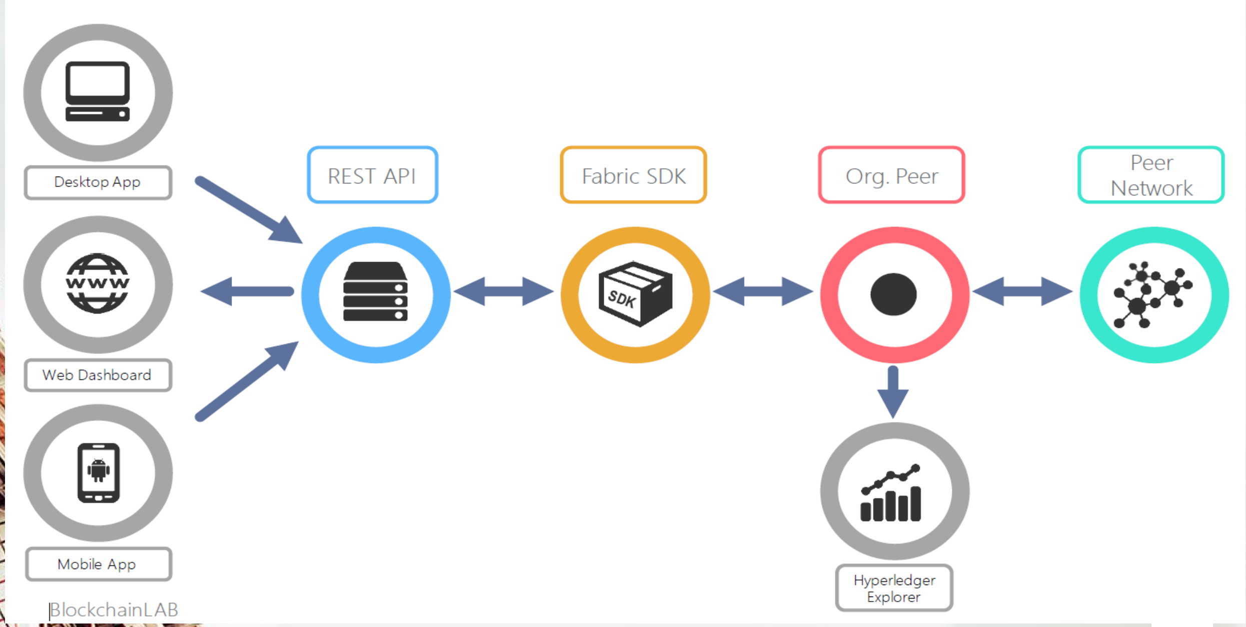
- **File content:**
  - **General details** of the demolition project
  - **Resulting waste streams**
  - **Reusable elements.**
  - **Environmental impacts.**
  - **Economic impacts.**



At ICEBERG, we've reached TRL7.

Tecnalia and LEZAMA Demoliciones are collaborating to explore new pathways for its market launch.

Cloud Traceability Platform-CTP



CTP: Traceability in construction

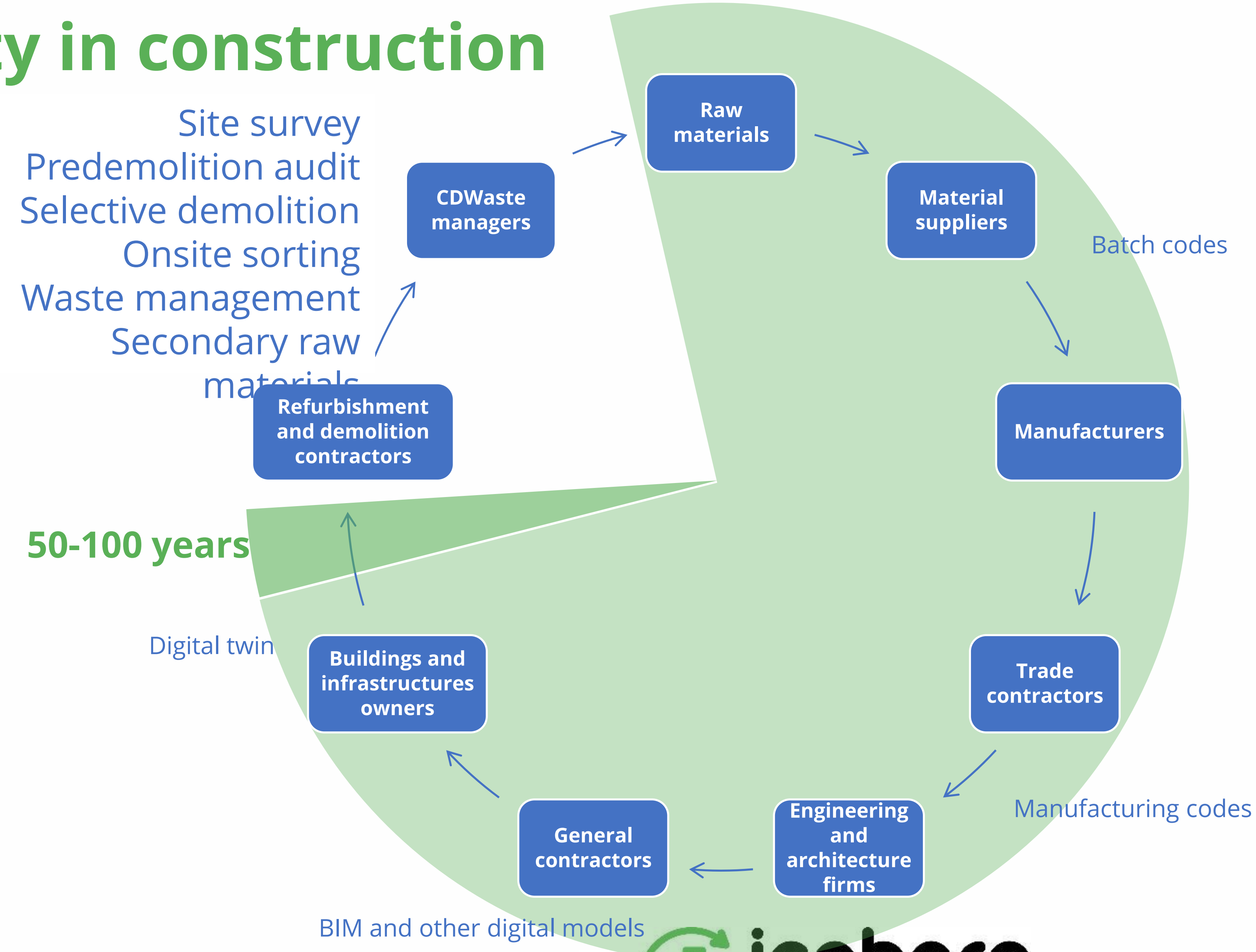
TRACE
Where were they?

TRACK
Where are they now?

CONTROL
Where are they going?

CHAIN OF CUSTODY
Who handled them?

Traceability enables quality assurance, environmental safety and process efficiency. It also builds trust with consumers.



CTP

The Cloud Traceability Platform is an adapted version of TRACEBLOCK, **a blockchain based traceability tool** developed by TECNALIA. It acts as a centralized repository for data across **the end-of-life stage to the elements and material valorization.**

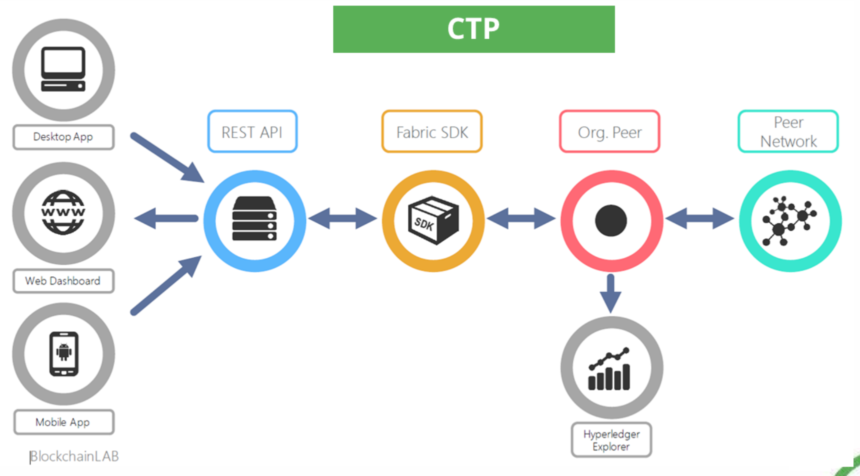
CTP records material modifications and transactions. It **manages information from various sources, including BIM4DW and the Identification and Authentication Toolkit (IAT), facilitating exchange among stakeholders.**

BIM4DW

Configurator
Demolition MCDM
Waste forecasting
Envirom impacts

IAT

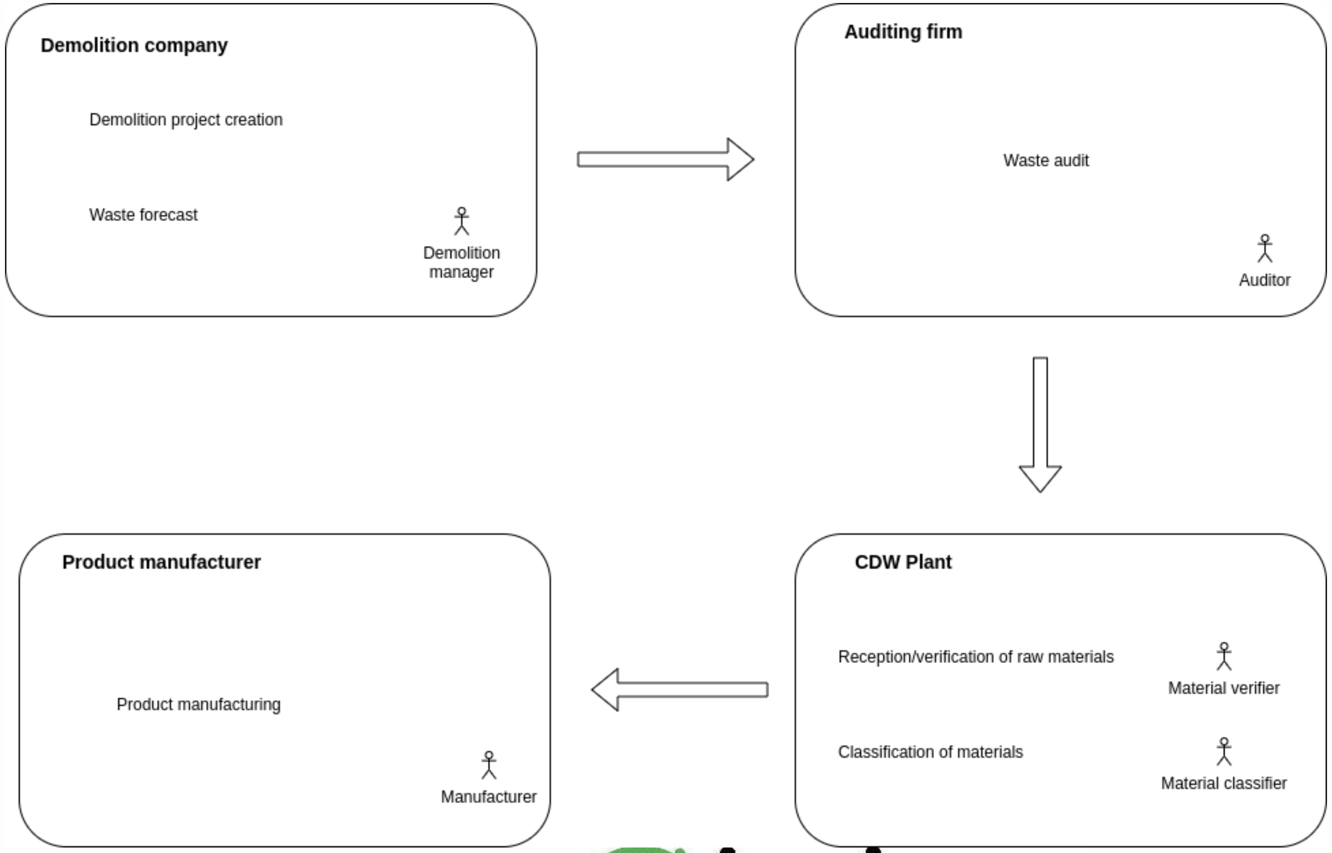
Characterization
Quality control
Information writing
Tagging



CTP: Types of organizations involved in the use case covered by ICEBERG

The tool was adapted and completed with specific interfaces (APIs) for the main agents in the value chain.

- **Promoter** (which also covers the building owner or building manager in some cases)
- **Demolition or refurbishment contractor**
- **External waste auditor.**
- **CDW management plant** (off-site or mobile)
- **Consumer of the resulting recovered materials and products** (manufacturer, civil works contractor or any other).

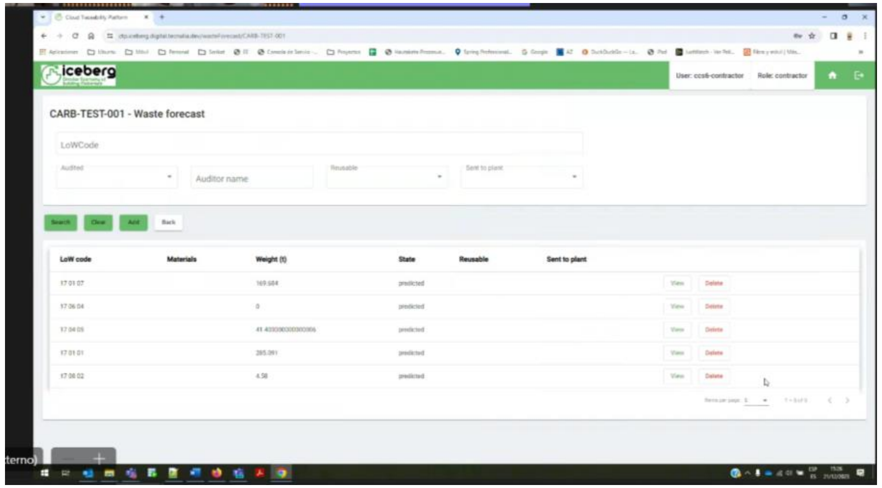


CTP

CTP was tasted in the 6 case studies.

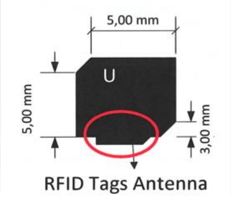
During the progressive definition of the CCS studies, the most suitable ICEBERG partners were associated to the respective platform role

	CCS1	CCS2	CCS3	CCS4	CCS5	CCS6
Owner/promoter	GBN	BESE		PURKU	LU	External
Contractor	GBN	BESE	TRACI MAT	PURKU	External	LEZA
Auditor	GBN	HU		VTT	LU	TECN
Waste management	GBN			TIIHO	ENVA	LENZ
Secondary materials consumer	ROOSENS	TEPE		TIIHO	GYP	SOPRE
IAT	TUD	-	-	-	-	KERA

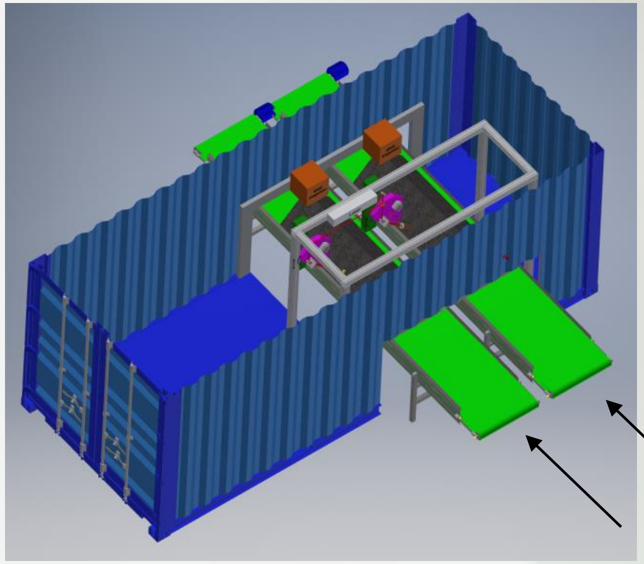


- The tool **shows good performance** and, after solving the errors and implement some improvements, can be a **serious platform to trace the materials in the construction sector**.

Identification and Authentication Toolkit (IAT)



LIBS QUALITY SYSTEM



Abraham Gebremariam
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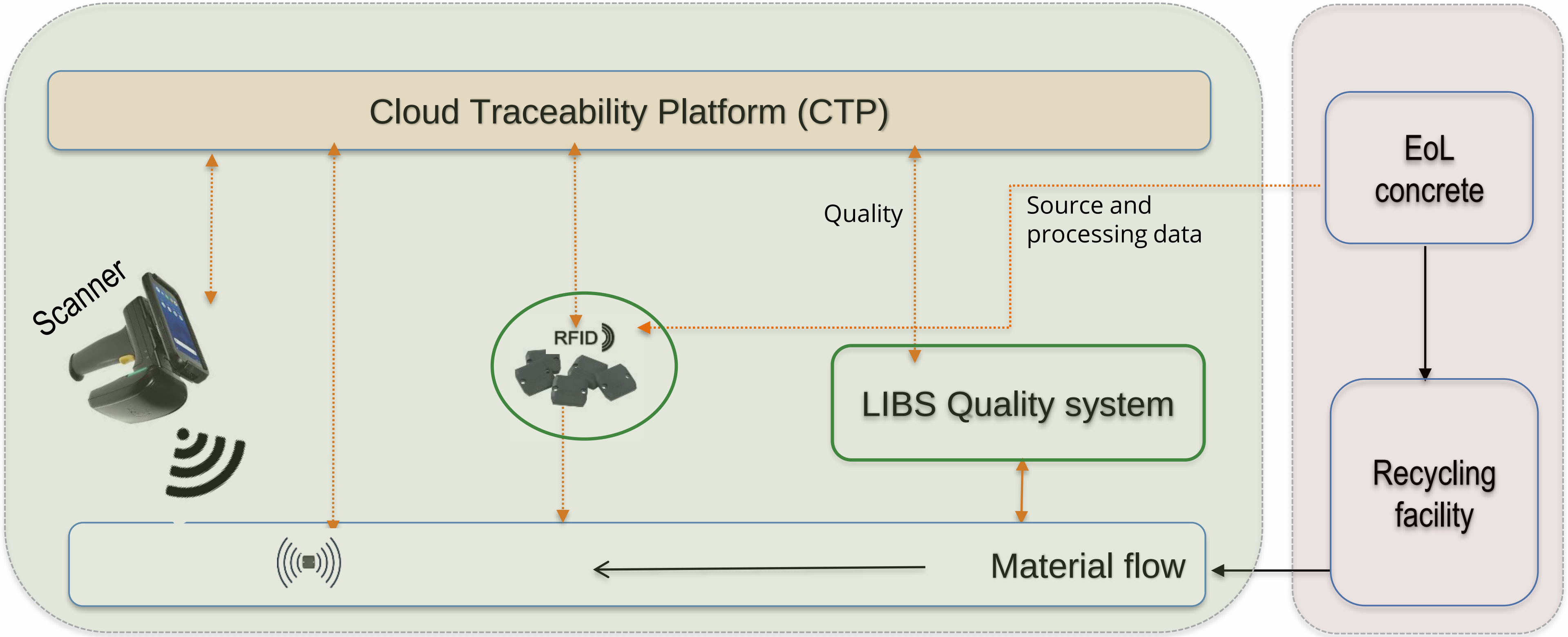
Ali Vahidi
Cheng Chang

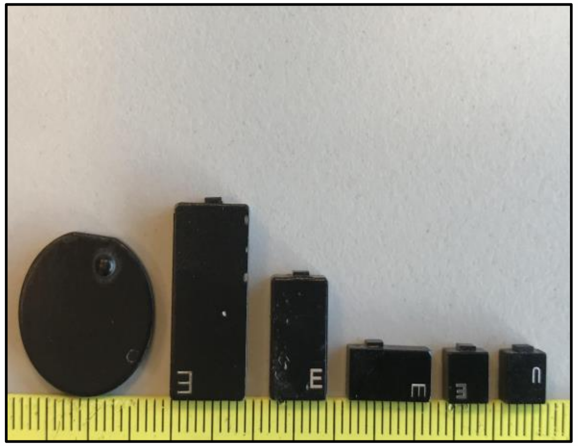
Delft University of Technology
Resources and Recycling

TASK 1.3: Automated Identification and Authentication Toolkit (IAT) for building materials

An integrated IAT, LIBS and CTP system

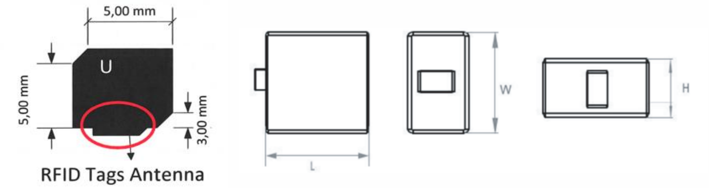


Contactless identification system



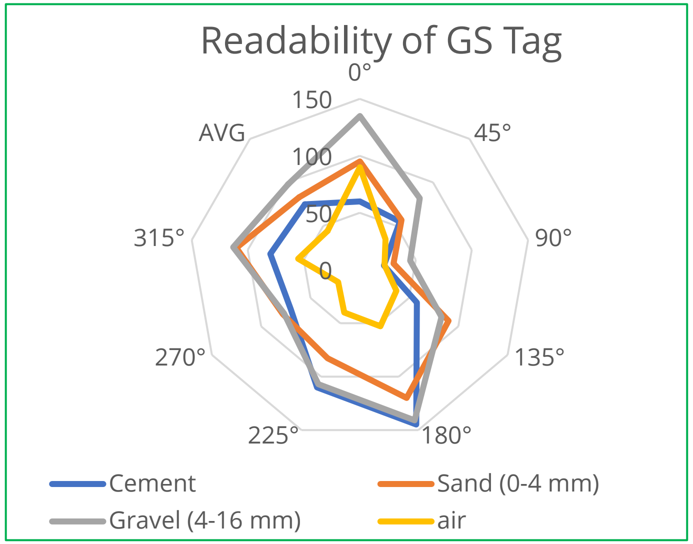
Criteria	Assessment
Readability	✓
Robustness	✓
Durability	✓
Sensitivity	✓
Validation	✓
Cost	✓ (?)

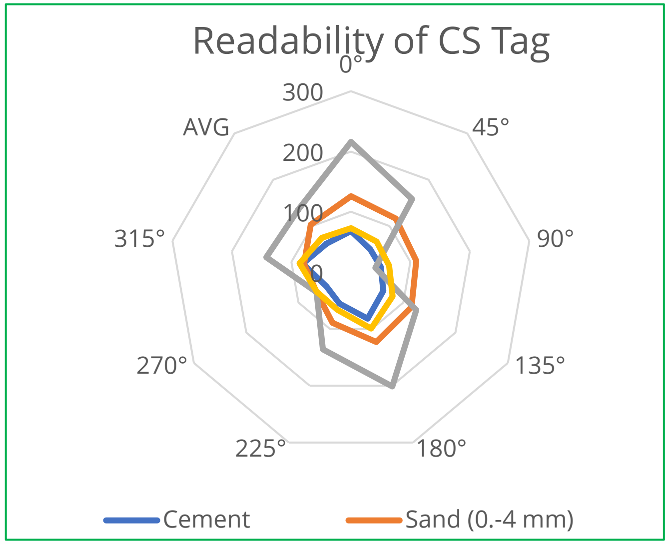
Product Model	Specification			
	GS	CS	CM	CL
Size (mm)	5x5x3	5x5x3	13x9x3	25x9x3
Weight (gr)	0.4	0.4	1.8	3.7
Operating Temperature (℃)	-40 to +85	-40 to +85	-40 to +85	-40 to +85
Cost (€)	4	1	1	1

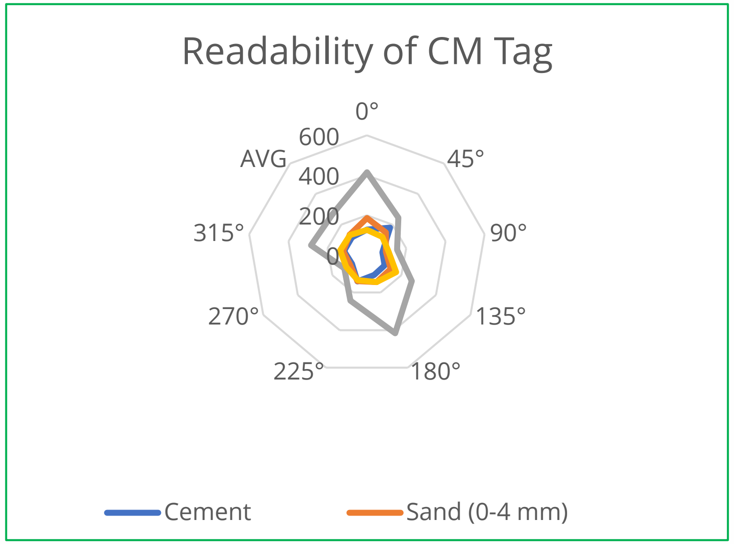


Contactless identification system ...

Readability tests:

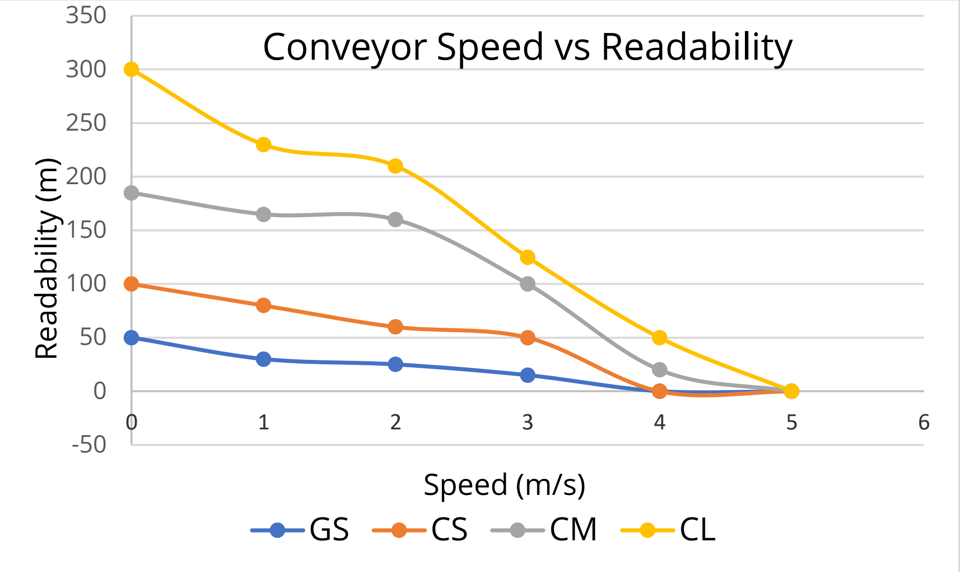






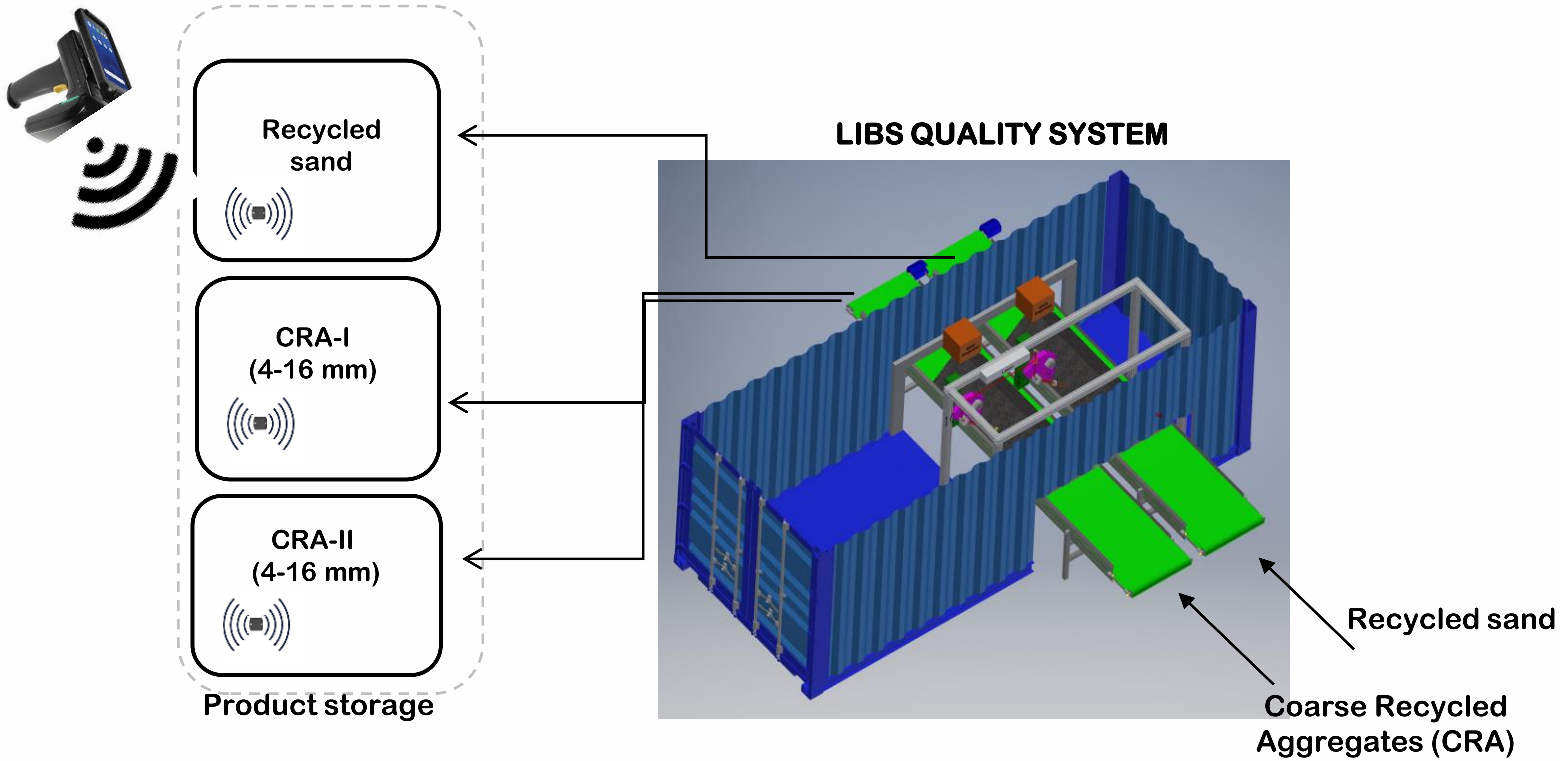
Abrasion tests:

Product Model	Abrasion Time					
	0 min	1 min	2 min	3 min	4 min	5 min
GS	100%	46%	18%	0	0	0
CS	100%	60%	51%	27%	19%	0
CM	100%	70%	60%	0	0	0
CL	100%	0	0	0	0	0



Upgraded industry-scale LIBS-based quality assessment system

- Integrated Gocator-LIBS-RFID system in one container



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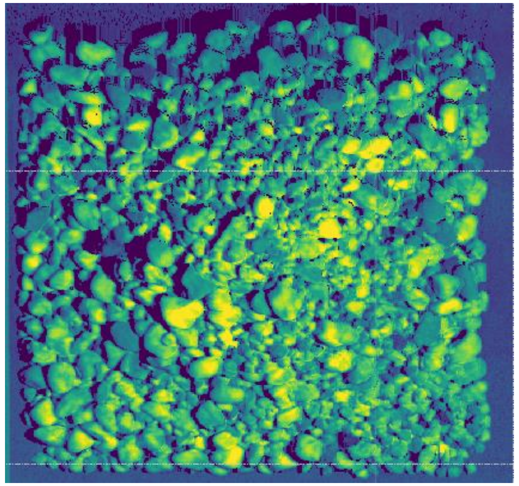
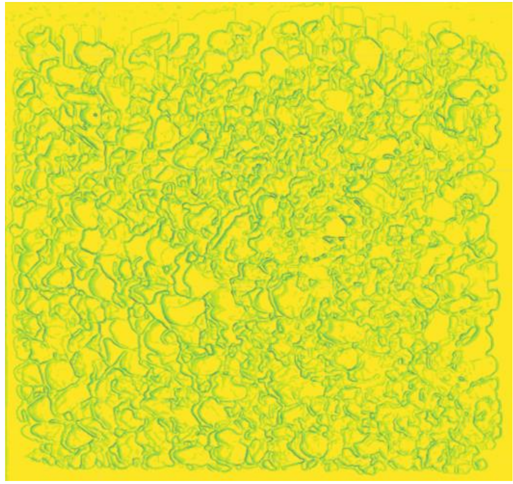
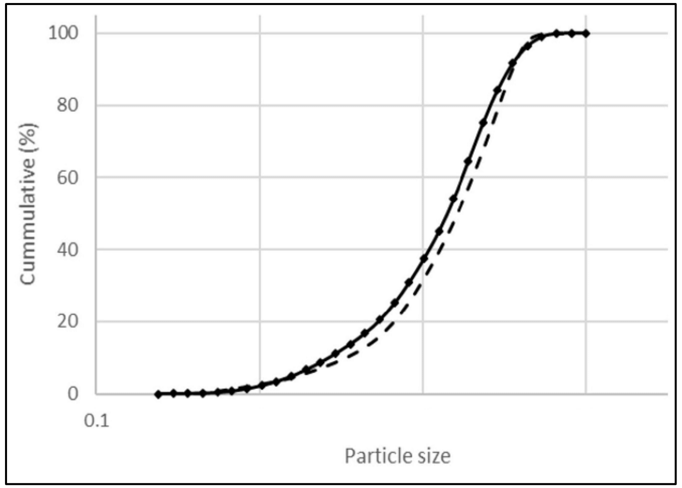
LIBS-based quality assessment system

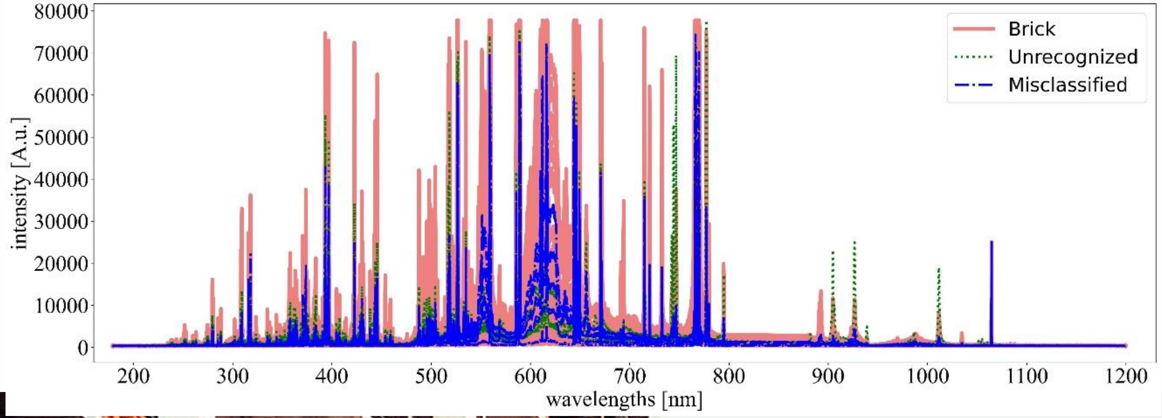
- ❑ Gocator (Surface profile and PSD)

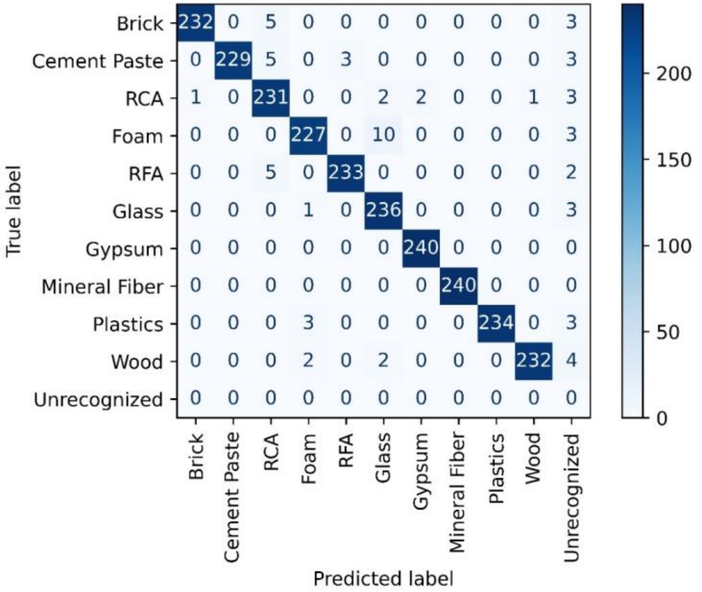




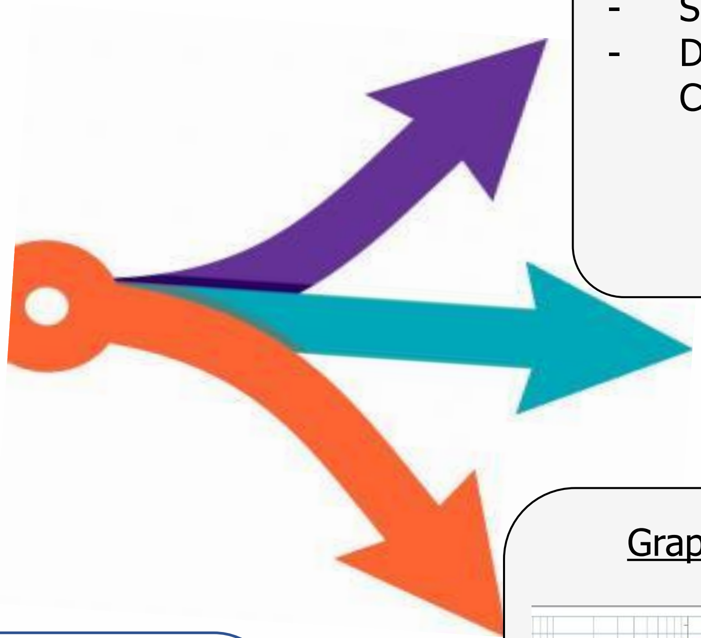


- ❑ LIBS (Composition and contaminants)





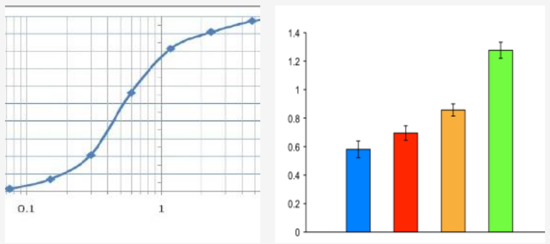
RFID Scanning and Display System



Gen. info
- Date
- Source
- Dem. Company

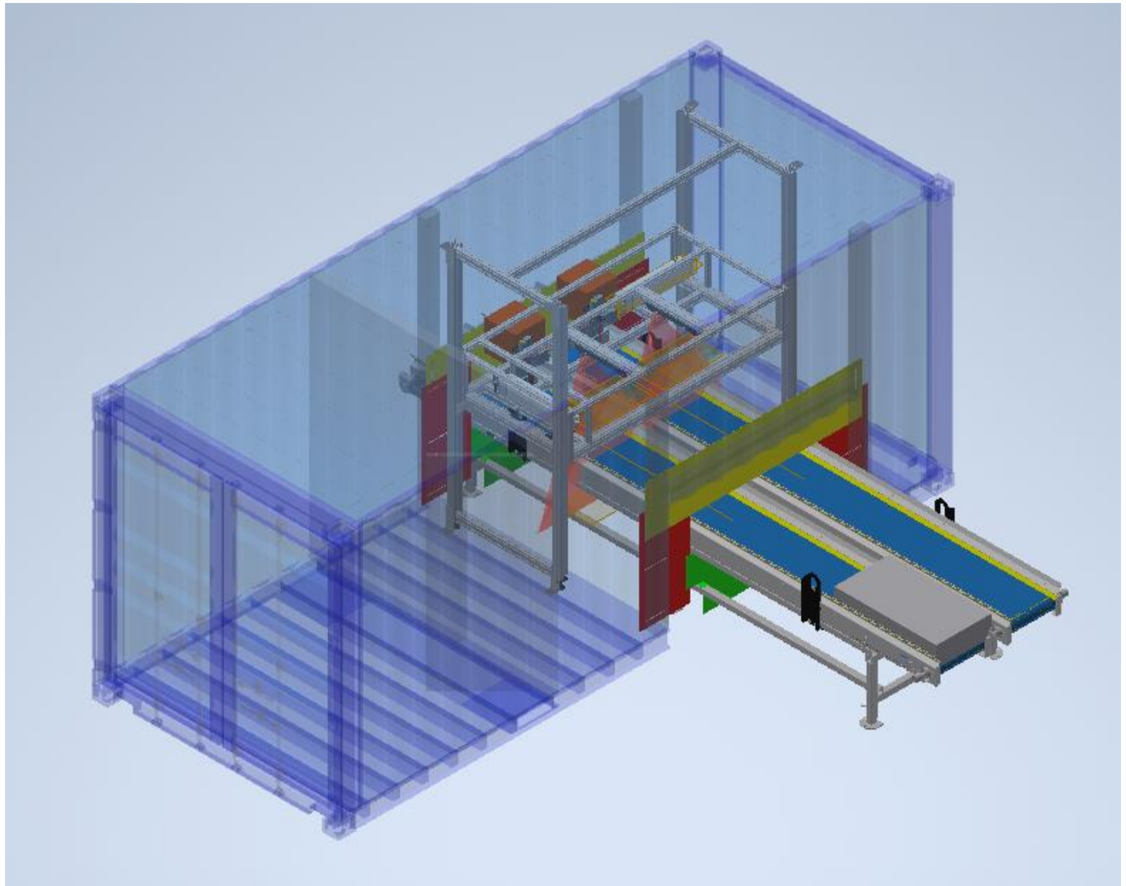
Contaminants
- Asbestos
- Wood
- Gypsum
- Glass
- Bricks
- others

Graphic PSD display



Products

Industry-scale LIBS-based quality assessment system …



Delay in the delivery of LIBS (Covid related and global delay in delivery of parts)

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Thank you

&

Question?

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This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 869336

Advanced Sorting & Recycling Technologies

ICEBERG Final Workshop, April 19th 2024

Advanced Sorting & Recycling Technologies

Company Profile

- Lenz Instruments S.L was established in 2011, and is based at Barcelona (Spain)
- We develop instruments and measuring systems for industrial inspection applications, and
- We also offer engineering services involving Advanced Sensing systems, and Automation Engineering

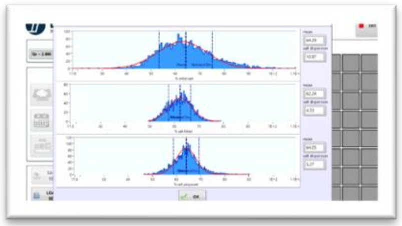
Advanced Sorting & Recycling Technologies

Meat Inspection Solutions

HAM INSPECTOR II™

Primal Cuts

HAM BRAIN™



AI-based Process Control Software for Meat Curing

Meat Trimmings

gm SCAN
PIG CARCASS GRADING

Pig Carcasses

QMEAT ANALYSER™

Primal Cuts

QMEAT PROBE™

Deboned meat and carcasses

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Advanced Sorting & Recycling Technologies

Meat Inspection Solutions

- ✓ Characterisation of meat composition (weight, lean, fat and salt content)
- ✓ Identification of Meat Defects

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Meat Inspection Solutions

Advanced Sorting & Recycling Technologies

LENZ INSTRUMENTS

Engineering Services: Customised Spectroscopic Systems

- Customer: *[Pharma Sector]*

- Development, manufacturing and installation of in-line UV-Vis sensor for real-time identification of material grades
  - Optomechanical design of the sensor head
  - Development and integration of instrumentation
  - Built-in real time spectral processing (1 ms)
  - External Data communication and interconnection of sensor with PLC in the manufacturing line
  - Self-calibration and diagnose routines

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Advanced Sorting & Recycling Technologies

Spectroscopy

OPTOSKY
Spectroscopy Solutions

- UV-Vis Spectroscopy
- NIR Spectroscopy
- FTIR Spectroscopy
- Raman Spectroscopy
- Fluorescence Spectroscopy
- Hyperspectral Imaging (HSI)

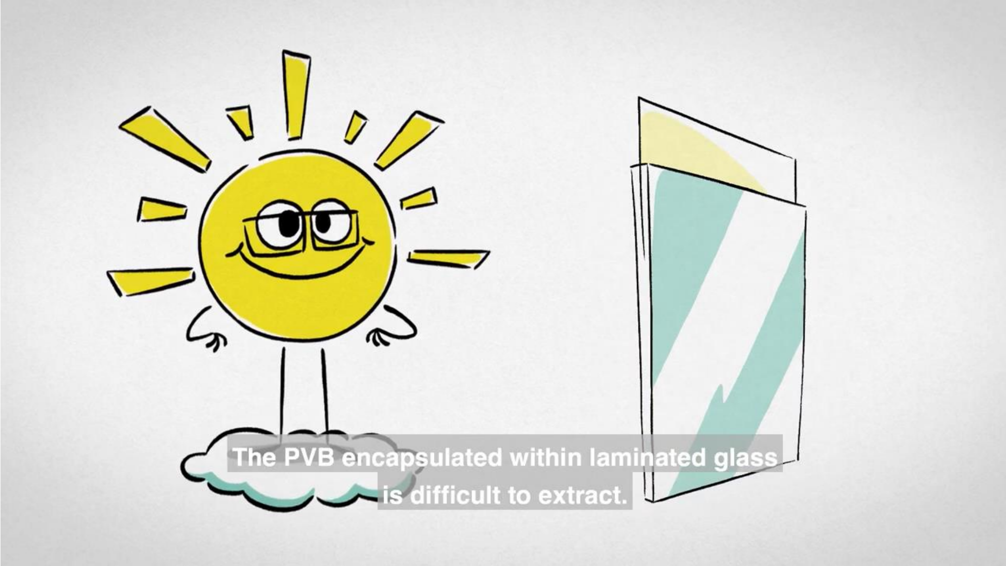
Advanced Sorting & Recycling Technologies

LENZ INSTRUMENTS

Research Projects:

SUNRISE: MultiSensor sorting tools in a circular economy approach for the efficient recycling of PVB interlayer material in high-quality prodUcts from laminated glass coNstRuction and demolItion waStEs

SUNRISE



Project Goal: To develop a multisensor tool to sort laminated glasses into different grades, and to develop thermomechanical processes for the recycling of PVB films

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 958243".

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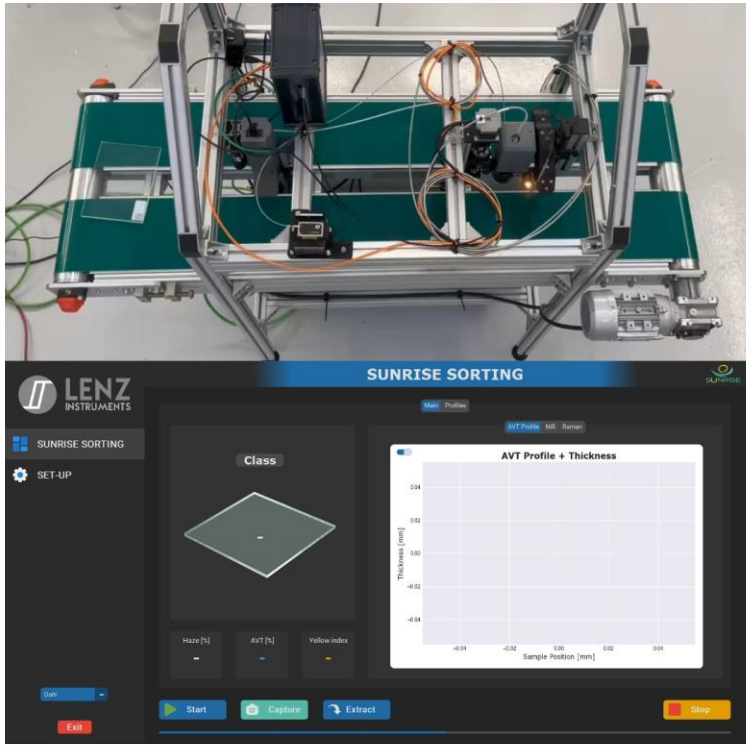
Advanced Sorting & Recycling Technologies

Research Projects:

SUNRISE: MultiSensor sorting tools in a circular economy approach for the efficient recycling of PVB interlayer material in high-quality prodUcts from laminated glass coNstRuction and demolItion waStEs



Advanced Sorting & Recycling Technologies

Outline

- **Introduction**
- Overview of Task Objectives
- Development of Sorting Line
- Development of Prediction Models
- System Validation
- Conclusions and Future Work

Introduction

The development of new circular products based on the recycling of CDW materials requires a solution:

- To **separate main fractions** in complex CDW streams (e.g. concrete and ceramics)
- To **remove impurities** from the stream, such as metals, plastics, wood, cardboard, gypsum, foams…

Currently, solutions for sorting CDW materials are still under development

Introduction

- Over the last decades, hand-sorting has been replaced by Automatic Waste Sorting methods. These processes are commonly based in the combination of a large area sensor and an automated mechanical means to separate different fractions
- The implementation of automatic sorting technologies is conditioned both by technical performance (sorting accuracy and reliability) and economic feasibility

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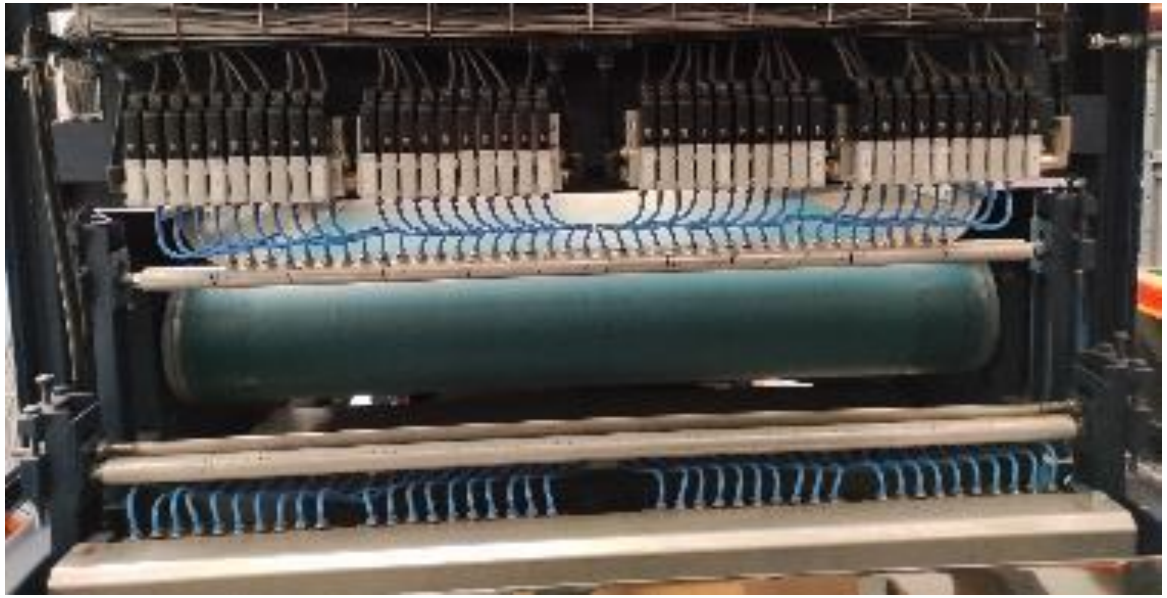
Introduction

- Overview of sensing technologies:
  - Electromagnetic sensors (separation of metals from mixed fractions)
  - Vision systems (separation of fractions based on colour or particle size)
  - Molecular Spectroscopy sensors: NIR, SWIR, MWIR (separation of different types of polymers)
  - Hyperspectral vision systems (HSI)
  - Elemental Spectroscopy sensors: XRF, LIBS (separation of different types of metals)

Commercial waste sorting lines from Steinert (left) and Tomra (right)

Introduction

- Overview of mechanical separation techniques
    - Air ejectors (up to three fractions)
    - Robotic arms



Advanced Sorting & Recycling Technologies

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Overview of Task Objectives

- To develop an automated, highly-flexible and mobile prototype sorting line (≥1 t/hour) based on HSI to increase sorting efficiency (>92%) of ceramic and concrete fractions by 10% in comparison with current practice (TRL5)

- To adapt and test HSI based sorting and purification of other application studies:
  - Separation of PU/PIR foams
  - Removal of impurities in plasteboard waste streams

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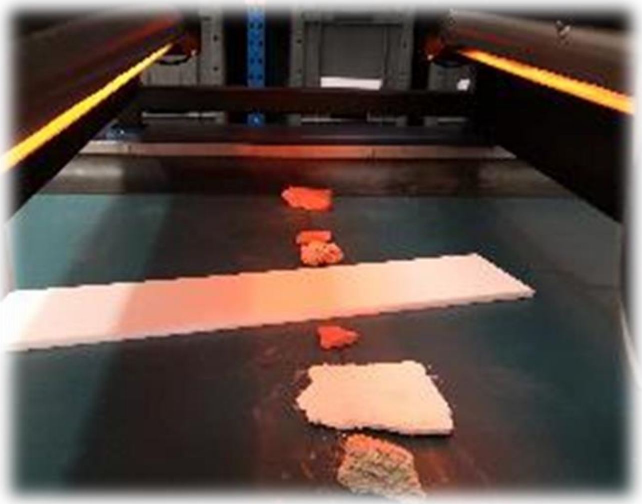
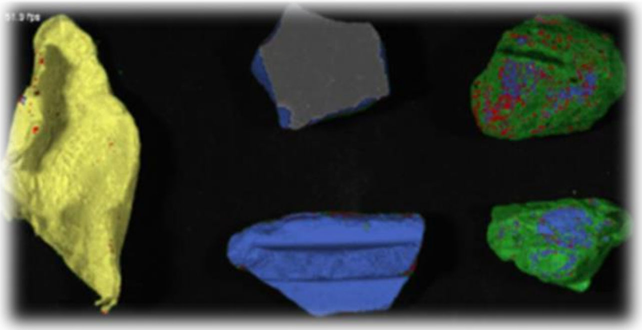
Overview of Task Objectives

Main Innovations

- **High Chemical Sensitivity:** Use of solid-state **Short Wave Infrared Hyperspectral Camera** (SWIR-HSI), with improved chemical sensitivity with respect to conventional NIR-HSI cameras
- **Smart AI-based classification:** Implementation of customized **Artificial Intelligence Algorithms** to recognize and identify CDW materials
- **High speed separation technology:** Integration of the technology into an **air-ejector sorting line** optimized for the separation of CDW into up to three fractions
- **Smart Flexibility:** Integrated **Training Algorithms** makes the system easily adaptable to process different mixed materials





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Advanced Sorting & Recycling Technologies

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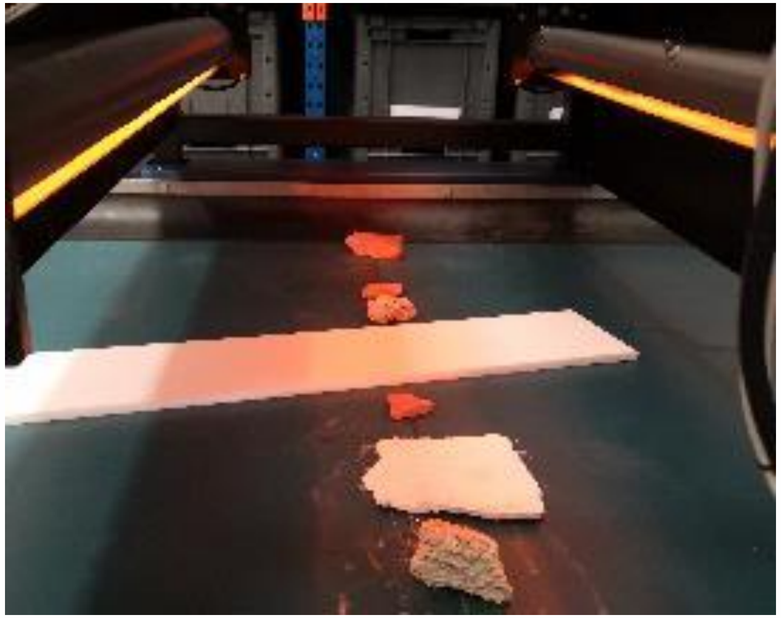
Development of Sorting Line

LENZ INSTRUMENTS

Sensing Technology

- **Sensing Module:**
  - SWIR-HSI camera (900 nm – 2500 nm), 380 fps
  - Field of view: 1100 mm (width)
  - Depth of field: 100 mm
  - Air-cooled cabinet with dust filters
- **Illumination Module:**
  - Tubular Halogen Lamps
  - Air-cooled rack reflection stainless steel casing



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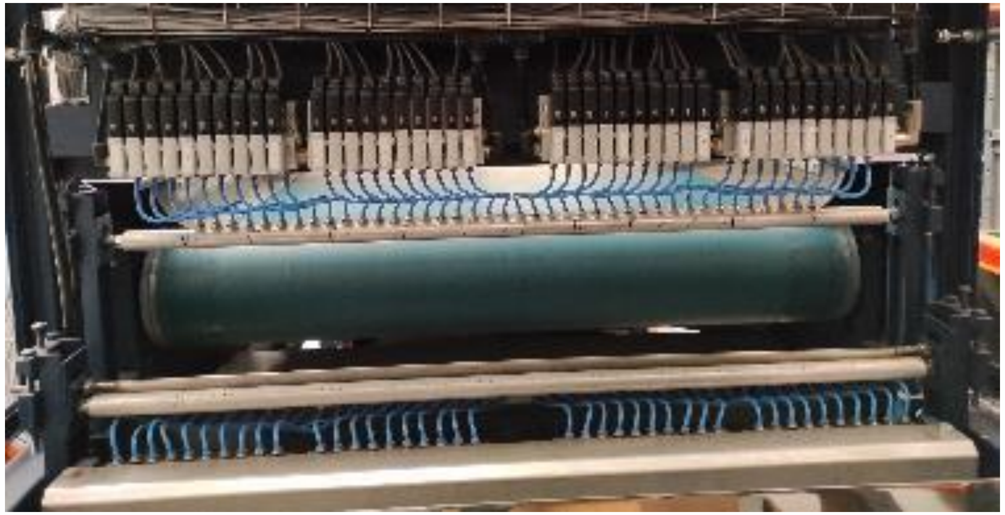
Development of Sorting Line

Air-ejection separation technology

- The two arrays of air-ejectors, operating up to 200Hz, combined with deviation plates, allow splitting the input material into three streams
- Medium weight (ceramic) and lightest (gypsum) impurities are down and up, respectively



Development of Sorting Line

Main System Elements

- A **conveyor band** to transport the material through the process at speeds up to 2 m/s
- An inspection module, integrating a high speed **Short Wave Infrared Hyperspectral Camera** (SWIR-HSI), producing a **chemical image** of the fragments across the conveyor band
- Two arrays of **high-speed air-ejectors**, which are able to blow downwards or upwards the material fragments, and to separate the stream into three separated fractions
- A **high speed control hardware** able to process the chemical images in real time, and to control and synchronize the activation of each individual air-ejector
- A control software, integrating **Artificial Intelligence processing algorithms**, which after being trained for a specific application, recognizes and sorts the fragments into up to three target fractions

Development of Sorting Line

ICEBERG Sorting line for CDW processing

- **Principle of operation:**
  - Sensor module: SWIR-HSI
  - Separation module: Array of Air-ejectors (2x40)
- **Dimensions:**
  - Length: 6.2 meters
  - Width: 1.7 meters
  - Height: 3.4 meters
- **Speed**: 2.0 m/s
- **Throughput**: 2-10 tons/h
- **Operational costs:** 4-20 €/ton

Development of Sorting Line

Integration of Self-Lerning Classification algorithms

- Waste classification and sorting is accomplished by means of integrated real-time machine learning algorithms, which allow classifying the waste stream into three discrete grades
- Self-learning capability allows optimizing the operation of the sorting line to the particular requirements of each application case
- Built-in self-compensation and calibration routines for ensuring long-term reliability

Advanced Sorting & Recycling Technologies

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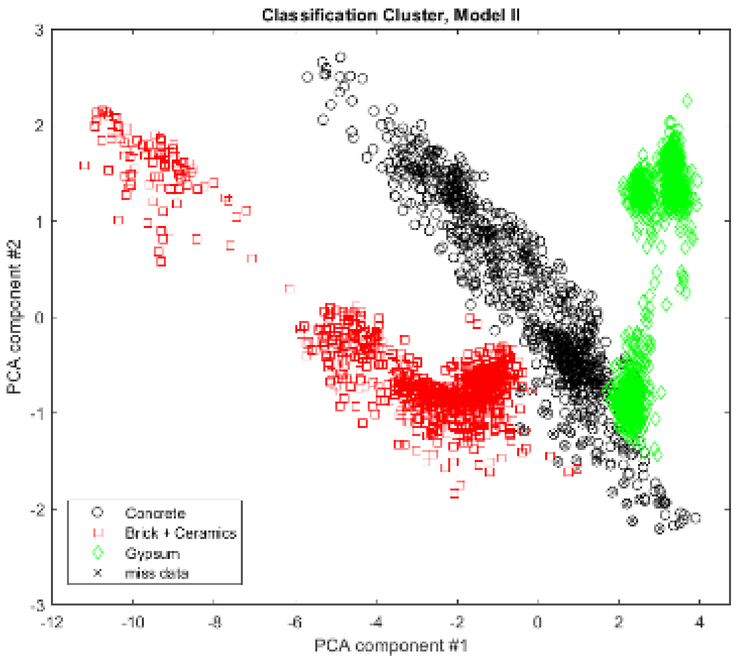
Development of Prediction Models

- **CS1: Separation of Mixed Stony Fractions**

Classification Accuracy:

98.6% (Concrete) | 99.0% (ceramics) | 98.7% (Impurities)

CS1: PLS-LDA Model for Mixed Stony Fraction with Gypsum Impurities (Three classes)		Predicted Class (EXTERNAL VALIDATION)		
		Concrete	**Ceramic**	**Impurities (Gypsum)**
Actual Class	**Concrete**	433	6	0
	Ceramic	5	493	0
	Impurities (Gypsum)	8	0	599



Development of Prediction Models

- **CS2. Separation of Impurities in Plasterboard fractions**

CS2: PLS-LDA Model for 10 PCs (Two Classes: Plasterboard & impurities)		Predicted Class	
		Plasterboard	Impurity
Actual Class	Plasterboard	1370	4
	Impurity	128	767

Classification Accuracy:
98.6% (Plasterboard)
93.3% (Impurities, excluding paper)
17% Paper Impurities

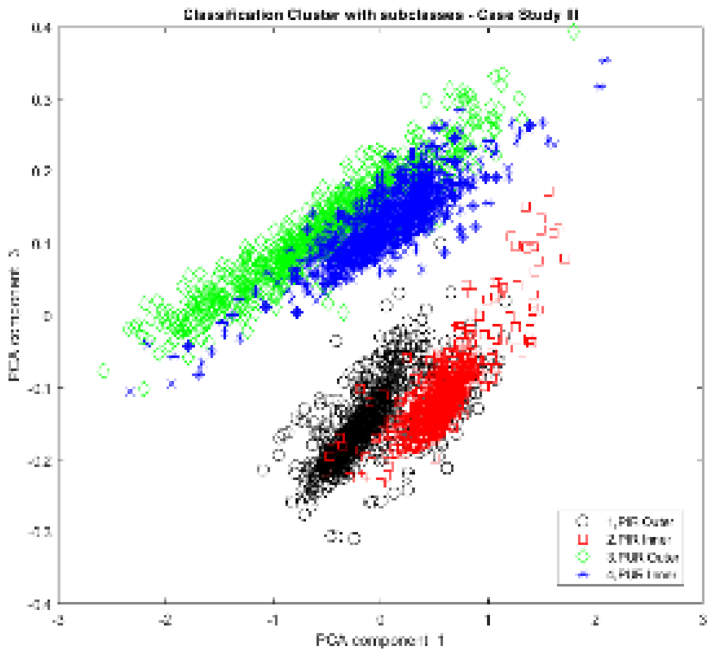
	25-50 mm Plaster 2 0.62%	50-80 mm Plaster 2 0.47%	Normal Gypsum 0 0%	Antihumidity Gypsum 0 0%	Fireproof Gypsum 0 0%
	Normal Gypsum, Paper side 0 0.00%	Antihumidity Gypsum, Paper Side 0 0.00%	Fireproof Gypsum, Paper Side 0 0.00%	Cotton Impurities 1 1.10%	Cable Impurities 24 14.63%
Subclass nº of errors % of error	Poliuretan Impurities 0 0.00%	Iron Impurities 1 2.70%	Wood Impurities 3 3.75%	Plastic Impurities 3 5.45%	Miscellaneous Impurities 8 9.88%
	Glass Impurities 5 17.86%	Brick Samples 0 0.00%	Ceramic Samples 0 0.00%	Concrete Samples 6 9.84%	Paperboard Impurities 77 83.70%

Development of Prediction Models

- **CS3. Separation of PU and PIR foams**

Classification Accuracy: 98.9% (PIR) | 100% (PU) | 100% (Foil)

CS3: PLS-LDA Model with 4 PCs (Three Classes: PU, PIR and impurities)		Predicted Class (EXTERNAL VALIDATION)		
		PIR	**PU**	**Other (foil)**
Actual Class	**PIR**	796	9	0
	PU	0	792	0
	Impurities (foil)	0	0	270



Advanced Sorting & Recycling Technologies

Outline

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- **System Validation**
- Conclusions and Future Work

System Validation

- **Implementation of Sorting line**

System Validation

Results: Separation of Mixed Stony Fractions

Classification Errors (HSI)			
	Concrete	Ceramic	Gypsum
Concrete	**99.0%**	1.0%	0.0%
Ceramic	0%	**100%**	0%
Gypsum	1.5%	0.0%	**98.5%**

The HSI allows classifying the incoming material with an accuracy above 99% (target accuracy: 92%)

System Validation

Results: Separation of Mixed Stony Fractions

Sorting Errors (50Hz)			
	Concrete	Ceramic	Gypsum
Concrete	**94.0%**	5.0%	1.0%
Ceramic	0.5%	**99.0%**	0.5%
Gypsum	5.0%	3.5%	**91.5%**
Estimated Throuhgput (tons/h):			**6.5**
Estimated Operational Cost (€/tons):			**6.3**

Parameter	Target	Achieved
Accuracy	92%	94% - 99%
Throughput	1 ton/hour	6.5 tons/hour

Average Particle Weight:

36.5 g (Concrete); 22.4g (brick); 25.5 (gypsum)

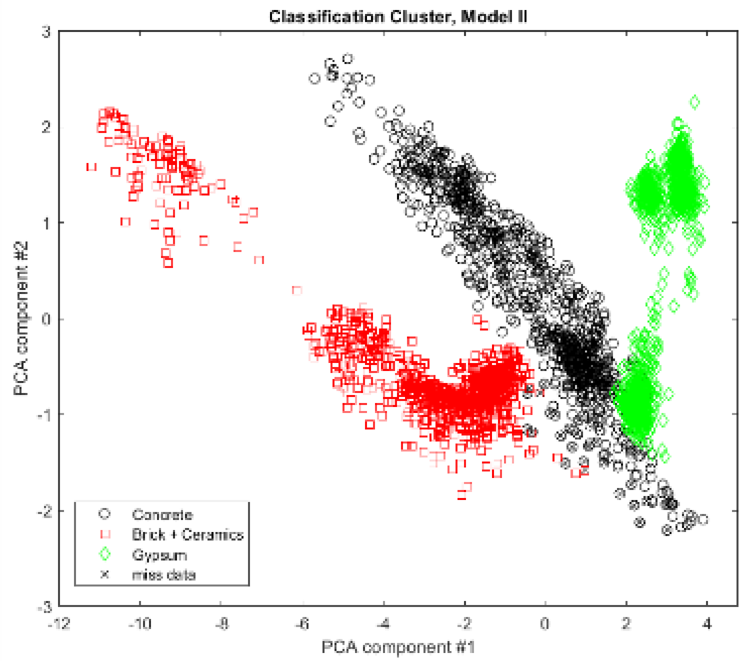
System Validation

- **DEMO Video**

System Validation

Performance parameters (demonstrator scale):

- Conveyor width: 1 m
- Target particle size: 25 – 80 mm
- Throughput: Up to 10 tons/hour
- Operational Cost: 4-20 €/ton
- Study Cases:
    - Separation of **Concrete** and **Ceramic** Fractions
    - Removal of **impurities** in **Mixed Stony Fractions**
    - Removal of **impurities** in **Plasterboard** waste
    - Separation of **PIR / PU foams**



Sorting Accuracy: >95%

Advanced Sorting & Recycling Technologies

Outline

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- **Conclusions and Future Work**

Conclusions and Future Work

Conclusions

- A pilot scale demonstrator for the separation of **Mixed stony fractions** was produced, calibrated and tested.
- The estimated nominal **throughput** achievable by the system is in the range of **2-10 tons/h**
- The **classification accuracy** of the Prediction Models developed for mixed stony fractions was in the **98%-99%** range (target accuracy: 92%). Major errors were found to be associated to silicious concrete fractions (95.8% accuracy).
- A preliminary cost analysis was performed. Under standard operational conditions of the line, the production cost was estimated in the range of 4€/ton ÷ 22€/ton, depending on the average particle size, density and operational conditions)

Conclusions and Future Work

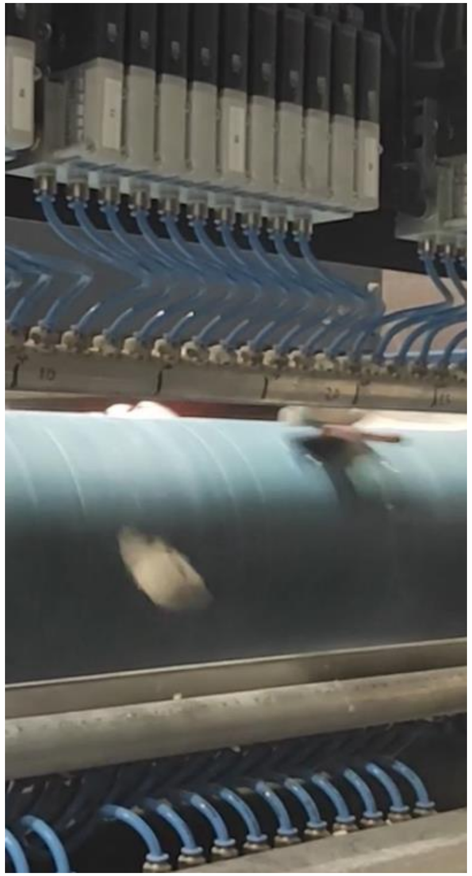
Conclusions

- In the case of **plasterboard fractions**:
  - The technology allows classifying a significant fraction of contaminants, including *ceramic, concrete, glass, plastic, iron, wood, foams*, and *cotton* particles, with an average **classification accuracy** of **93.3%**
  - The identification of paper impurities proved particularly challenging, due to the fact that paper is inherently present in the plasterboard fraction (16% accuracy)
- In the case of **PU/PIR foams**:
  - HSI technology proved highly sensitivity to the type of material, leading to **classification accuracies** above **99**% for both PIR and PU fractions.

Conclusions and Future Work

Future Work

- Full scale technology development and optimization
- Identification of first potential clients
- System Qualification
- Development of New Applications



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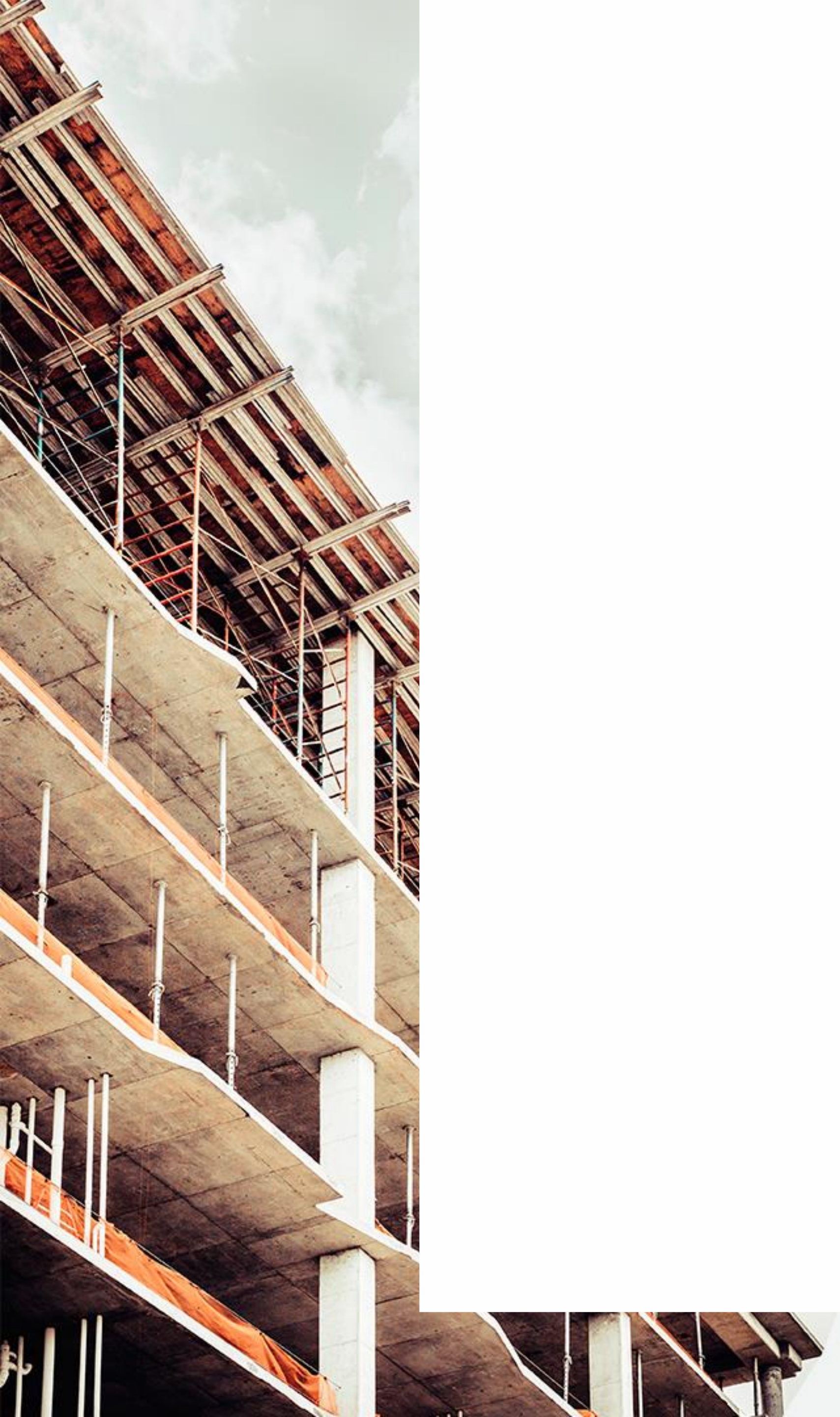

ICEBERG Final Workshop

April 19, 2024,

Belgium, Ghent

Abraham Gebremariam
Francesco Di Maio
Peter Rem
Ali Vahidi

TU Delft

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Advanced technologies for concrete recycling

Thermal attrition mobile unit (Heating air classification system, HAS)

Leader: C2CA

→ To design, optimize and up-scale a 10 t/h biofuel-based thermal attrition mobile unit for the production of high-quality recycled concrete sands and ultrafine cementitious materials (RCP)

- Process variables optimized (Spalling, residence time, temperature, milling)
- Upscaling the design to 10 t/h thermal attrition unit
- Quality of products evaluated

STATUS:

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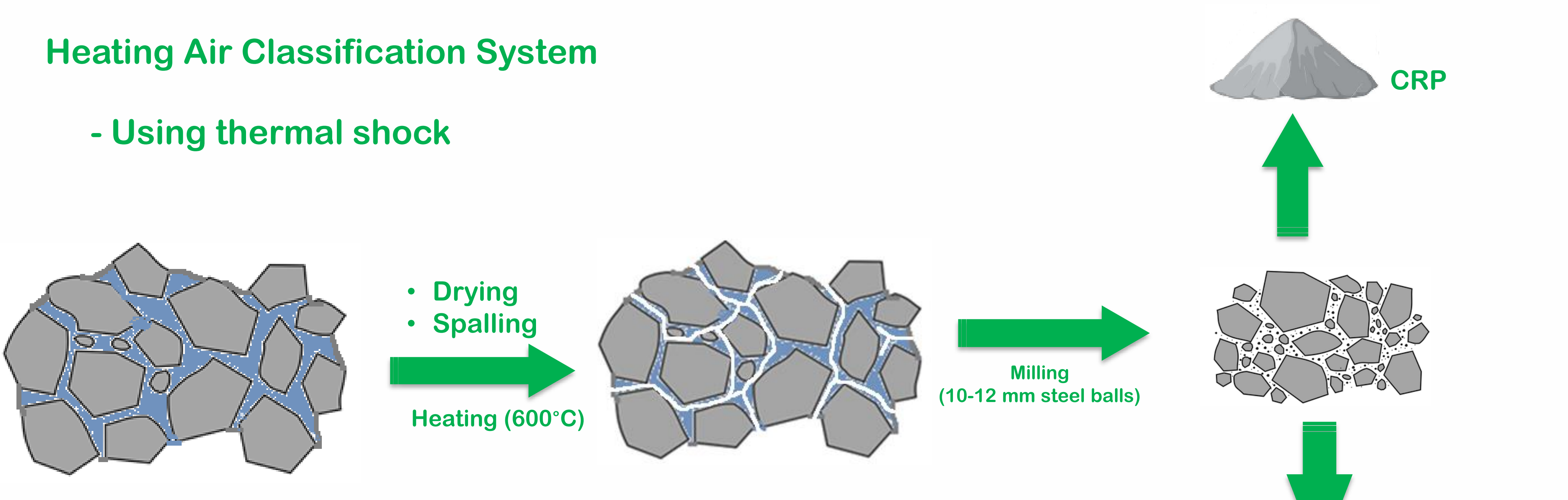
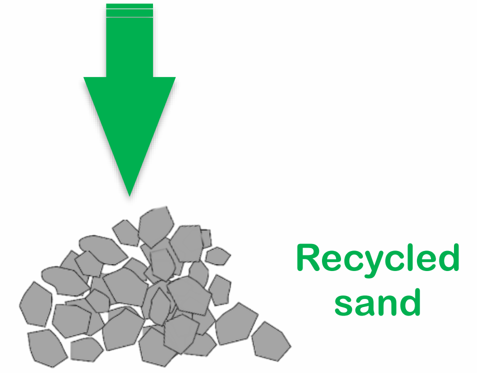
Principle: Thermal shock

Heating Air Classification System

- Using thermal shock





- **How much energy is required?**
- **How long should we expose it?**

Process variables: Energy consumption

- Theoretically the amt. of heat:

$$\boxed{Q_{duty} = \frac{(Tg - Ti)}{(Tg - To)}\left[m_s(X_i - X_o)\Delta H_v + m_s Cp_s \Delta T + \cancel{Q_{loss}}\right]}$$

11 % 54 % 7 % 28 %

$$\boxed{Q_{duty} = \left[m_w C_{pw} \Delta T\right] + \left[m_s(X_i - X_o)\Delta H_v\right] + \left[m_{steam} C_{Ps} \Delta T\right] + \left[m_s Cp_s \Delta T\right] + \left[Q_{loss}\right]}$$

- Practically the amount of heat supplied:

$$\boxed{Q_{HAS} = NCV_{diesel} V_{diesel} \;\; ; where\ NCV_{diesel}\ is\ (36 - 41)\frac{MJ}{l}\ and\ V_{diesel}\ is\ \frac{0.0085l}{s}}$$

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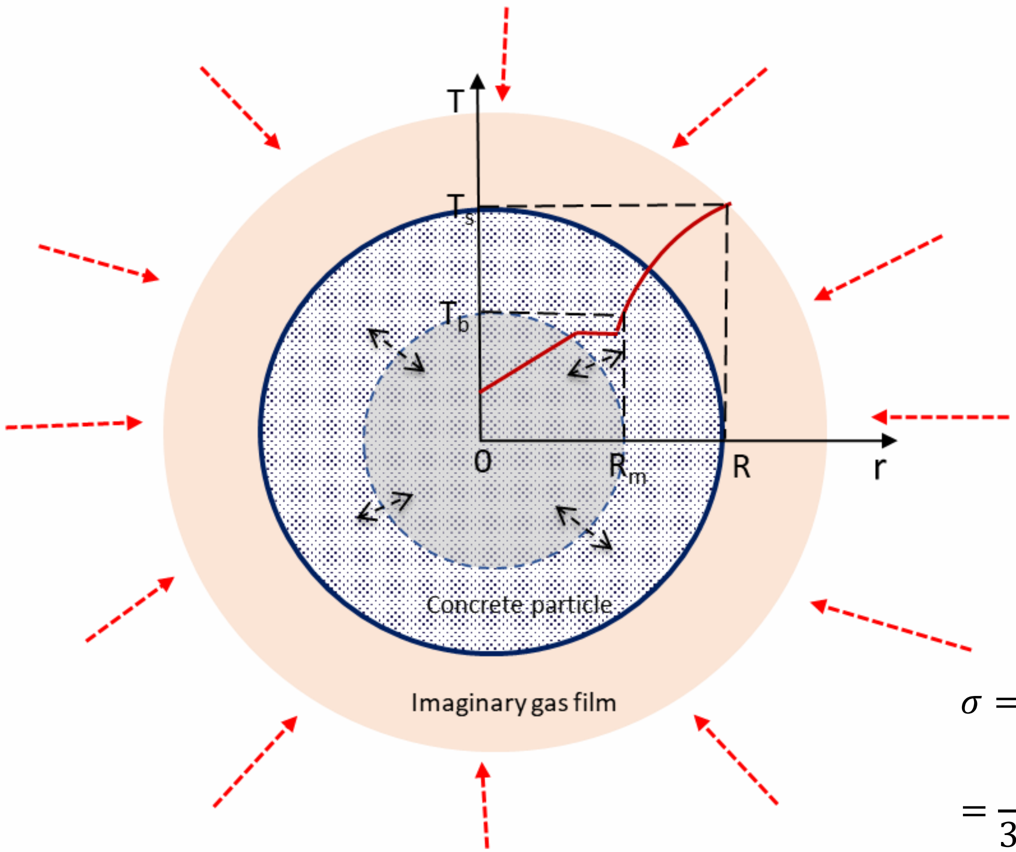
Process variables: Model

Model is used to predict the residence time and internal stress (spalling)



The temperature profile inside the particle is:

$$T(r,t) = \begin{cases} T_b & 0 < r < R_m \\ T_b + \dfrac{Q(t)}{4\pi\lambda_c}\left(\dfrac{1}{R_m(t)} - \dfrac{1}{r}\right) & R_m < r < R \end{cases}$$

The radial stress (σ) is given by:

$$\sigma = \frac{2E}{3(1-\upsilon)}\bar{X}(R,t) = \frac{2E}{3(1-\upsilon)}\left\{\left(\frac{1+F(t)}{2}\right)\frac{\alpha q(t)R^2}{\lambda_c A(t)R}\left(\frac{R}{R_m} + \frac{R_m^2}{2R^2} - \frac{3}{2}\right) - \mu m_0\left(1 - \frac{R_m^3}{R^3}\right)\right\}$$
$$= \frac{2E}{3(1-\upsilon)}\left\{\alpha(T_s(t) - T_b)\left(1 - \frac{1}{2}\frac{R_m}{R}\left(1 + \frac{R_m}{R}\right)\right) - \mu m_0\left(1 - \frac{R_m^3}{R^3}\right)\right\}$$

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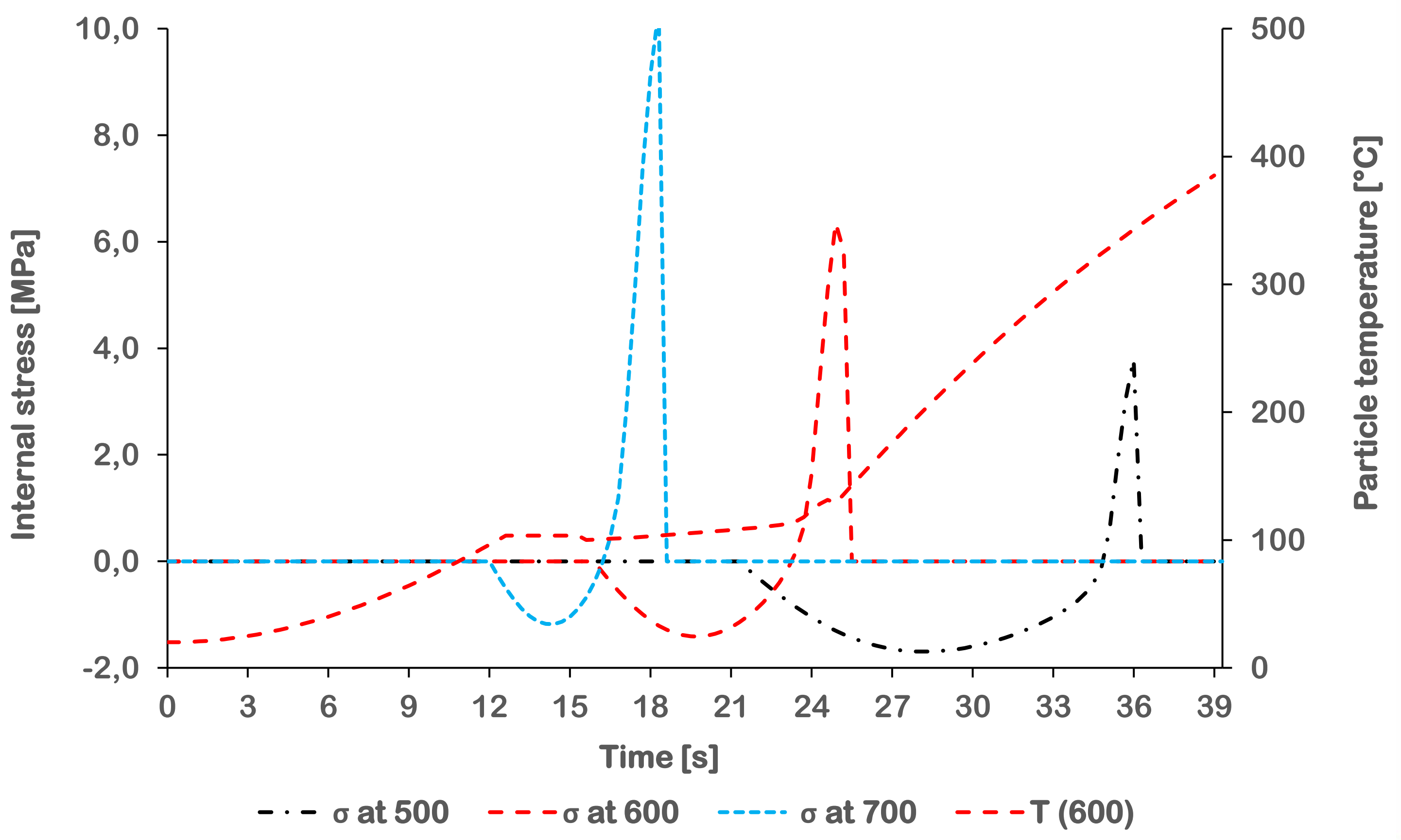
Model: Predicting spalling

Prediction of radial stress (σ) at different processing temperatures (2mm FRA)



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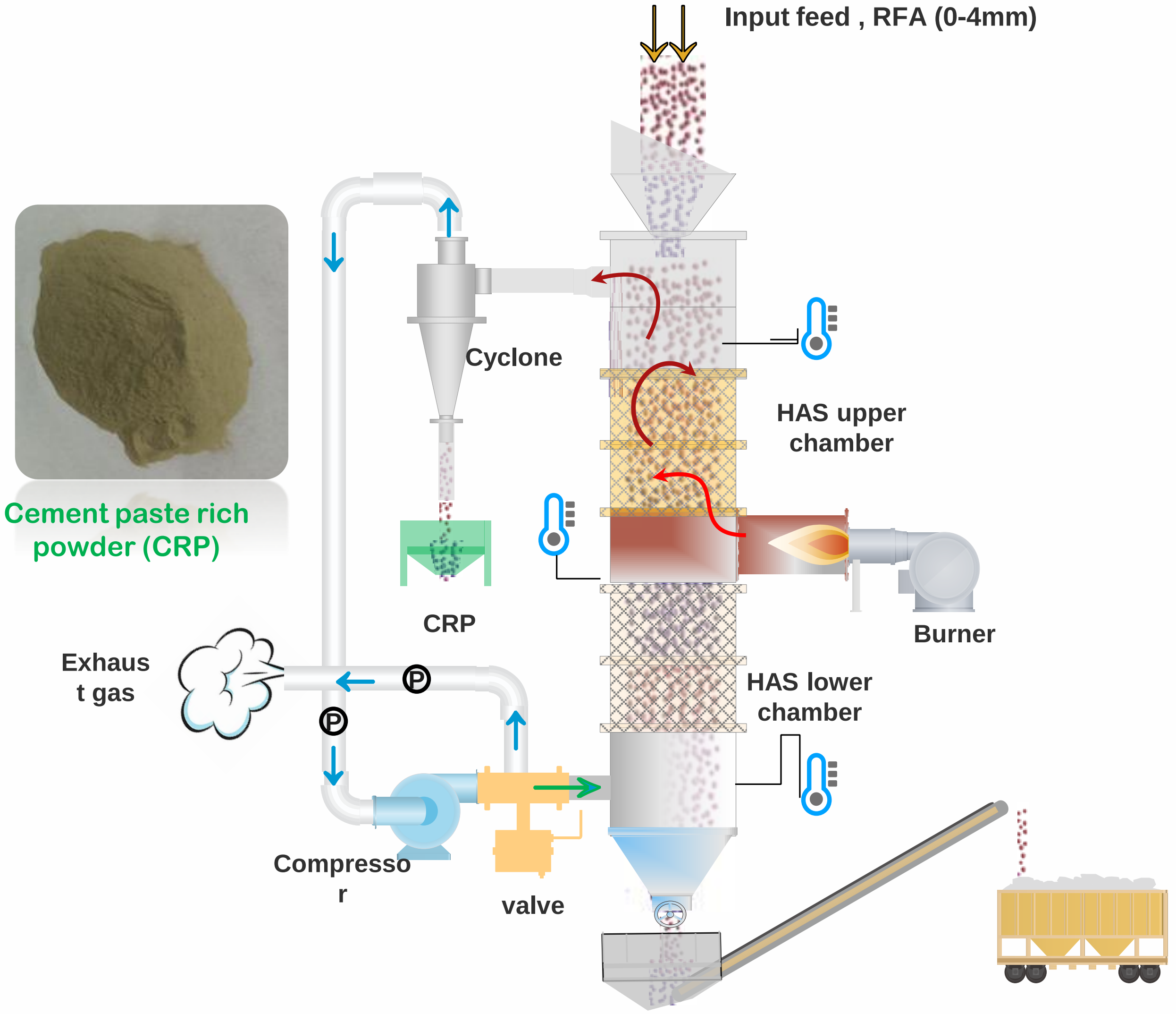
Working principle of the HAS



RFA (0-4mm)

Recycled sand product

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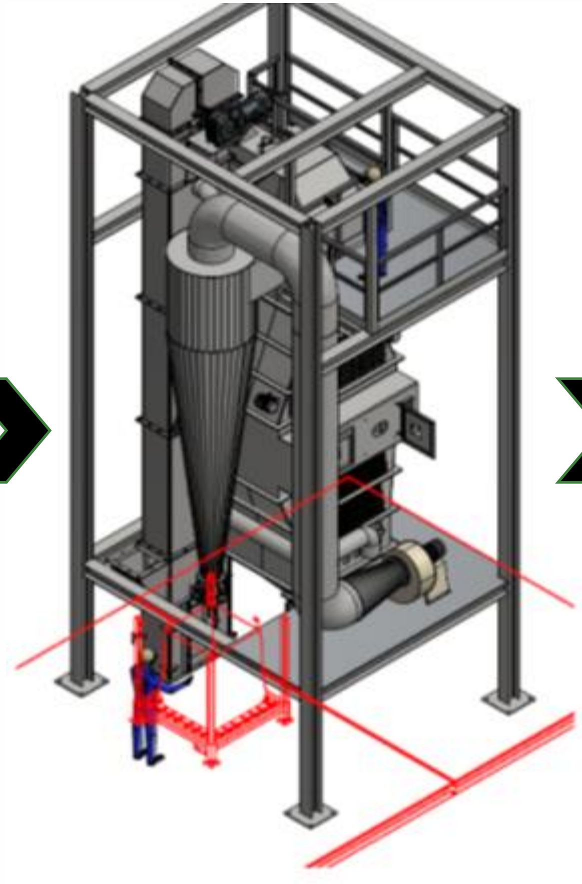
Upscaling progress of HAS

Pilot scale HAS (1.5 t/h)



Design phase of HAS (10 t/h)

HAS at Hoorn (10 t/h)

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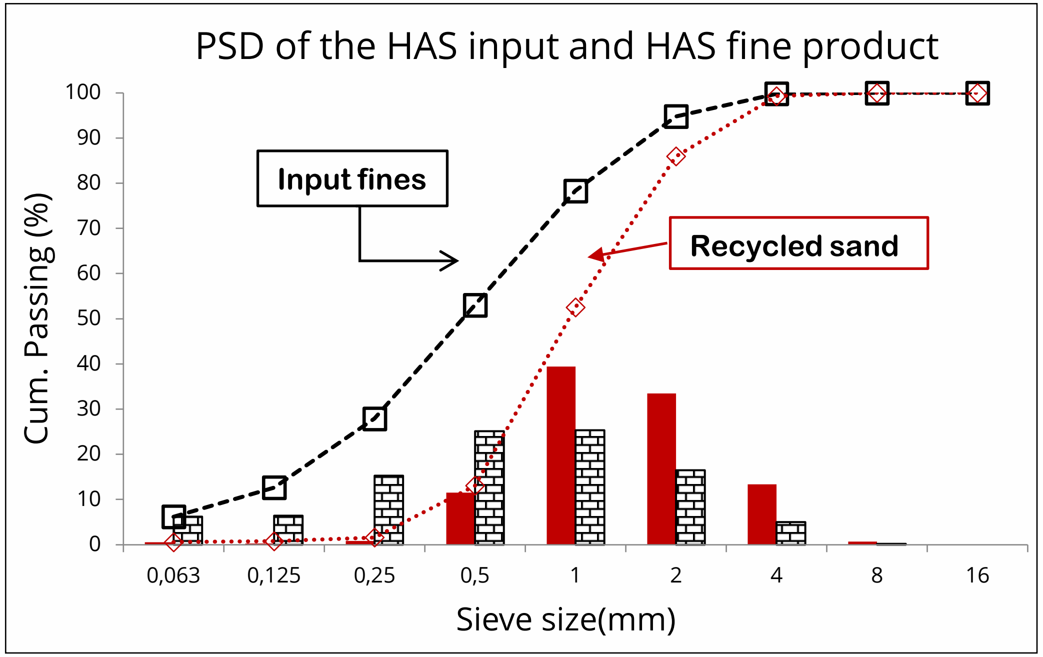
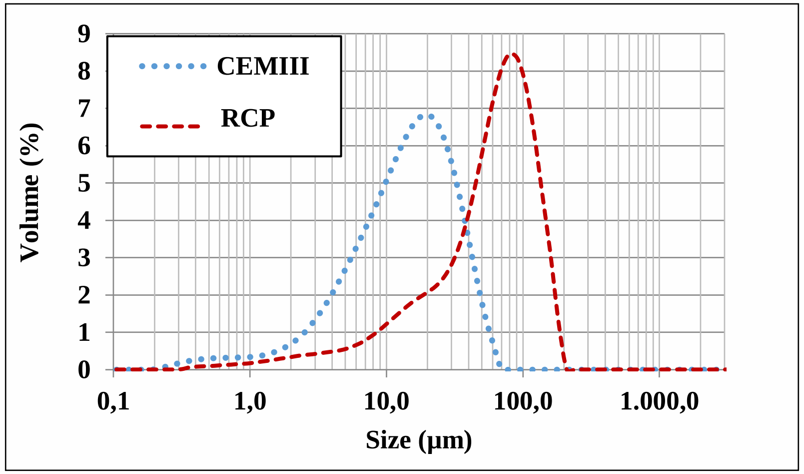
Product quality: RCP and Recycled sand

Recycled cement rich powder (RCP)

Recycled sand fraction (RFA)

Products quality: RCP and Recycled sand





PSD of RCP

Chemical composition of RCP compared to CEM III

Chemical composition		
%	**CEM III**	**RCP**
SiO_2	30.52	52.91
Al_2O_3	8.84	6.04
CaO	47.80	25.5
Fe_2O_3	1.14	2.3
MgO	5.42	2.1
SO_3	2.19	1.61
Na_2O	0.28	1.14
K_2O	0.71	1.06
TiO_2	0.78	0.41
P_2O_5	0.07	0.09
LOI	1.55	6.42

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Challenges

Cost : significantly increased cost

Time: it took more than expected

Automation: due to hostile process conditions, the function of sensors is affected

Demonstration of HAS


Thank you!

ICEBERG FINAL WORSHOP

New circular building products

Miguel Castro-Diaz / Vincent Barraud
19/04/2024

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CONTENT

I. ICEBERG project

II. Prototype design evaluation framework developed.

1. Production pre-industrial prototypes of circular plasterboards.
2. Production pre-industrial prototypes of circular PU based products.

I - ICEBERG project

A recent report revealed that the EU28 generates around 350 Mt of C&DW (construction & demolition waste), excluding excavation earths.

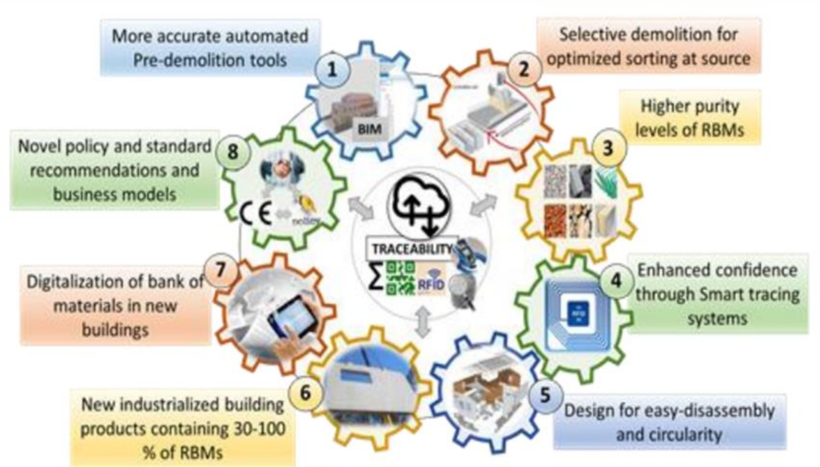

Fig. 1. ICEBERG overall concept

REUSE

To maximise the reused waste

SUSTAINABILITY

To promote sustainability

TRANSFER

To transfer technology

CO_2 FOOTPRINT

To reduce the carbon footprint

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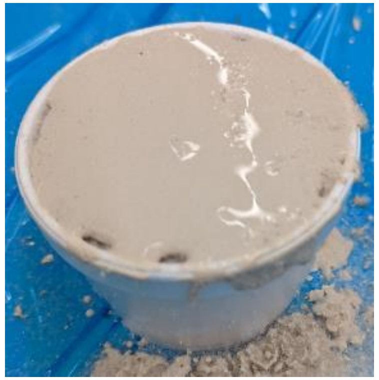
II.1 - Production pre-industrial prototypes of circular plasterboards (T3.6)

Objective

Develop multi-life circular plasterboard prototypes with 35 wt% recycled gypsum from EoL plasterboard, >50 wt% replacement of desulphurgypsum (DSG) by alternative purified phosphogypsum, 100 wt% recycled paper, and increased thermal insulation (20-60%) via the use of SICLA aerogels.

Purified phosphogypsum still contained toxic heavy metals above the levels demanded by plasterboard manufacturers



SICLA aerogel and gypsum cannot create the required homogeneous blend for plasterboard production

ICEBERG plasterboard prototype production

Pilot-scale ICEBERG acid leaching gypsum purification

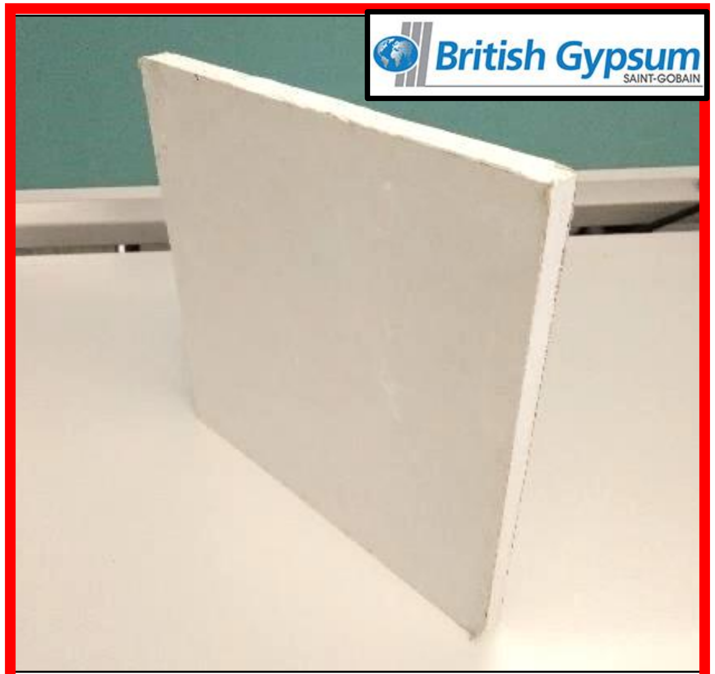
Step 1 - Acid leaching purification of gypsum from End-of-Life (EoL) plasterboard at 90°C for 1 hour using a 5 wt% sulfuric acid solution.

Step 2 - Neutralization of the residual sulfuric acid with hydrated lime to achieve pH 5-8.

Step 3 - Filtration.

enva

Purified gypsum from EoL plasterboard



ICEBERG plasterboard prototype (35 wt% purified gypsum)

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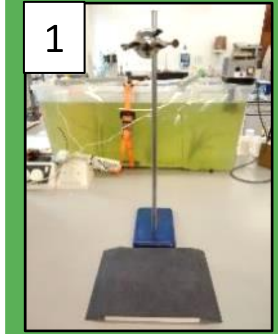
Results

Characterization	ICEBERG plasterboard prototype *(35 wt% purified gypsum)*	Business-as-usual plasterboard prototype *(10 wt% current recycled gypsum)*	**Requirements for standard plasterboards**
1. Surface hardness (mm) Mean value and std. deviation (mm)	13.18, 13.59, 13.45 **13.41 ± 0.17**	13.40, 13.40, 13.40 **13.40 ± 0.00**	BS EN 520 **≤ 15.00 mm**
2. Flexural strength (N) Mean value and std. deviation (N)	353, 674, 448 **492 ± 135**	796, 600, 666 **687 ± 81**	BS EN 520 **≥ 210 N transverse** **≥ 550 N longitudinal**
3. Thermal conductivity (W/mK) Mean value and std. deviation (W/mK)	0.208, 0.214, 0.219 **0.214 ± 0.004**	0.189, 0.193, 0.198 **0.193 ± 0.004**	BS EN 12524 **< 0.250 W/mK**

1

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3


ICEBERG plasterboard prototype with 35% purified gypsum from EoL plasterboard fulfills the mechanical and thermal requirements for standard plasterboards.

II.2 - Production pre-industrial prototypes of circular PU based products products (T3.7)

Objectives

New PU insulation products containing 10-50 wt% of recycled polyols fractions from end-of-life building materials.

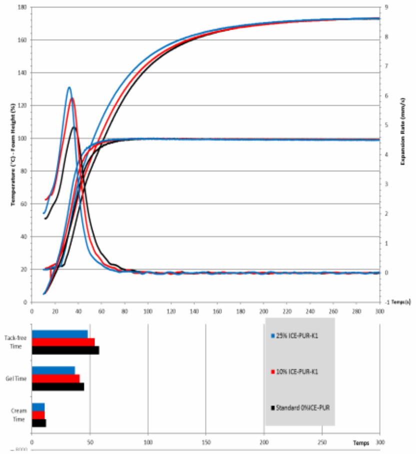
In the future, the landfill will be very expensive or prohibited

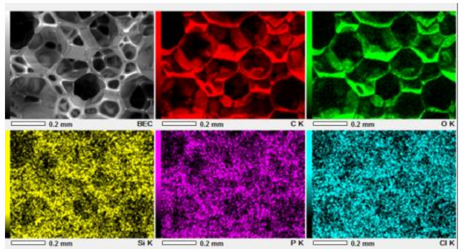
Tasks during the project (T3.7)

- Establish a polyol book of specifications
- Screen polyols → lab trials
- Characterize samples and optimize the product
- Manufacture prototypes

ICE PUR K1

Opaque brown polyol





Results

A pilot sample of polyol recycled by RAMPF (200 kg). Polyol obtained from the post-industrial PU waste of the SOPREMA PU plant.

- 2 trials done :
  - 2 products in PUR formulation with a content of 10 % recycled polyol vs virgin polyol (725 m² + 215m²).

SOPREMA

RAMPF

SOPREMA

Viuda de Sainz

Production waste

Machining Dust

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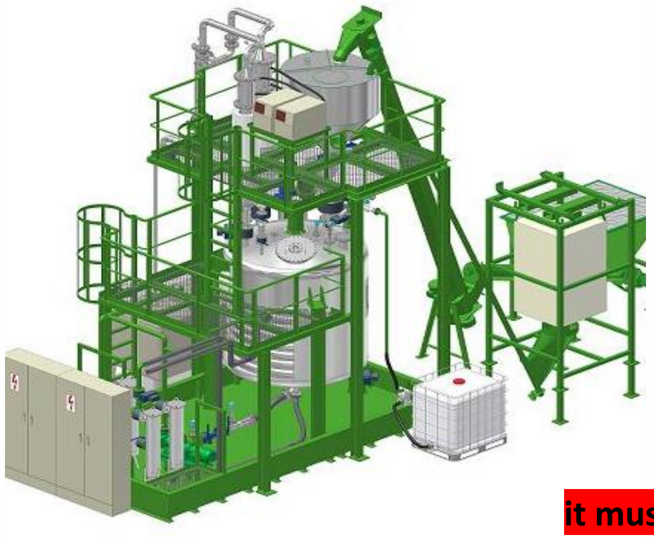
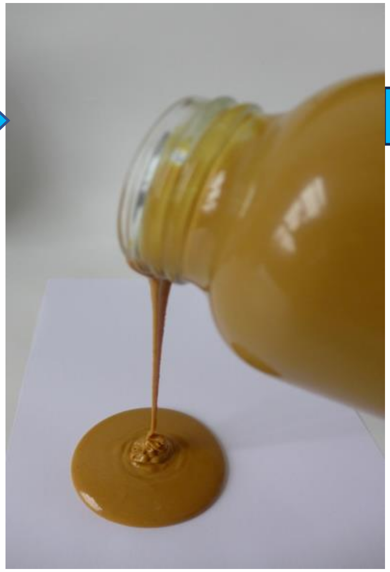
New plant investment in SOPREMA HOF (1,8 M€)

Solid filtrate





Product is ready for direct usage

Capacity: 840T/year

NO PAPER!!
it must be removed before the recycling process

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This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 869336

ICEBERG Final Workshop

Circular Case Studies

Frank Rens, GBN Groep
Ghent, 19-04-2024

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Content

Main objective

CCS 1 – Circular concrete

CCS 2 – Circular cement based products

CCS 3 – circular carbonated blocks

CCS 4 – circular wood-based products

CCS 5 – circular plasterboards

CCS 6 - circular ceramic, silica aerogel and PU based products

Overall conclusion

Questions

Main objective

The main objective in ICEBERG is to develop and demonstrate circular solutions to upgrade end-of-life building materials in new building products.

This is done through 6 circular case studies, covering building materials accounting for more than 85% by weight of the European built environment.

Circular Case Studies

circular case studies (CCS) across different locations in the EU

Each case study followed a common circular procedure:

1) Perform pre-demolition audit with BIM4DW;

2) execution of selective 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.

- Circular Concrete — THE NETHERLANDS
- Circular Cement based-products — TURKEY
- Circular carbonated blocks — BELGIUM
- Circular wood-based Products — FINLAND
- Circular plasterboards — UK
- Circular ceramic, silica aerogel and PU based products — SPAIN/FRANCE

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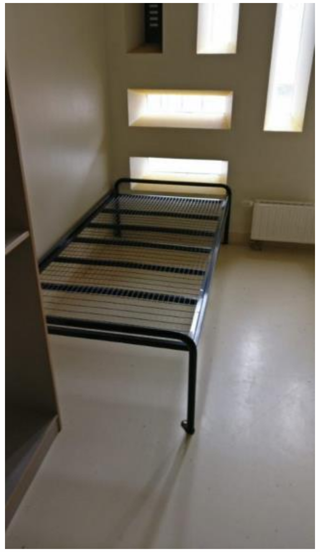
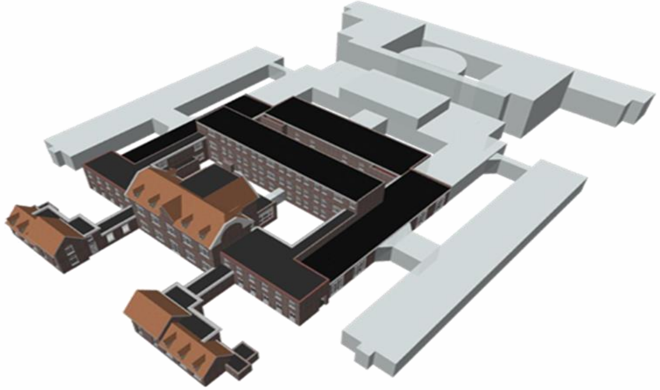
CCS 1 – Circular Concrete

Demolition of juvenile detention center

- Total area 10.000 m2

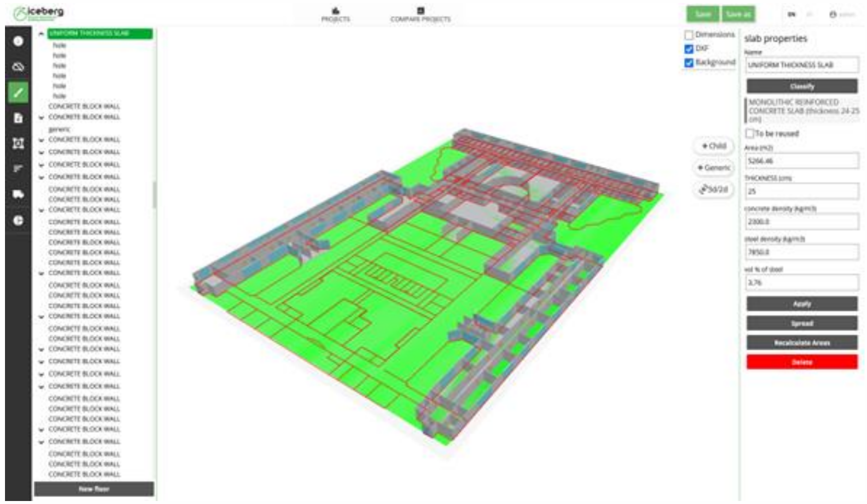




CCS 1 – Circular Concrete

Pre-demolition audit – BIM4DM-tool

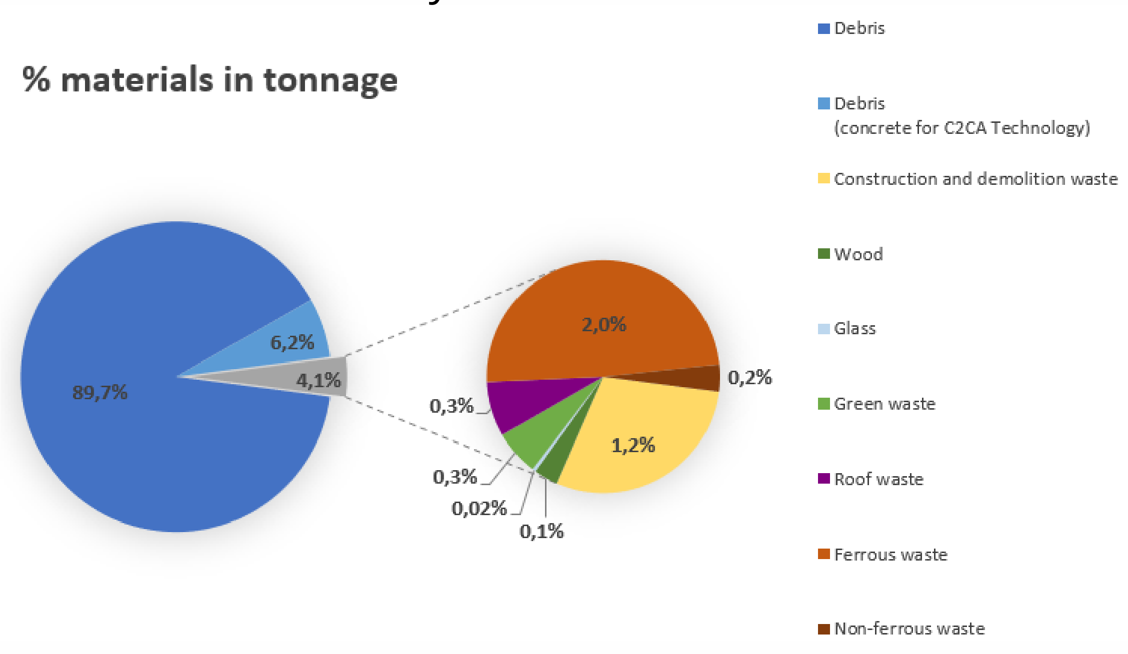
- BAU predemolition audit is compared with pre-demolition audit using the BIM4DW-tool
- Pre-demolition audit with BIM4DW-tool was performed within 8 hours
- 10 different materials where defined for recycling
- 29 different objects where defined for reuse
- Concrete by far the largest amount of CDW
- Manual audit: 10.500 ton of concrete, BIM4DW-tool 11.171 ton



CCS 1 – Circular Concrete

Selective demolition

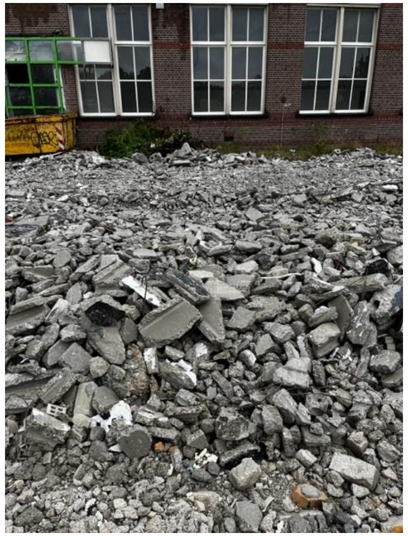
- 35% les unsorted CDW compared with a BAU demolition project.
- 16,187.4 tons of recycled materials
- 95% stony materials



CCS 1 – Circular Concrete

Processing EOL-concrete

- 15.000 tons EOL-concrete was crushed on site
- 1000 ton crushed concrete (0-16 mm) was transported to recyclinglocation of GBN for futher processing.
- Remaining amount remains on demolition site as foundation material (wish of building owner)



CCS 1 – Circular Concrete

Processing EOL-concrete

- C2CA proces: ADR → HAS → LIBS
  - Coarse and fine aggregates
  - Calcium rich ultra fines
- KEEY:
  - Aerogel
- ÇİMSA:
  - Eco-hybrid cement

Roosens received the sand and crushed aggregates from GBN at the end of September 2023. The materials are judged as impressive quality!

Figure 34. Recycled 0/4 sand (on the right) and recycled crushed 4/10 (on the left)

Figure 35. Recycled crushed 4/10

Figure 36. Recycled 0/4 sand

Figure 37. KeeyAerogel

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CCS 1 – Circular Concrete

Production new circular building products

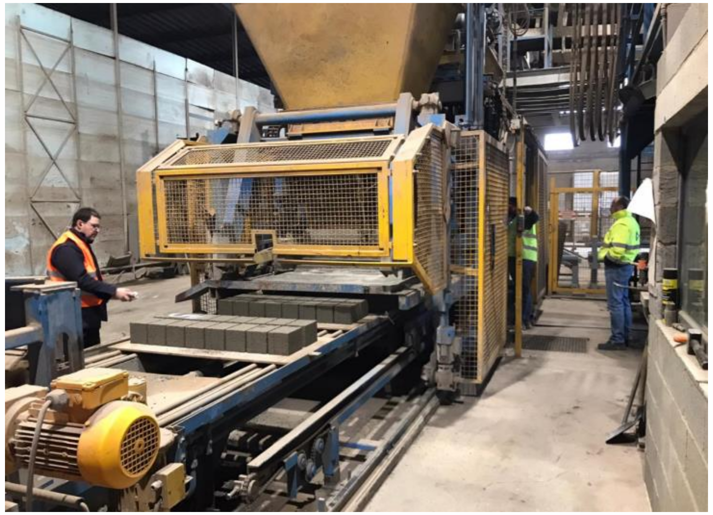
100 m² of 39x19x14 cm hollow blocks F8/1.6 based on the following formula:

recycled 0/4 sand: 1.050 kg/m3

recycled crushed 4/10: 970 kg/m3

Cement eco-hybrid: 125 kg/m3

Aerogel: 5 – 10%



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CCS 1 – Circular Concrete

Demonstration of the new digital EBM traceability service;

- Data from LIBS is uploaded to Tracebility platform, with a unique code on the RFID-tags a link is made between the concrete structure and the platform;
- Readability of tags is 20 – 60 cm depending on orientation of the antenna

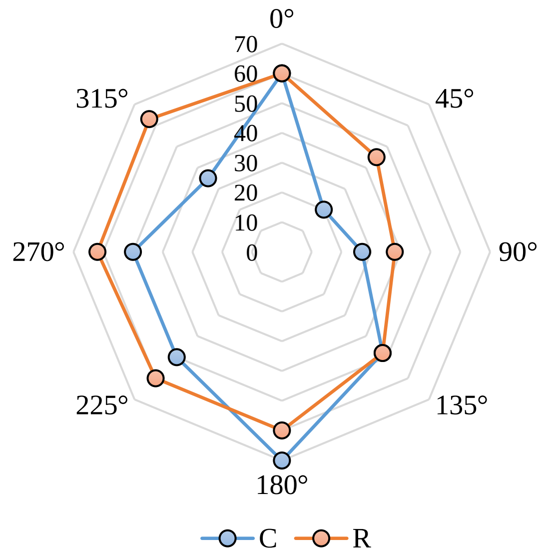
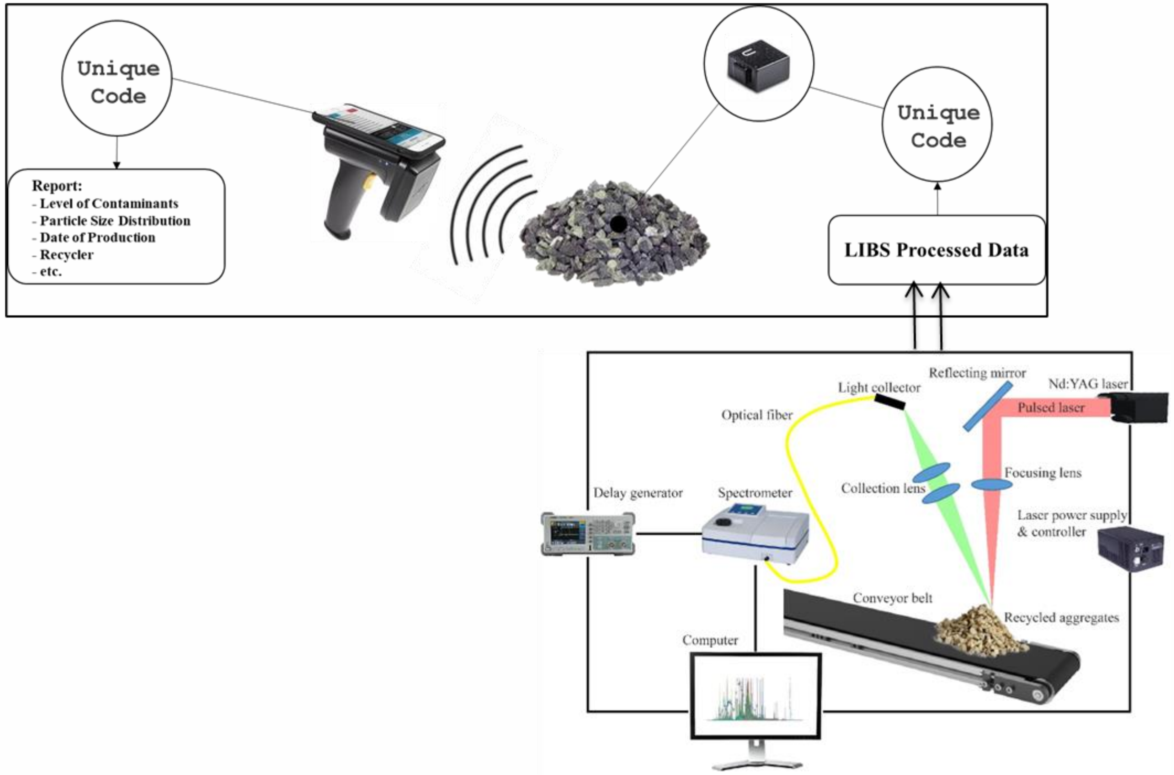


Figure 47. Average readability of 'CS' RFID tags in cm in concrete beam (C-centre and R-right)



Case study 2 (CCS2)

Demonstrating circular cement-based products

[Video]

Overall Conclusion

Within the ICEBERG project we demonstrated the circular solutions to upgrade end-of-life building materials in to new circular building material.

Great examples of:

1. How EOL-building materials are recycled 100% to new building materials;
2. Design and production of circular building elements from CDW which can be re-used;
3. The use of CO2 to improve material qualities and capturing the CO2 in the same time;
4. Use of biobased materials such as wood for new circular building materials;
5. Implementated EOL-buiding materials in existing manufactering processes to produce new circular buidling materials

Questions?

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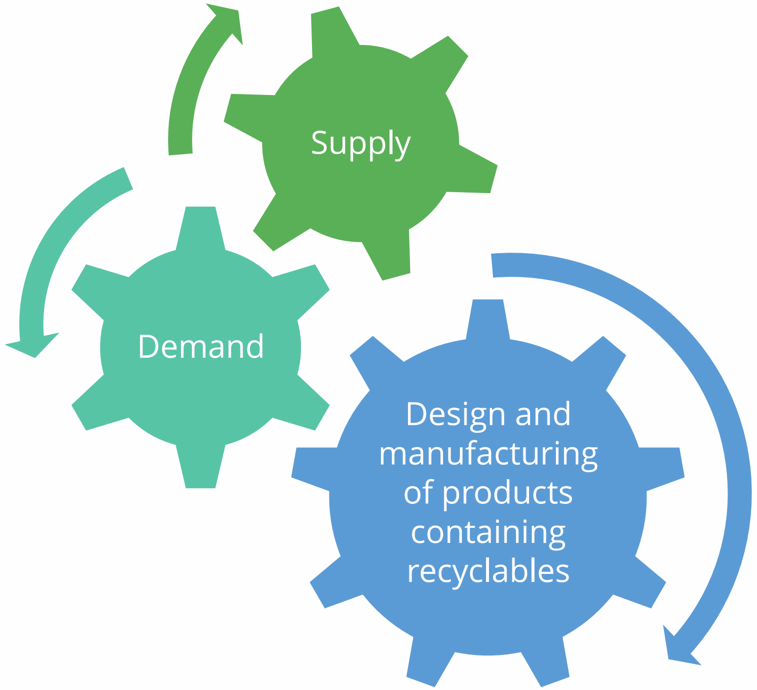
This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 869336

ICEBERG policy recommendations

Workshop 19, 2024

Margareta Wahlström & Elina Pohjalainen



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Outline

1. Research questions
2. Methodology, ICEBERG partners involved
3. *Opportunities and gaps in current legislation*
4. *Policy recommendations*
    - *Identification of barriers*
    - *Overview of measures supporting uptake of ICEBERG solutions*
    - *Learnings from interviews with ICEBERG partners*
    - *Survey on importance of measures and implementation timeline (focus Flanders)*
    - *Use of system dynamics – plasterboard example*
    - *Regional recommendations (good practice)*
5. *ICEBERG solutions contributing towards CE*

Involvement of ICEBERG partners in task

Preparation of Deliverable 6.3 ”Report on policy recommendations”

Overall support: reference group for advice on planning, task implementation
- Tracimat, VITO, OVAM, Loughborough university, Tecnalia, GBN

Subtask:
regional aspects
- OVAM
- IHOBE

Subtask:
EoW concept
- VTT,
- OVAM,
- VITO,
- Tecnalia

Subtask:
Pre-demolition audit
- Tracimat,
- VITO,
- Tecnalia,
- VTT

Subtask:
sustainability issues
- Leiden University,
- VITO,
- RINA,
- VTT

General Assembly workshops
- Interviews on conditions, challenges – ICEBERG stakeholders involved in 6 product groups

Diploma work on DPP: interviews with different stakeholder groups

Outside ICEBERG:
- CISUFLO: GA meetings
- CITYLOOPS: participation in CITYLOOPS reference group

Research questions:

1) How well does the EU regulatory framework support and foster ICEBERG solutions?

   (description of landscape, regulatory barriers & gaps)

2) Which are potential measures and policy solutions that could support the industrial uptake and scale-up of ICEBERG recycling activities in EU?

   (elaboration of policy options, solutions taking into account technological/market reality, stakeholder contacts)

3) How do the ICEBERG solutions contribute to the transition towards CE or Circular Building?

   (general assessment of their added value so they warrant efforts to overcome barriers)

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Approach

- High focus on ICEBERG solutions & views of ICEBERG stakeholder

Drivers (consumption of virgin resources etc) (reflected in EU policies, national strategies, company strategies)

Responses (policy recommendations)

Key barriers for uptake of ICEBERG solutions

Survey, workshop

Potential Measures to support uptake of ICEBERG solutions

Survey, workshop

Identification of most effectful measures (interviews)

Interviews, surveys, workshop

Q1: How well does the EU regulatory framework support and foster ICEBERG solutions?

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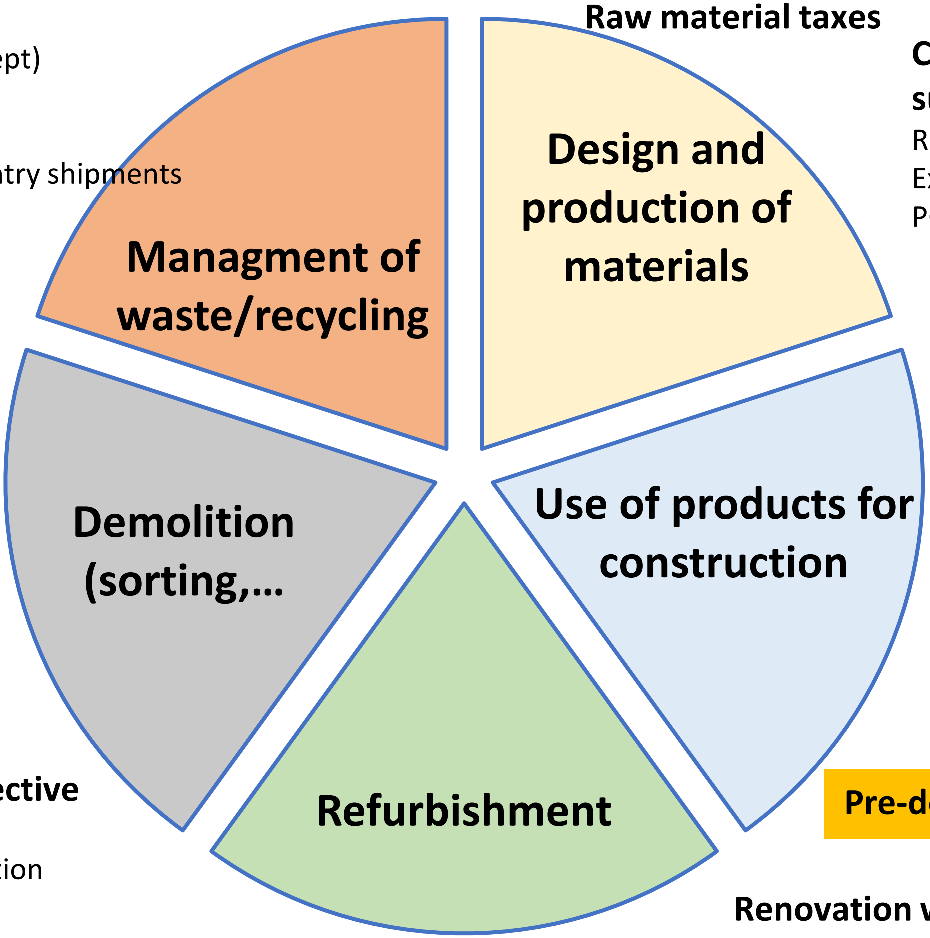
Desk study: support & gaps in EU regulation

WFD: End-of-waste

Waste legislation:
Waste Framework Directive (End-of-Waste concept)
Landfilling restrictions
Waste specific legislation (C&DW targets……)
Waste Shipments: permits needed for cross country shipments
POP regulation (persistent organic pollutants)
Green Public Procurement
REACH (removal of certain SVHC from the loop)

EU Taxonomy



Raw material taxes

Chemical legislation (allowed substances):
REACH / Substances of very high concern
Export/import of hazardous chemicals
POP (is there a risk that POP substances present)

Product legislation (Product safety):
Construction Products Regulation (NEW)
Sustainable Product Initiative and revision

Extended Producer Responsibility

Waste Framework Directive
Waste sorting/collection
Hazardous waste classification
Waste shipment

Pre-demolition audit

Renovation wave

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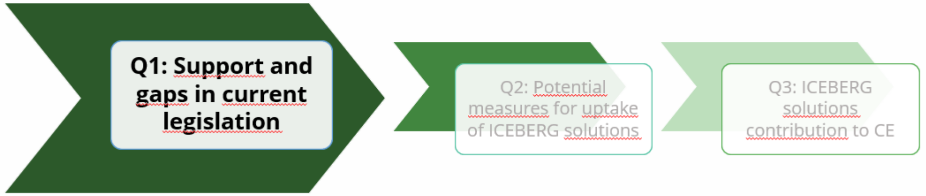
Desk study: support & gaps in EU regulation



Regulation	Support	Barriers
Waste Framework directive	Waste hierarchy – priorities in waste management End-of-waste option for recyclables Obligation for member states to take measure for selective demolition and facilitate sorting, separate collection of CDW – Future: waste material specific recycling targets	Product status in reuse needs clarifications No harmonised protocols for EoW concept Lack of collection and sorting criteria for CDW
NEW Construction products regulation	Lifecycle perspective, e.g. in harmonised standards (installation, maintenance and removal, recycling or reuse of the product) Use of digital product passport Development of sustainability requirements for green public procurement of construction products	CE marking of reusable products still unclear Confidentiality in data (to be published still to be ensured)
REACH, POP regulation	Substitution of hazardous substances if possible. (especially PFAS substances). Very low limits for POP substances allowed in recyclables (POP regulation)-> need for proper pre-demolition audit	Recycling of historical construction products with unknown composition Challenging to measure low POP concentrations (sorting, sampling procedure etc)
Waste shipment	Secure sufficient feed for processes	Classification of certain waste (e.g. insulation materials containing flame retardants) as hazardous waste not fully clear. Higher administrative burden for trading waste, destined for recycling within EU
EU taxonomy: CE Criteria	Support for ICEBERG solutions for high grade recycling	Guidance needed on how show compliance with criteria Influence of country specific conditions, e.g. insufficient supply of wooden materials and gypsum waste for recycling
Fiscal instruments	Increase the competitiveness of waste materials to replace virgin materials	Landfill taxes, bans may lead to waste used in low grade applications
Energy Performance of Buildings Directive	Focus on low carbon economy (= products should have low embodied energy)	

Q2: Which are potential measures and policy solutions that could support the industrial uptake and scale-up of ICEBERG recycling activities in EU?

Survey/workshop on barriers (October 2022)

- A literature conducted in Spring/Summer 2022 on barriers for uptake of CDW
- A survey was designed for 3 different stages of the value chain (on-line questionnaire, in total 34 questions)
- The survey was conducted with the aim of provoking thoughts for a workshop that followed right after
- Both material specific barriers and barriers related to different stage of value chain were analysed

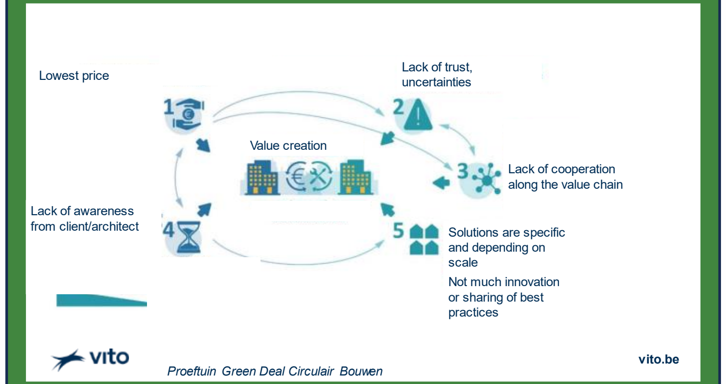


Figure. Relations between barriers

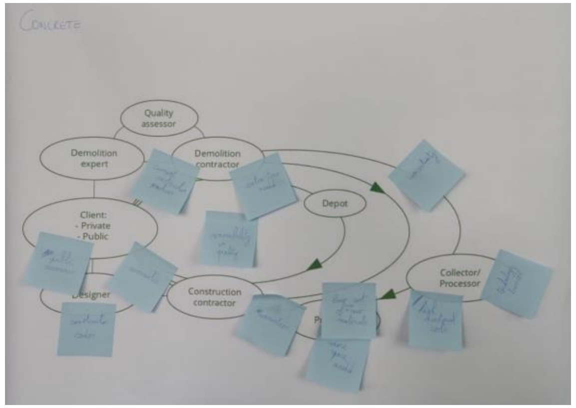


Figure. Workshop on barriers for the uptake of ICEBERG-solutions – Concrete

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Barriers identified in GA workshop 2022

Observation:

- material specific barriers;
- key barriers (example): quality & technical (blue) and costs (red)

	Circular concrete	Insulation material	Wood	Ceramics
Demolition contractor	• Lack of knowledge to differentiate high-value from low-value concrete • Lack of time for selective demolition • Selective demolition not possible due to spray products, EPS beats, etc.	• High transport costs • Selective demolition not possible due to use of glue	• Lack of expertise for sorting • Limited space for multiple containers • High risk of primary contamination with additives	• Lack of demolition methodology to obtain pure fractions • Lack of time/ money for selective demolition
Collector	• Need for quality control • High investment cost • Lack of recycling technology • Lack of storage space	• Lack of recycling technology whilst landfill will be banned • Bans on some of the raw materials of olders products, e.g. CFS (blowing agent) • Balance between cost of waste treatment and performance will be compared for the different synthetic insulation materials • Availability: limited market share of synthetic insulation	• Competition with energy recovery • Waste separation is not easy (soft wood, hard wood, solid wood, particle boards, …)	• Lack of technology for separation of mixed CD&W • Material flow doesn't have consistent quality
Producer	• Virgin materials are very cheap			• Environmental impact not taken into account
Client	• Lack of public awareness		• High cost for sorting on site	
Designer & contractor	• Lack of warranties and insurance schemes (standards, certificates)		• Lack of standards for secondary wood products	

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Analysis of selected measures

1

- A long list of potential measures to support uptake of ICEBERG solutions was created to respond to the identified barrier
- Survey & workshop in April 2023

2

- Desk study on relevance of selected measures for ICEBERG (based on results from the survey and measures presented in the proposal)

3

- Interviews with ICEBERG stakeholders (ranking) , regional reports on instruments and tools supported the preparation of policy recommendations
- Validation workshop,

Desk study on selected measures (copied from deliverable)

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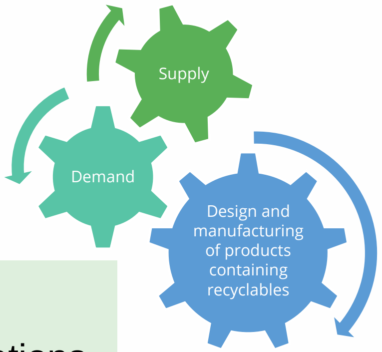
Potential measures – long list



Demand

Manufacturing and design

- Policy actions to make recyclables more competitive to virgin materials
- Incorporation of environmental impact into total price of construction products (e.g. impact of landfill, downcycling)
- Use of Green Public Procurement to drive demand for products with recycled content
- ….

Pre-demolition auditing, waste sorting

- Use of Green Public Procurement in demolition work to drive demand for ICEBERG recycling process

Certification/product status, knowledge and innovations

- Use of sustainable certification schemes (BREEAM, LEED etc) promoting recycling

Supply

Pre-demolition auditing, waste sorting

- National/regional requirements/ guidance/ recommendations for use of Pre-demolition audit
- Implementation of a demolition plan with information on waste management options of recoverable streams
- Mandatory source separation for materials for which recycling capacity exists

Demolitions/waste management

- More control (e.g. inspections) of construction or demolition works in relation to the correct CDW management
- Landfill tax, landfill ban for recyclable waste
- Traceability e.g. by using digital waste transfer notes, linked to a monitoring system and database
- ….

Certification/product status, knowledge and innovations

- End-of-waste criteria
- National standards

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Regional instruments and tools in 2 regions - drivers

Key drivers for high recycling rate are the following instruments::

Basque country/Spain:

- Mandatory predemolition audit including estimate of the quantities of waste expected, waste prevention measures, measures for separation at source, the inventory of hazardous waste to be generated, as well as an assessment of the expected cost
- Mandatory selective demolition and compulsory segregation of materials on site
- Environmental Criteria (for Green Public Procurement) for use of secondary materials (both GPP criteria for buildings and infrastructure works and a guide for using recycled materials)

Flanders region/Belgium:

- landfill ban and restrictions on incineration of unsorted mixed CDW
- certification of recycled aggregates based on EoW-criteria
- distinguish between materials debris with the high and low risk environmental profile
- mandatory demolition follow-up plans with follow-up by a demolition management organization
- A case-specific end-of-waste (EoW) declaration for certain application fulfilling a set of requirements (to obtain a "Resource certificate" as materials suitable for recycling).
- Separate collection of C&D-waste on site. Some fractions have to be collected separately on site (debris, asbestos, cellular concrete, gypsum). Mixed C&D waste has to sorted separately from other waste streams

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Interviews with ICEBERG partners

Purpose of the interviews:

- to get information on potential measures and policy recommendations that could support the industrial uptake and scale-up of ICEBERG products developed.
    - conditions enabling and issues preventing success of ICEBERG products
    - identify most effective measures for specific ICEBERG product groups
    - to get information on good practices for replication
- Input for policy recommendations

Process:

- An **online questionnaire** with specific questions for the different actors and ranking of measures
- **In-depth interviews** (1h) with 21 ICEBERG partners
- Also additional meetings and surveys with external stakeholders in Flanders

Interviews

Table. Summary of interviews: product groups and stakeholders

Product group	Demolition contractor	Recycler	Manufacturer	Installer	Building owner	Research institute, other
Concrete (and cement) based products	1	1			1	1
Ceramic			1	1		1
Wood	2	1	1			
Gypsum plasterboard	1	1	1	1		
Insulation foam	1	1	1			
Superinsulating aerogels (intermediate product)		1	2			

Outcome from interviews with ICEBERG stakeholders

Measures and good practices are **product group and region specific**

- generated amounts, collection and transport distances, local practices…
- To some extent, variety in priorities set by different actors in the value chain

Highlighted aspects (examples):

- Importance of education of stakeholders and sharing information in the value chain mentioned by all interviewees
    - E.g. knowledge on recycling possibilities and benefits of higher circularity
    - E.g. knowledge in the value chain regarding environmental performance of construction products
- Demonstrations, pilots to show feasibility in industrial scale

Strong drivers (examples):

- NL: Concrete Alliance for increasing use of recycled aggregates in new concrete (10%) (certification supports)
- BE: EoW strong driver for material acceptance (supported by Tracimat & certification)
- UK (gypsum): landfill tax
- Basque country & Italy: Environmental criteria for GPP

Outcome from interviews with ICEBERG stakeholders

Ranking of most effective measures

Color codes: green: highly important, light green: important. For each product 2-3 most effective measures marked with *** (if possible).

	Cement and concrete based product	Ceramic based product	Wood insulation panels	Circular plasterboard	PU based product	Other product groups
Legislative						
(Requirements for) pre-demolition audit						
EU wide EoW criteria		***				
National/regional EoW criteria	***	***				
Mandatory source separation			***	***	***	
EPR						
Economic						
taxes (virgin materials, carbon tax etc)						
Lower VAT for recycled materials		***	***			
Landfill tax					***	
GPP for public building						
GPP for demolition						
National economic support for development of innovative processes						

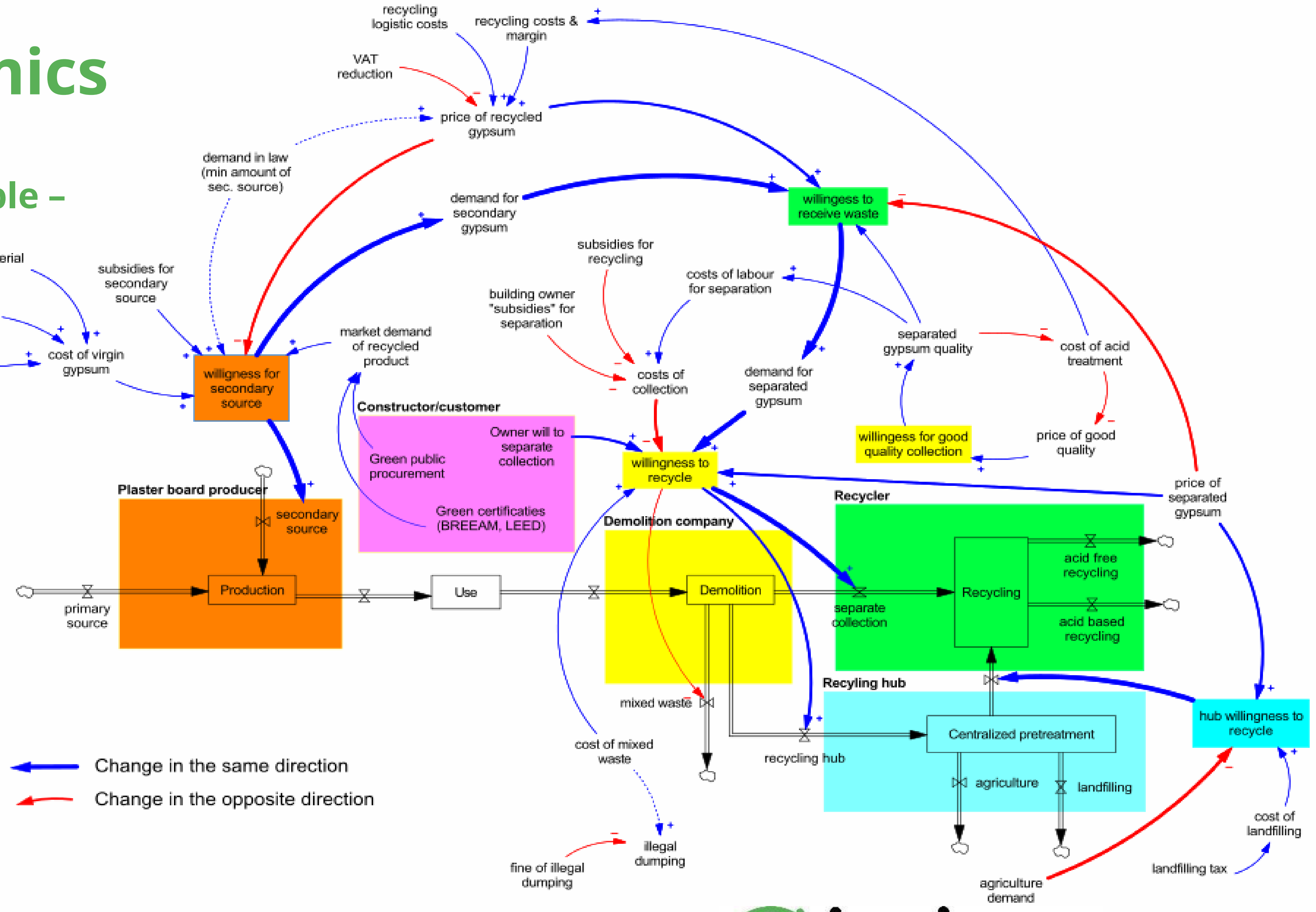
Outcome from interviews with ICEBERG stakeholders

Ranking of most effective measures

	Cement and concrete based product	Ceramic based product	Wood insulation panels	Circular plasterboard	PU based product	Aerogel/ other
Information, knowledge, other						
Regional initiatives for recycling centres/clusters				***		
Use of BIM for information on materials and quality						
Digital product passport including relevant information on recycled material						
Use of sustainable certification schemes (BREEAM, LEED etc) promoting recycling						
Knowledge, skills, education	***		***	***		
Standardisation						
National standards supporting innovation						
National standards supporting						

System dynamics method:

Plasterboard case example – identification of bottlenecks and relations



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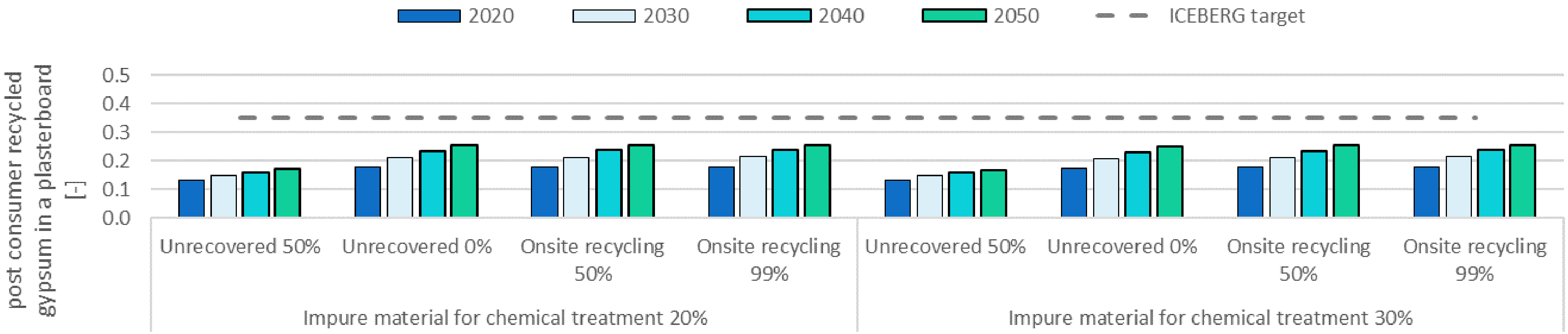
Massflow analysis on recycled content – example for gypsum recycling in plaster board



Calculations made based on assumptions on flows (input data: gypsum waste generated in 2020 and 2050, gypsum material needed for plaster board manufacturing, 6 % to agriculture in all scenarios

Parameters in flow:

- loss in mechanical treatment 1 %,
- loss in chemical treatment 20%,
- unrecovered material in demolition 50 % respective 0 %

-> Conclusion: even in best scenario, the outflow of recycled gypsum significant smaller than amount needed in manufacturing

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Topics for policy recommendations

- The ICEBERG policy recommendations have been elaborated based on the findings from task 6.1.
  - Interviews with ICEBERG stakeholders
  - Additionally, views on the barriers and further information needs presented in two workshops
  - Literature

Recommendations grouped:

- Political & legal
- Economic instruments
- Information instruments
- Technical instruments
- Concrete activities, initiatives, projects

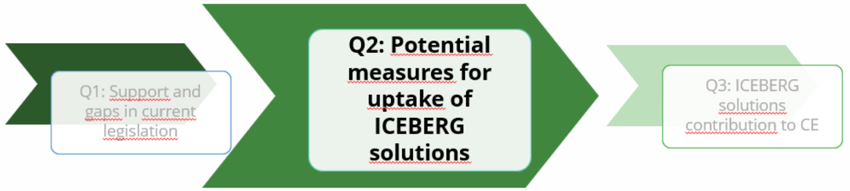
Template:

Challenge	
Description (goal)	
Actions (bullet points) – implementation	
o	
Actor(s)	all actors in value chain
Timeline	short – mid term
References	

Proposed policy recommendations:

Further presented as examples:

1. No 3 Sustainability criteria
2. No 5 GPP
3. No 8 skills
4. No 9 waste sorting



Political & legal instruments (recycling targets, bans, pre-demolition audit, EoW, standards, certifications, extended producer responsibility, permits…)
1. Harmonise End-of waste (EoW) protocols and certification schemes for high grade (closed loop) recycling and preparation for reuse from best technologies
2. Connect waste demolition plan and EU Taxonomy (alternative: Connect the pre-demolition audit and its qualitative follow-up to EU taxonomy)
3. Develop environmental sustainability criteria for comparison on environmental performance of construction products
Economic instruments (green public procurement, taxes, charges for waste management, marketplaces & distribution chains, taxonomy, extended producer responsibility...)
4. Support market demand and supply of waste related materials for closed loop reuse and recycling
5. Use GPP to support reuse and recycling
6. Incorporate in the price of construction products the costs for actions related to potential pollution control
Information instruments (digital product passports, BIM, digital material exchange platforms, skills, education…)
7. Linking DPP, BIM and building logbooks to support circularity of building materials
8. Improve knowledge about construction materials and products, procedures and technologies required for circular construction
9. Develop guidelines for waste sorting
Technical instruments (selective demolition, sorting, technical standards…)
10. Design construction products for reuse and recycling
Concrete activities, initiatives & projects (EU funded projects, financing…)
11. Finance demonstrations of circular design solutions and innovative recycling technologies and tools
12. Reward design strategies and best practices that involve the synergistic use of circular economy indicators both at product's level and at building level

Policy recommendation "Political & legal instruments"

No 3: Develop environmental sustainability criteria for comparison on environmental performance of construction products	
Challenge	• Harmonised indicators and tools for environmental sustainability lacking • Environmental sustainability covers circularity, CO2 savings, non-toxicity, biodiversity
Description (goal)	• development of circularity indicators (one or a few indicators) for assessment of environmental sustainability of products with recyclables • development of simplified sustainability indicator for Digital Product Passport • development of environmental sustainability criteria for comparison on environmental performance of construction products
Implementation	• To present a toolbox of potential methods and indicators suitable for construction products that can be used in the assessment • To highlight challenges in using current toolbox/indicators • To identify knowledge/information needs for development of sustainability criteria • To seek possibilities for combining a few indicators

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Policy recommendation “Economic instruments”

No 5: Use Green Public Procurement (GPP) to support reuse and recycling	
Challenge	• NEW Construction Products Regulation (2024): • to establish mandatory minimum environmental sustainability requirements (circularity goals, CO_2 savings) • Use of Green Public Procurement will drive demand • Lack of knowledge about potential criteria (structures, products, materials that could be recovered and used in new constructions). • Today, tendering documents do not often specifically address waste recycling • Only Italy: mandatory criteria for recycled content
Description (goal)	• Guidelines for including recycling and reuse in public tenders for construction, renovation and demolition
Implementation	• Development of indicators to be used in public tendering • *Revision of standards, legislation preventing use of recycled materials* • *Development of standard documents for tendering* • Development of education materials • Analysis of the role of marketplaces for securing recycling and reuse

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Policy recommendation "Information instruments"

No 8: Improve knowledge about construction materials and products, procedures and technologies required for circular construction	
Challenge	• The apparent lack of knowledge harms collaboration along the value chain for ensuring efficient planning and realization of recycling activities and providing needed information for end-users. • Information not presented in an understandable form
Description (goal)	A systematic overview on information needs by different stakeholders and actions to remove knowledge gaps.
Implementation	Actions to raise awareness and support communication and collaboration among actors in the value chain, e.g. • Development of tailored information packages for different target groups • Guidelines for good practice and standards • Forums for exchange of information • Dissemination of technology developments to reclaim waste streams • Technology platform for innovative solutions for material flow management (BIM, traceability, etc)

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Policy recommendation “Information instruments”

No 9: Develop guidelines for waste sorting	
Challenge	• High ranking in interviews for: “Mandatory source separation for materials for which recycling capacity exists” • Need for knowledge on quality requirements on waste materials suitable for recycling (impurities, hazardous substances, grain size …) • Sorting at demolition site or at sorting plant (methods, quality protocols..)
Description (goal)	• Guidelines and instructions on the sorting on site • Guidelines on the possibilities of joint or separate transportation of waste streams to sorting facilities, treatment or production sites • Guidelines on waste sorting
Implementation	• Mapping of commercial recycling technologies available and creating an overview for requirements for different waste streams for recyclers • Development on standards on key issues in quality protocol

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Q3: How do the ICEBERG solutions contribute to the transition towards CE or Circular Building?

Contribution to CE

Q1: Support and gaps in current legislation → Q2: Potential measures for uptake of ICEBERG solutions → **Q3: ICEBERG solutions contribution to CE**

Product	Current practise (BAU)	Environmental/economic benefits compared to BAU
• Cement- and Concrete-based products (Eco-Hybrid Cement, • Structural concrete elements, • Ultra-lightweight non-structural wall, green wood chip concrete panels and • demountable pre-cast carbonated blocks)	EBMs sent to landfill (Turkey) or downcycled into low-grade application in unbound sub-foundation (Belgium, the Netherlands)	• Reducing landfilling and savings of virgin materials • Costs of the ICEBERG products are often still higher than the benchmarks (the absence of an upscaled technology for the production process means higher associated expenses (e.g. labour, raw materials, energy)) • In case of carbonation, capturing CO2. when assessed on at product level both environmental and economic benefits. However, at building level ICEBERG carbonated blocks incur higher net costs compared to the BAU concrete blocks
• Ceramic based product (circular ceramic-based tiles)	heat treatment at higher temperatures; use of virgin raw materials for ceramic body	• Energy savings (CO2 savings), circularity • 30% lower impact in the Resource use, minerals and metals category, compared to the BAU solution,.
• Wooden product (circular wood fiber insulation panels)	use of virgin wood	• Saving of virgin wood • Minorly improve environmental impacts and marginally improve financial performance
• Gypsum-based product (circular plasterboards)	Typically 10% of recycled gypsum in plasterboard	• 35% recycled gypsum, saving of virgin material • reduced environmental footprint in all LCA impact categories
• PU-based product (PU aerogels and circular PU insulation panels)	Use of virgin polyols	• Reduce the Climate change, fossil impact by 25%. • Favourable in terms of economic impacts

Q1: Support and gaps in current legislation

Q2: Potential measures for uptake of ICEBERG solutions

Q3: ICEBERG solutions contribution to CE

ICEBERG solutions – design tool for illustration of benefits (Deliverable 4.4):

- Decision support tools enable stakeholders to make informed choices that prioritize resource efficiency, waste reduction, and sustainable practices
- A set of 6 indicators tested

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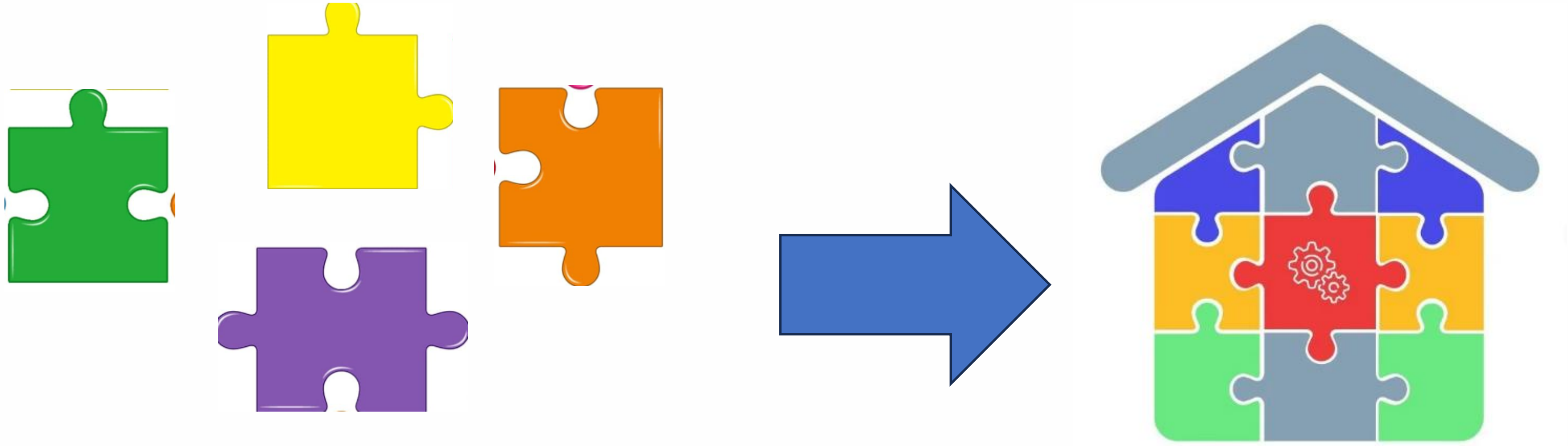
Thank you for your attention!



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Policy recommendation “Political & legal instruments”

No 1: Harmonise End-of waste (EoW) protocols and certification schemes for high grade (closed loop) recycling and preparation for reuse from best technologies	
Challenge	Needs: • EU wide: For waste materials shipped across border for recycling • For national EoW & case specific decision: need for harmonization of elements in EoW • Unclarities for EoW case decision on intermediates, clarifications for REACH To be checked: impact of EoW status in LCA

Description (goal)	• Development of a harmonized procedure for the assessment of EoW status of materials from recycling processes
	    • At EU level (same criteria)
	    • national level (same procedure but national criteria).
	    • case specific EoW decision.
	• Setting a databank with information on case specific EoW decisions in EU

Implementation	• data on characteristics of candidate EoW derived from recycling, sorting and recovery technologies • assessment of links to REACH for intermediates for non-mineral materials • development of new on-line tools for quality monitoring and decision on EoW status of materials

Policy recommendation “Political & legal instruments”

No 2: Connect the pre-demolition audit and its qualitative follow-up to EU taxonomy	
Challenge	• EU guidelines for pre-demolition audit non-binding, different interpretations • Lack on guidance for complying to the EU Taxonomy • The competence of the auditors/demolition experts needs to be ensured • A verification with the management process is needed
Description (goal)	• Linking the pre-demolition audit and the resulting qualitative follow-up of the (selective) demolition works to the EU taxonomy • Acceptance criteria / the requirements for (the quality of) different materials for recycling • Mandatory demolition and waste management plan
Implementation	• Development of an open platform/website with an overview of recycling routes for construction and demolition waste • Awareness, information and in-depth training for experts and contractors • Research on strategies to cover the extra cost of selective demolition.

Policy recommendation “Political & legal instruments”

No 3: Develop environmental sustainability criteria for comparison on environmental performance of construction products	
Challenge	• Harmonised indicators and tools for environmental sustainability lacking • Environmental sustainability covers circularity, CO2 savings, non-toxicity, biodiversity
Description (goal)	• development of circularity indicators (one or a few indicators) for assessment of environmental sustainability of products with recyclables • development of simplified sustainability indicator for Digital Product Passport • development of environmental sustainability criteria for comparison on environmental performance of construction products
Implementation	• To present a toolbox of potential methods and indicators suitable for construction products that can be used in the assessment • To highlight challenges in using current toolbox/indicators • To identify knowledge/information needs for development of sustainability criteria • To seek possibilities for combining a few indicators

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Policy recommendation "Economic instruments"

No 4: Support market demand and supply of waste related materials for closed loop reuse and recycling	
Challenge	• For many materials, high-grade (closed loop) recycling is more costly than the costs related to the use of virgin raw materials • Challenges to match the supply and demand • Information on recycling conditions (e.g. quality, supply) is not easily available
Description (goal)	Actions for supporting uptake of reusable products and products containing recycled materials from CDW • waste material specific measures at the EU and the national level for promoting reuse and high-grade recycling taking into account country conditions.
Implementation	• Analysis of economic barriers for high grade recycling options for specific waste streams (conditions, outlook) • Compilation of reliable data for market decisions (estimations on amounts generated in EU, nationally and regionally, quality) and conditions for reuse and recycling (requirements, standards, capacity, costs) • Develop waste material specific requirements for fostering high grade recycling • Creation of digital marketplaces (especially for reusable products)

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Policy recommendation "Economic instruments"

No 5: Use Green Public Procurement (GPP) to support reuse and recycling	
Challenge	• NEW Construction Products Regulation (2024): • to establish mandatory minimum environmental sustainability requirements (circularity goals, CO_2 savings) • Use of Green Public Procurement will drive demand • Lack of knowledge about potential criteria (structures, products, materials that could be recovered and used in new constructions). • Today, tendering documents do not often specifically address waste recycling • Only Italy: mandatory criteria for recycled content
Description (goal)	• Guidelines for including recycling and reuse in public tenders for construction, renovation and demolition
Implementation	• Development of indicators to be used in public tendering • *Revision of standards, legislation preventing use of recycled materials* • *Development of standard documents for tendering* • Development of education materials • Analysis of the role of marketplaces for securing recycling and reuse

Policy recommendation "Economic instruments"

No 6: Incorporate in the price of construction products the costs for actions related to potential pollution control	
Challenge	• Price difference between recycled materials and primary materials hinders the use of recycled materials • Environmental and economic impacts (impacts of material extraction, landfilling ...) are not incorporated into total price of the products • Challenging to determine and quantify the impact on the environment of the production and use of construction materials
Description (goal)	• Develop a method to determine the cost of the impact of primary and of recycled materials for particular application in construction • Create a basis to compare the cost-determined impact of materials for use in allocating support or dissuasion through taxes for either recycled or virgin materials • Create support for internalising environmental costs in pricing.
Implementation	• Study methodologies to determine the impact based on LCA and calculated on a monetary basis of the application of recycled and virgin materials • Develop a monetary basis for taxation and subsidies for the use of less favorable or support for materials with a lesser impact

Building Materials

Policy recommendation “Information instruments”

No 7: Linking DPP, BIM and building logbooks to support circularity of building materials	
Challenge	• Confidentiality & IPR issues, and interoperability of different systems have been highlighted as practical barriers/concerns about DPPs
Description (goal)	• Consolidation of data formats/standardization for their interoperability • Linking DPP to other data management and exchange protocols (BIM and to DBL) • Interoperability between DPPs in the value chain and specification of the distributed databases and communications channels • Integration of the digital information in the compliance checking and other regulatory processes
Implementation	• Using open standards for data storing and exchange • Development of relevant ontologies and open API specifications • Establishing traceability systems and certification schemes recognized by the relevant building authorities (e.g. to avoid unnecessary testing)

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Policy recommendation "Information instruments"

No 8: Improve knowledge about construction materials and products, procedures and technologies required for circular construction	
Challenge	• The apparent lack of knowledge harms collaboration along the value chain for ensuring efficient planning and realization of recycling activities and providing needed information for end-users. • Information not presented in an understandable form
Description (goal)	A systematic overview on information needs by different stakeholders and actions to remove knowledge gaps.
Implementation	Actions to raise awareness and support communication and collaboration among actors in the value chain, e.g. • Development of tailored information packages for different target groups • Guidelines for good practice and standards • Forums for exchange of information • Dissemination of technology developments to reclaim waste streams • Technology platform for innovative solutions for material flow management (BIM, traceability, etc)

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Policy recommendation "Information instruments"

No 9: Develop guidelines for waste sorting	
Challenge	• High ranking in interviews for: "Mandatory source separation for materials for which recycling capacity exists" • Need for knowledge on quality requirements on waste materials suitable for recycling (impurities, hazardous substances, grain size …) • Sorting at demolition site or at sorting plant (methods, quality protocols..)
Description (goal)	• Guidelines and instructions on the sorting on site • Guidelines on the possibilities of joint or separate transportation of waste streams to sorting facilities, treatment or production sites • Guidelines on waste sorting
Implementation	• Mapping of commercial recycling technologies available • Create overview for requirements for different waste streams for recyclers • Creation of database easily accessible • Development on standards on key issues in quality protocol

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Policy recommendation “Technical instruments”

No 10 Design construction products for reuse and recycling	
Challenge	• Lack of knowledge, design tools (check D3.5)
Description (goal)	• Design construction products for fulfilling circularity goals such as including for disassembly, reuse, recycling and designing long-lasting properties
Implementation	• Development of indicators and tools for ecodesign • Ecodesign criteria/recycled content requirement • Education of designers in business • Evaluate Extended producer responsibility concept for specific product groups • Green public procurement • Remove wastes containing substances of concern

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Policy recommendation “Concrete activities”

No 11 Finance demonstrations of circular design solutions and innovative recycling technologies and tools	

Challenge	• Demonstration projects provides information that are used for investments on important aspects not otherwise available (process changes, rejects, …)
	• especially needed for development of recycling technologies for challenging CDW such as
	    • materials that are difficult to recycle
	    • for waste materials where currently only low recycling processes are available
	• circular design of construction products and management of waste, material streams and products (e.g. tools for material identification and separation, traceability systems and documentations)
	• Public sector to act as a good example for circular solutions!
	• Innovative projects should be allowed to fail!

Description (goal)	• Financial support for demonstration of circular design solutions and innovative high grade recycling processes for CDW
Implementation	• Inventory of waste materials lacking treatement

Policy recommendation "Concrete activities"

No 12 Reward design strategies and best practices that involve the synergistic use of circular economy indicators both at product's level and at building level	
Challenge	Missing standardized, robust and reliable circularity metrics
Description (goal)	To recognize environmental potential of the circular building design

Implementation	• Develop guidance with examples how to apply EN 15804 Annex D in more complex situations e.g. involving more recovery options simultaneously or dealing with open-loop and closed-loop allocation in the same product system.
	• Support the collection of data and development of databases with information about recycling and reuse of different material streams. Such databases may be developed on national or EU level by the relevant authorities or industrial associations.
	• Establish a framework for rewarding design & construction bidding (e.g. as points) and design competitions (as financial support) in:
	    • C&D planning and strategies besides legislation requirements
	    • Demonstration of comparisons of products
	    • Application of circular indicators that are not yet standardized