D6.3

Policy recommendations for ICEBERG solutions

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Executive Summary

The aim of this deliverable, which is part of WP6 (Policies, social attitudes and standards recommendations), was to identify and analyse policy actions and measures supporting industrial uptake of ICEBERG products targeting 35-100 % recycled materials from construction and demolition waste (CDW) and to formulate policy recommendations to relevant authorities and other stakeholders on needed actions.

The document addresses three research questions:

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

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

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

Chapter 2 presents the barriers for industrial uptake of ICEBERG solutions. In the workshop discussions, it became evident that the barriers were material specific and probably also affected by the maturity of the different recycling technologies demonstrated. Examples of key barriers for the uptake of ICEBERG solutions are the quality of waste, economic aspects (low price of virgin raw materials and costs related to additional processing steps), and lack of knowledge/awareness and skills among stakeholders. The barriers are often interlinked.

Chapter 3 reviews relevant EU policies, and the legislative framework relevant for ICEBERG solutions and highlights drivers and gaps in legislation. In the EU policies, especially the European Green Deal (COM/2019/640) and the new Circular Economy Action Plan (COM/2020/98) launched by the European Commission provide the drivers towards environmentally sustainable products with recycled content. The new Construction Products Regulation (adopted revision of EU/305/2011) is responding to these policy ambitions by supporting improved knowledge of environmental characteristic and use of digitalization tools such as digital product passport to deliver all the information on construction products, including safety information, instructions of use and the declaration of performance and conformity. Furthermore, the Waste Framework Directive sets targets for recycling, introduces the end-of-waste concept, and frames the waste hierarchy. The chemical legislations set bans and restrictions for use of materials containing hazardous substances. This means that hazardous materials need to be identified in the pre-demolition audit and removed from the buildings prior to demolition.

Chapter 4 continues by presenting potential measures for removal of the barriers. A long list of measures was created based on a desk study and views of the ICEBERG partners (through workshop discussions and interviews with ICEBERG stakeholders). Some of the measures are discussed in more detail in chapter 4, such as the end-of-waste concept, pre-demolition audit, waste sorting, green public procurement, digital product passports, extended producer responsibility,

and tools for converting environmental footprint into a single score. The chapter also reviews various policy instruments and tools to support recycling already implemented or planned to be implemented in two European regions with high recycling rates (Flanders in Belgium and Basque country in Spain). Measures listed in Chapter 4 also present a policy mix with interlocking elements that are likely to work best in combination to foster recycling.

Chapter 5 reports the outcome from interviews with ICEBERG stakeholders linked to ICEBERG cases. The purpose of the interviews was to learn about conditions enabling and preventing the success of ICEBERG products as well as to identify the most effective enabling measures for market uptake of ICEBERG circular products. Furthermore, information on good practices for replication was collected. Supplementary to the interviews, stakeholders in Flanders (and also in Basque country) replied to a survey on importance and implementation timeline of different measures for increasing CDW recycling (not limited to ICEBERG solutions). The outcome showed that almost all of the measures included in the survey were seen as possible to be implemented by 2030. Three measures stand out in the Flemish and Spanish survey: VAT reduction for construction products with recycled content and virgin material tax, the demolition plan and the mandatory source separation. For both regions, these last two highly ranked measures have already been implemented (or will be in the near future). The first one has an expected implementation date around 2030.

The document also discusses how the ICEBERG solutions in six ICEBERG circular case studies contribute to the transition towards CE. All solutions give savings in the use of virgin materials, but in many cases, the CO_2 and costs are increased by the additional processing needed in the recycling technologies. The document reviews the existing circularity assessment metrics and indicators and the environmental sustainability aspects covered in key EU regulations relevant for construction. The document also identifies the future needs for assessment of the environmental sustainability of ICEBERG circular products, such as the use of life cycle assessment, the development of harmonised methodologies and data, and the integration of social and economic aspects.

Based on collected information, 12 policy recommendations were formulated to support the industrial uptake of ICEBERG solutions and validated in a workshop with ICEBERG stakeholders. The policy recommendations were grouped in five topics as follows:

Topic 1: 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-quality (closed loop) recycling and preparation for reuse from best technologies
2. Connect qualitative pre-demolition audit, demolition plan and follow-up to EU Taxonomy
3. Develop environmental sustainability criteria for comparison on environmental performance of construction products

Topic 2: Economic instruments (green public procurement, taxes, charges for waste management, marketplaces & distribution chains, EU 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

Topic 3: 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

Topic 4: Technical instruments (selective demolition, sorting, technical standards…)

10. Design construction products for reuse and recycling

Topic 5: 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

Acronyms

ADR	Advanced dry Recovery
BAU	Business as usual
BIM	Building information modelling
BREEAM	Building Research Establishment Environmental Assessment Method
bSDD	buildingSMART Data Dictionary
BWR	Basic work requirement
CCS	Circular Case Studies
CDW	Construction and demolition waste
CE	Circular economy OR CE marking for products sold in the EEA
CEAP	Circular Economy Action Plan
CFC	Chlorofluorocarbon
CPI	Circular economy performance indicator
CPR	Construction product regulation
CSS	Chemicals Strategy for Sustainability
D&B	Design and Building
DBL	Digital Building Logbook
DPP	Digital product passport
EBM	End-of-life Building Materials
ECHA	European Chemicals Agency
EGD	European Green Deal
EoL	End-of-life
EoW	End-of-waste
EPD	Environmental product declaration
EPR	Extended producer responsibility
EPS	Expanded Polystyrene
GA	General assembly
GDP	Gross domestic product
GHG	Greenhouse gas
GPP	Green public procurement
GWP	Global warming potential
HBCDD	Hexabromocyclododecane
HCFC	Hydrochlorofluorocarbon

HFC	Hydrofluorocarbon
IFC	Industry Foundation Classes
JRC	Joint research centre
L/S	Liquid to solid ratio (in leaching test)
LCA	Life cycle assessment
LCC	Lifecycle costing
LERM	Low environmental risk material
LoW	List of Waste
MCI	Material Circularity Indicator
MFA	Material/mass flow analysis
MS	Member state
ODS	Ozone depleting substance
OECD	Organisation for Economic Co-operation and Development
PAH	Polycyclic aromatic hydrocarbons
PCB	Polychlorinated biphenyls
PDA	Pre-demolition audit
PEF	Product Environmental Footprint
PFAS	Per- and polyfluoroalkyl substances
PFOA	Perfluorooctanoic acid
PFOS	Perfluorooctanesulfonic acid
POP	Persistent organic pollutants
PRO	Producer responsibility organization
PU	Polyurethane
PVC	Polyvinyl chloride
QR code	Quick response code
REACH	Registration, Evaluation, Authorisation and Restriction of Chemicals
RED	Renewable Energy Directive
RFID	Radio-frequency identification
SCIP	Substances of Concern In articles as such or in complex objects (Products)
SDG	Sustainable development goals
SDS	Safety data sheet
SPI	Sustainable Products Initiative
SRF	Solid recovered fuel

SVHC	Substances of very high concern
TOTEM	Tool to Optimise the Total Environmental impact of Materials
UNDP	The United Nations Development Programme
VAT	Value added tax
WFD	Waste Framework Directive
WP	Work package
WSR	Waste shipment regulation
XPS	Expanded polystyrene

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1 Introduction, aim and methodology

1.1 Background

Construction and demolition waste (CDW) comprises the largest waste stream in the EU[1]. Although the recovery rate of mineral CDW is rather high in Europe, the recovery is largely based on backfilling operations and low-quality recovery. There are also huge variations in the recovery of CDW in the EU.

According to Eurostat data for 2020[2], about 330 million tonnes of hazardous and non-hazardous construction and demolition waste (including infrastructure, but excluding soils, track ballast, dredging spoils and asphalt) were generated in EU27. This number includes all the waste produced by the construction and demolition of buildings and infrastructure, as well as road planning and maintenance. The Eurostat waste statistics are available for certain waste categories (e.g. mineral waste, metal waste, wooden waste, and plastics waste). The amount of stony mineral waste was in 2020 around 305 Mt, followed by metal waste (18 Mt) and waste wood from construction (approximately 8.6 Mt) (Eurostat 2023).

Based on mass flow analysis (MFA) modelling[3], the amount of waste arising from demolition of buildings in 2020 has been estimated to 132 Mt (Damgaard et al. 2022[4], Caro et al 2024[5]). The composition of CDW varies between member states in EU27 largely depending on construction materials and products used. In all member states, concrete was the largest material fraction, ranging between about 38 % in Northern Europe to about 61 % in Western Europe. (see Figure 1)

[1] EEA, 2020. Construction and demolition waste: challenges and opportunities in a circular economy. Briefing. https://www.eea.europa.eu/publications/construction-and-demolition-waste-challenges

[2] Eurostat data retrieved September 5, 2023

[3] Estimates calculated based on data for building stock composition in different building types, ages in representative member states

[4] Damgaard, A., Lodato, C., Butera, S., Fruergaard, A. T., Kamps, M., Corbin, L., Tonini, D., & Astrup, T. F. (2022). Background data collection and life cycle assessment for construction and demolition waste (CDW) management. https://doi.org/10.2760/772724

[5] Caro, D., Lodato, C., Damgaard, A., Cristóbal, C., Foster, G., Flachenecker, F., Toninim, D. 2024. Environmental and socio-economic effects of construction and demolition waste recycling in the European Union, Science of the Total Environment 908 (2024) 168295 https://doi.org/10.1016/j.scitotenv.2023.168295

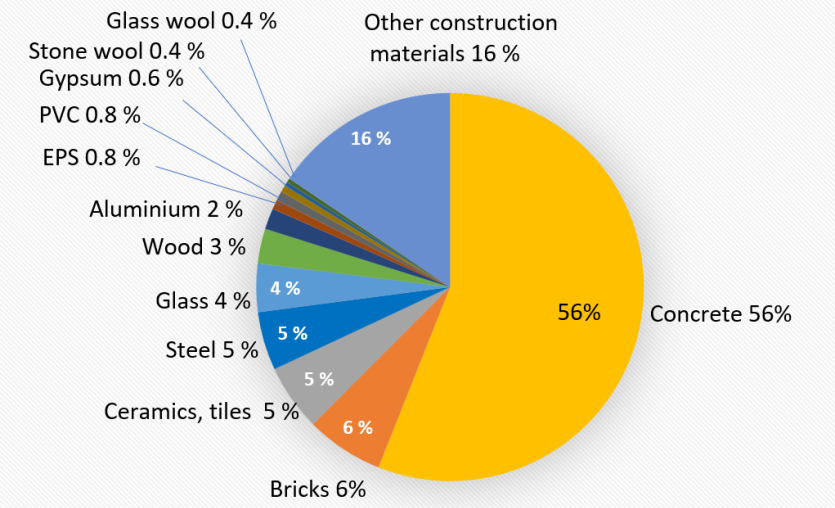


Figure 1 Estimated average contribution of relevant material fraction to the CDW composition in EU 27 expressed as % of the total CDW generation in 2020 for buildings.

Examples of other construction materials are other construction minerals, cardboard, paper, copper, electronics, sand, paint and glue, (Damgaard, 2022, Caro 2024)

In ICEBERG, high-quality recovery solutions are developed for the recovery of high purity secondary raw materials which are further utilized in the production of new construction products containing 30wt% to 100wt% recycled content. Demonstrations are carried out through 6 pilot circular case studies (CCS), covering various building materials: concrete, mixed aggregate, plasterboard, wood, glass, polymeric insulating foams and inorganic superinsulation materials. Furthermore, cross-cutting solutions are developed for quantification and traceability of CDW from end-of-life (EoL) buildings including BIM-aided-Smart Pre-Demolition (BIM4DW) tool linked to a Traceability platform via RFID and QR based identification systems.

The ICEBERG solutions contribute to the following ambitions:

- Improved, accurate and cost-efficient pre-demolition and renovation audits and planning.
- Improved traceability and quality of end-of-life building materials.
- Advanced sorting and classification technologies for purer building materials recovered from CDW fractions.
- Development and optimisation of building products containing high amounts (between 30% and 100wt%) of high-purity materials recycled from CDW.

Table 1 includes a list of waste materials studied in ICEBERG circular case studies. An important step is to also demonstrate the use of the products developed from waste materials in new constructions. Examples of applications are collated in Table 2 also with information on change to current situation. Table 2 only covers part of applications studied in ICEBERG project.

Table 1 Waste & input materials included in ICEBERG solutions

Product	Waste streams	End-application	Remark
1. Cement/concrete-based products			
• Eco-Hybrid Cement	Waste brick, concrete, and gypsum in CDW	to be part of concrete elements, see below	
• Concrete with eco-hybrid cement and recycled concrete aggregates	Inert CDW	Large structural elements such as beam, column, wall and slab	Ecohybrid cement + 100% coarse recycled aggregate
• Ultra-lightweight non-structural wall elements	Inert CDW	Thermal insulation element	Eco-hybrid cement, fine recycled concrete aggregates, silica aerogel
• green wood chip concrete panels	Waste wood in CDW	Thermal insulation panel	Recycled wood chips
• Demountable precast hollow-core blocks produced by accelerated carbonation	Waste concrete in CDW	Concrete block for walls	75% fine recycled concrete fraction, concrete fines (0-4 mm)
• intermediate aerogel product	High silica containing CDW, e.g. glass waste, siliceous concrete		Used for thermal insulation
2. Circular ceramic tiles	waste ceramic in CDWs	Circular ceramic floor tile	Up to 55% wt secondary raw materials
3. Wooden insulation panels	Waste wood in CDW	Wall, ceiling	(Indoor application requires fulfilling product legislation) Wood waste chips and bioresin from pyrolysis of wood waste
4. Circular plasterboards	Waste gypsum in CDW	Gypsum plasterboard, use in building	35 wt% recycled gypsum
5. Circular PU insulation panels	Waste PUR and PIR from the deconstruction	Floor	Recycled polyols from the deconstruction

Table 2 Iceberg demonstration cases

Circular Case Study (CCS)	Product	Current practise	Environmental benefits
CCS1 – Circular concrete, CCS2 – Circular cement-based products CCS3 – Circular carbonated blocks CCS6 - Circular ceramic, silica aerogel and PU based products	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)	CDW sent to landfill (Turkey) or downcycled into low-quality application in unbound sub-foundation (Belgium, the Netherlands)	Reducing the amount of materials sent to landfill; reducing the necessity to extract virgin raw materials. In case of carbonation, capturing CO_2.
CCS6 – Circular ceramic, silica aerogel and PU based products	Ceramic based product (circular ceramic-based tiles)	Heat treatment at higher temperatures; use of virgin raw materials for ceramic body	Energy savings, reducing CO_2 emission, saving virgin raw materials
CCS4 – Circular wood-based products	Wooden product (circular wood fiber insulation panels)	Use of virgin wood	Saving of virgin wood

Circular Case Study (CCS)	Product	Current practise	Environmental benefits
CCS5 – Circular plasterboards	Gypsum-based product (circular plasterboards)	10% recycled gypsum sourced from plasterboard construction offcuts	35% recycled gypsum (incl. 25% purified gypsum from EoL plasterboards: less virgin resources needed
CCS6 – Circular ceramic, silica aerogel and PU based products	PU-based product (PU aerogels and circular PU insulation panels)	Use of virgin polyols	Reducing the use of fossil resources

1.2 Links to other EU projects

Ongoing or recently completed EU projects were mapped in order to recognize potential overlaps and collaboration possibilities and to look through public deliverables for information. Table 3 presents a selection of projects which have joint interests with ICEBERG.

Table 3 Recently completed and ongoing (EU) projects with links to ICEBERG

Short name (years)	Full name	Call	Focus	Topics with links to ICEBERG
CITYLOOPS https://cityloops.eu/ (2019-2023)	Closing the loop for urban material flows	H2020-EU.3.5.4	Biowaste and CDW	CE, pre-demolition audit, procurement, tools
CIRCuIT https://www.circuit-project.eu/ (2019-2023)	Circular Construction In Regenerative Cities (CIRCuIT)	H2020-EU.3.5.4	Lifetime extension of building, reusable products, recycling	Green Public Procurement, tools
CISUFLO https://www.cisuflo.eu/ (2021-2025)	CIrcular SUstainable FLOor coverings	H2020-EU.3.5.4	Closed loop recycling for different floorings (laminate, vinyl, textile).	Digital product passports
COLLECTORS https://www.collectors2020.eu/ (2017-2020)	waste COLLECTiOn systems assessed and good pRacticeS identified	H2020-EU.3.5.3	Paper, WEEE and CDW collection.	Policy recommendations to improve collection.
DDC https://www.gtb-lab.com/digital-deconstruction (2019-2023)	Digital deconstruction	Interreg	Digitalisation tools	Innovative digital decision support system, integrating various digital tools (3D scanning, Building Information Modelling, a digital materials & buildings database, blockchain technology)
BAMB, https://www.bamb2020.eu/ (2015-2019)	Buildings as Material Banks: Integrating Materials Passports with Reversible Building Design to Optimise Circular Industrial Value Chains	H2020-EU.3.5.4	Indicators for assessment of circularity of buildings	Electronic material Passports

1.3 Goal and methodology

The key questions to be answered in this deliverable were as follows:

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

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

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

To describe the operational environment affecting the ICEBERG solutions, with special focus on circular economy solutions in the value chain, a methodology was developed with the aim of identifying regulations, instruments, measures and factors that can contribute to the fulfilment of upcoming policy objectives related to circularity/environmental sustainability. A stepwise approach was followed:

1. Analysis of barriers for the uptake of the circular economy solutions in the value chain (Literature review and workshop with ICEBERG partners: Chapter 2.1)
2. ICEBERG stakeholder contacts on information needs (survey and workshops with ICEBERG partners: Chapter 2.2)
3. Mapping of key policies and regulations of relevance for the circularity/sustainability in construction sector (linked to construction products, only to limit extent buildings) in the EU (Chapter 3)
4. Identification and analysis of potential solutions/measures (regulatory and non-regulatory) for removal of the identified barriers (in cooperation with ICEBERG stakeholders). Report on good practice in the Basque country of Spain and Flanders/Belgium. (Chapter 4)
5. Interviews with ICEBERG stakeholder for identifying measures with high effects or contribution for uptake of ICEBERG solutions (Chapter 5)
6. Review on important indicators/tools in assessment of environmental sustainability of ICEBERG circular products (Chapter 6)
7. Validation of findings in a workshop and formulation of policy recommendations (Chapter 7)

The focus on this report was on uptake of ICEBERG solutions at EU level and primarily at construction product level (not building level). Measures that will support uptake of ICEBERG circular products were highlighted. If information available, experience from implementation specific measures for removal of barriers was analysed.

The information on the European Commission´s webpage on policies and strategies related to European Green Deal, particularly the circular economy objectives and targets, and especially actions relevant to construction sector, provided the background for this report. Potential actions for improving the recyclability and circular economy ambitions at different lifecycle stages in the construction value chain relevant for ICEBERG solutions were reviewed from literature.

Figure 2 illustrates the approach of the task. The ICEBERG partners´ perspectives (views) were collected through surveys, workshops and interviews with stakeholders linked to certain ICEBERG product groups. The realization of the surveys and interviews is further described together with the results/outcome from the activity.

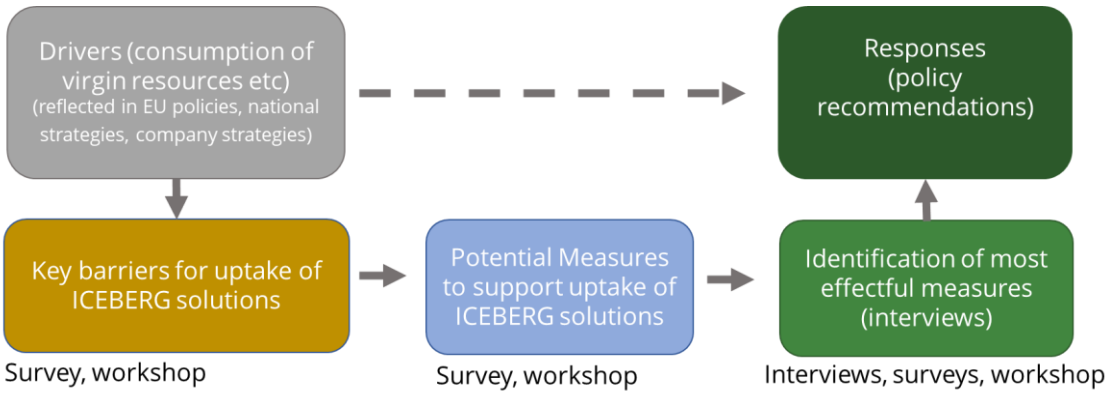


Figure 2 Methodology used for development of policy recommendations.

The work was led by the task leader VTT (FIN). At the start of the work, a reference group of ICEBERG partners (Tracimat (BE), VITO (BE), OVAM (BE), Loughborough university (UK), Tecnalia (ES), GBN (NL), IHOBE (ES)) was established to follow up the work progress and to support with advice and feedback. During the work, following four subtask groups were established to discuss specific challenges and solutions related to the uptake of ICEBERG solutions:

- Subtask on end-of-waste: VTT (FIN), OVAM (BE), VITO (BE)
- Subtask on barriers: Tracimat (BE), VTT
- Subtask on pre-demolition audit: Tracimat, VITO, VTT, Tecnalia (ES)
- Subtask on environmental sustainability criteria: Leiden University (NL), VITO, RINA (I), VTT
- Subtask on regional practice in the Basque country and Flanders: IHOBE (ES) and OVAM (BE)

2 Iceberg partners' perspectives on current barriers and information needs for potential measures

Key messages:

ICEBERG general barriers:

- Barriers (regulatory, technical, economical, societal) occur in all lifecycle stages.
- Barriers are product and application specific and partly interlinked.
- Historical construction materials containing legacy substances are challenging due to restrictions for recycling.

ICEBERG specific:

Examples of key barriers for uptake in new ICEBERG products include

- quality of waste containing impurities and potentially hazardous substances,
- complex processing,
- uncertainty related to stable supply,
- cheap virgin materials,
- and lack of knowledge among stakeholders.

2.1 Barriers identified (literature, survey)

2.1.1 Literature overview

The successful implementation of a circular economy is hampered by many bottlenecks – barriers related to the reuse and recycling of waste materials in construction as well as barriers related to the production, design, and construction of buildings.

Numerous studies on barriers for the industrial uptake of CDW have been carried out in the recent years. As an example, the EEA report[6] on industrial uptake of secondary raw materials lists examples for barriers along the value chain and also analyse the characteristics for market functionality. The reuse and recycling potential of these depend on the material (some materials have already well-functioning market, e.g. steel), supply and demand (e.g. reusable components), environmental quality (potential content of hazardous materials or substances, separation process in demolition, recycling processes), technical quality, price (also abundance of virgin materials like wood and aggregate).

The EEA report included an analysis of the industrial uptake of aggregates from construction and demolition waste. The maturity of the aggregate market was seen as not well-functioning due small size, weak demand — even with increasing supply — and inadequate technical specifications. Despite a strong policy push to increase recycling and the resulting steady supply of recyclates, the supply side of recycled aggregate markets remain challenged due to

[6] zu Castell-Rudenhausen, M. et al 2022. Investigating Europe′s secondary raw material markets. EEA report 22/2022. https://www.eea.europa.eu/publications/investigating-europes-secondary-raw-material

problems including insufficient specifications and lack of end-of-waste criteria. The demand side, on the other hand, was found to be hampered by a lack of trust in the quality and the traceability of recycled aggregate.

Economic barriers such as the low market price for natural resources and virgin raw materials are presented in a study by Williams et al. (2020)[7] to highly prevent the widespread uptake of recovered materials from CDW. Additionally, in many countries the generally low landfill taxes and typically high costs of treatment result lower the competitiveness of recovered materials compared with virgin alternatives (with respect to both cost, quantity and quality).

Furthermore, a Nordic study (2023)[8] on barriers and opportunities for circular construction highlights various barriers that relate to awareness, knowledge, cultural behaviour. A main takeaway from the analysis of these barriers on knowledge is that they are interlinked. For example, lack of experience and knowledge results from a lack of opportunity to gain that expertise. At the same time, this lack of expertise means that it is difficult to commission circular-focused projects. Additionally, it also leads to longer project durations and higher costs.

The following list includes aspects that have been analysed in recent literature from different perspectives:

- EU, national and local policies as well as targets setting the frames for the operational environment: recycling targets in regulations, financial instruments.
- Characteristics of different types of products and materials used in the construction sector.
- Market for recovered materials (established market for some materials like metals, material availability, systems/technologies in place, technical requirement on construction products)
- Actors (who pays what, role of legislator in pull of market through financial support for reuse/recycling or bans): how are costs covered by actors (e.g. building owners, demolition company, recyclers, constructors, governmental supports)?

A summary of major barriers for industrial uptake of CDW based on literature is presented in Table 4.

[7] Rob Williams, Artola, I., Beznea, A., Nicholls, G., 2020. Emerging Challenges of Waste Management in Europe: Limits of Recycling.. Trinomics, The Netherlands.

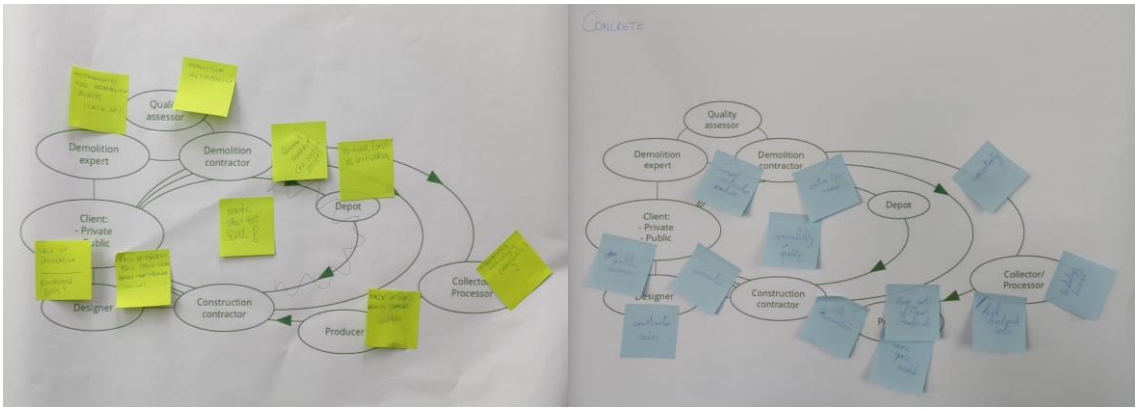
[8] Watson, D. et al. 2023. https://pub.norden.org/nord2023-031/nord2023-031.pdf

Table 4 Major emerging barriers for industrial uptake of CDW by phase of the value chain (sources: EEA report, Watson et al 2023, William et al 2020)

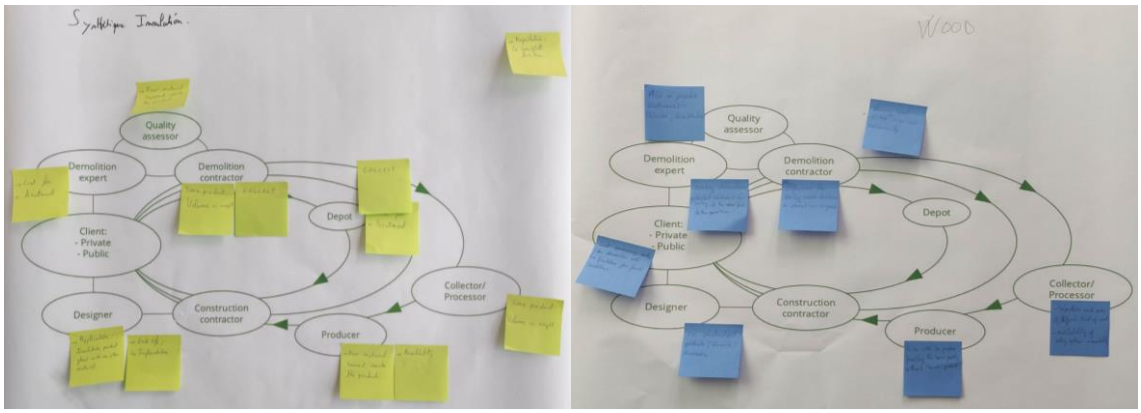
Phase of the value chain	Product design and manufacture	Supply of CDW			Demand of CDW (substitution of primary material, new uses)
Type of barrier		Input availability/quality	Collection/sorting/ dismantling	In waste recycling (manufacturing)	
From regulation and legislation	- No regulation (targets) on recyclable content - No established EPR schemes	- Strict rules for waste shipment - Lack of national instructions/ standards for use of recyclables (CE-marking)	- No requirements for selective demolition or sorting of CDW - No incentive for separate extraction of valuable materials	- Lack of EoW criteria for most materials at EU level, different national classifications - Recycling targets by weight promotes the recycling of heavy materials - Unclear, complex or incomplete legislative frameworks hindering recycling activities, investments - Lack of landfill bans on recyclable waste	- Weakness of obligations to use CDW - Weakness of GPP criteria and enforcement in many countries - Conflicts with other legislation (energy efficiency?, toxic free environment?)
From technology and quality	- Risks of presence of legacy substances in historical products - Lack of traceability - Buildings not designed for deconstruction	- Instability of waste input supply and its quality	-	- Complexity of products (many layers, products glued) - Insufficiency of technical specifications and standard for many SRM	- Technical difficulties in introducing recycled materials - Distrust in recycled materials by consumers
From industrial capacity / investments	- Benefits of investment not clear		-	- Lack of capacity in non-mature CDW markets - Risk and uncertainty of investing in new processes/ technologies	- Uncertainty/ instability of demand
From economic factors (prices, costs, information etc)	- Lack of incentives to introduce recyclability in product due to low price of virgin material		- High costs linked to selective demolition - High costs of sorting for high-quality recycling - High up-front investment costs	- High up-front investment costs - Instability of prices for CDW and subordination to the primary market (prices) - Limited market power of small CDW producers (if no obligations on use of CDWs)	- High overall costs of CDW compared to virgin materials (not perfect substitutes) - Construction products from virgin materials cheaper as not all environmental costs included in price
Others	- Preferences of architects for traditional solutions - Lack of knowledge on product performance				- Lack of knowledge, collaboration between actors in value chain - Sceptical attitudes of end-users (“everything should be new”)

2.1.2 Outcome from GA survey and workshop

To identify more specifically the barriers for the different ICEBERG solutions, a survey and workshop (Figure 3) was carried out in the ICEBERG GA in October 2022, in Bilbao, Spain.



Barriers - Ceramics | Barriers – Concrete



Barriers - Synthetic insulation | Barriers – Wood

Figure 3 Workshop on barriers for the uptake of ICEBERG-solutions[9]

The outcome of the survey and the workshop highlight several general barriers, as well as material specific barriers for increasing circularity.

At the stage of design, manufacturing and recycling, barriers related to technology (e.g. lack of recycling process, complex recycling process, lack of qualitative secondary (raw) materials, lack of quality guarantee for CDW, variability of waste input, ...) were indicated for aerated concrete (lack of technology for separation of mixed CDW and lack of recycling technology), ceramics, concrete, synthetic insulation and wood (complex waste separation of different wood types). The lack of a recycling technology is especially pressing for synthetic insulation due to an upcoming ban for landfill (in France). Also financial barriers (e.g. high investment costs, high processing costs, market volatility for secondary materials, ...) and barriers related to taxation (e.g. lack of

[9] The workshop was organized in which the ICEBERG-partners were asked to map barriers along the value chain of an ICEBERG-material of their expertise. This was done by applying sticky notes on a physical sheet containing a diagram of a value chain for four ICEBERG-materials: ceramics, concrete, synthetic insulation and wood. Afterwards, one of the group members was asked to present the results of the exercise to the entire consortium. The presentations were recorded.

taxation on primary materials, incineration and landfill) are recurring for ceramics (environmental impact not being taken into account), concrete (virgin materials being very cheap, high investment costs), gypsum and synthetic insulation (imbalance between costs of waste treatment and performance for some products). A specific barrier for the uptake of circular wood solutions at the stage of design, manufacturing and recycling is competition with energy recovery. For ceramics and concrete the need for quality control (of secondary resources) was highlighted. Specifically for concrete, barriers related to End-of-waste criteria (e.g. lack of (harmonized) EoW-criteria, need for permits, ...) were indicated.

When it comes to **the use stage**, barriers related to knowledge and awareness (e.g. lack of common circularity indicators, lack of best practice exemplary cases, lack of experts in circular (de)construction, lack of public awareness, ...) were indicated for almost all ICEBERG-materials.

At the stage of construction, deconstruction and waste collection, financial barriers (e.g. supplementary cost for selective demolition, ...) were identified for almost all ICEBERG-materials. Specifically for synthetic insulation, high transport costs were highlighted as a barrier. Also, contamination with other materials is mentioned as a barrier for several materials. The type of contamination considered differs for the different materials: where circular concrete solutions are hampered by the presence of spray products, EPS beads, etc., circular synthetic insulation products are hampered by the presence of banned raw materials in older products and the use of glue, and wooden circular solutions by a high risk for primary contamination with additives. These barriers, mostly encountered during deconstruction, may give rise to (policy) recommendations for the design, manufacturing, construction and use: where not already in place, bans might have to be considered for certain components and fixing methods. For ceramics, concrete and wood, lack of a demolition methodology to obtain pure fractions, lack of knowledge to differentiate high-value from low-value concrete and lack of expertise for sorting were respectively highlighted as barriers. Specifically for concrete and wood, barriers related to standards and certification (e.g. unsatisfactory standards for CE-marking, lack of warranties and insurance schemes, ...) were highlighted throughout the entire value chain.

Summary of barriers identifies in the GA workshop, and categorized according to the Iceberg product types and value chain actors is presented in Table 5. The general and material specific barriers were taken into account when analysing measures and formulating policy recommendations.

Table 5 Summary of barriers identified in GA workshop discussion

	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 beads, 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
Waste 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 older 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	

A few lessons can also be learned from the way the survey was designed and conducted. Conducting a survey during the general assembly facilitated a high (and representative for the consortium) response rate. The survey took place at the end of the general assembly, if it had taken place halfway, the response rate would likely have been even better. On the other hand, the way of answering the ranking questions was unclear to many of the respondents. The formulation of the questions appeared too long, wherefore respondents didn't read the bottom part which contained instructions for answering.

2.2 Information needs on potential measures recognized by ICEBERG partners

2.2.1 Selection of potential measures for further analysis

Following identification of barriers, an analysis of the most potential measures for overcoming the barriers was carried out. The identification of measures was divided into two steps. Already at the start of the task, some measures were recognized and partly mentioned in the project proposal. A list of measures identified at the start of the task is presented in Table 6.

Table 6 Measures identified at start of the task.

Measure	Focus
End-of-waste concept	Relevance for Iceberg solutions discussed
Pre-demolition audit (PDA) / traceability	Role, good practice, development needs
Digitalization and product/material passports	Benefits of digital product passports
EU taxonomy – part of PDA?	Links to PDA and CE criteria
Extended producer responsibilities	Approach in the French EPR for construction products – potential experiences?
Regional policies and instruments in Flanders and Basque country	Policy instruments and tools supporting recycling

In the second step, the focus was to find solutions that might remove barriers identified in the survey (Chapter 2.1). A long list of potential measures was collated based on findings in a literature study and barriers and solutions presented in other projects focussing on recycling and reuse of construction and demolition waste.

Then an online survey among ICEBERG partners was conducted in order to rate issues for which further information is needed (Chapter 2.2.2). The outcome of the survey was discussed in a workshop arranged in the GA meeting in April 2023 for further comments (Chapter 2.2.3).

The impact/effectiveness of each potential measure on ICEBERG solutions was further investigated in different subtasks (Chapter 4) and by carrying out

interviews (Chapter 5). The input from the subtask analysis and the interviews were basis for formulation of policy recommendations.

2.2.2 Online survey on potential measures – information needs

A long list of potential measures (31 in total) was created. An online survey was designed to gather input from ICEBERG partners. The measures were grouped as actions influencing the product design or manufacturing stage and actions influencing the construction, deconstruction, waste collection and recycling stages. The list of potential measures also included topics identified at start as important. The survey was sent to all ICEBERG partners. In total 23 replies were received.

The measures were rated based on where more information is needed (e.g. impacts, effectiveness, lessons learned) by using a rating: 1 not important, 2 slightly important, 3 neutral, 4 important, 5 very important for further checks.

The box below presents the measures which received the highest scores (average > 4.0) in the questionnaire, i.e. measures that were considered most interesting for further analysis. (Highest scores, ≥4.1, are marked as bold)

Full list of measures rated in the survey is available in Appendix 1.

Box 1. Potential measures for further analysis

A: measures related to product design and manufacturing

- **4. Further development of sustainability criteria for use of recyclables in products (extending scope, harmonization (technical, environment, circularity))**
- **9. Digital tools for traceability (e.g. product passports; avoidance of green washing; mandatory product information on recyclable composition, indicators)**

B: measures related to construction, deconstruction, waste collection and recycling

- 13. Financial support for sustainable recycling processes
- **14. Incorporation of environmental impact into total price (impact of landfill, downcycling, …). (e.g. taxes of virgin materials, VAT reduction, national support for local markets..)**
- 16. Toolbox, methods for assessment of performance, requirements for key CDW streams (e.g. acceptance criteria for secondary raw materials)
- 17. Harmonisation of building and waste regulation to better accommodate waste hierarchy and circularity goals
- 21. Guidance on requirements for demolition waste recycling (for demolition companies, authorities, recycling companies)
- **24. Development of common sorting criteria and standards**
- 26. Guidance on requirements to which materials should apply in order to be recycled
- **28. Financial support for demolition/collection/sorting (EU taxonomy related to CE requirements)**
- **31. Financial support for demonstration projects (especially development of recycling technologies for challenging CDW)**

2.2.3 Workshop discussions on potential measures

As complementary input to the results from the survey, results from a Belgian study on barriers were presented for initiating discussion on measures for uptake of ICEBERG solutions (see Box 2).

Box 2 Systemic bottlenecks for CE in constructions – Belgian study

De Proeftuin Circulair Bouwen, a scientific consortium that formulates policy and practice recommendations based on research and practical experience, commissioned by the Flemish waste management organization OVAM, speaks of "systemic bottlenecks" for Urban Mining and has identified five such bottlenecks:

1) A dominant focus on the lowest price in procurements,
2) Uncertainties about the quality of recycled materials for companies later in the value chain,
3) A lack of knowledge and data about Urban Mining,
4) The demolition process does not get a strong focus from building owners, architects and main contractors in construction projects.
5) A fragmented sector with project-specific solutions causes relative low innovation.

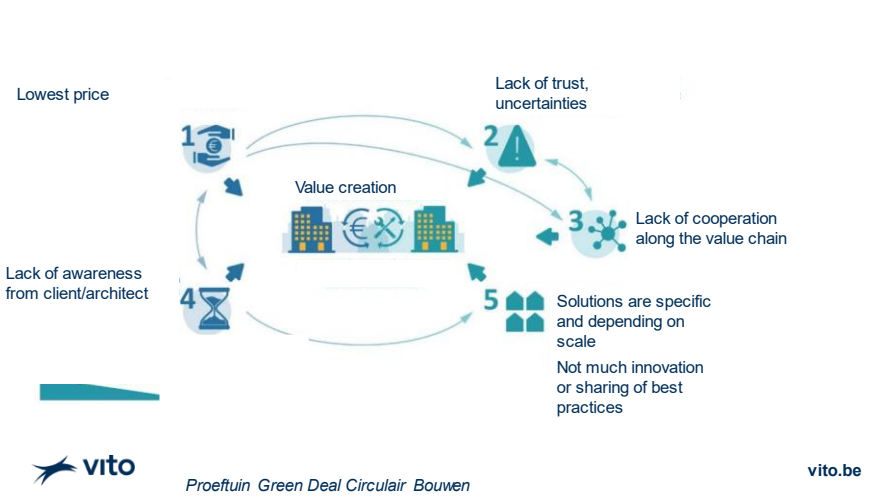


Figure 4 Systemic barriers for CE in construction

Source: Debacker W., Vrijders J., Voorter J., Vergauwen A., Bergmans J., Stouthuysen P. (2021). Urban Mining van gebouwen. Proeftuin Circulair Bouwen, commissioned by OVAM.

In the discussions, the following issues were brought up:

Barriers/challenge	Response:
Acceptance criteria	- EoW criteria create confidence and stakeholders willing to pay the costs in proving the low risk - Fast track for acceptance: NL CROW provides a quick way to validate innovative concrete and concrete products, to bring them to the market. As such, the way from technology to innovation could be reduced from six years to six to ten weeks. (ref. https://www.crow.nl/thema-s/infratechniek/betoninnovatieloket/betoninnovatieloket)

Barriers/challenge	Response:
	- a lot of different technologies has been developed. The acceptation criteria for use of waste should take all operational technologies into account
Demolition	- Criteria are now mostly based on construction, not so much on deconstruction. It could be extended to deconstruction, but developing criteria for demolition is even more difficult than for construction, because no one wants to spend more money on demolition (no promotion material). Unless you impose it/give the good example.
Quality	- Important to separate high-quality from low-value concrete based on some characteristics (concerns both recycler and demolition contractors). The problem is rather a lack of technology than lack of knowledge. Also crucial in demolition to separate high and low-quality concrete - In pre-demolition audit: the quality of the materials not really examined.
Role of architects	- Gap between client, architect and product. Not sure that we can expect clients to know this, but yes we can expect it from architects. Government should appeal to a local, professional party. Important educating professionals about recyclable materials - UK: Material inventory for BREEAM: every material supplier that wants to be considered sustainable has to be registered at BREEAM (expensive). This makes the job of the architect relatively easy. Started in 2019. Since then, nice development. Architects have continuous professional development. - Lack of collaboration with architects on Design: in the case of Design and Building (D&B) projects, clients have no influence on the choice of materials. If a contractor is obliged to use certain materials, the price will go up. As such, D&B practice plays a great role in the choice of materials. It's important to identify these 'problems'. What kind of contractual relations can be used? - Drawbacks of building solutions should be discussed. Designers do not think that's their responsibility. the results will only be visible in 20+ years, when the buildings are demolished. Results of currently designed circular building solutions are yet to be seen.
Future trends	- Creation of databases including information on new products with recyclables. - Observation from cement production: stakeholders start to request certain CO_2-reduction + recyclable materials. No common situation in today's market, but certain companies with impact are starting with it. - Use of certificates (e.g. BREEAM) will increase interest for selective demolition/recovery of recyclables - CDW management according to EU CDW management protocol and recycling also part of EUTaxonomy - To think: introducing carbon tax on demolition? No one wants to spend more money, but demolition = small percentage of budget for entire project, whereas the impact could be tremendous. - Suggestion to tax demolition instead of landfill, e.g. per ton of waste produced. - ban for bad practices? The biggest issue for demolition companies = sprayed insulation. In future, design should focus more on separation of layers. How to separate different layers in a buildings?

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

This section focuses on EU policies and regulation in place supporting circularity in the construction sector. The focus here is mainly on construction materials/products level not at building level. This review is also limited to environmental aspects in policies and legislation relevant for ICEBERG solutions. The effects of different pieces of policies and regulations on ICEBERG solutions are shortly evaluated at the end of the section, both the support as well barriers and gaps in legislation are highlighted.

Key messages:

- Several policies and regulations will affect the CDW recycling business along the ICEBERG value chain. In EU, a high focus is on energy efficiency and resource efficiency actions in the building sector, but also on land use, need for improved living standards in buildings (socioeconomic issues)
- Key strategies affecting actions on construction products level include European Green Deal/Circular Economy Action Plan, and important regulations include the New Construction Products Regulation aligned with Sustainable Products Initiative and Ecodesign Sustainable Products legislation.
- Key areas of importance in the implementation of regulations:
    - Several drivers towards sustainable products (recent regulations support recyclable content in products)
    - Supports for improving knowledge in material data: Digitalization is encouraged with focus on consumer awareness
    - High focus in policies is on reduction of CO_2 emissions in the construction sector promoting construction products with low embodied carbon and actions improving energy efficiency.

3.1 EU policies and strategies, and global context

The EU policies and strategies indicate the ambitions and goals that are later implemented in regulations, with a focus at product level and/or at building level. Knowledge and follow-up on the policies are important for understanding the future priorities in the construction sector.

The Sustainable Development Goals (SDGs) within the 2030 Agenda for Sustainable Development of the United Nations Development Programme (UNDP) and the Paris Agreement under the United Nations Framework Convention on Climate Change are two important global initiatives adopted in 2015 by most EU member states. The former focuses on environmentally friendly, sustainable economic growth and universal prosperity by defining 17 sustainable goals and the latter on reduction of CO_2 emissions and adaption to climate change. Both these initiatives form the basis in EU policies.

The European Green Deal is a roadmap to realign Europe's economy with the trajectory to net zero, help implement the Paris Agreement and build a more sustainable and fairer society. The European Green Deal is a package of policy initiatives, which aims to set the EU on the path to a green transition, with the

ultimate goal of reaching climate neutrality by 2050. The European Commission has adopted a set of proposals to make the EU's climate, energy, transport and taxation **policies fit for reducing net greenhouse gas emissions by at least 55% by 2030**, compared to 1990 levels. The EGD is focused on climate change mitigation, but it also covers investment, growth, other harmful effects and related strategies such as adaptation to climate change, research, innovation and training.

Figure 5 European Green Deal and its link to different ambitions[10]

As a consequence of the European Green Deal, a number of strategies and action plans to reduce human and environmental health degradation have been launched on the circular economy (CE), resource efficiency and raw materials[11], the low-carbon economy[12] and the Zero Pollution Ambition for a toxic-free environment[13]:

- The circular economy aims to foster an economy that retains as much of the value of materials as possible, for as long as possible (EEA, 2016[14]). To achieve a transition to a CE, action needs to address all products'

[10] Figure source: https://euinasean.eu/eu-green-deal/
[11] EC, 2020, 'A new Circular Economy Action Plan - For a cleaner and more competitive Europe'. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM:2020:98:FIN
[12] https://ec.europa.eu/clima/policies/strategies_en
[13] EC, 2021. Zero pollution action plan Towards zero pollution for air, water and soil. https://ec.europa.eu/environment/strategy/zero-pollution-action-plan_en
[14] EEA, 2016, Circular economy in Europe — Developing the knowledge base, EEA Report No 2/2016, European Environment Agency (https://www.eea.europa.eu/publications/circulareconomy-in-europe)

lifecycle stages, and therefore needs to go beyond waste management and improved recycling.

- The low-carbon economy aims to minimise emissions of GHG to the atmosphere. Focus areas include shifting from fossil fuels to renewable sources of energy and promotion of energy efficient products and processes.
- The Zero Pollution Ambition for a toxic-free environment, and the Chemicals Strategy for Sustainability towards a non-toxic environment (CSS) (EC, 2020[15]), both aim to avoid harm from pollution to people and the environment. The CSS emphasises the need to prevent further pollution by substances of concern, particularly for those that accumulate or cause effects that accumulate in people or the environment. Persistent chemicals such as PFAS are highlighted examples. The Zero Pollution Ambition has also links to biodiversity, as the pollution causes loss of the biodiversity (e.g. causing loss in native species, harming wildlife).

In the **Circular Economy Action Plan** from 2015 (EC, 2015)[16], construction and demolition were mentioned as a priority area and the plan listed three actions related to construction and demolition waste (CDW) required for the achievement of a circular economy. The New Circular Economy Action plan (2020) contains a legislative initiative proposal to widen the Ecodesign Directive to the broadest possible range of products rather than just energy-related ones. The new Action Plan announces initiatives along the entire lifecycle of products, targeting, for example, their safe and sustainable design, promoting CE processes, fostering sustainable consumption, and aiming to ensure that resources used are kept within the EU economy for as long as possible. It introduces legislative and non-legislative measures targeting areas in which action at the EU level brings real added value.

The following guidance or framework documents have been developed as a response to these actions (EC, 2019[17])

- **Waste Management Protocol**: this aims to ensure recovery of valuable resources and adequate waste management in the construction and demolition sector. (see further Box 3)
- **Waste Audit Guideline**: pre-demolition guidelines to boost high-value recycling as well as voluntary recycling protocols aimed at improving quality and building confidence. An EU guidance for pre-demolition audit has been published setting the frame on elements to be included in the audit. In several member states, a national guidance has been published. None of the guidance documents address especially multi-material

[15] EC, 2020. Chemicals strategy The EU's chemicals strategy for sustainability towards a toxic-free environment. https://ec.europa.eu/environment/strategy/chemicals-strategy_en

[16] https://ec.europa.eu/environment/topics/circular-economy/first-circular-economy-action-plan_en

[17] EC, 2019, Commission Staff Working Document accompanying the document Report from the Commission to the European Parliament, the Council, The European Economic and Social Committee and the Committee of the regions on the implementation of the Circular Economy Action Plan, European Commission, Brussels, Belgium.

products. (the status in the countries presented by ICEBERG partners is discussed in section 4.3)

- **EU Level(s) – European reporting framework for sustainable buildings**: this aims to facilitate the assessment of the environmental performance of buildings. (see Box 3)

Box 3. Links to construction sector - Tools supporting EU strategies promoted by CEAP 2015

The **EU Waste Audit Guideline** was published by the European Commission (DG GROW) in 2018. The Guideline provides information about the best practices for the assessment of CDW streams prior to demolition, deconstruction or renovation of building or infrastructure, called "waste audit". Part of the audit can be compulsory due to legal obligation to report hazardous materials or voluntary (e.g. for BREEAM accreditation). The aim of the Guideline is to facilitate and maximize the recovery of materials and components for beneficial reuse and recycling without compromising the safety measures and practices outlined in the **EU Construction & Demolition Waste Management Protocol**. This CD Waste Management Protocol states that:

- "*Any demolition, renovation or construction project needs to be well planned and managed in order to reduce environmental and health impacts while providing important cost benefits.*
- *Waste audit (part of pre-demolition audit as defined in the CD Waste Management Protocol) is to be carried out before any renovation or demolition project, for any materials to be reused or recycled, as well as for hazardous waste.*
- *Public authorities should decide upon the threshold for pre-demolition audits.*
- *Pre-demolition audits take full account of local markets for CDW reused and recycled materials.*
- *A good pre-demolition audit must be carried out by a qualified expert (the auditor)"*

The EU guidance documents (Figure 6) give the basis for the implementation of the pre-demolition audit. The detailed and practical implementation of most elements of the pre-demolition audit is decided on national level.

European Commission's Level(s) provides a methodology for measuring the resource use and environmental performance during a building's lifecycle, health and comfort and cost, value, and risk. Several pieces of EU legislation (e.g. Construction Products Regulation, EU taxonomy) make references to EU Level(s).

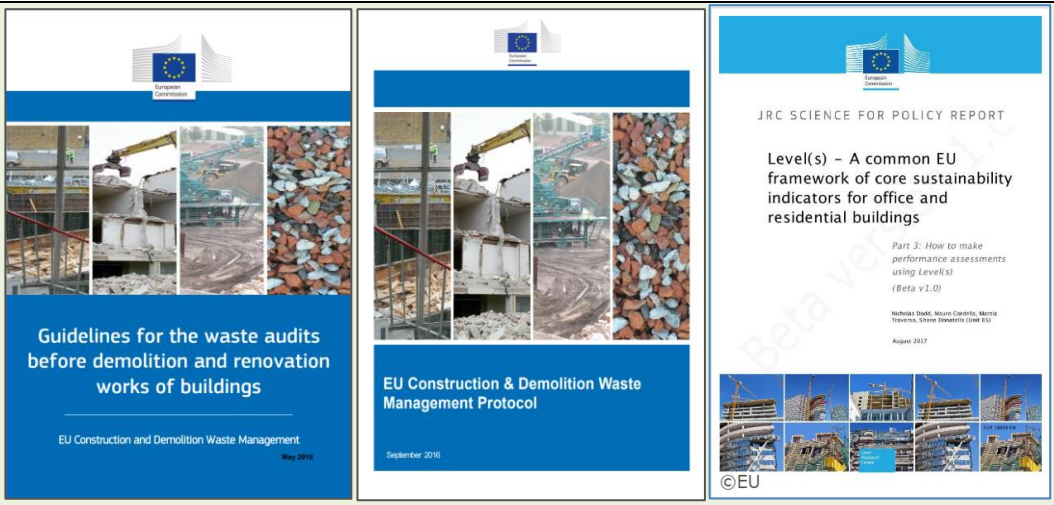


Figure 6 Guidelines and protocols published by the European Commission: EU guidelines for the waste audits (2017)[18], EU Construction & Demolition Waste Management Protocol[19] and A Framework for Level(s)[20].

Further reading:
Pre-demolition audit: https://projectsites.vtt.fi/sites/parade/
EU Level(s): https://environment.ec.europa.eu/topics/circular-economy/levels_en

The New Circular Economy Action Plan (CEAP)[21] was launched in 2020 and focuses on sustainable resource use, especially in resource-intensive and high impact sectors such as **construction and buildings**. Here one measure emphasized is the ambition to make sustainable products, with a focus on the safety of consumers and the environment. As a follow-up action, the Commission published in March 2022 several proposals to make sustainable products the norm and boost Europe's resource independence as follows: The proposal for **sustainable products policy initiative (SPI)**, including the review and widening of the EU Ecodesign directive (see Box 4: definition of sustainability). These requirements have been considered in the preparation of the new Construction Products Regulation (section 3.2.1).

[18] European Commission. 2018. Guidelines for the waste audits before demolition and renovation works of buildings https://ec.europa.eu/docsroom/documents/31521

[19] European Commission "EU Construction and Demolition Waste Protocol", available online from https://ec.europa.eu/growth/content/eu-construction-and-demolition-waste-protocol-0_en (2016)

[20] https://environment.ec.europa.eu/topics/circular-economy/levels_en

[21] https://eur-lex.europa.eu/resource.html?uri=cellar:9903b325-6388-11ea-b735-01aa75ed71a1.0017.02/DOC_1&format=PDF-

Box 4. Principles presented in the sustainable products initiative (SPI)[22]

Ecodesign requirements based on the **sustainability and circularity aspects with focus on following characteristics (performance requirements):**

- Improving product durability, reusability, upgradability and reparability, addressing the presence of hazardous chemicals in products, and increasing their energy and resource efficiency
- Increasing recycled content in products, while ensuring their performance and safety
- Enabling remanufacturing and high-quality recycling
- Restricting single-use and countering premature obsolescence
- Introducing a ban on the destruction of unsold durable goods
- Incentivising product-as-a-service or other models where producers keep the ownership of the product or the responsibility for its performance throughout its lifecycle
- Reducing carbon and environmental footprint
- Mobilising the potential of digitalisation of product information, including solutions such as digital passports, tagging and watermarks
- Rewarding products based on their different sustainability performance, including by linking high performance levels to incentives

The **EU Industrial Strategy**[23] consider digital technologies as a "critical enabler for attaining the sustainability goals of the Green deal in many different sectors". In parallel, the European Data Strategy acknowledges the need for digital technologies to contribute to sustainable development (EC, 2021)[24].

Actions in most strategies relate to actions along the whole life cycle. In some cases, the strategy documents also list concrete actions that are then turned into regulations and guidelines for implementation (e.g. waste audit in CEAP). In EU, a high focus is on circular economy targets, i.e. retaining the value of a product (e,g, prolongation of lifetime, high-quality recycling).

Issues relevant for construction products:

- Supporting BIM, digital product passport
- Digital Building Logbooks to track information on construction, renovations, material use and safety aspects

The revised **Waste Framework Directive** (WFD)[25] (2008/98/EC, amended 2018/851) can also be seen as policy document together with CEAP 2020[26].

[22] European Commission, 2022, Green Deal: New proposals to make sustainable products the norm and boost Europe's resource independence, press release, https://ec.europa.eu/commission/presscorner/detail/en/ip_22_2013

European Commission, 2022, COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS - On making sustainable products the norm, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52022DC0140&qid=1649112555090

[23] https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/europe-fit-digital-age/european-industrial-strategy_en

[24] https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/europe-fit-digital-age/european-data-strategy_en

[25] https://ec.europa.eu/environment/topics/waste-and-recycling/waste-framework-directive_en

[26] The scope of the Directive is: To lay down measures to protect the environment and human health by preventing or reducing the generation of waste, the adverse impacts of the generation and management of

WFD defines the waste hierarchy in waste management, setting waste prevention as the highest priority. It sets clear targets for the reduction of waste and requirements for waste management and recycling, including quantitative recovery targets for CDW, to be achieved by 2020. The Directive also introduces the end-of-waste concept (EoW) and defines criteria to establish when a waste ceases to be a one and becomes a secondary product or material.

The focus of the **EU Renovation Wave initiative** (EC, 2020)[27] is to improve the energy performance of buildings. The Commission aims to at least double renovation rates in the next ten years and make sure renovations lead to higher energy and resource efficiency. It makes explicit reference to the circular economy agenda, by stating that the renovation wave activities need to respect and be in line with the circular economy principles. The building renovation, both public and private, is included in the EU economic recovery plans in many countries as it also contributes significantly to job and value creation. The Renovation Wave will further increase the market share of products and materials needed for renovation. There will therefore likely be an increased demand for new insulation panels.

In the Renovation Wave Strategy, it is announced that the Commission will develop a 2050 roadmap for reducing whole life-cycle carbon emissions in buildings via the use of bio-based materials and review of material recovery targets. The strategy also emphasises the need to develop and encourage circular skills in the construction workforce.

Issues relevant for construction products:

1. the renovation initiative provides opportunities also for non-energy related renovation action for increasing comfort (here CE solutions to be promoted).
2. Low carbon economy means that construction products should have low embodied energy.

3.2 Role of specific regulatory tools for ICEBERG solutions - snapshots

There are numerous pieces of legislation in construction along the lifecycle of buildings. Figure 7 illustrates specific regulations of importance for ICEBERG solutions at different lifecycle stages. In the analysis of the environmental impacts from construction material and products, all aspects need to be included in the assessment (e.g. impacts from material sourcing, processing needs of feed, rejects, yield of process, purity of end-product, energy use, emissions).

Here only examples of some regulatory issues of importance for the ICEBERG solutions are presented in this section, and the overview is not exhaustive.

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waste and by reducing the overall impacts of resource use and improving the efficiency of such use, which are crucial for the transition to a circular economy and for guaranteeing the Unions long-term competitiveness

[27] EC, 2020, A Renovation Wave for Europe - greening our buildings, creating jobs, improving lives. https://energy.ec.europa.eu/topics/energy-efficiency/energy-efficient-buildings/renovation-wave_en

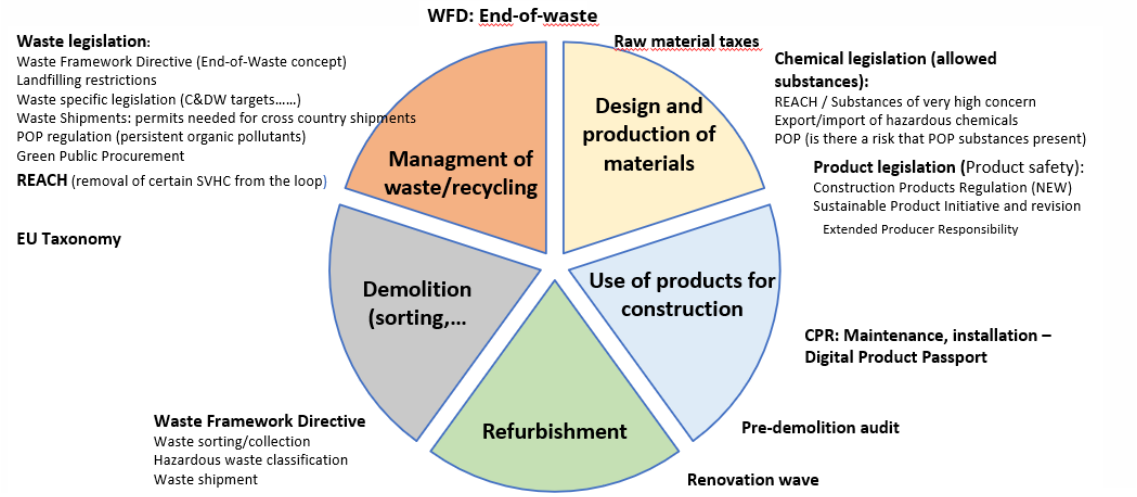


Figure 7 Regulations of importance for ICEBEG solutions at different lifecycle stage

The new **Construction Products Regulation** is of particular importance for the ICEBERG solutions setting e.g. reporting requirements for manufacturers (see further Section 3.2.1). The upcoming requirements in the **Waste Framework Directive** also needs attention. The Commission shall by 2024 consider inclusion of preparing-for-reuse and recycling targets for CDW and its material-specific fractions in the Waste Framework Directive. It is possible that instead of mass-based recovery targets, climate effects of recycling solutions need to be considered. Other ambitions may be on measures for promotion for reuse and high-quality recycling, sorting and collection obligations, and selective demolition/waste audits. Other important legislation such as **REACH, POP regulation** concerns restrictions of substances in new products.

3.2.1 New Construction products regulation

The aim of the Construction Products Regulation (CPR) (305/2011) is to remove barriers to trade of construction products between member states in the European Economic Area. Box 5 summarizes the scope of the current CPR. Further information on the CPR is provided in the ICEBERG deliverable D6.4[28].

Box 5. Current Construction products regulation in a nutshell

The Construction Products Regulation concerns “any product or kit which is produced and placed on the market for incorporation in a permanent manner in construction works or parts thereof and the performance of which has an effect on the performance of the construction works with respect to the basic requirements for construction works."

The main aim of the Construction Products Regulation (305/2011/EU) is to remove barriers to trade of construction products between member states in the European Economic Area. It makes CE-marking mandatory for most construction products sold in EU countries, which are

[28] ICEBERG Deliverable D6.4 (2024). Report on the contribution to the standardization system and ETA opportunities

covered by a harmonised product standard or a construction product that conforms to a European Technical Assessment, which has been issued for the product.

The CPR requires that harmonised test methods are used in the performance declarations in order to remove trade barriers between member states. The CPR does not intend to harmonise existing national regulations and requirements concerning the actual construction works (e.g. national regulation for indoor air quality). Member States and public and private sector procurers are free to set their own requirements on the performance of buildings and construction works and therefore performance levels of products.

CE

Figure 8 The CE marking indicates that a construction product is in conformity with its declared performance according to a harmonised European Product standard or according to a procedure set in a European Technical Assessment

The current Construction Products Regulation has been revised and the new version was approved on April 10, 2024 and will at latest in 2025 be published in the Office Journal of the EU[29]. The current CPR and the new CPR will exist in parallel for many years; the current CPR would be repealed in 2039. The transition period to the new CPR is long to avoid bottlenecks.

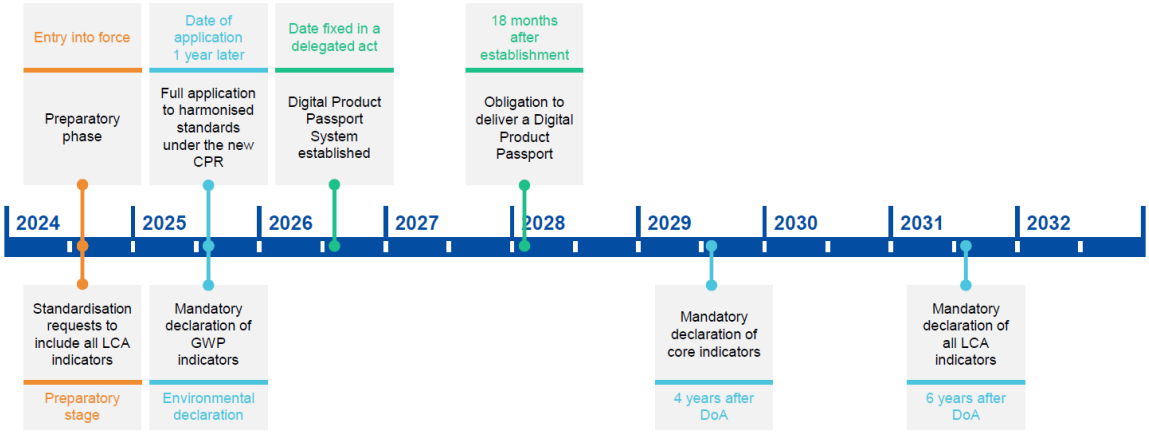


Figure 9 Overview of the new CPR timeframe (EC, 2024)[30]

The goal of the new CPR is to make sustainable products the norm in the EU, boost circular business models and empower consumers for the green. The new CPR is aligned with the goals set in the Sustainable Products Initiative/the Eco-

[29] The new CPR is subject to the 'corrigendum procedure' under Rule 241 of the European Parliament's Rules of Procedure, which will delay its final adoption.

[30] Nieto-Sanz, O. 2024. Presentation on environmental aspects of the new Construction Products Regulation. Presented at Webinar on 'EU initiatives advancing circular economy and climate mitigation in construction, High level construction Forum, March 12, 2024

design for sustainable products regulation[31]. Some key changes to the current CPR which are also relevant for ICEBERG solutions are presented as follows:

- mandatory declaration of the global warming potential for construction products entering the system as of 2025. The environmental indicators to be reported will be broadened by 2031 to the full list of lifecycle assessment indicators by 2031 (see Figure 9). There are already examples on methodologies to be used for calculation and reporting of environmental performance. For example, the Environmental Product Declarations (EPDs) are a proven method for which sector specific standards are developed. The EN15804+A2 standard[32], specific for the construction industry, is used in the LCA studies conducted for ICEBERG solutions for measuring a product's environmental performance throughout its lifecycle.
- in the development of harmonised standard, a lifecycle perspective is required. This means that relevant information on potential impacts on product characteristics during the installation, maintenance and removal, recycling or reuse of the product need to be taken in to account.
- faster procedures for development of harmonised standards, involvement of all stakeholders at early stage for definition of the scope (possibilities for the Commission to use delegated acts e.g. to introduce classes of environmental performance and thresholds or to influence the standard development).
- the use of digital product passports by 2028 including environmental information
- the new CPR sets EU rules for GPP for building materials, which will be established from the end of 2026. These new rules will introduce mandatory minimum environmental sustainability requirements for public procurement of construction products, which will facilitate the emergence of lead markets for low-carbon products. This emphasizes the growing emergence of more mandatory GPP requirements at Member State level.

Relevance for ICEBERG solutions: Important elements in the new CPR for which also ICEBERG responds with solutions:

- in future, requirements for greener and safer construction products (reporting obligations for manufacturer)
- digital information on product characteristics
- obligation for manufacturer on environmental reporting (information on climate effects changed to mandatory)
- product traceability important (use of digital product passport)

3.2.2 Waste Framework Directive

A short description of WFD is presented in Box 6. Relevant issues for ICEBERG solutions are as follows:

a) New targets for recovery of certain C&D waste (e.g. concrete, wood, plastics….) under consideration by the Commission

[31] https://environment.ec.europa.eu/publications/proposal-ecodesign-sustainable-products-regulation_en

[32] Sustainability of construction works - Environmental product declarations - Core rules for the product category of construction products

b) Waste sorting at construction site if possible
c) Hazardous waste classification rules given
d) End-of-waste concept
e) Bans (e.g. restrictions in landfilling of gypsum waste)

In order to provide background data for a potential revision of the recovery target set in the WFD, a background study[33] was conducted by the Joint Research Centre (JRC) in agreement with DG Environment (DG ENV). The overall aim of the study is to provide detailed techno-economic data and environmental assessment of CDW management, with focus on individual material fractions. As a follow-up of this work, a socio-economic study of CDW management options in the EU including additional CDW streams was conducted at JRC (Caro et al 2024[34] , Cristóbal et al 2024[35]). From a lifecycle perspective, environmental impacts, environmental and societal life cycle costs of different treatment options for selected priority fractions of CDW (concrete, bricks, PVC, EPS, wood/timber, aluminium, steel, glass, gypsum, glass & rock wool, ceramics & tiles) were calculated and compared. The key waste streams are projected to year 2050 considering the CO_2 savings in different recycling options. For concrete waste recycling, the high-quality recycling is defined as the recovery of cement which can be used for new concrete along with gravel and fines whereas recycling of concrete waste as aggregate is not counted as high-quality recycling[36]. The study concludes that concrete and bricks have the highest potential in terms of environmental improvements.

Links to the ICEBERG project:

- ICEBERG responds to several of the WFD ambitions by providing new innovative solutions for recycling construction and demolition waste
- WFD includes the EoW concept to support use of waste derived materials as secondary raw materials
- Focus is on high-quality recycling, e.g. savings of CO_2 emissions, resources
- Waste sorting supported by sensor technologies developed in ICEBERG
- Waste traceability and pre-demolition protocols

In the future, the waste status of recovered secondary raw materials also needs to be clarified. For example, under which conditions can the recovered

[33] European Commission, Joint Research Centre, Damgaard, A., Lodato, C., Butera, S. et al., Background data collection and life cycle assessment for construction and demolition waste (CDW) management, Publications Office of the European Union, 2022. See: https://data.europa.eu/doi/10.2760/772724

[34] Caro, D., Lodato, C., Damgaard, A., Cristóbal, J., Foster, G., Flachenecker, F., & Tonini, D. (2024). Environmental and socio-economic effects of construction and demolition waste recycling in the European Union. Science of the Total Environment, 908, 168295. See: https://www.sciencedirect.com/science/article/pii/S004896972306922X

[35] European Commission, Joint Research Centre, Cristóbal García, J., Caro, D., Foster, G. et al., Techno-economic and environmental assessment of construction and demolition waste management in the European Union Status quo and prospective potential, Publications Office of the European Union, 2023. See: https://data.europa.eu/doi/10.2760/721895

[36] Low-quality recycling here refers to recycling where only gravel and fines are recycled into new concrete where it replaces gravel, where high-quality recycling includes the recovery of cement which can be used for new concrete along with gravel and fines.

construction materials, building components, structures, and materials remain as products (not reaching the waste status).

Box 6. Waste Framework Directive (WFD) in a nutshell

WFD defines the waste hierarchy in waste management, setting waste prevention as the highest priority (Figure 10). It sets clear targets for the reduction of waste and requirements for waste management and recycling, including quantitative recovery targets for CDW, to be achieved by 2020. The Directive also introduces the **end-of-waste concept** (EoW) and defines criteria to establish when a waste ceases to be a one and becomes a secondary product or material.

Figure 10 The waste hierarchy according to Waste Framework Directive. (ref. JRC EU Level(s)[37])

According to WFD, by 2020, 70 % by weight of non-hazardous construction and demolition waste shall be reused/recycled. The Directive also requires that Member States promote selective demolitions to facilitate high-quality recycling by selective removal of materials and ensure the establishment of sorting systems for construction and demolition waste at least for wood, mineral fractions, metal, glass, plastic and plaster.

By 2024, the Commission shall consider setting preparing-for-reuse and recycling targets for CDW and its material-specific fractions

Box 7. End-of-waste concept

The End-of-Waste (EoW) concept means that a specific waste fraction can cease to be a waste under certain criteria given in the Waste Framework directive:

a) the substance or object is commonly used for specific purposes;
b) a market or demand exists for such a substance or object;
c) the substance or object fulfils the technical requirements for the specific purposes and meets the existing legislation and standards applicable to products; and
d) the use of the substance or object will not lead to overall adverse environmental or human health impacts.

If the criteria are fulfilled, the material will no longer be classified as a waste and it will instead become a product subject to free trade and use (although for specific purposes). If no EoW legislation has been given at the EU level, member states can develop national EoW legislation for a certain waste material or make a case decision as part of the environmental permit. In the latter case, the material and conditions are limited to the case described in the environmental

[37] PG Section Documents | Product Bureau (europa.eu)

permit. Different routes for achieving an EoW status are illustrated in Figure 11. If a waste material obtains EoW status and ceases to be waste, it becomes a product. In that case the use of the material will be regulated entirely by legislation on products.

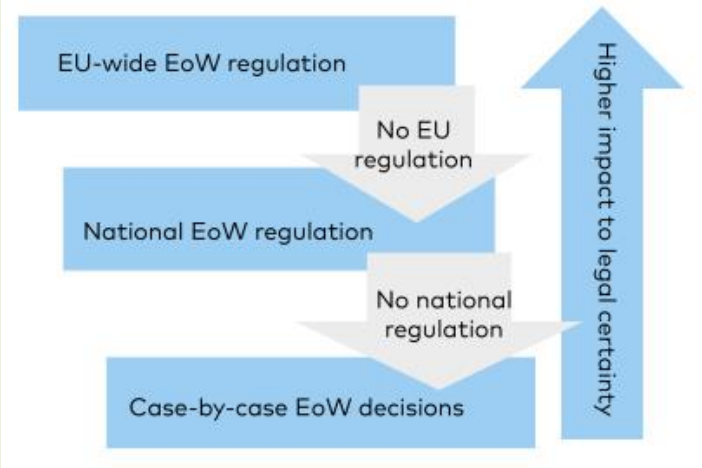


Figure 11 Different routes for achieving End-of-Waste status.[38] If a material obtains EoW status and ceases to be waste, it becomes a product and fulfils the requirements for virgin materials

Additional information: The EoW criteria are further presented in the EU HISER project deliverable D6.1 Report on Policy Recommendations (2019, see https://www.hiserproject.eu/).

3.2.3 Legislation for hazardous substances

Hazardous substances are regulated in product regulation and in waste regulation. The latter part is of importance if new products are produced from recycled construction products or materials.

The European regulatory framework imposes to all EU members precautionary principles and limit values, but each country is free to tighten those principles. The requirements are different for wastes and products. For waste, the main concern relates to safe waste management. For products, the requirements are highly dependent on application and risk related to the use of the product (exposure routes, receptors, environment conditions etc). If waste is used as products, the product regulation needs to be considered.

Waste:

- Waste management (hazardous waste classification (Waste Framework Directive), End-of-waste concept[39], landfilling[40], incineration, permits, shipment etc)

[38] *Turunen, T. 2018. The concepts of waste and non-waste in the circular economy. PhD dissertation.* *http://epublications.uef.fi/pub/urn_isbn_978-952-61-2920-4/*

[39] Waste Framework Directive includes option to set criteria under which specified waste fractions shall cease to be waste and be regarded as product

[40] Directive 1999/31/EC defines landfill categories and landfill acceptance criteria are established in Council Decision 2003/33/EC

- Bans (asbestos[41] - human safety, POPs[42] – waste to be destroyed)

Products (relevant for recyclables):

- Bans (asbestos[9] - human safety, POPs[10] – use as chemicals in production)
- REACH and ECHA: restriction of substances of very high concern (SVHC) (e.g. additives in plastics)
- Material/Application specific limits (wood, End-of-Waste materials, electronics, construction products - materials in contact with drinking water, indoor air….)
- Additionally for use in earth construction: leaching criteria

Challenges for ICEBERG solutions:

- recycling of historical materials and products requires reliable information on composition and potential exposure during use phase (e.g. spills, fires…). List of banned or restricted substances will never be finalized as new information on toxicity of substances will set need for new additions in the list. This sets needs for constant follow-up, e.g. in selection of raw material.

3.2.3.1 Chemical regulations (REACH)

The aim of the chemical regulation REACH[43] is to ensure that all substances are manufactured and used safely. REACH concerns use of substances in products manufactured in EU or imported to EU. In REACH certain substances are listed as Substances of very high concern (SVHC) and published on the webpage of the European Chemical Agency ECHA. SVHC substances may be found in plastics products, e.g. phthalates (DEPH) or flame retardants. The list is constantly updated, and new hazardous substances are introduced. The Construction Products Regulation makes references to the Chemical Regulation. It is specifically mentioned that, where applicable the declaration of performance should be accompanied by information on the content of hazardous substances in the construction product in order to improve the possibilities for sustainable construction and to facilitate the development of environmentally friendly products.

All manufacturers and importers of substances must identify risks linked to the substances they manufacture and market in the EU. REACH provides a framework in which information can be passed from manufacturers and importers to the downstream users of chemicals. The main carrier of information is the Safety Data Sheet (SDS). In time SDS will include information on relevant exposure scenarios based on the intended use of a specific substance.

[41] Protection of workers from the risks related to exposure to asbestos Council Directive 2009/148/ECtad

[42] The Stockholm Convention is an international agreement with the aim of reducing and eliminating production, use and release of persistent organic pollutants (POPs). The convention comprises production (both intentional and unintentional), use, waste management and environmental supervision of POPs.

[43] The EU regulation REACH (Regulation No 1 907/2006) stands for Registration, Evaluation, Authorisation and Restriction of Chemicals and came into force in 2007.

Companies that produce, assemble, import or distribute products on the EU market which contain SVHCs on ECHA's Candidate List in a concentration above 0.1 % weight by weight have to notify them to the ECHA's SCIP database[44].

Since REACH applies to all chemical substances and their use, a large number of products (defined as "articles") will in principle be affected by the regulation. Products used in construction are not excluded from the general obligations in REACH. However, the greater part of products used in construction will only be subject to the substance-based information flow obligations and mainly in the direction from manufacturers/importers of chemicals to the producers of building materials/products in their role as downstream users of chemicals.

In addition to the substances already regulated, so-called substances of very high concern (SVHC) cannot be placed on the market or used after a date to be set unless the company is granted an authorisation. Current and previous consultations on proposals for identification of SVHC can be found on ECHA´s homepage.

3.2.3.2 POP regulation

Persistent organic pollutants (POPs) are defined in regulation (No 2019/1021 replacing 850/2004), which requires that wastes containing substances listed in its annexes, such as PCB, certain brominated flame retardants or fluorinated substances (e.g. PFOS and PFOA), and exceeding specific concentration limits need to be destroyed and not re-circulated in new products.

The POP regulation is of concern both for waste and for secondary raw materials used in new products:

- wastes containing substances listed in the annex IV to the regulation and exceeding certain concentration limits (so called POP wastes) need to be destroyed and not circulated in new products.
- secondary raw materials and products containing substances listed in the annex I and exceeding the limits are prohibited to be put on the market (and thus cannot be recycled). It should be noted that for many POP substances the limits in the annex I are very low.

3.2.3.3 Ozone depleting substances

Many buildings today contain insulation foams that were blown with ozone-depleting substances (ODS) or hydrofluorocarbons (HFC)s. Both substance groups are "super greenhouse gases" as they have very high global warming potentials (GWP) (many several thousand times higher than CO_2).

Ozone depleting substances (ODS) and hydrofluorocarbons (HFCs) or other substances with high global warming potential (GWP) fall under the Montreal Protocol unless otherwise noted (UNEP, 1987[45]; Regulation (EC) No 1907/2006,

[44] SCIP database https://echa.europa.eu/scip

[45] UNEP (1987) 'The Montreal Protocol on Substances that Deplete the Ozone Layer'. Available at: https://ozone.unep.org/treaties/montreal-protocol/montreal-protocol-substances-deplete-ozone-layer

2006; United Nations, 2016[46]). The Montreal Protocol includes a phase-out plan for both the production and consumption of ozone-depleting substances. The landmark agreement was signed in 1987 and entered into force in 1989.

Restriction in the use of blowing agents in insulation materials and waste management obligations:

- For buildings, the use of ODS in the EU ended in 2003 for all foam applications. CFC use ended by end 1994 in the EU-15 and ended few years later in Eastern countries.
- Demolition waste from the building sector can be assumed to contain CFC-11/12 or their replacement substances HCFC 141b/142b, which were often used blowing agents for polyurethane (PU) & extruded polystyrene (XPS) foams until the CFC ban in 1994–1995 and HCFC bans (as blowing agent) in 1998–2000.
- Emissions from these foams occur mostly when buildings are renovated or demolished and no effort is made to prevent the emissions of these gases from the foams.
- From 2025, when old buildings are renovated, refurbished or demolished, ODS and fluorinated gases (Fgas-)containing foams in laminated foam boards and foam panels, must be handled in a way to ensure that emissions are avoided and the gases therein are destroyed (Joint obligation on building owners and contractors)

3.2.3.4 Hazardous waste classification

Waste is classified as hazardous or non-hazardous. Hazardous waste is a waste that, due to its (intrinsic) chemical or other properties poses a risk to the environment and/or human health.

The classification is primarily based on the European List of Waste (LoW) (2014/955/EU) or based on a waste's hazardous properties. In the LoW, wastes are primarily categorised as hazardous, non-hazardous, or potentially hazardous/non-hazardous according to their origin or source – for example, asbestos wastes are classed as hazardous whereas textile wastes from households are deemed to be non-hazardous. In some cases, a particular type of waste on the list can be either hazardous or non-hazardous depending on its specific properties and in these cases the waste status has to be assessed based on its hazardous properties[47].

The waste classification has several implications (e.g concerning landfilling, permits). The Waste Shipment Regulation (WSR) (No. 1013/2006), for example, requires permits for the export or import of hazardous waste both within EU and

[46] United Nations (2016) Chapter XXVII Sub Chapter 2.f. Amendment to the Montreal Protocol on Substances that Deplete the Ozone Layer. Kigali: United Nations. Available at: https://treaties.un.org/Pages/ViewDetails.aspx?src=TREATY&mtdsg_no=XXVII-2-f&chapter=27&clang=_en

[47] The European Commission's Regulations No 1357/2014 and 2017/997 define the hazardous properties for hazardous waste classification referring to assessment methods developed in the European Commission's Classification, Labelling and Packaging Regulation (CLP).

between the EU and OECD countries outside the EU and bans exports to OECD countries.

3.2.3.5 Limits for hazardous substances – example brominated flame-retardant

Brominated flame retardants are used in numerous construction products, e.g insulation materials and paints. EPS and XPS insulation in buildings is the most significant waste stream containing hexabromocyclododecane (HBCDD). The flame retardant content of HBCDD in EPS insulation is 0.67 p-% (6 700 mg/kg) and 1.5 p-% (15 000 mg/kg) in XPS products (Myllymaa et al., 2015[48]; Ramboll, 2019)[49]. The use of HBCDD was phased out in 2015.

According to Annex 1 of POP regulation, the limits for residue concentrations in feedstock are generally very low (for HBCDD: 100 mg/kg). This means that a small quantity of HBCDD containing EPS or XPS in waste hinders recycling. In the pre-demolition audit, it is therefore highly important that the potential presence of brominated flame retardants in the XPS and ESP insulation materials is identified, and the hazardous insulation materials are removed and kept separated.

Table 7 Historical construction products potentially containing hazardous substances/materials.

Regulation	Specification	Limit	Remark
Waste Framework Directive	Hazardous waste classification	HBCDD: 30 000 mg/kg	Classification of a POP waste as non-hazardous or hazardous waste may affect whether the treatment plant can accept the POP waste in question or not
POP-regulation	Annex I: feedstocks	HBCDD: 100 mg/kg	Prohibits manufacturing, placing on the market and use if limits in Annex 1 are exceeded.
	Annex IV: POP waste definition	HBCDD: 1000 mg/kg	CreaSolv® method based on solvents suitable for separation of flame retardants
	Annex V: defines the permitted recovery and disposal methods for waste	HBCDD: 1000 mg/kg	Only for waste mentioned in Annex V
Industrial Emissions Directive (2010/75/EU)	Waste incineration	If hazardous waste with a content of more than 1% of halogenated organic substances[50] is incinerated or co-incinerated, the temperature should be at least 1 100 °C with a minimum residence time of 2 seconds in	If the concentration of halogenated organic compounds in hazardous waste is less than 1 %, or the waste containing these compounds has been classified as non-hazardous waste, the temperature requirement for incineration is 850 ºC.

[48] Myllymaa T. (ed.), Moliis K., Häkkinen E., Seppälä T., 2015. Occurrence, identification and separation of Persistent Organic Pollutants (POP) from plastic waste. Reports of the Ministry of the Environment 25/2015. Ministry of the Environment. Helsinki, 2015.

[49] Ramboll, 2019. Study to support the review of waste related issues in annexes IV and V of Regulation (EC) 850/2004, Final report. Ramboll Environment & Health GmbH. European Commission, January 2019. https://data.europa.eu/doi/10.2779/500330

[50] expressed as chlorine (requiring recalculations for bromide)

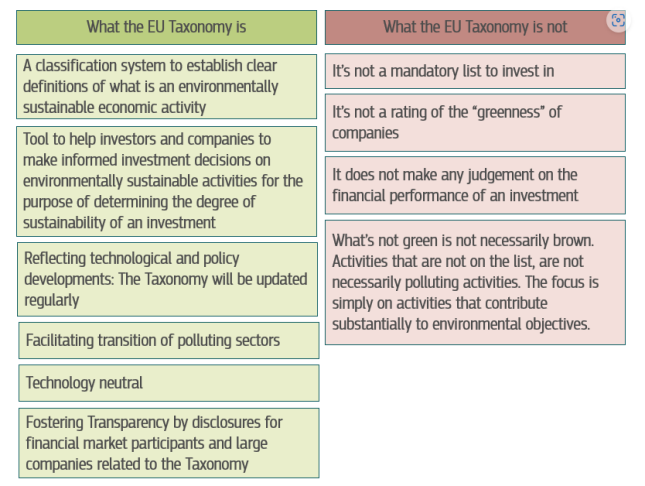
Regulation	Specification	Limit	Remark
		order to mineralise all organic compounds.	

3.2.4 EU taxonomy regulation

The EU Taxonomy is a voluntary system for reporting compliance with a set of sustainability criteria and to be used in financial support for investment. The EU Taxonomy is a classification system defined in the EU Taxonomy regulation that lists environmentally sustainable economic activities and is used to support the implementation of the European Green Deal in order to act as an incentive for the expansion of sustainable investments. It provides policymakers, companies, and investors with appropriate definitions of which activities can be classified as environmentally sustainable. Box 8 summarises the EU taxonomy concept.

Box 8. EU taxonomy in a nutshell

The EU Taxonomy is a classification system that helps companies and investors identify "environmentally sustainable" economic activities to make sustainable investment decisions. The EU Taxonomy is a tool to help investors identify environmentally sustainable economic activities, promote a transition to a zero-carbon future and guide funding towards solutions to tackle the climate crisis and prevent further environmental degradation.



The Taxonomy Regulation lays the foundation for the EU Taxonomy by establishing six overarching criteria that an economic activity must meet to be considered environmentally sustainable. These six environmental goals are as follows: 1) mitigation of climate change (delegated act; criteria defined); 2) adaptation to climate change (delegated act; criteria defined); 3) sustainability and protection of water and marine resources; 4) transition to a circular economy; 5) Pollution prevention and control; 6) protection and restoration of biodiversity and ecosystems. The economic activity shall give a substantial contribution to at least one of the EU's climate and environmental objectives, while at the same time not significantly harming any of the other five objectives and meeting minimum safeguards (see Figure 12).

Figure 12 Taxonomy alignment[51] (delegated acts: EU regulation 2021/2139 for climate change/adaption and EU regulation 2023/2486 for other goals)

Source: https://finance.ec.europa.eu/system/files/2023-06/taxonomy-regulation-delegated-act-2022-environmental-annex-2_en_0.pdf

Technical screening criteria for CE (EU regulation 2023/286) are presented separately for new construction, renovation and demolition. As an example, Table 8 lists the CE screening criteria given for renovation.

The published CE criteria opens discussions on the interpretation on some of the criteria (e.g. how to demonstrate compliance with the criteria, what to be included

[51] Source: EU Taxonomy Navigator (europa.eu)

in the assessment of compliance, what kind of proofs are needed). There is therefore a high need for guidance on how to implement the CE criteria. Also guidance documents on which types of taxonomy criteria are most suitable for certain activities (e.g. is it easier to prove compliance to the climate criteria easier than to CE criteria for certain activities). The rationale for the CE criteria and the background information in setting the criteria have not been published or are not easily available. Background information on existing technologies to achieve a replacement of virgin materials and conditions for recycling would be helpful. The supply of material might be critical in some countries (e.g supply of high-quality material for recycling such as wood, gypsum, plastics, concrete). The supply depends on country specific conditions, e.g. availability of virgin materials, logistics.

Some of the CE criteria e.g. for replacing part of metals with metal scraps are easily achievable, while others may be challenging in some countries, e.g. CE criteria for share of virgin gypsum. Furthermore, here ICEBERG solutions may provide recycling technologies for replacing virgin materials with recyclable material and information on conditions for different solutions and thus the EU taxonomy can give a push for introduction of recycling. The PDA practices and traceability concept are further discussed in section 4.3.

Table 8 Technical screening criteria to be used in renovation of buildings (example).

No	Description	Criteria	Specification	ICEBERG context
1	sorting systems and pre-demolition audits		EU CDW Protocol and Pre-demolition audit (PDA) guide to be followed	Pre-demolition audit – proof of concept for traceability of waste management not currently included in PDA systems in ICEBERG countries. Linking pre-demolition audit and its qualitative follow-up (including demolition plan) to EU taxonomy to serve as proof that the CE criteria are fulfilled
2	re-use or recycling (backfilling excluded) of the non-hazardous construction and demolition waste generated on the construction site	At least 70% (by weight)	soil waste excluded recycling and reuse definitions in WFD	
3	life cycle Global Warming Potential (GWP) of the building's renovation works		disclosed by demand for investors and clients	Note! Sets requirement for information on GWP at product level
4	Construction designs and techniques supporting circularity via the incorporation of concepts for design for adaptability and deconstruction		reference to EU Level(s) indicators 2.3 and 2.4 at Level 2	
5	original building retained	At least 50%	calculated based on the gross floor area retained from the original building using the applicable national or regional measurement methodology, alternatively using the definition of 'floor area'	
6	maximum amount of primary raw material used in renovation (also from other sources than CDW)	Threshold values	three heaviest material categories newly added to the building in the renovation of the building, measured by mass in kilogrammes	
	• concrete, natural or agglomerated stone	85%	The thresholds are calculated by subtracting the secondary material from the total	ICEBERG solutions
	• brick, tile, ceramic	85 %		ICEBERG solutions

	• biobased products	90 %	amount of each material used in the works measured by mass in kilogrammes. Where the information on the recycled content of the construction product is not available, it is to be counted as comprising 100% primary raw material. Where a construction product is re-used, it is to be counted as comprising zero primary raw material.	ICEBERG solutions
	• glass, mineral insulation	85 %		products available
	• non-biobased plastic	75 %		ICEBERG solutions
	• metals	65 %		products available
	• gypsum	83 %		ICEBERG solutions

Relevance for ICEBERG solutions:

- EU taxonomy fosters the uptake of technologies providing sustainable solutions e.g. in waste management. However, there is still lack of experience of the EU taxonomy, especially on the use of the CE criteria.

3.2.5 Waste shipment regulation

Waste is exported for recovery or in some cases even final treatment for example due to a lack of treatment capacity in the country where waste is generated. Also gate fees at treatment facilities, environmental taxes, and legislation may affect the shipment. Barriers for a waste shipment are often transport costs and potential permits needed for cross-country shipment.

EU's revised Waste shipment regulation (WSR) was approved in spring 2024[52]. The main objectives of the revision include reducing shipments of problematic waste to outside the EU, as well as promoting the use of waste as a resource in a circular economy within the EU.

The WSR sets up control procedures for the waste shipment, which depend on waste characteristics (hazardous, non-hazardous), final destination (EU, OECD, outside OECD), and treatment operation (recycling, landfilling). In the revised WSR, for the waste shipments within EU, general information requirements apply to green listed waste (non-hazardous waste, listed in Annex III or Annex IIIB) destined for recovery, whereas prior written notification and consent is required for hazardous waste (e.g. wastes listed in Annex IV, as well as contaminated green listed waste to certain extent) and waste destined to landfills.[53]

Bureaucratic aspects may be a barrier for the cross-country shipment of waste (needed permits, lengthy paper-based procedures). The revision aims to improve the functioning of the EU internal market for waste destined for recycling/reuse by e.g. digitalising and simplifying the procedures for intra-EU shipments. Paper based notification procedures will be shifted to central electronic system operated at the Union level. Furthermore, fast track procedures for certain eligible facilities designated by the Member States will also be made easier and more efficient.

[52] https://www.consilium.europa.eu/en/press/press-releases/2023/11/17/waste-shipments-council-and-parliament-reach-agreement-on-more-efficient-and-updated-rules/
https://ec.europa.eu/commission/presscorner/detail/en/ip_23_5818

[53] https://data.consilium.europa.eu/doc/document/ST-16528-2023-INIT/en/pdf
https://data.consilium.europa.eu/doc/document/ST-16528-2023-ADD-1/en/pdf

3.3 Fiscal instruments

3.3.1 Landfill taxes

Landfill taxes, landfill bans and high disposal costs are often presented as efficient drivers for recovery and recycling (Deloitte 2017)[54]. Landfill taxes were introduced about 30 years ago in many EU countries in order to increase the recovery of waste and to reduce landfilling[55]. Only in Cyprus, Germany, Luxembourg, Malta and Slovakia no landfill taxes are collected (according to data for year 2022). The waste material affected by the landfill tax differs between countries (in some countries e.g. soils are exempted from taxes). Furthermore, landfilling of biodegradable waste (e.g. wooden waste) is banned or limited in many European countries. In many countries there are also bans for landfilling certain waste types (e.g. recyclable waste e.g. in the Netherlands, combustible waste in Denmark, separately collected waste for reuse and recycling in Belgium/Flanders).

The non-hazardous mineral CDW may be disposed at landfills for inorganic waste (low organic content), and in some cases at landfills for inert waste (e.g. rocks, stony materials) whereas the non-hazardous CDW with organic content may be disposed at landfills accepting organic (biodegradable waste) such as municipal waste. The landfill tax for municipal waste and inert mineral waste varies significantly between countries. The EU27 simple tax average for municipal waste was in 2023 approximately 39-46 euro/tonne[56] with Latvia and Denmark applying highest taxes (95 euro/tonne respective 79 euro/tonne) whereas Italy has the lowest tax rate of 5-25 euro/tonne and for inert waste. For combustible wastes, Flanders and Wallonia apply a tax over 110 euro/tonne. Several countries have lower taxes for mineral waste, e.g. for ICEBERG countries the range is between 3 and 80 euro/tonne with Finland applying the highest taxes (waste tax increased to 80 euro/tonne for 2023).

There are different views on the impact of landfill taxes on the recycling rate (e.g. referred by Garcia (2024)[57]). Some researchers state that there is no link between landfill tax and landfilling/recycling rate whereas other researchers claim that landfill taxation supports recycling activities. Many countries apply a low taxation rate for stony waste classified as inert waste making the taxation as less effective as tool for diverting landfilling. However, e.g. for gypsum waste for which a with a high landfill taxes is applied in UK, the taxation has an impact on diverting

[54] Deloitte, 2017. Study on Resource Efficient Use of Mixed Wastes, Improving management of construction and demolition waste – Final Report, Prepared for the European Commission, DG ENV. https://op.europa.eu/en/publication-detail/-/publication/78e42e6c-d8a6-11e7-a506-01aa75ed71a1/language-en

[55] EEA 2023. Overview of landfill taxes on municipal waste used in EU Member States, 2023. https://www.eea.europa.eu/data-and-maps/figures/overview-of-landfill-taxes-on

[56] EU average is calculated as a simple average of the tax level used by the MS, and for the MS using a minimum and a maximum, both the lower and upper level of the tax are taken into account, resulting in an average lower tax level and an average higher tax level.

[57] Cristóbal García, J., Caro, D., Foster, G., Pristerà, G., Gallo, F., Tonini, D. Techno-economic and environmental assessment of construction and demolition waste management in the European Union, Publications Office of the European Union, Luxembourg, 2024, doi:10.2760/721895, JRC135470

gypsum waste from landfilling. In the interviews with ICEBERG stakeholders, it was pointed out that landfill taxes, fees and ban are an important driver for recycling of gypsum waste.

Additionally to landfill tax, also landfill gate fee and transport costs direct CDW towards recycling. Landfill gate fee vary highly in the European countries and it depends also on the waste type (typically mixed wastes with high fee).

The high cost of landfill tax and gate fee direct waste to other types of waste destinations, especially for stone waste generated in high quantities, the waste may be used in low-quality applications (e.g. backfilling)

Table 9 Landfill ban and landfill taxes in ICEBERG countries

	Belgium	Finland	France	Germany	The Netherlands	Spain	UK	EU 27 average
Mineral CDW generation per capita[58]	1 802	219	906	1074	1194	303		683
Recycling rate for mineral CDW[59]	98.2%	60.8 %	73 %	91.3 %	99.7	72.6 %		88 %
Share of recycled aggregate of total aggregate[60]	30 %	5 %	17 %	14 5 %	27 %	3 %	24 %	
Landfill tax (euro/tonne)								
• municipal[61]	63-114	80[62]	25-42	no	37	2.7	118.96[63]	39-46
• inert[64]	1.67	80	no	no	16.79	3	3.79	19[65]
Bans	sorted, recyclable waste	ban for disposal of organic waste (TOC > 10 %)	ban for landfilling certain CDW in 2030		recyclable waste			

[58] Eurostat data (wasgen), data retrieved September 5, 2023

[59] Eurostat 2024: Recovery rate of construction and demolition waste (CDW) in the European Union (EU-27) in 2020, by country. https://www.statista.com/statistics/1316268/recovery-rate-of-construction-and-demolition-waste-eu-by-country/

[60] UEPG. 2024. https://www.aggregates-europe.eu/facts-figures/figures/ (accessed March 26, 2024)

[61] EEA background report 2023. https://www.eea.europa.eu/data-and-maps/figures/overview-of-landfill-taxes-on

[62] In Finland, the landfill tax for municipal and inert waste was for 2023 increased to 80 euro/tonne (EEA report includes a lower rate of 70 euro/tonne, used in the calculation of EU 27 average)

[63] UK Government 2024. Excise Notice LFT1: a general guide to Landfill Tax - GOV.UK (www.gov.uk) (accessed March 29, 2024)

[64] Luciano, A. et al. 2022 Critical issues hindering a widespread construction and demolition waste (CDW) recycling practice in EU countries and actions to undertake: The stakeholder's perspective. Sustainable Chemistry and Pharmacy 29 (2022) 100745. https://www.sciencedirect.com/science/article/pii/S2352554122001498

[65] Cristóbal García, J., Caro, D., Foster, G., Pristerà, G., Gallo, F., Tonini, D. Techno-economic and environmental assessment of construction and demolition waste management in the European Union, Publications Office of the European Union, Luxembourg, 2024, doi:10.2760/721895, JRC135470

	Belgium	Finland	France	Germany	The Netherlands	Spain	UK	EU 27 average
Remarks		soil excluded from taxes						

Relevance for ICEBERG solutions:

- The impact of landfill taxes depends both on the waste type concerned, the level of taxation and on the country conditions (e.g. availability of landfills). In the countries with low landfill tax, the push to uptake of new recycling technologies is probably low. There is also a risk that the landfill tax direct waste to low-quality recycling (e.g. backfilling).
- Bans for landfilling recyclable waste are introduced in a few countries (Belgium, the Netherlands) and seems effectful in view of high recycling rate.

3.3.2 Taxes on virgin materials

The price of primary material does not include the environmental or climate costs of their extraction and processing which need to be covered by future generations. This gives primary materials an unfair price advantage over recycled materials. An example of a measure to increase the price of primary raw materials is the introduction of a tax on primary raw materials. Such a tax, accounting for the environmental impacts related to the use of primary materials, may support the competitiveness of recycled materials (Eckermann et al., 2015[66], EEA 2016[67]).

Only a few member states (e.g. Denmark, Estonia, France, Sweden and UK) in Europe have introduced the aggregate levy (i.e. tax on sand, gravel and rock).

UK has the highest recycling rate (proportion of recycled aggregate to total primary and recycled aggregate production) among EU member states. [68] For UK the main driver is the aggregate levy. The aggregates levy drives up the use of recycled aggregates. In UK, 24 % of aggregates used (in year 2022) was from recycled and secondary sources[69]. The aggregates levy is a tax on sand, gravel and rock that is dug from the ground or dredged from the sea in UK waters. The tax addresses the environmental damage caused by these business activities in the form of noise, dust and loss of biodiversity.[70]

[66] Eckermann, F., Golde, M., Herczeg, M., Mazzanti, M., Zoboli, R. and Speck, S., 2015, Material resource taxation an analysis for selected material resources, European Topic Centre on Waste and Materials in a Green Economy (ETC/WMGE), Mol, Belgium (http://wmge.eionet.europa.eu/sites/etc-wmge.vito.be/files/ETCworking-paper-material-resource-taxation_final.pdf).

[67] EAA.2016. Environmental taxation and EU environmental policies. EEA Report, No 17. 2016.

[68] British Aggregates Association. 2009. The effects pf the landfill tax and aggregate levy by an analysis of aggregates markets since 1990.

[69] UEPG Figures https://www.aggregates-europe.eu/facts-figures/figures/ (accessed February 9, 2024)

[70] https://www.netregs.org.uk/environmental-topics/carbon-reduction-and-efficiency/environmental-tax-obligations-and-breaks/aggregates-levy/ (accessed February 9, 2024)

In UK, quarry operators must pay a tax of £2.00 per tonne of sand, gravel or rock (corresponds to 2.34 €/tonne) Based on information in an EEA report[71] , the primary aim of the aggregate levy in UK has been to reduce the environmental costs associated with quarrying operations (e.g. noise, dust, visual intrusion, loss of amenity and damage to biodiversity). Secondly the tax aims to create a market for CDW derived aggregate by encouraging the use of alternative materials, i.e. substitute virgin aggregate materials that are exempt from the levy or recycled aggregate materials.

Another example is Denmark, also applying a tax on raw materials. However, e.g. in Denmark the tax on aggregates and stone extraction is not very high, especially compared to the high landfill tax (67 euro/tonne). Therefore, it is probably not contributing to the reduction of raw materials extraction as much as the landfill tax is pushing the level of recycling.

3.3.3 Incineration taxes

Only 9 member states apply taxes for waste incinerated with energy or without recovery. The average tax is significantly lower than landfill taxes (approximately 19-29 euro/tonne) and vary significantly from 5 euro/tonne (Italy) to 75 euro/tonne (Denmark). Some countries with incineration have a higher tax for incineration without energy recovery. Finland has a ban for incineration of recyclable waste.

The incineration tax is applied for certain wastes with the aim of making incinerating them more expensive and thus recycling and prevention more competitive. They are sometimes set at a lower level if incineration with energy recovery is used than if incineration without energy recovery is used. High existing incineration capacities might also compete with efforts to increase recycling. In addition, the effectiveness of the instruments depends on their exact design, implementation, timing and enforcement.

Main types of CDW streams sent for incineration are as follows:

- wood waste
- plastic waste
- polymer insulation waste

Based on available information it is not clear whether incineration taxes have an impact on recycling, incineration or landfilling.

3.3.4 Other proposed taxes

The Council of the European Union issued in 2023 a proposal for the introduction of a reduced value-added tax (VAT) rate specifically targeted at products composed of recycled materials [72] . A tax reduction could encourage manufacturers, consumers and the whole value chain to give priority to the use of recycled materials. This could also support the uptake of innovative recycling

[71] Legg, D. 2008. Effectiveness of environmental taxes and charges for managing sand, gravel and rock extraction in selected EU countries. EEA report, 2/2008 https://www.eea.europa.eu/publications/eea_report_2008_2/file

[72] EC, 2023. https://www.dlapiper.com/en/insights/publications/vat-monthly-alert-series/2023/vat-monthly-alert-june-2023/european-union-reduced-vat-rates-for-recycled-products

technologies, processes and business models. Increased recycling also results in savings of raw materials and creates jobs. A lower VAT on reusable construction products and construction products with recycled content could support the competitiveness of products containing recyclable materials or reuse of products (Høibye & Sand 2018[73]).

In some cases, implementing an energy tax in the production may give indirect incentives for recycling. Eckermann (2015) [74] presents as an example the production of aluminium from bauxite or iron from ore which requires far more energy than the recycling of aluminum scrap.

3.3.5 Competition to energy recovery from biobased waste

In EU, the strategies for the use of renewable energy and the circular economy and the EU waste hierarchy, sets a competition between waste recycling and energy recovery.

The Renewable Energy Directive (RED; 2009/28/EC) and the revised Renewable Energy Directive (REDII; EU, 2018) promote the recovery of waste as fuel. The major streams with high caloric value are mixed plastic waste and solid recovered fuel (SRF) from e.g. construction and demolition (C&D waste) wastes. According to the 2030 Biodiversity Strategy[75], only residues and non-reusable and non-recyclable waste should be used to produce bioenergy.

The use of waste materials with a high caloric value (paper, wood, plastics) as energy source also provides economic benefits by replacing fossil fuel e.g. in the cement industry and thermal power plants. However, there is fluctuation in prices in relation to supply and demand which hampers economic planning of the use of wooden waste streams. In the energy sector, the demand of heat varies much between seasons. Also the supply of energy from different sources influence the interest for wooden waste as energy.

For SRF, several countries have introduced a grading system for wood to be used for energy. European standards and the ongoing development of ISO 21640 have been developed for monitoring the quality of solid recovered fuel. There are already a competitive market and established concepts for SRF. The use of certified SRF according to the quality standards has supported the trading of this fuel material. In some countries (e.g. Austria, Italy), an end-of-waste concept have been introduced for SRF. SRF with the EoW status is not subjected to waste legislation.

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[73] Høibye L. & Sand H. 2018. Circular economy in the Nordic construction sector. Nordic Council of Ministers. https://norden.divaportal.org/smash/get/diva2:1188884/FULLTEXT01.pdf

[74] Eckermann, F., Golde, M., Herczeg, M., Mazzanti, M., Zoboli, R. and Speck, S., 2015, Material resource taxation an analysis for selected material resources, European Topic Centre on Waste and Materials in a Green Economy (ETC/WMGE), Mol, Belgium (http://wmge.eionet.europa.eu/sites/etc-wmge.vito.be/files/ETCworking-paper-material-resource-taxation_final.pdf).

[75] EC, 2020c, Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions 'EU Biodiversity Strategy for 2030: bringing nature back into our lives' (COM(2020) 380 final).

The Box 9 lists main bottlenecks of using recycled wood as raw material in front as energy souse.

Box 9. Bottlenecks presented in literature for use of wooden waste from construction and demolition as raw material.

- Quality of wood waste. At the construction sites, all non-hazardous waste is typically collected together and afterwards sorted manually. For high-quality applications, only full wood products (roof constructions, inner walls) can be recycled (max. 30 % of wood waste is sufficient clean for high-quality recycling).
- Sorting methods should be improved, in order to allow the recycling of different waste wood categories. (Garcia 2017[76])
- Also the logistics involved in the collection, transport and treatment significantly affect the recycling process of wood (Interreg Alpine Space Greencycle, 2018[77]).
- One of the bottlenecks of using recycled waste wood as raw material is the logistics involved in the collection, transportation and treatment. Collection logistics of waste wood is the key parameter of the supply chain. (Garcia 2017)
- Limited waste wood applications due to lack of markets different than energy production (Garcia 2017).

3.4 Identified support and regulatory barriers and gaps in legislation for ICEBERG solutions

The EU policies and strategies set future goals for legislation. The focus is on requirements for greener and safer construction products and impacts from the whole lifecycle of products need to be considered.

Table 10 summarises the barriers and opportunities given in the key legislations relevant for ICEBERG circular solutions. In EU legislations, requirements presented to address the sustainability performances of construction products (e.g. climate change effects will be mandatory in the new CPR).

Table 10 Overview of key regulation affecting ICEBERG solutions.

Regulation	Support	Barriers
Construction products regulation (new)	Digital product passport Lifecycle perspective, e.g. in harmonised standards – reporting of product information that is relevant for the installation, maintenance and removal, recycling or reuse of the product to be included in harmonised standards Commission is empowered to develop sustainability requirements for green public procurement of construction products	Reuse need further clarification for CE marking Confidentiality in data to be published still to be ensured in digital product passports

[76] Garcia, C.A. et al 2017 State-of-the-art of waste wood supply chain in Germany and selected European countries. https://www.sciencedirect.com/science/article/pii/S0956053X17306931?via%3Dihub

[77] https://www.alpine-space.eu/project/greencycle/

Regulation	Support	Barriers
Waste Framework directive	End-of-waste option for recyclables Policy obligations (such as future recycling targets for CDW and material specific fraction) can support and help steering the recycling value chain to better CDW management (the concerned waste streams are still to be defined) Obligation for sorting, separate collection of CDW -> high-quality recycling by selective removal of materials, and to ensure the establishment of sorting systems for construction and demolition waste at least	No harmonised protocols for EoW concept Clarification on product and waste status for recovered materials (under which conditions can materials/products remain with product status) Lack of collection and sorting criteria for CDW
REACH, POP regulation	Toxic free materials/products Substitution of hazardous substances if possible. Especially focussing on restriction on hazardous substances (example of substance of concern are PFAS substances, e.g. used in paints). Importance of identification and removal of hazardous materials prior to demolition (importance of pre-demolition audit) as low limits for POP substances in secondary raw materials (recycling prohibited)	Recycling of historical construction products with unknown composition Guidelines needed for surface treated products (how to assess surface materials containing banned substances)
Waste shipment	Secure sufficient feed for processes	Classification of certain waste (e.g. insulation materials containing flame retardants) as hazardous waste not fully clear. The restrictions on shipment of waste classified as hazardous (permit needed for cross country shipment – potentially a barrier for recycling) Higher administrative burden for trading waste, destined for recycling within the EU.
EU taxonomy	Support for ICEBERG solutions for high-quality recycling	Country specific conditions to be taken into account, e.g. insufficient supply of wooden materials and gypsum waste for recycling Guidance needed on how to implement the CE criteria (proofs, scope in assessment)

Regulation	Support	Barriers
Fiscal instruments (landfill/incineration taxes, taxes on virgin materials)	Increase the competitiveness of waste materials to replace virgin material	Landfill taxes, bans may lead to waste used in low-quality applications
Energy Performance of Buildings Directive	Focus on low carbon economy (= products should have low embodied energy)	Use of sprayed insulation materials may hamper recycling (difficult to separate)

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

In this section, key measures that respond to removing barriers related to uptake of ICEBERG solutions are identified and analysed. The focus is on measures related to products containing recyclables and linked recycling technologies. The aim is here to highlight measures and planned ambitions that may be of importance in future and for which regular follow-up actions may influence the business.

A key feature for securing the uptake of recycled CDW is the known quality and traceability. Also cost factors hinder recycling if no measures are taken to make the use of recyclables competitive to the use of virgin materials. The key barriers were identified by ICEBERG partners and the selection criteria of potential measures for removing these barriers is described in Chapter 2.

4.1 Overview on potential policy measures and tools supporting ICEBERG circular products

In the analysis of potential ICEBERG measures, the lessons learned in the EU Collectors project[78] on a well-working secondary raw material market were taken as a starting point (see Box 10). The main boundary conditions for market uptake have been analyzed for several household end-of-life products in the EU Collectors project. One key message is that a well-working market for secondary raw materials requires to consider the “uptake of secondary raw materials” from the view of the end-users – this is indicated with an “eye” at the right corner of the Figure 13 in Box 10. Also the information requirements of the different stakeholder groups are here indicated. These observations are also valid for the uptake of ICEBERG circular products, especially for high-quality recycling products.

Box 10. Lessons learned: Characteristics of a well-working secondary raw material market presented in the EU Collectors project

A well-working or ‘mature’ secondary market is characterised by being/having a significant share of the total market for that material (with respect to the primary material), representative prices properly reflecting demand-supply interaction, international scope of transactions, economic self-sustainability even without the support of (waste) policy, robust industrial-use capacity for recycling/recovery, good availability of market information, good product standardization. In this context it can be mentioned that the legal status of the secondary raw material as a waste can be a hinder[79].

The main difference between primary and secondary materials production processes is that while in the first case purchasers can be highly selective in choosing their feedstock qualities, the choices with respect to waste-based feedstock are restrained to the compositions and volumes of generated and collected wastes. (EU Collectors project, 2019)

[78] Vanderreydt, I. et al. 2019. EU Collector project. Deliverable 2.2 Report on boundary conditions for implementation. https://www.collectors2020.eu/wp-content/uploads/2019/09/COLLECTORS_D2.2.pdf

[79] zu Castell-Rudenhausen, M. et al. 2022. Investigating Europe′s secondary raw material markets. EEA report 22/2022. https://www.eea.europa.eu/publications/investigating-europes-secondary-raw-material

For a household waste collection system (also applicable to the CDW), the main boundary conditions from a circular economy perspective that can improve the sorting and recycling process following the waste collection are as follows:

- Quality of the waste: the (sorted) waste should meet some quality requirements to enhance recycling into marketable secondary materials.
- Traceability of the collected waste: what is exactly collected, and what not;
- Supply of collected waste: in order to be able to operate in a steady way, a minimum amount of waste must be supplied to the sorter and recycler;

Figure 13 Boundary conditions for market up-take of waste as recyclable (from the view of demand see "eye at right").[80]

Table 11 summarises potential key policy measures to support uptake of ICEBERG circular products based on the follow-up of the policy recommendations/measures proposed in the EU HISER project[81], desk study and based on views of the ICEBERG partners (discussed in workshops conducted in connections to General Assembly meetings as well as the numerous meetings with the reference group to this task). Also the reports (Section 4.10) from two regions contributed with ideas for measures. The Table presents a policy mix with interlocking elements that are likely to work best in combination to foster recycling.

The previous EU HISER project 2015-2019 (providing the most important sources for technological inputs to ICEBERG) presented measures to improve the quality of waste materials for recycling (e.g. recommendations for mandatory pre-demolition audit, selective demolition, demolition plan, sorting, etc), measures to raise the competitiveness of recyclables compared to virgin

[80] Source: EU Collectors project https://www.collectors2020.eu/.
[81] EU HISER-project (Holistic Innovative Solutions for an Efficient Recycling and Recovery of Valuable Raw Materials from Complex Construction and Demolition Waste. 2019. Deliverable D6.1. Report on Policy Recommendations

materials (e.g. GPP, standards, certification systems) and measures to increase knowledge and awareness. All listed measures are still valid.

In the following sections, some selected measures that may influence future business are discussed in more details. In the policy recommendations presented in chapter 7, actions needed for some measures are described. The focus in the measures should be to direct the waste materials to high-quality recycling and also to avoid that the policy measures (e.g., landfill taxes, bans) lead to use in low-quality applications for cost reasons.

Table 11 Overview of potential policy measures for supporting uptake of ICEBERG solutions.

Measure		Specification	Expected contribution (example)	Key actors (examples)	Reference in report
Manufacturing and design					
1	Policy actions for supporting construction products containing recyclables to make recyclables more competitive to virgin materials	e.g., taxes on virgin materials, VAT reduction for products containing recyclables, national support for local markets	demand for recyclables	national authorities	section 3.3 policy REC no 4
2	Develop environmental sustainability criteria for comparison on environmental performance of products	to develop a common approach for assessment of environmental sustainability	demand for recyclables	manufacturer, end-user	chapter 6 policy REC no 3
3	Digital product passports (including information on the recyclables) for supporting traceability	to provide relevant circularity information on recyclables	trust, confidence	manufacturer, end-user	section 4.6 policy REC no 4
4	Incorporation of environmental impact into total price of construction products (e.g., impact of landfill, downcycling)	to make recyclables more competitive to virgin materials	demand for waste material	manufacturer, end-user	policy REC no 6
5	Use of Green Public Procurement to drive demand for products with recycled content for public buildings	to set criteria and awarding for recycling of waste in tendering	demand for recyclable content in new products	public sector	section 4.5 policy REC no 5
6	Extended producer responsibility	to extend producer's responsibility to the end of their product's lifecycle	demand of recyclables in new products	manufacturer, product associations	section 4.6

Measure	Specification	Expected contribution (example)	Key actors (examples)	Reference in report
7 Take-back business models	to design products for recycling	demand for waste material	manufacturer, recycler, end-users	policy REC no 10
Pre-demolition auditing, waste sorting				
8 National/regional requirements/ guidance/ recommendations for use of Pre-demolition audit	to collect information on hazardous materials and waste materials by auditing	supply of recyclables Removal of hazardous material, estimates of waste quantities for recycling	demolition company, pre-demolition experts	Section 3.2.4 & 4.3 policy REC no 2
9 Implementation of a demolition plan with information on waste management options of recoverable streams	to evaluate the quality requirements and market uptake for recoverable streams in demolition	supply Quality, knowledge	demolition company, pre-demolition experts, recyclers, end-users	Section 3.2.4 & 4.3 policy REC no 2
10 Use of BIM (Building Information Modeling) for information on materials and quality	to collect information on waste materials using BIM	supply of recyclables estimates of waste quantities for recycling	demolition company, recycler	section 4.6.4 policy REC no 7
11 Mandatory source separation for materials for which recycling capacity exists (on-site/off-site)	to ensure quality, supply of material	supply of recyclables (quality)	demolition company, recycler	section 4.4 policy REC no 9
12 Use of Green Public Procurement in demolition work to drive demand for ICEBERG recycling process	to set requirement for recyclable content	demand for recyclables	public sector	section 4.5 policy REC no 5
Demolitions/waste management				
13 More control (e.g., inspections) of construction or demolition works in relation to the correct management of construction and demolition waste	to follow-up correct management	supply of recyclables (quality)	regional, local authorities	Section 4.10 and Appendix 2 – PART 2 Regional report Basque Country
14 Landfill tax	to make recycling more competitive as end-of-life management option	supply of recyclables	national legislators	Section 3.3 policy REC no 4

Measure	Specification	Expected contribution (example)	Key actors (examples)	Reference in report
15 Landfill ban for recyclable waste	to direct recyclable waste for recycling	supply of recyclables	national legislators	Section 3.3 policy REC no 4
16 Traceability. E.g., by using digital waste transfer notes, linked to a monitoring system and database	to collect information on availability of waste for recycling	supply of recyclables	national authorities. demolition companies	partly to section 4.3
17 Regional initiatives for recycling centers/clusters	to provide conditions for recycling of small streams	supply of recyclables	regional, local authorities, demolition companies, recyclers	Chapter 5 (interviews)
Certification/product status, knowledge and innovations				
18 Certification system for quality of recycled material	to provide relevant reliable quality information recyclables	trust, confidence	manufacturer, recyclers, certification bodies	Section 4.2.3, ICEBERG deliverable D6.4
19 End-of-waste criteria (EU wide, national, case decision)	procedures for end-of-waste	supply of material	authorities, recyclers	Section 4.2 policy REC no 1
20 Improving knowledge and skills among stakeholders in value chain	to secure sufficient knowledge of stakeholders in value chain	supply/demand of recyclables	all stakeholders	Chapter 5 (interviews) policy REC no 8
21 National economic support for development of innovative processes	to enable demonstration of demanding solutions	supply/demand of recyclables		policy REC no 4, 11, 12
22 National standards supporting innovation	to develop standards for products from innovative technologies	supply of recyclables	national standardization bodies	ICEBERG deliverable D6.4
23 National standards supporting development of EU standardization	to influence EU standardization by experience/needs at national level	supply of recyclables	standardization bodies	ICEBERG deliverable D6.4
24 Use of sustainable certification schemes (BREEAM, LEED etc.) promoting recycling	to give credits for including recyclables in new buildings	demand for waste material	builder, certification bodies, manufacturers	Section 4.8.3 chapter 5 (interviews)
25 Guidance for how to comply in CDW management with the circular economy criteria in EU taxonomy (e.g.,	to provide economic support	demand for waste material	builder, financiers	Section 3.2.4

Measure	Specification	Expected contribution (example)	Key actors (examples)	Reference in report
types of proofs needed)				

4.2 End-of-waste concept – issues relevant for ICEBERG cases

In this section the following issues are addressed:

- applicability of existing the End-of-waste concept for the new products developed in the ICEBERG project
- analysis on how ICEBERG tools and solutions (e.g. BIM-SD, RFID….) can be used to support the EoW classification procedure for the new ICEBERG products developed
- analysis of possibilities/benefits for an EoW classification of waste streams used for the new ICEBERG products developed in WP3 (here focus on some member states with EoW regulation)
- identification of knowledge gaps and information needs for development of national EoW regulation for some waste streams used in ICEBERG product solutions

The information collected in this section formed the background for the policy recommendation no 1 “Harmonise End-of waste (EoW) protocols and certification schemes for high-quality (closed loop) recycling and preparation for reuse”.

4.2.1 Background

In the national legislations in EU, the EoW concept has not been broadly applied for CDW. Only a few European countries (e.g., Austria, Belgium (Flanders), Finland, the Netherlands and UK) have introduced national legislation or protocols for stony CDW to cease to be a waste and to be used as aggregate both for unbound and bound construction. Additionally, a case-by-case decision on EoW status is applied to some extent in some member states (e.g., Ireland[82]).

Almost all member states mentioned above require also pre-auditing prior to demolition and the use of selective demolition (e.g. removal of materials containing hazardous substances or impurities and sorting of materials into different fractions). The EoW concept has especially been developed for concrete waste (List of Waste (LoW) code 17 01 01, 17 01 07). The developed national legislations include requirements on quality assurance systems and the acceptance criteria for concrete waste is mainly based on risks of release to soil and water.

In Belgium/Flanders, a system with raw materials declarations (“*grondstofverklaring*”) has successfully been implemented in legislation, and applicable for different waste streams (not limited to concrete waste) fulfilling the conditions set for EoW status (see Box 11). The approach in UK for the EoW concept differs from other countries by being based on developed Quality Protocols. The Quality Protocols are voluntary EoW frameworks for specific

[82] https://www.epa.ie/publications/compliance--enforcement/waste/FINAL-EoW-Criteria-for-Recycled-Aggregates---IMS.pdf

waste streams and end uses based on relevant EoW case law. In order to demonstrate the EoW, the processes undertaken must meet the requirements set out in the relevant Quality Protocol[83]. No environmental testing is required routinely.

Box 11. Use of Raw materials declaration in Belgium/Flanders

A raw material declaration can be issued for a specific material produced by a specific producer or resulting from a specific production process, and for which a specific application is intended. There are specific EoW criteria for secondary raw materials used as a (mineral) construction material. For recycled aggregates, the EoW criteria are further elaborated in the so called "Unity Regulation". It regulates the certification of the recycled aggregates and guarantees the quality of the aggregates and the correct use.

For other secondary (mineral) raw materials* used as a construction material, special conditions may be imposed in the raw material declaration, when added assurance for protection of the soil and groundwater is required. Through this system, a waste stream fulfilling the set criteria (maximum content of heavy metals and certain organic substances, leachability of metals) and potential additional requirements can reach the EoW status. This allows that decisions are made also on a case-by-case approach. For example, additional parameters that pose a risk can be monitored via the raw material declaration. Conditions for use (use restrictions) can also be imposed. These restrictions must guarantee the use in "the third life".

*)Some are listed in the Catalogue of raw materials (in Dutch). https://bouw.grondstoffencatalogus.be/grondstoffen/

The main challenge is the definition of a low-risk waste stream, especially for waste streams where the purity may vary and the characteristics for the waste stream depends on conditions from the use phase. Special challenges are also linked to the use of waste derived materials in indoor applications, due to risk for harmful indoor exposure. The construction products may also be contaminated during the use phase (e.g. spills) that means that the purity of EoW candidates must be controlled. For example, the Finnish EoW legislation given for certain plastic streams recovered by mechanical processes excludes plastic waste from demolition/renovation due to the risk for potential contamination of products/material streams during the use phase,. For plastic waste from demolition/renovation, only a case-specific EoW decision is possible in Finland.

The Condereff report (2022)[84] highlights the main barriers for setting EoW criteria:

- *"Lack of coherence among member states' approaches to established criteria and the classification as waste or non-waste, mentioned by many as a major barrier to the trans-frontier shipment of EoW. Different regulations among the member states, posing also competitive disadvantages for companies located in countries applying higher environmental standards, if materials with lower quality requirements are introduced in the market;*

[83] The base for the quality protocol for aggregate is a survey of different samples from the waste of concern which have been tested for different properties. A risk evaluation has also been conducted prior to the development of the Quality Protocol.

[84] Luciano, A. et al 2022. Critical issues hindering a widespread construction and demolition waste (CDW) recycling practice in EU countries and actions to undertake: The stakeholder's perspective. Sustainable Chemistry and Pharmacy 29 (2022) 100745

- *Inhomogeneities in the case-by-case EoW implementation within the same country, in particular when regional authorities are in charge of defining the EoW status;*
- *Lack of monitoring and of information on case-by-case decisions;*
- *Lack of traceability systems supporting the EoW status certification and lack of traceability of the materials once they reach the EoW;*
- *Characterization problems/costs for small batches of inert CDW;*
- *Variability of the composition inert CDW, unless selective demolition is implemented, and therefore potential presence of critical substances (such as gypsum), in specific batches."*

Table 12 summarizes national EoW criteria given in some member states for key CDW streams (EU study 2020[85]). In addition to the information in the table, there might exist national case specific EoW decisions in some countries. Additional information might be presented in the ongoing EU study financed by DG GROW and conducted by TAUW to be published in April 2024 (aiming to present a prioritisation list for CDW as EoW candidates)[86].

Table 12 EoW situation in some European countries (focus on construction and demolition Waste).

	Member states	Remark
Construction materials, aggregates	AT, BG, HR, BE, UK, NL, FIN	
Waste wood	AT, FR (packaging waste)	
Substitute fuels, solid recovered fuels	AT, IT, CZ, HR	CZ, HR – general criteria
Recovered plastics: flakes, agglomerates and granules	PT	FIN: in construction, only waste from construction can potentially be classified as EoW as contamination may occur during use phase.
Flat glass	UK	

Source: EU study financed by DG ENV (2020) – data updated for Finland.

4.2.2 Applicability of existing EoW criteria for ICEBERG cases

4.2.2.1 Applying EoW status on input material

Typically, an EoW status is given for the input material used in the recycling process. In Table 13, the waste materials used in ICEBERG products are analysed for compliance with the scope of some national EoW regulations (list not exhaustive). There are currently no EoW criteria for polyurethane nor pyrolysis oil from wood in the investigated member states.

If the ICEBERG materials are not covered or do not fulfil the conditions given by the national legislation, then a case-specific EoW decision or an environmental permit is needed.

[85] EU study financed by DG Environment conducted by Umweltbundesamt GmbH (EAA) and ARCADIS Belgium NV. 2020. Study on Member States practices on by-products and end-of-waste: Reference: N° 070201/2018/793241/ENV.B.3. https://images.chemycal.com/Media/Files/KH0420276ENN.en.pdf

[86] EU study financed by EU GROW: Background Data Collection forFuture EU End-of-Waste (EoW) Criteria of Construction and Demolition Waste (CDW) – Contract GROW/2022/OP/0015

In the EoW regulations for recycled concrete (with exception for UK WRAP protocols), there are tables with criteria to be met. These tables consist of standard values for environmental quality and regulations for the use of the construction material. The limit values refer to maximum concentrations of heavy metals (not in all countries with EoW) and organic contaminants such as PAHs. The criteria also include the leaching of elements to the soil and groundwater.

Table 13 Verification of selected EoW concepts for input materials recycled in ICEBERG solutions. LoW = European list of waste.

Input material		Flanders/ Belgium	Finland	The Netherlands	UK (waste protocols)
Concrete	LoW code	17 01 01, 17 01 02, 17 01 09			
	Application	Unbound or bound	Unbound or bound[87]	Unbound or bound	Aggregate must be destined for use in civil engineering and construction[88] and appropriate product descriptions must be used on delivery documentation. List of standards for different uses to be fulfilled.
	Remark	Certification under the Unity Regulation	Not applicable for on-site crushing of concrete waste at demolition site Low limits for leaching of SO42- (Figure 14)	A quality product certification KOMO is required.	
Brick	LoW code	17 01 02			
	Application	Unbound or bound	No specific EoW for bricks. However, concrete waste may contain up to 10 weight % bricks/tiles	No	No
	Remark	Certification under the Unity Regulation For recycling of production waste in same plant, no decision needed.			
Metal slag	LoW code	10 02 01, 10 02 02			
	Application	The Raw Material Declaration allows that decisions are made also on a	Blast furnace slag and steel slag classified as by-products (not	No	No

[87] EoW reclaimed concrete can only be placed with a distance of 2 meters above the groundwater table. Another aspect is that in the declaration of the EoW product, it has to be mentioned that the pH of the leachate of the EoW has a pH of 11.

[88] Unbound - including sub-base, capping, general fill, pipe bedding and drainage; Bound - including hydraulically bound applications, concrete and asphalt.

Input material		Flanders/ Belgium	Finland	The Netherlands	UK (waste protocols)
		case-by-case approach[89]	classified as waste)[90,91]		
Gypsum	LoW code	17 08 02			
	Application	The Raw Material Declaration allows that decisions are made also on a case-by-case approach, in line with maximum values in soils and ground water[75]	No national EoW regulation	No national EoW regulation	Recycling into new plaster boards (quality protocol defines the specifications for three material grades of reprocessed gypsum, and the sampling and test methods required to verify compliance with the specifications.

In countries with national EoW legislation, the EoW concept for use of (mineral) raw materials is covering all types of construction applications (e.g., for concrete waste both use in earth constructions as well as use in new concrete). This has led to very tight limit values for EoW concrete waste. Limit values vary between countries and are not comparable. Some member states have very strict values on certain substances, while others on other substances (the differences are caused e.g., by the protection level and the point of compliance).

If the point of compliance in the EoW concept could be set on the product level (e.g., for a specific application where binding agent are used for reaching a technical performance like compression strength), this means higher limit values can be applied as the actual environmental risks are reduced because the binding agents immobilise the release (leaching) of metals and salts. However, this means that prior to the point of compliance the waste is to be regarded as waste.

Even if the national EoW legislation covers some ICEBERG input waste materials, there are differences in approaches applied in setting EoW-criteria. The limit values are depending on the country specific policies for level of protection. Other EoW-criteria (such as certification under the Unity Regulation or the Raw Material Declaration) are based on the policy of selective demolition and separate collection at the demolition site or on the control of the production

[89] An EoW status ('grondstofverklaring', VLAREMA 2.4) can be obtained when a company can show that the use of a specific recycled material in a specific application poses no threat to health and environmental, is a useful application and the recycling company has an adequate quality insurance system. In case the company ceases to comply with one of these conditions, it loses the EoW status

[90] https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:52007DC0059&from=EN

[91] Decision psavi/42/04.08/2012

of secondary raw materials. Also the quality assurance systems differ (Luciano, 2022)[92], test method for compliance testing varies (grain-size, leaching test type (batch or percolation test)).

Main characteristics in the EoW leaching criteria for recycled concrete aggregate are as follows (see Figure 14). Some remarks:

- some countries do not include limit values for following elements: Antimony (Sb), Barium (Ba), Molybdenum (Mo), Selenium (Se), Vanadium (V), Fluoride (F), Chloride (Cl), Sulphate (SO_4)
- high differences for some elements:
    - a factor over 10 between smallest and biggest values for maximum leaching values are for Lead (Pb), Barium (Ba) and Sulphate (SO_4) and additionally factor over 5 for Arsenic (As), Antimony (Sb), Vanadium (V), Fluoride (F)

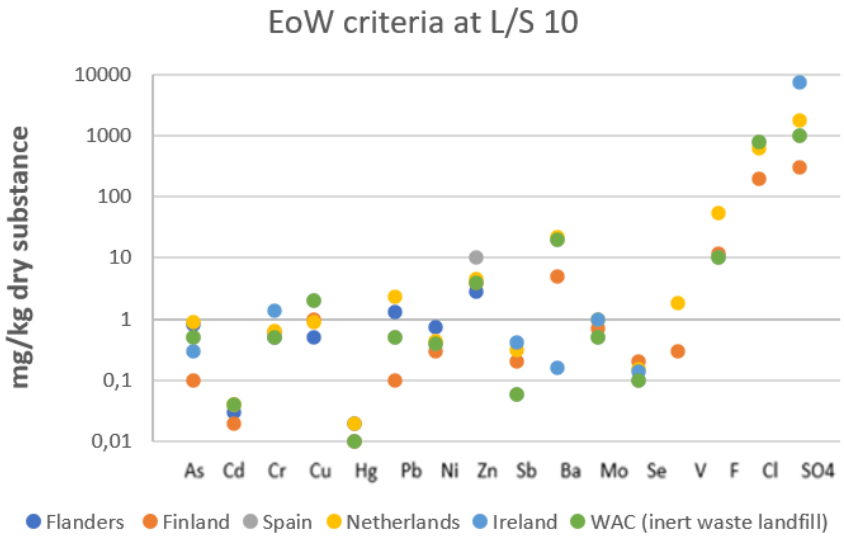

Figure 14 Leaching criteria for concrete waste in some existing national EoW legislations.[93] EoW criteria are linked to a leaching test conducted at a liquid to solid (L/S) ratio 10 (criteria referring to both batch and percolation tests). Figure includes for comparison WAC = waste acceptance criteria given for waste disposed at inert landfill (Council Decision 2003/33/EC)

4.2.2.2 Applying EoW status on end applications and intermediates (case specific assessment)

In Belgium/Flanders, the point of compliance for the waste stream to achieve the EoW status can be set after undergoing a recycling process (meaning that the

[92] Luciano, A. et al 2022. Critical issues hindering a widespread construction and demolition waste (CDW) recycling practice in EU countries and actions to undertake: The stakeholder's perspective. Sustainable Chemistry and Pharmacy 29 (2022) 100745

[93] Source: https://publicaties.ecn.nl/PdfFetch.aspx?nr=ECN-E--17-010; Finland: The Finnish EoW Governmental Decree 466/2022 for reclaimed concrete. An English translation available from the TRIS database (no 2021/667/FIN (Finland)). Ireland: https://www.epa.ie/publications/compliance--enforcement/waste/FINAL-EoW-Criteria-for-Recycled-Aggregates---IMS.pdf

end application is taken into account). In cases where the point of compliance in the EoW concept can be set at the application/product level, then the actual environmental risks can be noted. For example, for concrete waste, the concrete matrix immobilises the release of metals and salts.

The EoW status can be set on material streams used for production or also on intermediates in processing or in case of case specific EoW decision also on products. The latter is often bound to a certain feed (e.g., obtained from a specific source/plant). Possible points of compliance for the EoW as follows (see Figure 15):

1. recovered building products/materials from dismantling or selective demolition (e.g., pretreatment for reuse of structural parts). Note! in some cases, reusable products are not waste and their product status remains. The reuse of production surpluses in the production process are not considered waste treatment.
2. sorted (crushed) material recovered from selective demolition (e.g., ceramic/brick fractions)
3. pretreated/processed material/products (e.g., fines from the Advanced Dry Recovery (ADR) technology for the valorization of end-of-life concrete)
4. intermediates prepared from CDW (e.g., pyrolysis oil, aerogel)
5. products prepared from waste derived materials

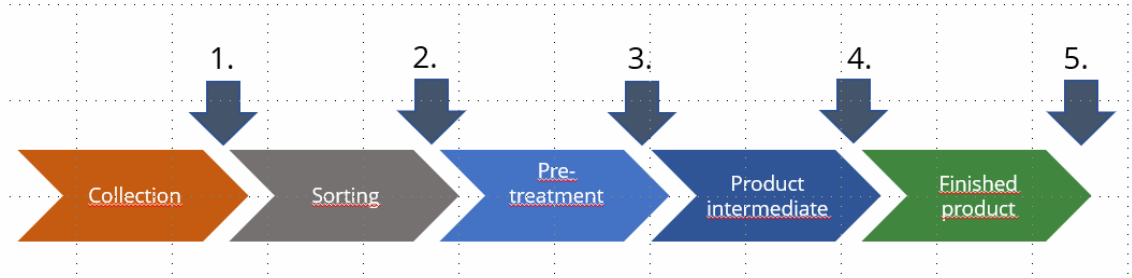

Figure 15 Point of compliance for assessment of EoW status of CDW stream.

In conclusion, a more case-by-case approval (allowing change of point of compliance to the point where the material has been processed) would be more suitable for waste streams where the process used is changing the properties of the input waste. Such as system has been established in Flanders.

Also for development of EU-wide EoW criteria, there might be a need to set the point of compliance after the waste has undergone a recycling process. For example, immobilized metals show lower leaching characteristics.

4.2.3 ICEBERG tools/systems supporting EoW concepts

The requirement for pre-demolition audit and selective demolition is mentioned in all national EoW legislation concepts for concrete waste. The most elaborated pre-demolition audit system has been developed in Flanders region of Belgium. Before the demolition works start, the demolition expert (on behalf of the client) must provide the demolition audit to Tracimat. Tracimat must approve the demolition audit. After the approval by Tracimat and when the work starts, the

contractor notifies Tracimat[94]. While the hazardous waste is removed, an inspection visit on site (to confirm removal of the hazardous waste) is performed by the demolition expert and an inspection report is drawn up. Once the inspection report is approved by Tracimat, the demolition contractor can apply for an approval for acceptance as low environmental risk material (LERM), allowing to deliver the stony demolition waste as LERM to the crusher. Once the demolition works are finished, Tracimat checks - based on a desk control of the discharge certificates/processing documents, as well as random intermediate inspections at construction sites - whether both the hazardous waste and the non-hazardous waste have been selectively and properly disposed of. If so, Tracimat will issue a certificate of selective demolition, thereby confirming the quantity and the quality of the stony demolition waste fraction. If all waste flows have been disposed of correctly, Tracimat will issue a demolition certificate.

Lessons learned defining low risk streams, benefit also other member states. The stony fraction with low environmental risk material (LERM) means a simplification in the EoW quality control schemes.

Depending on material stream, RFID tags or QR codes can in future be used for verifying traceability of pure input materials during demolition work.

4.2.4 Benefits/risks – with focus on concrete waste

Benefits:

The requirements linked to the EoW materials (e.g., quality requirements in collection, sorting) improve the quality. Quality control on input material is addressed in the national EoW legislation.

The EoW criteria make that aggregates from CDW (and other materials with a Raw Material Declaration) are considered as equal to natural materials. Stringent EoW criteria can eliminate the mistrust related to the quality of recycled materials due to negative experience in the past when the waste streams were poorly controlled and managed. The EoW criteria also reduce the administrative burden of recycling waste. If applied within a concise regulatory framework, the outcome of the assessment of the EoW criteria is faster and more transparent. Professionalism is required along the value chain.

As many companies operate in several countries, a more harmonised common practice in the way of evaluation of the EoW-status would be beneficial for all stakeholders in the value chain.

Risks:

In the interviews with manufactures, the following aspects were brought up:

- if EU-wide EoW legislation would imply that criteria are less strict than those currently used in some regions, there is a risk that material flows with low-quality will be flooding into a country with previously stricter criteria.
- for the EoW gypsum in UK, it was pointed out in interviews that if the point of compliance is before the processing, then it will be no initiatives to clean

[94] Demolition management organization for certification of selective demolition and traceability of waste

up the gypsum (remove paper, impurities) and the gypsum can be used directly in agriculture instead of used as recyclable in new plasterboard
- Problems with historical products (no background/not sufficient knowledge).
- among member states, different points of compliance used for determination of waste status.

4.2.5 Proposals for further development of EoW concepts

Pre-demolition audit and selective demolition together with waste sorting are the only ways to control the quality of CDW for EoW status. It is important that the recovered waste is free from contaminants and impurities. This is especially important for high-quality concrete aggregates for which the degree of impurities are more stringent. Also the traceability of the material streams needs to be ensured.

In interviews with ICEBERG stakeholders, the need for EoW criteria was often ranked highly. EU-wide criteria were seen as important for materials that needs to be shipped to another country for achieving a sufficient supply for the recycling process, or for companies that operate close to a border. For materials not shipped for treatment to another country, a national EoW regulation was seen as sufficient. However, there were different views on the need of EU-wide EoW criteria for concrete waste. From the experience in earlier study, the development of common EoW criteria in EU for waste materials with potential for recycling and use in high-quality applications is challenging and time-consuming due to different approaches used currently in member states with EoW criteria for recycled aggregate.

Proposal for further work:

- to set requirements for the use of pre-demolition audits and set up a management system of following-up the demolition process and the transport of the waste streams to a licenced facility (sorting or recycling unit). Here sorting standards, quality requirements and potential sampling systems can also be an important part of the EoW assessment procedure.
- the project group suggests that national EoW criteria are developed if no EU-wide EoW criteria are available. For EU-wide EoW criteria, the attention could be on harmonisation of EoW protocols for waste materials with potential for recycling and use in high-quality applications. A priority in the assessment of the EoW candidates should be on materials that can be recycled several times and giving high environmental benefits if recycled, e.g., on materials creating CO_2 savings if recovered.
- If the point of compliance could be set on application/product level, e.g. shaped/moulded products fulfilling performance criteria (e.g. durability), this would make it easier to fulfil criteria for the acceptable emissions to the environment as harmful substances would be bound to the matrix and the release very low.
- A common list of low-environmental risk materials suitable for recycling in certain applications is suggested to be developed Examples of low-risk materials are those with low content or with low leachability of hazardous

metals. Candidate waste streams for an EoW concept are gypsum and flat glass (e.g., in UK already a protocol). Additionally wastes generated in small quantities (e.g., insulation materials) and PVC.

- For ICEBERG streams such as wood waste and insulation materials, the approach for controlling environmental risks needs to be different due to the material characteristics (e.g., heterogeneity, impurities during use, potential indoor exposure – here controlling emissions is challenging and might be too complicated for creation of an harmonised EoW scheme). For chemical recycling of wood waste (pyrolysis) and insulation material (glycosis), a protocol for EoW status of intermediates and also guidance on links to REACH are needed.

A specific issue that often is not discussed but relevant in demolition process relates to how to evaluate surface-treated structures (e.g. use of glues and paints potentially containing hazardous substances). Is the removal of the surface layer needed or can it be justified to leave the surface layer? Here, a list of acceptable (containing only paints without high metal concentrations) and non-acceptable surface layers (e.g., containing PFAS, PCB) could be established.

It Is important that in the future EoW streams are included in EU waste statistics. Potentially, special recovery targets could be given to EoW streams encouraging the data collection of materials that are used in high-quality applications.

Table 14 summarises key issues to be considering in harmonisation of national/regional and case specific EoW protocols.

Table 14 Key issues to be considered in development of EoW regulations.

Issue	Focus	Suggestion for further work
Reuse (waste prevention)	Structural elements, interiors	Clarification on product/waste status
Harmonisation of approach	Low risk materials & materials creating high benefits if recycling (CO_2 savings or self-sufficiency in EU)	Drawing up a list of low-risk materials (collection of existing knowledge in member states) Harmonisation of procedures as far as possible (in harmonised procedure limit values for soil/water protection are excluded and to be set at national/regional/case level)
Point of compliance in EoW assessment	EoW assessment on product level (not feed material)	Harmonisation of tools
Pre-demolition audit		To be mandatory especially for EoW
Selective demolition	Also linked to sorting	See above
Use of sorting technologies	Sorting at site or off-site is possible	Development on sorting standards with quality requirements Potential simplification in quality control schemes for low-risk materials
Waste statistics	Reporting of waste prevented	Inclusion of EoW streams in waste statistics

Issue	Focus	Suggestion for further work
Certification schemes linked to EoW concept	Experience already in some countries (Flanders/Belgium, Finland)	Benefits and drawbacks to be evaluated Elements to be included in the certification scheme

4.3 Pre-demolition Audit – lessons learned from Tracimat

4.3.1 Background

The EU guidelines for waste audits[95] define waste audits as "the assessment of construction and demolition waste streams prior to demolition or renovation of buildings and infrastructures". They are often referred to as "pre-demolition audits".

The aim of pre-demolition audits could be described as maximizing the recovery of materials and components from the demolition or renovation of buildings and infrastructure for beneficial reuse and recycling, without compromising the safety measures and practices. In the non-binding guidelines published by the European Commission, improved waste identification is motivated with the overall aim of increasing confidence in the CDW management process and the trust in the quality of construction and demolition recycled materials.

95 Guidelines for the waste audits before demolition and renovation works of buildings. European Commission, 2018. https://ec.europa.eu/docsroom/documents/31521

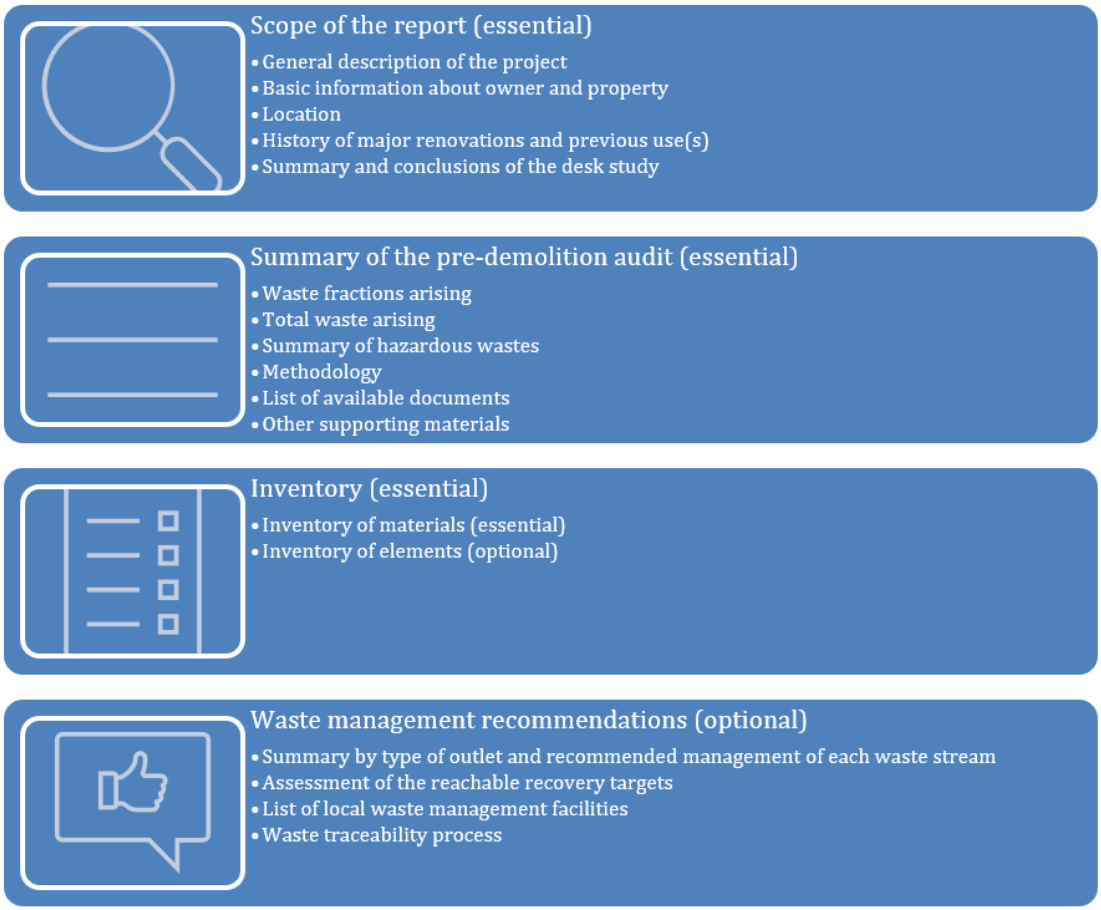

Figure 16 Preferred outline for pre-demolition audits.

4.3.2 Pre-demolition audit practices in selected countries

Although several EU countries have implemented a legal framework or guidance regarding the assessment of CDW streams (regularly in the format of a waste audit), the practices throughout the different countries are not always aligned. Table 15 gives an overview of the practices of a pre-demolition audit in different EU countries represented in the ICEBERG consortium.

It should be noted that the pre-demolition audit practices of each country aren't equally developed in detail, same goes for their purpose and implementation (in some cases mandatory, others voluntary). The table reveals the current praxis with the shortcomings and opportunities to grow for each aspect of the pre-demolition audit.

Table 15 Overview of pre-demolition audit practices in selected countries.

Pre-demolition audit practices in selected countries represented by ICEBERG partners					
	Flanders	**Finland**	**Basque Country**	**Netherlands**	**France**
Legislative framework					
National/regional obligations for using PDA	✓ (for defined scope)	✓ (for asbestos and sometimes hazardous)	✓ (mandatory in next Decree)	✓ (for asbestos and hazardous)	✓ (for defined scope)
PDA as mandatory requirement for permit	✓ (for defined scope)	× (only asbestos)	× (only estimation mandatory)	× (only asbestos and total	×
Mandatory sorting/collection of specific waste streams	✓	✓	✓	✓	✓
Inventory					
Inventory of hazardous materials, materials containing asbestos and non-hazardous materials	✓	✓	✓	✓	✓
Chemical analysis for hazardous materials	✓ (asbestos and tar)	✓ (asbestos)	✓	✓ (asbestos and tar)	✓ (asbestos and other)
Identification/listing of materials with high-quality recycling potential	✓ (sometimes)	×	✓	✓ (sometimes, 20% of cases)	×
Identification/listing of materials with high reuse potential	× (in separate reuse inventory)	×	✓	✓ (sometimes, 20% of cases)	×
Quality					
PDA carried out by qualified, independent expert	✓	✓ (for inventory of asbestos)	✓ (mandatory in next Decree)	✓ (for inventory of asbestos)	✓
Adequate education and specific training for demolition experts	✓	× (optional for asbestos)	✓	× (only for expert asbestos)	✓ (not obligatory but optional)
Verification with the management process	✓ (limited to asbestos)	×	✓	✓ (only if certified cf. SVMS-007)	×
Quality assessment of PDA by (independent) third party	✓ (detailed)	×	✓ (mandatory in next Decree)	×	×
PDA linked to a (central) database	✓	× (under discussion)	✓ (mandatory in next Decree)	×	✓
Waste management recommendations					
Recommendations regarding health and safety precautions	× (in separate safety plan)	✓ (part of demolition plan)	✓	✓ (part of demolition plan)	✓
Requirements for quality (acceptance criteria) and separation of waste	× (work in progress)	×	✓	✓ (for 10 waste streams)	×
Recommendations on recovery routes (reuse, recycling, …) e.g. list of potential processors/purchasers	× (work in progress)	×	✓	✓ (if SVMS-007, part of demolition plan)	×
(PDA linked to) a demolition and waste management plan	✓ (as of July 2024)	✓ (plans for future)	✓ (mandatory in next Decree)	✓ (if SVMS-007, part of demolition plan)	✓ (following material)

4.3.3 Tracimat's traceability system as good practice

If materials are not collected separately at the source, it is often difficult to separate them afterwards, making it impossible to get clean waste streams. This is certainly the case for hazardous materials (e.g. asbestos), but also for other materials. Mixing recyclable waste can limit or inhibit recycling (e.g., mixing aerated concrete and gypsum blocks).

However, clean streams are essential to produce good recyclates and to maintain user confidence. Therefore, there is a need for action at the source: selective demolition and traceability of CDW to establish a higher quality of CDW. This led to the recognition of Tracimat as a private and independent non-profit demolition management organisation by the Flemish government in 2017.[96]

Tracimat certifies the quality of pre-demolition audits as well as the selective demolition process by issuing a "certificate of selective demolition" for demolition waste that has been selectively and safely collected and subsequently gone through a tracing system. Because of the proper identification of all materials in a building by an extended waste inventory, the follow–up of the selective demolition process and of all the demolition waste materials set free during the works, more guaranties about the quality of the demolition waste material can be given.

In order for pre-demolition audits researching their full potential in facilitating maximum recovery of materials and components from demolition or renovation of buildings and infrastructure, an audit prior to the works should be followed by a traceability system where material processors can rely upon.

The flow diagram below shows Tracimat's traceability system with the actions for the different stakeholders throughout the process and an overview of the various certificates issued by Tracimat.

[96] Tracimat, a Flemish demolition management organisation. https://www.tracimat.be/

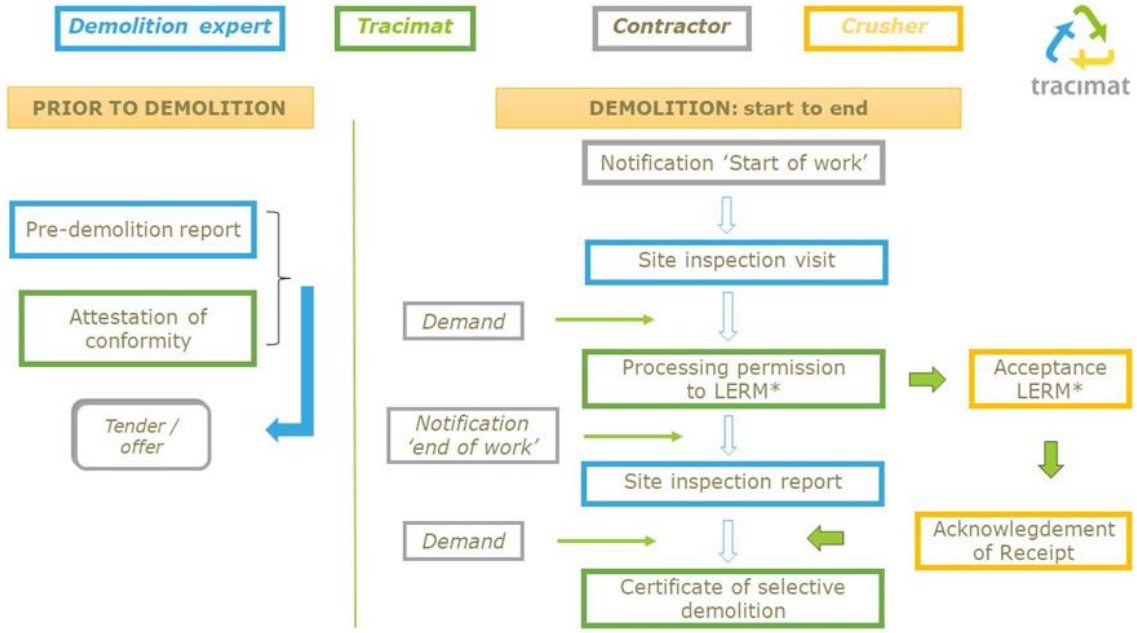

Figure 17 Flow diagram of Tracimat's traceability and quality assurance system of CDW
* LERM = low environmental risk material. LERM only applies to the stony fraction of the waste, in particular concrete and mixed debris (not including cellular concrete, glass or other impure streams in the waste).

Ideally, the elaboration of a pre-demolition audit by a demolition expert, following specific standard procedures, is the starting point of such a traceability process. Prior to demolition, the quality of the audit is checked by Tracimat, who issues an "attestation of conformity" if the report meets the legal requirements and complies with the standard procedures. This certificate, together with the pre-demolition report, is included in the tender specifications for the demolition works to inform the demolition contractor before the start of the demolition works.

The quality of the pre-demolition audit is guaranteed by Tracimat through information and in-depth training of experts and contractors on the different stages of the recycling route (e.g., identification and quantification of hazardous waste, high potential recycling waste, demolition techniques, acceptance criteria of recyclers). In addition, quality is pursued by a follow-up on site. Identification and quantification of materials is only a first step in quality assurance. Guidance and control is needed on the selective removal of the materials, as part of the traceability.

Furthermore, monitoring demolition sites allows to identify bottlenecks to which solutions are found through research projects.

An example of such a research project is the *Data-driven sloop en recyclage project*[97] funded by the Flemish government, in which Tracimat has examined how it can improve its way of working in order to strengthen high-quality recycling of CDW.

When uploading a pre-demolition audit for quality assessment by Tracimat, experts are asked to enter the total estimated quantities of all materials for uptake

[97] Data-driven sloop en recyclage. Project for Vlaanderen Circulair, 2023. https://www.tracimat.be/editor/files/2023/03/230317_Data_driven_sloop_en_recyclage_Eindrapportage.pdf

in the Tracimat-database defined by a list of materials. In this research project, acceptance criteria of material processors were collected and translated to the Tracimat-tools: drawing-up 'recycling sheets' for take-up in the pre-demolition audit template and detailing the list of materials in order to differentiate between materials flows with different recycling processes.

The research results show that collecting information for take-up in pre-demolition audits as well as recommendations for selective demolition are very material dependent. Furthermore (considering the extra regional nature of the ICEBERG-project) collecting essential information for the assessment of recovery routes, might be location dependent as well, i.e. dependent on regional recycling facilities and their acceptance criteria.

4.3.4 Pre-demolition audit and EU Taxonomy

Zooming in on the construction and real estate sector in the EU Taxonomy[98], more specifically on the activities of demolition and renovation of buildings, it is clear that for the contribution to the circular economy objective, the pre-demolition audit plays an essential role. For both activities, the pre-demolition audit is mentioned as one of the *substantial contribution criteria* saying it should be in line with the EU CDW Protocol[99]. Although the pre-demolition audit isn't explicitly mentioned for the *do not significant harm criteria* concerning circular economy, again the accordance with the EU CDW Protocol is emphasised. But this Protocol consists of non-binding guidelines, which is insufficiently measurable and rather a guide to good practice than a checklist with hard criteria. So how can one demonstrate compliance with the EU taxonomy?

The EU taxonomy poses a need for a common framework such as for the interpretation of the criteria, the reporting documents as well as the necessary data flow. It should be noted that the CE criteria refer to a framework called *Level(s)*, indicator 2.2 for CDW and materials[100]. This among others provides an excel template for estimating (Level 2) and recording (Level 3) amounts and types of CDW and their final destinations. Although at first glance the excel looks rather cumbersome, the content and purpose are in line with the pre-demolition audit.

In the taxonomy, a minimum percentage (by weight) is set for non-hazardous CDW on the demolition site to be prepared for re-use or recycling. This means that a verification with the management process is necessary to check the actual quantities recovered and to proof that the waste planned to recover is actually reused/recycled. In other words, a pre-demolition audit alone is not sufficient proof of compliance with the EU taxonomy. Its qualitative follow-up is a necessary sequence, which is implicitly indicated in the CE criteria of the EU taxonomy.

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[98] EU Taxonomy Navigator. European Commission, 2024. https://ec.europa.eu/sustainable-finance-taxonomy/taxonomy-compass/the-compass

[99] EU Construction and Demolition Waste Protocol and Guidelines. European Commission, 2018. https://ec.europa.eu/newsroom/growth/items/455097/en#:~:text=Its%20overall%20aim%20is%20to,Improved%20waste%20logistics

[100] Level(s) indicator 2.2: Construction waste and materials. JRC Technical Reports, 2021. https://susproc.jrc.ec.europa.eu/product-bureau/sites/default/files/2021-01/UM3_Indicator_2.2_v1.1_40pp.pdf

The traceability system of Tracimat is an example of such a qualitative follow-up. Many aspects that are mentioned in the criteria of the EU taxonomy are reflected in this system. For example, the minimum percentage stated in the CE criteria can be verified using the “certificate of selective demolition” that is issued by Tracimat, which contains information on the waste treatment, the effective amount of waste disposed and its first destination.

Although the pre-demolition audit and its qualitative follow-up partly overlap with the EU taxonomy, there is not yet a concrete and simple way to demonstrate that all criteria are met. However, this streamlining would bring many benefits. A company would no longer incur additional costs in reporting for the EU taxonomy (at least for the circular economy objective and in the context of demolition/renovation of buildings). On top of that, it provides additional motivation to prepare a pre-demolition audit and pursue its qualitative follow-up.

4.3.5 Barriers and opportunities of pre-demolition audit

The potential for growth of a pre-demolition audit (PDA) in the context of waste management is shown in the table in section 4.3.2. A demolition and waste management plan prepared by the contractor can provide an overview of how the site will be organised and, ideally, gives recommendations for health and safety precautions and precautions to be taken during deconstruction regarding recovery. The demolition and waste management plan should be considered alongside the PDA. It is also useful to provide information on quality requirements, source separation and recommendations for possible recovery routes. For example, a PDA may include a list of potential processors/purchasers and their acceptance criteria. This is not yet common practice in most EU countries, as the table shows. Overall, a verification of the PDA with the management process is an important step in ensuring the quality of demolition works. Additionally, the pre-demolition audit usually doesn’t focus on reuse. However, reuse cannot be promoted without a proper pre-demolition audit.

In the CITYLOOPS project[101] Mikkeli is mentioned as an example where reusable items are connected to a digital marketplace. In Flanders, reuse is not yet integrated in the PDA. However, multiple parties (researchers, demolition experts, the government...) are examining the application of a ‘reuse inventory’. Even though there are already several initiatives (e.g. opalis.eu), there is a need for a unified template or platform, accessible and applied by everyone. The extra data on the ‘reuse potential’ of different materials should then be incorporated in the pre-demolition audit. When uploading the pre-demolition audit on the Tracimat’s portal, the extra information on reuse is integrated in the databank. This would make it possible to link information on reuse of materials to a digital marketplace, as mentioned in the CITYLOOPS example.

[101] Circular construction in Europe: handbook for local and regional governments, 2023. https://cityloops.eu/fileadmin/user_upload/Resources/City-Loops-Circular-Construction-handbook.pdf

4.4 Requirements on sorting for waste for which recycling capacity exists

In this section, a follow-up to the information in HISER-report[102] is presented.

4.4.1 Background

Many European countries have requirements on sorting of specific waste fractions (e.g., concrete, gypsum, wood, plastics) in their legislation. Sorting of CDW is crucial for enabling reuse and high-quality recycling. The material recovery also minimises the amount of waste to be landfilling or incineration.

CDW can be sorted at a demolition site or at the processing site for CDW (e.g., in case of limited space in renovation/demolition works). Ideally, different types of materials are collected separately at the site. Mixing of different CDW streams prevents in many cases high-quality recycling as the recycling processes typically set restrictions for the feed quality (limits for impurities or hazardous materials).

The base for sorting of specific material fractions is the information on quality requirements for recycling and reuse set by the recycler or end-users and also the market information (demand for sorted fractions and also information of availability of recycling plants interested in the sorted fractions). The sorting possibilities are dependent on the separability of materials in the building to be demolished. Materials attached to other materials need to be crushed prior to separation in order to be collected separately (methods described in the HISER report). Especially challenging is materials covered with sprayed products or glued products, which are not designed for recycling.

Furthermore, information on hazardous materials, e.g., reported in pre-demolition audits, needs to be considered and the undesirable materials removed - if possible - prior to the demolition works. The importance of removing of all hazardous substances is described in section 3.2.3.

Information on technologies for sorting/concepts is needed. Technologies for automated sorting are also entering the market. Furthermore, the rapid development of new innovative recycling technologies requires constant updates of information on quality requirements on the feed material.

Information on quality requirements for specific CDW is often scattered even if reported in several sources. Some guidelines/background documents are available on quality requirements and recycling options but typically these only address one aspect to be known in sorting.

Examples of background documents on CDW management and requirements are: the PARADE education documents on hazardous materials [103], and

[102] HISER project, 2019. D6.1 Report on Policy Recommendations, https://ec.europa.eu/research/participants/documents/downloadPublic?documentIds=080166e5c10510a8&appId=PPGMS

[103] Wahlström et al., 2019. Hazardous substances in construction products and materials: PARADE. Best practices for Pre-demolition Audits ensuring high quality Raw materials. https://cris.vtt.fi/en/publications/hazardous-substances-in-construction-products-and-materials-parad

recyclability/reusability of key waste streams[104] and the Spanish Guide to the Use of Recycled Materials in Construction[105].

4.4.2 Towards high-quality recycling - Quality assurance for sorting facilities

It is necessary to distinguish between quality requirements of CDW for recycling in high-quality applications (with the meaning of meeting specifications of non-recycled products to be substituted) versus low-quality applications (with the meaning of downcycling) in future work (Garcia et al., 2024[106]). It is crucial that the quality of the recovered waste is suitable for high-quality recycling (closed loop).

The management of concrete and brick waste have the highest potential in terms of environmental improvements (e.g., use as aggregate in concrete or replacing cement), especially considering the high share of this fraction in the total CDW. Other examples of high environmental (CO_2 savings) benefits relate to the recycling of PVC and aluminium. In renovation works, the glass waste is one of the dominating streams due to renewal of windows in renovations for energy savings. In Box 12 some illustrative examples of the importance of sorting for high-quality recycling are collated.

[104] Bergmans et al., 2019. Recyclability and reusability of key waste streams: PARADE. Best practices for Pre-demolition Audits ensuring high quality RAw materials. https://cris.vtt.fi/en/publications/recyclability-and-reusability-of-key-waste-streams-parade-best-pr

[105] Ihobe, 2018. Guía para el uso de materiales reciclados en construcción. https://www.ihobe.eus/publicaciones/guia-para-uso-materiales-reciclados-en-construccion-3

[106] Cristóbal García, J., Caro, D., Foster, G., Pristerà, G., Gallo, F., Tonini, D. Techno-economic and environmental assessment of construction and demolition waste management in the European Union, Publications Office of the European Union, Luxembourg, 2024, doi:10.2760/721895, JRC135470.

Box 12. Examples of CDW streams where the sorting is crucial for high-quality recycling[107]:

- **Stony materials** may at demolition site be collected together with other stony materials, e.g., concrete and bricks. These fractions are interfering the production of high-quality aggregates for recycling.

- **Aluminium scrap** can be mechanically recycled into new aluminium products by shredding and sorting. Most aluminium scrap from demolition ends up at the smelter via a scrap recycler. The scrap recycler usually does not distinguish between high- and low-value applications. Today, it is possible to sort other metals from aluminium scrap via high-tech sorting lines. However, the technology to distinguish between different aluminium alloys is still under development.

- **PVC profiles,** PVC tubes and flexible PVC products should be separately sorted for recycling. PVC for recycling from post-consumer PVC profiles can be mechanically recycled back to new PVC profiles through two cycles of sorting and grinding. PVC tubes have different quality characteristics (contain less titanium and more chalk) and need to be separated physically (e.g. by density) and directed to another recycling route. Due to a lack of inspection mechanisms, PVC recyclate for the production of profiles can only be recycled in non-visible parts of PVC profiles. The technology required for high-quality recycling of PVC window frames (again and again) is already available in Flanders.

- **Glass** can be classified in different ways. Important for the recycling process are a distinction between flat glass and packaging glass, as well as a distinction between ordinary and heat-resistant glass, called 'soft glass' and 'hard glass' respectively. Applications of heat-resistant glass include laboratory glass, pharmaceutical glass, lighting, cookware, oven glass and hobs. Glass is inert and can be mechanically recycled again and again into new glass products. Postconsumer flat glass can be recycled into new glass products by sorting, cleaning and grinding it into cullets. To the extent that cullets meet European End-of-Waste criteria after the above steps, they acquire raw material status at that point. The cullet with the highest quality can be processed by the flat glass industry into new flat glass by remelting it. The technology required for high-quality recycling is already available in Flanders. Lower-quality cullet is recycled into packaging glass or mineral insulation.

The material acceptance for high-quality recycling sets needs for a quality assurance system for the recycling process (also covering the origin of the waste material processed). Especially for the end-of-waste status, the management system of the material supplier needs to be certified by a third party conformity assessment body (e.g. accredited body qualified for the activity).

For high-quality recycling, the quality assurance system involves all actors along the value chain. For EoW materials (e.g., metals), also a certification scheme with a third party for controls is needed. For example, the EoW regulation

[107] Tracimat & Buildiwse, 2023. Data-driven sloop en recyclage. Project funded by Vlaanderen Circulair. https://www.tracimat.be/editor/files/2023/03/230317_Data_driven_sloop_en_recyclage_Eindrapportage.pdf

(1179/2012) [108] for glass cullet requires a set of documented procedures concerning each of the following aspects:

- monitoring of the quality of glass cullet resulting from the recovery operation (including sampling and analysis);
- acceptance control of waste used as input for the recovery operation;
- monitoring of the treatment processes and techniques;
- feedback from customers concerning compliance with glass cullet quality;
- record keeping of the results of monitoring conducted under points (a) to (c);
- review and improvement of the management system;
- training of staff.

Similar types of quality assurance systems are also needed for other streams for high-quality recycling.

4.4.3 Relevance for ICEBERG cases

In almost all interviews conducted with ICEBERG stakeholders, mandatory sorting requirements for waste for which recycling possibilities exist were ranked as highly important. Here it is important that the requirements for recycling of materials are communicated to the demolition contractor.

The demolition contractor can take extra effort in the demolition activity. However, this will raise the demolition costs to be covered by building owner. Demolition of buildings involves the use of various methods, such as excavators or drills, which can significantly affect the composition and quality of CDW. The main obstacles to achieving high-quality CDW involve economic considerations, uncertainty about the quality of separated materials, and the risk of damaging reusable construction products during demolition. Implementing a traceability system could improve trust in the recovered materials' quality.

It was also emphasized in interviews that the construction products used in buildings are often not designed for recycling, making waste sorting very challenging.

Guidelines for the quality assurance system (e.g., procedures for control, skills) are needed. Especially for EoW materials, a certification scheme involving a third party inspection would create trust for the quality of the sorted material.

4.5 Green Public Procurement criteria supporting recycling and reuse

In this section, the current status for GPP criteria for recycling was analysed. The outcome from the analysis and the information from the regional policies (see section 4.10) was used for the development of the ICEBERG policy recommendation no 5 “Use GPP to support reuse and recycling”.

[108] EC. 2012. Commission Regulation 1179/2012. stablishing criteria determining when glass cullet ceases to be waste under Directive 2008/98/EC of the European Parliament and of the Council, https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32012R1179

4.5.1 Background

Green Public Procurement (GPP) is a voluntary instrument defined as "a process whereby public authorities seek to procure goods, services and works with a reduced environmental impact throughout their life cycle when compared to goods, services and works with the same primary function that would otherwise be procured."[109] The public sector organizations can apply environmental criteria in the public procurement processes in construction, renovation and demolition work. The GPP is a potential tool for enhancing the demand of products with recycled content, or directing waste recovered in demolition works for recycling.

In the second CEAP (2020)[110], the Commission set a goal to propose sectoral legislation for minimum mandatory GPP criteria and targets related to product reuse, recycling, remanufacturing and end-of-life in order to enhance circularity. For promoting circularity principles throughout the lifecycle of buildings, the EU Level(s) is proposed to be used to integrate life-cycle assessment (LCAs) in public procurement and the EU sustainable finance framework.

The New CRP (2024) presents initiatives for the development of green public procurement rules for construction products. The Commission is given the task to establish mandatory minimum environmental sustainability requirements through delegated acts for public procurement of construction products, to incentivize supply of and demand for environmentally sustainable products. These rules can apply to every contract that contains construction products, including contracts for construction works, where Member States want to introduce environmental requirements for these products.[111] The new CPR does not specify the minimum environmental sustainability criteria, which will be given separately in delegated acts for different product groups concerned. However, the Annex I.3.3 to the new CPR on Inherent Product Environmental Requirements includes examples of requirements, such as whole life cycle greenhouse gas emissions, resource efficiency, and reusability.

The national strategies for circular economy presented by many EU countries define construction sector as a prioritized sector. The goal, for example, in the Nordic countries is to support increasing innovation through more circular projects by setting requirements on climate and environmental savings in public procurements.[112]

4.5.2 Examples of public procurement criteria for recycling and reuse relevant for ICEBERG solutions

Many EU countries have adopted national GPP plans for the use of green public procurements for construction. As an example, Italy has as a first EU country

[109] European Commission COM (2008) 400 final Public Procurement for a Better Environment. http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2008:0400:FIN:EN:PDF

[110] https://eur-lex.europa.eu/resource.html?uri=cellar:9903b325-6388-11ea-b735-01aa75ed71a1.0017.02/DOC_1&format=PDF

[111] https://www.consilium.europa.eu/en/press/press-releases/2023/12/13/circular-construction-products-council-and-parliament-strike-provisional-deal/

[112] Simon Kaarsberg and Lea Kress. 2023. Policies Enabling the Reuse of Construction Products in the Nordics. Nordic Innovation. 2023. https://pub.norden.org/us2023-441/us2023-441.pdf

published following mandatory criteria for GPP in building projects for promoting closed loop with the following requirements[113]:

- minimum and certified recycled content in all major construction materials and products;
- mandatory implementation of pre-demolition audits;
- mandatory compliance with the 70 % recovery threshold for construction and demolition waste as required by the European Waste Directive;
- obligation to implement selective demolition processes as well as;
- design for disassembly/deconstruction for 50 % of all materials use.

Guidelines for the use of green public procurement for construction works have been published by numerous countries, cities and regions. For example, in the Basque country, a guide [114] for environmental criteria for Green Public Procurement defined for different construction product categories. The Finnish Ministry of the Environment has developed a guideline [115] for GPP for the demolition of public buildings. Several regions/cities are developing criteria for GPP in construction and demolition work (e.g, CITYLOOPS Deliverable D5.5[116]),

The EIT KIC-report[117] reviews the benefits of incorporating circular procurement at city and district level. The report contains procurement examples in 10 city cases covering design, maintenance, renovation and demolition works. Several bottlenecks were identified as obstacles to circular construction procurement at a municipal level, including unclear or vague expectations of the purchaser, discrepancies between the planning and implementation (i.e. lack of enforcement), and lack of circular economy expertise at every stage of procurement.

At the EU level, applicability of different Green Public Procurement criteria for the procurement process for office buildings has been presented by JRC (2016)[118]. Among others, the criteria can be set to award resource use for specific construction products (e.g. incorporation of recycled or re-used content in concrete and masonry) or lifecycle activity (e.g. maximum waste generation per square meter in renovation works) or use of non-toxic material in construction (e.g. flooring materials complying to given indoor air emission limits).

[113] According to information presented by the CONDEREFF project, referred by Luciano, 2022 in Interreg project website. https://www.interregeurope.eu/good-practices/mandatory-italian-gpp-minimum-environmental-criteria-for-buildings

[114] https://www.ihobe.eus/criterios-ambientales

[115] Kuittinen, M. 2019. Circular economy in public demolition projects. Procurement guide. Publ. of the Ministry of Environment 2019:31. http://urn.fi/URN:ISBN:978-952-361-038-5

[116] Circular Procurement in Europe: Handbook for local and regional governments Deliverable 5.5 cityloops.eu

[117] EIT Climate, KIC's Circular Cities project. The challenges and potential of circular procurements in public construction projects. White paper. Procurements-in-Public-Construction.pdf (climate-kic.org)

[118] EC 2016, EU GPP Criteria for Office Building Design, Construction and Management: https://ec.europa.eu/environment/gpp/pdf/swd_2016_180.pdf

A JRC draft report (2022)[119] frames aspects and approach that could be used for developing a concept for the use of GPP in public tenders. New Green Public Procurement criteria for buildings is set to include requirements on energy consumptions and GHG, material circularity, efficient use of water resources, occupant comfort and wellbeing, vulnerability and resilience to climate change, and life cycle costing, and biodiversity. For example, for demolition works, it is suggested following the methodology defined in Level(s) indicator 2.4 ("Design for deconstruction, reuse and recycling") that a minimum circularity score of 40% by mass and 40% by cost shall be demonstrated. Here also recycling *results* and experiences demonstrated in EU projects for specific material flows could be used as examples of potential indicators and criteria.

Also the EU CIRCuIT project[120] concludes based on inputs from the cities participating in the project as follows:

- criteria currently in use focus primarily on new construction and material circularity; they often rely on third-party certifications; and
- they are often formulated as award criteria, rather than minimum requirements.
- The criteria set in guidelines are typically rather general.

According to interviews carried out in the CONDEREFF project, the GPP is still only implemented to a limit extent in the EU as the mandatory criteria are seldom set in the tendering documents. The price is often still used as awarding criteria in case not policy measures influence the decision for reuse and recycling. Also the lack of knowledge among the authorities for formulation of tenders as well as in decision making was mentioned as barrier for the use of GPP to support the recycling.

Box 13. EU CIRCuIT project – Criteria for public tenders on construction https://www.circuit-project.eu/

The EU CIRCuIT project supports the creation of regenerative cities by implementing sustainable and circular construction practices. One task in the project was to develop a set of (technical) criteria relevant to circular construction that could be used within public tenders of construction and refurbishment of public buildings and open spaces and to provide recommendations for public procurement in cities.

A short summary of the results of the task (published as D7.4 Recommendations: Criteria for public tenders on construction):

- public procurement for municipality buildings and for the competitive tendering for construction on municipal land gives municipalities the opportunity to implement their vision and pioneer new circular solutions to inspire private developers.
- the following bottlenecks were observed for achieving high ambition circularity goals in cities through procurement: lack of mandatory frameworks and policies, lack of clarity in terms of circular economy concept and specific criteria, and overreliance on third-party sustainability certifications.

[119] Donatello et al., 2022. EU Green Public Procurement (GPP) criteria for the design, construction, renovation, demolition and management of buildings. https://susproc.jrc.ec.europa.eu/product-bureau/sites/default/files/2022-03/GPP_Buildings_TR_v1.01.pdf

[120] https://www.circuit-project.eu/

- Based on the market engagement and CIRCuIT's experience, tender criteria work best when formulated as minimum requirements and not awarding criteria.
- the task provides suggestions for new circularity criteria and for the approach to evaluate the bids, that municipalities could incorporate into their public procurement policies and tender strategies. Tender criteria were developed for various projects (renovation, demolition, and new construction) and various tenders (project development, design, and execution stage) that municipalities can use in their own procurement processes.

Box 14. EU CITYLOOPS[121] - Closing the loop for urban material flows project

Cityloops demonstrated the potential of small to medium sized city administrations in guiding the transition to a circular economy (CE), with one focus on CDW management. The project showed the possibility to upscale these approaches in the cities/regions involved and replicate them in other European regions.

CityLoops developed a circular procurement handbook, aiming to inspire and guide procurement professionals, local and regional European public authorities of all sizes, policymakers– as well as private entities that want to know more about the current procurement practices – to use the purchasing power in their transition towards a circular economy.

The handbook provides tools to establish the necessary conditions for both internal and external factors, including stakeholder engagement and knowledge creation, to facilitate the effective implementation and success of a circular procurement project. Furthermore, it offers practical guidance for project implementation. This includes examples and tools for incorporating circular procurement practices during the pre-tender, tender, and post-tender activities. Finally, it outlines methods to ensure the scalability and integration of these activities as the new norm within an organization.

In addition to the Circular Procurement Handbook[122]), CityLoops also developed a Circular Procurement Toolkit[123]), aimed at local and regional governments. The toolkit provides an overview of all the public procurement tools developed in the CityLoops and the different phases (pre-tender, tender and post-tender) in which they should be applied for CDW.

The aim of the toolkit is to assist cities in implementing circular procurement strategies for managing construction demolition and bio-waste more sustainably. By adopting circular procurement practices, cities can promote resource efficiency, reduce waste generation, and contribute to a more sustainable construction sector.

[121] www.cityloops.eu

[122] Circular construction in Europe: handbook for local and regional governments. 2023; https://cityloops.eu/fileadmin/user_upload/Resources/City-Loops-Circular-Construction-handbook.pdf

[123] Deliverable D5.3. Circular Procurement Toolkit
https://cityloops.eu/cities-and-the-circular-economy/circular-procurement

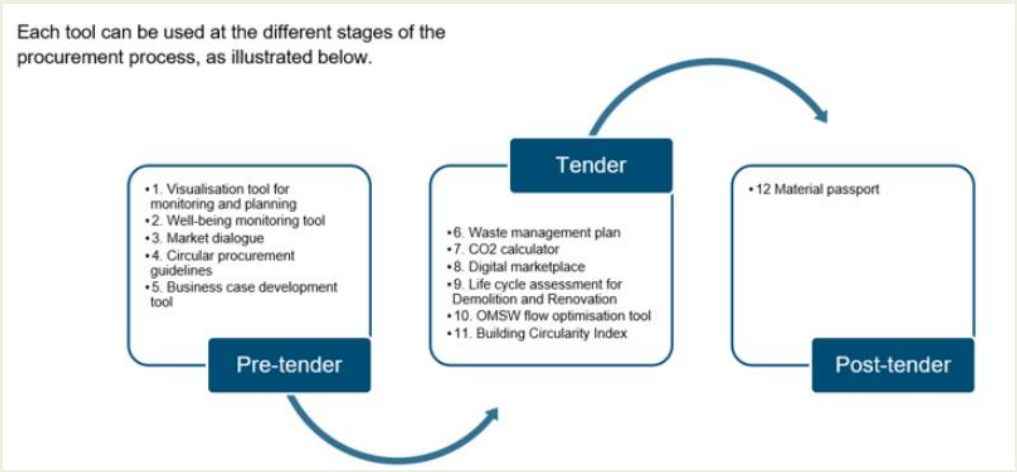

Figure 18 Circular Procurement Toolkit

4.5.3 Relevance for ICEBERG circular products

To raise the competitiveness of construction products containing recyclables, it is important that sustainability criteria promoting circular economy goals are included in the procurement tender. The decision makers need to get information on how to introduce the sustainability criteria in procurement tenders (e.g., selection of suitable criteria for construction products containing recyclables). Procurement can also be set for demolition works to promote the use of the pre-demolition audit, selective demolition and waste sorting.

The experience from ICEBERG circular products can provide a base for the development of procurement criteria (see Chapter 6). The use of sustainable criteria sets needs for new knowledge of public authorities, construction products manufacturers and e.g., architects/designers, constructors selecting products for constructions and renovations.

The GPP can also be used to support demonstration of innovative technologies and could thus through a successful demonstration promote the uptake of ICEBERG circular solutions.

4.6 Digital Product Passports

4.6.1 Background

Lack of information and traceability on the (construction) product as well as lack of sharing information in the value chain are often mentioned in literature as barriers for circularity. Digital product passports (DPPs), material passports, circularity passports etc, have been proposed as a tool for increasing traceability and facilitating circular practices. DPPs collect and store data on all life cycle phases of a product, and share it across the entire value chain for different stakeholders. Typically, the information is accessible via e.g., QR code, RFID or similar data carrier, and stored in a centralized or a decentralized data storage system (e.g., cloud platform).

DPPs have been introduced in various EU policies and regulations including for example battery regulation and Strategy for Sustainable and Circular Textiles.

Moreover, it is also included in the revised version of the Construction Products Regulation (CPR), which introduces the construction DPP system, building on the DPP established in the ESPR, and including e.g., safety information, instructions of use, and the declaration of performance and conformity.

4.6.2 Objective of analysis

Despite the presumed benefits of a DPPs for circularity, there are some notable gaps in literature, particularly within the construction industry. Therefore, a Master's thesis[124] was carried out to study:

- the benefits of a DPPs
- the data needs of key stakeholders in the construction product value chain for a DPP
- the barriers and challenges in implementing the DPP.

The study was carried out in January-June 2023, and the results are based on literature, interviews and an online survey. In stakeholder interviews, the aim was to obtain insights on DPPs from the perspective of key stakeholders in the construction industry. The interviews aimed not only to recognize the benefits and barriers of a DPP, but also to assess the attitudes and current views. In the survey, the aim was to gather quantitative data on the research topic, and to complement and verify results of the interviews.

4.6.3 Outcome of the thesis study

Within the thesis study, several benefits were identified for DPPs, which stem from enhanced traceability, and are connected to different stages of a product's life cycle. From improved resource efficiency to facilitated decision-making, accessible information retrieval and improved data management, the findings emphasize the role of the digital product passport in transforming to a circular economy. Especially the following aspects were highlighted as potential benefits:

- Improved traceability and transparency
- The access to product information, history and life cycle was considered beneficial. Moreover, the digitalization of product information and enabling direct access to information for all actors throughout the value chain was seen as a valuable aspect.
- The facilitation of the reuse practice with a DPP was strongly highlighted.
- DPP could be useful during project planning and execution, not only by organizing the construction phase regarding e.g., logistics and transportation, but also by efficient resource allocation.

To ensure that the digital product passport is beneficial, the identified required contents include manufacturing, usage, end-of-life and lifecycle data. The main barriers that could impede successful implementation of the tool include business confidentiality issues, such as protecting intellectual property. Other challenges involve ensuring data quality, for instance, keeping the information up to date.

[124] https://aaltodoc.aalto.fi/server/api/core/bitstreams/0f4c25ec-e9a7-4827-9950-060a6294847c/content

In both interviews and survey, all data types, i.e. manufacturing, usage, end-of-life and life-cycle data, were considered relevant in a DPP. Especially the following data types were deemed important in the interviews/highlighted in the survey:

- Interviewees particularly emphasized manufacturing data, more specifically, the technical data, information on the product composition, physical and chemical properties, and other product information. Some interviewees pointed out that certain data may currently seem irrelevant but turn out to be useful in the future or they may not recognize its relevance.
- Information of material contents (such as physical and chemical properties, hazardous materials and the source of materials) was considered the most important by survey respondents.
- Recycling and disposal instructions including extended producer responsibility (EPR) obligations.
- The information on environmental impacts and circularity performance.

Based on the thesis work, while DPP systems are being established for various sectors, there is still a lack of a standardized framework, regarding e.g., data content, format, storage and interoperability. Future research should further refine the framework by determining precise data of each data type. Moreover, the study indicates that the data content of a digital product passport should be tailored to each product group. Herein, an optimal level of detail that adheres to intellectual property while ensuring transparency needs to be found.

4.6.4 Future actions /conclusions

DPPs for construction products will be mandatory in 2028. The data requirements are defined in ESPR and specifically for the construction products also in the new Construction Product Regulation (CPR). The examples are presented in Table 16.

Table 16 The most relevant data fields from DPP

Data category	Examples of data fields
Administrative	unique product identifier, data carrier, passport level, accessibility
Substances of concern	names, locations, concentrations, instructions for safe removal
Product performance	durability and reliability of the product or its components; ease of repair, maintenance, upgrading, re-use, remanufacturing, refurbishment and recycling; weight and volume; environmental or carbon footprint ; microplastic release; generated waste
Instructions and guidance	installation, maintenance, repair, disassembly, return and disposal
Other relevant information	information under other Union law and so on

The use of a Digital Building Logbook (DBL) is not regulated at the moment, but based on the EASME report[125], large parts of the required data will be readily available in DPPs and possible to exchange in IFC format (see Table 17).

Table 17 The most relevant data fields from DBL

Data category	Examples of data fields
Administrative	Unique building identifier, maintenance, utilities, and licenses
General information	Year built, soil/terrain, accessibility, safety manual
Building description and characteristics	BIM, design documentation, technical systems and utilities, expected lifetime, fire evacuation plan, historical context
Building operation and use	EPC rating, total calculated energy consumption, renovation recommendations, climate resilience potential
Building material inventory	Types, locations, volumes/weights, embodied carbon, life span, waste categories, chemical declarations, certificates
Smart readiness	SRI result, smart district potential, demand/response potential, charging infrastructure for e-mobility
Finance	Property value, maintenance cost, yield, valuation, other costs

Independently on the development of ESPR and CPR, the ICEBERG project consortium identified certain data fields that would be important for the information exchange in the project scope. They are identified in Table 18.

Table 18 The most relevant data fields from ICEBERG project

Data category	Examples of data fields
Administrative information	Unique product identifier, product type, etc.
Product operation and use	Dates and geolocations of demolition, sorting, storage, transport, use within the current building
Product description and characteristics	Real properties observed or measured during inspections/testing such as range of sizes, lengths and thicknesses, total volume or mass, surface coating, impregnation or another treatment, classification (quality, decay rating, strength grading …), observed damage
Nominal properties and certification	Declaration of Performance, Environmental Product Declaration and other characteristics declared by the manufacturer/dealer
Other relevant information	Photos

DPPs, BIM, and DBL can potentially complement each other. For example, information in the construction product DPPs could be integrated into BIM models to provide a comprehensive digital representation of the building's components, and to support e.g., maintenance, refurbishment or demolition activities. When DPPs for different building elements are available, those could be integrated to BIM. However, the situation is different for old buildings for which BIM are not existing as majority of building stock predates BIM technology. Furthermore,

[125] Volt, J., Toth, Z. 2020. *Definition of the Digital Building Logbook: Report 1 of the Study on the Development of a European Union Framework for Buildings' Digital Logbook*, Brussels

existing BIM models, even when available, may be outdated as BIM is at the moment mostly used during design and construction, thus modifications or changes to the original design may not be included in the BIM. Scan to BIM techniques (such as BIM4DW in ICEBERG) are potential method for creating the BIM model for existing building, which could then e.g. facilitate demolition planning (materials, amounts created).

4.7 Extended producer responsibility (EPR)

4.7.1 Background

Extended Producer Responsibility (EPR) is an environmental policy that extends a producer's responsibility to the end of their product's lifecycle. It requires that the producers are responsible for the waste management of their products and reaching set recycling targets. Typically, the waste management is carried out by an executing entity, the Producer Responsibility Organization (PRO), and the producers pay a fee based on the products they put on the market. EPR can be also a tool to promote eco-design via ecomodulation of the EPR fees. This means that the fees the producers pay are modulated based on certain product criteria, such as recyclability and material choices. Lack of incentives for design products that are easily recyclable and/or reusable has been recognized as an important barrier in literature (Chapter 2).

EU EPR policies cover waste from end-of-life vehicles, electrical and electronic equipment (WEEE), batteries, and packaging. In addition, national EPR schemes exist for various types of products. For construction products, only a few examples exist on EPR schemes in the EU. The main barrier for implementing EPR for construction products is the long lifetime, typically several decades. Other barriers include the diversity and complexity of the construction products and their materials[126]. Further challenge is that as the construction products are part of the building, the manufacturers of construction products may have limited decision-making power on the lifecycle of the product[127].

In France, a law relating to anti-waste and the circular economy n° 2020-105 creates new EPR schemes for 11 product categories. This includes an EPR scheme for building and construction products[128,129]. The EPR scheme aims to reinforce the sorting, reuse and recovery of CDW by e.g., improving collection (increasing amount of collection points, free take back systems) and proposing sorting obligations for several fractions[130].

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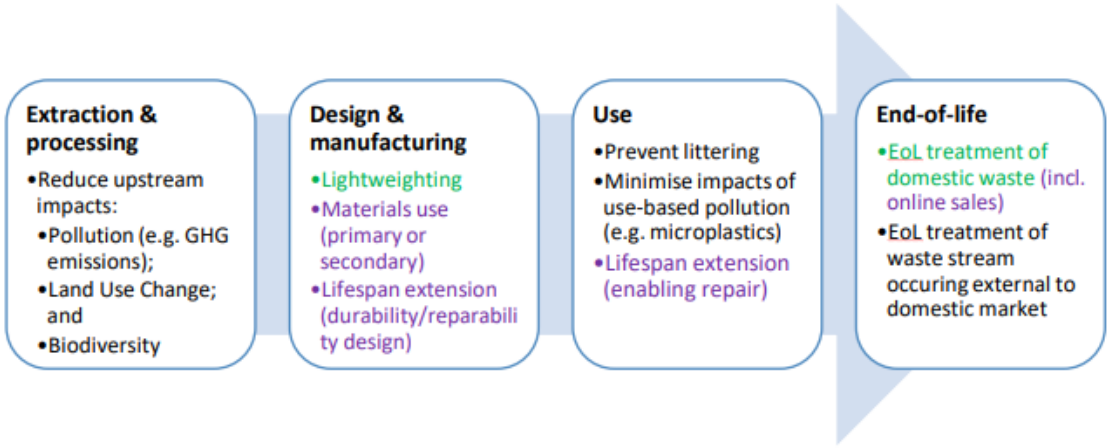
[126] Construction Products Association UK, 2022. Applying EPR in the Construction Products Sector.. https://www.constructionproducts.org.uk/our-expertise/sustainability/resource-efficiency-zero-avoidable-waste-and-the-circular-economy/applying-epr-in-the-construction-products-sector-discussion-paper/

[127] https://www.construction-products.eu/publications/epr/

[128] Vernier J. 2021. Extended producer responsibility (EPR) in France. Industry and Waste: Towards the circular economy. https://journals.openedition.org/factsreports/6557

[129] Diemer A. et al., 2022. Waste Management and Circular Economy in the French Building and Construction Sector. Front. Sustain. https://www.frontiersin.org/articles/10.3389/frsus.2022.840091

[130] Webinar 2022: Collection and recycling of construction and demolition waste: Key learnings. https://www.interregeurope.eu/find-policy-solutions/webinar/collection-and-recycling-of-construction-and-demolition-waste-key-learnings



Note: Green marks the actions traditionally covered by an EPR. Purple marks the actions that are currently explored or implemented in some EPR systems for some product categories. **Black** mark actions to avoid but are currently not considered in EPR systems.
Source: Authors own.

Figure 19 Possible objectives of EPR to reduce environmental impacts throughout a product's lifecycle[131].

In addition, in some EU countries (voluntary) EPR schemes are in place for specific construction products/materials, such as flat glass in NL[132]. This has supported the separate collection and treatment of flat glass for already over two decades in the Netherlands.

4.7.2 EPR for construction products – French example

Currently, France is the only example in the EU where an EPR scheme has been established for all building and construction waste, which entered into force from May 2023. The French EPR is part of the anti-waste law for a circular economy, and it concerns all companies manufacturing and placing construction products on the French market[133]. Due to the recent introduction, there is not yet data available on the benefits and impact of this regulation.

The anti-waste law and the EPR for construction industry includes the following obligations[134]

- Obligation for the manufacturers to adhere a producer's responsibility organisation or to create an individual system of waste management.
- Obligation for the producer's responsibility organisations to ensure the traceability of waste.
- Obligation to organise sorting on site and a separate collection of waste.

[131] Brown A. et al. (2023). New Aspects of EPR: Extending producer responsibility to additional product groups and challenges throughout the product lifecycle. OECD. https://one.oecd.org/document/ENV/WKP(2023)17/en/pdf

[132] www.vlakglasrecycling.nl

[133] https://www.rfn.fr/en/news/new-regulation-1-may-2023-extended-producer-responsibility-epr-construction-products-and

[134] ALTAROAD Deliverable, TRACK4REUSE - Defining new waste tracking standards for the green Demolition and Construction industry, 2021, https://ec.europa.eu/research/participants/documents/downloadPublic?documentIds=080166e5dc4277be&appId=PPGMS

- Obligation to draft every five years an action plan that specifies how they intend to prevent the creation of waste and how they will ensure a maximum rate of reuse and recycling of their products. These action plans are to be made public.
- New professional waste management sites are to be established in order to increase the territorial grid. The installations of these new sites will be financed by the producer's responsibility organisations.

In practice, four producer's responsibility organisations (PRO) have been approved by the French government for the management of CDW: Ecomaison, Ecominero, Valdelia and Valobat, which take care of inert (e.g. concrete, aggregates, ceramics etc) or non-inert (e.g. wood, plastics etc) waste fractions, or both. The aim of the law is to improve the collection of CDW by creating a network of collection points accessible throughout the country to professionals and construction companies to treat waste as close as possible to construction sites as well as free take-back of waste financed by PRO[135].

The companies manufacturing construction products will pay an eco-contribution to the PRO organization to contribute to the waste management of their products (unless organizing own collection). Depending on the PRO organization and the product category, the fee (eco-contribution) may be modulated based on the products properties. As an example, Valobat offers eco-modulation for several products according to certain criteria. In case of polyurethane insulation, a lower tariff is offered for insulation products which incorporates more than 10 % pre- and post-consumer recycled material, in open and closed loops, contains no more than 0.1 % recycling disruptors and hazardous substances, and the addition of recycled material does not reduce the recyclability of the product.[136]

4.7.3 Conclusions and future outlook

EPR is a potential tool to incentivize design of products which are more durable, repairable, reusable, and easily recyclable in the end of the products lifecycle. Especially eco-modulation of the fees paid to the PRO organization based on certain criteria could potentially be a powerful tool to reward innovation in design and improving the circularity of products[137]. Especially modulation of EPR fees based on the share of secondary materials in a product could promote the use of secondary materials. Examples of eco-modulation according to the recycled content criteria are found for example in the packaging sector.[138] Potentially higher EPR fees could be introduced for products that are difficult to recycle (e.g., in REACH also restrictions for substances difficult to manage at the end-of-life).

Although EPR schemes for construction products are still rare, apart from the French example, there has been discussion in many industry sectors on the potential of EPR. For example, the European carpet and rug association (ECRA)

[135] https://www.ecologie.gouv.fr/deploiement-nouvelle-filiere-rep-des-dechets-du-batiment-pmcb-au-1er-janvier-2023

[136] https://www.valobat.fr/bareme-pmcb-2024/

[137] https://www.construction-products.eu/publications/epr/

[138] Brown A. et al. (2023). New Aspects of EPR: Extending producer responsibility to additional product groups and challenges throughout the product lifecycle. OECD. https://one.oecd.org/document/ENV/WKP(2023)17/en/pdf

has recently published a position paper on the EPR for the carpet industry, in which a tailor made EPR scheme for the carpet industry at European level is supported.[139] In the flooring sector, many company specific takeback schemes already exist, mainly focusing on the takeback of installation waste.

Potentially EPR schemes are more suitable for certain types of products than other, depending on the lifetime, reuse potential, etc, but more information is needed for the applicability to different product categories. In addition to stimulating design for recycling, EPR schemes could be important for improving the collection, which is one of the key objectives of the French EPR for construction products.

In the interviews with ICEBERG partners, extended producer responsibility was seen as an effective measure to promote circularity and ICEBERG innovations. However, challenges were also recognized, especially the long lifetime of some of the products. For certain products reuse is not feasible, due to technical aspects. Takeback schemes for own products were mainly considered feasible for the installation waste.

4.8 Other supporting measures

4.8.1 Harmonised Product Standards

The Construction Products Regulation (CPR) lays out harmonised standards for construction products (declared with the CE-marking). There is the possibility to apply for a European Assessment Document (EAD) specifically for the construction product not covered by harmonised standards and use this as a basis to apply for a European Technical Assessment (ETA), which may form the basis for a CE mark on the preparation for the reuse of construction products.

The availability of harmonised standards for ICEBERG circular products and the possibility for the ETA process according to the current CPR are further described in the ICEBERG deliverable 6.4.

In the new CPR, the scope is going beyond the one of the current CPR and allows for product information that is relevant for the installation, maintenance and removal, recycling or reuse of the product. Requirements for the whole life cycle need to be considered. For the technical performance and the use of the construction product, also aspects that change or influence the characteristics needs to be covered in future harmonised standards.

Relevance for ICEBERG cases:

- experience from demonstration cases can provide information on elements to be included in the harmonised standards. Especially in the definition of the scope of the future standards, the inclusion of recyclable content is important.

[139] ECRA position paper 2024: Extended producer responsibility. https://ecra.eu/wp-content/uploads/sites/3/2024/03/2024-01-30-EPR-Position-Paper-Final-Version.pdf

4.8.2 Building codes

Building codes are binding sets of rules for obtaining construction permits that ensure compliance with public health, safety, and material standards. These codes should play an essential role in promoting circular design practices such as the use of secondary materials or design for disassembly and reuse. The European building codes are developed by the European Committee for Stadardization (CEN) as design standards (the Eurocodes) and harmonized execution standards. Unfortunately, the current European building codes are often efficiently preventing circular building practices because they do not provide any guidance for the assessment and safety levels of already used materials and components. Therefore, the recent European Commission mandates (e.g., EN Mandate M/515 for amending existing Eurocodes and extending the scope of structural Eurocodes) led to an amendment of these standards to incorporate climate impact concerns. Large focus has been set to the development of rules for the assessment of existing materials and structures to extend their service life or to enable their deconstruction and reuse. For instance, CEN/TC135 “Execution of steel structures and aluminium structures” developed a provision to declare performance and CE mark structural steelwork with reused elements including the detailed material testing protocol introduced in 2023 as a supplement of EN 1090-2 “Technical requirements for the execution of steel structures”. It is assumed that the development of the corresponding Eurocode (part of EN 1993 series “Eurocode 3: Design of steel structures”) by CEN/TC250 “Structural Eurocodes” will follow this protocol.

4.8.3 Volunteer systems

A great number of certification systems to assess the environmental quality of buildings were introduced during the last decades. They have a significant impact on many project decisions worldwide. Such certification systems are being developed and promoted mostly by the national branches of the Green Building Council (GBC) or by the similar organizations. Some of the most common systems have international variants and can be used worldwide.

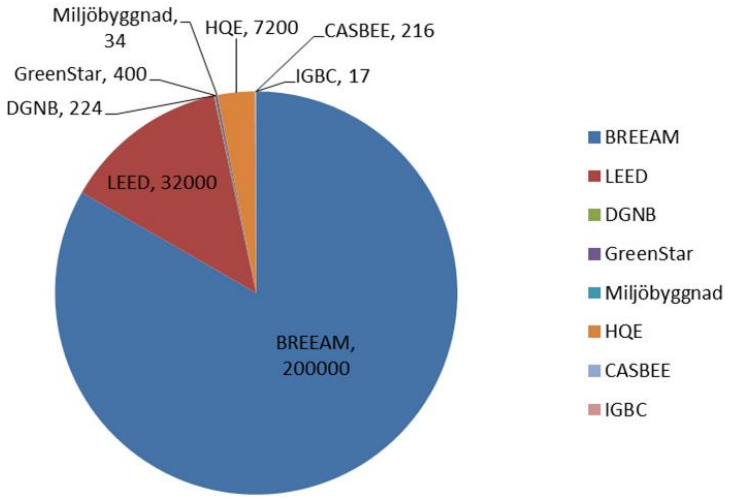


Figure 20 Number of certified buildings in 2012 based on data from Heincke & Olsson (2012)[140]

The need to develop a common European assessment system following the European and international standards led to the introduction of Level(s). However, harmonization of certification procedures in Europe is difficult and slow process because these methods are strongly depending on the local building practices and the climate.

The focus of certification on various environmental categories is different in each system. Some emphasize indoor air quality; others are more energy or process oriented. Building resource efficiency can be represented by “materials” and “waste” categories that occupy altogether less than 20% in all of the selected systems [23] as demonstrated in Figure 21.

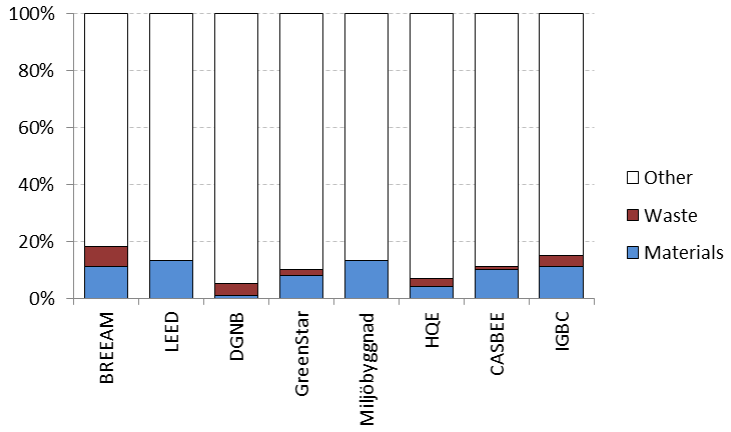


Figure 21 The proportion of "materials" and "waste" categories.

The findings of FORCE[141] criticized that less than 5 % of credits are attributed directly to life-cycle performance of building products and materials in the four major schemes, BREEAM certification from the UK Building Research Establishment (BRE), US Leadership in Energy and Environmental Design

[140] Heincke, C. & Olsson, D. Simply Green. Kvänum, Sweden: Conny Nilsson, Swegon Air Academy, 2012. 111. ISBN ISBN 978-91-977443-5-5.

[141] FORCE Technology final report. Schmidt, A. Analysis of five approaches to environmental assessment of building components in a whole building context. Lyngby, Denmark: 2012.

(LEED), German Sustainable Building Council (DGNB) certification and French Highe Environmental Quality (HQE) scheme, with LEED not utilizing LCA results at all. The situation has greatly improved nowadays, since of the schemes (also LEED v4, GreenStar since 2013) can use quantitative measures of environmental impact (such as CO_2e originating from LCA calculations). However, only DGNB and HQE are fully harmonized with international standards for LCA reporting (EN 15804 “Sustainability of construction works. Environmental product declarations. Core rules for the product category of construction products”, EN 15978 “Sustainability of construction works. Assessment of environmental performance of buildings. Calculation method.” and ISO 14044 “Environmental management. Life cycle assessment. Requirements and guidelines”).

4.8.4 Green product labels

The demands for sustainable development and the customer´s awareness for environmental values set requirements for green products[142].

The EU Ecolabel is the only European ecolabel, while the other ecolabels are designed at national level. Examples of national ecolabels in Europe are the Blue Angel and the Nordic Swan also meeting the International Organisation for Standardization (ISO) definition for a Type 1 Ecolabel. If a product has been has received both a national and the EU Ecolabel, both two logos can be displayed next to each other on the product.

When new criteria are developed for the EU Ecolabel, existing criteria under other officially recognized ecolabelling schemes in the Member States are considered. Newly developed criteria under these schemes should be at least as strict as the existing EU Ecolabel criteria.

For construction products, EU ecolabel criteria can be awarded to hard covering products (e.g., floor tile, wall tile, roof tile, block, slab, panel for internal or external use) complying with strict criteria for reduced impacts caused by quarrying of raw materials, limited emissions of pollutants, and the restricted use of hazardous substances. Manufacturers are also encouraged to use renewable energy and to incorporate of recycled/secondary material content, where appropriate.

Further information on ecolabelling is presented in the ICEBERG Deliverable D6.4.

Relevance for ICEBERG cases:

- ICEBERG task 6.2 (Social attitudes towards circularity of building products) reports about mistrust and concern regarding the safety, and quality of secondary construction materials. The Green product labels can here be used as a powerful tool to create confidence the products containing recyclables.

[142] Green products are products fulfilling sustainability criteria such as free of Ozone depleting chemicals, hazardous compounds and don’t produce hazardous by-product, made of recycled materials, energy efficient, durable and often have low maintenance requirements

Figure 22 Examples of logos for EU Ecolabel and national ecolabels.

4.9 Tools for converting environmental footprint into a single score

The potential environmental impact of a product or a building can be calculated in an LCA. By default, LCA results are expressed as individual environmental impact indictors (also called characterised results). Examples of individual impact indicators are: Global Warming Potential (expressed in kg CO_2 equivalents) and Depletion potential of the stratospheric ozone layer (expressed in kg CFC-11 equivalents). The ISO 14040/14044 standards do not prescribe which environmental impact indicators should be considered when performing an LCA or developing an EPD nor which related impact methods to apply. The Environmental Footprint (EF) method by EU-JRC however does include a default list of 19 impact indicators and related impact methods that need to be assessed. The EN 15804+A2 standard prescribes the same list of 19 indicators and methods as the EF method but makes a differentiation in core indicators that are mandatory and additional indicators that are optional to report in an EPD. All 19 indicators nonetheless need to be calculated and included in the accompanying project report of an EPD in line with EN 15804+A2. The European Level(s) framework[143], which has been applied in the ICEBERG LCA's, only considers 10 of 19 impact indicators of the EF method.

By considering 19 individual environmental impact indicators burden shifting is limited compared to only considering one indictor like done in case of carbon footprinting. However, interpreting the results, making comparisons, drawing conclusions, and the decision-making process become more difficult with 19 indicators. An environmental footprint based on characterised LCA results can be converted into a single score, allowing an easier comparative assertion and decision-making process. In LCA, this conversion is done by applying normalisation and weighting. Normalisation and weighting increase the uncertainty of the results and are considered optional steps in the ISO 14040/14044 framework. The EN 15804+A2 does not include rules on normalisation and weighting, but the EF method[144] does. The single score based on the EF method is expressed as environmental points (Pt).

To avoid oversimplification, in the LCAs performed in WP5 of the ICEBERG project, the EF normalisation and weighting approach was included as an optional step. Not all case studies applied weighting, the Belgian case study

[143] Level(s) indicator 1.2: Life cycle Global Warming Potential (GWP), 20201013_New_Level(s)_documentation_Indicator 1.2_Publication v1.0.pdf (europa.eu)

[144] Sala S. 2018. Development of a weighting approach for the environmental footprint. JRC Technical Reports. https://eplca.jrc.ec.europa.eu/permalink/2018_JRC_Weighting_EF.pdf

(CCS3) for example did include the single score in their LCA-results. The next two sub-sections describe LCA-based tools implemented by two member states that also convert an environmental footprint into a single score.

4.9.1 In the Netherlands

The *Milieu Kosten Indicator* (MKI), also known as Environmental Cost Indicator (ECI), consolidates environmental impacts into a single score expressed as external environmental costs (in Euro). It facilitates the comparison of the environmental performance of different civil engineering design during tendering.

The ECI is used as an important criterion to determine the winning bid in public procurement tenders. By providing an ECI for their proposal, contractors can receive a fictional discount on their offer. The offer with the lowest external environmental costs receives the highest discount. ECI values can also serve as thresholds in tenders. Offers with a higher environmental cost get automatically rejected.

The ECI is calculated by using LCA data, with impact categories being weighted by weighting factors [145]. Due to the revised European EPD standard for construction works EN 15804+A2, the ECI will be updated[146]. Among others, the number of impact categories increased from 11 to 19 and the CO_2 emission cost increased from €50/tCO_2 to €116/tCO_2.

The assessment method behind the ECI is also applicable for buildings, and called *MilieuPrestatie Gebouwen* (MPG - Environmental Performance of Buildings). The MPG expresses the external environmental costs per m^2 gross floor area per year based on a building service life of 75 years for residential buildings or 50 years in case of office buildings. Calculating the MPG is mandatory with each application of a building permit. Since January 2018, the MPG has been subject to a maximum limit[147].

4.9.2 In Belgium

The Tool to Optimise the Total Environmental impact of Materials (TOTEM) is a free Belgian web tool developed by the three Belgian regions[148]. TOTEM allows users to calculate the environmental impacts of their (designed) building elements and buildings over a total building life cycle of 60 years. The three regions developed the tool with the aim to disseminate knowledge and understanding of the environmental performance of buildings and facilitate dialogue within the construction sector. Using this tool, it is possible to calculate and communicate the environmental performance of building elements and buildings in a uniform way, neutral and adapted to the specific Belgian context. This tool is already used by architects to assess the impact of certain material choices on the overall environmental performance of a building. It can also regard the environmental impact of demolition of existing materials before new construction, and in-situ and ex-situ reused materials.

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[145] https://ecochain.com/blog/environmental-cost-indicator-eci/

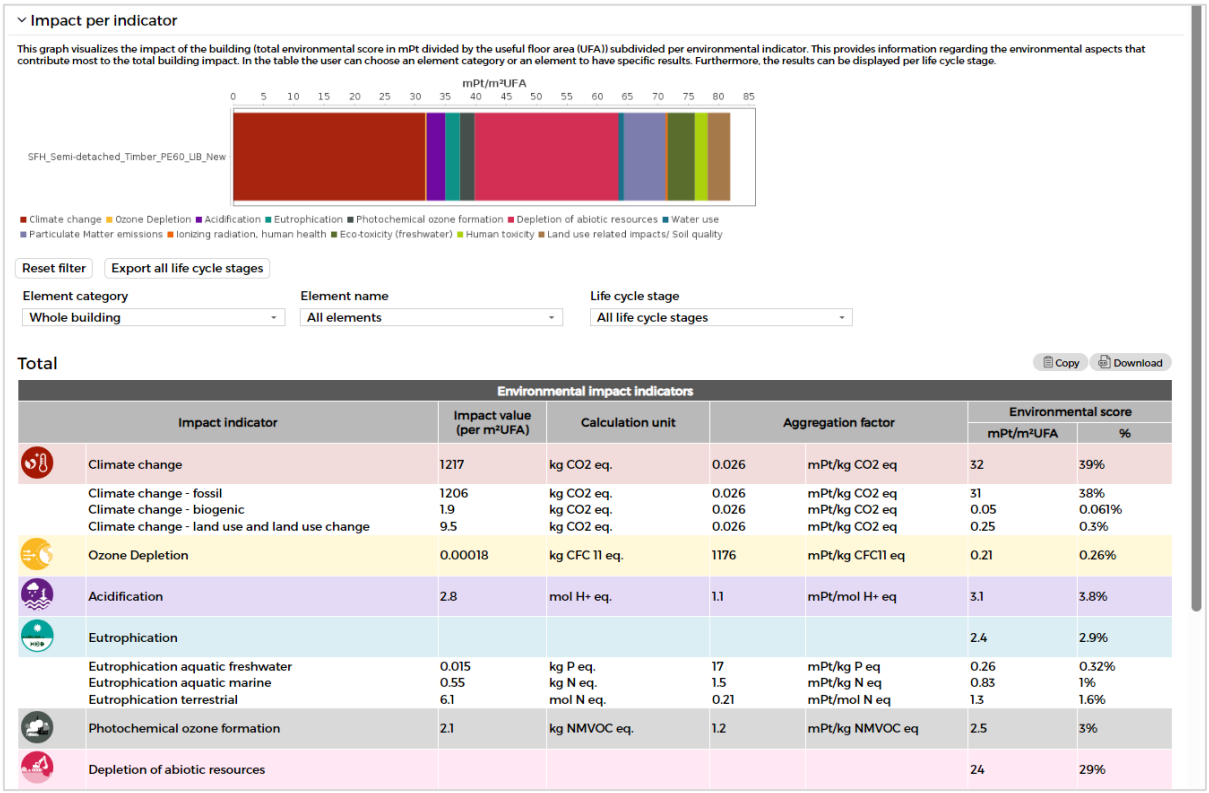
[146] Levels-Vermeer J.B. (2023). Herziening mpg-score referentiegebouwen op basis van de herziene bepalingsmethode versie A2. Ministerie van Binnenlandse Zaken en Koninkrijksrelaties, The Netherlands.

[147] https://www.rvo.nl/onderwerpen/wetten-en-regels-gebouwen/milieuprestatie-gebouwen-mpg

[148] https://www.totem-building.be/

The environmental impacts in TOTEM are calculated based on EN 15804+A2. The characterised results of all 19 environmental impact indicators are included as possible detailed outputs. Moreover, the results are expressed as a single score based on the 19 indicators. The single score in TOTEM is calculated with the EF normalisation and weighting method (expressed as milli-environmental points, mPt per functional unit), see screenshot included as Figure 23.

In the first versions of TOTEM when it was still based on EN 15804+A1, the single score was also expressed as external environmental costs[149] comparable as the Dutch MKI/MPG method. With the update to EN 15804+A2 impact indicators, the Belgian regions decided to refer to a European method for calculating the single score instead of applying a Belgian framework.



Environmental impact indicators								
Impact indicator		Impact value (per m²UFA)	Calculation unit	Aggregation factor		Environmental score	
						mPt/m²UFA	%
	Climate change	1217	kg CO2 eq.	0.026	mPt/kg CO2 eq	32	39%
	Climate change - fossil	1206	kg CO2 eq.	0.026	mPt/kg CO2 eq	31	38%
	Climate change - biogenic	1.9	kg CO2 eq.	0.026	mPt/kg CO2 eq	0.05	0.061%
	Climate change - land use and land use change	9.5	kg CO2 eq.	0.026	mPt/kg CO2 eq	0.25	0.3%
	Ozone Depletion	0.00018	kg CFC 11 eq.	1176	mPt/kg CFC11 eq	0.21	0.26%
	Acidification	2.8	mol H+ eq.	1.1	mPt/mol H+ eq	3.1	3.8%
	Eutrophication					2.4	2.9%
	Eutrophication aquatic freshwater	0.015	kg P eq.	17	mPt/kg P eq	0.26	0.32%
	Eutrophication aquatic marine	0.55	kg N eq.	1.5	mPt/kg N eq	0.83	1%
	Eutrophication terrestrial	6.1	mol N eq.	0.21	mPt/mol N eq	1.3	1.6%
	Photochemical ozone formation	2.1	kg NMVOC eq.	1.2	mPt/kg NMVOC eq	2.5	3%
	Depletion of abiotic resources					24	29%

Figure 23 Screenshot of a part of the detailed results overview within TOTEM – with in the top part the single score shown as graph with the contributions to the single score per impact indicator indicated with colours and underneath it the individual results per impact indicator shown in the table.

4.10 Regional policies and instruments in two regions – good practices in Flanders region (BE) and Basque country (ES)

The circular economy in the construction and demolition sector is addressed in national and regional strategies. Compared to EU strategies, regional strategies contain more detailed practices and responsibilities for reaching targets, with a more practical follow-up system for ensuring realisation of set targets such as planning and requirements for public procurement. The level of detail of the

[149] De Nocker L. & Debacker W. (2017). Monetisation of the MMG method. Commissioned by OVAM. https://www.totem-building.be/pages/downloads.xhtml?id=296

strategies is often linked to the distribution of responsibilities within the member states.

Regional practices have been analysed in two European regions with high recycling rate and representing ICEBERG partners. Both regions are the predominant authorities on waste and materials management.

Their strategies contain detailed practices and responsibilities for reaching targets, with a practical follow-up system for ensuring realisation of set targets such as planning and requirements for public procurement. The aim was to identify examples where local policies, requirements regulations and guidelines have supported CE solutions in recycling of CDW.

Detailed reports on the regional practices in the Basque country of Spain and the Flanders Region of Belgium are attached in Appendix 2.

4.10.1 Key features of the Basque country and Flanders Region

Both the Basque region and Flanders, the construction industry play an important role for the economic. The Gross domestic product (GDP) of construction over the Basque economy reached 5.8% in 2021. In Flanders, the Gross Regional Product (GRP) of the construction sector is almost 6.5 % of the total gross product of Flanders. These values can be compared to Gross value added of the construction sector in the EU that was 5.5 % of GDP in 2021.

The CDW generation was 1.4 Million tonnes (2018) in the Basque country and 11.3 Million tonnes in Flanders. The recycling rates of CDW are high in both regions; 78 % and 95 % in the Basque Country and in the Flanders Region respectively.

4.10.2 Key drivers for high recycling rate

4.10.2.1 Basque country in Spain

The key drivers for a high recycling rate are the following instruments:

- Mandatory pre-demolition audit including estimation 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[150])
- Mandatory selective demolition and compulsory segregation of materials on site (as of 2022) for wood, mineral fractions (concrete, bricks, tiles, ceramics and stone), metals, wood, glass, plastic, paper and cardboard and gypsum (Basque Country: Order of 12/01/2015[151])
- Environmental Criteria (for Green Public Procurement) for use of secondary materials (both GPP criteria[152] for buildings and infrastructure works and a guide[153] for using recycled materials)

[150] Waste Management Study (EGR - ESTUDIO DE GESTIÓN DE RESIDUOS)
[151] http://www.lehendakaritza.ejgv.euskadi.eus/r48-bopv2/es/bopv2/datos/2012/09/1203962a.shtml
[152] GPP criteria for public administrations working on developments and possible bidders https://www.ihobe.eus/criterios-ambientales
[153] https://www.ihobe.eus/publicaciones/guia-para-uso-materiales-reciclados-en-construccion-3

In order to improve the ratio of audits performed and the correct management of CDW, the Basque Country requests the owner to deposit the amount of money needed to perform waste management according to the budget. This deposit is paid back when the monitoring against real data has been performed and necessary justifications provided. Public contractors or owners contracting certified companies do not need to deposit this fee.

The requirements for mandatory material specific separation of CDW at site also includes threshold of 10 tonnes for concrete, bricks and tiles and 250 kg for glass and paper and cardboard.

4.10.2.2 Flanders Region of Belgium

In Flanders, a legal framework for the sustainable management of CDW was set in place at an early stage, especially for the recycling of the stony fraction of CDW (recycling rate over 95%) in collaboration with the actors of the C&D sector. Key drivers are as follows:

- A landfill ban and restrictions on incineration of unsorted mixed CDW
- Certification of recycled aggregates based on EoW criteria
- Distinction between stony fractions of CDW with a high and low risk environmental profile
- Mandatory demolition follow-up plans with follow-up by a demolition management organization (for large demolition yards) leads to debris with low risk environmental profile. Aggregates processed by material with low risk environmental profile need less control in management.
- Demolition certificate (for large demolition yards): mandatory follow-up by a demolition management organization until the completion of the works.
- A case-specific EoW declaration for certain application fulfilling a set of requirements (to obtain a “Resource certificate” as materials suitable for recycling).
- Separate collection of CDW on site. Some fractions have to be collected separately on site (debris, asbestos, autoclaved aereated concrete, gypsum, …). Mixed CDW has to be sorted separately from other waste streams.

Certification of recycled aggregates based on EoW criteria and mandating follow-up by a demolition management organization from demolition follow-up plans to a demolition certificate and tracing of material flows in the Flemish Region is crucial for responsible demolition waste management.

Flanders is introducing more platforms and modes of exchange for electronic waste and materials data in general, and also in construction. The identification forms of waste shipments have gone online from 2021. The reporting of data of waste and materials in recycling plants will be conducted electronically in the MATIS platform[154]. This will improve the quality and detail of the data on waste and material streams.

[154] After the revision of the WFD in 2018, MATIS (the material information system, https://ovam.vlaanderen.be/matis) was developed to give information on waste treatment and the actual recycled amount. In MATIS, it is not the waste producer that is reporting, but the

4.10.3 Good practices

4.10.3.1 Basque country in Spain

Guidelines with acceptance criteria have been published for promoting the use of secondary materials in different types of works. Information is presented about technical requirements and relevant standards. In addition, the guideline includes a list of commercial products which contain recycled materials above a certain limit and supplied with a third-party accreditation.

A calculation tool has been developed for comparison of bids in public tenders and aimed to be used both by the public administration issuing the call to tender and by the bidders in order to assess and submit bids. Also training for raising awareness and improving knowledge on legislations related to selective demolition and waste separation on construction sites is arranged by IHOBE, the environmental agency in the Basque country. Especially information on content of pre-demolition audits, tools for reporting in demolition works and tools for a better waste management are provided. Reports with information on best practices have been published.

4.10.3.2 Flanders Region of Belgium

Certification of recycled aggregates ("Unity Regulation") based on EoW criteria with a distinction in the processing between the stony fraction of CDW with a high and a low risk environmental profile.

The follow-up of the selective demolition process by a demolition management organization (DMO) has been developed in Flanders. The purpose of the DMO is to act as a traceability system providing quality assurance for the selective demolition process and the waste streams produced. Tracimat covers the following elements:

- demolition follow-up plans;
- monitoring and supervision of waste flows;
- supervise that the demolition waste has been selectively collected on site and gone through a tracing system
- assuring the processing company of the quality of the debris
- guarantee its origin/source of the waste streams and guarantee that the debris is free of contaminants that could hinder the recycling process.

Online tools and a database support the quality system. The materials identified in the building are put into the online platform of the demolition management organization (Tracimat) by the expert. This database holds information about available quantities of various recyclable materials and is of great value for

waste collectors and the waste facilities. Waste collectors report each collected waste stream with its origin (the waste producer) and the destination (the waste treatment facility or storage/transshipment site). Waste facilities report each waste stream entering the facility with its origin, each waste stream leaving the facility with its destination and if applicable the input in the recycling operation. Waste collectors and treatment facilities are reporting since 2022 in MATIS. When MATIS is fully operational, no extrapolations or estimations would be needed. All waste data will be registered at the level of the list of waste codes.

investors in their decision on in what technologies to invest and/or will help in dimensioning new recycling plants.

A link has been established between BIM and TOTEM [155], a web-based calculation tool which allows to assess the environmental impact of buildings over their whole life cycle. The development of building elements for calculation in the tool can be imported from several BIM systems. The results of calculations and design in TOTEM are accessible in the digital logbooks of buildings.

4.10.4 Conclusions and further work needed

In both regions, pre-demolition audits, selective demolition and mandatory separation of materials are required. Additionally, especially in Flanders the landfill ban of recyclable material was brought up in interviews with several stakeholders as an efficient instrument.

The following actions for further work in order to further improve the waste management in the Basque Region:

- Instruments for identification of materials and new technologies for the minimization of waste
- Tools for better on-site separation in small works
- More research, technology development and demonstration projects in new uses of secondary materials
- Improvement in already existing regional regulation
- More control of construction works in relation to the correct management of construction and demolition waste.
- Additional inspection and control mechanisms to be promoted by the environmental authorities.

In Flanders, the demolition monitoring by Tracimat is limited at present to the safe removal of hazardous materials, the follow-up of the quantities of the stony fractions that originated from the demolition and the matching of the data of acceptance and production of the crushing plants. Soon this will also be extended with the supervision of the correct selective removal of non-stony materials. The final demolition certificate issued by the demolition monitoring organization will certify that all steps in the demolition process and the treatment of the resulting waste streams were followed. This will also include comparing the data on produced and treated quantities.

Further steps will be taken to keep the quality of the on-site sorting of CDW and the performance of sorting facilities better in line with the requirements of producers who wish to apply recycled or reusable materials in the production of building or other materials.

This leaves further steps to be taken on:

- Extending the framework and regulations on demolition monitoring to more waste streams

[155] https://energyville.be/en/project/totem-tool-to-optimise-the-total-environmental-impact-of-materials/

- Extend the application of pre-demolition audit and demolition monitoring to a wider range of smaller sites
- Investigate means to match the supply and demand of CDW materials for high-end recycling or reuse

5 ICEBERG stakeholder interviews for identification of effectful measures and good practices

5.1 Purpose and approach of the interviews

A series of interviews combined with an online survey were conducted with ICEBERG stakeholders along the value chain linked to ICEBERG product groups (circular case studies): concrete, plasterboard, ceramic, aerogel (intermediate product), wood panels and insulation (PU) panels. The aim of the stakeholder interviews was to learn about conditions enabling and issues preventing the success of ICEBERG products and to identify the most effective enabling measures for a market uptake of the new circular ICEBERG products. Furthermore, information on good practices was collected.

The key actors in the ICEBERG circular product value chain were identified for each product type and typically included demolition contractor, waste recycler, product manufacturer, and installer/end-user/building owner. An online questionnaire with specific questions for the different actors was designed. The questionnaire also included multichoice questions for ranking of potential measures supporting recycling. The questionnaire template is in Appendix 3.

Following the questionnaire, in-depth stakeholder interviews were carried out between December 2023 and March 2024 and were conducted online via Microsoft Teams. The interview template that was used can be found in Appendix 3. The interview set up was planned by VTT together with ICEBERG partners (research organizations) related to respective case studies. VTT was responsible for the interviews, partly supported by research organization also involved for the case. The summary of conducted interviews is presented in Table 19.

Table 19 Conducted interviews and online surveys with ICEBERG partners

Product group	Demolition contractor	Recycler	Manufacturer	Installer	Building owner	Research institute, other
Concrete and cement based products	1[156]	1[157]			1	**1**
Ceramic			1	1		1
Wood	1[158]	1	1			
Gypsum plasterboard	1	1	1	1		
Insulation foam	1	1	1			
Insulating aerogels		1[159]	2			

[156] plus additional online surveys with external stakeholders in Flanders

[157] plus additional interview/survey with external stakeholder in Flanders

[158] plus 1 additional interview in competition between material recycling vs energy use (SRF)

[159] also manufacturer of the aerogel

5.2 Outcome and highlights from the interviews

A summary of the interviews was compiled for each ICEBERG product group including identified good practices, specific aspects (challenges, measures) concerning manufacturing and product design, supply of high-quality waste, demand on products with high share of recycled content, as well as ranking of most effective measures to support uptake of ICEBERG solutions. The product group specific interview summaries are in Appendix 3. A summary and key observations from the interviews are presented in this chapter.

In general, the identified measures that were considered potentially most effective as well as examples of good practices are to some extent product group and region specific. There are significant differences on the generated CDW amounts from the specific products and materials, as well as on collection and transport distances, and demand for the recyclates in different regions. Furthermore, the ICEBERG products are also in different phases regarding the TRL level, for example some of the concrete based products are already rather advanced whereas some other circular case products are still in more early stage of development. These differences are reflected in the views presented in the interviews and ranking of the measures.

5.2.1 Common observations for all product groups concerning design, supply and demand

There was some variety in the ranking of the most effective measures between different product groups, and some variety was also observed in priorities set by different actors in the value chain. However, certain aspects were highlighted by almost all stakeholders for all product groups.

Especially the importance **of increasing knowledge and education of stakeholders and sharing information in the value chain** was mentioned by almost all interviewees. Lack of knowledge was mentioned concerning recycling possibilities and benefits of higher circularity among, and environmental performance of construction products and assessment methods.

Collaboration and communication between actors in the value chain was emphasized for ensuring that all actors in the value chain have understanding about the possibilities for reuse and recycling and how this sets needs for additional actions along the value chain. Especially information on crucial steps in recycling should be clearly communicated (why are certain steps to be followed, consequences, targets in processing). For the demolition stage it is important to communicate e.g., to demolition contractor why some materials need to be separated and the quality requirements for the high-quality recycling (e.g., impurity limit values for high-quality recycling). Furthermore, an understanding that more space is needed for material separation and more actions are required for the selective recovering of materials with high-quality, which impacts the costs of the demolition work.

<u>Manufacturing and product design</u>

Lack of information sharing was mentioned in several interviews. Especially communication between the manufacturer and the recycler is needed to ensure

that the quality of recyclates is suitable for manufacturing of new products, as well as ensuring recyclability of the manufactured products. Currently, many construction products are not designed for recycling and easy dismantling. This creates challenges for the demolition and recycling which may take place decades later. The potential of e.g., GPP and EPR to stimulate better design is discussed in previous chapters (4.5, 4.7).

Supply of good quality waste

Legislative tools (e.g., taxes) were mentioned in numerous interviews to overcome economical barriers and support green innovations. In some cases, using recycled materials can be more expensive than using virgin materials. However, if landfilling, incineration, or low-quality recycling options are restricted or become more expensive, it can serve as an incentive to develop innovative recycling solutions. Financial incentives may be especially useful for boosting the market in the early stage.

Especially extra costs due to selective demolition were mentioned by several interviewees and the need to cover those in demolition contracts. Demands for the demolition are set by the client who also bears the potential extra costs.

Sorting of the materials, not only based on the main fractions but also according to quality (e.g., high/low purity fractions requiring potentially different treatments) were emphasized. Based on the quality, different gate fees set by the recycler are used to accept the materials (in some countries) and were mentioned to stimulate better sorting of the materials.

For many materials (other than stony materials), a significant challenge is to get sufficient amount of input for recycling as from one demolition site only limited amount of material can be recovered. Collection of waste materials from several building sites may be required but may cause variation in quality. Local recycling hubs/clusters were considered an interesting opportunity for non-stony material fractions.

Difficulties exist in matching supply and demand of waste materials. Digital marketplaces could stimulate the reuse of some building components, but this also requires standardization, and perhaps also new business models.

Quality of the recovered waste fractions were mentioned as a significant barrier for recycling in many interviews. There are several measures which improve ensuring quality and enhance trust for the recycled materials. Especially requirements (national requirements, guidelines or recommendations) for pre-demolition were considered important measure in the survey. Pre-demolition audits and current practices in different countries in the EU are discussed in Chapter 4.3. A good pre-demolition audit also includes information on waste management of the material fractions recovered. Especially it was emphasized that the pre-demolition audit alone is not enough but needs a follow-up process to ensure acceptable waste quality. Furthermore, certification schemes create confidence for the produced material, as described in section 5.2.2 for good practices in the concrete case. For Netherlands it was brought up that certification of demolition process creates a market value in tendering process.

Demand of products with recycled content

Lack of demand for the secondary materials was mentioned as barrier in several interviews which hinders the separate recovery of material fractions. Thus, the demand for products with a high share of recycled content is the key to ensure the separate recovery and recycling. Due to a growing demand for environmentally friendly products, a growing market was estimated for products containing recycled materials in several interviews. Some interviewees estimated that end-users might be willing to pay a small premium for eco-friendly products. On the other hand it was estimated that the price difference between primary and secondary materials could not be significant. Especially the role of the public sector was recognized in several interviews. GPP for construction works or in demolition is further analyzed in chapter 4.5. In the Basque country, a guide[160] for environmental criteria for Green Public Procurement is defined for different construction product categories.

For some products, circularity, CO_2 savings, and non-toxicity are all important aspects, but these may be sometimes in conflict. For instance, the circularity aspect and non-toxicity are the most important environmental drivers for concrete recycling, whereas the CO_2 savings are not the main focus. However, for product design it is still important to understand where impacts arise and where design can make an improvement. Typically for end-users, the CO_2 savings is often seen as most important environmental driver due to green certification schemes for buildings. In the interviews, the lack of knowledge and skills (and resources) for the environmental impact assessment was also mentioned. In chapter 4.9, tools to convert an environmental footprint into a single score are presented. The Dutch MKI (MilieuKostenIndicator)[161] was also mentioned as a good practice in an interview as this system makes it possible to include the prevented environmental costs in the quotation.

5.2.2 ICEBERG products - Examples of good practices and strong drivers

Examples of good practices which promote the recycling and uptake of several ICEBERG waste materials in different regions were identified in the interviews.

Concrete case (NL&BE)

Current practices at the demolition site and conventional separation technologies used by the recycling sector have limitations to produce high-quality recycled aggregates for use in new concrete with a high recycled content. The quality requirements (limits for impurities, hazardous material) for high-quality recycling of concrete waste were emphasized in all interviews related to concrete case.

The **selective demolition and systems for sorting** are especially advanced in the Netherlands. Both in the Netherlands and in Flanders, the **certification system for recycled aggregate** is an important driver for recycling. Especially

[160] https://www.ihobe.eus/criterios-ambientales

[161] https://co2-prestatieladder.ams3.digitaloceanspaces.com/media/uploaded-files/Studio%2016%20-%201215-1300%20-%20Sessie%204%20-%20Martijn.pdf

in the Netherlands, the clients set pressure for recycling and certification and guidelines have been created for selective demolition. In Flanders, EoW criteria for aggregates have been a strong driver for material acceptance, supported by Tracimat system and certification.

In the Netherlands, the established Concrete Alliance (Betonakkoord[162]) is an important driver for using recyclable aggregates in new concrete. It aims for a high-quality recycling rate of 100% by 2030. The Flemish Concrete Agreement[163] is a similar activity organized in Flanders.

Plasterboard case (UK)

Nowadays, the recycled gypsum content in plasterboards manufactured in the United Kingdom is limited to between 5%-20% because gypsum is exclusively reclaimed from clean construction plasterboard waste (pre-consumer) and there is not enough supply of this plasterboard waste. Gypsum from refurbishment and demolition plasterboard waste (post-consumer) cannot be reclaimed for plasterboard manufacturing because of its high level of contamination with other end-of-life building materials, which limits the efficiency of current plasterboard recycling processes, and ultimately, impacts plasterboard performance.

Selective demolition as well as special solutions for the purification of gypsum from post-consumer plasterboard are required to ensure high-quality (> 96%) recycled gypsum, which requires extra workload and increases costs. Thus, legislative requirements (e.g., taxes) were mentioned in all interviews to overcome economical barriers and support green innovations. The **landfill tax** in the United Kingdom has been an important driver for developing new solutions for plasterboard recycling.

Ceramic case (ES)

Currently, there is a lack of demand for the ceramic waste fractions from CDW, which hinders the development of recycling options. Furthermore, there are technical challenges in using recycled ceramic fractions due to their different properties compared to virgin materials.

Demonstrations and industrial scale pilots were thus highlighted as important measure to show technical feasibility of the developed innovation and processability of a waste stream. As an example, a valuable takeaway from the ceramic recycling case in the ICEBERG project has been the successful pilot run which demonstrated that recycling of ceramics with high recycled content (even 50 %) is technically feasible. Ceramic materials are also highly available in demolition waste and the use of recycled fractions in new ceramics can be an option in the future. The performance may not always be exactly the same as with virgin materials, but this is not necessarily a problem as there are many types of applications with different requirements.

Wood (FI & FR)

[162] https://www.betonakkoord.nl/

[163] https://www.circular-concrete.be/living-lab-circulair-beton/

The quality of recovered wood waste creates the main barrier for high-quality recycling. Also, wood waste needs to be collected from several sites to ensure sufficient supply. This may increase the variation in quality, setting needs for quality control. Today, there is a high competition for wood waste from the energy sector, and lack of demand for wood waste for recycling and use in the manufacturing of new construction products. Wood sorting and processing for recycling is also time consuming and more complex compared to production of solid recovered fuel from wooden waste. On the other hand, there is a high interest of the use of biobased materials in construction. Especially the CO_2 savings aspect is seen as most important environmental driver due to green certification schemes for buildings.

Although energy recovery is currently the main use for wood waste, **glulam beams are successfully dismantled and collected for reuse**. There is evidence in a recent JRC study that both preparation for reuse and recycling of wood waste are preferred options over incineration with the highest net savings across the impact categories (when considering cascading uses, i.e. incineration later after reuse/recycling)[164].

Insulation foams (FR & DE)

Challenges of insulation foams (PU/PIR) recycling relate to the quality and quantity of the recovered waste. PU/PIR insulation foams are only a small fraction in the CDW, which are also laborious to separate, requiring extra workload. Use of selective demolition and training of personnel for responding to new requirements in waste separation are needed (e.g., new methods for hindering dust to be spread at the demolition site). There are also quality challenges related to old insulation materials (impurity fractions & banned substances, may contain CFC, other hazardous substances (e.g., PFAS)) which sets demand on identification and removal prior to demolition.

Requirements to use recycled content have been an important driver for recycling and using waste materials in new insulation foams. In Italy, there are already requirements for use of recycled polyols in new products for Green Public Procurement[165]. Clients also require recycled content in France. Since 2023, there is an EPR system concerning building and construction wastes also covering PU foams in France, which means that the manufacturer has to pay an EPR association a tax to cover future waste management costs. In the French EPR schemes, a lower tariff is placed for some products containing recycled materials above certain %.

5.2.3 Summary and ranking of measures

In the online survey, a ranking of measures was carried out by all interviewed ICEBERG partners to evaluate their importance on fostering high-quality recycling. The list of measures categorized by ICEBERG product groups and evaluated importance is presented in Table 20. Some measures were highlighted by almost all stakeholders in different ICEBERG cases, while other measures

[164] https://publications.jrc.ec.europa.eu/repository/handle/JRC130992

[165] https://gpp.mite.gov.it/sites/default/files/2022-08/GURI_183_06_08_22_Allegato_Edilizia.pdf

received a different score in different product groups. Especially the importance of knowledge, skills, and education was recognized by almost all respondents. Knowledge and sharing of information between stakeholders in the value chain is discussed in previous chapter 5.2.1.

Mandatory source separation when sufficient recycling capacity exist was considered highly important or important by all respondents. For the source separation to be reasonable, cost-efficient recycling routes should exist and high enough volumes of waste material be available for the recycling. Lack of resources for inspection by authorities was on the other hand estimated as a major barrier, even when separation of certain material streams is required.

ICEBERG products have major differences on the existing EoW criteria (materials, countries), as well as in the need to transport waste materials across countries. EoW aspects are more deeply analysed in Chapter 4.2. In the ranking of measures, especially national/regional EoW criteria were considered important by almost all respondents. Also EU wide EoW criteria were considered important by some respondents and for some products, but concerns were expressed for the EU wide EoW, and especially on the potential conflict between already existing national/regional EoW.

Economic support was considered important in many interviews to overcome market related barriers (low cost of virgin materials, extra costs of selective demolition…). In the ranking of measures, taxes (on virgin materials, carbon tax etc), lower VAT for products with recycled content, and a landfill tax were considered important measures. It was stressed that economic support might be required in the early stage of market penetration, but in ideal case the products with recycled content should be competitive on their own.

It should be noted that some of the measures may not have been fully recognized as important because they are still in development. For example, DPPs and the use of BIM for information on materials and quality were not ranked as most important in the survey. However, in the surveys their potential was recognized but practical implications were not yet totally clear. Especially the importance of DPPs for declaring information on hazardous and banned substances was mentioned. BIM was mentioned in several interviews as a useful tool for estimating the waste amount and planning of demolition, and is already in use e.g., in NL. However, it's challenging to apply BIM for old buildings with no existing models. The potential of BIM to become more dynamic data deposits in future was mentioned by one interviewee.

Table 20 Ranking of measures by ICEBERG stakeholders per product group based on the online survey. Color codes: green: highly important, light green: important. For each product 2-3 most effective measures marked with *** (if possible).

	Cement and concrete based	**Ceramic based**	**Wood insulation panels**	**Circular plasterboard**	**PU based**	**Other product groups**
Legislative						
(Requirements for) pre-demolition audit						
EU wide EoW criteria		***				

	Cement and concrete based	Ceramic based	Wood insulation panels	Circular plasterboard	PU based	Other product groups
National/regional EoW criteria	***	***				
Mandatory source separation			***	***	***	
EPR						
Economic						
taxes (virgin materials, carbon tax etc)						
Lower VAT for products with recycled content		***	***			
Landfill tax					***	
GPP for construction						
GPP for demolition						
National economic support for development of innovative processes						
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 development of EU standardization						

5.2.4 Plasterboard case example – identification of bottlenecks and relations with system dynamic method

System dynamics is a methodology and mathematical modelling technique for framing, understanding, and discussing complex issues and problems. Originally developed in the 1950s to help corporate managers improve their understanding of industrial processes, it is now widely used in fields such as economics, public policy, environmental studies, and engineering. System dynamics enables the identification and modelling of different elements in a system and their interconnections. The goal is to study how changes in one part of the system affect the rest of the system over time, allowing for better decision-making and system optimization. It is particularly useful for visualizing complex systems interconnections, understanding nonlinear behaviour in complex systems over time, and for analysing the unintended consequences of decisions.

The purpose of the exercise was to identify bottlenecks and the most critical steps of plasterboard recycling ecosystem and visualize the relationships between actors within it. A systemic view of the ecosystem and the causalities within it is presented in a causal loop diagram (Figure 24). Firstly, a simple stock-and-flow diagram was made to visualize the material flows between different lifecycle steps (Production, Use, Demolition etc.). The stakeholders acting in different lifecycle steps were identified with colored boxes (plaster board producer, constructor/customer, demolition company, etc.) and the relationships between the actors with texts and arrows.

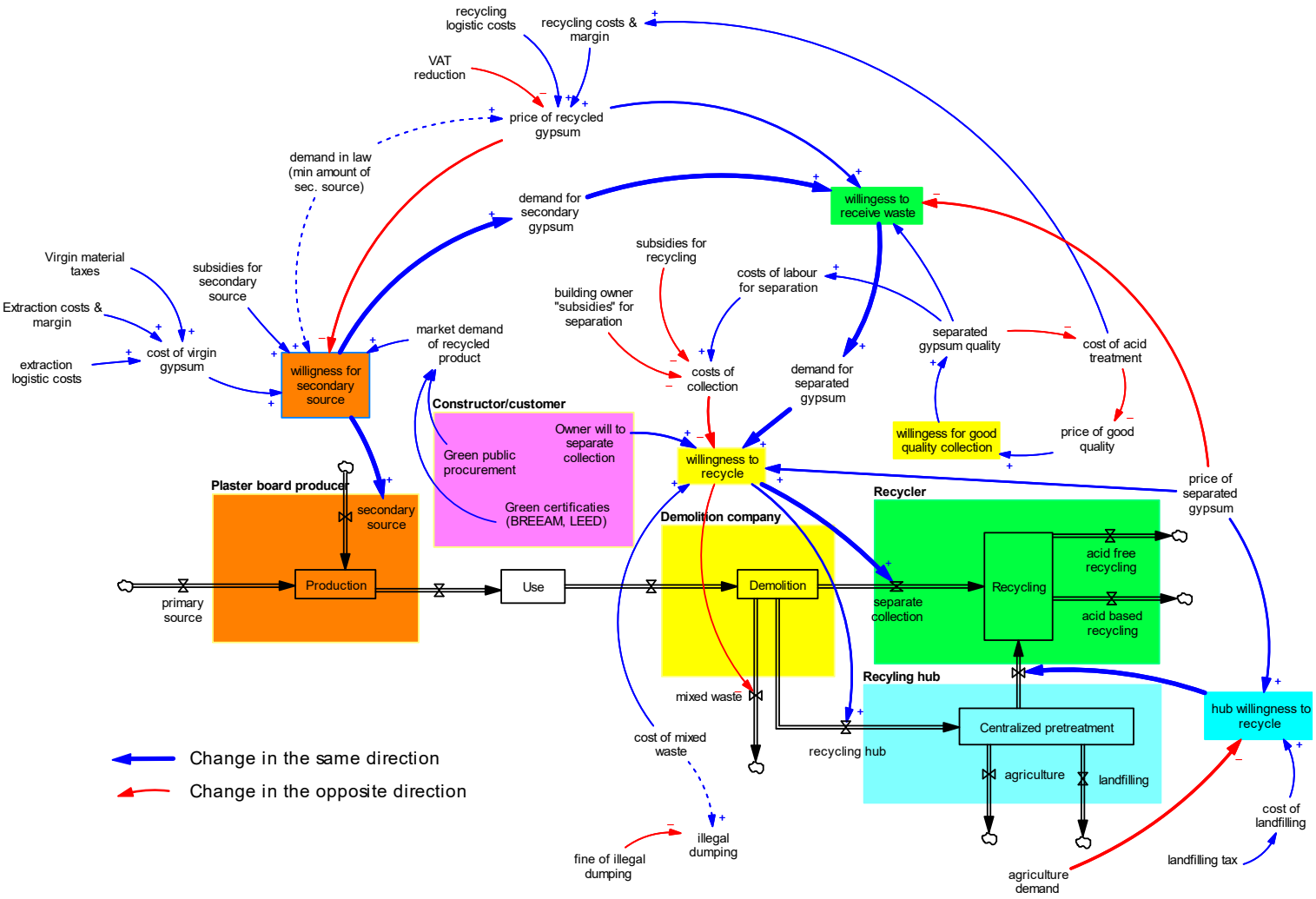


Figure 24 Causal loop diagram of plasterboard recycling ecosystem.

It seems that demolition company's willingness to recycle is behaving as a valve enabling the flow of plasterboard into recycling. Willingness to recycle is formed through economic realities, but also from recycling company's willingness to receive separated plasterboards, which again is affected by the plasterboard producer's willingness to use secondary sourced materials. Also, the building owner plays a role in increasing separate collection by instructing the demolition contractor to maximize the separation of plasterboards. A centralized pretreatment hub could act as an intermediary between demolition contractor and recycler lowering the barriers of separate collection and acting as collector and buffer to ensure steady flow of material to the recycler. There is although a challenge to ensure that the material flow is directed to recycling and not to the alternative directions: agriculture and landfilling.

Production seems not to be the bottleneck, since plasterboard manufacturers could utilize all secondary source gypsum flown to them. However, the price that the production company is willing to pay extra, can heavily affect the willingness for more circularity of other players in the value chain (e.g. willingness of the recycler to produce the high-quality recyclates, and the willingness of the demolition contractor for the selective demolition).

Based on the plasterboard recycling ecosystem presented in Figure 24, material flows can be simulated. An example calculation for maximum recycled content in different recycling scenarios is illustrated in Box 15.

Box 15. Mass flow analysis on recycled content – example for gypsum recycling in plasterboard

Gypsum flows in the value chain, as presented in Figure 24, were simulated. The starting point of the calculation is the gypsum inflow to construction, and the gypsum outflow from demolition. The maximum achievable recycled content was estimated for three simple scenarios to illustrate how changes in the demolition and recycling routes affect the material availability:

- Unrecovered gypsum is here considered to be the stream that is not separately collected and is directed to mixed mineral CDW (50%). Separately collected plasterboard is directed to recycler where it is assumed that 80% undergoes mechanical treatment and the rest requires chemical treatment, i.e. acid treatment developed in ICEBERG plasterboard case study. (1st scenario: unrecovered 50%).
- With improvements in the manufacturing of plasterboard and with more selective demolition practices, more plasterboard can be disassembled and separately collected with less impurities. In the 2nd scenario (unrecovered 0%), all plasterboard is assumed to be separately collected.
- Better quality of the collected plasterboard can facilitate onsite treatment including only mechanical treatment (3rd scenario: onsite recycling 50%).

Scenarios	Unrecovered gypsum towards mixed mineral CDW	Onsite recycling	Gypsum from separate collection to recycler
Unrecovered 50%	50%	0%	49%
Unrecovered 0%	0%	0%	99%
Onsite recycling 50%	0%	50%	49%

Only approx. 50% increase of recycled gypsum in manufactured plasterboard can be achieved in a 30-year timespan, if all plasterboard is separately collected. The increase in the recycled

content doesn't change significantly for different recycling routes as the efficiency of mechanical recycling process is assumed very high and only a small fraction of impure material is directed to chemical treatment. In all cases the level of recycled content is below the ICEBRG target of 35% (Figure 25). Lowering the demand for gypsum in the manufacturing and construction stage, e.g., by designing and manufacturing resource-efficient materials, would lead to higher recycled content of gypsum in manufactured plasterboards.

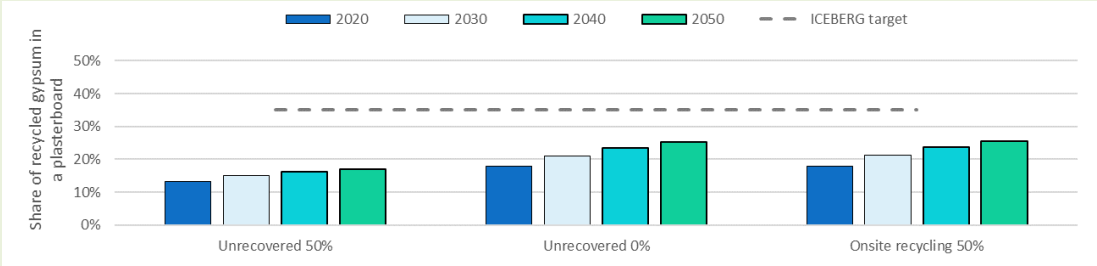


Figure 25 Post consumer recycled gypsum content in the manufacturer plasterboards based on calculated material availability.

In 2020, the total outflow of gypsum from demolition represents only about 10% of the inflow to construction (750 kt; from Damgaard et al. (2022)[166]). In 2050, the total outflow from demolition represents about 20% of the inflow to construction (2 187 kt; from Damgaard et al. (2022)). This means that even if all material outflows were to be prepared for recycling, only a fraction of the primary material needed for construction can be substituted.

5.3 Ranking of measures supporting recycling – case Flanders (and Basque country)

Different regional stakeholders involved in the value chain in Flanders (and Basque country) were contacted to get their view on potential measures that could effectively support recycling of CDW (not limited to ICEBERG solutions). They were asked to score the importance of listed measures and give an indication of a possible implementation timeline by means of an online survey.

The Flemish questionnaire was completed by eight diverse profiles representing different stakeholder groups: recycler (1), manufacturer (2), demolition expert (2) and contractor (1), building owner (1) and the Flemish sector organisation for construction companies (1). The questionnaire in the Basque country was completed by only two persons: a recycler and a construction company.

For each measure, the respondents (not limited to ICEBERG partners) were asked to rank the impact of the measure on promoting CDW recycling (no importance/no opinion, somewhat important, important or highly important) and to mark when the measure can be achieved at the earliest (already in place and implemented, already in place but still not fully implemented, can be achieved by 2030 or can be achieved by 2050).

The questionnaire template is shown in Appendix 4.

[166] Damgaard, A., Lodato, C., Butera, S., Fruergaard, A. T., Kamps, M., Corbin, L., Tonini, D., & Astrup, T. F. (2022). Background data collection and life cycle assessment for construction and demolition waste (CDW) management. https://doi.org/10.2760/772724

The results of the Flemish online survey are presented in the graphs below (x: implementation, y: scale of importance) and grouped in four different categories. The scoring of importance and timeline is calculated as a simple average (no importance/no opinion was scored with value 0, somewhat important as 1, important as 2 and very important as 3 – this means that in case of scoring over value 2 at least 4 of 8 responses ranked the measure as very important).

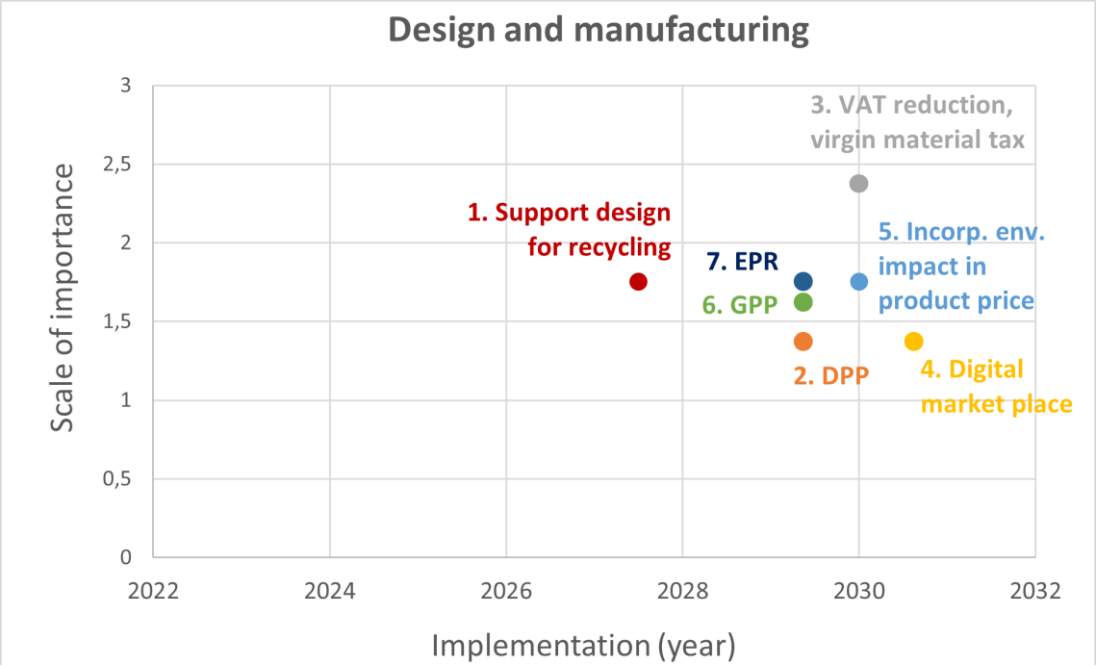


Figure 26 Ranking of measures linked to design and manufacturing.

The suggested measure of policy actions for supporting construction products containing recyclables (e.g. taxes on virgin materials, VAT reduction for products with recycled content, national support for local markets) was agreed on by the different stakeholders as one with high importance. The figure also shows that the measures regarding the **design and manufacturing** are not yet in place and most of them are only estimated feasible around 2030.

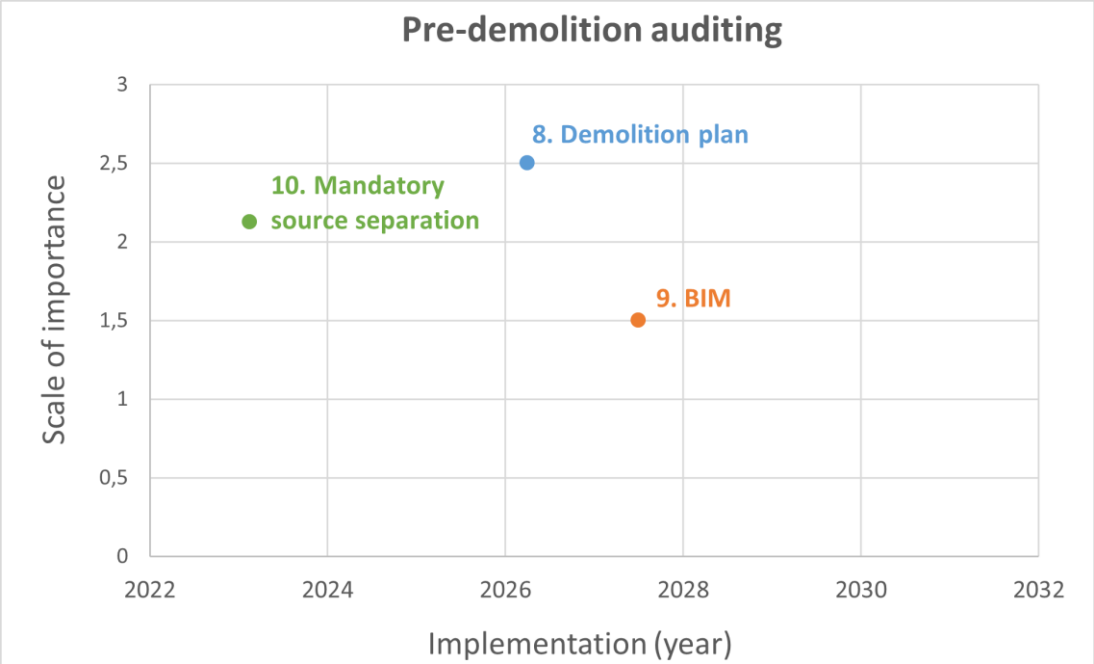


Figure 27 Ranking of measures linked to pre-demolition auditing

This is in contrast with the measures concerning **pre-demolition auditing** allowing earlier implementation with the mandatory source separation already in place (for materials for which a recycling capacity exists).

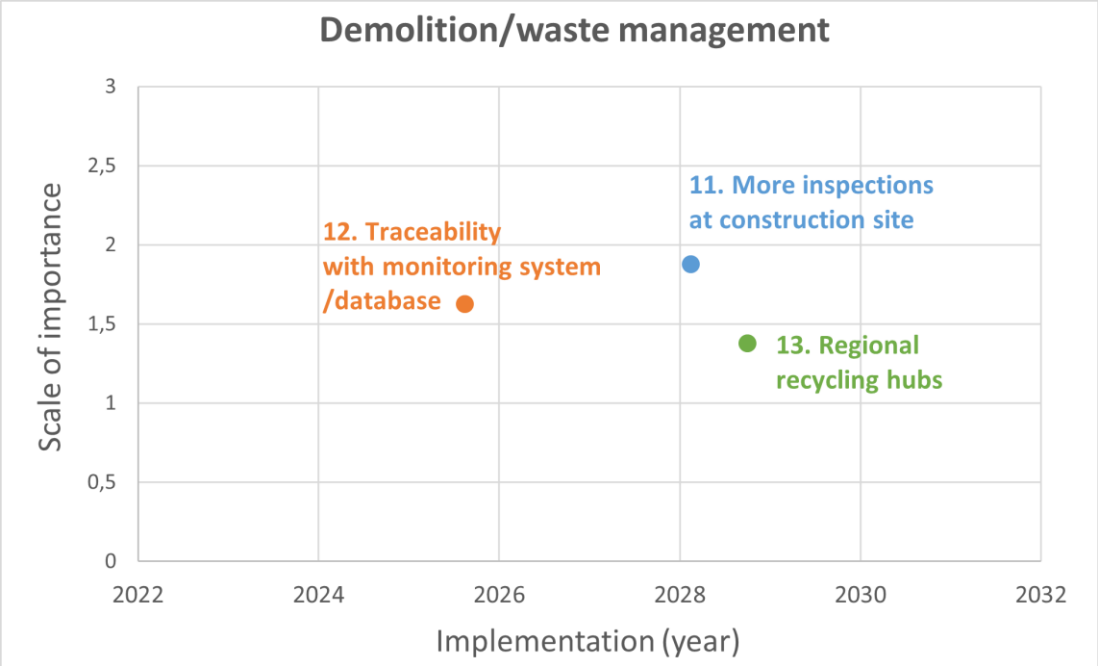


Figure 28 Ranking of measures linked to demolition and waste management

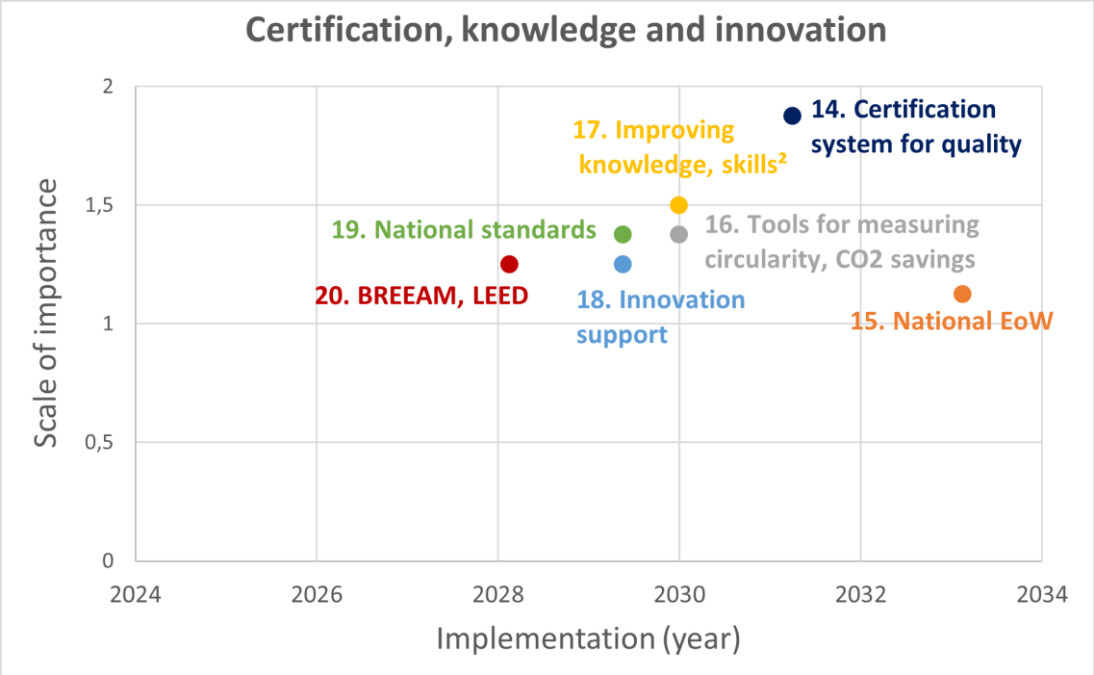


Figure 29 Ranking of measures linked to certification, knowledge and innovation

While the **demolition/waste management** measures are considered to be of medium importance and implementation time, the measures related to **certification, knowledge and innovation** generally score lower on the importance scale and their performance is estimated to be achieved at a later stage.

Three measures stand out in the Flemish and Spanish survey: VAT reduction for products with recycled content and virgin material tax, the demolition plan and the mandatory source separation. For both regions, these last two highly ranked measures have already been implemented (or will be in the near future). The first one has an expected implementation date around 2030.

6 How do the ICEBERG solutions contribute to the transition towards Circular Economy

6.1 General

Both the terms circularity and sustainability are often used in connection with construction products. Sustainability is a wider concept to which circularity is contributing. It includes not only resource efficiency but also climate and other environmental aspects as well as economic and societal aspects.

In a Circular Economy (CE), the general aim is to retain the functionality of materials in their use cycles at a level as high as possible. Circularity concept refers to the design of systems, products, and processes that minimize waste and retain the value of the materials and products. In practice, a CE minimises waste through reusing, repairing, refurbishing, and recycling existing materials, components, and products. The central element of the implementation of the CE is the change of the companies' business models, which they adapt through so-called R-strategies: reduce, reuse, recycle, recover. In particular to circular transition of the built environment, there are 6 R-strategies, as illustrated in [167]: i) Efficient design and production (R1-R2), ii) More intensive use (Use), iii) Lifetime extension (Use, R4), iv) Material substitution (R1-R2), v) Component reuse (R3), and vi) Enhanced recycling and recovery (R5-R6). These strategies should represent the basis for organisations aiming at improving the circularity of their businesses.

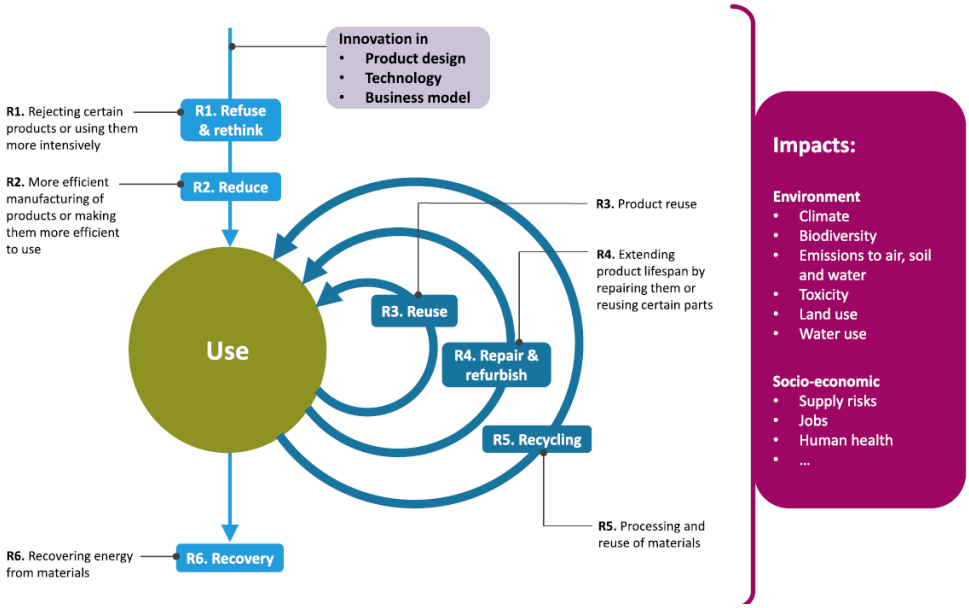


Figure 30 Circularity strategies and socio-environmental impacts (ref: Tukker et al 2023)[168]

[167] Tukker A., Behrens P., Deetman S., Hu M., Alejandre E.M., van der Meide M., Zhong X. and Zhang C. (2023). Circular construction: Six key recommendations, One Earth (6)11: 1425 – 1429. https://doi.org/10.1016/j.oneear.2023.10.021

[168] The left side of the figure shows so-called ''R'' strategies to reduce the inflow of primary raw materials in a product system, or the built environment, in our case. By this, the same primary materials are kept much longer in economic use. This is expected to have

Circularity from a life cycle perspective (from material sourcing to the end-of-life stage) demands metrics and indicators to provide tangible measurements of how efficiently resources are being utilized, recycled, and reintegrated into the production cycle. By offering a comprehensive view of the circularity of operations, these metrics and indicators can enable businesses to identify areas for improvement, optimize resource usage, and ultimately reduce waste. Moreover, circularity assessment metrics could serve as a powerful tool for demonstrating the environmental and economic benefits of adopting circular practices. They could facilitate transparency and accountability, allowing companies to showcase their commitment to sustainability to stakeholders, investors, and consumers alike. While, despite the undeniable benefits, there are barriers that need to be overcome to fully leverage circularity assessment metrics and indicators. These barriers include technological limitations, lack of standardized methodologies, and resistance to change within organizations.

For instance, common indicators for measuring the circularity are missing but a standardisation work under ISO is ongoing (a draft ISO DIS 59020 presents circularity indicators for organisations to measure and assess circularity, but not specific to buildings or construction products). In Italy, a technical specification is already available: the UNI/TS 11820 "Measurement of circularity – Methods and indicators for measuring circular processes in organizations". This technical specification, currently intended to be certifiable as a claim, has been included in the current version of the Italian strategy for the circular economy and has also been proposed internationally as a basis for drafting ISO 59020 "Circular economy — Measuring circularity framework," developed by the ISO/TC 323 technical committee. Recent work (Wong et al., 2024)[169] summarizes the current building circularity assessment metrices and indicators as shown in Table 21.

a beneficial effect on impacts mentioned at the right side of the figure, such as climate-related emissions, biodiversity loss, and reduction of supply risks.

[169] D.H.Wong, C. Zhang, F. Di Maio, M. Hu (2024) Potential of BREEAM-C to support building circularity assessment: Insights from case study and expert interview, Journal of Cleaner Production, 442:140836, ISSN 0959-6526, https://doi.org/10.1016/j.jclepro.2024.140836.

Table 21 Existing circularity assessment metrics/ indicators (ref: Wong et al 2024)

	Year	Developed/ proposed by	Characteristics	Focus
Material circularity indicator (MCI)	2015	EMF and Granta Design (Ellen Mac Arthur Foundation, a Granta Design, 2015)	Measures how restorative the material flows are at product level	End- of-life circularity
Building circularity indicator	2016	Veberne (Veberne, 2016)	Determines circularity at building level using indicators for Materials (MCI), Products (PCI), Systems (SCI)	Input, functionality, and output performance of building
Building circularity indicator (BCI)	2018	van Vilet from Verbene´s BCI	Determines circularity at building level	Disassembly potential
Building circularity index (BCIX)	2018	Alba Concepts (Alba Concets, 2018)	Determines circularity at building level	Technical cycle and disassembly potential
Madaster circularity indicator	2018	Madaster Foundation (Bronsvoort and van Oppen, 2018)	Has its basis on MCI developed by EMF Improved & adapted for circularity at building level BUT did not take into account circularity of different building layers	Circularity scored according to circular properties of materials & Products used during the Construction, In-use and End-of-Life phases
Framework of circularity indicators (BREEAM-C)	2018	Building Research Establishment Environmental Assessment Method (BREEAM)	Expanded from BREEAM´s green building certification scheme (BREEAM-G) Rooted in Metabolic´s 7 CE pillar and Circle Economy´s 8 key CE elements	7 desired impact areas with 47 proposed indicators mainly under Material, Energy and Water Cycles
Platform CB´23 Guide for measuring circularity in construction	2020	Ministry of Infrastructure and Water Management, the Netherlands	Measurement goals: material preservation, environmental protection and value retention Quantitative indicators for objects/sub-objects Qualitative indicators listing adaptive properties for each building layer	Adaptive capacity of the building BUT lacks an overall BCI

Sources:

Ellen Mac Arthur Foundation, a Granta Design, 2015 https://www.ellenmacarthurfoundation.org/resources/apply/circulytics-measuring-circularity

Veberne, 2016 Building Circularity Indicators: an Approach for Measuring Circularity of a Building, Master's Thesis. Eindhoven University of Technology, Eindhoven, The Netherlands (2016)

Alba Concets, 2018, https://albaconcepts.nl/buildingcircularity-index/

Bronsvoort and van Oppen, 2018, https://madaster.com/madaster-circularity-indicator/

Table 22 Metabolic's seven CE pillars and Circular Economy's eight key CE elements (Wong et al 2024)

Circular Economy	
Metabolic - 7 pillars	**Circle Economy - 8 key elements**
Materials maintained in continuous high-value cycles	Prioritize regenerative resources
Energy all based on renewable sources.	Stretch the lifetime
Water managed in a 100% circular fashion	Use waste as a resource
Biodiversity structurally supported and enhanced	Design for the future
Human society and culture preserved	Rethink the business model
Health and wellbeing of humans and other species structurally supported	Incorporate digital technology
Human activities generate value in measures beyond just financial.	Team up to create joint value
	Strengthen and advance knowledge

Table 23 Summary of number of strategies and indicators under BREAAM-C (Wong et al 2024)

CIRCULAR BUILDING			
Desired Impact Areas	No. of Strategies	No. of Sub-Strategies	No. of Indicators
Material Cycle	4	13	32
Energy Cycle	4	5	9
Water Cycle	3	5	6
Biodiversity & Ecology	4	5	-*
Human Culture & Society	3	3	- *
Health & Wellbeing	3	6	2
Multiple Values	2	2	-

Investing in the development and implementation of a robust standardised circularity assessment framework is crucial for realizing the full potential of the circular economy. By doing so, businesses can not only enhance their competitiveness and resilience but also contribute significantly to the broader goal of achieving sustainable and responsible resource management.

However, it should be noted that, while the principles of circularity and sustainability often intersect, their relationship is not consistently straightforward across all contexts. In some cases, circular initiatives may inadvertently lead to negative environmental impacts or social disparities if not implemented thoughtfully. For this reason, it is essential to evaluate the implications of circularity initiatives within the specific context of each situation. LCA and LCC, for example, represent valuable tools for these evaluations, considering environmental and economic life cycle impact indicators. These methodologies have been applied in WP5 of the ICEBERG project to assess whether the innovative solutions developed within the project also have the potential to reduce environmental and economic impacts, in addition to enhance the system's circularity. Specific indicators related to circularity (such as detachability and reusability) were not explicitly quantified but reflected in the LCA-LCC studies in WP5 as reduced costs and environmental impacts due to savings in time and new production. The main findings of the executed LCA-LCC studies are reported in the following section.

6.2 ICEBERG solutions

Contributing to the transition towards a circular economy besides developing new construction products with secondary materials from CDW, the ICEBERG project has advanced two types of technologies:

- ***Processing technologies***, which allow for the recovery of high purity secondary raw materials from CDW for the substitution of primary raw materials in new construction products, targeting on Enhanced material recycling (R5) and Material substitution (R1 - R2);
- ***Information technologies***, for quantification and traceability of CDW from end-of-life buildings.

The effects of the innovations have been demonstrated in 6 circular case studies. The related environmental impacts and potential financial consequences have been assessed from a life cycle perspective.

Conclusions from CCS1 - demonstrating circular concrete

This LCA/LCC assesses the environmental and economic performance of the innovative ICEBERG solutions for the recovery and recycling of EoL concrete, using the demolition of the Eikenstein building in the Netherlands as a case study. The main findings indicate that the ICEBERG solutions, which use the C2CA technologies of ADR and HAS to process EoL concrete into new concrete blocks, demonstrate improved environmental and economic performance compared to current practices. This is primarily due to the reduction in the use of virgin materials and waste generation. The production of aggregates with the C2CA technology was found to be the most significant factor contributing to these improvements. With these technologies, the conversion losses of EoL concrete to new aggregates are very low. These technologies could thus become very beneficial for reducing reliance on virgin resources and improving the circularity of the construction sector. Furthermore, exploring the option of including cementicious Recycled Concrete Fines (RCF) in other products (e.g., mortar) to reduce the use of cement shows a big potential to reduce CO_2 emission.

Conclusions from CCS2 - demonstrating circular cement-based products

The LCA and LCC studies performed for CCS2 assess the environmental and economic impacts of ICEBERG Cement-based products compared with the equivalent benchmarks (Business as Usual, BAU). The studies concern the processing and use of End-of-Life Building Materials (EBMs) coming from the demolition of a building, being re-inserted into a new life cycle in which they are inputs for the manufacturing of Cement-based products.

On product level, LCA results show that ICEBERG products have some positive performances from environmental perspective, since the EBMs use could reduce the impacts coming from virgin raw materials. Despite positive evidence in many impacts categories, some of the CCS2 products still suffer from not-yet-upscaled manufacturing processes. From LCC analysis, indeed, the costs of the ICEBERG products are often still higher than the benchmarks, since the absence of an upscaled technology for the production process still makes them express higher associated expenses (e.g., labour, raw materials, energy).

The final LCA-LCC study also assesses the building level approach, where the Cement-based products are installed: from LCC points of view, the ICEBERG building has higher costs than the benchmark, as expected from the results of product level approach, while environmental performances are better than BAU.

Conclusions from CCS3 – demonstrating circular carbonated blocks

In CCS3, two products have been developed in which recycled concrete aggregates are used as secondary raw materials. In addition, carbonation is applied to strengthen the blocks or to upgrade the aggregates, and to capture carbon. The products assessed on product and building level in CCS3 are:

- Carbonated blocks (in comparison with BAU concrete blocks),
- Recycled aggregate concrete mixture with carbonated recycled concrete aggregates (RCA) (in comparison with BAU ready-mix concrete with only virgin raw materials).

The results of the final LCA-LCC show that the ICEBERG CCS3 products perform better than their BAU counterparts, both environmentally and economically, when assessed on product level. This positive trend also holds true when considering the comparison on building level from an environmental standpoint. However, when assessing the products on building level from an economic perspective, there is a divergence. While the ICEBERG recycled aggregate concrete mixture continues to demonstrate a lower economic impact similar to that observed on product level, the ICEBERG carbonated blocks incur higher net costs compared to the BAU concrete blocks. This is caused by the use lime mortar instead of cement mortar, although a cement mortar could also be used with the carbonated blocks. This discrepancy highlights the delicate balance between environmental impacts and economic considerations in sustainable construction practices.

Conclusions from CCS4 - demonstrating circular wood-based products

The environmental and financial performance of CCS4 was compared to a BAU alternative, for the production process of insulation panels, as well as building demolition and energy recovery of the materials. The insulation panels assessed in the CCS4 case have been found to minorly reduce environmental impacts and marginally improve financial performance. For the impact categories that have assessed, the results indicate that the improvement potential for insulation panels can be limited if solely substituting virgin wood with recycled wood sources. A critical factor in these results is the accounting for biogenic carbon. Using EPD input data given by the producer to replicate its CO2 emission results, we have spotted that different modeling approaches on biogenic carbon flows could cause significant differences in the climate change impact results and conclusions but are currently not explicitly communicated. We recommend a more detailed investigation into the modeling and reporting of the -CO_2 from biogenic sources- in LCA. Understanding the benefits of keeping biogenic carbon out of the atmosphere for longer periods could have implications for the LCA results as

well[170,171], leading to additional circularity benefits, which we have not accounted for in this study. This could potentially lead to more accurate and comprehensive models, thereby enhancing the reliability and robustness of the results.

Conclusions from CCS5 – demonstrating circular plasterboards

The assessment conducted within CCS 5 compares the LCA and LCC of the BAU plasterboard (90% virgin gypsum, 10% pre-consumer gypsum waste) and the ICEBERG circular plasterboard. This evaluation examines their impact throughout their life cycle, considering both product and building levels. The LCA follows the recycling and production processes currently practiced by ICEBERG partners ENVA (plasterboard recycler) and GYPS (plasterboard manufacturer). The ICEBERG plasterboard is comprised of 65% virgin gypsum, 10% recycled gypsum using the BAU recycling process, and 25% purified gypsum from EOL plasterboards using the ICEBERG purification process, following the approach proposed in Task 2.5. Its production process aligns with GYPS's current practice. The LCA outcomes highlight ICEBERG plasterboard's superior cradle-to-gate environmental performance over BAU within the most studied impact categories, even without full optimization at the semi-industrial production stage. ICEBERG exhibits a reduced environmental footprint compared to BAU, primarily due to the recovery of waste plasterboard and the reuse of raw materials, reducing dependence on virgin resources.

Conclusions from CCS6 - demonstrating circular ceramic, silica aerogel and PU based products

The aim of the study performed on CCS6 is to assess the environmental and economic impacts associated to:

• The recycling of the stony fraction and PU/PIR waste coming from demolition, to be treated with the automated HSI-based sorting to obtain high-quality secondary raw materials;

• The production of building products, both for wall and floor applications, made with the obtained high-quality secondary raw materials. In particular, ceramic tiles and PU panels are included in the study.

The results show that the ICEBERG products is very promising: the substitution of virgin materials with secondary raw materials coming from EBMs has the potential to reduce the environmental impacts across most categories. In particular, circular ceramic tiles show a 30 % lower impact in the *Resource use, minerals and metals category*, compared to the BAU solution, while PU panels reduce the *Climate change, fossil* impact by 25 %. ICEBERG products are also favourable in terms of economic impacts. In addition, the recycling of EBMs can represent a good solution, especially if compared to the utilization of the same fractions for low-quality applications.

[170]Cherubini F. et al. (2011). CO_2 emissions from biomass combustion for bioenergy: atmospheric decay and contribution to global warming. Global Cange Biology Bioenergy.

[171] Guest G. et al. (2013). Global Warming Potential of Carbon Dioxide Emissions from Biomass Stored in the Anthroposphere and Used for Bioenergy at End of Life. Journal of Industrial Ecology.

Box 16 - Use of circularity indicators in the design phase - ICEBERG example

In ICEBERG, the role of circularity metrics and key performance indicators was explored as a means to support decision-making in the design phase.[172]

Circular design in the construction sector involves considering the entire lifecycle of a building, from material selection and construction processes to operation, maintenance, and eventual end-of-life considerations. By adopting circular design principles, stakeholders can minimize the use of virgin resources, promote reuse and recycling, and optimize the longevity and adaptability of buildings. This holistic approach can lead to not only environmental benefits but also economical and social benefits.

By integrating circularity metrics and data, decision support tools enable stakeholders to make informed choices that prioritize resource efficiency, waste reduction, and sustainable practices. As part of the EU-funded research project Buildings as Material Banks (BAMB) from 2015 to 2019, a set of indicators was developed with the involvement of EPEA to assess the circularity of buildings. These indicators are used to evaluate and document the circularity of buildings. The results are issued as a Material Passport in the form of the Circularity Passport® (CP).

Following this approach, circularity assessment was carried out in WP4 for ICEBERG products using the following Key Performance Indicators (KPIs):

- Embodied Carbon: The construction-related CO_2 footprint, the so-called embodied carbon, is determined through a Lifecycle Assessment (LCA).
- Material Sourcing: origin of the materials (renewable, secondary, or primary sources)
- Material Recovery: recyclability (recycling, downcycling, energy recovery, landfilling)
- Dismountability: removability and separability of the functional units
- Separability: potential to disassemble as many structures as possible into their components or recycling units
- Material Health: Harmful ingredients

As an example, circularity assessment for ICEBERG Structural precast concrete exterior wall is presented in Figure 31, including the circularity metrics (KPIs) listed above. The results are compared to the business as usual (BAU) case. The assessment allows to compare different solutions and identify potential areas for improvement.

[172] ICEBERG deliverable Catalog and Guidelines for Building Professionals (Part II).

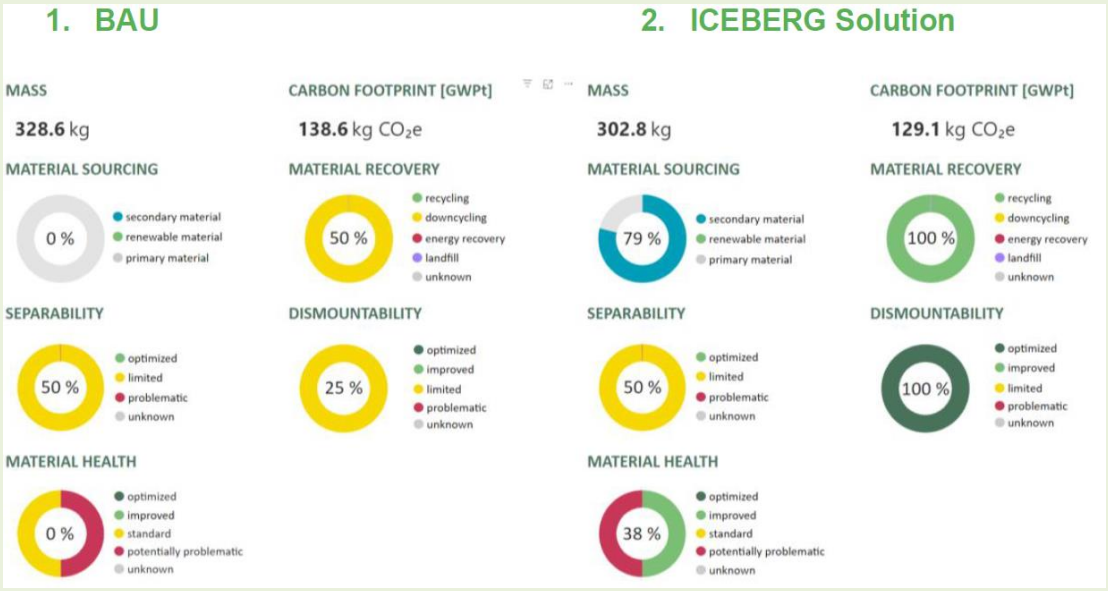


Figure 31 Example of circularity assessment: Structural precast concrete exterior wall BAU and ICEBERG solution. (functional unit: 1 m^2)

6.3 Assessment of the environmental sustainability – future needs

Environmental sustainability is mentioned in numerous recent EU strategies and legislations. Table 24 gives an overview of environmental aspects included in current and coming from EU legislation relevant for construction products. The targets in environmental performance (e.g. savings in use of materials, CO_2 emissions, waste prevention, healthy products) set needs for indicators and later for some characteristics also criteria.

As environmental sustainability covers many different aspects, several different types of indicators and consequently also methods or approaches are needed for the assessment. Indicators can be set at building level or construction products level. However, indicators at building level also affect use of construction products (e.g., promoting products with low embedded carbon). Circularity and sustainability aspects need to be assessed over the whole life cycle of the building to optimise the reduction of carbon emissions and material flows. Also toxicity aspects (good indoor air quality secured by low emitting products, low release of toxic substances into water, soils) need to be considered.

Impacts from crosslinking between different goals (e.g., energy, decarbonization, or material efficiency, circularity) are only to a limited extent assessed, potentially causing so-called burden shifting in energy solutions. For construction products, environmental sustainability focuses mainly on energy and resource efficiency along the value chain. Attention is also on toxicity (use of hazardous chemicals, emissions of hazardous substances) especially if regulated. To some extent, also the generation and management of rejects in the manufacturing processes need to be considered. Biodiversity aspects are seldom included and there are no clear targets set. Furthermore, there is limited data published on the impact of building systems on biodiversity. Only for use of biobased construction products (e.g., timber), literature impact on biodiversity has been reported. The impacts of

buildings are generally limited in the built environment (mainly local impacts in certain areas, e.g., in mining and foresting and as well as impacts from the use of water or in the extraction of raw materials).

The new construction products regulation (CPR) will in the future make the declaration of greenhouse gas emissions compulsory by using LCA methodology for all construction products, but no targets or minimum requirements will be established at this stage. There are no minimum requirements for using recyclables in construction products, and thus reporting of recycled content in construction products will not be mandatory in declaration of performance.

Even if not mandatory for reporting according to the new CPR, the use of recyclables is supported by several policies and regulations setting also demands for an indicator for recycled content. Examples are requirements in green public procurements, EU taxonomy criteria for circular economy and national bans for landfilling of recyclable materials. There are already examples on methodologies to be used for calculation and reporting of environmental performance. For example, Environmental Product Declarations (EPDs) are a proven method for which sector specific standards are developed. The EN15804+A2 standard, specific for the construction industry, is used in the LCA reports for measuring a product's environmental performance throughout its lifecycle, including its recyclability.

The ambitions for increasing resource efficiency as well as the overall EU and national targets for recycling and reuse of construction and demolition waste give initiatives for reuse and developing new products containing recyclables, but there is a lack of a standardized way to report recycled content.

The needs for harmonization of tools for measuring and reporting of environmental sustainability and also the needs for developing environmental sustainability criteria for comparison on environmental performance of construction products are further discussed in the policy recommendation number 3 (section 7.3).

Table 24 Environmental sustainability aspects covered in key EU regulations relevant for construction.

Policy/ regulation	Focus	Resource efficiency, circularity	Climate aspects	Toxicity	Bio-diversity
Construction products regulation	Uniform assessment methods on the performance of construction products to remove barriers in their trade	x	x	x	
Fit for 55 (EU Climate law, Energy Performance of Buildings Directive…)	Focus on energy efficiency by e.g., increasing the share of renewable energy, improve energy efficiency, and introduce the carbon border adjustment mechanism. No net emissions of greenhouse gases by 2050		x		

Policy/ regulation	Focus	Resource efficiency, circularity	Climate aspects	Toxicity	Bio-diversity
Renovation wave (including Renewable Energy Directive)	Making existing buildings more sustainable and energy-efficient through circular economy to reduce demand for new materials and minimize waste, and the larger scale adoption of low-carbon materials.	x	x		
Ecodesign	Making sustainable products as a norm in EU.	x	x	x	
Waste Framework Directive	Hierarchy in waste management and End-of-waste concept	x		x	
Toxic free environment	Substitution of harmful material, low emissions during whole life cycle			x	
EU taxonomy	Help companies and investors identify "environmentally sustainable" economic activities to make sustainable investment decisions.	x	x	x	x
Green public procurement (GPP)	A voluntary instrument to be used by municipalities to improve the environmental performance of a service	x	x	x	
Green Claims	To provide end-users with reliable, comparable, and verifiable information about the environmental impacts of a product or the trader itself.	x	x	x	
Safe and sustainable by design[173]	Focus on hazardous substances in design, use and end-of-life stage.	x	x	x	

[173] COMMISSION RECOMMENDATION (EU) 2022/2510 of 8 December 2022 establishing a European assessment framework for 'safe and sustainable by design' chemicals and materials

7 Overview on potential policy measures and Policy recommendations

7.1 Approach

The ICEBERG policy recommendations have been elaborated based on the findings from task 6.1. Especially, the insights gathered from the interviews with ICEBERG stakeholders regarding actions that promote the uptake of ICEBERG solutions were considered. Additionally, views on the barriers and further information needs presented in two workshops arranged in conjunction with ICEBERG GA meetings were taken into account. Due to the significant involvement of construction products manufacturers in ICEBERG, “a material-oriented approach” was adopted along the value chain when formulating the policy recommendations.

The list of policy recommendations was grouped according to the types of instruments: political and legal instruments, economic instruments, information instruments, technical instruments, and concrete activities, initiatives & projects. A reporting template was created and used for all policy recommendations. To some extent, several policy recommendations are interconnected. Whenever feasible, references to results from other EU projects or related studies were included. In the preparation of ICEBERG policy recommendations, contacts have been taken to representatives for some EU Horizon projects and feedback to the policy recommendations was received from representatives from CISUFLO and CITYLOOPS.

The draft policy recommendations were presented to ICEBERG partners in a validation meeting on March 25, 2024. The final policy recommendations (Table 25) were formulated based on the discussion in the validation meeting and the received written feedback.

Table 25 Policy recommendations grouped according to the types of measures/instruments

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-quality (closed loop) recycling and preparation for reuse from best technologies 2. Connect qualitative pre-demolition audit, demolition plan and 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

7.2 Political & legal instruments

7.2.1 Recommendation 1: Harmonise End-of waste (EoW) protocols and certification schemes for high-quality (closed loop) recycling and preparation for reuse from best technologies

Challenge
The market needs assurance that recycled materials and reusable products are suitable for their use as resources in building or other products. This assurance includes both the technical and environmental suitability. This assessment has to be clear, replicable and sound. The process of determining the EoW status should be transparent and swift, with minimal costs to all parties concerned. Across the EU member states, this process should be comparable, but norms and parameters involved should reflect local circumstances. For materials where this is possible, EoW criteria should be aligned within the EU. However, for many materials national or regional sets of parameters can be applied. Focus in the discussion on the need for EoW concepts has in many member states been on stony materials used in infrastructure, e.g., road materials. In a JRC study (2014)[174], it was concluded that it would be challenging and time consuming to set EoW criteria for aggregates derived from CDW at EU level. This is partly due to different approaches in the assessment of acceptable risks to soil and groundwater especially from leaching. In several interviews, ICEBERG stakeholders claimed that for waste materials not shipped to other

[174] Saveyn, H. et al. 2014. Study on methodological aspects regarding limit values for pollutants in aggregates in the context of the development of end-of-waste criteria under the EU Waste Framework Directive

countries for recycling, there are mainly needs for national and regional EoW concepts.

Many innovative technologies developed for recycling of specific CDW fractions (e.g., insulation materials) require a sufficient supply of material for processing. For waste materials shipped from one country to another for recycling, there is a need for an EU-wide EoW assessment. Priority should be given to waste streams and technologies whose EoW status could provide important environmental benefits. Furthermore, a discussion is needed on the point of compliance for EoW assessment for those materials that are processed and transformed through e.g., chemical recycling methods, or immobilization.

A case specific EoW decision for waste materials often depends on the recycling processing, the material characteristics, the market and environmental conditions in the member state. Here, a common protocol of elements to be included (e.g., protocols for quality assessment, background documents needed for an EoW decision) could be helpful for gaining more uniform case specific EoW criteria in Europe. Also, a database on case specific decisions (with information on waste materials, criteria, conditions) could guide national authorities making their own EoW decisions. This will increase transparency of the decision-making process and could increase the acceptance and trust in the recycled materials, regardless of their origin.

In some cases, approval of waste material for recycling through a simplified environmental permit system governed by waste regulations (e.g. using a notification procedure with fast approval for a waste stream fulfilling the requirements defined in the given regulation – however, here the waste status remains) can be an easier solution than the use of the EoW concept. Some countries have a pass-fail scheme for assessing and allowing the use of products in certain construction works based on the fulfilment of defined requirements (material specific leaching limit values for certain defined use scenarios).

A harmonization of procedures is suggested covering minimal requirements on pre-demolition audit and monitoring of demolition activities, the use of norms and quality standards in the sorting process, sampling procedures, and skills for experts. This applies both for national EoW concepts as for a simplified environmental permit system.

An EoW status of intermediates (e.g., in case of pyrolysis oil for resin production) needs clarifications on the interface to REACH legislation. Guidance for recyclers and manufacturers is needed.

Description (goal)

- Development of a harmonized procedure for the assessment of the EoW status of materials from recycling processes at EU level especially for materials that are shipped across borders for high-quality recycling processes and at national level for waste streams that are not shipped for recycling outside the country.
- Development of harmonized schemes for case specific EoW decision.
- Setting a databank with information on case specific EoW decisions in Europe.

Actions (bullet points) – implementation	
- assessment of links to REACH for intermediates for non-mineral construction products - development of new on-line tools for quality monitoring and sorting - collection of data on characteristics of materials derived from recycling, sorting and recovery technologies - development of assessment tools for evaluating different environmental benefits (resource savings, CO_2 savings, toxicity free) to potential risk (pollution of soil, water)	
Actor(s)	Commission, national/regional authorities, manufacturers, end-users, recyclers
Timeline	Midterm
References	Regional EoW concepts used in Flanders and Basque countries (regional reports, Appendix 2) Section 4.2.1 Orveillon, G., Pierri, E., Egle, L., Gerbendahl, A., Wessman, P., Garcia John, E. and Saveyn, H., Scoping possible further EU-wide end-of-waste and by-product criteria, EUR 31007 EN, Publications Office of the European Union, Luxembourg, 2022, ISBN 978-92-76-49046-3, doi:10.2760/067213, JRC128647. Saveyn H, Eder P, Garbarino E, Muchova L, Hjelmar O, Van Der Sloot H, Comans R, Van Zomeren A, Hyks J, Oberender A. Study on methodological aspects regarding limit values for pollutants in aggregates in the context of the possible development of end-of-waste criteria under the EU Waste Framework Directive. EUR 26769. Luxembourg (Luxembourg): Publications Office of the European Union; 2014. JRC91036

7.2.2 Recommendation 2: Connect qualitative pre-demolition audit, demolition plan and follow-up to EU Taxonomy

Challenge
There is a need for gathering the different acceptance criteria imposed by recyclers. Since selective demolition will become the new normal, it is important that demolition contractors know the requirements for (the quality of) different materials for recycling. Another hurdle is the lack on guidance on proofs for complying to the EU Taxonomy. At present, a pre-demolition audit doesn't result in an EU Taxonomy-proof certificate of selective demolition or any kind. Since there is no direct link, effort is sometimes duplicated or the threshold for providing both is too high.

In addition, the competence of the auditors/demolition experts needs to be ensured to pursue the quality of the pre-demolition audit and the follow-up process. Often there is no obligatory experience or education required prior to the drafting of a pre-demolition audit. Knowledge of materials (especially hazardous materials such as asbestos) is necessary.

Furthermore, a pre-demolition audit cannot stand on its own. Follow-up of the separate collection is essential. A verification with the management process is needed (not only “the what” but also “the how”). A contractor should describe the choices made regarding the management of the waste, prioritizing selective demolition and source separation of waste streams. Information not only on the amounts and separation rates but also on the type of waste management performed is essential to validate the quality of the (selective) demolition works.

Lastly, selective demolition is more labor-intensive, inevitably leading to higher demolition costs that cannot always be compensated by the price recyclers/processors pay for this secondary raw material or by the savings of nothing having to dump/incinerate. These costs are usually passed on to the contractor or client. Policymakers are challenged to think about how to cover this extra cost and among whom this extra cost should be divided.

Description (goal)

- Alignment of the content and procedures to draw up a pre-demolition audit in the different EU countries. In addition, it is paramount to figure out how to link the pre-demolition audit and the resulting qualitative follow-up of the selective demolition works to the EU taxonomy. It would benefit companies and investors if the (follow-up of the) pre-demolition audit and the follow-up of separate collection of recyclable materials can somehow serve as proof that the demolition works were executed in an ‘environmentally sustainable’ way as described in the objectives of the EU taxonomy.
- Description of acceptance criteria of recyclers for all materials to make sure that all necessary information (e.g., impurity limit values, interfering substances, damage…) is directed to the demolition contractors. A list of potential purchasers (reuse/recycling) with the corresponding acceptance criteria can be included in the pre-demolition audit.
- Awareness, information and in-depth training for experts and contractors on the different stages of the recycling route (identification of hazardous waste, high potential recycling waste, demolition techniques, acceptance criteria of recyclers…) to safeguard the quality of the pre-demolition audit.
- Mandatory demolition and waste management plan drawn up by the demolition contractor describing the organization of the waste management to guarantee clean and pure material streams. It can outline the different steps of the demolition, the materials to be collected selectively, transport and follow-up. In the demolition and waste management plan a clear link should be pursued with the pre-demolition audit.

Actions (bullet points) – implementation

- Development of an open platform/website with an overview of recycling routes for CDW. The platform lists potential purchasers for each waste stream with their corresponding acceptance criteria. This platform needs to

be updated regularly and can be referred to in the pre-demolition audit. (reference: VITO and Tracimat recently participated in a Flemish project called VISUM that made the first steps to develop such a platform) - Quality checks by independent third parties (e.g., third-party certified auditor, public bodies or professional associations): o Assurance on the competence of the experts and contractors by organizing in-depth training and information sessions. o The quality of the pre-demolition audit and demolition/management plan and their link to the execution of the demolition works. o The audit is preferably linked to a databank/platform to monitor the materials from demolition/renovation from its origin until the first processor. This monitoring and quality control throughout the process must be carried out by an independent party (reference: Tracimat's traceability system). - Research on strategies to cover the extra cost of selective demolition. Examples: o Lower labor tax, higher tax on virgin materials o Extended producer responsibility o Take-back obligation o High landfill or incineration taxes - Possible extensions of the pre-demolition audit: o To include an inventory of materials with reuse potential, together with a list of potential buyers and the associated acceptance criteria. o To link the audit to a digital platform, for example to create an online marketplace for materials with reuse/recycling potential	
Actor(s)	all actors in value chain
Timeline	short – mid term
References	Section 4.3 in Deliverable 6.3 EC Guidelines for the waste audits before demolition and renovation works of buildings EU Taxonomy regulation (delegated act) Tracimat website/documents: www.tracimat.be VISUM project, platform: www.bouwensloopafval.be CITYLOOPS documents https://cityloops.eu/fileadmin/user_upload/Resources/City-Loops-Circular-Construction-handbook.pdf CIRCUIT documents, e.g. D7.5 https://www.circuit-project.eu/post/latest-circuit-reports-and-publications

7.2.3 Recommendation 3: Develop environmental sustainability criteria for comparison on environmental performance of construction products

Challenge
The construction sector aims to create and achieve sustainable solutions in design and manufacturing of construction products as well as in the

management of end-of-life products. The manufacturers are selecting raw materials with suitable characteristics for products and developing their process for manufacturing of products with recyclable content and with the required performance for the end-users. Especially the customer's awareness for environmental values set requirements for green products. Here indicators and tools for environmental sustainability assessments would support decisions. Moreover, construction products are often marketed and sold across borders, which sets a need for a common approach in the assessment of environmental sustainability.

Environmental sustainability goals are mentioned in numerous pieces of legislation coupled to CDW management. The environmental sustainability concept covers different environmental aspects such as resource efficiency/circularity (waste prevention, durability, high recycling rate, high recycled content...), climate effects and a toxic free environment. The resource use does not only concern the current demand, but also enables to cover future demand, without reducing resource reserves and ensuring at the same time climate mitigation, toxic-free environment, and biodiversity (land use).

Additional to ambitions for low carbon emissions and circularity, EU also sets goals for a safe and toxic free environment that calls for reducing pollution and especially addresses a need to rapidly address the risk posed by hazardous chemicals and phase-out of substances of concern, with a specific focus on very persistent chemicals. For achieving environmental sustainability goals, also other sustainability aspects such as biodiversity need to be considered (e.g. in selection/extraction of raw materials) even if the importance of biodiversity is often more linked e.g., to land use of buildings.

There is a risk for burden shifting if not all aspects in the assessment of environmental sustainability are considered. Currently, the life cycle assessment (LCA) is the main tool for assessing environmental performance of products in a more comprehensive way. ISO 14044:2006 "*Environmental management - Life cycle assessment - Requirements and guidelines*" requires a deliberate assessment of all relevant impact categories for a LCA study; therefore, it is not allowed to leave out impact categories that have a significant impact. There is a large amount of LCIA methods and models available, developed by various research teams all over the world. As required in the EN 15804+A2, in ICEBERG project the Environmental Footprint (EF) 3.0 method has been used for the 10 impact categories of Level(s). On top of these mandatory impact categories, others such as the indicators describing the resource use and the waste required in Environmental Product Declarations could be used.

Our study shows that recycling is frequently more financially costly than waste disposal and may also bring about potential side effects; often there is a conflict between high recycling rate or high-quality recycling contra greenhouse gas emissions or high amounts of rejects generated in the recycling process. Therefore, establishing standardized LCA-based tools can support environmental and financial performance-based policymaking for material circularity. On the other hand, treatment options are also dependent on the demand of secondary markets in a region. For instance, CDW is more inclined

to be recycled as aggregate in concrete in countries that are having extensive construction activities; CDW may end up as road base filler in countries that are experiencing large-scale infrastructure expansion. Hence, analyses of supply and demand conditions of secondary markets are also needed for specifying the EU waste hierarchy in a localized situation. The CPR (EU 305/2011) sets out basic work requirements (BWR) for construction works to be considered for CE marking. One of these relates to the sustainable use of natural resources that is highly relevant in the context of attaining the circular design goals. This BWR focuses on reuse or recyclability; durability; use of environmentally compatible raw and secondary materials. Currently, no harmonised EU standard has taken this requirement into account and this BWR has not yet been implemented. According to the new CPR, the scope of this BWR has been expanded also to cover maximization of resource efficiency, minimizing embodied carbon during whole lifecycle. Several building circularity assessment matrix/indicators are currently used (see chapter 6), attempts to evaluate circularity of concrete recycling from a life cycle perspective have been made in Zhang et al. (2023)[175]. Though the applicability and feasibility of the proposed method still needs to be tested. It should also be noted that when incorporating the evaluation of circularity into LCA, it is important to define how to deal with end-of-life allocation approaches and formulas, as there are various possible options. Allacker et al. (2017)[176] provides a good overview of the different possibilities, also presenting the main differences. Following this study, a sensitivity analysis has been included in the LCAs carried out within the ICEBERG project, to highlight how this methodological choice can influence the conclusions of the studies and also to stress out the importance of a common approach in the assessment of environmental sustainability.
Description (goals)
- development of circularity indicators for assessment of environmental sustainability of construction products containing recyclables - development of simplified sustainability indicator for digital product passport - development of environmental sustainability criteria for comparison on environmental performance of construction products
Actions (bullet points) – 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 indicators (also experience from the use)

[175] Zhang C. et al. (2023). Life cycle assessment of material footprint in recycling: A case of concrete recycling. Waste Management. https://doi.org/10.1016/j.wasman.2022.10.035

[176] Allacker et al. (2017). The search for an appropriate end-of-life formula for the purpose of the European Commission Environmental Footprint initiative. The International Journal of Life Cycle Assessment. https://link.springer.com/article/10.1007/s11367-016-1244-0

- To identify knowledge/information needs for development of sustainability criteria - To seek possibilities for combining a few indicators	
Actor(s)	all actors in value chain; standardization organization; academy
Timeline	short – mid term
References	Zhang et al. 2022, An overview of the waste hierarchy framework for analyzing the circularity in construction and demolition waste management in Europe. Science of The Total Environment Volume 803, 10 January 2022, 149892 https://www.sciencedirect.com/science/article/pii/S0048969721049676?via%3Dihub Zhang et al 2023. Life cycle assessment of material footprint in recycling: A case of concrete recycling. https://doi Waste Management Volume 155, 1 January 2023, Pages 311-319.org/10.1016/j.wasman.2022.10.035). Wong et al 2024. Potential of BREEAM-C to support building circularity assessment: Insights from case study and expert interview, Journal of Cleaner Production, 442:140836, ISSN 0959-6526, https://doi.org/10.1016/j.jclepro.2024.140836.

7.3 Economic instruments

7.3.1 Recommendation 4: Support market demand and supply of waste related materials for closed loop reuse and recycling

Challenge
For some materials, especially high-quality (closed loop) recycling is more costly than the costs related to the use of virgin raw materials or recycling in low-quality applications (downcycling) (ref. JRC report (2022)[177]). In some cases, high-quality recycling also causes higher CO_2 emissions than the use of virgin materials due to additional process steps required (e.g., material separation, purification). Currently, the environmental and economic impacts (impacts of material extraction, landfilling…) are not incorporated into the total price and actions for potential pollution control are potentially to be paid by the future generations. Impacts of policy actions for supporting reuse and use in high-quality applications are material and also country dependent. Reuse of products may also be hampered by cost factors (e.g., due to dismantling and storage costs). For reusable products, there are also difficulties to match the supply and demand. This sets needs for increasing the awareness and competence in reuse among actors throughout the value chain and, considering reuse aspects earlier in the demolition or renovation process. Moreover, it also requires developing continuous and comprehensive reuse

[177] JRC 2023. Background data collection and life cycle assessment for construction and demolition waste (CDW) management. https://publications.jrc.ec.europa.eu/repository/handle/JRC130992

inventories to increase the supply of reusable building products, developing more efficient reverse logistic solutions, and providing storage solutions, all of which are considered as key aspects needed to be developed and streamlined. In case of the reuse of construction products, the interest in reuse needs to be communicated to the demolition contractor to avoid the risk of damage to reusable construction products during dismantling that lowers the product value.

For recycling of specific CDW streams, documented information on recycling conditions (e.g., quality) is not easily available for actors in the value chain. A strong collaboration and commitment in the whole value chain is required for a successful high-quality recycling, e.g., quality requirements on input materials need to be communicated to the demolition contractor by the recycler. A lack of clarity about the quality of the separated fractions hampers selective demolition and influences the value.

Taxes are often mentioned as effective drivers for directing waste materials to recycling or reuse. However, waste materials are often recycled in low-quality applications due to a lack of economic incentives for high-quality recycling (closed loop) and a lack of clear acceptance procedures (legislative, environmental/technical). One conclusion from ICEBERG task 6.2 (Social attitudes towards circularity of building products)[178] is that affordability emerges as a significant motivator, with a large percentage of survey respondents indicating that cost savings would incentivize the purchase of houses built with secondary materials.

National rules for Green Public Procurement (GPP) are not addressing uniformly use of recycled content in new construction products.

Examples of actions promoting supply/demand:

- create EoW criteria (administrative costs lower)
- use of GPP (increases demand)
- increase waste management costs (landfill taxes, incineration taxes, landfill bans, etc)
- introduce taxes on virgin materials, i.e. incorporate the environmental costs of the use of raw materials. This involves the cost of extraction and transportation, processing of virgin materials set against the same for the recycling process or the conditioning for reuse…)
- EU taxonomy (financing of activities fulfilling EU taxonomy criteria)
- develop digital marketplaces for trading materials
- introduce fiscal measures like VAT reduction on products containing recyclables, virgin material taxes
- support employment for companies working with circular solutions
- less taxation for circular building

Description (goal)
Actions for supporting uptake of reusable products and products containing recycled materials from CDW

[178] ICEBERG D6.2 Social attitudes towards Circularity of Building Products - Part II

- creation of reuse centres (depots, material banks…) and digital marketplaces - support waste specific policy measures (actions, instruments) - compilation of reliable data for market decisions (estimations on amounts generated in EU, nationally and regionally, quality), conditions for reuse and recycling (requirements, standards, capacity, costs)
Actions (bullet points – implementation)
- Analysis of economic barriers for high-quality recycling possibilities for specific waste streams (conditions, outlook) - Analysis of waste material specific actions at the EU and the national level for promoting reuse and high-quality recycling taking into account country conditions. - Develop waste material specific requirements for fostering high-quality recycling - Analysis of the role of marketplaces for securing recycling and reuse - Support the development at the local and national levels of tools to support the market demand

Actor(s)	Commission, national authorities, regional and local authorities, manufacturers, end-users, building owners,
Timeline	short – mid term
References	D6.3. chapters 3, 4, 5

7.3.2 Recommendation 5: Use GPP to support reuse and recycling

Challenge
Local, regional, and federal authorities, which possess significant purchasing power for implementing various new construction and renovation projects, as well as building maintenance and demolitions, can direct these substantial investments to support the objectives of the Green Deal. By promoting the use of recycled materials in construction products or reuse of construction products, not only are circularity goals addressed, but also a positive contribution is made to combating global climate change. The new CPR gives the Commission the task to develop procedures for setting mandatory minimum environmental sustainability requirements for public procurement of construction products for facilitation the use of low-carbon products. These rules can apply to every contract that contains construction products, including contracts for construction works, where Member States want to introduce environmental requirements for these products. The new CPR does not specify the minimum environmental sustainability criteria, which will be given separately in delegated acts for different product groups concerned. The national strategies for circular economy presented by many EU countries define construction sector as a prioritized sector. The goal for example, in the Nordic countries is to support increasing innovation through more circular

projects by setting requirements on climate and environmental saving in public procurements.[179]

At the EU level, applicability of different Green Public Procurement criteria for the procurement process for office buildings, has been presented by JRC (2016)[180]. Among others, the criteria can be set to award resource use for specific construction products (incorporation of recycled or re-used content in concrete and masonry) or lifecycle activity (e.g. maximum waste generation per square meter in renovation works) or use of non-toxic material in construction (e.g. flooring materials complying to given indoor air emission limits).

JRC report (2022)[181] frames aspects and approach that could be used for developing a concept for the use of GPP in public tenders. For example, for demolition works, it is suggested following the methodology defined in Level(s) indicator 2.4 ("Design for deconstruction, reuse and recycling") that a minimum circularity score of 40% by mass and 40% by cost shall be demonstrated. Here also recycling results and experiences demonstrated in European projects for specific material flows could be used as examples of potential indicators and criteria.

National/regional guidelines have also been published. Additionally, guidance documents have been prepared in several EU Horizon projects with different focus (e.g. on cities). EU CITYLOOPS project includes concrete examples and tools for incorporating circular procurement practices during the pretender, tender, and post-tender activities. In the EU CIRCuIT project with a full list of criteria, it is stated that more attention is needed in procurement process on using materials that are either reused or recycled, using materials that can be either reused or recycled, supporting material reuse and recycling via design choices.

However, the public sector often lacks knowledge about structures, products, materials that could be recovered and used in new constructions. Tendering documents do not often specifically address waste recycling.

Guidance on process and development of requirements in the Green Public Procurement tenders on use of recyclables in new construction are not addressing uniformly use of recyclables in new construction.

Templates for the public procurement tendering documents with examples of standard specification (here references to EU Level(s) framework) supporting sustainability and innovation could be helpful to promote the achievement of circularity goals in buildings.

[179] https://pub.norden.org/us2023-441/us2023-441.pdf

[180] EC 2016, EU GPP Criteria for Office Building Design, Construction and Management: https://ec.europa.eu/environment/gpp/pdf/swd_2016_180.pdf

[181] https://susproc.jrc.ec.europa.eu/product-bureau/sites/default/files/2022-03/GPP_Buildings_TR_v1.01.pdf

Description (goal)	
Guidelines for including recycling and reuse in public tenders for construction, renovation and demolition	
Actions (bullet points) – 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	
Actor(s)	Commission, national, regional (public sector)
Timeline	short term
References	D6.3. see 4.5 EU Level(s)

7.3.3 Recommendation 6: Incorporate in the price of construction products the costs for actions related to potential pollution control

Challenge
Currently, the environmental and economic impacts (impacts of material extraction, landfilling …) are not incorporated into total price of the products, and actions for potential pollution control are potentially to be paid by the future generations. To make the investments in circular construction more interesting, it is important to consider other costs, benefits and environmental impact throughout the life cycle and not just direct financial costs (investment, maintenance, etc.). An LCA shows that in many cases the environmental impact and the resulting costs of construction products can be largely attributed to the extraction, processing, manufacturing, and transportation of construction materials. Recycling has a lesser impact in these stages, but this is seldom reflected in the market. It remains difficult to determine and quantify the impact on the environment of the production and use of construction materials. Thus, any system of taxation or subsidies aimed at steering the market towards recycled materials misses a solid basis for calculation. We should also examine how environmental impact can be considered in pricing and can be used as a criterion in public procurement in a legally underpinned manner. The price differences between recycled materials and primary minerals or raw materials hinder the development of circular materials management, in particular the use of recycled 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 - We create support for internalising environmental costs in pricing.
Actions (bullet points – 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

Actor(s)	Commission, national authorities
Timeline	short – mid term
References	D6.3. section 4.9 and Appendix 2 – PART 1 - The case of Flanders Region in Belgium

7.4 Information instruments

7.4.1 Recommendation 7 – Linking DPP, BIM and building logbooks to support circularity of building materials

Challenge
Lack of data and challenges in tracking materials and building elements are two major barriers highlighted in literature for circular economy and high-quality recycling in the building and construction industry. Digital product passports (DPPs) are a tool that have been suggested to increase data availability and sharing, and traceability of the construction products during their lifecycle. Related concepts (material/circularity passports and building logbooks etc) exist for the building level. The above-mentioned challenges were supported in the interviews with ICEBERG partners: - the data content of a digital product passport should be tailored to each product group. - Especially the need for enhanced collaboration in the value chain were highlighted. - Information on the hazardous substances not allowed anymore and hindering recycling is crucial for the recycling value chain. - As an example, the challenge of sharing all the necessary information to e.g. building owners was mentioned. - Creating material passports (e.g. at building level) is challenging, due to availability of information (need to be shared in the value chain). DPPs have been introduced in the Ecodesign for Sustainable Products Regulation (ESPR), and specifically for construction products in the new nearly ready CPR (2024[182]). The construction digital product passport system in CPR

[182] https://data.consilium.europa.eu/doc/document/ST-5762-2024-REV-1/en/pdf

builds on the requirements presented in the ESPR, and a delegated act is adopted to set up the construction DPP system. Although the EU regulative framework for DPPs is currently being formed for various product categories, the specific content, data formats, and data structures of DPPs are not yet fully defined.

In the interviews, the knowledge about DPPs was varying. Although the potential of DPPs was in general recognized, the benefits are not yet fully realized. Confidentiality & IPR issues, and interoperability of different systems have been highlighted as practical barriers/concerns about DPPs. Therefore, an optimal level of detail that adheres to intellectual property while ensuring transparency needs to be found. Further challenges result from the need to collect and maintain data in the DPPs during the product lifecycle. Concerning e.g. material content, the manufacturers are reluctant to share detailed compositions of their products. However, the constantly evolving knowledge of the chemicals and introduction of new restrictions would require as detailed knowledge of the included substances as possible.

Today, BIM, as well as DPPs, are mainly static tools. In the interviews it was mentioned that there is potential for BIM to become a more dynamic model which is updated constantly during the lifecycle being a platform for the future digital twin of the building. DPPs, BIM, and DBL can potentially complement each other. For example, information in the construction product DPPs could be integrated into BIM models to provide a comprehensive digital representation of the building's components, and to support e.g. maintenance, refurbishment or demolition activities. When DPPs for different building elements are available, those could be integrated to BIM.

Description (goal)

- Consolidation of data formats/standardization to ensure their interoperability
- Linking DPP to other data management and exchange protocols
    - Link to BIM: It is recommended to use open standards, in particular to develop the classification of building elements and their links according to ISO 16739-1:2018 (Industry Foundation Classes (IFC) for data sharing in the construction and facility management industries). It is recommended that the data requirements will be specified in bSDD data dictionary on national or regional level depending on the scope of the specific building regulations. It is recommended that Information Delivery Specifications (IDS) for the particular products will be developed to enable machine processing of the data in BIM.
    - Link to DBL: Since DBL itself can be largely integrated in BIM process, the recommendations from the DPP-BIM integration are also valid here. Moreover, the security end encryption protocols for the data are needed to ensure the communication between different stakeholders accessing the DBL repository.
    - Link to other DPPs: The complex structure of different assembly, sub-assembly, constituent products and materials providers in the

building industry needs to specify the distributed databases and communications channels as open API standards that can be then integrate in authoring softwares and material exchange platforms. - Establishing traceability systems and certification schemes recognized by the relevant building authorities to decrease the need of unnecessary testing of materials and products and to decrease the amount of downcycled and discarded material in general. These systems should be fully integrated with BIM, DPP and DBL concepts.
Actions (bullet points) – implementation
The building industry already has powerful tools to improve the management and sharing of information throughout the lifecycle of project or asset. The most important of them is Building Information Modelling (BIM). BIM is a process involving a generation and management of digital representations of the physical and functional characteristics of buildings and engineering structures. BIM is supported by various tools, technologies and contracts. BIM information is often saved in proprietary data formats, but the integration of BIM in the whole building value chain (including the public authorities) promoted the use open data in recent years. Open data specifications such as Industry Foundation Classes (IFC) enable end users to better collaborate and cooperate regardless of which software application they are using. IFC is digital description of the building asset developed by buildingSMART international and it is specified in open, international standard ISO 16739-1:2018. Nowadays the most common interdisciplinary data exchanges in the building industry are based on the IFC and the standard is supported by all the major software developers in the area. While IFC provides structure and relation characteristics of different building entities, the particular properties are defined in dedicated dictionaries such as buildingSMART Data Dictionary (bSDD). The bSDD is an online service hosting classes (terms) and properties, allowed values, units, translations, relations between those and more. It provides a standardised workflow to guarantee data quality, information consistency and interoperability.

Actor(s)	manufacturers, end-users, building authorities, product associations, standardization committees
Timeline	Midterm
References	New Construction Products Regulation 2024 DDC project: https://vb.nweurope.eu/projects/project-search/digital-deconstruction/

7.4.2 Recommendation 8 – Improve knowledge about construction materials and products, procedures and technologies required for circular construction

Challenge
During interviews and workshops with ICEBERG stakeholders, the lack of knowledge was highlighted in almost all discussions. There is a lack of

knowledge regarding new recycling technology developments, environmental assessment tools and interpretation of results, approval processes and policies for approval of construction products.

Examples of knowledge shortcomings recognized by different stakeholder groups are:

- product designers - concepts of full circularity (recycled content, durability, separability, sustainability indicators)
- architecture/engineering/consultancy firms - lack of tools and visibility
- building owners - recycling requirements (including sustainability criteria) to be included in tender documents
- demolition contractors - legal requirements on recoverable materials
- pre-demolition auditors - information on waste management options, especially for waste streams that are difficult to segregate and recover
- recyclers - actual information on waste streams generated and possibilities for identifying users of the recycled materials
- manufacturers - understanding of the impact of recycled materials on manufacturing processes, product performance and business models
- standardization bodies – characteristics of construction products containing recycled materials
- end-users – availability on market, performance of alternatives to traditional constructions products
- consumers – information on benefits and existing products on market. ICEBERG task 6.2 (Social attitudes towards circularity of building products) reports that there exists a notable concern regarding the perceived health, resistance, safety, and quality of secondary construction materials. The lack of experience with secondary materials and skepticism about their environmental benefits contribute to some resistance.
- research organizations and education institutions - universities, schools, professional training organizations
- consultants - product approval and liabilities
- financiers
- public authorities/regulators - information on reuse potential and recyclability of construction products and regulatory barriers faced
- product associations/demolition waste management organizations/organizations for professionals (e.g., architects, construction)

Education to provide a wide understanding on the conditions and opportunities for reuse and recycling.

A significant challenge is that information is often too technical, too detailed, not easily accessible, requiring background knowledge, or it is not available in national language. Knowledge gaps harm collaboration within the value chain, which has been recognized in the interviews to be very difficult to establish.

In summary, 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.

Description
- A systematic overview on information needs by different stakeholders. Important that all relevant aspects included in analysis of information needs for achieving sustainable recycling solutions. - An action plan to remove knowledge gaps to be developed (what, who, when). Identification of key actions. - Actions to raise awareness and support communication and collaboration among actors in the value chain.
Actions (bullet points) – implementation
Focus could be on: - creation of technology platform for innovative solutions for material flow management (BIM, traceability, sorting, etc.) - dissemination of technology developments to reclaim waste streams (universities) - skills development and adjustments in the labour market - integrating training clauses in public procurement - guidelines for good practice and standards for material management (raw materials, intermediates, products) and waste acceptance - up-to-date information on operation conditions (e.g. legislative boundaries, available material streams, taxation, business models), - financing possibilities (e.g., EU taxonomy) - forums for exchange of information - integrating training clauses in public procurement Technology: - creation of education materials for different stakeholder groups - development of new technologies supported at national and EU levels - information spreading from demo cases in EU's Horizon projects Product acceptance: - standardization bodies/product associations - legislator (acceptance criteria) End-users: - product information/digital product passports

Actor(s)	all actors in value chain
Timeline	short - mid
References	PARADE - Best practices for Pre-demolition Audits ensuring high-quality Raw materials. (https://projectsites.vtt.fi/sites/parade/index.html) Guía para el uso de materiales reciclados en construcción. Departamento de Desarrollo Económico, Sostenibilidad y Medio Ambiente. Basque Country, Spain (https://www.euskadi.eus/documentacion/2018/guia-para-el-

	uso-de-materiales-reciclados-en-construccion/web01-a2inguru/es/) ICEBERG D6.2 Social attitudes towards Circularity of Building Products - Part II CITYLOOPS/CIRCuIT EU BUS League project: https://busleague.eu/

7.4.3 Recommendation 9 – develop guidelines for waste sorting

Challenge
Demolition contractors often lack information on the quality requirements for recycling of recovered materials from demolition or information on the quality specification for reusable construction products. In almost all interviews conducted with ICEBERG partners, it was also mentioned that the stakeholders in the value chain would profit if information on quality requirements e.g. for certain recycling process could be available. Construction product manufacturers who want to include recycled materials have specific needs and requirements for the feed materials (e.g. EoW materials) that are offered by the demolition contractors and the operators of sorting installations. A good match is needed between the supply of recoverable materials and the demand by the recyclers. For the uptake of the material, it requires that the recyclable materials is suitable and applicable in the production process for new construction products with recyclable content. Main principles for sorting plants: - Industrial residual waste and mixed construction and demolition waste are always sorted out (processed) via separate batches. Simultaneous treatment in one sorting line is prohibited; - Shredding prior to treatment can take place only under strict conditions; - Sorting residue from mixed construction and demolition waste must be stored separately from residue from company residual waste; - Sorting residue must comply with specific criteria (maximum content of recyclable materials) if it is sent to landfill or incineration (e.g. in Belgium due to ban on the incineration of recyclable waste); - sorted residue sand (fine residue (< 20mm)) must be certified as a construction material or transported to a cleaning plant - The sorted fractions must be disposed of in function of reuse or material recycling; - Acceptance criteria - must be in line with those of the further processor; Consequently, this sets need for a quality assurance system for sorting facilities for mixed construction and demolition waste fulfilling the following conditions: a) Guaranteeing; - the traceability of incoming and outgoing streams

- monitoring the quality of the fractions obtained after processing

b) Monitoring the process and material flows to ensure continuous optimisation of sorting processes and sorting efficiency

c) Optimising the sorting process and sorting efficiency:

- minimise the sorting residue of mixed construction and demolition waste obtained after sorting the mixed construction and demolition waste
- maximise the sorted fractions disposed of for reuse or material recycling.

This can be done through a strict acceptance policy or by adapting the sorting techniques used.

Information is needed e.g. on the following topics:

- quality requirements for the materials to be recovered (e.g. allowed impurity content, composition, grain distribution) from the recycling plants or material producers
- limits for content of hazardous substances (also disturbing materials) or for recycling interfering substances such as particles of wood, plastic, ... in the recycling process of rubble
- characteristics of the materials for recycling (e.g. grain size requirements)
- separability of materials (aspects influencing)

and potentially also:

for sorting plants (ex situ)

- tools for analyzing characteristics of recovered materials (especially for reusable products also quality analysis prior to demolition)
- minimum amount of materials needed for processing
- requirements for storage
- special requirements in waste handling
- protocols for quality assurance (sampling, approval systems…)
- traceability requirements for high-quality recycling

at the construction site (in situ)

- demolition methods at site
- potentially also techniques to be used at demolition site for sorting/material separation, processing of materials
- waste collection systems (e.g. labelling)
- role of different stakeholders in the value chain
- handling of rejects from pretreatment at site

Description
- 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 off site

Actions (bullet points) – implementation	
- Mapping of commercial recycling technologies available and creating an overview for requirements for different waste streams for recyclers - development of a standard on key issues to be included in a quality protocol	
Actor(s)	all actors in value chain
Timeline	short -mid
References	PARADE education material Standard procedures demolition monitoring in Flemish Region Guidance documents prepared in the Basque country Horizon projects Vlarema

7.5 Technical instruments

7.5.1 Recommendation 10: Design construction products for reuse and recycling

Challenge
Ideally, construction elements and products are designed to be easy to adapt, easy to dismantle and are hardly ever demolished. The design phase of construction products and buildings is key to facilitating sustainable material use, easy maintenance, easy adaptation of intended use and increased lifespan. Identified drivers for the design phase were mainly local and national building strategies. Examples of actions: - designing-out waste arising during construction; - using reclaimed materials and components in design; - applying lean design principles to reduce demand for resources and associated waste Current regulation does not have indicators for waste prevention such as eco-design, recycled material content and recyclability. For product design (e.g. choice of raw materials for the products), harmonised indicators and criteria are lacking for assessment of environmental performance of the product along the whole lifecycle. Role of GPP (financier) – procurement recommendations are particularly relevant in the design stages of the project and need to cover all steps of the product´s lifecycle according to the ecodesign regulation. Here also need for new business models (new logistics - take back) Extended producer responsibility can in future be for some product groups an instrument for accelerating recycled content. A certain recycled content in new

products could be also incorporated in the national building regulation to create a market pull for recycled materials.
Description (goal)
- design construction products for fulfilling circularity goals such as including for disassembly, reuse, recycling and designing long-lasting properties
Actions (bullet points) – 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

Actor(s)	Commission, public sector, manufacturer, recyclers, end-users, architects
Timeline	mid term
References	D3.5

7.6 Concrete activities, initiatives & projects

7.6.1 Recommendation 11: Finance demonstrations of circular design solutions and innovative recycling technologies and tools

Challenge
Demonstration projects are often the base for investments in full scale. In several interviews with the ICEBERG manufacturers, the importance of demonstrations at high TRL-level was highlighted. Demonstration projects give economic, technological and environmental information on crucial aspects/conditions in the whole value chain. Especially in cases where several actors are involved in the processing a waste or when the wastes are to be shipped to another country for recycling, procedure for efficient collaboration and exchange of information on material characteristics can be developed and tested. In this context, legal and administrative aspects related to recycling process can be investigated. In future, financial support for demonstration projects especially needed for development of recycling technologies for challenging CDW, i.e. materials that are difficult to recycle or for waste materials where currently only low recycling processes are available. Examples of potential streams are as follows: - insulation materials (amount will increase in future, also voluminous) - products with multilayer materials - materials containing hazardous substances with focus on removal of hazardous substances (e.g. flame retardants, persistent organic pollutants, PFAS)

- rejects from recycling processes (e.g. especially processes with low yield and high generation of rejects) - fines from sorting plants Also circular design of construction products and management of waste, material streams and products are part of innovative recycling technologies. such as tools for material identification and separation, traceability systems and documentations. At the EU level, there are several types of financing instruments available (e.g. H2020, Life[183], COSME[184], EFSI[185], ERDF[186]). National and regional financing available e.g. through ministries, national government organization for innovation funding, city/regional clusters offer possibilities for funding for demonstration projects. Here also the public sector (e.g. through GPP) could be a frontrunner to demonstrate new circular solutions. For company investments, e.g. the European Investment Bank, an European institute owned by its member states, make long-term finances available for investments contributing to the EU policy goals. Innovation projects should be allowed to fail sometimes. In the Netherlands, there are government initiatives in that direction. For example, extended producer responsibility could be used to finance a “failure fund” for innovative construction demonstration that encounter unexpected issues.
Description
Financial support for demonstration of circular design solutions and innovative high-quality recycling processes for CDW
Actions (bullet points) – implementation
- inventory on waste materials lacking recycling technologies for further development and upscaling, including economic calculations. - upscaling of solutions for circular design of products - demonstration of technologies for identification and separation of materials for recycling - demonstration of technologies for high-quality recycling, including removal of hazardous substances/difficult impurities hindering recycling - boost the sorting through innovation; - demonstration of circular building design (for deep renovation and new construction)

Actor(s)	EU, national funding, regional level, banks/financial institutions

[183] Financial instrument supporting the implementation of the EU’s environmental and climate policy through co-financing of projects in member states.

[184] EU programme for the Competitiveness of Enterprises and SMEs

[185] European Fund for Strategic Investments

[186] EU fund that strengthens economic and social cohesion in the EU by financing investments that reduce imbalances between regions.

Timeline	Short – Midterm
References	

7.6.2 Recommendation 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
In the regulatory and legislative arena, a closer link should be made between material production, product-level certifications and the building process. To date life cycle of a building material is assessed from Cradle to Gate, that is from the extraction of raw material to the factory gate. Once the product is used in a building, service life and end of life are often underestimated. Consequently, the value of the material that was created during the extraction of the raw material is lost at the Gate. In the circular economy the aim is to minimize the consumption of resources by closing the loop by extending service life, and the reuse or recycling of material. The existing policy instruments have only a limited applicability to clearly distinguish circular solutions from those where the low environmental impact is achieved by another means. One of the already standardized circularity indicators is Module D “Benefits and loads arising from the reuse of products or the recycling or recovery of energy from waste materials resulting from the construction stage, the use stage and the end of life stage.” specified in Section 6.3.3 and Annex D of EN 15804 “Sustainability of construction works. Environmental product declarations. Core rules for the product category of construction products”. This information is becoming a legal requirement in new building projects several Member States (e.g. in Finland since 2026). Although, its declaration is mandatory in all Environmental Product Declarations (EPDs), it is often underestimated or ignored completely because of lack of the data about possible future recycling or reuse options, its difficult interpretation or just simply because it does not bring any additional value to the organization developing the EPD. It should be noted that there are also many other circularity indicators which are not standardized, but may be more easily understandable than Module D, such as the Circular Footprint Formula of the PEF methodology or various Circular Indicators based on the Ellen MacArthur’s Material Circularity Indicator.
Description (goal)
As for the use of Digital Product Passport, closed loop processes can be monitored also through circular economy indicator at building level. Design strategies which minimize resource consumption and best practices of demolition, separation, or disassembly, and reuse/recycling should be rewarded and the benefits of such processes should be communicated upstream to the material producers and product manufacturers Establishing robust and understandable metrics for circularity assessment is therefore one of the priorities.

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: o C&D planning and strategies besides legislation requirements o Demonstration of comparisons of products o Application of circular indicators that are not yet standardized	
Actor(s)	Designers, professional associations, building authorities
Timeline	short term
References	EU Level (s) protocol

Appendix 1

Measures – online survey

D6.3 - Policy recommendations for ICEBERG solutions

Lead beneficiary: VTT

Due date: 30.04.2024 (M48)

Type of deliverable: R

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

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1	30.4.2024	VTT	Final draft.

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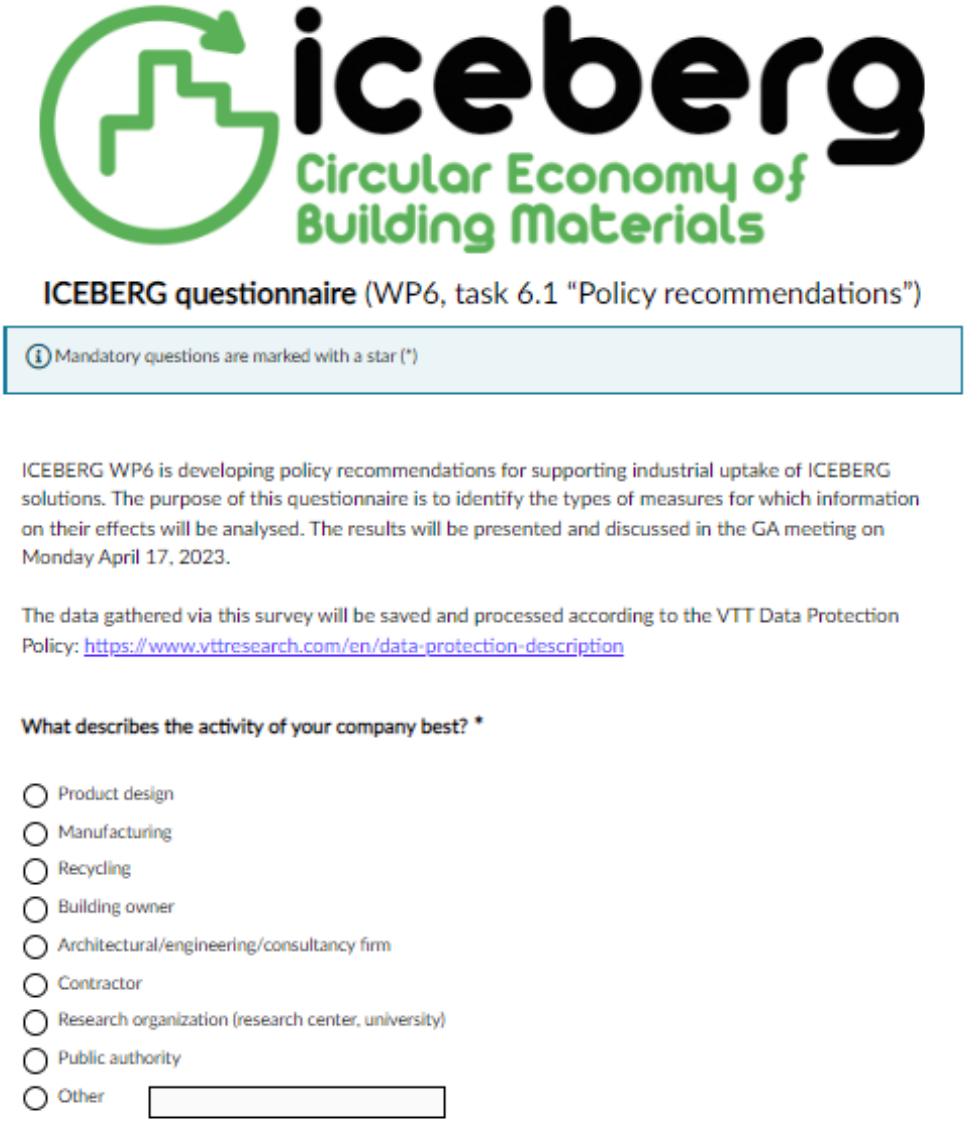
ICEBERG website: www.iceberg-project.eu

1. Online survey on measures for further analysis

An online survey was created and circulated among ICEBERG partners. The purpose of the survey was to identify the types of measures for further analysis. In total, 23 responses were received. Results of the survey are presented in Tables 1-6. The results of the survey were further discussed in the ICEBERG GA meeting in April 2023.



ICEBERG questionnaire (WP6, task 6.1 "Policy recommendations")

Mandatory questions are marked with a star (*)

ICEBERG WP6 is developing policy recommendations for supporting industrial uptake of ICEBERG solutions. The purpose of this questionnaire is to identify the types of measures for which information on their effects will be analysed. The results will be presented and discussed in the GA meeting on Monday April 17, 2023.

The data gathered via this survey will be saved and processed according to the VTT Data Protection Policy: https://www.vttresearch.com/en/data-protection-description

What describes the activity of your company best? *

- ◯ Product design
- ◯ Manufacturing
- ◯ Recycling
- ◯ Building owner
- ◯ Architectural/engineering/consultancy firm
- ◯ Contractor
- ◯ Research organization (research center, university)
- ◯ Public authority
- ◯ Other

Figure 1 Online survey for ICEBERG partners to identify measures with information needs

Table 1 Online survey respondents

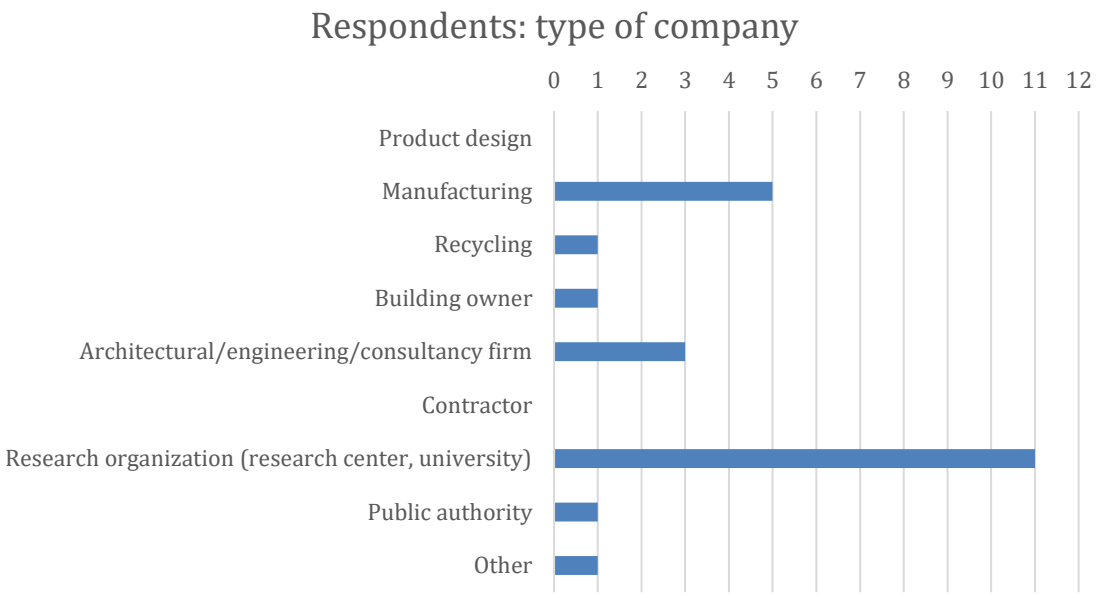


Table 2 Online survey respondents

Table 3 Online survey respondents

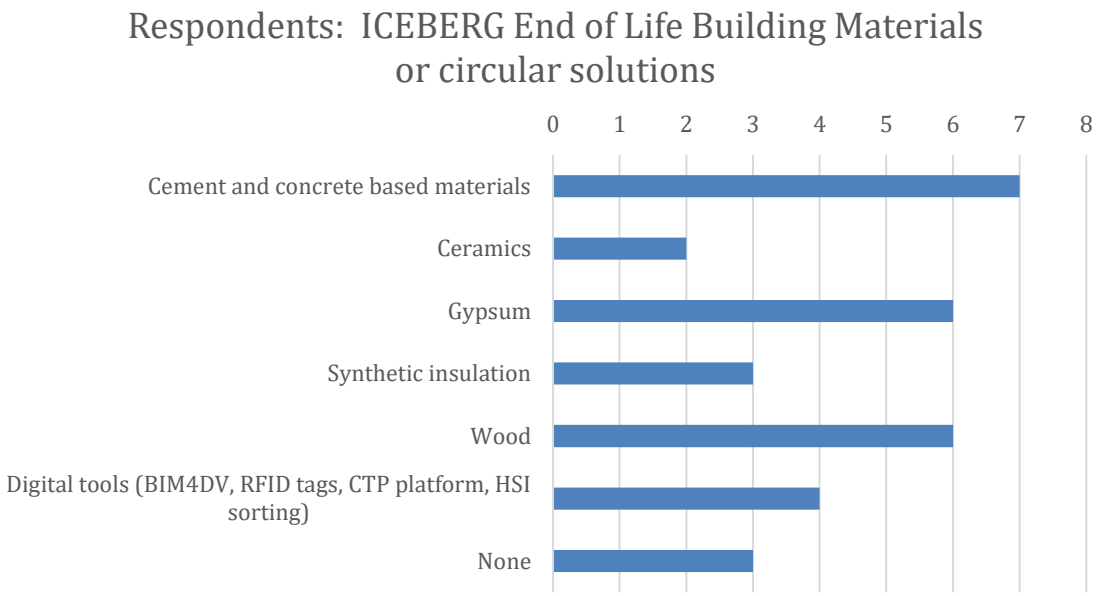


Table 4 Measures to support the uptake of ICEBERG solutions in product design and manufacturing

	1 - not important	2	3	4	5 - very important	I don't know	Average
1. Requirement on design for removal and disassembly in product manufacturing	0 %	5 %	23 %	41 %	32 %	0 %	4,0
2. Requirements related to Green Public Procurement (GPP)	0 %	14 %	33 %	29 %	24 %	0 %	3,6
3. Requirements related to Extended Producer Responsibility	5 %	0 %	36 %	32 %	27 %	0 %	3,8
4. Further development of sustainability criteria for use of recyclables in products	0 %	0 %	18 %	50 %	32 %	0 %	**4,1**
5. Designing for recyclability by introducing minimum design requirements	9 %	5 %	14 %	36 %	36 %	0 %	3,9
6. Development of tools for architects, engineers	0 %	14 %	32 %	32 %	18 %	5 %	3,6
7. Development of standardisation work	0 %	5 %	46 %	18 %	27 %	5 %	3,7
8. Actions for knowledge raising of architects, engineers	0 %	14 %	41 %	23 %	18 %	5 %	3,5
9. Digital tools for traceability	0 %	0 %	18 %	36 %	45 %	0 %	**4,3**
10. Development of new business models	5 %	5 %	27 %	32 %	27 %	5 %	3,8
11. Knowledge/awareness, expert education – material knowledge, processing, digitalization, economics	0 %	9 %	23 %	36 %	27 %	5 %	3,9
12. Actions for better collaboration between stakeholders in the value chain	0 %	0 %	33 %	33 %	33 %	0 %	4,0

Table 5 Measures to support the uptake of ICEBERG solutions in construction, deconstruction, waste collection and recycling (1/2)

	1 - not important	2	3	4	5 - very important	I don't know	Average
13. Financial support for sustainable recycling processes	0 %	5 %	14 %	50 %	27 %	5 %	4,0
14. Incorporation of environmental impact into total price	0 %	0 %	9 %	45 %	46 %	0 %	**4,4**
15. Promotion of easier trading of CDW across countries	5 %	9 %	14 %	41 %	27 %	5 %	3,8
16. Toolbox, methods for assessment of performance, requirements for key CDW streams	0 %	5 %	18 %	46 %	32 %	0 %	4,0
17. Harmonisation of building and waste regulation to better accommodate waste hierarchy and circularity goals	0 %	5 %	14 %	50 %	27 %	5 %	4,0
18. Promotion of material specific targets in Waste Framework Directive (WFD) and national legislation	0 %	0 %	24 %	52 %	19 %	5 %	4,0
19. Harmonisation of End-of-waste concept	0 %	5 %	29 %	38 %	29 %	0 %	3,9
20. Clarification on waste/product status	5 %	23 %	18 %	27 %	23 %	5 %	3,4
21. Guidance on requirements for demolition waste recycling	0 %	5 %	14 %	55 %	27 %	0 %	4,0
22. Guidance for pre-demolition auditing/recycling and reuse activity (hazardous substances in waste, REACH …)	0 %	9 %	18 %	27 %	36 %	9 %	4,0

Table 6 Measures to support the uptake of ICEBERG solutions in construction, deconstruction, waste collection and recycling (2/2)

	1 - not important	2	3	4	5 - very important	I don't know	Average
23. Pre-demolition audits, (Mandatory) waste audits	0 %	19 %	19 %	33 %	29 %	0 %	3,7
24. Development of common sorting criteria and standards	0 %	5 %	18 %	32 %	36 %	9 %	**4,1**
25. Development of certificates for key streams securing sufficient quality	0 %	0 %	35 %	35 %	25 %	5 %	3,9
26. Guidance on requirements to which materials should apply in order to be recycled	0 %	0 %	23 %	46 %	27 %	5 %	4,0
27. Traceability systems for waste recovered from demolition	0 %	5 %	27 %	36 %	32 %	0 %	4,0
28. Financial support for demolition/collection/sorting	5 %	0 %	9 %	46 %	36 %	5 %	**4,1**
29. Responsibilities of stakeholders	0 %	0 %	36 %	45 %	9 %	9 %	3,7
30. Knowledge/awareness (knowledge centres, training, communication…)	0 %	5 %	36 %	18 %	32 %	9 %	3,9
31. Financial support for demonstration projects	0 %	0 %	14 %	27 %	50 %	9 %	**4,4**

Appendix 2

Description of regional development instruments for the improvement of CDW management and the promotion of circular economy in the construction sector

PART 1: The case of Flanders Region in Belgium

Lead beneficiary: OVAM

Due date: 30.04.2024 (M48)

Type of deliverable: R

Dissemination level		
PU	Public	X
PP	Restricted to other programme participants	
RE	Restricted to a group specified by the consortium	
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Acronyms

BIM	Building information modeling
CDW	Construction and demolition waste
DMO	Demolition Monitoring Organization
EPD	Environmental Product Declaration
GRP	Gross Regional Product
LCA	Life Cycle Assessment
OVAM	the Public Waste Agency of Flanders
SME	Small and Medium-sized Enterprises
TOTEM	Tool for Optimized Building Environments

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1 INTRODUCTION

1.1 Overall task and focus of this report

This report is part of a study on regional policies in two regions representing ICEBERG partners. The aim of the task is to show and explain the relevant policies and good practices that underpin the transition for increased recycling of construction and demolition waste (CDW), both in the Basque Region of Spain and in the Flanders Region of Belgium. It will collate information of relevant good practices in both regions. It will highlight the aims and development of applicable policies in both Regions. Furthermore, it will give insight in the challenges they were devised for. This can serve as an inspiration for other regions and member states in the developing of their policies. Particular attention is paid to the use of digital methods in all stages of the value chains of materials in construction.

In the pursuit of sustainable development and reduced environmental impact, the construction and demolition industry has increasingly recognized the critical role it plays in shaping a circular economy. The development of circular building and the circular management of Construction and Demolition waste (CDW) is a focal point for driving this transition.

The aim is also to provide information that can be used as background for ICEBERG policy recommendations**.**

This report focuses on policies in Flanders Region of Belgium. A similar separate report has been collated for the Basque Region in Spain.

1.2 Short description of Flemish construction business

The construction sector is important for the economy of the Flanders region of Belgium. Beyond erecting buildings, it contributes significantly to the Gross Regional Product (GRP), creating a ripple effect that stimulates growth across industries.

In economic terms, the construction sector contributes to the Gross Regional Product (GRP) of Flanders. In 2021 the GRP of the construction sector in Flanders amounted to 16680 million euro. This is almost 6,5 % of the total gross product of Flanders[1]. The construction of new buildings, the renovation of existing structures, and the development of infrastructure projects collectively inject a significant influx of capital into the region's economy.

The construction sector is instrumental in advancing infrastructural development in Flanders. It is the driving force behind the creation of modern transportation networks, energy-efficient buildings, and sustainable urban environments. The sector's innovative practices contribute to the region's competitiveness. By embracing innovative technologies and sustainable building practices, the

[1] These data come from the Belgian National Bureau of Statistics, (https://sta.nbb.be).

construction sector helps Flanders position itself as a forward-thinking and environmentally conscious region.

The building resources are limited in the Flemish region. Sands, clay and gravel are mined in different parts of the region. The use of primary resources is limited. The bulk of the materials are secondary and derived from the recycling or reuse of end-of waste materials. The use of alternatives is an economic necessity for the Flanders region.

When only considering alternatives deployed as replacements for Flemish primary minerals, the usage in Flanders in 2018 amounted to 63,925 kton, of which:

- Flemish primary minerals: 5,089 kton (8%)
- Imported minerals: 21,861 kton (34%)
- Alternative raw materials: 36,976 kton (58%)
  - Recycled aggregates from construction and demolition waste: 17,177 kton (27%)
  - Excavated soil and dredged material: 18,396 kton (29%)
  - Other alternative raw materials: 1,403 kton (2%)

There are significant differences in the ratio of Flemish minerals/imported minerals/alternatives. In the case of coarse sand applications, the imported share was 76%, while in finer sand applications, 76% consisted of excavated soil. From MDO report for 2018, VPO, Departement Omgeving.[2]

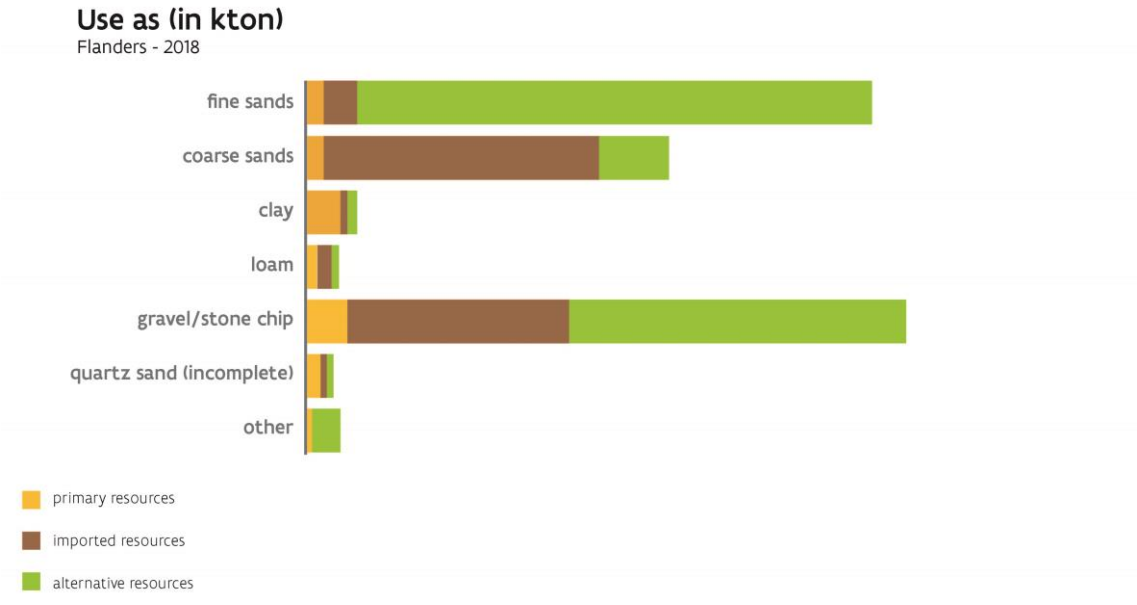

Figure 1 Use of resources in Flanders (MDO 2018)

The demand of resources is still increasing, but the increase of this demand is lower than the overall growth in the production and sale of building materials. The

[2] Samenvatting van de cijfers uit het MDO | Departement (vlaanderen.be) (in Dutch)

main source of primary materials is import from the North Sea and from neighbouring countries. Only very pure quartz sands are important in the export figures.

Construction and demolition waste consists of 2 major fractions:

- the stony fraction. They include concrete granulate, masonry granulate, mixed granulate produced (at least 40% concrete rubble), asphalt granulate (tarry or non-tarry) and the respective screen sands.
- the non-stony fraction (approx. 5% by weight) consists of wood waste, plastics, old metals and rebar, paper and cardboard, gypsum waste, glass, aerated concrete, bituminous materials such as roofing, insulation, and the like.

Every year, around 11.3 million tonnes of construction and demolition waste is generated in Flanders when buildings and structures are built, demolished, and renovated, or when roads and pavements are built and demolished. This makes it the largest waste stream in Flanders by weight.[3]

These data are drawn from monitoring of the use of resources (MDO) in 2018. The estimate is further based on the amount of certified recycled aggregates and other waste streams. More detailed information will be available when the online waste declaration (MATIS) will be implemented.

[3] MDO report for 2018, VPO, Departement Omgeving

2 FLEMISH POLICIES ON CDW management

2.1 Focus in Flemish policies

The Circular Economy (CE) initiatives are organized around six strategic agendas aligned with the EU Green Deal. These agendas cover crucial areas like manufacturing, chemistry and plastics, water cycles, bioeconomy, food chain, and circular construction. Each agenda operates autonomously with dedicated coordinating entities, working towards specific ambitions and implementing on-the-ground actions.

The transition towards the circular economy thrives on a dynamic public-private partnership, called 'Circular Flanders' (Vlaanderen Circulair). Circular Flanders is currently the hub and the inspiration for the transition to a circular economy in Flanders. This multi-stakeholder partnership, embedded in OVAM, consists of governments, companies, civil society, research institutes and financial institutions, acting together to make Flanders circular by 2050. For the transition within the construction sector a work agenda has been devised.[4]

The development of suitable policies and regulation is steered by a suitable policy program developed in close cooperation with stakeholders. The policy program 'towards circular construction' sets to achieve certain goals by 2030 to reach a full transition towards circularity of the construction sector by 2050 (Towards circular construction – policy program 2022-2030, OVAM).

The Flemish Region recognizes the significant amount of construction and demolition waste generated and emphasizes the importance of an effective policy to reduce waste, promote reuse and recycling, and minimize negative environmental impacts. The policy aims to adhere to European directives and international environmental objectives by reducing environmental impact, promoting responsible waste disposal, and encouraging reuse and recycling. Furthermore, the wider policy on circular construction supports the transition of the construction sector to a circular economy. This is achieved through two main pillars: the circular materials management, which focuses on optimizing the use of materials from existing buildings and infrastructure, and the circular design and (re)construction, which aims to make sustainable choices for structures and materials.

The regional policy on C&D waste has six main components and goals:

- Firstly, it aims to prevent and minimize construction and demolition waste by promoting efficient use of materials and designing buildings that are adaptable.
- Secondly, it prioritizes the reuse and recycling of construction waste materials, finding and reintroducing usable components into the building chain to reduce the need for new raw materials and promote a circular economy. To support this, regulations and instruments have been developed to guarantee the origin and quality of reused and recycled materials.

[4] https://vlaanderen-circulair.be/nl/onze-aanpak/werkagenda-s/circulair-bouwen

- Thirdly, the policy encourages innovation in construction techniques, materials, and processes to reduce waste and improve resource efficiency. Research and development are promoted to find new methods of waste management and treatment, as well as encourage innovative design concepts for buildings and materials.
- Fourthly, a clear legal framework and regulations play a crucial role in promoting responsible and environmentally friendly management of construction and demolition waste. These regulations cover various aspects such as the separation, storage, transport, and processing of waste and materials.
- Additionally, there are legal frameworks in place to encourage the use of recycled materials and the reuse of construction materials, supplying guidance to providers and potential users. The regulations also extend to building design and material choices, ensuring that new structures or modifications align with the best use of new and reused materials, as well as the effective closure of cycles. To achieve the goals of circular construction, the policy encourages collaboration between governments, industry, research institutes, and civil society organizations.
- Lastly, education campaigns are also implemented to increase awareness and inform stakeholders about the benefits of responsible practices.

Overall, the policy looks to minimize waste and promote sustainability in the construction industry. The policy emphasizes the need to consider waste from buildings and infrastructure as a valuable resource. It also aims to minimize the negative impact of the production and use of building materials on the environment. By focusing on waste prevention, reuse, recycling, and collaboration, it aims to create a sustainable future in which the construction sector plays a positive role in preserving the environment and promoting a circular economy.

2.2 Policy targets and key regulations linked to CDW management

The waste management plans and the plans and agenda for the transition towards a circular economy in construction fit in the overall policy targets of the Flemish Energy and Climate Plan 2021–2030:

- decrease Flemish material footprint by 30 % by 2030;
- decrease residual waste production in households from 146 kg to 100 kg per inhabitant in 2030;
- achieve a comparable reduction of residual waste production in companies by 2030.

The Flemish Region has set goals for sustainable, circular materials management in the construction sector, aiming to lessen environmental impact, enhance resource efficiency, support a circular economy, minimize waste, and foster innovation. These goals are supported by key principles which include designing for circularity, using recycled materials, prioritizing longevity, sourcing materials locally, effectively managing construction waste, encouraging

collaboration, supplying economic incentives, and checking progress. The Flemish Region has implemented various programs and initiatives to achieve these goals, engaging stakeholders and promoting sustainable and circular practices in the construction industry. As Flanders heavily relies on materials and resources, transitioning to a circular economy is vital to reduce dependence on imports and alleviate pressure on natural resources.

The policy program aims for the reuse or recycle 95% of stony materials and 70% of non-stony materials from construction works. The design and (re)construct 25% of buildings and infrastructure (new-build or renovation) will be conducted following the principles of circular construction.

Flanders aims to achieve the targets set out in the policy program for recycling and reusing materials by monitoring material cycles from site to processing. The goal is to reuse at least half of the materials in a quality manner. This will be achieved through a system of raw material certification for waste streams, ensuring the safe use of recycled materials in a second or third life. The focus is on cooperation within the value chain to achieve this goal. In addition, Flanders aims to design new or renovated structures in a change-oriented way, considering changing needs and minimizing environmental impact. The goal is to have a full digital overview of material stock and to have material data available at the time of final delivery. The aim is to score below a maximum material level for each structure, preferably integrated into an overall environmental impact score.

The results and effects of the policies incorporated in the policy program are assessed on a regular basis. This is done based on waste data, trends in the market and polls trying to estimate the perception of the impact and progress of the transition towards circular building. Progress is slow but susceptible to changes in the market and the wider economic environment.

The policy program is a policy-preparing and supporting instrument within the framework of the waste and materials policy, while a strategic (work) agenda is a dynamic partnership with a broader focus. Both are mutually reinforcing.

The management of waste and material streams is guided by two principal elements in the legal framework:

- The Materials Decree is a decree that enshrines sustainable materials management in Flanders. It aims to minimize the harmful effects of raw material consumption and waste, both for people and the environment.
- The VLAREMA is the implementing decree of the Materials Decree. It holds more detailed regulations on (special) waste, raw materials, selective collection, transport, the register obligation, and extended producer responsibility.

The key objectives of the regional policy are focused on reducing the ecological impact of the construction sector. The first goal aims to decrease CO_2 emissions, energy consumption, and waste generation, thereby reducing the sector's ecological footprint. The second goal highlights the importance of resource efficiency, maximizing the use of recycled materials and minimizing the reliance on primary resources to prevent resource depletion. Another goal is to promote a circular economy, where materials are reused, repaired, improved, and

recycled to extend their lifespan. Minimizing waste is also emphasized through efficient design, selective demolition management, and recycling of materials. Finally, stimulating innovation is seen as crucial, encouraging research and development of new sustainable materials, technologies, and methods that promote sustainability and circularity within the construction sector.

The waste management policy of the Flemish region is linked to the transition towards the circular economy. This applies to the construction sector through sustainable management of resources with closed value chains. The circular and life cycle approach is central to the waste policies of Flanders. This is highlighted in the so-called materials ladder. Most efforts are aimed at avoiding the use of resources, energy, and the production of waste. Reuse and recycling are level in importance in the policy development. There has been a significant shift towards reuse, while recycling targets high-end use and avoiding downcycling. Reuse is extended to buildings elements and entire structures through the application of the principals of adaptable construction. This particularly relevant to the policies and management of waste and material stream in construction. Incineration and landfilling of construction and demolition waste is limited to unrecyclable streams and hazardous waste like tar and asbestos. A new challenge is dealing with hazardous and other substances of concern like PFAS.

2.3 Key actors

The development, instigation, and monitoring of policies on CDW is a responsibility of the OVAM, the Flemish Waste Management Authority. The OVAM has developed policy programs for the development of sustainable materials management in the Flemish Region. In 2022 the OVAM completed a follow-up with the program ‘Towards Circular Construction’. This is a blueprint for the necessary steps by 2030 to achieve the transition towards a circular economy in the construction sector by 2050.

The development and introduction of new policies and regulations, often as part of the incorporation of EU legislation, happen in close cooperation and often co-creation with professional bodies from the construction sector. This partnership involves all stakeholders from the important value chains of materials in construction. Chief actors are the contractors, the environmental management companies, recyclers, producers of building materials, architects, etc.

The contractors are involved through their professional bodies EMBuild and Bouwunie. The recyclers of aggregates take part in this process through VSOR (Vereniging van sloop-, ontmantelings- en recyclingbedrijven) and Denuo. Denuo participates in developing of policies from the perspective of the recyclers and the companies involved in moving waste streams. The BMP (Belgian Materials Producers) unites the manufactures of materials, partly used in construction. The ceramic industry is directly represented by BBP (Belgian Brick Producers). The NAV (Netwerk Architecten Vlaanderen) has a Flemish branch to represent the view of architects. Several organizations involved in quality control and certification take part in deliberations on policies.

Box 1 Links to the key actors´ webpage

https://ovam.vlaanderen.be/afval-materialen

https://denuo.be/bouw-sloopafval (Dutch and French)

https://www.circulairebouweconomie.be/ (Dutch and English) by EMBuild

https://www.embuildvlaanderen.be/international/ (English)

https://bmppmc.be/ (Dutch and French)

https://www.baksteen.be/ (Dutch and French)

https://www.nav.be/ (Dutch)

https://www.vsor.be/nl (Dutch). Merger of the professional bodies representing crushing plant operators, demolition contractors, sorting facilities

3 INSTRUMENTS FOR THE DEVELOPMENT OF REGIONAL POLICIES FOR THE IMPROVEMENT OF CDW MANAGEMENT

In this section, instruments created for improved CDW management are described. For each instrument, links for further information are included.

3.1 Conducting pre-audits and demolition monitoring

The Flemish Region has an obligation to prepare a demolition follow-up plan, with a pre-demolition audit included when demolishing buildings and infrastructure. This obligation is outlined in the Flemish Regulation concerning the sustainable management of material cycles and waste (VLAREMA). This obligation extends to the demolition of most industrial and commercial buildings, as well as larger dwellings or many houses. For the demolition of infrastructure such as roads, bridges, … this can apply as well. The main criterium is the total volume of buildings, or the estimated amount of waste materials for the work on infrastructure. For dwellings, the threshold is higher than for industrial buildings, while single homes are exempt from this obligation.

The demolition follow-up plan contains several elements. Firstly, it provides a description of the demolition works, outlining the specific buildings or infrastructure. Additionally, the audit includes an inventory detailing the composition of construction and demolition waste and the respective quantities involved. Moreover, if hazardous substances, such as asbestos, are present, a precise identification and description of these substances is imperative.

The Demolition Monitoring Organization (DMO) Tracimat has developed an innovative approach known as demolition tracking, which involves monitoring and managing demolition waste, and follow-up of the quality of the stone fraction and its conversion into recycled aggregates. The monitoring of Tracimat consists of the declaration of the conformity of a demolition follow-up plan, and the demolition inspection report (if necessary). Upon completion of the works, the executor requests a demolition certificate from Tracimat, who will then verify that the works were conducted according to the legislation and the procedures of Tracimat based on the legislation and issue the certificate. The builder or their representative must deliver the demolition certificate to the holder of the environmental permit.[5]

In the future, the procedure will be expanded to include the preparation of a waste management plan by the contractor. In this plan the contractor must formulate a waste management strategy, delineating how the generated waste will be appropriately treated, recycled, reused, or disposed of.

The demolition monitoring by Tracimat is limited at present to the follow-up of the quantities of the stony fractions that originated from the demolition and the matching of the data of acceptance and production of the crushing plants. Soon this will also extend to other waste streams. The final demolition certificate issued by Tracimat will certify that all steps in the demolition and the treatment of the

[5] More information on the demolition monitoring is available on https://www.tracimat.be/ (in Dutch)

resulting waste streams were followed. This will also include comparing the data on produced and treated quantities.

The pre-demolition audit and the monitoring were at first applied on a voluntary basis. From 2022 this became compulsory for the larger demolition works and for many of the break-up of infrastructure. The link with the environmental permit has ensured large compliance. The quality of the audits has improved because of training and certification of the demolition experts who draw them up. As a result, there is a better insight in the quantities and quality of the waste streams from demolition sites. With an increase in the electronic transfer of data platforms can develop where retrieved materials can be offered for re-use.

A neutral and independent non-profit Demolition Management Organisation such as Tracimat can play a central role in the demolition process. In addition to ensuring the quality of demolition materials, it can commit itself to training experts in the identification and quantification of materials (hazardous and non-hazardous) and to disseminating knowledge to experts and contractors on the potential reuse and existing recycling routes for materials. It also plays a crucial role in bringing together the various stakeholders (practical and theoretical) such as contractors, experts, clients, material producers, research institutions and authorities to find solutions to identified bottlenecks and barriers and to establish partnerships. In addition, the database managed by the Demolition Management Organisation can be used for research to strengthen the circular economy in construction.

3.2 Compulsory segregation of materials

Selective demolition is not compulsory in Flanders. However, waste streams that result from the demolition activities should be collected and kept separately as much as possible. In the waste management plan the contractor had to specify how the separate removal of particular waste from buildings or infrastructure will be organized in a proper way. Thus the decision on how to carry out the demolition is left to the contractor in conjunction with the owners, or an expert actin on their behalf.

The effective management of construction and demolition waste is crucial. This process starts at construction sites, where waste is collected into fractions potentially (art. 4.3.2 Vlarema) suitable for recycling or reuse and ensuring decontamination and reduced environmental impact. Hazardous materials such as asbestos are separated. The contractor of de demolition or dismantling of buildings or infrastructure is responsible for the management of the waste streams that originate from this process. The ownership is in practice the demolition company, but by contractual agreements this can be adapted to the owner of the building, or another considered party. By contract the parties involved can plan for the reuse of elements or materials from the building.

Article 4.3.2 of Vlarema lists the industrial waste streams that have to be collected separately at source. A recent change in this legislation adds fractions typical of construction and demolition. In addition to glass, metal, hard plastics, and wood already mentioned the following construction and demolition waste fractions can also be recycled and reused in the materials cycle: inert rubble consisting of

concrete rubble, masonry rubble or mixed rubble, aerated concrete, glass wool, rock wool, plasterboard and gypsum blocks, bituminous roofing material or sealing material.

In some cases, separate collection is not required on site. These are sites where, due to space constraints or technical or safety reasons, separate collection at source is not possible or desirable. In such cases, all dry non-hazardous fractions of construction and demolition waste may be collected in the same container provided that the mixed construction and demolition waste is further treated as stipulated in the legislation.

This means that mixed construction and demolition waste should comply with a quality assurance scheme that will be determined by the minister. This quality assurance scheme will promote sustainable practices, sorting efficience and responsible waste management. Overall, Flanders' waste sorting and management align with environmental goals and circular economy principles.[6]

3.2.1 Separate collection on-site

Construction and demolition waste tends to be collected separately at the source of generation, such as construction sites. On-site separate collection involves segregating waste materials into various categories. This ensures a minimal presence of physical decontamination. The most important is keeping hazardous waste like asbestos apart from the stony fractions.

For stone rubble, compliance with the demolition follow-up schemes, as monitored by Tracimat, determines its environmental risk profile. This refers to the potential environmental effects and risks associated with the management of this type of waste.

In compliance with the recent regulatory update, Vlarema 9 now mandates the on-site separate collection of construction and demolition waste during construction activities. This obligation aims to enhance waste management practices within the construction industry, fostering sustainability and minimizing environmental impact. Small sites with limited room to store segregated waste streams before transporting to a treatment plant are exempted from this obligation. If the selective demolition is technically not feasible or potentially dangerous the exemption is also granted. Nevertheless, all mixed fraction of C&D waste can be removed from the sites to sorting facilities.

For larger construction and demolition sites contractors are required to make a demolition monitoring plan that indicates which techniques will be used for demolition, which waste fractions will be released and where these fractions will be transported to.. This proactive approach aligns with Vlarema 9's commitment to reducing the volume of waste destined for landfills and promoting the responsible disposal of construction and demolition materials.

The contractors or other parties are not financially rewarded for the separate collection. The sorting residue after sorting mixed construction and demolition

[6] The extent to which construction and demolition waste must be sorted is explained on the OVAM website: https://ovam.vlaanderen.be/sortereneninzamelenbouwensloop (in Dutch)

waste can only be incinerated or landfilled. The number building waste streams that are exempt from the ban on incineration or landfill is limited. Levies are put on the tonnage of construction and demolition waste incinerated of landfilled without pressing environmental need.

The Flemish Region has established regulations and standards for the production and use of recycled aggregates. These end of waste -criteria includes quality manual with control schemes for acceptance, processing, product control (chemical contamination, asbestos and physical contamination) and transport to use. Within the framework of the so-called "eenheidsreglement gerecycleerde granulaten" (EHR) or Unified Regulation for Recycled Aggregates, a distinction is made between high and low environmental risk profiles. Debris that originates from sites without certification of the demolition process by Tracimat will be considered high risk.

The control schemes for the production of low-risk stone rubble requires less monitoring and can be done in larger production batches. By maintaining this distinction during the process of screening the crushing process, we have more assurances about the suitability of the recycled aggregates in terms of environmental requirements. All stages from the acceptance to the marketing of the product are monitored. To produce aggregates from high risk input the follow-up and bringing the output on the market is conducted in batches. Only aggregates that have been certified under this regulation can be used in or as building materials.

Box 2 Links to additional information.

The procedures and framework for recycled aggregates (unity regulation) are explained in this document:

https://www.vlaanderen.be/publicaties/eenheidsreglement-en-beheersysteem-gerecycleerde-granulaten (in Dutch)

More information on this regulation can be found on these websites:

- https://www.vsor.be/nl (Dutch)
- https://certipro.be/ (Dutch and French)
- https://www.copro.eu/nl (Dutch)

3.2.2 Off-site sorting

Mixed waste streams must be sorted out.

A quality assurance scheme will promote sustainable practices, sorting efficiency and responsible waste management. This assurance scheme will be developed and will be based on the existing scheme that guarantees the quality of the sorted rubble. Debris can only be processed in crushing plants under the Unified Regulation when the sorting facility that has extracted them is certified by this scheme.

The compulsory separation at source of demolition waste had led to a marked improvement in the quality of the waste streams. Notably the presence of

hazardous substances, in particular asbestos, has diminished over the past years.

Box 3 Quality Assurance System

VLAREMA, the Flemish Regulation on Sustainable Waste Management, focuses on quality assurance in sorting facilities. The goal is consistent waste management, reduced environmental impact, and optimal waste sorting and treatment for sustainable material cycle management.

Effective management of sorting facilities involves several key components. Firstly, facilities must undergo registration and gain recognition, enabling proper oversight. Secondly, a robust quality assurance system should be in place, encompassing collection, sorting, storage, and processing processes. Regular internal checks are essential to ensure the correct implementation of this system. Additionally, external audits conducted periodically by independent entities serve to verify compliance and assess the overall effectiveness of the facility's operations.

3.3 Transformation of waste into secondary materials.

In the Flemish Region, diverse granular materials play a crucial role in construction, serving as aggregates and raw resources for applications like concrete and asphalt. The selection of these materials depends on project goals, technical requirements, and sustainability aims. They originate from construction and demolition waste as well as external sources.

3.3.1 Monitoring raw materials

Determining the total construction and demolition waste and recovery involves various inputs. Stony fractions, largely from demolition sites, are processed in crushing plants under monitored waste streams. Inert materials comprise 90% of the total, estimating 20 million tons of C&D-waste in Flanders. About 95% of the stony fraction is recycled, mainly for use in foundations or underlayer of roads.

In the Flemish Region, a regulatory framework guides the incorporation of bottom ashes, metal slags, and sifting sands as construction materials, fostering sustainable practices and waste reduction.

The following describes how these materials are used and how the regulatory framework and the declaration of raw materials play a role:

1. Bottom Ash: Residues from waste incineration, used in construction. Quality standards confirm their suitability, approved by a compliance declaration.

2. Metal Slags: By products of metal production, used in construction. Regulatory specs ensure safe use, validated through a compliance declaration.

3. Sifting Sands: Separated from construction waste, often used in foundations. Regulatory standards ensure suitability, supported by a compliance declaration.

The role of the monitoring of raw materials is crucial as it officially confirms that the recycled materials meet the established quality standards and can be safely used in construction projects. This increases confidence in the sustainability and

reliability of these materials. The regulatory framework provides clear guidelines to ensure that the use of bottom ashes, metal slags, and sifting sands as construction materials aligns with the environmental and safety standards of the Flemish Region.

Monitoring and regulating the use of waste streams as raw materials is governed by different element of legislation with regulations and particular procedures.

3.3.2 Certification of the quality of recycled aggregates

Recycled aggregates, sourced from processed demolition waste and construction debris, provide an eco-friendly alternative to traditional virgin aggregates in Flanders. They conserve resources, reduce landfill waste, and cut carbon emissions. Over the past five years, Flanders has seen a 20% rise in recycled aggregate production, reaching 16 million tons in 2022, driven by heightened environmental awareness in construction.

Recycled aggregate management brings various advantages, including reduced quarrying and landfill strain, aligning with climate targets by lowering carbon emissions.

Challenges involve material variability, demanding advanced sorting and processing technologies for consistency. Continuous research aims to improve technical properties, expanding their use in construction.

Flanders' approach showcases sustainable construction practices, reshaping the industry's ecological impact. Through rigorous certification, technology investment, and industry-regulation collaboration, Flanders champions a greener, more sustainable construction future.

3.3.3 Unity Regulation and COPRO's Role

A pivotal component in the successful management of recycled aggregates is the "Unity Regulation". This regulation, overseen by the Public Waste Agency of Flanders (OVAM), outlines the guidelines for the sustainable management of construction and demolition waste. The Unity Regulation sets forth clear requirements for the quality, sorting, and processing of recycled aggregates, ensuring that they align with environmental and safety standards.

Playing a crucial role in the certification of recycled aggregates are COPRO and CERTIPRO, recognized certification bodies for construction products and services. Their meticulous inspection and testing processes validate the compliance of recycled aggregates with the Unity Regulation and the Quality Protocol. This not only instils confidence in consumers and construction professionals but also contributes to the region's sustainable development goals.

The management of recycled aggregates in Flanders yields a multitude of advantages. Beyond resource conservation and reduced landfill pressure, the carbon footprint associated with aggregate production is substantially diminished, aligning with the region's climate targets.

Nonetheless, challenges persist. The variable nature of input materials can impact the consistency of recycled aggregates, necessitating sophisticated sorting and processing methods. Innovation remains key to improving the technical properties of these aggregates, broadening their range of applications.

3.3.4 Resource declaration for other streams as building materials

The "Flemish Regulation concerning the sustainable management of material cycles and waste." is the regulatory framework that pertains to waste and resource management. Within this framework, the 'resource declaration' falls under its scope.

A resource declaration is a document that shows the origin of a specific waste material and demonstrates that this waste material meets the criteria to be considered a resource rather than waste. In other words, it shows that the waste material is suitable for recovery and no longer needs to be classified as waste, because it meets the end-of-waste criteria as set in the Waste Framework Directive of 2008 (EU). This declaration includes restriction to the use of the resource and specific guidelines on the recipe and the mode of application to limit the potential risk to the environment by pollution or leaching.

The specific regulations and procedures for obtaining a resource declaration under Vlarema include:

- Application Procedure: The entity planning to have a waste material recognized as a resource must apply to the relevant authorities. This application should include relevant information about the nature of the waste material, the intended uses, and the evidence that the waste material meets the required criteria.
- Assessment: The competent authorities evaluate the application and decide whether the waste material can indeed be recognized as a resource. This assessment considers factors such as the technical and environmental aspects of the proposed use.
- Conditions: To qualify for a resource declaration, the waste material must meet certain conditions, such as avoiding adverse environmental impacts, safety for humans and the environment, and suitability for the intended application.
- Burden of Proof: The applicant must prove that the waste material meets these conditions. This may involve conducting analyses, supplying technical data, and evaluating potential risks.
- Periodic Review: A resource declaration can be reviewed periodically to ensure that the waste material still meets the applicable criteria.

The resource declaration pronounces if a material is suitable for useful application. It further specifies the use of the material in the intended application, the restrictions of the use and the conditions under which this is permissible. Cases these conditions are stringent. The recipe of the application refers to the proportions of materials used (primary and / or end-of-life resources).

The use of the materials with resource declaration are subject to continuous scrutiny based on the regular analysis of the composition of the materials. If the quality and composition of the end-of-waste materials is uncertain, or if the production of the waste stream is subject to changes this follow-up will be frame in a quality assurance scheme. If the uncertainty is limited the producer of the resource provides the required independent self-analysis on an annual basis.

The formal system of determining the conditions under which waste streams comply with the end-of-waste criteria had improved the image of secondary raw materials and has increase the confidence in the market for their use. The resources certificates and the certification under the so-called unity regulation are an important factor that explains the high proportion of substitutions of primary raw materials in Flanders.

3.4 Green procurement of secondary materials

Flanders has been actively fostering GPP practices to align public procurement with broader sustainability goals. This initiative aims to leverage the purchasing power of public entities to drive demand for eco-friendly goods and services, ultimately contributing to a more sustainable and circular economy.

One key aspect of the green public procurement strategy is the emphasis on life-cycle thinking. This comprehensive approach ensures that the chosen goods and services adhere to stringent environmental standards throughout their entire existence. This helps to minimize the ecological footprint associated with public procurement.

The progress in construction has been slow. The government and local authorities make efforts to incorporate as many elements of circular building as possible.

3.4.1 Assessment tools: TOTEM

TOTEM (Tool for Optimized Building Environments) is an innovative software designed for building design, integrating architecture, and sustainability. It offers real-time feedback during the design process, allowing designers to assess the impact of changes on the fly. This iterative approach leads to better-designed structures and fewer surprises during construction.

An essential feature of TOTEM is its focus on sustainability. It assesses a building's ecological impact, considering energy sources, materials, water usage, and waste production. This ensures that designs align with current sustainability standards and anticipate future environmental requirements.

In essence, TOTEM is a next-generation design tool reshaping building creation. With its simulations, real-time analyses, and sustainability focus, TOTEM empowers designers to craft buildings that enhance our living environment while pushing architectural and construction boundaries.

When integrated with digital logbooks, TOTEM becomes a powerful tool for efficiently managing and accessing critical information about a building's systems and components.

Digital logbooks serve as repositories for detailed records of a building's maintenance history, equipment specifications, and performance data. These logs can be seamlessly integrated with BIM, providing a comprehensive digital representation of the building. TOTEM leverages this integration by utilizing BIM data to enhance its decision-making capabilities.

The integration of TOTEM, digital logbooks, and BIM establishes a symbiotic relationship that optimizes facility management processes and contributes to the long-term sustainability of buildings.

A protocol voor data-uitwisseling tussen materiaalpaspoort/BIM/TOTEM is gemaakt; outcome kan verder gebruikt worden input voor dataplatform bouwwerkpaspoort

Small and Medium-sized Enterprises (SMEs) need assistance in developing Environmental Product Declarations (EPDs) based on Life Cycle Assessment (LCA). This support aims to enhance sustainability practices, promote environmental responsibility, and foster competitiveness within the SME sector. At present in Belgium and Flanders the support for the development of EPD is limited. However, a platform to exposed them and making the data of the EPD available for use in TOTEM was developed.

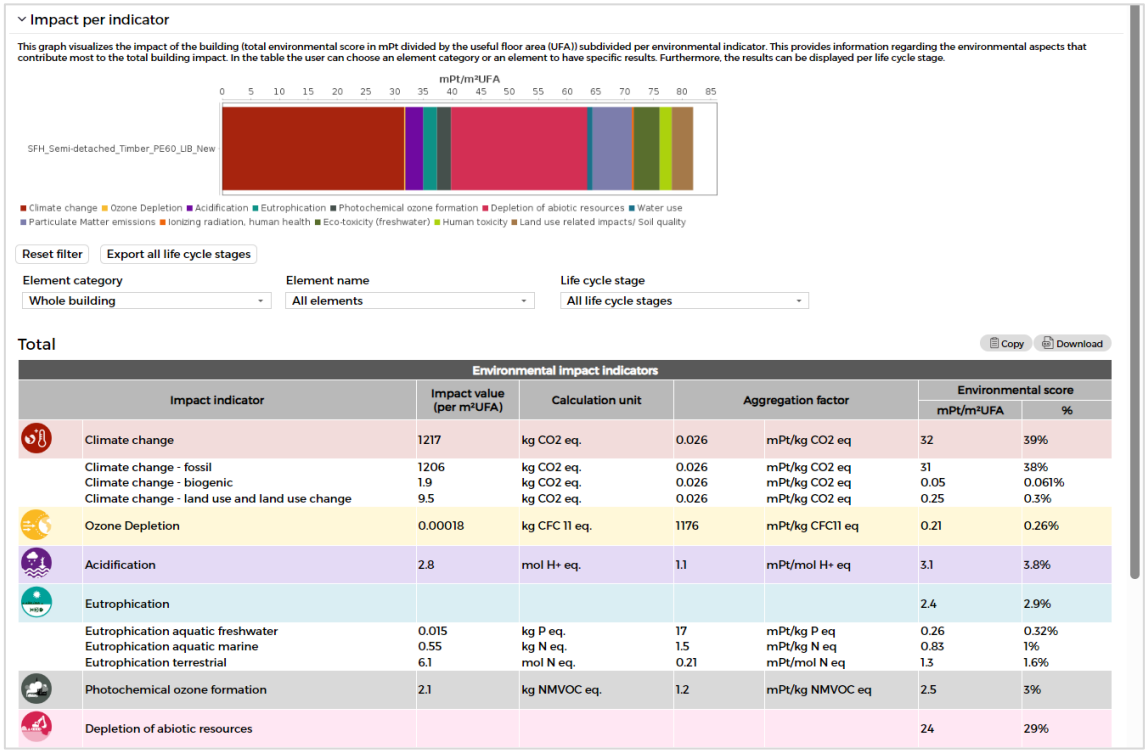

Figure 2 Screenshot of a part of the detailed results overview within TOTEM – with in the top part the single score shown as graph with the contributions to the single score per impact indicator indicated with colours and underneath it the individual results per impact indicator shown in the table.

3.5 Communication and information on CDW.

The OVAM provides information on the legal framework for the management of construction and demolition waste. This section of the OVAM website also mentions the policies and initiatives with regards to the phasing out of asbestos applications.[7]

[7] https://ovam.vlaanderen.be/afval-in-de-bouw1 (in Dutch)

Vlaanderen Circulair provides information on the transition towards the circular economy in the construction sector. It covers the opportunities for networking and the setting up of projects and living labs on various aspects of circular construction. Their website dedicated to circular building offers the results of trials and research, as well as good practices for inspiration.[8]

Tracimat, the CDW management organisation, recognized by the Flemish minister of environment for tracing CDW from its source to the first processor, also provides training for demolition experts on recognition and quantification of hazardous waste and waste with high recycle potential in constructions, as well as training on selective demolition for contractors. Their newsletters and social media posts reaches a lot of actors involved in the sector (their affiliated members (contractors, demolition experts, building owners, …), producers of building materials, …).

Information about construction in Flanders and the use of materials is also available from Buildwise, EMBuild and Bouwunie.

Box 4 Links to sources for further information

Buildwise provides mainly technical assistance and consultancy to the construction sector. The organisation is involved in many studies on the development of sustainable and circular building. https://www.buildwise.be/en/ (publications only in Dutch or French)

EMBuild and Bouwunie provide information the activities of the contractors.

https://www.embuildvlaanderen.be/international/

https://www.bouwunie.be/nl/ (in Dutch)

3.6 Digital development of waste data in construction

Flanders is introducing more platforms and modes of exchange for electronic waste and materials data in general, and in construction. The identification forms of waste shipments have gone online from 2021. The reporting of waste data and data on the use of materials will be conducted electronically in the MATIS platform. This will improve the quality and detail of the data on waste and material streams. Up until recent the calculations and reporting were based on educated estimates and extrapolations for the construction sector.

A link has been established between the BIM and TOTEM. The development of building elements for calculation in the tool can be imported from several BIM systems. The results of calculations and design in TOTEM are accessible in the digital logbooks of buildings. Similar developments are considered for the design and management of infrastructure.

[8] https://vlaanderen-circulair.be/en

4 CONCLUSIONS

4.1 Supporting policy instrumentsfor the main regional regulatory developments in CDW management

In Flanders, legal framework for the sustainable management of CDW was set in place at an early stage, especially for the recycling of the stony-fraction of CDW (recycling rate over 95 %) in collaboration with the actors of the C&D sector. Key drivers are as follows:

- landfill ban
- mandatory requirements for separate collection of several waste fractions (e.g. gypsum) and ongoing research on recycling technologies for these fractions
- quality requirements for the sorting of mixed C&D waste
- Tracimat system for distinguishing between materials with the high and low risk environmental profile

The landfill and incineration ban on construction and demolition waste in the Flemish Region has spurred the use of recycled materials and advanced recycling technologies. This shift has led to better waste management practices, reduced reliance on primary resources, and increased sustainability awareness in the construction sector. The ban has prompted the separation and reuse of materials, promoting a circular approach to construction activities, and fostering eco-friendly designs. Overall, this ban has positively impacted the industry's environmental practices and resource efficiency.

4.2 Current state and outlook for the main regional regulatory developments in CDW management

The implementation of stricter rules for separate collection and quality assurance systems for recycling aggregates and for sorting in the Flemish Region, outlined in Vlarema regulations, particularly for construction and demolition waste, has led to improved waste management and sustainability. These rules encourage efficient separation of materials at the source and meticulous post-sorting, enhancing the quality of recycled materials and reducing residual waste. The Public Waste Agency of Flanders (OVAM) has played a pivotal role in shaping and enforcing these regulations. This approach conserves resources, lessens environmental impact, and advances sustainable waste practices across the region.

Standards and an assessment framework for processing resource declarations are essential to ensure consistency, reliability, and sustainability in the use of recycled materials in the construction sector. They provide for uniform assessment, quality assurance, and comparability of environmental impacts. These standards promote innovation, enhance consumer confidence, and contribute to a more sustainable and circular construction industry.

The Unity Regulation for recycled aggregates and the development of parallel monitoring systems for other granular materials offer substantial value and impact in terms of sustainable construction practices. These initiatives establish

consistent quality standards, bolster transparency, and encourage the use of recycled materials. As a result, they contribute to environmental protection, energy savings, economic growth, waste reduction, and overall progress towards a circular economy in the construction industry.

Mandating demolition follow-up plans and tracing of material flows in the Flemish Region is crucial for responsible demolition waste management. In the waste management plan the contractor had to specify how the separate removal of particular fractions from buildings or infrastructure will be organized in a proper way. This initiative ensures careful handling of materials, encourages recycling and reuse, and promotes sustainability. It enhances waste reduction efforts, guarantees the quality of recycled materials, and contributes to the shift towards a circular economy.

In short, mandating demolition follow-up with a plan and tracing in the Flemish Region underscores the importance of responsible and sustainable demolition waste management. It contributes to waste reduction, encourages reuse and recycling, promotes high-quality recycled materials, and supports the transition to a circular economy.

The policies and initiatives of Flanders are in line, and often exceeding, the targets and expectations of EU policies. The applications such as TOTEM and the guidelines on circular and adaptable buildings consider the results and target expressed in the Levels policy of the EU.

Appendix 2

Description of regional development instruments for the improvement of CDW management and the promotion of circular economy in the construction sector

PART 2: The case of the Basque country in Spain

D6.3 - Policy recommendations for ICEBERG solutions

Lead beneficiary: IHOBE

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ICEBERG website: www.iceberg-project.eu

Acronyms

CDW	Construction and demolition waste
EGR	ESTUDIO DE GESTIÓN DE RESIDUOS (Waste Management Study)
GDP	Gross domestic product
IHOBE	The Basque Government's Public Company for Environmental Management
PPGR 2030	The Basque Country Waste Prevention and Management Plan 2030
RTD	program for the implementation of Eco-innovation and Circular Economy projects
SME	Small and Medium-sized Enterprises

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1 INTRODUCTION

1.1 Overall task and focus of this report

This report is part of a study on regional policies in two regions representing ICEBERG partners. It aims to gather information on the different practices developed on the management of CDW in the Basque Country that promote the transition towards a circular economy. The aim of the task is to present and explain the relevant policies and good practices that underpin the transition for increased recycling of construction and demolition waste (CDW), both in the Basque Region of Spain and in the Flanders Region of Belgium. The study reflects some of the solutions developed at the local level, which can serve as an influence in other parts of the European Union. Particular attention is paid to the use of digital methods in all stages of the value chains of materials in construction.

In the pursuit of sustainable development and reduced environmental impact, the construction and demolition industry has increasingly recognized the critical role it plays in shaping a circular economy. The development of circular building and the circular management of Construction and Demolition waste (CDW) is a focal point for driving this transition.

The aim is also to provide information that can be used as background for ICEBERG policy recommendations**.**

This report focuses on policies in the Basque Region in Spain. A similar separate report has been collated for the Flanders Region of Belgium.

1.2 Short description of construction sector in Basque Country country

1.2.1 Construction sector in the Basque Country

Key figures for the construction sector in the Basque country[1]:

- The employed population of the construction sector in the Basque Country in 2021 was 52.8 thousand people.
- The relative weight of the GDP of construction over the Basque economy as a whole is 5.8% in 2021.
- As far as the business fabric is concerned, the construction sector had 20,265 establishments on January 1, 2021. The great majority of them were micro-companies or SMEs, with a notable presence of self-employed workers.
- The construction sector had a turnover of 4,024 million euros in 2021.

[1] El sector de la Construcción en 2021 (Construction sector in 2021) https://www.euskadi.eus/contenidos/documentacion/ovv_construccion2021/es_def/adjuntos/contruccion_2021.pdf

1.2.2 Generation and management of CDW in the Basque Country

The Basque Country Waste Prevention and Management Plan 2030 (hereinafter PPGR 2030) states that waste generation in the Basque Country reached 6,089,377 tons during 2018, of which 20% corresponded to construction and demolition waste (CDW). This figure represents an increase in CDW generation of 17 % compared to 2010, from 1,200,000 tons to 1399,460 tons in 2018.

As regards CDW management, according to data provided by the same department, both the management and traceability of the waste generated has been improving year after year (Table 1). In 2009, the percentage of recycled CDW was 42%, 18% was disposed of, while the management of the remaining 40% was unknown. In 2020, the percentage of recycled CDW was 78%, the percentage of disposal was 12% and the percentage of unknown management was 10%.

Table 1 Management of CDW in the Basque country.

	2009	2012	2013	2015	2016	2017	2018	2019	2020
Recycling	42%	42%	54%	59%	63%	62%	74%	79%	78%
Landfilling	18%	12%	15%	19%	12%	12%	13%	16%	12%
Unknown	40%	46%	32%	22%	25%	26%	13%	5%	10%
Total (tn)	**1.382.314**	**1.083.273**	**1.025.343**	**1.011.296**	**1.261.661**	**1.397.163**	**1.399.460**	**1.298.374**	**1.201.776**

Source: Department of Economic Development, Sustainability and Environment. Statistics on Construction and Demolition Waste in the Basque Country.

Of the CDW recycled in 2020, 46.60% was recycled at a fixed plant and 15.16% at a mobile plant, while 38.16% was sent to other managers and 0.08% of the recycled waste was hazardous.

1.2.3 Main Actors (Associations of construction companies, CDW managers, etc. ....)

The PPGR 2030 identifies in the Basque Country 5 fixed plants for the management of CDW (2 in Bizkaia, 2 in Gipuzkoa and one in Araba), 13 minor fixed plants, 19 authorized mobile plants and 24 CDW sorting plants. The plan considers that the capacity of these managers is sufficient to treat the volume of CDW, focusing future efforts on improving waste segregation at source and activating the demand for these materials to replace natural aggregates.

Box 1. CDW managers and CDW plants:

The Department of Economic Development, Sustainability and Environment of the Basque Government keeps the lists of authorized waste managers up to date:

https://www.euskadi.eus/informacion/registro-de-produccion-y-gestion-de-residuos/web01-a2inghon/es/ ("Production and waste management registration")

Some of the fixed plants in the Basque Country formed in 2010 the ASSOCIATION OF FIXED PLANTS FOR RECYCLING CONSTRUCTION AND DEMOLITION WASTE OF EUSKADI (APPR.EUS)

https://www.aprr.eus/asociacion/

Associations of construction companies:

ERAIKUNE. The Construction Industry Cluster in the Basque Country is a non-profit association that integrates more than a hundred companies in the Basque construction sector. http://www.eraikune.com/#:~:text=The%20Cluster%20of%20the%20Industry,unite%20to%20get%20more%20business%20.

ASCONGI. Association that gathers the construction companies of Gipuzkoa. http://ascongi.com/

UNECA. The Unión de Empresarios de la Construcción de Álava is the non-profit business organization that brings together the companies in the construction sector in Alava. http://www.uneca.es/informacion_general

Clusters:

ERAIKUNE. The Construction Industry Cluster in the Basque Country is a non-profit association that brings together more than a hundred companies in the Basque construction sector. http://www.eraikune.com/#:~:text=The%20Cluster%20of%20the%20Industry,unite%20to%20get%20more%20business%20.

ACLIMA. This is the environmental industry cluster of the Basque Country, which represents the value chains of waste, contaminated soils, integral water cycle, air and climate change, ecosystems and efficient manufacturing and eco-design. https://aclima.eus/somos/

2 REGIONAL PLANNING IN TERMS OF CDW

This section describes how CDW is considered in the regional waste planning.

The PPGR 2030 (Basque Waste Prevention and Management Plan 2030)[2] sets out 4 macro strategic objectives to be achieved by 2030:

1. Prevention: reduce by 30% the waste generation rate per unit of GDP compared to 2016 and reduce by 15% in absolute generation compared to 2010.
2. Selective collection and separation: to achieve 85% of waste segregated at source by 2030.
3. Recovery: to achieve 85% of waste reconverted into secondary resources by 2030, while limiting energy recovery to less than 15%.
4. Reduce disposal: reduce waste management through disposal operations to less than 15% of waste generated by 2030.

In addition, the PPGR 2030 sets out specific strategies for the main waste streams. Thus, the following specific objectives are contemplated for CDW:

Table 2 Specific objectives in PPGR 2030 for CDW management

Overall objective	Specification
1. Prevention objectives	1.1 Reduce by 10% by 2025 and by 30% by 2030 the generation of CDW in relation to construction GDP, compared to 2010 (excluding LER 170504). 1.2. Reduce the generation of waste consisting of excavated soil by 15% in relation to the construction sector's GDP compared to that generated in 2020 by 2025, and by 30% by 2030. (not excavated + reused on site).
2. Selective collection targets	2.1. To reach 100% by 2025 of demolitions carried out selectively, separating at least the following fractions: wood, mineral fractions, metals, glass, plastic, insulating materials and gypsum.
3. Recovery targets	3.1. To reach 80% in 2025 and 85% in 2030 of CDW recovery rate (excluding LER 170504). 3.2. To reach 85% in 2030 and 75% in 2025 for the recovery of excavated natural materials. 3.3. Reach 65% recovery of "non-natural" excavated soils and stones (preparation for reuse and recovery) by 2025 and 75% by 2030.
4. Landfill minimization targets	Zero landfill of waste without pre-treatment (Target applicable to all fractions)

[2] PLAN DE PREVENCIÓN Y GESTIÓN DE RESIDUOS DE EUSKADI 2030 https://www.ihobe.eus/wastes

3 INSTRUMENTS FOR THE DEVELOPMENT OF REGIONAL POLICIES FOR THE IMPROVEMENT OF CDW MANAGEMENT IN THE BASQUE COUNTRY

A summary of key relevant legislation in the Basque country is collated in point 16 in Appendix 1.

3.1 Conducting pre-audits

Decree 112/2012 on Construction and Demolition Waste, which regulates the production and management of construction and demolition waste, aims at the legal regime of the production and management of construction and demolition waste in the Basque Country. The Decree obliges the producers of CDW from major works to prepare a Waste Management Study (EGR - ESTUDIO DE GESTIÓN DE RESIDUOS), which must be included in the Project of the work.

The study includes an estimate of the quantities of waste expected to be generated during the construction work. On the other hand, it includes a series of 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 of CDW management. The EGR must be signed by a competent professional person and endorsed by the corresponding professional association.

In demolition works of potentially contaminated buildings or facilities, an additional study must be prepared. The study must contain an inventory of abandoned materials/waste and an investigation of the building's activity to identify contaminated areas to be removed prior to demolition. This process is also accompanied by an environmental monitoring and control plan. Prior to demolition, the environmental body of the Autonomous Community must issue a report on the adequacy of the study.

Finally, before the start of the work, the company in charge of carrying out the work (the person in possession of the CDW) must present a plan in which the measures proposed by the EGR are developed and specified. The Plan must designate the person responsible for its correct execution. In order to improve the ratio of audits performed and the correct management of CDW, the Basque Country requests the owner to deposit the amount of money needed to perform waste management according to the budget. This deposit is paid back when the monitoring against real data has been performed and necessary justifications provided. Public contractors or owners contracting certified companies do not need to deposit this fee.[3]

In order to facilitate the preparation of the necessary documents and procedures prior to the start of the work, the following tools and manuals of good practices developed at regional level have been made available to the different actors:

EEH Aurrezten. The Basque Government's Public Company for Environmental Management (IHOBE) has developed a web application for compliance with the

[3] https://www.europeandemolition.org/cms/files/2016_07_DGGROW_SR2_First-Progress-Report.pdf

obligations set out in Decree 112/2012. The EEH Aurrezten application serves as a tool for the different actors at the construction site when preparing and performing calculations of Waste Management Studies, Waste Management Plans and Final Management Reports. The tool contains templates for drafting all the documents and its database is fed with the waste generation ratios proposed by Decree 112/2012 and the management prices from the Euskadiprecios database.

Box 2. Supporting tools (templates) for the waste management study:

(In Spanish)

https://www.ihobe.eus/publicaciones/eeh-aurrezten-manual-para-herramienta-apoyo-a-redaccion-y-revision-egrs-pgrs-e-ifgs

https://www.ihobe.eus/eeh-aurrezten

Manual for the drafting of CDW studies in building, rehabilitation and demolition works. This tool, developed by IHOBE, serves as a basis for guiding those responsible for designing a Waste Management Study (point 8 in Appendix 1).

https://www.ihobe.eus/publicaciones/manual-para-redaccion-estudios-rcds-en-obras-edificacion-rehabilitacion-y-demolicion-2

Manual for the drafting and implementation of a Construction and Demolition Waste Management Plan. Good practices. This tool, developed by IHOBE, aims to provide support to construction companies that carry out their activities within the legislative framework of the Basque Country in the drafting of Waste Management Plans and their implementation on site (point 9 in Appendix 1).

https://www.ihobe.eus/publicaciones/manual-para-redaccion-e-implantacion-plan-gestion-residuos-construccion-y-demolicion-buenas-practicas-2

3.2 Compulsory selective demolition and segregation of materials on site

Within the Basque Region, there is the obligation for selective demolition (the Basque Country: Order of 12/01/2015[4]). Construction and demolition waste must be sorted into at least the following fractions: wood, mineral fractions (concrete, bricks, tiles, ceramics and stone), metals, glass, plastic and gypsum. This sorting will be carried out preferably at the place where the waste is generated.

Table 3 Mandatory material-specific separation of CDW at site (Order of 12/01/2015)

Description	Code: European list of waste	Quantity
Concrete	170101	10 t.
Bricks and tiles	170102 / 170103	10 t.
Metal	1704xx	always
Wood	170201	always
Glass	170202	0,25 t.

[4] http://www.lehendakaritza.ejgv.euskadi.eus/r48-bopv2/es/bopv2/datos/2012/09/1203962a.shtml

Plastic	170203	always
Paper and cardboard	150101	0,25 t.
Gypsum	170802	always

3.3 Promotion of the use of secondary materials

Acceptance criteria has been developed for the use of secondary materials in different levels and types of works: building, rehabilitation, urbanization, civil works, hydraulic works, coatings, envelopes, etc.

The opportunity to include recycled materials in the different work units are described systematically. Information is given about technical requirements and relevant standards. In addition, commercial products which are including recycled ingredients above a certain threshold and supplied with a third-party accreditation, are listed. These recycled materials can be used by industry stakeholders (developers, planners, construction companies) for different applications. In this way, they can make a circular economy effective by reintegrating the materials used into the economic cycle while minimizing the consumption of raw materials.

Box 3. Criteria and guidelines for secondary materials

Environmental Criteria (for Green Public Procurement) defined for different product categories (point 4 & 5 in Appendix 1)

https://www.ihobe.eus/criterios-ambientales

Guide to the Use of Recycled Materials in Construction

https://www.ihobe.eus/publicaciones/guia-para-uso-materiales-reciclados-en-construccion-3

3.4 Promotion of innovation in the area of CDW

Annually the Basque Government runs a program (RTD program) for the implementation of Eco-innovation and Circular Economy projects. Program has been running for more than a decade. Throughout this decade, the involvement of this line in the promotion of circularity and new materials and uses from waste streams in the construction value chain has been constant.

For example in the 2018-2022 period, of the total of 105 projects financed, 19 have belonged to the construction sector. These include 9 projects that have given rise to new recycled materials that in some cases have already led to regulatory progress in this regard. Even involving high added value uses from CDW such as fines and ceramics with limited final destinations to date. Also worth mentioning are projects that involve disruptive progress in pre-demolition audits through easily accessible digitalization tools or those aimed at progress in the servitization/reuse of buildings.

Large participation of Basque Country construction sector, Academia and Administration in IRCOW, HISER and ICEBERG granted by the EU.

3.5 Communication and information on CDW

The Sustainable Building and Rehabilitation Guides have the potential to be used as systems for recognizing the environmental sustainability of buildings. Also practical examples in which the use of recycled materials from CDW are relevant. It is intended to function as a "tourist guide" to check live and direct the potential of these materials:

Box 4. Communication on good practice:

This publication gathers buildings that were recognized as "Cases of Environmental Excellence" according to the methodology of the Guidelines (point 3 in Appendix 1):

- Edificación y rehabilitación ambientalmente sostenible en Euskadi. 13 casos de excelencia Ambiental ("Environmentally sustainable building and renovation in the Basque Country. 13 Best practice cases") https://www.ihobe.eus/publicaciones/edificacion-y-rehabilitacion-ambientalmente-sostenible-en-euskadi3-casos-excelencia-ambiental-2

Examples of good cases (point 6 in Appendix 1):

- Buenas prácticas en el uso de materiales reciclados en obra civil en el País Vasco ("Good practices in the use of recycled materials in civil works in the Basque Country") https://www.ihobe.eus/publicaciones/buenas-practicas-en-uso-materiales-reciclados-en-obra-civil-en-pais-vasco-3

Example of training: IHOBE has arranged webinars to raise awareness and improve the knowledge among the stakeholders in the Basque Region on legislations related to selective demolition and waste separation on construction sites. Sessions also included information on content of predemolition audit, tools for reporting and safety issues in demolition work (presentations can be downloaded):

https://www.ihobe.eus/agenda/demolicion-selectiva-y-separacion-residuos-en-obras-construccion-2 (see point 13 in Appendix 1)

3.6 Identification of the main regional (not only) regulatory developments in the area of CDW

In line with the Circular Economy Strategy of the Basque Country 2030 and the Waste Prevention and Management Plan of the Basque Country 2030, the legal regime applicable to construction and demolition waste in the Autonomous Community of the Basque Country is to be established towards the achievement, under environmentally safe conditions, of the hierarchy in the management of construction and demolition waste, prioritizing prevention, preparation for reuse,

recycling and material recovery of construction and demolition waste and minimizing its disposal towards "0" landfilling.

In this line, the aim is to guarantee the traceability of the waste through compliance with the obligations of all the actors involved in the construction and demolition process through the concept of shared responsibility. In addition, it is committed to selective demolition (which is equivalent to deconstructing a building, in the opposite direction to construction, making the most of materials that can be reused or recycled). The prescription of segregation at source of the different fractions that make up construction and demolition waste is further intensified, minimizing the generation of mixed construction and demolition waste (European list of waste: code 17 09 04). This is an urgent and unavoidable guideline in order to materialize a circular and low-carbon economy in the field of CDW by boosting the solvent production of recycled aggregates from construction and demolition waste and its placing on the market.

Construction and demolition wastes are considered as a priority waste stream given their volume of generation and their potential for recovery of the resources embedded in them. They are specifically included in Chapter 17 of the European Waste of List (Order MAM/304/2002). The European Environment Agency states in its latest 2020 report that the construction sector constitutes the largest waste stream in the European Union, and that greater efforts must be made to prevent its generation and guarantee a high level of recycling in order to achieve the objectives of the Union's waste policy.

In this sense, the European Commission, already in 2015, approves the Communication of December 2 on "Closing the loop: an EU action plan for the circular economy" in order to promote the transition from a linear economy to a more circular, sustainable, low-carbon, resource-efficient and competitive economy, in coordination with the twelfth goal of the United Nations 2030 Agenda, aimed at ensuring sustainable consumption and production patterns. In addition, the European framework is completed with the following references related to the planning and management of CDW: Directive 2018/851 of the European Parliament and of the Council, amending Directive 2008/98/EC, which analyzes the management of CDW in European countries, identifying obstacles to its recycling and non-compliance with European legislation and introducing conceptual innovations such as the recovery of materials or the definition of back filling, the European Commission's Communication "Towards a circular economy: A zero waste agenda for Europe "1 , which promotes the circular economy as a path to sustainable growth and proposes using GDP in relation to raw material consumption as an indicator of resource productivity, and the Pre-demolition Audit Guidelines, which are the first European document on the strategies, obligations and content of pre-demolition audits in European countries.

On the other hand, through the Communication from the Commission to the European Parliament, the European Council, the European Economic and Social Committee and the Committee of the Regions, the European Green Pact was published in September 2019, which establishes an action plan, among others, to promote an efficient use of resources through the transition to a clean and circular economy and within this plan is the construction sector.

In Spain, the State Waste Framework Plan (PEMAR 2016-2022) is in force, which establishes recovery targets for CDW and for clean earth and stones, Royal Decree 105/2008, of February 1, which regulates the production and management of CDW and is currently in the process of revision, and Royal Decree 553/2020 regulating the transfer of waste within the territory of the State. And particularly, in relation to the code 17 05 04 in European List of waste, APM Order 1007/2017, of 10 October, on general rules for the recovery of excavated natural materials for use in backfilling operations and works other than those in which they were generated.

Royal Decree 105/2008, of February 1, 2008, establishes that certain aspects of the matter must be regulated by specific legislation approved by the Autonomous Communities. This is the case, for example, with the possibility of requiring the posting of a bond to guarantee compliance with the obligations imposed by the regulation or the regulation of recovery and disposal operations for construction and demolition waste.

For its part, Law 3/1998, of February 27, 1998, General Law for the Protection of the Environment of the Basque Country, establishes, in Article 71, that the Autonomous Community of the Basque Country, by regulation, may establish specific authorization regimes for the different activities of production and/or management of waste.

The Basque Government, approved Decree 112/2012, of June 26, 2012, regulating the production and management of construction and demolition waste.

Consequently, the Decree regulated all those aspects of regional competence specifying what was established in the State Royal Decree in order to facilitate compliance with the objectives on the recovery of construction and demolition waste in the Basque Country.

In addition, in order to specify some articles of Decree 112/2012, the Basque Government prepared guidelines for the verification of the Final Waste Management Reports by the Environmental Collaboration Entities. Subsequently, the Order of January 12, 2015, of the Minister of Environment and Territorial Policy was published, establishing the requirements for the use of recycled aggregates from the recovery of construction and demolition waste.

At the state level, Law 7/2022, of April 8, on waste and contaminated soils for a circular economy, was approved in 2022. Its articles also include new obligations to ensure the correct separation at source of key streams included in CDW by 2022, as well as the requirement to carry out selective demolitions as of January 1, 2024. The criteria for granting the end of waste status or by-product status are also included, opening the possibility for the Autonomous Communities to establish such criteria for waste streams for which they are not defined by the European Union or the Spanish State.

Taking into consideration the experience accumulated during the validity of the aforementioned regulation and the advances at European and State level, as well as the related regional (Basque Country) plan, it is necessary to review and

update Decree 112/2012, with the modification and incorporation of new aspects (compulsory use of the instruments developed by the Environmental Regional Administration for conducting compulsory preaudits, among others).

4 MAIN CONCLUSIONS

After preparing this study, it is clear that there are a wide range of regional regulations, instruments, guides, tools, innovation projects, etc. developed for the management of CDW and the transition to a circular economy to the construction sector. It should not be forgotten that, together with these regional measures, there is a European regulatory framework, as well as some strategies, which accompany the achievement of the regional objectives. It should be noted that waste policies, and specifically in the management of CDW, are alive, and therefore, the implementation of some instruments is already underway.

However, for political success, it is very important that the measures, as well as the instruments developed for their execution, are understood by the actors in charge of implementing them (administration, designers, construction companies, managers, etc.). So, it is necessary to develop and work on pedagogical tools that serve to transmit the whole battery of policies and instruments developed, underlying the need to implement them, as well as transmitting the reasons for and benefits of fulfill these measures.

Thus, since more than one decade regulating waste management in the Basque Country, there have been improvements in the sections of waste separation on site, in the treatment of waste in recovery plants and in obtaining better quality recycled aggregates, and some new uses for recycled aggregates have been demonstrated. In addition, since 2018 the target threshold of 70 % recovery of CDW has been exceeded with a continued decrease in management by landfill and unknown or illegal management**.** Key drivers for the improved management of CDW include at least:

- Mandatory pre-demolition audit named as Waste Management Study (EGR - ESTUDIO DE GESTIÓN DE RESIDUOS) 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 (as of 2022) for wood, mineral fractions (concrete, bricks, tiles, ceramics and stone), metals, glass, plastic and gypsum
- Environmental Criteria (for Green Public Procurement) for use of secondary materials

However, additional instruments and measures are needed to achieve the new challenges, to promote the **prevention and minimization** in the generation of Construction and Demolition Waste, its **correct management**, prioritizing its **on-site recovery** and use, as well as the criteria for the **end of the waste status** and its reintroduction into the productive cycle.

Among others we do believe that there is room for improvement in these areas:

- Instruments and new technologies for the minimization of waste
- Tools for better on-site separation in small works
- More RTD and demonstration projects in new uses of secondary materials

- Improvement in already existing regional regulation
- More control of construction works in relation to the correct management of construction and demolition waste.
- Additional inspection and control mechanisms to be promoted by the environmental authorities.

Appendix 1.

INSTRUMENTS RELATED TO THE PROMOTION OF SUSTAINABLE CONSTRUCTION AND THE IMPROVEMENT OF CDW MANAGEMENT IN THE BASQUE COUNTRY

TITLE	FUNCTION	TARGET AUDIENCE	LOCATION	COMMENTS
1. Building Retrofitting and Sustainable Urban Development in the Basque Country Manuals	Tool aimed at improving building projects by means of incorporating sustainable construction solutions. It includes a system to measure the environmental sustainability of buildings, meaning it is the source of a set of derivatives in order to foster the supply and demand of sustainable properties.	Construction value chain with special emphasis on planners and developers.	www.construccionsostenible.eus	It also includes dissemination training items available on the Ihobe website
2. Sustainable Industrialised Construction in the Basque Country Manual	Instrument illustrating the reality of sustainable building and to provide a reasoned decision regarding the suitability of the incorporation of sustainable industrial construction in a project, by means of taking all the relevant sections and variables into consideration. It includes a quantitative/qualitative calculation tool	Construction value chain with special emphasis on planners and developers.	https://www.ihobe.eus/publicaciones/guia-construccion-industrializada-sostenible-pais-vasco-3	It also includes dissemination training items available on the Ihobe website
3. Environmentally Sustainable Building and Retrofitting in the Basque Country. 13 Environmental Excellence Case Studies	The Sustainable Building and Retrofitting Guides offer the possibility of being used as systems to recognise the environmental sustainability of properties. The	Private and public developers, planners	https://www.ihobe.eus/publicaciones/edificacion-y-rehabilitacion-ambientalmente-sostenible-en-euskadi3-casos-excelencia-ambiental-2	

	publication features buildings that were recognised as "Environmental Excellence Case Studies" according to the Guides' methodology			
4. Construction green public procurement criteria	Reviewed criteria in different levels of complexity for distinct types of works: Building, retrofitting, urban developments, civil works, hydraulic works, cladding, cladding, building envelopes, etc	Public administrations working on developments and possible bidders	https://www.ihobe.eus/criterios-ambientales	It also includes dissemination training items available on the Ihobe website
5. Guide for using recycled materials in construction	Systematised description in a datasheet format of the opportunities to include recycled materials in the different works units. The relevant standardisations and technical descriptions are provided in each case. Furthermore, the annex contains commercial products with third-party accredited recycled materials over certain thresholds. Those recycled materials can be used by the sector's stakeholders (developers, planners, construction companies) for different purposes. Thus, those stakeholders can implement a circular economy by returning the	Construction value chain and administrations	https://www.ihobe.eus/publicaciones/guia-para-uso-materiales-reciclados-en-construccion-3	It includes a calculation tool that can be used both by the public administration issuing the call to tender and by the bidders in order to assess and submit bids in a common and comparable language. With a protocol to structure the incorporation of new proposals into the Guide

	materials used to the economic cycle, thus minimising the consumption of raw materials			
6. Best practices in the use of recycled materials in civil works in the Basque Country	Practical examples with significant use of recycled materials from CDW. It seeks to be a "tourist guide" to check the achieved potential of those materials live and in real time	Planners and construction companies	https://www.ihobe.eus/publicaciones/buenas-practicas-en-uso-materiales-reciclados-en-obra-civil-en-pais-vasco-3	
7. EEH Aurrezten applications	Application that combines all the stakeholders involved in a building project and which embodies the documentary and physical flow, together with the calculations related to CDW management as per current legislation.	Developers, planners, builders, CDW managers, professional associations, local councils.	https://www.ihobe.eus/residuos#RCD%EHH	Free web application requiring registration
8. Manual for preparing CDW studies in building, retrofitting and demolition works.	Manual that seeks to guarantee the quality of the conducting of the CDW Management Studies required by law, in order to ensure coherent management of the budgets and finances linked to the procedure.	Works developers (companies and administrations), along with planners	https://www.ihobe.eus/publicaciones/manual-para-redaccion-estudios-rcds-en-obras-edificacion-rehabilitacion-y-demolicion-2	
9. Manual to prepare and implement Construction and Demolition Waste Management Plan. Best practices	Manual aimed at fostering the correct drafting and implementation of the required Site Waste Management Plans pursuant to current legislation	Construction, demolition companies	https://www.ihobe.eus/publicaciones/manual-para-redaccion-e-implantacion-plan-gestion-residuos-construccion-y-demolicion-buenas-practicas-2	It includes best practices per trade and possibles measures that exceed the legal framework

10. Technical instruction to check CDW Management Studies	Underway			
11. Technical instruction to check final CDW management reports	Instruction that summarises and standardises the decision-making and assessment work related to the legally required verification of the final CDW management reports on major works.	Accredited entities for CDW verification	https://www.euskadi.eus/contenidos/informacion/rcd/es_def/adjuntos/directricesRCDs.pdf	
12. Construction base prices	Including the prices of the different operations related to managing CDW and derivative recycled aggregate in the Euskadiprecios base prices	Construction value chain	http://www.euskadieuprecios.com/	This section of the base is completed by Ihobe
13. Course on selective demolition and waste sorting at selective demolition construction sites	Course to drive legislative compliance related to selective demolition and waste sorting on site	Construction value chain, with special focus on construction and demolition companies	https://www.ihobe.eus/agenda/demolicion-selectiva-y-separacion-residuos-en-obras-construccion-2	
14. Different Ekostegunak (ecoefficiency days) on incorporating recycled materials in works	Technical sessions aimed at different types of recycled materials and/or different stakeholders to encourage their requirement and use in works	Developers, planners and builders		Locatable using the Ihobe agenda secion
15. Nature-based solutions. Selection of best practices in the BAC	These nature-based solutions provide alternatives for more than one goal and are usually sustainable, cost-effective, multi-use and flexible. Working with rather than against nature is moving	Private and public planning authorities. Planners, Developers, Builders	https://www.ihobe.eus/publicaciones/soluciones-naturales-seleccion-buenas-practicas-en-capv	

	towards a more efficient economy with greener and more competitive resources. It can also help to create new jobs and improve the economy by means of manufacturing and distributing new products and services, while improving natural capital. Practical case studies in the Basque Country			
16. Related legislation	Legislation that establishes the legal and technical framework for a solvent market with recycled materials	Construction value chain	-Decree 112/2012 regarding CDW production and management in the Basque Country - ORDER of 12 January 2015, of the Basque Minister for the Environment and Spatial Planning establishing the requirements to use recycled aggregates from recovering and reusing construction and demolition waste DECREE 64/2019, of 9 April, on the legal system applicable to the recovery and reuse of black slag from steel-making in electric arc furnace -Basque Environmental Administraiton Act 10/2021, of 9 December	

Appendix 3

Interviews with ICEBERG partners

D6.3 - Policy recommendations for ICEBERG solutions

Lead beneficiary: VTT

Due date: 30.04.2024 (M48)

Type of deliverable: R

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

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1 Introduction

The aim of the stakeholder interviews was to learn about conditions enabling and issues preventing the success of ICEBERG products and to identify the most effective enabling measures for market uptake of ICEBERG circular products. Furthermore, information on good practices for replication was collected.

The aim was also to collect information from ICEBERG stakeholders for the development of the policy recommendations.

A series of interviews combined with an online survey were conducted with ICEBERG stakeholders along the value chain linked to ICEBERG product groups (circular case studies): concrete, plasterboard, ceramic, aerogel (intermediate product), wood panels and insulation (PU) panels.

Online questionnaire

The key actors in the ICEBERG circular product value chain were identified for each product type and typically included demolition contractor, waste recycler, product manufacturer, and installer/end-user/building owner. An online questionnaire with specific questions for the different stakeholders was designed. The questionnaire also included multichoice questions for ranking of potential measures supporting recycling.

The online questionnaire contained three parts. First the background of the respondent was identified. In the second part, specific questions were formulated for each stakeholder category: demolition contractor, recycler, manufacturer, installer. Finally, ranking of most important measures was included for all respondents. The online questionnaire template for plasterboard case is presented in Annex 1 (the template was slightly modified for each case).

1 Interviews

Following the questionnaire, in-depth stakeholder interviews were carried out between December 2023 and March 2024 and were conducted online via Microsoft Teams. The interview template that was used can be found in Annex 2. The template was circulated with the interviewees before the interviews. The interview set up was planned by VTT together with the ICEBERG partner from Loughborough University and with feedback from other ICEBERG partners (research organizations) related to respective case studies. The experience from the first interview on plasterboard case was benefitted for the other cases (e.g. in selection of relevant targeted questions). VTT was responsible for the interviews, partly supported by research organization also involved for the case.

Conducted interviews are summarized in Table 1.

Table 1 Conducted interviews and online surveys with ICEBERG partners

Product group	Demolition contractor	Recycler	Manufacturer	Installer	Building owner	Research institute, other
Concrete and cement based products	1[1]	1[2]			1	1
Ceramic			1	1		1
Wood	1[3]	1	1			
Gypsum plasterboard	1	1	1	1		
Insulation foam	1	1	1			
Insulating aerogels		1[4]	2			

A summary of the interviews was compiled for each ICEBERG product group including identified good practices, specific aspects (challenges, measures) concerning manufacturing and product design, supply of high-quality waste, demand on products with high share of recycled content, as well as ranking of most effective measures to support uptake of ICEBERG solutions. The interview reports are presented in Chapters 2-7.

In the core text of the D6.3, an overview summary and key observations from the all interviews are presented.

[1] plus additional online surveys with external stakeholders in Flanders

[2] plus additional interview/survey with external stakeholder in Flanders

[3] plus 1 additional interview in competition between material recycling vs energy use (SRF)

[4] also manufacturer of the aerogel

2 Interview report – Concrete case

2.1 Background

2.1.1 Context

Construction and demolition waste contains about 56 % concrete[5]. At present, the current practices at the demolition site and the conventional separation technologies used by the recycling sector have limitations to produce high-grade recycled aggregates for use in new high-quality concrete. Concrete waste is currently mainly recycled in the form of open-loop recycling (usually in road-base applications), with a small amount of closed-loop recycling (as aggregates in new concrete, typically 20 %).

2.1.2 Objective

Case 1: To demonstrate smart circular building solutions by using concrete fractions (containing coarse, fine and ultrafine fractions) recycled on-site (>75 wt%).

Case 3: to demonstrate smart circular building solutions for enhanced recovery of EoL concrete by carbonation of coarse recycled concrete aggregates for improving technical quality like water absorption and subsequent production of structural concrete and new demountable building blocks by the carbonation of recycled concrete fines (>60 wt%, U<0.22 W/m2K).

2.2 Stakeholder interviews

2.2.1 Scope

The following key actors in the concrete value chain were contacted: demolition contractor, concrete recycler, building owner, and authority. Additional to interviews (with 5 stakeholders), information was also received from surveys with demolition contractors in Belgium (3) and Spain (1). In the case of concrete, the recycler and the concrete manufacturer are often the same. A questionnaire with specific questions for the different actors was designed. The questionnaire also included multichoice questions for ranking of potential measures supporting recycling.

The interviews were planned and conducted by VTT and VITO.

2.2.2 Outcome

In all interviews, the quality requirements (limits for impurities, hazardous material) for high-grade recycling of concrete waste were emphasized. Both in the Netherlands and in Belgium, a certification system for recycled aggregate is an important driver for recycling. Especially in the Netherlands, the clients set pressure for recycling and there are also certification schemes and guidelines for green demolition. BIM models are also used for estimations of waste amounts arising from demolition.

[5] Damgaard, A., Lodato, C., Butera, S., Fruergaard Astrup, T., Kamps, M., Corbin, L., Tonini, D. and Astrup, T.F., Background data collection and life cycle assessment for construction and demolition waste (CDW) management, EUR 31323 EN, Publications Office of the European Union, Luxembourg, 2022, ISBN 978-92-76-59147-4, doi:10.2760/772724, JRC130992. https://publications.jrc.ec.europa.eu/repository/handle/JRC130992

In the Netherlands, the established Concrete Alliance (Betonakkoord[6]) is an important driver for using recyclable aggregates in new concrete. It aims for a high-grade recycling rate of 100% by 2030. The Flemish Concrete Agreement[7] is

Table 2 summarizes some key enabling conditions mentioned for efficient recycling of concrete. Furthermore, specific aspects concerning manufacturing and product design, supply of waste materials, and demand of products containing high recycled content brought up in interviews are collated in Table 3. The need for strong collaboration among all actors in the value chain was especially emphasized.

Especially the EU taxonomy was seen as an important driver for selective demolition and separation of high-grade concrete for recycling. Currently there is not sufficient guidance on how to show compliance with the requirements. Recycling of aggregates is even more important in regions that lack sand and rock quarries (e.g., Flanders). Currently in Belgium, there is a demand for recycled aggregates for foundation purposes and the use is thus justified. However, it is anticipated that this demand will decrease in the future, and therefore also the need for high-grade recycling will increase.

For concrete recycling especially the circularity aspect and non-toxicity are important environmental drivers, whereas the CO_2 savings are not the main focus. However, it is important to understand where impacts arise. When calculating environmental costs (e.g., by using Dutch MKI (MilieuKostenIndicator)[8] all emissions from the use of machinery (type of fuel or solar panels as energy sources) are included which also sets attention on the CO_2 emissions for achieving the set target for environmental costs. This system makes it possible to include the prevented environmental costs in the quotation.

Finally, a ranking of the most important measures to support the uptake of ICEBERG solutions is presented in Table 4. From the replies on importance of measures supporting high-grade concrete recycling, especially skills and knowledge was emphasized followed by national EoW criteria and taxes on virgin materials. However, it could be noticed that there was a big variety in priorities set by different actors replying – which to some extent is partly country dependent too.

Table 2 Enabling conditions for high grade recycling of concrete demolition waste.

Actor	Conditions/Good practice	Remark
Demolition contractor	In the Netherlands, there are guidelines for sustainable selective demolition and reuse[9], certification of the demolition process creates a market value in tendering process. Good pre demolition audits also include information on waste management of the material fractions recovered (Dutch building owners are currently also requiring this information) In the Dutch Pre-demolition	Traceability for quality control of material at steps before arrival to the recycling plant (cfr. Tracimat system): good idea to ensure quality of the material. From then on, the recycling plants are responsible for the quality of their products. In many countries, no protocol for assessing the performance of demolition projects. Furthermore, no requirements on the competence of the

[6] https://www.betonakkoord.nl/

[7] https://www.betonakkoord-vlaanderen.be/

[8] https://ecochain.com/blog/environmental-cost-indicator-eci/

[9] https://www.sgs.com/en-nl/services/brl-svms-007-certification

Actor	Conditions/Good practice	Remark
	protocol (SVMS-007 [10]). information included: hazardous waste (asbestos, Chromium VI). Amount and type of waste, possible materials for reuse. Current practice in the Netherlands: - Removal of reusable materials, selective demolition and separation of mono streams which can be recycled With the 3D scan of the BIM4DW we can quickly inventory the location and the amount of materials.	consultant drawing a pre-demolition audit. These are crucial for a performant system. More inspections by authorities in demolition works are advisable, to level the playing field. Quality requirements for concrete recycling: the amount of impurities is the most important quality requirement. For high-grade concrete aggregates, all materials other than concrete should be avoided. Need to keep the transport kilometers below 50 km to keep LCA in positive balance, need to stay more local than some other materials => Need a few recyclers in every province.
Recycler/manufacturer	The recycler receiving end-of-life concrete applies quality criteria (e.g., maximum content of materials like wood and plastics). Important that concrete is kept clean when recovered and not contaminated by these impurities. Based on the quality, different gate fees are used to accept the materials. The brick fraction is separated upfront in the demolition process. Integration of environmental effects: this is a good idea. The Dutch MKI (MilieuKostenIndicator) makes it possible to include the prevented environmental costs in the quotation.	If the recycling business follows an optimal business model, financial support is not a requirement. However, the sector could get a positive boost from support (e.g., tax steering). Bottom ashes from incineration plants have been used in pavement concrete. It is not possible to visually identify this, testing needed. The presence of bottom ash makes a risk for iron bars in new concrete due to their chloride content. Products passports could become important in the view of the EU Taxonomy legislation (information on the recycled content of construction products).
Building owner	For the building owner it is important to have a transparent demolition offer including information on costs for material separation and also management of waste streams. Communication with demolition contractor about requirements of recyclers for collection of high-quality concrete highly important	Mixed or unknown quality is always regarded as low-quality material only suitable for low-grade applications (for example, parking floors are regarded as low quality due to a potential contamination with de-icing agents). Important to sort also different types and quality of concrete. Hard to get all the information to the building owner, challenging to create materials passports (information needed from various stakeholders in the value chain). Not every information is available, need to get information from the manufactures to the market. ICEBERG carbonated product: local companies need to develop a system to produce it locally because otherwise the transport costs will be too high + environmental impact too big.
Authority (interview with OVAM)	Important to bring together all actors in value chain. Tracimat[11] system for material traceability in Flanders: ensuring the crusher that the material (rubble) originates from a demolition site that was monitored by Tracimat, is free of hazardous materials and that the substances that hinder recycling are present to a limited extent in the material (rubble) so recycling and use in high grade applications are possible. Certification system for waste recycling is a high driver. Certification bodies: check the	In the future, need to make the waste management plan compulsory with information on separate collection and including information to where the material will be transported. It is important to know from the recycling companies what their acceptance criteria are -> for new products/buildings collect information from the beginning so it will be easier in the end to hand it over

[10] https://www.veiligslopen.nl/en/

[11] https://www.tracimat.be/

Actor	Conditions/Good practice	Remark
	composition and the quality of recycled aggregates. A+ aggregates for recycling in concrete have stricter limit values. Recycling companies also do periodic test themselves and periodically the certification bodies come by to do tests also -> random testing on the entire process. Certification of recycled aggregates is compulsary, otherwise you can't use them or put them on the market. Certification in Flanders: COPRO [12] /CERTIPRO [13] . Certifciation is an extra cost (not government funded). Through the Flemish certification bodies, a regional EoW concept is in place (already several years of experience) for the stony fraction of CDW. Resource declaration can be attributed for waste materials for a particular application provided they comply with EoW criteria. The procedure for application and granting of the declaration is fixed in legislation with norm and standards for content and leaching of metals and organic compounds. This offers certainty about the quality of secondary raw materials.	
Demolition management organization for certification of selective demolition (Tracimat)	Focus on decontamination and making sure that hazardous materials such as asbestos do not end up at recycling companies Certificate of Low/ Environmental Risk Profile (origin is known to be safe or materials hazardous materials have been removed safely/not checked or known origin, higher risk)	Tracimat needs to spread the knowledge to the whole sector, all actors in the value chain. In future, plans to develop the system also in order to provide the recycling company with more information about the presence of potential impurities. Recycler can choose what to do with this information, does he want to accept the material in these conditions or not? Collecting information from the beginning that can be useful for the next person in the chain.

Table 3 Specific challenges concerning manufacturing, supply of waste and demand of products with recycled content.

Issue	Specification/challenge	Factors affecting/examples of solutions presented
Manufacturing and product design	Lack of information sharing. In Flanders, materials like EoL concrete panels containing insulation materials are classified as low-quality concrete waste. Also flooring at parking areas are not suitable as high-grade quality (asphalt covering, deicing agents etc). If reusable products can't be reused on site, mostly it gets downcycled. Within a larger organization as Colruyt reuse of certain construction products is possible, but market with small individual players harder -> there is a need for standardization, market business has to be willing to develop. Need for revision of standards: The use of fine aggregates has to be included in the EN-206. The use of supplementary cementitious material from recycled concrete has to be included in the standards.	Information sharing increases trust and cooperation. In the future, need for designing prefabricated panels where different materials (e.g. insulation materials) are easy to be separated.In parking areas, development of a surface layer that can be easily separated. Modular buildings like schools, supermarkets with similar modules used, reuse of modules/products and components are possible if there is a market and if not too big in size or too heavy (causing transport, storage problems): need for standardization of construction modules (e.g. standardizing their dimension, components) in order to enable reuse.

[12] www.copro.eu

[13] www.certipro.be

Issue	Specification/challenge	Factors affecting/examples of solutions presented
		In the Netherlands, higher replacement rates of the coarse aggregates are allowed (CUR-recomm. 112:2014). The new EN 197-6 allows for the use of recycled concrete fines as SCM.
Supply of concrete waste for recycling	EU taxonomy sets requirements to prove that over 90 % of the waste ends up as recycled (not just sent to a recycler) The recycling market could use initial support to create a strong new value chain For reuse, you need a direct match on a short term.	EU taxonomy requires proofs (documents, need to develop new systems for tracing recycling of wastes), stakeholders in the value chain need to communicate with each other. In Flanders the system of demolition follow-up (Tracimat-system) must must comply with the EU taxonomy requirements. Mandatory waste management plan requested by demolition contractors containing waste management information. Close collaboration along the value chain-important to create a big network of stakeholders that are communicating with each other on information sharing. Extended producer responsibility (cfr. the system in France), green public procurement. Digital market places for reusable elements.
Demand on products with high recyclable content	In the future, a need to recycle aggregates at the high-grade recycling level. Perhaps not the situation currently, but need to be ready when there is not enough market on the foundation market. Waste streams from other industrial sectors may provide secondary materials that can be used as foundation material. Not all demolition companies will go for separating concrete in different qualities if there are not a very clear demand or legislative requirements for use of recycled aggregate in concrete because more manpower is required at demolition site and this will drive up the demolition price.	The government has a strong example function, and should promote the use of high-grade products with recycled materials in their construction projects. Green public procurement is an important tool that should be used more.

Table 4 Ranking of measures to support uptake of ICEBERG solutions.

Measure	Aspects mentioned in interviews	Remarks
Ranked as highly important by 2 actors and as important by at least 1 (of 5)		
Knowledge, skills, education	Important that all actors in the value chain have understanding about the possibilities for reuse and recycling and how this sets needs for additional actions along the value chain.	Important to explain e.g. to demolition contractor why some materials need to be separated (e.g. all materials not suitable for high grade recycling). There is then also an understanding that more space is needed for material separation and more actions are required for recovering of materials with high quality.
EU wide end-of-waste criteria	Interviews with Dutch stakeholders: support for EU-wide EoW criteria (materials could be more easily shipped over borders). Flemish interviews: no need for EU wide EoW as already regional regulation in place. EU wide Eow criteria could create an influx of lower-grade materials from neighboring countries and an export of lower grade materials to other member states for use in low-quality applications. This undermines selective demolition, recycling and the optimal closing of material loops.	Flemish interviews: EoW criteria should be very strict (both in terms of standardization and inspection frequency and also in terms of quality assurance/certification of the recycling process and of the EoW materials). Moreover, the EoW criteria should be linked to the policy of selective demolition and demolition monitoring. Therefore it is difficult to establish EU generic EoW criteria. EU-wide EoW criteria for materials from the demolition and renovation sector can only be established if there is a common EU policy on - construction and demolition waste, - demolition follow-up - and quality assurance for sorting and recycling.

Measure	Aspects mentioned in interviews	Remarks
		And this policy has been implemented in an equivalent manner in the different EU-member states. Establishing EU-wide EoW criteria is not the right way to facilitate cross-border transport. This is improper use of the EoW criteria. To facilitate cross-border transport, it is appropriate to amend the relevant directive. For example, establishing conditions under which a waste material is 'green listed'.
National End-of-waste criteria	In the regions of the interviewed stakeholders, regional EoW criteria are already in place. The interviewees deemed this to be essential for a good-working system.	
Lowering VAT for recycled materials		
Ranked as important as highly important by 1 actor and as important at least by 2		
National requirements/guidance/ recommendations for use of pre-demolition audit	In Flanders, the pre-demolition audit is mandatory and the audit report is verified during site visit	
Taxes of virgin materials (e.g. Carbon tax increases the costs of virgin products and helps to make recycling more competitive)		
Use of Green Public Procurement to drive demand for ICEBERG products for public buildings (criteria supporting recycling		
Mandatory source separation for materials for which recycling capacity exists		
Digital product passport including relevant information on recycled material	Products passports could become important in the view of the EU Taxonomy legislation (information on the recycled content of construction products).	

3 Interview report – Ceramic case

3.1 Background

3.1.1 Context

Construction and demolition waste contains about 6.50 % bricks and 5.61% ceramics and tiles[14]. At present at industrial scale, only less than 10 % of ceramics is circulated back into tiles since recycled ceramics hinder the shaping of large-format pieces because of their limited plasticity.

3.1.2 Objective

The aim was to develop ceramic wall tiles containing about 50 % of recycled ceramics by using a wet micro grinding process for a separately collected ceramic fraction from CDW and in the sintering processing use cold sintering that reduces the temperatures and leads to about 40 % energy reduction in the manufacturing process.

The manufacturing of novel circular, easily disassemble tiles was demonstrated in use in a 250 m^2 floor.

3.2 Stakeholder interviews

3.2.1 Scope

The following key actors in the ceramic recycling value chain were contacted: installer, recycler/manufacturer, and research organization. A questionnaire with specific questions for the different actors was designed. The questionnaire also included multichoice questions for ranking of potential measures supporting recycling.

The interviews were planned and conducted by VTT.

3.2.2 Outcomes

The most valuable takeaway from the ceramic recycling case has been the successful pilot run in the ICEBERG project which demonstrated that recycling of ceramics with high recycled content (even 50 %) is technically feasible. Ceramic materials are also highly available in demolition waste and use of recycled fractions in new ceramics can be an option in future. The performance may not always be exactly the same as with virgin materials, but this might not be always a problem as there are many types of applications with different requirements.

Table 5 summarizes some key enabling conditions presented in the interviews for efficient recycling of ceramic waste in new ceramic tiles. Especially the pre-

[14] Damgaard, A., Lodato, C., Butera, S., Fruergaard Astrup, T., Kamps, M., Corbin, L., Tonini, D. and Astrup, T.F., Background data collection and life cycle assessment for construction and demolition waste (CDW) management, EUR 31323 EN, Publications Office of the European Union, Luxembourg, 2022, ISBN 978-92-76-59147-4, doi:10.2760/772724, JRC130992. https://publications.jrc.ec.europa.eu/repository/handle/JRC130992

demolition audit is seen to be an important driver for selective demolition and separation of high-quality ceramic fraction for recycling. Furthermore, in manufacturing and product design, supply of waste materials, and demand of products containing high recycled content were identified as crucial (see Table 6). The need for strong collaboration between demolition contractor and recycler was strongly emphasized in the interviews. Furthermore, demand for secondary materials is the key to ensure the separate recovery of ceramics.

For ceramic recycling business especially the circularity aspect is seen as most important environmental driver followed by the CO_2 savings whereas the end-users (financiers, building companies, tendering client) typically awards the CO_2 savings as more important than circularity (savings of resources).

The market value is believed to generally increase due to the growing demand for sustainable building materials, advancements in recycling technologies, and consumer willingness to invest in eco-friendly products. Stakeholders are willing to pay somewhat more for green products, but policy measures are needed to make products with recyclable content more competitive. A ranking of most important measures to support the uptake of ICEBERG solutions is presented in Table 7.

Table 5 Enabling conditions for ceramic product with high content of recyclable content.

Actor	Conditions/Good practice	Remark
Demolition contractor	In Basque country, in case of demolition works with impact on soil, there are requirements for a mandatory pre-demolition audit prior to demolition including inventory of waste, separation measures. Inspections at site to follow the implementation of audit are carried out by competent experts when possible.	Clear benefits in using BIM4DW for forecasting and planning of demolition work. However, still challenges in BIM modelling for demolition work taken into account time and efforts needed for accurate building information. Currently no market for separately recovered ceramic fraction (no demand in the area). Challenges with sufficient waste amount from one demolition site. Cheap landfilling costs compared to some other EU countries, but regulation exist to prevent landfilling of recoverable materials. Typically mixtures of concrete and bricks used in civil works. Separation of ceramic waste means extra workload and costs.
Recycler/Manufacturer	Good collaboration with demolition contractor about quality requirements for recovery of ceramic fraction for recycling and use in new ceramic tiles. Beneficial if no extra steps and equipment in manufacturing required compared to virgin materials. (Demolition contractor crucial – new role as raw material supplier) Company protocol for monitoring quality developed (e.g. sample visual assessment, sieving) New technique developed and demonstrated for grinding.	In future, need for more Collaboration and Partnerships: Industry Collaboration, Public-Private Partnerships Impurities attached to the ceramic fractions (especially mortar, gypsum) need to be avoided. Demolition contractor conducts the sorting and pre-grinding of large sized fractions and sieving of impurities. Grinding of porcelain tiles in the ceramic fraction requires more efforts and time for grinding than bricks or wall tiles.

	Support for innovative processes	EU Taxonomy will encourage investment in sustainable products but requires companies to adapt and prove their practices align with strict environmental standards. Maximum distance for transport: 50 km
Research organization	Important securing homogenous stream for good control of processing conditions	Constant supply and quality of material important. With use of ceramic waste as feed, at start there is a need to adapt processing conditions. Price of recyclable feed lower than price for virgin material (cost factor) New processing step; generation of rejects (costly treatment);
Installer	Manufacturer needs to provide EPD and information on recycled content	No extra installation efforts needed compared to tiles manufactured by virgin material.

Table 6 Specific challenges concerning manufacturing, supply of waste and demand of products with recycled content.

Issue	Specification/challenge	Factors affecting/examples of solutions presented
Manufacturing and product design	Development need for a new standard: Challenges related to mechanical resistance for the tiles with high recyclable content in order to fit into the classification of EN 14411 standard. The new product may vary in their specifications such as density, water absorption or mechanical properties. Recycling involves often high production costs and sets need for economic initiatives (however, scale of process also influencing – critical volumes to be studied, small increment in costs may be accepted by client – information needed about cost factors)	Need for new classification for tiles with high recyclable content. Regulatory Measures important such as Mandatory Recycling Content, Green Building Standards. Tax, subsidies and Grants. Action are also needed to facilitate the enhanced recycling infrastructure: Investment in new technologies, especially in Collection and Sorting Systems. End-users typically request the type II ecolabel (ISO 14021), information on recycled content and in some cases information on equal performance as the virgin product for the application
Supply of ceramic feed for recycling	New process and no previous experience at industrial scale Maximum 50 km transport to manufacturing plant. Need for collaboration with several demolition contractors to achieve sufficient waste amounts for process. Demand and supply need to meet.	ICEBERG pilot case offered possibilities for a successful demonstration - showcase projects (such as ICEBERG) Proximity of supplier of feed important (heavy material)
Demand on products with high recyclable content	There seem to be a growing awareness and demand for green products by many end-users.	awareness and education, information campaigns, training programs could still foster this.

Issue	Specification/challenge	Factors affecting/examples of solutions presented
		Incentives for Green Building Practices: Market Development Initiatives: Certification and Labeling

Table 7 Ranking of measures to support uptake of ICEBERG solutions.

Measure	Aspects mentioned in interviews	Remarks
Ranked as highly important by 2 actors (of 3)		
National requirements/guidance/ recommendations for use of predemolition audit	Ceramic fractions are typically not separated in demolition works	Separation is a cost factor and requires more time
EU wide end-of-waste criteria	ceramic waste rather inert	
National/regional end-of-waste criteria	Regional EoW in Basque country for concrete and mixed aggregates has been working well, possible to take into account local conditions	ceramic waste is heavy and not transported long distances
Taxes of virgin material	Economic measures needed if virgin materials are cheaper than recovered materials for recycling	
Lowering VAT for recycled materials	Economic initiatives	
Mandatory source separation for materials for which recycling capacity exists	Linked to requirement on mandatory predemolition audit, role of demolition contractor crucial for high quality feed for processing. Sorting (e.g. optical tools) might increase costs, difficulty in sorting fractions attached to other fractions (for manufacturing process, material could be grinded)	demolition contractor contact is important for providing secondary raw material for manufacturer New regulation in Basque country: Separation at site (effectiveness not yet evaluated) Authorities do not have the tools for inspections/penalties
Knowledge, skills, education	Collaboration in value chain important: End-users should understand that recycling is possible.	Trust important in business
Ranked as important (at least one ranking as very important and one as important)		
GPP in demolition work	GPP can be linked to predemolition audit and requirements for waste recycling	

4 Interview report – Wood case

4.1 Background

4.1.1 Context

Construction and demolition waste is estimated to contain 2.9 % of wood waste[15]. In the EU, about 70 % of the wood is used in construction and furnishing (Verkasalo, 2021[16]). The highest amounts are generated in Germany (3.0 Mtonnes), France (1.7 Mtonnes) and in the Netherland (1.5 Mtonnes) (Eurostat 2022). In the Northern Europe, the share of wood waste of total CDW generated is over 14 % of total CDW due to the high share of wood used in construction.[17]

At present wooden insulation panels are manufactured using virgin materials or cutoffs from timbers production. Currently the wooden waste from construction and demolition is used in particle boards (Denmark, Germany), but mainly incinerated. Landfilling of wooden waste is banned in many countries.

4.1.2 Objective

Wooden waste was collected from several places in Finland in order to ensure a sufficient amount for processing. After sorting and pretreatment, the milled wooden fraction was sent to France for use in insulation wooden panel. The aim was to demonstrate the use of a high share of recycled wood in wooden insulation panels (targeting 100 % wooden waste - share to be reduced e.g. to 50 % if not sufficient properties (e.g. mechanical) achieved in order to have a certified product complying with the product requirements).

4.2 Stakeholder interviews

4.2.1 Scope

The following key actors in the insulation foam recycling value chain were contacted: demolition contractor, recycler and manufacturer. A questionnaire with specific questions for the different actors was designed. The questionnaire also included multichoice questions for ranking of potential measures supporting recycling.

The interviews were planned and conducted by VTT.

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[15] Caro, D. et al. 2024. Environmental and socio-economic effects of construction and demolition waste recycling in the European Union. Science of the Total Environment 908 (2024) 168295. https://www.sciencedirect.com/science/article/pii/S004896972306922X

[16] Verkasalo, E. et al., 2020, WoodCircus, Underpinning the vital role of the forest-based sector in the Circular Bioeconomy, D2.2 Resource Efficiency, Side Streams and Value Chain Analysis – WP2 Final Report, Luke & Cosmob, p. 110;

[17] Damgaard, A., Lodato, C., Butera, S., Fruergaard Astrup, T., Kamps, M., Corbin, L., Tonini, D. and Astrup, T.F., Background data collection and life cycle assessment for construction and demolition waste (CDW) management, EUR 31323 EN, Publications Office of the European Union, Luxembourg, 2022, ISBN 978-92-76-59147-4, doi:10.2760/772724, JRC130992. https://publications.jrc.ec.europa.eu/repository/handle/JRC130992

4.2.2 Outcomes

The quality of recovered wood creates the main barrier for recycling. About 30 % of wooden materials is estimated by one demolition contractor as maximum share for fulfilling the quality requirements for high quality recycling. Good wood quality can be obtained from roof structures and inner walls. Today, there is a high competition to use as energy, with less strict quality and pretreatment requirements. On the other side, there is a high interest of use of biobased materials in construction. Especially the CO_2 savings aspect is seen as most important environmental driver due to green certification schemes for buildings.

Table 8 summarizes some key enabling conditions presented in the interviews for efficient recycling of wooden insulation panels. Especially the collection of wooden feed for recycling is challenging, as waste needs to be collected from several building in order to have a sufficient amount for processing. Quality control requiring extra work efforts and metal nails etc impurities is hindering recycling (Table 9). The need for strong collaboration between demolition contractor and recycler was strongly emphasized in the interviews.

The market value for biobased products is believed to generally increase due to the growing demand for sustainable building materials. Logistics need also to be considered in wood recycling (not possible to ship wood materials from Finland to Central Europe). Here alternative sources can offer possibilities (e.g. wooden pallets).

A ranking of most important measures to support the uptake of ICEBERG solutions is presented in Table 10.

Table 8 Enabling conditions for insulation panels product with high content of recyclable content.

Actor	Conditions/Good practice	Remark
Demolition contractor	Glulam beams are dismantled and are successfully collected for reuse.	Wooden waste sent for incineration due to no demand for wooden waste (hampered also by big variations in quality). In future, production of biochar from wooden waste might be an option.
	Pre-demolition audit will be mandatory next year in Finland (currently a pre-demolition audit, in approximately 30 % of all demolition cases).	The estimation for the amounts of different waste types is typically done by the demolition contractor who often has best knowledge for estimation on waste amounts that will be generated. Sometimes the customer has made (by consultant). In future, if audit is conducted by a certified auditor with good knowledge on construction (e.g. products used, construction methods used), it would further improve the quality of the pre-demolition audit.
		Waste reports on CDW amounts to authorities often based on estimations, reports seldom revised based on actual amounts – this is an issue if data used for statistics.
		Waste sorting at site can be further improved (however, this would require additional inspections by environmental authorities who currently lack resources for checks at demolition sites)

		Good hard wood waste quality can be obtained from roofing structures and inner walls. Maximum 30 % of wooden materials in buildings are suitable for recycling (e.g. glued boards in kitchen furniture). Maximum 10 % of wooden construction products suitable for reuse (e.g. beams). Maximum distance for transport:
Recycler	A detailed predemolition audit and follow-up in demolition work are crucial for ensuring good wood waste quality for recycling (i.e. detection of wires and metal components in hidden construction and removal of hazardous materials, impurities harming recycling)	Collected wood waste is sorted by manually (hard wood preferred quality – e.g. kitchen melamine boards to be removed, wooden elements with small amounts of glue acceptable Wood waste often contains significant amounts of metals (especially nails, wires, door handlers, hinges..) that must be carefully removed during precrushing and milling Wood sorting and processing time consuming (several crushing steps) – far more complex process compared to production of solid recovered fuel from wooden waste. Wooden waste is stored outside under roof before treatment, no degradation in quality noticed during storage. Important that wooden waste not in contact with laying material in soil. However, quality of crushed wood can be endangered by fungi if stored for long time. Also risks for fires.
Manufacturer	Previous experience only with fresh virgin materials from beam trunks cutting - Demonstration of real wooden waste in wooden panels gives valuable information for future planning (different characteristics of wood in buildings to fresh wood, processing conditions, logistics). Use of wooden products supported by green certification schemes (notable CO_2 savings). Low footprint from wooden panels containing wooden waste. Environmental Product Declaration used for wooden products (important information on CO_2 emissions)	Wooden waste from buildings often very dry, resulting in problems in processing – not possible to add water to too dry wooden fibres (due to changed properties of fibres, pores in fibres are water resistant). In future, possible that fresh wood of good quality not available in sufficient degree (e.g. related to need for carbon storage, biodiversity requirements, limits in forest growth). French legislation on extended producer responsibility recently approved,

Table 9 Specific challenges concerning manufacturing, supply of waste and demand of products with recycled content.

Issue	Specification/challenge	Factors affecting/examples of solutions presented
Manufacturing and product design	Wooden waste may contain metals (e.g. nails problematic) and some historical wood products may contain old paint (e.g. lead). Wooden materials are coming from several buildings meaning that quality may vary.	Certification schemes (e.g. Blue Angel) requires analysis of heavy metals in the wooden products. Testing of stock material for production (possible to have stock stored and quality tested). Quality protocol on wooden panel products used to guarantee properties for a certified products

Issue	Specification/challenge	Factors affecting/examples of solutions presented
		developed. Traceability schemes could be used for wood sorting/identification of wood origin.
		Challenges with wooden materials not visible, attached to other materials.
	Wood materials from different wood species requires specific manufacturing process (e.g. cooking time) – hardwood difficult to use in rigid boards.	Certified end product means that the end-product comply with the product requirement (no differences to standard products with virgin materials). Potential indoor air emissions to be measured.
	Awareness raising of all stakeholders in value chain (also to workers in the manufacturing process)	
	Competing use of wooden waste for energy (current energy market favorizes the use of solid recovered fuel). Less processing needs and only part of wood waste suitable for recycling.	
Supply of wood waste feed for recycling	At the demolition site, hazardous wood waste (mainly impregnated wood waste) is collected separately. Other wood wastes are typically not sorted at site (sorting off-site).	Impurity fractions (gypsum, plastics etc) due to demolition methods.
		More careful on-site sorting is possible but because of current energy use, there has not been incentives.
	Typically from one demolition site hundreds of tonnes to thousands of tonnes of CDW materials. Collaboration with several demolition companies to reach sufficient supply.	Extra costs of improved sorting could be roughly 5% more expensive. Client would have to pay. Requires also more time and effort, as well as storage space.
	Sorting of wood mandatory, but more surveillance needed. Lack of resources from the authority.	
	Competition with energy use. Also biochar potential end use.	
Demand on products with high recyclable content	In France, high interest in biobased construction materials due to low footprint	Wooden materials are due to material availability more commonly used in the Northern Europe than in other parts of Europe.
	In France, price of virgin material higher compared to the recyclable feed	In Finland, no manufacturers for panels. (currently only one company producing particle boards using sawchips from neighboring company).

Table 10 Ranking of measures to support uptake of ICEBERG solutions.

Measure	Aspects mentioned in interviews	Remarks
Ranked as highly important or important 2 actors (of 3)		
Regional initiatives for recycling centres/clusters		

Measure	Aspects mentioned in interviews	Remarks
National/regional end-of-waste criteria	National EoW beneficial, if requirements not too strict. Potentially extra costs for the quality monitoring	
Taxes of virgin material		
Lowering VAT for recycled materials	Use of construction wooden products containing recyclables lowers the CO2 footprint of buildings (also supported in green certification schemes)	
Mandatory source separation for materials for which recycling capacity exists	Sorting of waste at demolition site can be further improved (clear requirements from end-users)	
Knowledge, skills, education	Important also to raise awareness of workers	information on crucial steps in recycling to be clearly communicated (why are certain steps to be followed, consequences, targets in processing)
Ranked as very important by 1 actor and important by 2		
National requirements/guidance/ recommendations for use of predemolition audit	quality of feed depending on removal of unsuitable materials (hazardous, metals, impurities) during demolition work	
Extended producer responsibility	Since 2023, EPR schemes extended also to construction products...	No experience yet documented

5 Interview report – Plasterboard case

5.1 Background

5.1.1 Context

Nowadays, recycled gypsum content in new plasterboards is limited to between 5% and 20% in the United Kingdom because gypsum is exclusively reclaimed from clean construction plasterboard waste (pre-consumer). Gypsum from refurbishment and demolition plasterboard waste (post-consumer) cannot be reclaimed for plasterboard manufacturing because of its high level of contamination with other end-of-life building materials, which limits the efficiency of current plasterboard recycling processes, and ultimately, impacts plasterboard performance.

5.1.2 Objective

The objective of the plasterboard case study is to develop novel recycling technologies for post-consumer plasterboard waste to produce recycled gypsum with consistently high purity (> 96%) and demonstrate the production of new plasterboards with high recycled gypsum content (35%). Focus was to use gypsum from refurbishment and demolition plasterboard waste as feed.

5.2 Stakeholder interviews

5.2.1 Scope

The following key actors in the plasterboard value chain were contacted: demolition contractor, plasterboard waste recycler, plasterboard manufacturer, and installer. A questionnaire with specific questions for the different actors was designed. The questionnaire also included multichoice questions for ranking of potential measures supporting recycling.

The interviews were planned and conducted by VTT and Loughborough University.

5.2.2 Outcomes

Table 11 summarizes some key enabling conditions mentioned for efficient recycling of post-consumer plasterboard waste. Furthermore, specific aspects concerning manufacturing and product design, supply of waste materials, and demand of products containing high recycled content brought up in interviews are collated in Table 12. The need for strong collaboration among all actors in the value chain was especially emphasized. The landfill tax has also been an important driver for gypsum recycling mentioned in all interviews. Furthermore, legislative requirements (e.g. taxes) were mentioned to overcome economical barriers and support green innovations.

Circularity, CO_2 savings, and non-toxicity are all important aspects but may be sometimes in conflict. Especially the manufacturer and installer brought up challenges for LCA information (knowledge by actors, training needs, costs for e.g. EPDs).

Finally, a ranking of most important measures to support the uptake of ICEBERG solutions is presented in Table 13. From the replies on importance of measures

supporting plasterboard manufacturing with high recycled gypsum content, it could be noticed that there was a big variety in priorities set by different actors.

Table 11 Enabling conditions for recycling gypsum from renovation and demolition waste.

Actor	Conditions/Good practice	Remark
Demolition contractor	Use of pre-demolition audit, includes information on the location of plasterboards in the building, estimated amount for recovery, and protocols on plasterboard dismantling and segregation Daily 10 min briefing (reminders of activities on site, required standards and work locations - reduces the chance of errors), training of staff Quality requirements by recycler, e.g. plasterboards for recovery must be clean (no wood, nails, screws, or wall paper)	Safety. Logistic issues influence material recovery The older the building is, the harder it is to use BIM4DW for waste estimation and to execute the demolition (e.g. due to add of structures over time) Challenges involve extra workload; in logistics and in dismantling (new praxis); small quantities to be collected (<1 tonne, typically averages between 1-10 tonne per site) In UK, no obligation to collect and sort gypsum waste from buildings Waste transfer notes for all recovered waste
Recycler	Close collaboration with demolition contractors and manufacturers In future: - Collaboration with several demolition companies to reach sufficient supply - Development of new collection schemes for transporting recovered plastic boards together with other recyclable demolition waste to a collection site for recycling; - Need for mobile units for pretreatment/upgrading before shipment to recycling; - Need for centralized recycling units - to be commercially viable the recycling units would need to be >30,000t pa - Development of data systems where information on recoverable streams and their locations is uploaded and shared with recyclers No specific limit for transport distance of plasterboard waste, case specific situation WRAP PAS 109:2008 “Specification for the production of recycled gypsum from plasterboard” includes a detailed protocol on procedures and acceptance criteria for End-of-	No problem with open container due to later processing with water (note! EoW acceptance criteria for collected plasterboards according to PAS 105 require that the waste in the stockpile is protected for wet weather) All materials entering the recycling unit have waste status. It becomes a non-waste product once it's been processed either through a recycler or a manufacturing plant. Challenges: - Important to minimise cross contamination with other wastes and materials - Need for special solution in upgrading/ purification (drying, neutralisation etc); purification is slow and requires addition of acids and then stabilisation prior to a filter press to create a cake which is only 50% dry matter and then requires drying to achieve the criteria for plasterboard manufacture

	waste status for recycled gypsum from waste plasterboard[18]	
Manufacturer	Close collaboration with other actors (involving all actors of the value chain is crucial for efficient recycling of plasterboards) Certification and approved documentation on health and safety, and environmental information of the purified gypsum. This information is required by all manufacturing sites to ensure compliance with legal and regulatory requirements	Challenges: - to find a method to dry the purified gypsum prior to manufacturing. An extra stage of drying and blending gypsum was required in order to enable use of the material in production Environmental performance - Circularity aspects and carbon savings are to some extent competing, need for balancing the requirements - policy or regulation fastly increasing requiring EPDs and manufacturers asking their supplies for EPD (need for a dynamic model for creating an EPD considering case specific conditions)
Installer	Installer big buyer of construction products, following technical requirements by client (e.g. recyclability) Manufacturers provide products complying to the requirements, standards, No difference to products with only virgin gypsum, high focus on fire rating of construction products (application specific)	Demand on information from the recycler about recycled content, use of Environmental Product Declaration Big knowledge gaps in value chain on environmental performance (e.g. circularity, carbon saving) – importance of LCA tool. Yet not a clear recycling target in construction products, but the importance of EPDs is growing. For sustainability certification, recyclability can be a way to achieve carbon savings (somewhat higher costs acceptable)

Table 12 Specific challenges concerning manufacturing, supply of waste and demand of products with recycled content.

Issue	Specification/challenge	Factors affecting/examples of solutions presented
Manufacturing and product design	Quality of feed: - Challenges with waste containing nails, adhesives, foams, wall papers, setting needs for sorting and pretreatment. - Sorting of gypsum of different quality/grade need separation into low and high purity fractions (different need for purification) - PAS 109 for EoW requires a system for on-site materials identification and traceability/conformity requirement. Plasterboards are not designed for recycling	ICEBERG-project provides information on the processability of demolition waste; recyclers can give specifications to demolition companies on acceptable streams Manufacturers should establish agreements with recyclers before introducing products to the market to ensure easy recyclability. Currently, there is a lack of communication between these actors, thus, recyclers have to deal with the problems that the manufacturers are creating artificially. The challenge arises once the building is built, concerning what people do over the next

[18] https://www.yumpu.com/en/document/read/10596832/bsi-pas-109-specification-for-the-production-of-wrap (accesssed January 15, 2024)

Issue	Specification/challenge	Factors affecting/examples of solutions presented
	DPPs still evolving, critical how the physical link realized (tagging of each element?) and the costs. Link to BIM model. Cost factors: Cost for transport is case specific (may be prohibitive)	decades in terms of decoration and wall treatments Waste transfer notes used Good knowledge needed on true costs for processing demolition waste (good information through rough ICEBERG project)
Supply of gypsum waste for recycling	Use of predemolition audit for identification of available streams for recovery At least 50 % of gypsum is lost waste in demolition, however, recovery of "hidden gypsum waste" is time consuming and contains impurities setting processing needs Small quantities collected at one site, need to collect streams from several demolition sites. Installation of low costs collection stations	Collaboration/strong partnership between actors, communication between actors is crucial Legislation promoting recycling (e.g. landfill tax) Higher payments from building owners can enable the recovery of challenging streams in demolition – here fairness crucial for "awarding" of demolition companies demonstrating high recovery (high competition between demolition contractors) Role of building inspectors in future to ensure correct recovery of materials from buildings If end-users could pay more for products with high recyclable content, then there is a push for high recovery rate
Demand on products with high recyclable content	Recycling gives carbon savings, savings of natural resources. However, there can be conflicts with drivers as high gypsum content may result in increased treatment needs lowering the carbon savings – need to balance different drivers Less need for gypsum mining (avoided environmental impacts on mine sites)	Role of legislation, policies promoting recycling Awareness of consumers/clients (end-users interested in carbon savings, circularity)

Table 13 Ranking of measures to support uptake of ICEBERG solutions.

Measure	Aspects mentioned in interviews	Remarks
Ranked as highly important by at least 2 actors (of 4)		
National requirements/guidance/ recommendations for use of predemolition audit	The recycling activity starts at the demolition stage	In the future BIM can be a library of materials in the building (currently not used)

Measure	Aspects mentioned in interviews	Remarks
Regional initiatives for recycling centres/clusters	Especially collection of small streams for recycling, knowledge sharing	
Landfill tax	Landfill tax mentioned by all interviewees as one of the most important drivers for recycling gypsum	in force since 1996[19]
Mandatory source separation for materials for which recycling capacity exists	Separation of difficult streams will increase costs which are beard by building owners, end-users (clients) Important to separate different grades (less processing needs for streams with low contaminations) Need for equal requirements for all demolition contractors	
Extended producer responsibility	Challenges with long lifetime of products (no need to take back own products, focus on recovered gypsum) Take back-schemes work for construction waste, but in old buildings challenging to trace plasterboards back to manufacturer, often also many product suppliers.	Focus more on the raw material "gypsum" and not on the origin of the product. Take back of own products for recycling not relevant for gypsum.
Knowledge, skills, education	Importance of education of stakeholders and sharing information in the value chain mentioned by all interviewees Often lack of knowledge on recycling possibilities and benefits of higher circularity among all actors Significant lack of knowledge in the value chain regarding environmental performance of construction products, e.g. LCA	Training and education of actors along the value chain
Ranked as important by at least 3 (of 4)		
National/regional End-of-waste criteria	EoW-status speeds up the start of recycling process Point of compliance: processed gypsum waste fulfilling specifications for manufacturers (problem if the gypsum waste leak out from the loop and used in agriculture)	WRAP protocol in UK Selection of point of compliance for EoW in order to promote plasterboard recycling instead of use of gypsum in agriculture.
Taxes of virgin materials (e.g. carbon tax increases the costs of virgin products and helps to make recycling more competitive)	Legislative actions for promoting recycling mentioned by several actors	
Lowering VAT for recycled materials	See above	
Use of BIM for information on materials and quality	Potential of BIM model to become a dynamic model	

[19] England & Northern Ireland: Rates from 1st April 2022 to 31st March 2023: £98.60/t (standard rate) ref. https://www.cewep.eu/wp-content/uploads/2021/10/Landfill-taxes-and-restrictions-overview.pdf (accessed January 15, 202

Measure	Aspects mentioned in interviews	Remarks
Use of sustainable certification schemes (BREEAM, LEEDS etc) promoting recycling	Certification schemes are drivers for use of construction products with recyclables due to credits given for carbon savings as well as material recycling	Fire safety of high importance in buildings The fire ratings depending on the application, especially with plasterboard.

6 Interview report – Insulation foam case

6.1 Background

6.1.1 Context

In constructions, rigid PU foams are used for their good insulating properties which is assured by the blowing gas trapped within the cell structure of the materials.

Construction and demolition waste contains about 0.3 % insulation materials consisting mainly of inorganic mineral wool[1, 2]. There is no statistics on polymer based insulation materials (PUR, PIR, XPS) as these are often classified as plastic waste. However, as the PU/PIR foam came later to the market, the share of PU/PIR foam waste of CDW is currently significantly lower.

At present at industrial scale, no insulation foam wastes are circulated back into new insulation materials. Currently the PU foam from construction and demolition waste is incinerated (e.g. suitable for co-fired municipal solid waste incineration plants) or landfilled.[3]

6.1.2 Objective

The initial aim was to demonstrate the use of the glycosis process to recover polyols from PU/PIR foam and to use them in the manufacturing of new PU/PIR panels. In the glycosis process, PU/PIR foam is depolymerized down to polyols using glycols in the presence of catalysts and other additives. Glycosis has successfully been used for PET waste, but not commercially demonstrated for PU/PIR rigid foams.

However, the impurities (e.g. facing materials such as paper and aluminium) in the PU/PIR foam recovered from demolition waste could not be removed to sufficient degree and was hindering the planned recycling process. In the case demonstration, it was decided to use the manufacturer´s post-industrial PU/PIR waste (e.g. cutoffs) for the production of rigid PU foam insulation products. In conclusion, the use of the recycled polyol from the post-industrial PU waste is attainable for the production of panel insulation.

PU aerogel could be synthesized from recycled polyols up to 50 wt.%. The properties of PU aerogels based on recycled polyols were similar to PU aerogel based on commercial polyols and the tested products for the demo were compliant with the declared product certification. However, the quantity of recycled polyols were not enough to scale up and produce the PU aerogel. Therefore standard silica aerogel was used for the demonstration in the PU panels, but the demonstration was not successful even at 2 %.

6.2 Stakeholder interviews

6.2.1 Scope

The following key actors in the insulation foam were contacted: demolition contractor (collecting insulation materials, but not specifically PU foams), recycler and manufacturer. A questionnaire with specific questions for the different actors

was designed. The questionnaire also included multichoice questions for ranking of potential measures supporting recycling.

The interviews were planned and conducted by VTT.

6.2.2 Outcomes

The recycling of PU foams is not yet realized at commercial scale. The challenges in recycling of insulation foams relate to the quality of the recovered foam from the demolition activity (e.g. impurities and contamination due to former use of flame retardants and blowing agents - some of these banned today). The management of the impurities present in the recovered foams are still to be solved. In the future, a traceability system for the identification of the composition of products will be required for a successful recycling process.

Table 14 summarizes some key enabling conditions presented in the interviews for efficient recycling of insulation foam waste in insulation materials. Especially the recovery of insulation foams from buildings for recycling is challenging, requiring extra work efforts. The waste amount from one building that can be recovered is small and this is setting needs for collaboration with other demolition companies in order to have sufficient amount for the recycling process. (Table 15).

In recycling, it is crucial to ensure that the demand of recyclables meets the supply. One interviewee brought up the need to develop specific platforms that correspond to a concept of supply and demand and at the same time are regionally visible. This means that recyclers, after appropriate raw material sorting, can disclose this information as suppliers to other recyclers/recyclables producers and communication between the two parties can be initiated. This could be structured similarly to an offer portal for heating oil with providers for accepting residual materials for recycling, but at the same time also display what can be purchased as a recycled product. In this way, shorter routes can be discovered, more offers can be obtained and compared, and regional differences can be shown.

For insulation foam recycling business both the CO_2 savings aspect and the circularity aspects are important environmental drivers for recycling.

The market value is believed to generally increase due to the growing demand for sustainable building materials, advancements in recycling technologies, and consumer willingness to invest in eco-friendly products. Stakeholders are willing to pay somewhat more for green products, but policy measures are needed to make products with recyclable content more competitive. A ranking of most important measures to support the uptake of ICEBERG solutions is presented in Table 16.

Table 14 Enabling conditions for ceramic product with high content of recyclable content.

Actor	Conditions/Good practice	Remark
Demolition contractor	Use of selective demolition and training of personnel for responding to new requirements in waste separation. For example, collection of insulation material sets needs to work out new methods for hindering dust to be spread at the	Important to have regular dialogue/meetings with the regulators/authorities on possibilities and challenges in recovery of specific and challenging waste streams such as insulation materials. Insulation materials are voluminous, but not big in quantities for recovery.

	demolition site (e.g. use of isolation textiles around walls at work place). Zero-waste policy in company (over 95 % of demolition waste from buildings are recovered). Proofs of competence is part of the demolition offers (price often fixed). For big stony streams: Use of mobile crushers that can be brought at demolition site for processing of recovered concrete waste for recycling or backfilling, detailed testing protocols exist, and the demolition contractor can be authorized and prove compliance with regulation.	Impurities are impossible to separate cost efficiently if insulation material is attached to the wall. Recovery of difficult streams often requires manual work (extra time and work efforts). Also need for sufficient supply of good quality for recycling. Collaboration with other demolition companies possible in future, but this requires storage places. Low value of recovered material hinders long transport distances. Landfilling of waste materials with impurities and contamination currently most cost efficient. There are a variety of insulation materials – mineral wool most common, insulation foams more challenging. Historical insulation materials may contain CFC, other hazardous substances (e.g. PFAS) which sets demand on identification and removal prior to demolition Currently lack of economic initiatives for recovery of insulation materials. Demolition contractors need to follow-up on technological development in recycling processes. For other materials to be recovered, contacts with the recyclers and end-users crucial for traceability (e.g. reuse of beams, recycling of concrete waste into new concrete)
Recycler/Manufacturer	In future, the use of Digital product passport/traceability tools: for acceptance of feed into the recycling process need for the evidence documentation of the materials used (manufacturer's product names). Information also required to the waste management company in case of landfilling or incineration.	PU waste takes a lot of space. It would be more feasible to reduce the volume through briquetting the material for higher amount of material per delivery. Collaboration with several demolition companies to reach sufficient supply; Need for mobile units for pretreatment/upgrading before shipment to recycling; Transport distance > 100 km Minimum amount for transport: 14 tons
Manufacturer	A densification method is used for reducing the volume of recovered PU foam (important for transport, logistics)) In France, there is a system concerning buildings also covering PU foams, which means that the manufacturer has to pay an EPR association a tax to cover future waste management costs (starting from last year). The recycling process enables several recycling loops (improving the environmental performance, e.g. CO_2 emissions)	Knowledge and control of hazardous material in foam to be recovered important (e.g. historical foams may contain blowing materials, flame retardants). Using labelling with chemical information is possible, but there is a risk that confidential information leaks out if all substances must be declared. Digital product passports can give good information on the product, but better if the data could be documented at building level (providing information for the demolition activity)

Table 15 Specific challenges concerning manufacturing, supply of waste and demand of products with recycled content.

Issue	Specification/challenge	Factors affecting/examples of solutions presented
Manufacturing and product design	Insulation foams not designed for recycling The recovered PU foam waste included up to 5 % facing material (e.g. paper) hindering the recycling process In future, important for business to establish a collaboration along the value chain (demolition contractors, collectors, recyclers,	Mandatory Recycling Content may change design of insulation material End-users are requiring products containing recyclable content In future, landfilling will be banned or limited End-users: Willingness to spend a little more money for a safe and sustainable product.

Supply of ceramic feed for recycling	Management of facing materials to be solved. Developing a usable polyol with specifications from partner in parameters for usability. Reducing all known content of possible toxic substances below the threshold for safety concerns. Finding suitable catalysts and process parameters like time, heat and further additive reagents, while looking for an overall high amount of waste material usage per batch.	The recycling process delivers high quality polyol that can be used in new products and the process can be realized economically. Conditions for recycling: Price of virgin material higher compared to the recyclable feed (cost factor); Supply ensured, Traceability of feed ensured
Demand on products with high recyclable content	Historical foams may contain blowing agents (e.g. CFC now restricted, requiring special measures) and hazardous substances (e.g. flame retardants, PFAS)	In Italy, there are already requirements for use of recycled polyols in new products. Clients also require recyclable content in France. Pressure from legislation also important driver for recycling Use of product passport offers solutions for making information for decades easily available on chemical composition (e.g. types of isocyanates, foaming agents) for the recycling process and also traceability to increase trust

Table 16 Ranking of measures to support uptake of ICEBERG solutions.

Measure	Aspects mentioned in interviews	Remarks
Ranked as highly important by at least 2 actors of 3		
Landfill tax	Landfilling cheap in many member states and competing with recycling	Landfilling allowed until 2030 e.g. in Germany. (no landfill tax in Germany). However, it is likely that landfilling will be banned in future in many member states. Incineration is possible.
Mandatory source separation for materials for which recycling capacity exists	Production of "pure fractions". A lot of things currently end up in mixed containers for subsequent sorting at the recycler. This must be collected separately in advance to ensure good purity. Based on the manufacturer's instructions for such panels, they must also be sorted into different fractions. Do not mix PUR to PIR , just like material A from MDI with material from B with TDI	Insulation foams containing CFC or banned substances need to be collected separately at demolition site.
Ranked as important (at least one ranking as very important and one as important)		
Regional initiatives for recycling centres/clusters		
EU wide end-of-waste criteria	recycling process requires feed from several sources which means that insulation foams may in future be shipped for treatment to another country	low density requires that waste is compacted (e.g. briquetted) for transportation
National/regional End-of-waste criteria	in case, sufficient amounts can be collected for treatment without shipment from another country	
Extended producer responsibilities	a rapid change to include EPR for construction products not foreseen generally in member states	France has recently introduced regulation to include construction products in EPR schemes. Manufacturers have to pay a tax to an EPR association when selling construction products.

7 Interview report – Aerogel intermediate product for different end products

7.1 Background

7.1.1 Context

Aerogels are used in various applications especially because of their superior thermal insulation properties. In addition to construction products, several other potential applications exist such as EV batteries and paintings. For use in building applications, the drawback is the high production cost related to raw materials price and manufacturing process.

In ICEBERG the process of silica aerogel production consists of three main steps, 1. Silica precursor preparation from CDW; 2. Silica aerogel synthesis; 3. Drying process. In general, waterglass or sodium silicate (Na_2SiO_3) is used as silica precursor for silica aerogel manufacturing. The commercial waterglass is usually produced by reacting quartz sand with sodium hydroxide (NaOH) solution at elevated temperature and pressure. In Iceberg project, the quartz sand was replaced with high silica containing CDW materials to obtain low-cost waterglass for aerogel synthesis.

7.1.2 Objective

The aim in ICEBERG is to develop an optimized continuous production (1000 l/day line) of highly homogeneous silica closed-loop granular aerogels (λ<0.016 W/mK) from high silica content EBM (e.g. glass waste, siliceous concrete), using Silicic Acid hydrothermal synthesis and multi-solvent Low Temperature Super-Critical Drying (LTSCD).

Granular silica aerogels are an intermediate product and utilized as raw materials for the production of 1) precast building blocks with circular silica granular aerogels for external and internal walls, 2) ultra-lightweight panels and 3) plasterboard.

7.2 Stakeholder interviews

7.2.1 Scope

The following key actors in the concrete value chain were contacted: recycler/manufacturer of aerogel material and end users of the aerogel (manufacturers of precast building blocks and ultralightweight panels). A questionnaire with specific questions for the different actors was designed. The questionnaire also included multichoice questions for ranking of potential measures supporting recycling.

The interviews were planned and conducted by VTT.

7.2.2 Outcomes

The production of aerogels includes several steps which makes the aerogel a high quality product produced from waste. However, the complex process will lead to a price that must be covered by the benefits the use of aerogel gives to

the application. The suitability of using aerogels in each application needs to be tested case by case.

Table 17summarizes some key enabling conditions mentioned for efficient recycling of silica based waste to manufacture aerogel. Furthermore, specific aspects concerning manufacturing and product design, supply of waste materials, and demand of products containing high recycled content brought up in interviews are collated in Table 18. Key challenge for recycling aerogel containing products in the end of life is the design of the products, typically aerogel is used as additive which I difficult to separate.

Specific remarks for the prefabricated building blocks are presented in Table 19. Possibility to dismount and reuse the building blocks can have significant impact on the lifetime and carbon footprint of the products, and takeback system has been recently established.

Finally, a ranking of most important measures to support the uptake of ICEBERG solutions is presented in Table 20Table 10. From the replies on importance of measures supporting high grade recycling, EoW criteria was seen important (both EU and national). However, considering the transport costs, local sourcing was seen most beneficial. Increasing knowledge was also considered crucial, e.g. for enhancing the trust for recycled materials.

Table 17 Enabling conditions for high grade recycling of silica containing demolition waste to produce aerogel.

Actor	Conditions/Good practice	Remark
Demolition contractor	Recycler set clear data need on composition (silica content, content of impurities).	Transport distance > 100 km Minimum amount for transport: 1 ton
Recycler & Manufacturer (aerogel intermediate)	100% aerogel (e.g. aerogel panel) can be recycled and fed back to aerogel manufacturing process. More challenging when used as additive. A mobile pretreatment plant using local waste feed (e.g. concrete waste) and situated near the client (the manufacturer using aerogel) will reduce transport costs of feed and final product Significant amount of solid residue formed in the process, but contact established to company that receive the solid residue rejects, thus landfilling not needed.	Separation is the challenge when aerogel is used as additive. Other fractions should be avoided but the process is somewhat flexible for the feed (e.g. particle size and the purity). XRF analysis can be used by contractor or recycler to check the quality. No specific requirements for storing of waste/feed material prior recycling process (outside storage under roofing).
Manufacturer/User of aerogel	Good thermal properties achieved by 5 % additions of aerogel.	Use of aerogel in wooden panels tested for first time in small scale (however, promising results for industrial scale).

Table 18 Specific challenges concerning manufacturing, supply of waste and demand of products with recycled content (aerogel).

Issue	Specification/challenge	Factors affecting/examples of solutions presented
Manufacturing and product design	design, standards, etc depend on the end product and thus the manufacturer of the end product has the most important role when it comes to design and required properties - e.g. in the plasterboard case the incorporation of silica aerogel was not possible (gypsum and silica blend did not meet technical criteria) High cost of the aerogel is a challenge.	
Supply of concrete waste for recycling	Transport costs important for the feed, therefore materials sourced near. In addition, production should be close to the end client (user of aerogel).	EoW important if the feed is from abroad Mobile units offers a possibility for local production of aerogel both near the site for waste generation and the end client.
Demand on products with high recyclable content	The good thermal properties by using aerogel in wooden panels supports reduce energy consumption in buildings (cost factor) as well as contribute to CO_2 savings. EPDs required (important especially for "green products"), even if time consuming especially at start Proof of traceability in future Information on recyclable content	

Table 19 Specific aspects identified for prefabricated blocks.

Good practice	Remarks, challenges
Design of prefabricated blocks that can be dismounted at the end of the use.	Transport distance: 50 km (high value concrete products max 300km) CO_2 burden in transport: for each 50 km transport an increase of about 2 % in CO_2 value (loose the gain with products if long transport distances) Mortar impact on carbon footprint significant (normal solution: contributes to nearly 50 %). The prefabricated blocks have low CO_2 footprint compared to traditional masonry products. In future, more attention should be on the embodied carbon in construction products. However, important also to pay attention to changed habits of building residents (due to increased comfort, eg. high inside temperature etc).

Raw materials based on recycled materials (aggregate, sand, recycled cement) and use of special mortar with only 1 % cement.	With use of mainly reusable materials, the start is zero footprint and you only have to balance the production and transport footprint If a carbon footprint is put on waste, then it make the use less attractive.
Take-back system (10 % of value paid back, corrected with index changes in life costs) – production costs/emissions can be avoided by reusing old blocks (just inspections and polishing). The recovered blocks for reuse are certified again to comply with the set requirements. Small blocks that easy to handle (product size can be adapted to the needs). The wall is made up by several small blocks.	Ideally in future (e.g. 30 years), there is no need for production of new blocks if future needs can be covered through reuse and only manufacture small amounts
Smart installation solution by using a rebar beam along the top of the wall: possible to make an opening e.g. for window	Carbon footprint of products can be lowered by 50 % (additionally possible to use low footprint insulation material in the blocks) extended lifetime of building has a huge impact (earlier 60 years, now often 24 years) – performance of product should be at least 50 years

Table 20 Ranking of measures to support uptake of ICEBERG solutions.

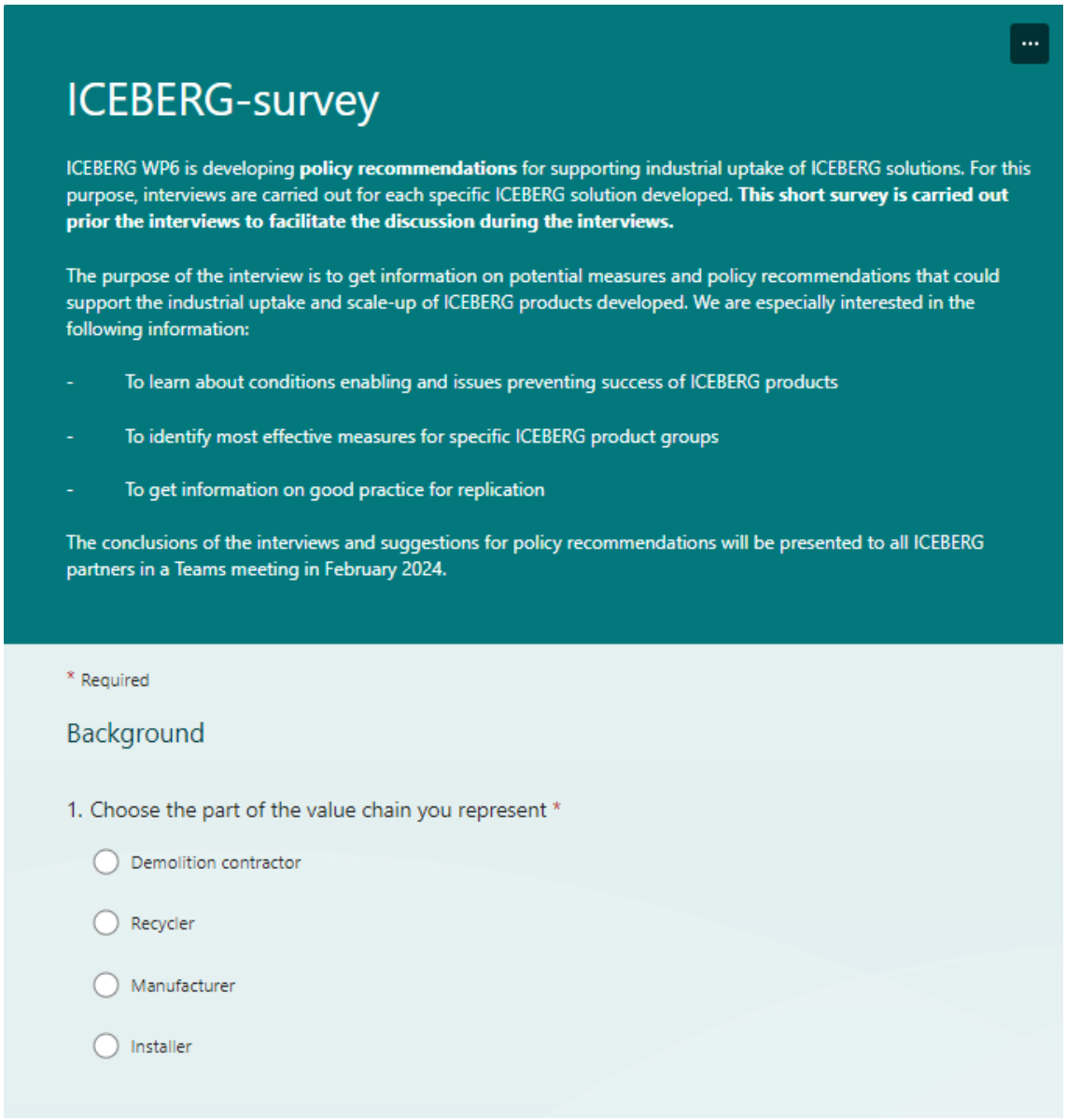
Measure	Aspects mentioned in interviews	Remarks
Ranked as highly important by 2 (out of 3)		
EU wide End-of-waste criteria	Due to transport costs, it is important that the feed is sources close. However, if feed from abroad, EoW important	Uniform quality important
National/regional End-of-waste criteria	If waste from national source, national EoW regulation important	
Lowering VAT for recycled materials	Increases demand for products containing recyclables	
National standards supporting innovation	Demonstration of proved quality important, compliance with standards creates trust	
National standards supporting development of EU standardization	see above	
Knowledge, skills, education	Many end-users have hesitations with product containing recyclable content For client: education for understanding data provided in EPDs	education of workers also important (use of recyclables materials requires to understand new steps in the production, adjustment of recipe)

Measure	Aspects mentioned in interviews	Remarks
Ranked as highly important (1) and important (1 reply)		
Mandatory source separation for materials for which recycling capacity exists	Concrete feed suitable for aerogel	Glass waste also tested but higher silica content in concrete feed
Taxes of virgin materials	No specific views presented on these measures.	No specific views presented on these measures.
Landfill tax		
Use of Green Public Procurement to drive demand for ICEBERG products for public building		
Extended producer responsibility		
National economic support for development of innovative processes		
Digital product passport including relevant information on recycled material		
Useof sustainable certification schemes (BREEAM, LEED etc) promoting recycling		

8 Annex 1 - Online survey template

The online questionnaire was created using Microsoft Forms. In the following, questionnaire for plasterboard case is presented. The questionnaire was slightly modified for each product group.

In the first step, respondents chose the part of value chain they represent: demolition contractor, recycler, manufacturer and/or installer. In the second step, specific questions tailored to each part of the value chain followed. In the final part, ranking of measures was included.



ICEBERG-survey

ICEBERG WP6 is developing **policy recommendations** for supporting industrial uptake of ICEBERG solutions. For this purpose, interviews are carried out for each specific ICEBERG solution developed. **This short survey is carried out prior the interviews to facilitate the discussion during the interviews.**

The purpose of the interview is to get information on potential measures and policy recommendations that could support the industrial uptake and scale-up of ICEBERG products developed. We are especially interested in the following information:

- To learn about conditions enabling and issues preventing success of ICEBERG products
- To identify most effective measures for specific ICEBERG product groups
- To get information on good practice for replication

The conclusions of the interviews and suggestions for policy recommendations will be presented to all ICEBERG partners in a Teams meeting in February 2024.

* Required

Background

1. Choose the part of the value chain you represent *

- Demolition contractor
- Recycler
- Manufacturer
- Installer

* Required

Demolition contractor

2. Do you have a common pre-demolition protocol for all your demolition projects? Please, specify what information is typically included. How is the competence of the pre-demolition auditor ensured? *

Enter your answer

3. What best demolition practices does your staff utilize? Please, specify *

Enter your answer

4. What benefits and challenges are there to using BIM4DW? *

Enter your answer

5. What types of information were included in the predemolition audit of plasterboards for recovery? *

Please choose right alternatives (one or several)

- [ ] Information about location of plasterboards in the building
- [ ] Information on amount for recovery estimated
- [ ] Information about plasterboard dismantling and segregation protocol
- [ ] Other

6. If you chose "Other" in the previous question, please specify

Enter your answer

7. What quality requirements were given by recycler on materials to be recovered? *

Enter your answer

8. How is the sufficient quality of recovered plasterboards best ensured? *

Please choose which types of approach/method are used

- [ ] Use of company protocols
- [ ] Training programmes for personnal
- [ ] Schemes for visual assessment on quality used, e.g. concerning impurities (please specify in the following question)
- [ ] Supporting analytical methods used (please specify in the following question)
- [ ] Other

9. If you chose "Schemes for visual assessment on quality used" or "Supporting analytical methods used" or "Other", please, specify

Enter your answer

10. Any additional information on good practices?

Enter your answer

11. Which are the challenges to dismantle and segregate ICEBERG plasterboards? *

Please choose appropriate alternatives (one or several)

- [ ] Extra workload
- [ ] Lack of quality requirements for collected plasterboard (e.g. purity)
- [ ] Challenges in logistics in dismantling (new praxis)
- [ ] Small quantities to be collected
- [ ] Demand for specific containers
- [ ] Other

12. If you answered "Small quantities to be collected" in the previous question, please indicate typical range of amount collected at site

Enter your answer

13. If you answered "Demand for specific containers" or "Other" in question 11, please specify

Enter your answer

* Required

Recycler

2. In which types of containers are recyclable plasterboard typically transported from the demolition site? *

Please choose one alternative

- ◯ Bags
- ◯ Closed container
- ◯ Open skip container
- ◯ Other

3. Please specify the size of the bag or container. If you chose "Other", please specify.

Enter your answer

4. Which type of vehicles were used in transport (e.g. maximum load)? *

Enter your answer

5. Any critical issues in handling/transport (e.g. issues of special attention)? *

Please specify about requirements given to demolition contractor about the collection at demolition site

Enter your answer

6. Any minimum quantity for transport? *

Please choose one alternative

- ◯ 100 kg
- ◯ 200 kg
- ◯ 500 kg
- ◯ Case specific (e.g. distance to collection place)

7. Maximum distance for transport? *

Please choose one alternative

- ○ 20 km
- ○ 50 km
- ○ 100 km
- ○ > 100 km

8. In the future, how can sufficient supply for processing be ensured? *

Please choose appropriate alternatives (one or more)

- ☐ Collaboration with several demolition companies to reach sufficient supply
- ☐ Need for mobile units for pretreatment/upgrading before shipment to recycling
- ☐ Development of new collection schemes where recovered plastic boards are transported with other recyclable demolition waste to a collection site for later recycling
- ☐ Development of data system where information on recoverable streams and their location is uploaded and shared with recyclers

9. Do you see a need for establishing a few centralized recycling units in your country/Europe in order to secure a sufficient supply? What could be the capacity range per such unit? *

Enter your answer

10. What were the key bottlenecks that you faced during the processing? *

Please choose appropriate alternatives (one or several)

- ☐ Need for special solution in mechanical sorting
- ☐ Need for special solution in crushing
- ☐ Need for special solution in upgrading/ purification (drying, neutralisation etc)
- ☐ Need for sourcing equipment and materials
- ☐ Other challenges

11. Please specify your answer to the previous question *

Enter your answer

12. Did you apply for specific permits to initiate the ICEBERG gypsum purification plant? *

Please choose one option

- ○ Yes (easily done)
- ○ Yes (efforts needed)
- ○ No need for specific permit in this project

* Required

Manufacturer

2. How was the ICEBERG purified gypsum stored? *

Please select all options that apply

- [ ] A dedicated space to store all the material
- [ ] Stored in smaller quantities at several places
- [ ] Indoor storage
- [ ] Outside storage (only roofing)
- [ ] No extra efforts compared to use of virgin raw materials
- [ ] Other

3. If you chose "Other", please specify.

Enter your answer

4. Any specific bottle necks in processing? *

Please especially indicate what is different from standard procedure with virgin material?

- [ ] New solutions in blending
- [ ] New solutions in blend milling
- [ ] New solutions in gypsum calcination
- [ ] New solutions in gypsum hardening
- [ ] New solutions in plasterboard tagging
- [ ] New solutions in plasterboard storage
- [ ] New solutions in plasterboard certification tests
- [ ] New solutions in transport to installation site
- [ ] Difficult rejects (costly treatment)

5. Please shortly describe the challenges (e.g. processing time, conditions) *

Enter your answer

6. Which are the key conditions to make the use of recyclable feed interesting or possible? *

Please choose one or several options

- [ ] Price of virgin material higher compared to the recyclable feed (cost factor)
- [ ] Good properties of purified gypsum (e.g. pH, moisture content, calcination behaviour)
- [ ] Technical challenges solved in the manufacturing process
- [ ] Legislative requirements consistent
- [ ] Traceability of feed ensured
- [ ] Supply ensured, please indicate minimum quantity needed for processing
- [ ] Suitable storage conditions for feed arranged
- [ ] Suitable storage conditions for end-product arranged
- [ ] Other

7. If you chose "Other" or wish to elaborate more, please specify below

Enter your answer

8. Is there a need for new standards? *

- ( ) Need for revisions of EU standards to better cover ICEBERG circular plasterboard
- ( ) Need for European Technical Assessment to better cover ICEBERG circular plasterboard.
- ( ) No need/no opinion

9. If you chose "Need for revisions of EU standards to better cover ICEBERG circular plasterboard", please specify the main concerns with the current standard

Enter your answer

10. What type of information do you request from your suppliers and providers (source, quality, etc)? *

Enter your answer

11. What type of information is typically demanded by the client (end-users) related to the feed/product, e.g. recyclable content, Environmental Product declaration, traceability? *

Enter your answer

* Required

Installer

2. Did you develop a specific protocol for the installation of the ICEBERG circular plasterboard? *

	Yes (please specify in the next question)	No
Was there any differences in installation schedule	○	○
Was there any differences in avoiding damage to tags	○	○
Was there any differences in binding system	○	○
Was there a specific need for training of personnel	○	○

3. If you answered "Yes" in the previous question about developing specific protocols, please specify

Enter your answer

4. What type of information would you demand in the future from the manufacturer? *

Please choose one or several options

- ☐ Demand on label
- ☐ Demand on Environmental Product Declaration
- ☐ Demand on recycled content
- ☐ Demand on digital information
- ☐ Proof of traceability
- ☐ Other

5. If you chose "Other", please specify

Enter your answer

* Required

Final question

6. Key aspects of the national landscape influencing market uptake of ICEBERG product *

Please score the importance of the following aspects in future for promoting your ICEBERG product.

	No opinion	Not important	Somewhat important	Important	Very important
National requirements/guidance/ recommendations for use of predemolition audit	○	○	○	○	○
Regional initiatives for recycling centres/clusters	○	○	○	○	○
EU wide End-of-waste criteria	○	○	○	○	○
National/regional End-of-waste criteria	○	○	○	○	○
Taxes of virgin materials (e.g. Carbon tax increases the costs of virgin products and helps to make recycling more competitive)	○	○	○	○	○
Lowering VAT for recycled materials	○	○	○	○	○
Landfill tax	○	○	○	○	○
Use of Green Public Procurement in demolition work to drive demand for ICEBERG recycling process	○	○	○	○	○
Use of Green Public Procurement to drive demand for ICEBERG products for public building (criteria supporting recycling)	○	○	○	○	○
Mandatory source separation for materials for which recycling capacity exists	○	○	○	○	○
Extended producer responsibility	○	○	○	○	○
National economic support for development of innovative processes	○	○	○	○	○

Use of BIM for information on materials and quality	○	○	○	○	○
Digital product passport including relevant information on recycled material	○	○	○	○	○
National standards supporting innovation	○	○	○	○	○
National standards supporting development of EU standardization	○	○	○	○	○
Use of sustainable certification schemes (BREEAM, LEEDS etc) promoting recycling	○	○	○	○	○
Knowledge, skills, education	○	○	○	○	○

9 Annex 2 - Interview template

SECTION ONE: Views of value chain actors (related to the ICEBERG solution)

Discussion:

1. At which stage of the value chain is it important to make an extra effort to manage specific risks (e.g. risk about not achieving purity levels? risk for losing circularity opportunities) …. How can these risks/characteristic features be controlled/managed/mitigated/avoided?
    - *Examples:*
        - *demolition companies (e.g. waste sorting),*
        - *recyclers (adaption of process/machinery, managing of impurities),*
        - *manufacturers of construction products (new procedures)*
        - *installers (new routines),*
        - *end-user/client (by offering more money for the waste stream/potential material),*
        - *authorities (acceptance procedures),*
        - *comments on current collaboration?*
    - *Role of building owner to bear the cost for circular economy initiatives? (today CDW is often sorted based on costs)*
    - To what extent would you say that the recycling benefits trump the risks or vice versa?

2. Potential actions for improved collaboration along value chain? Is there a need for new actors (e.g., consultants, coordinators) to be part of the value chain? At which stage?
    - *Need for training/accreditation?*
    - *Need for better synchronizing demolition work to reuse/recycling activities by minimizing storage requirements, balancing supply and demand.*
    - *new business models (take-back systems?)*

SECTION TWO: Focus on feed/product

1. How important do you see the role of traceability? Based on your expertise, how to realize it in practice?
    i. role of selective demolition
    ii. are there quality requirements for sorting (onsite or also offsite)
    iii. critical points in value chain to be controlled (by whom?)
    iv. role of BIM for information on materials/quality?

2. In general, how do you think the introduction of EU end-of-waste criteria would affect the development of the market? Would you support the introduction of EU end-of-waste criteria for the specific raw material used in the ICEBERG solution? Why/why not?

    i. benefits/challenges with EU/national EoW criteria
    ii. point of compliance for setting EoW status?
    iii. problems if legislation changes?
    iv. second or third recycling loop
    v. problems if some materials are with waste status and other not

3. How important is it for ICEBERG product to develop a local market (avoidance of long-distance & long storage time, cost factor?)
    benefits and challenges
4. Environmental performance:
    i. To which degree do you think that the following environmental aspects are supporting the use of ICEBERG products:
        - Circularity [20]
        - GHG savings
        - non-toxicity requirements
        - any opinions about indicators - need for who? challenges?
    - demanded by end-users (financiers, building companies, tendering client):
        - Circularity
        - GHG savings
        - non-toxicity requirements
    - Role of Environmental Product Declaration

5. Which are the ways to share that environmental info with supplier, clients, etc (annexed paper documents, digital documents with/without structured data, automatically through specific platforms…)
    i. harmonised data reporting model (what data could be mandatory/voluntary)

[20] examples of circularity solutions are related to material need (minimizing resources need, reduction in the use of virgin material), use of biobased materials (regeneration of natural systems), content of recycled materials (minimizing use of virgin material), recyclability after use (minimizing use of virgin material, avoiding loss of materials), durability (minimizing use of resources by extending lifetime) and use of non-toxic materials (reducing hazardous materials)

6. How do you think the market for “recycled” products using ICEBERG solution will develop over the next five years? What are the main reasons/factors and why?
    - How will it develop concerning the market value?
    - How will it develop concerning the volume of sales?

7. Are there needs for new business models: ”take-back”, “product as a service” - need to sell concepts (e.g. “green demolitions, construction of green buildings)”

8. How does the new EU taxonomy influence the choice of an ICEBERG solution (any difficulties - e.g., how to demonstrate compliance with taxonomy criteria e.g. for circular economy)? (EXTRA)

9. What information should be included in digital product passports or material recycling sheets (EXTRA):
    - For supporting planning of demolition work & for traceability …
    - inclusion of data on circularity properties (recyclable content, repairability, dismantability/waste collection…

Any ideas for measures that can increase or support the market uptake of ICEBERG product?

Appendix 4

Importance of measures in Flanders (and Basque country) for enabling high grade recycling of CDW – assessment by regional stakeholders

D6.3 - Policy recommendations for ICEBERG solutions

Lead beneficiary: Tracimat

Due date: 30.04.2024 (M48)

Type of deliverable: R

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

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1	30.4.2024	Tracimat	Final draft.

Main author(s) (in alphabetical order)		
Name	*Surname*	*Organisation*
Lies	Mertens	Tracimat

ICEBERG website: www.iceberg-project.eu

1. Importance of measures – assessment by regional stakeholders

Different regional stakeholders involved in the value chain in Flanders (and Basque country) were contacted to get their view on potential measures that could effectively support recycling of CDW (not limited to ICEBERG solutions). They were asked to score the importance of listed measures and give an indication of a possible implementation timeline by means of an online survey. The online survey template is presented below.

ICEBERG WP6 is developing policy recommendations for supporting industrial uptake of ICEBERG circular products. For this purpose, stakeholders involved in the value chain are contacted about measures that support recycling (not limited to ICEBERG solutions/partners).

The purpose of the survey is to get stakeholders´ views on potential measures that could effectively support the recycling of construction and demolition waste in new construction products. Please score the importance of the listed measures and your opinion on the implementation timeline in the following survey.

Choose the stakeholder group that you represent:

- *demolition contractor*
- *demolition expert*
- *recycler*
- *manufacturer*
- *end-user of construction product/building owner*
- *other, please specify*

MEASURES	Please rank the impact of measure on promoting CDW recycling 0 – no importance/no opinion 1 - somewhat important 2 – important 3 – highly important	Effort (time/feasibility) Please mark when measure can at earliest be achieved			
		already in place and implemented	already in place but still not fully implemented	can be achieved by 2030	can be achieved by 2050
Design and manufacturing					
1. Actions supporting/requirement on construction products designed for recycling					
2. Digital product passports (including information on the recyclables) for supporting traceability					
3. Policy actions for supporting construction products containing recyclables (e.g. taxes on virgin materials, VAT reduction for products containing recyclables, national support for local markets - in order to make recycling more competitive)					
4. Digital marketplace available for recyclables and reusable products from buildings					
5. Incorporation of environmental impact into total price of construction products (e.g. impact of landfill, downcycling)					
6. Use of Green Public Procurement to drive demand for products with recycled content for public buildings					
7. Extended producer responsibility					
Pre-demolition auditing					
8. Implementation of a demolition plan with information on waste management options of recoverable streams					
9. Use of BIM (Building Information Modeling) for information on materials and quality					
10. Mandatory source separation for materials for which recycling capacity exists (on-site/off-site)					
Demolition/waste management					
11. More control (e.g. inspections) of construction or demolition works in relation to the correct management of CDW					

12. Traceability e.g. by using digital waste transfer notes, linked to a monitoring system and database					
13. Regional initiatives for recycling centers/clusters					
Certification, knowledge and innovation					
14. Certification system for quality of recycled material					
15. National End-of-Waste criteria					
16. Availability of assessment tools for measuring circularity, CO2 savings, environmental impact					
17. Improving knowledge and skills among stakeholders in value chain					
18. National economic support for development of innovative processes					
19. National standards supporting innovation/technology development					
20. Use of sustainable certification schemes (BREEAM, LEED etc.) promoting recycling					