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Construction and demolition waste: description and recovery

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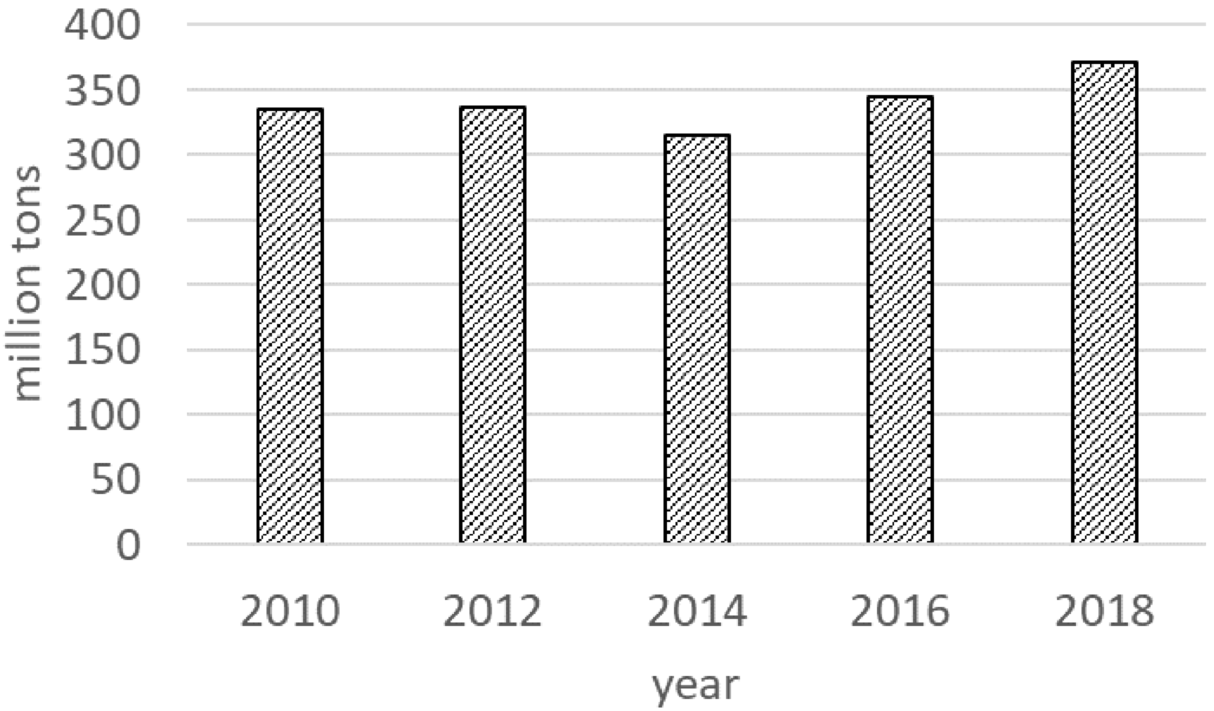
Generation of construction and demolition waste EU, 2010–2018, million tons.



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Source Eurostat 2022

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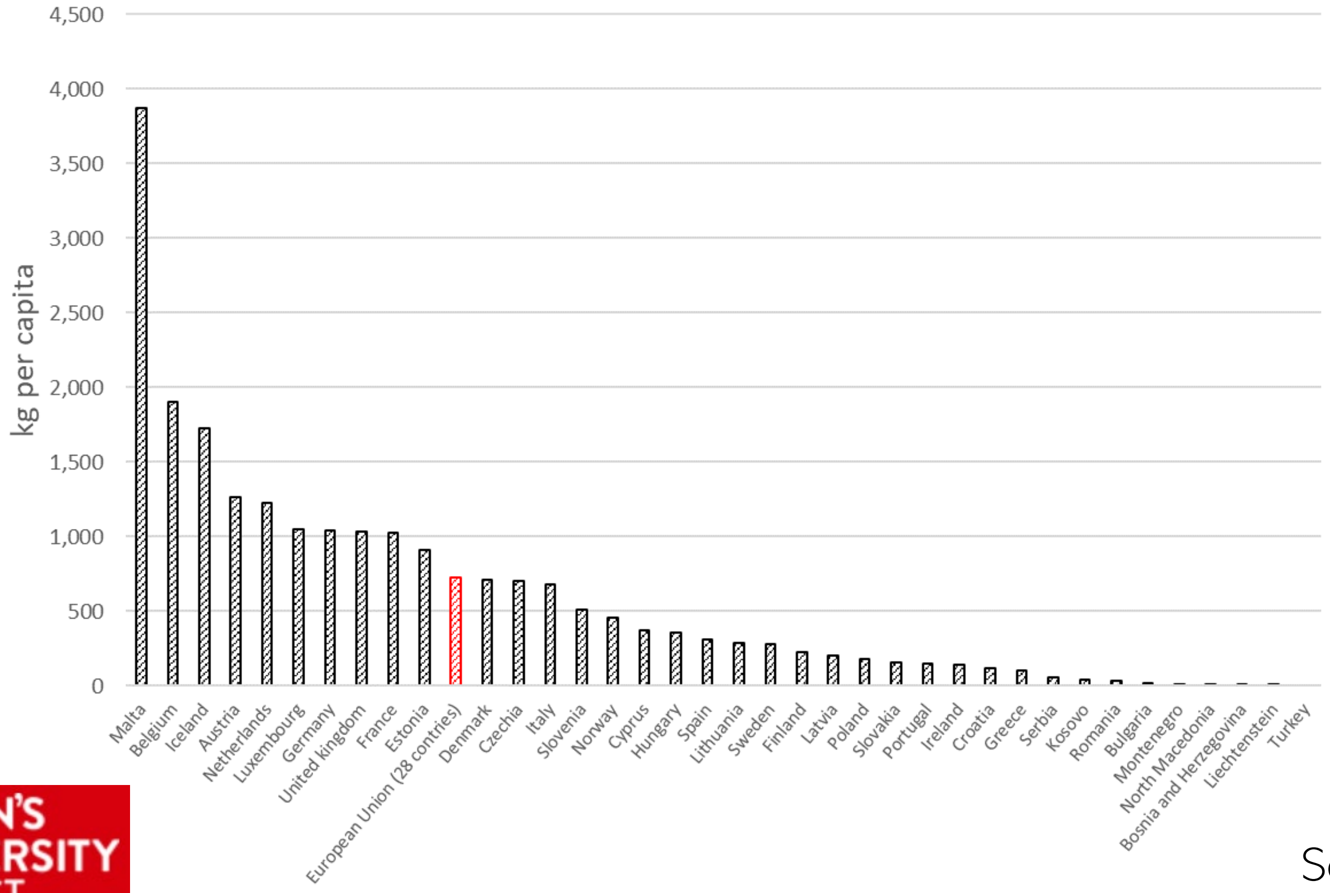
Generation of construction and demolition waste, EEA, 2018, tons per person.



Source Eurostat 2022

reliability of CD&W statistics in Europe:

- quality score of 2.3 out of 5, with a range from 1.5 to 4.3.
- misclassification of soil waste is one of the most important issues
- data are present only for 'Mineral waste from construction and demolition' (EWC-Stat 12.1)'; this means that recycling rates are overestimated as a higher amount of the mineral fraction is recovered.

The revised Waste Framework Directive requires the EU Member States to take the necessary measures to achieve the re-use, recycling and other material recovery, including backfilling, of a minimum of 70 per cent by weight of non-hazardous C&DW by 2020

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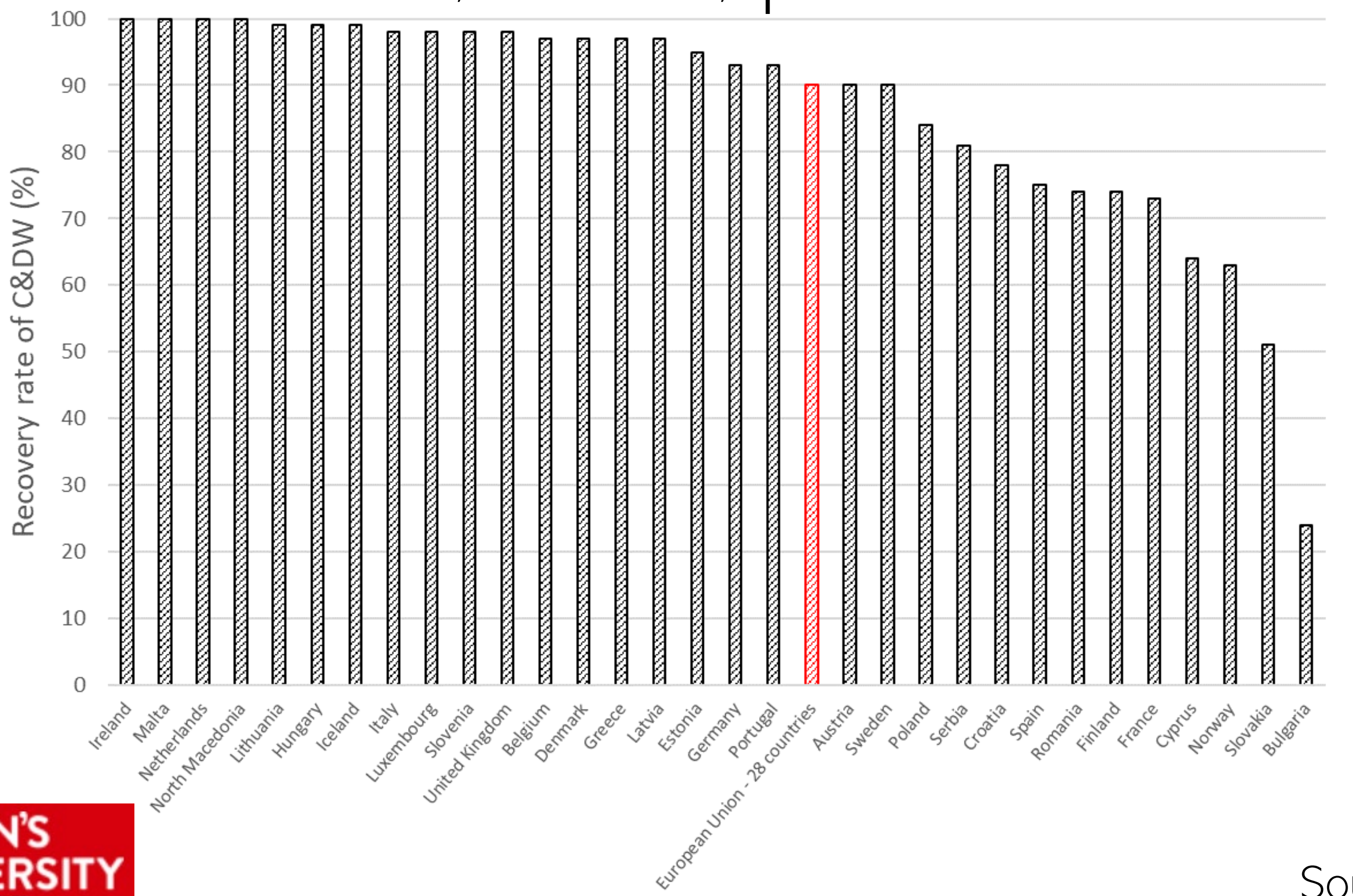
Recovery rate of construction and demolition waste, EEA, 2018, percent.



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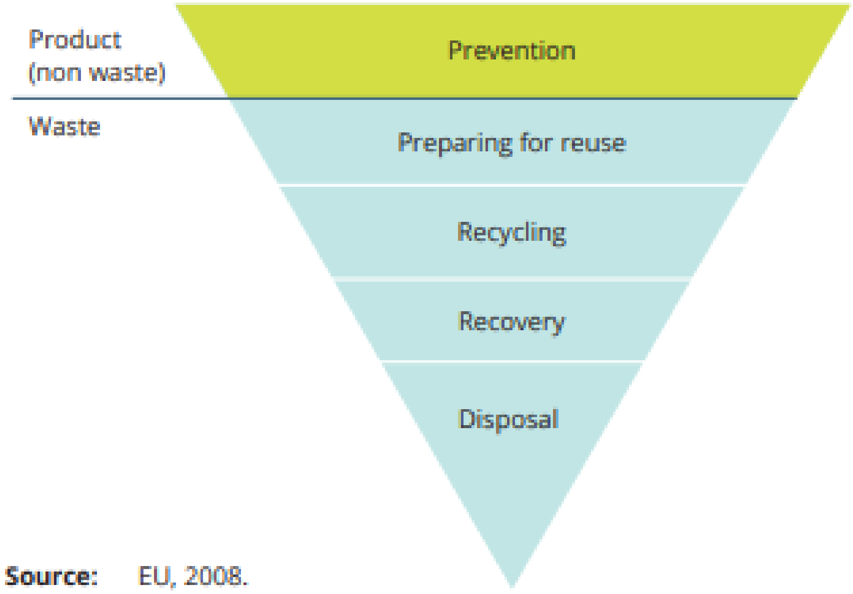
Source Eurostat 2022

The building sector hardly uses any secondary materials – in the Netherlands, secondary materials only represent 3%÷4% of all materials used in buildings. Therefore, despite high recycling rates, the recycling of C&DW is largely **downcycling**.

In low-grade applications, when no alternative secondary materials are available, the use of materials from C&DW is not necessarily undesirable. However, it is likely that the market of these more low-grade applications will decrease as, for example the EU's 2050 zero land take objective could decrease the market for road building materials.

The waste hierarchy ranks waste management options according to their sustainability. The top priority is on waste prevention, followed by recycling, energy recovery and finally disposal, for example by landfilling.



Source: EU, 2008.

The waste hierarchy according to the Waste Framework Directive.

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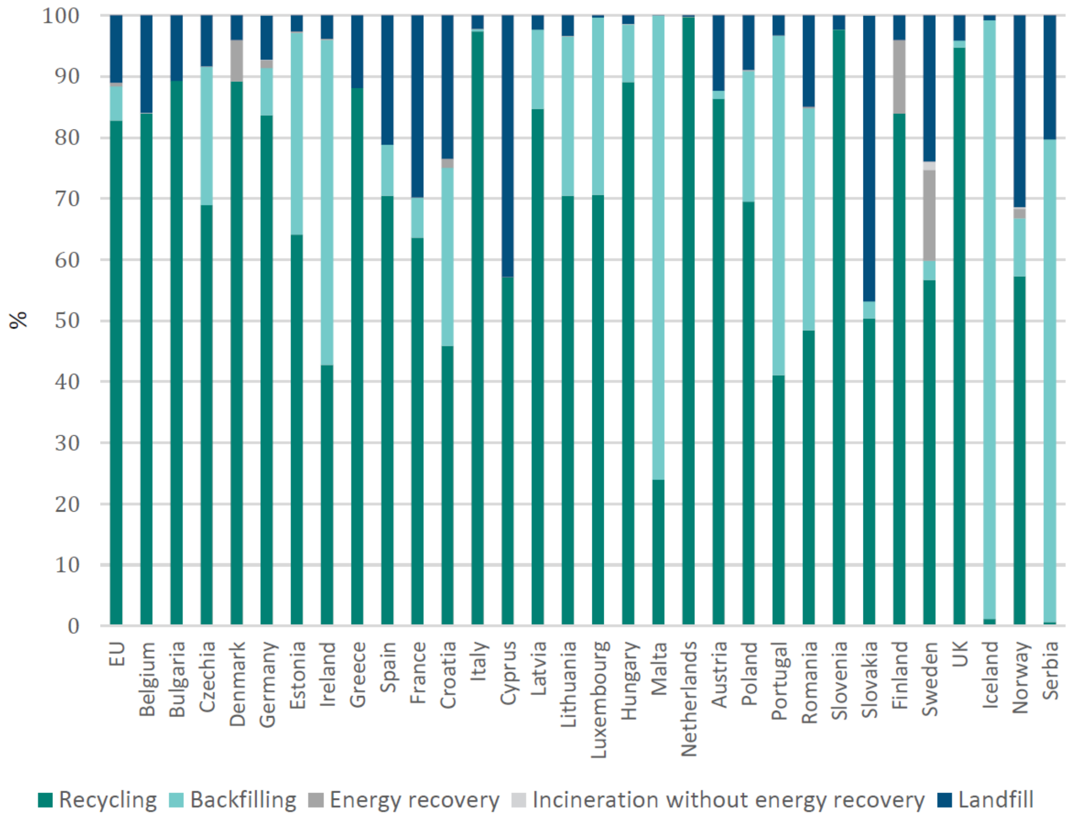
Treatment of mineral waste from C&D, EEA, 2018, per cent.



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Source Eurostat 2022

The proportion of backfilling appears to be small in most countries with the exception of Iceland, Ireland, Malta, Portugal and Serbia, where more than 50 per cent of mineral C&DW is backfilled. However, there are discrepancies in the reporting of backfilling to the European Commission. Although only 13 EU Member States supplied data on backfilling volumes, 13 of the remaining 15 countries that reported no C&DW backfilling actually have backfilling operations. For these countries, it is unclear whether the backfilled amounts are included in their recycling figures or not included at all.

National EoW criteria for C&DW mainly concern the use of mineral waste from construction as aggregate. The EoW concept lowers the administrative work in handling permits for the use of C&DW and may increase the trust in the quality of recycled materials. However, only Austria, Belgium, France, the Netherlands and the UK have developed such national criteria though they are in preparation in some other countries. All these countries have recycling rates above the EU's 70 per cent target.

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granulats naturels et recyclés = pré-mélanges contrôlés (adaptés aux contraintes des unités de fabrication des bétons)

Guides techniques pour le recyclage

Sortie du statut de déchet

Règlement UE 305/2011 PDC
MIE granulats (pour ACV)
ACV des PDC
Taux de recyclage
Commande publique

Normes et cahiers des charges

[NF P18-545] Granulats

[NF EN 12620] Granulats pour béton

[NF EN 206] Béton

Eurocodes 2, 4,...

Fascicules 23, 63,64,...

Pas de déchets résiduels dangereux ou non recyclables dans la déconstruction

Granulats et bétons = produits locaux de construction

Proximité entre lieux de production et lieux de mise en œuvre = empreinte du transport pour les pondéreux

Lutte contre les dépôts sauvages et les pollutions

Optimisation des flux de déconstruction

Acceptation en milieu urbain

Gestion des plateformes

Diagnostic déchets avant travaux

Tri des déchets (à toutes les étapes de la vie de l'ouvrage)

GRANULATS RECYCLES dans l' ECONOMIE CIRCULAIRE

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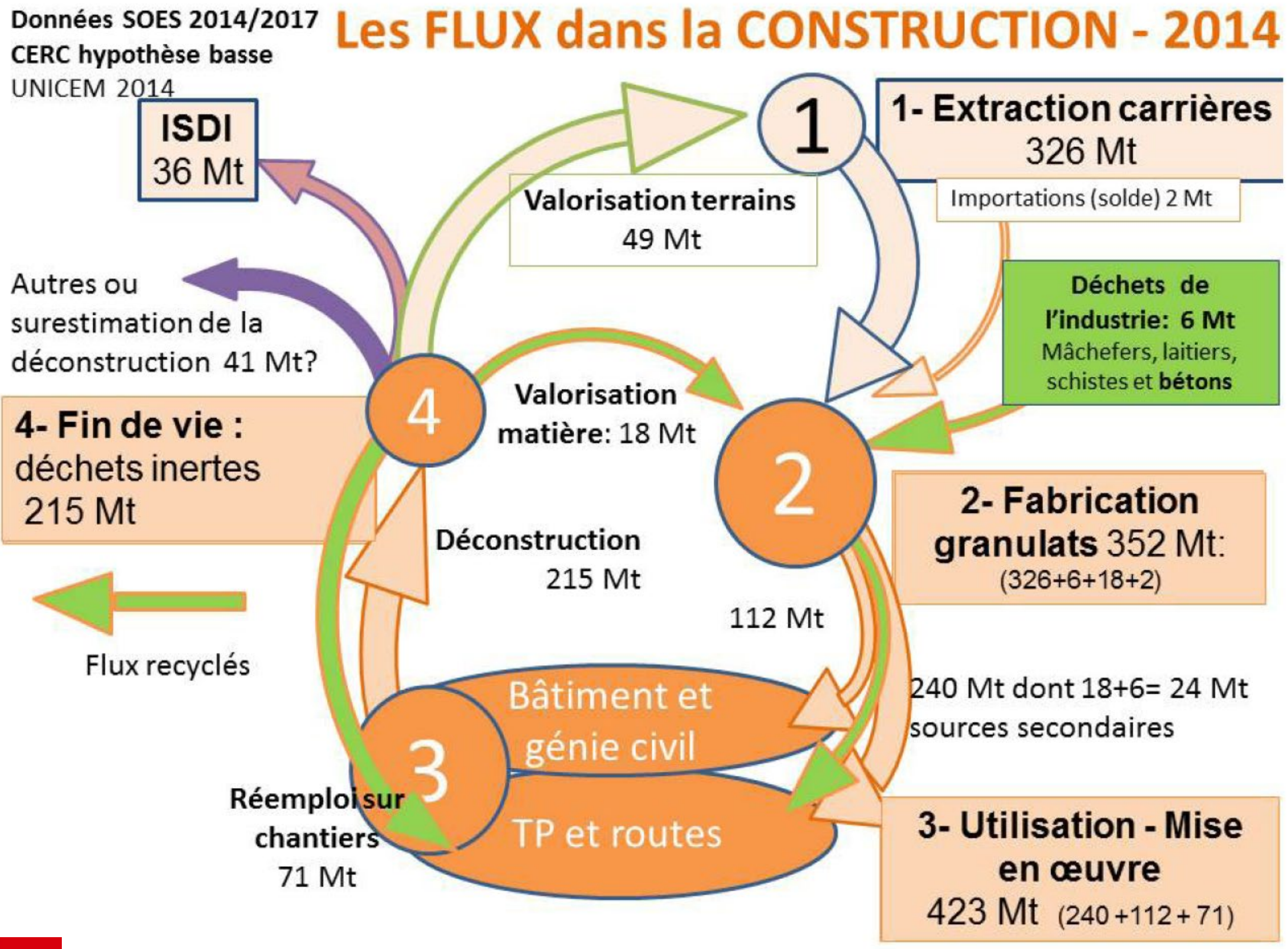
Données SOES 2014/2017
CERC hypothèse basse
UNICEM 2014
Les FLUX dans la CONSTRUCTION - 2014
1
1- Extraction carrières
326 Mt
Importations (solde) 2 Mt
ISDI
36 Mt
Valorisation terrains
49 Mt
Déchets de l'industrie: 6 Mt
Mâchefers, laitiers, schistes et bétons
Autres ou surestimation de la déconstruction 41 Mt?
4
Valorisation matière: 18 Mt
2
4- Fin de vie :
déchets inertes
215 Mt
2- Fabrication granulats 352 Mt:
(326+6+18+2)
Déconstruction
215 Mt
112 Mt
Flux recyclés
240 Mt dont 18+6= 24 Mt
sources secondaires
Bâtiment et génie civil
3
TP et routes
Réemploi sur chantiers
71 Mt
3- Utilisation - Mise en œuvre
423 Mt (240+112+71)

Apart from C&DW recycling, circular economy inspired action made in early stages of a building's lifecycle may affect the management of the building's waste in a profound way. In particular:

- Material production phase: (i) the materials are highly durable and therefore have a long lifetime and (ii) the building materials are not hazardous.
- Design phase: (i) modular and easy-to-disassemble buildings, (ii) durable, flexible structures and (iii) minimum amount of materials used by avoiding over specification and using higher-strength materials.

- Construction phase: (i) create a material passport during construction to be update during service life and (ii) building information management (BIM) to create and maintain value through the entire lifecycle of a building and its parts.
- End of life phase: (i) qualitative pre-demolition material auditing and waste management planning, (ii) decontamination of the built environment: removal and safe handling of hazardous materials, (iii) selective demolition, (iv) increase traceability, quality assessment and certification of C&DW streams and (v) improved sorting systems for materials that cannot be collected separately during demolition.

Summarizing

- Production phase: New high-grade products being non-toxic,
- Design phase: Design for disassembly (DfD),
- Construction phase: Material passports,
- Use phase: Lifetime extension of existing structures and updating of material passports,
- End of life phase: Selective demolition.

Note that

- Including a high content of recycled aggregate from C&DW in high-grade products does not have a significant benefit for CO_2 emissions due to the additional processing needs. The main environmental benefit relates to savings of natural resources,
- Most barriers to DfD are related to economic concerns related to the higher investment costs. It is difficult to estimate the actual financial savings in the decommissioning, as they will occur in the future and are highly context dependent.

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Buildings designed to be flexible, increasing life span: Wiener Postsparkasse

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Wiener Postsparkasse

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Wiener Postsparkasse

Buildings designed to be flexible, increasing life span

Postsparkasse (1912)

Designed by Otto Wagner, this building's structure is made from reinforced concrete filled with masonry. The high span between pillars made it possible to use non-structural partitions in the office space, allowing for flexibility.

Buildings designed to be flexible, increasing life span: Zacherlhaus

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Zacherlhaus

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Buildings designed to be flexible, increasing life span

Zacherlhaus (1904)

Designed by Jozef Plečnik, a student of Otto Wagner, this commercial/residential building is the first in Vienna to use reinforced concrete ceilings. Hitherto concrete was not yet regarded as suitable for this application and had only been used for industrial buildings. In the years that followed, reinforced concrete grew more and more popular. In addition to the visionary use of concrete, the building's façade is clad in granite and forms a stark contrast to the ornamental plaster façades of Historicism.

Key point for C&DW upcycling: selective demolition

Climate action in the built environment is often strongly focused on the minimisation of greenhouse gas emissions during the lifetime of buildings. When such action is implemented without taking circular economy principles into account, it can have an adverse effect on the other lifecycle stages. Selective demolition may be strongly hampered by the presence of thermal insulation materials that were difficult to remove separately – for example, suspended ceilings were filled with loose expanded polystyrene beads and spray-foam insulation was stuck to the walls and ceilings

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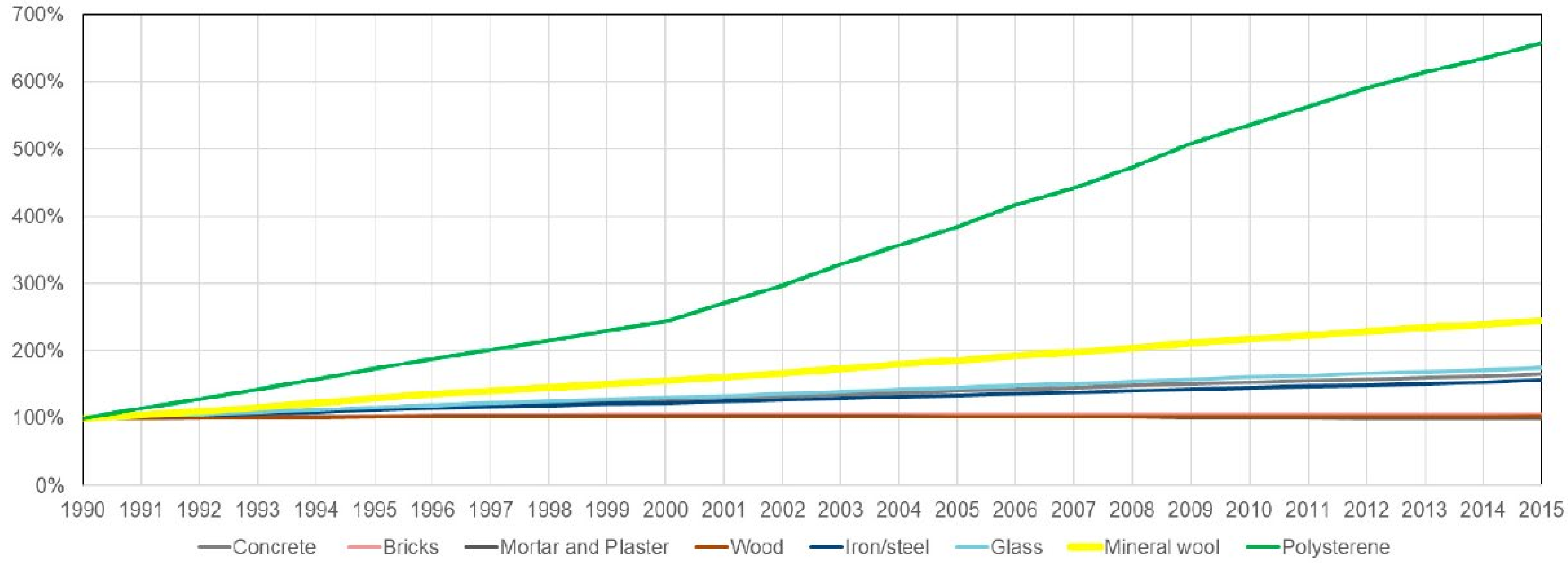
This trend is evidenced in the balances of urban metabolism: case of Vienna in the years 1990-2015



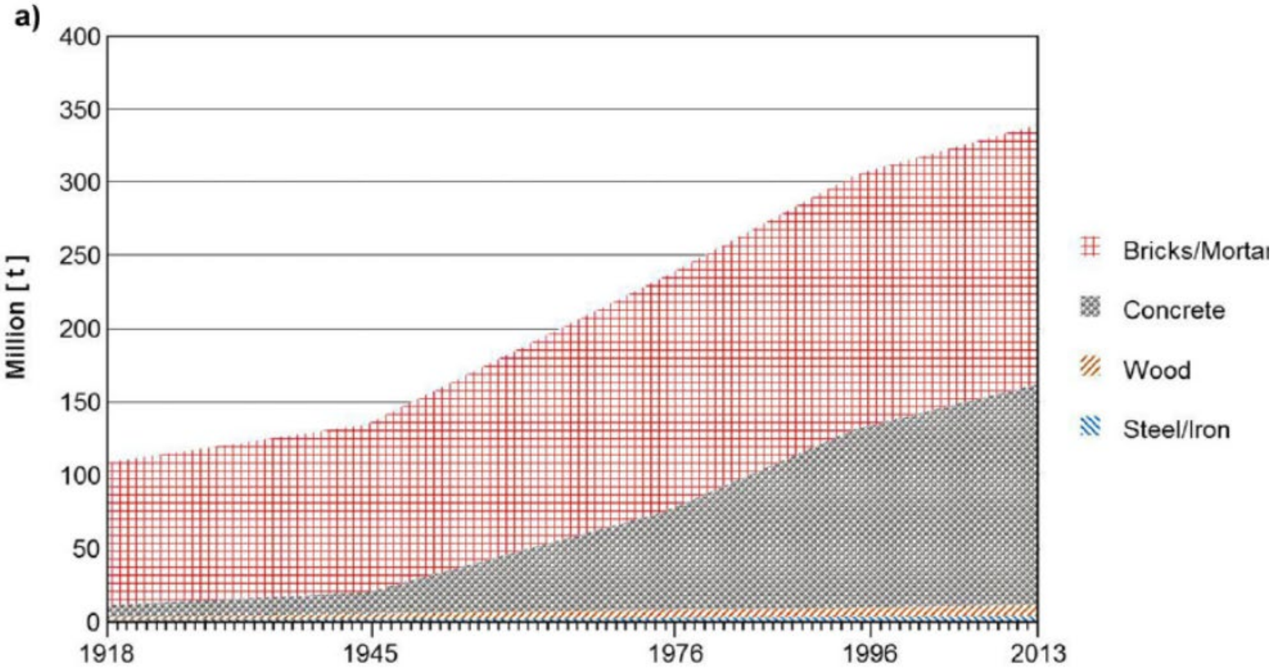
Normalized material's stock, Lederer et al. Sustainability 2020, 12, 300

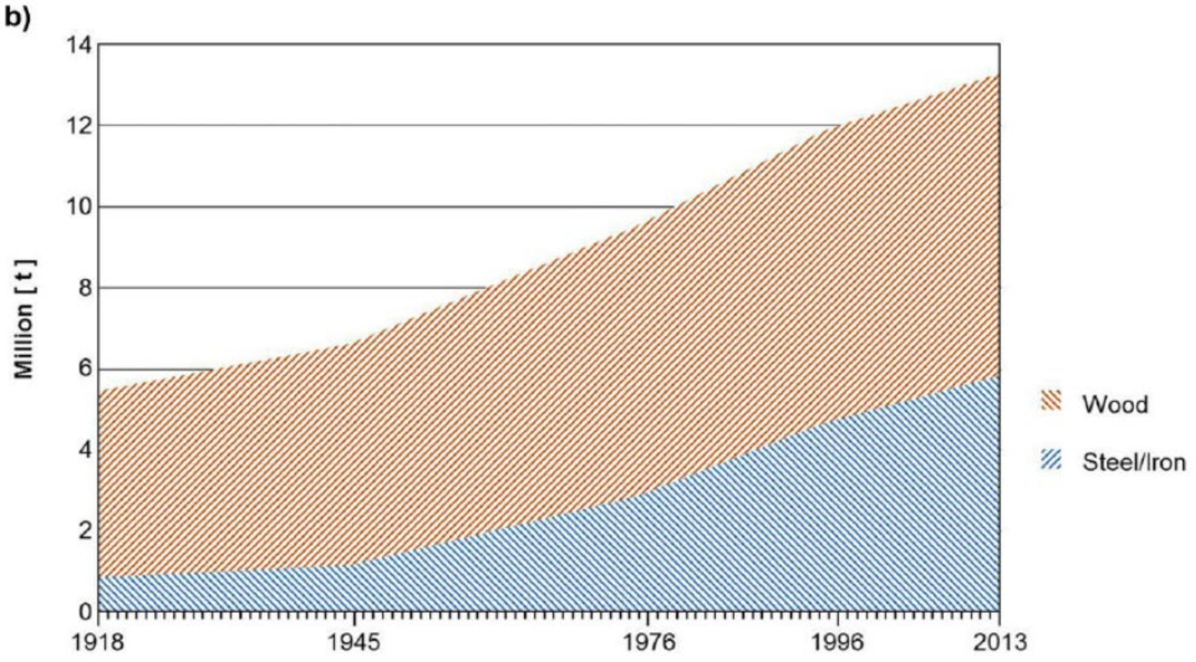
Built environment as a material's bank

The Circularity Gap Report (Circle Economy) calculates that 62% of global greenhouse gas emissions, excluding those from land use, land-use change and forestry, are released during the extraction of materials, their processing and the manufacturing of goods. Construction and maintenance of the built environment consumes almost half of all materials entering the global economy and generates about 20 per cent of all greenhouse gas emissions.

The CO_2 emissions embodied in construction materials make up 40%÷50% of the total carbon footprint of an office building, primarily due to the production of the cement and steel required.

Net accumulation of selected materials in the building stock of Vienna





Kleemann et al. J. Ind. Ecology 2016, 21, 368-380

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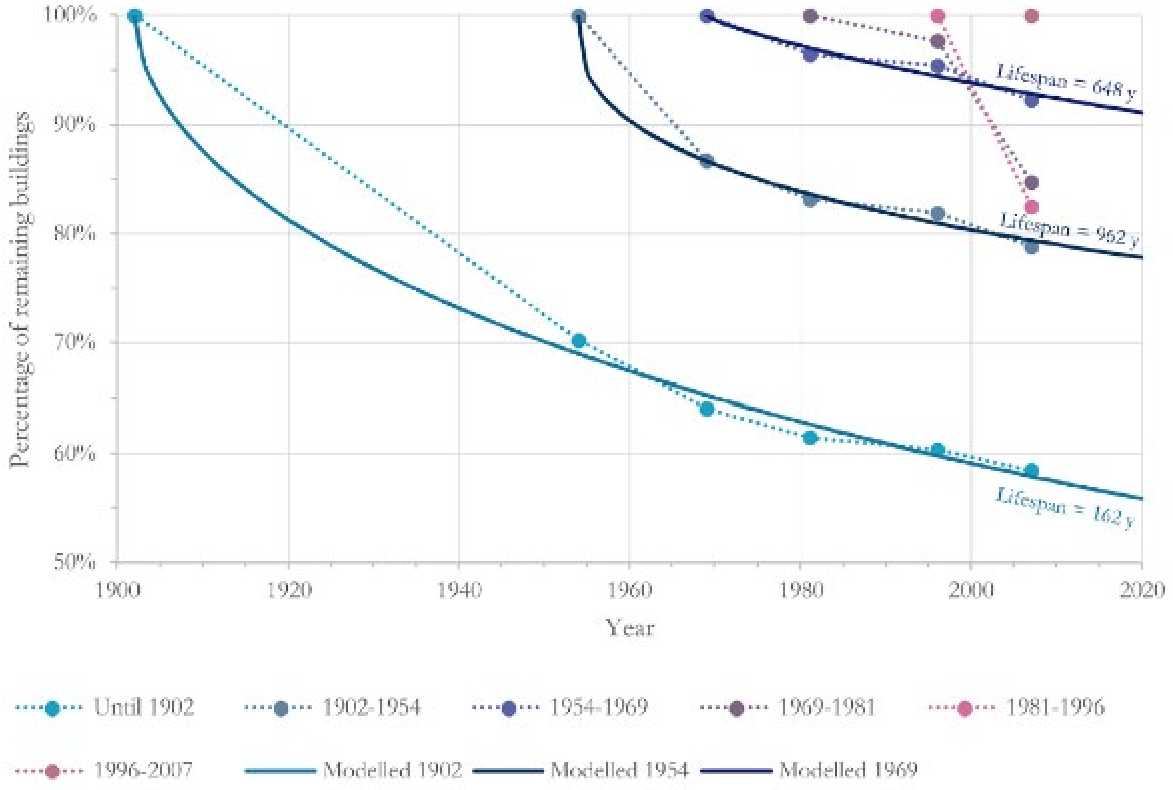
In addition to recycling, life extension is crucial: life expectancy of building in the city center of Padua



Miatto et al. Resources, Conservation & Recycling 2019, 142, 245-256

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Recycling of demolition waste in Merseyside (Liverpool): concrete towers

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Recycling of demolition waste in Merseyside (Liverpool): council houses are primarily masonry buildings

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The threat of contamination in the C&DW-derived aggregate is one of the biggest barriers to its use in construction products. These contaminants include both organic and inorganic materials, such as wood, bitumen, glass and metal.

Selective demolition is based on information from the pre-demolition audit. It recovers high-quality (pure) material fractions for recycling or reuse. The audit identifies hazardous materials to be removed prior to demolition and assesses the recycling potential. Selective demolition is followed by the processing of the material fractions to ensure high-quality recovery. Selective demolition does not reduce the total amount of waste generated but enables the recovery of fractions for high-quality recycling.

The European Commission published in May 2018 the "Guidelines for the waste audits before demolition and renovation works of buildings". A pre-demolition audit is the first step towards understanding the type and amount of elements and materials that will be deconstructed and/or demolished, and aims to provide recommendations on their further handling. An inventory of construction materials and their treatment is developed in order to provide information to clients and contractors. The audit is extended throughout the three main phases of demolition: (a) before, (b) during and (c) after demolition. The process includes five stages: (i) Desktop Study, (ii) Field Survey, (iii) Inventory, (iv) Waste Management Recommendation, and (v) Reporting.

Selective demolition is closely linked to waste sorting requirements. National legal requirements for material-specific separation of C&DW

	Denmark	Finland	Sweden
Brick/tiles	X	X	X
Concrete	X	X	X
Glass	X	X	
Gypsum	X	X	X
Insulation	x (stone wool)		X
Mixed stony fraction	X		
Mixed concrete and asphalt	X		
Paper	X	X	X
Cardboard	X		
Plastics	X	X	X
Polyvinyl chloride (PVC)	X	X	
Scrap metal	X	X	X
Stone materials, e.g. granite	X		
Tiles and ceramics	X		X
Wood	X	X	X

Source: Wahlström *et al.* (2019)

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Inspecting the effectiveness of "soft stripping" prior to demolition

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Implosion of Kenley Tower in Liverpool

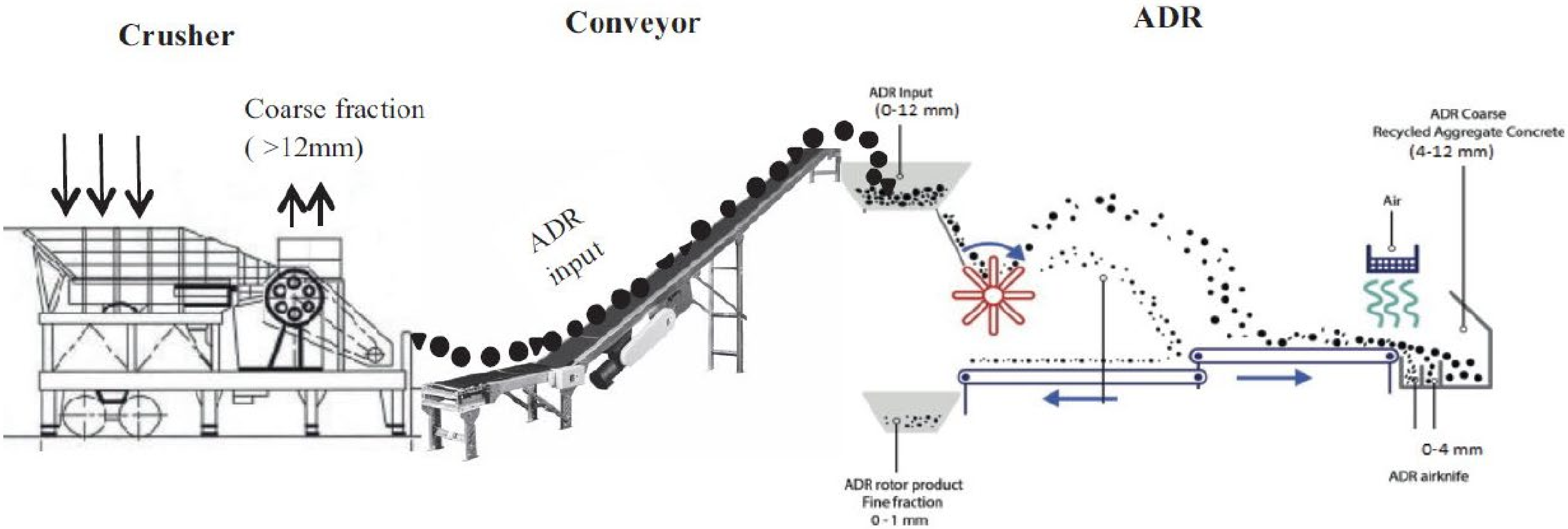
Demolition & Processing Equipment

The equipment used by demolition contractors to demolish and process C&DW had remained largely unchanged in the 1990s. Demolition contractors typically used mobile jaw crushers to produce a crushed concrete and masonry of a particle size of 75mm which was intended for use as a road subbase material. Screening after the material had been crushed would have been necessary if any control was to be exerted over the particle size of the finished product. Material was typically moved by conveyor from the crushing equipment. This equipment is constituted by mobile plants where it is possible to introduce variations in the plant layout depending on the requirements of the end product.

Mobile crushing plant

View of underside of crushing plant showing 10mm and 5mm sieves

Working principle of advanced dry recovery, to separate fines below 1mm



Gebremariam et al. 2018

If selected demolition is not performed on site separation is done after

Screening and separation

A plant for the screening and separation of the demolition rubble must be able to sort the material into three streams:

- mineral matter to be recycled,
- light fraction (paper, plastics and wood, contaminations),
- metal fraction

The main phases of a process of treatment and recovery of C&DW are:

- crushing to reduce the dimensions of the waste to make it suited to the final use,
- separation to eliminate the undesired fractions in the final product,
- size screening to classify the material into homogeneous size fractions

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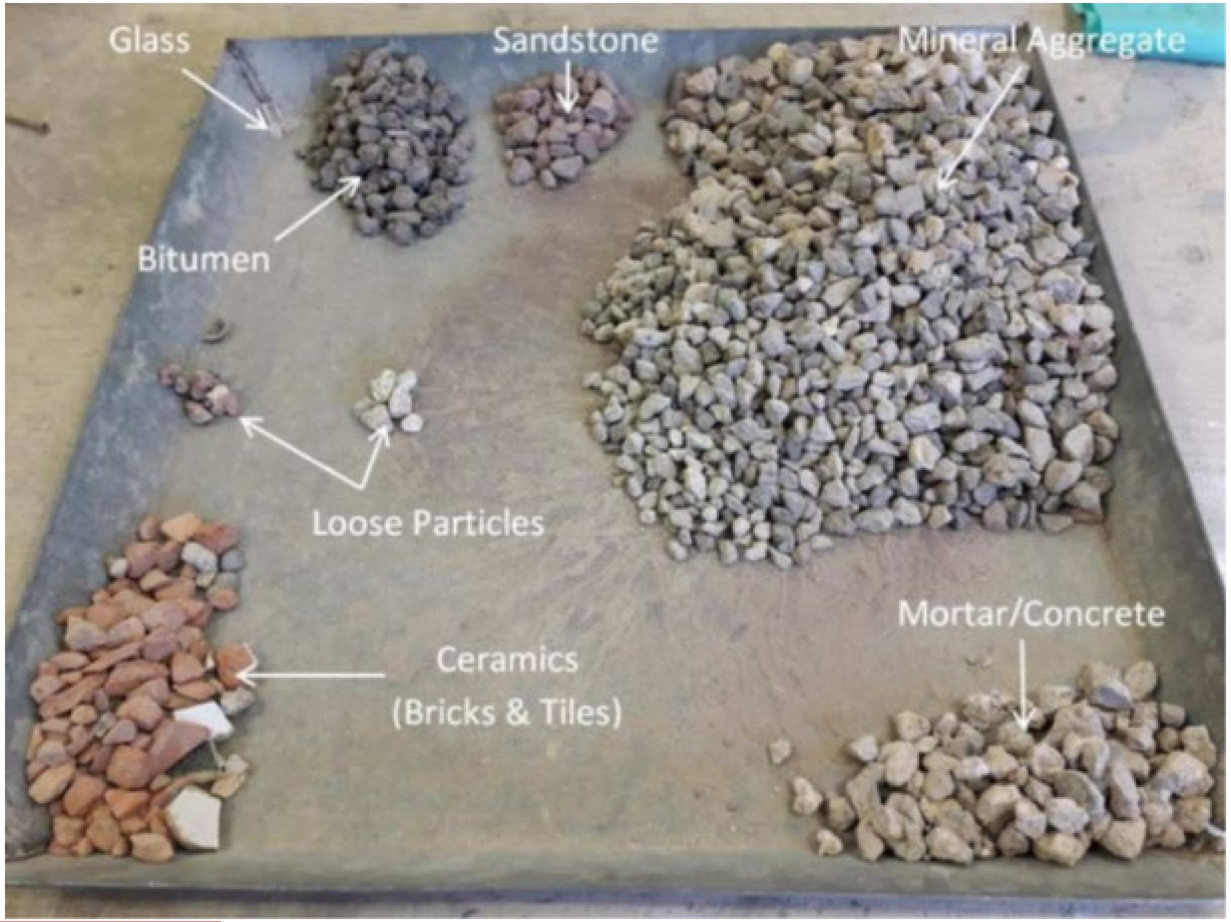
Constituents of recycled demolition aggregate



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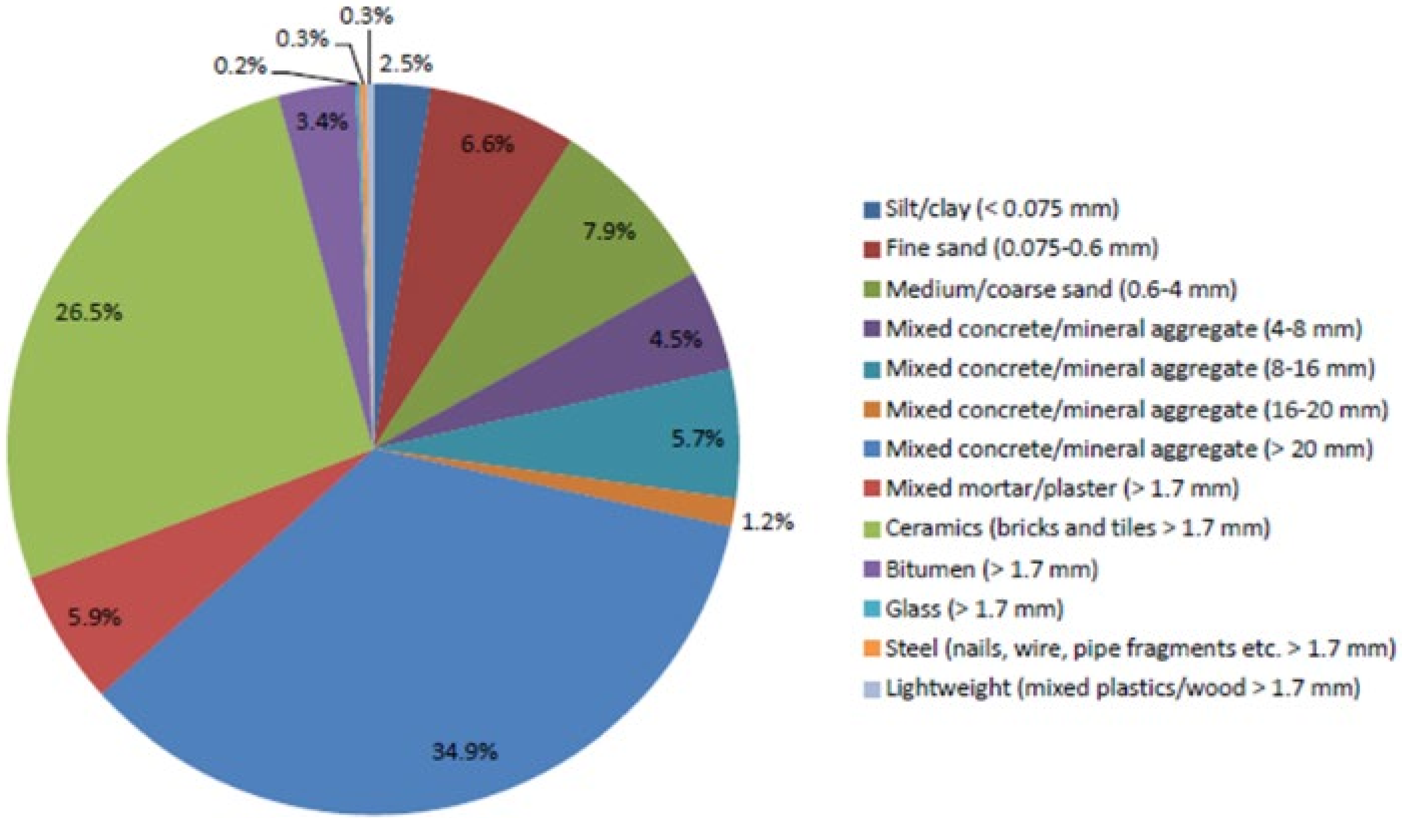
Typical composition of recycled aggregates from the North EU region



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Use of recycled concrete aggregate

In concrete, 20%÷30% of virgin material can be substituted by waste material in several applications. Higher replacement, including multi-recycling cycles, in high-grade applications can be achieved if fines are separated from concrete waste. As the coarse fraction, with a diameter of more than 4 mm, makes almost half of concrete waste, ideally half of concrete waste could be recycled in high-grade applications.

Recycling bricks in 1950's Vienna

About one eighth of all apartments in Vienna were destroyed during World War II (Vienna History Wiki 2020) and the reconstruction program had to alleviate the housing shortage in a very short time, but initially had to contend with severe difficulties in procuring building materials and transporting them, as well as a shortage of workers. In the first few years, a lot was built with hollow blocks with crushed bricks aggregates, obtained from the rubble of the destroyed buildings, and dry-earth concrete blocks were used as a cost-effective and resource-saving alternative to brickwork. Aggregates such as crushed bricks and pumice were used for the first time, which also improved thermal insulation

(Steppan 1950, Ruczka 1952)

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Vibrostein

Fines as clinker source and CO_2 sink

Natural carbonation of concrete is usually limited to several millimeters of exterior surface exposed to the atmosphere. Therefore, crushed concrete aggregate derived from C&D waste (mainly the internal part of old concrete) represents a potentially large source of alkalinity for the formation of carbonate minerals.

- The interfacial transition zone (ITZ) is more compact
- CO_2 is captured and stored

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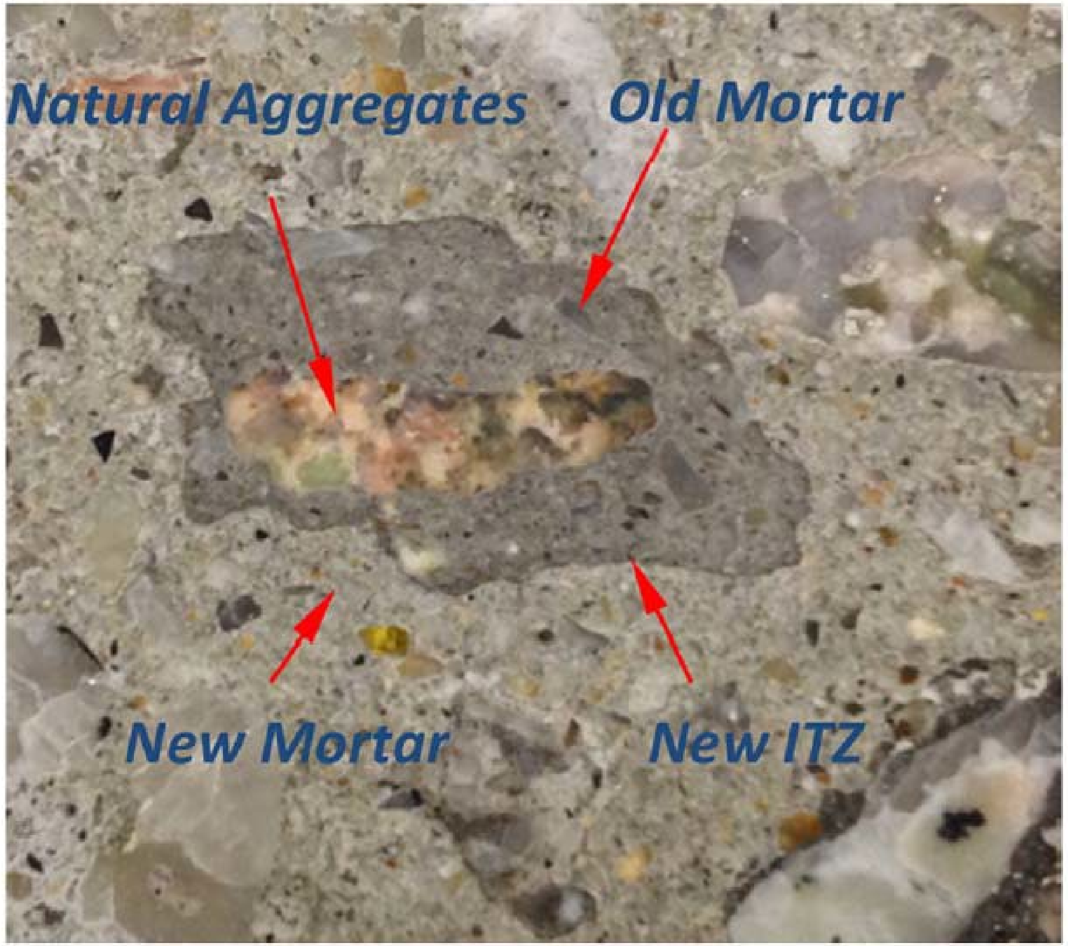
Microstructure and ITZ of carbonated concrete with recycled concrete aggregates (RCA)



Kaliyavaradhan et al. J. CO_2 utilization 2017, 20, 234-242

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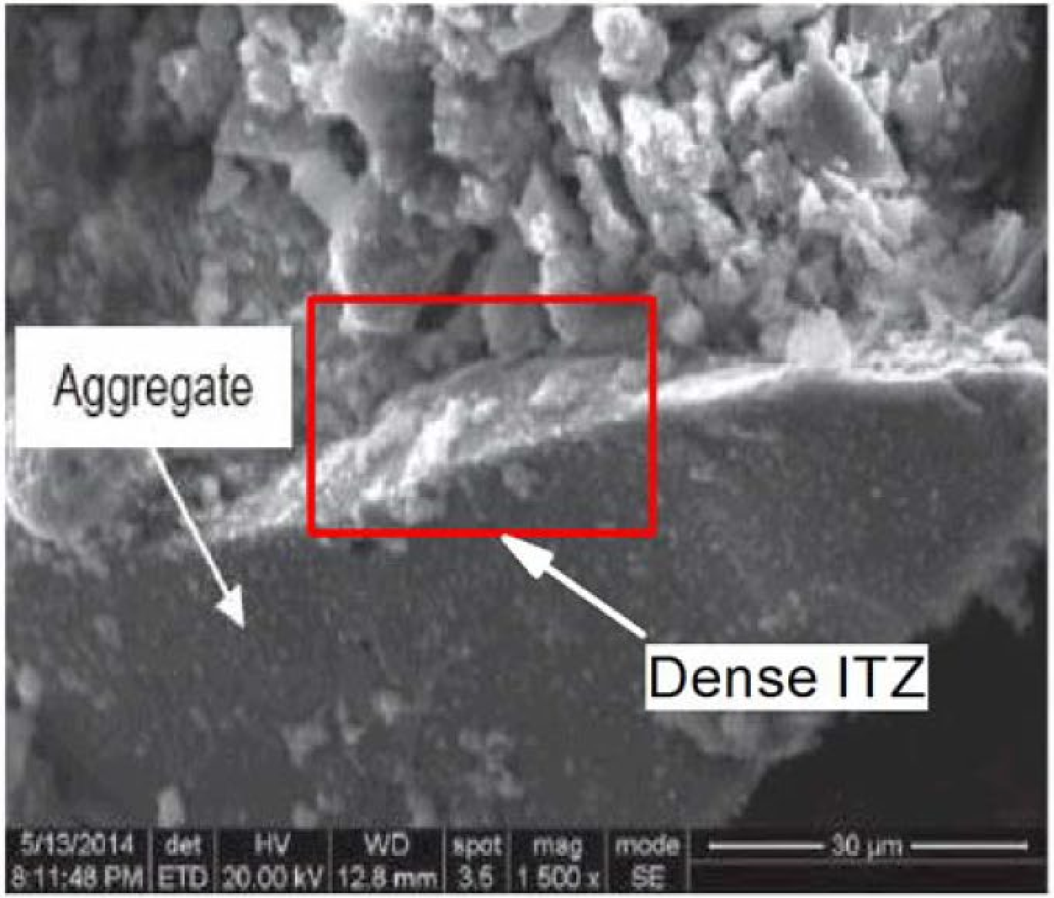
ITZ of RCA at 28 days: non-carbonated and carbonated



Kaliyavaradhan et al. J. CO_2 utilization 2017, 20, 234-242

Fines as clinker source and CO_2 sink

It has been determined that:

- 1 ton of crushed concrete can take up 11 kg of CO_2
- RCA with particle sizes from 5-20 mm sequestrate on average 7.9 kg of CO_2 per ton of crushed concrete
- Finer recycled aggregate sequestrates about 20 kg of CO_2/ton
- The fine waste < 100 μm can sequestrate up to 110 kg of CO_2/ton

Kikuchi et al. , J. Adv. Concr. Technol. 2011 9 115-124
Xuan et al. Cement Concrete Comp. 2016 65 67–74
Xuan et al. ICCC 2015

Conclusion: economic and social benefits from circular economy

- The barriers are primarily economic. Manufacturing processes using waste as input material will only work when production costs are lower than the cost of using virgin materials and market uptake can be assured.
- In the future, a shortage in primary resources may change these market conditions in regions with limited mineral resources.
- Customers' increasing acceptance of recycled aggregate as a replacement for quarried materials is an important incentive for the investments needed as it demonstrated that there would be a market for the recycled products.

Conclusion: economic and social benefits from circular economy

- Contaminants shall be avoided. This is achieved by selective demolition, pre-demolition audits and separation of the resulting rubble.
- The material then passes in a crushing and washing plant. It is classified in granulometric classes, and the fines are recovered and valorized.
- The washing plant can be used in all weather conditions with the additional benefits of increasing the quality of the recycled aggregate.

The Urban Quarry: washing plant capable of processing up to 120 tons per hour

Recycling is not only sustainable but also profitable

Product	Recycled Aggregate Price	Quarried Equivalent Price
0-4mm	£5-£6	£10-£12
0-6mm	£5-£6	£10-£12
6-10mm	£12 (inc delivery)	£15
10-20mm	£11 (inc delivery)	£15