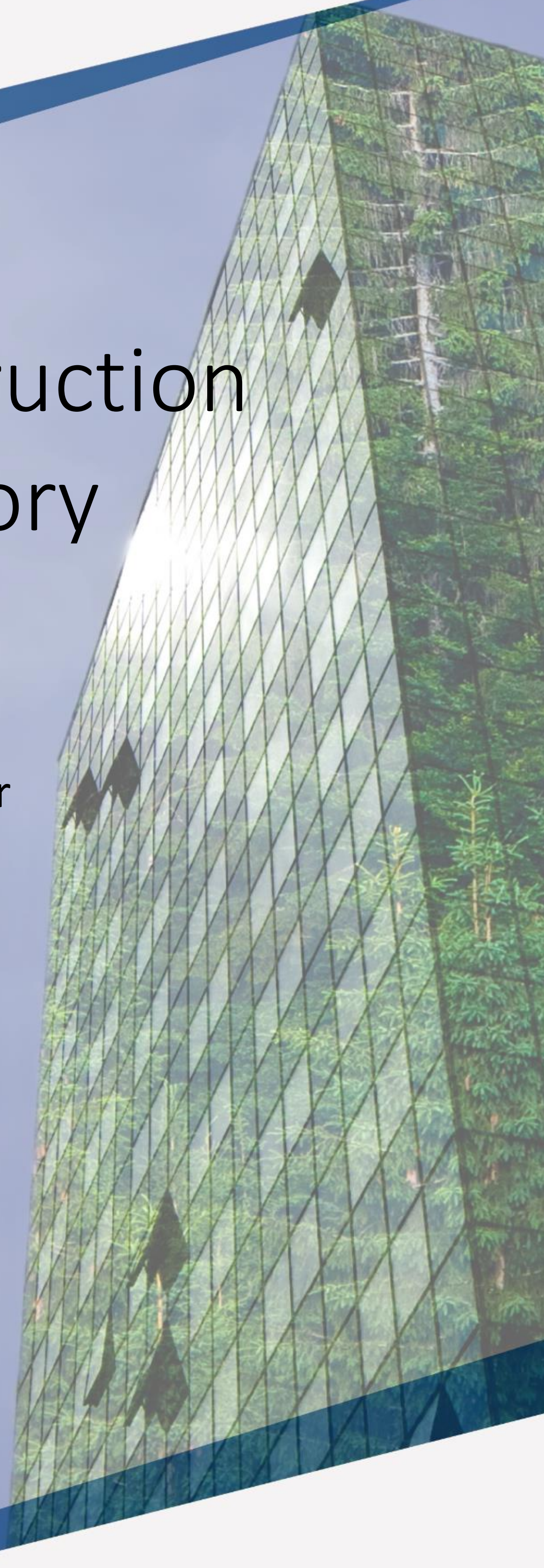
European Construction Sector Observatory



EU construction sector: in transition towards a circular economy

Trend Paper Series

April 2019

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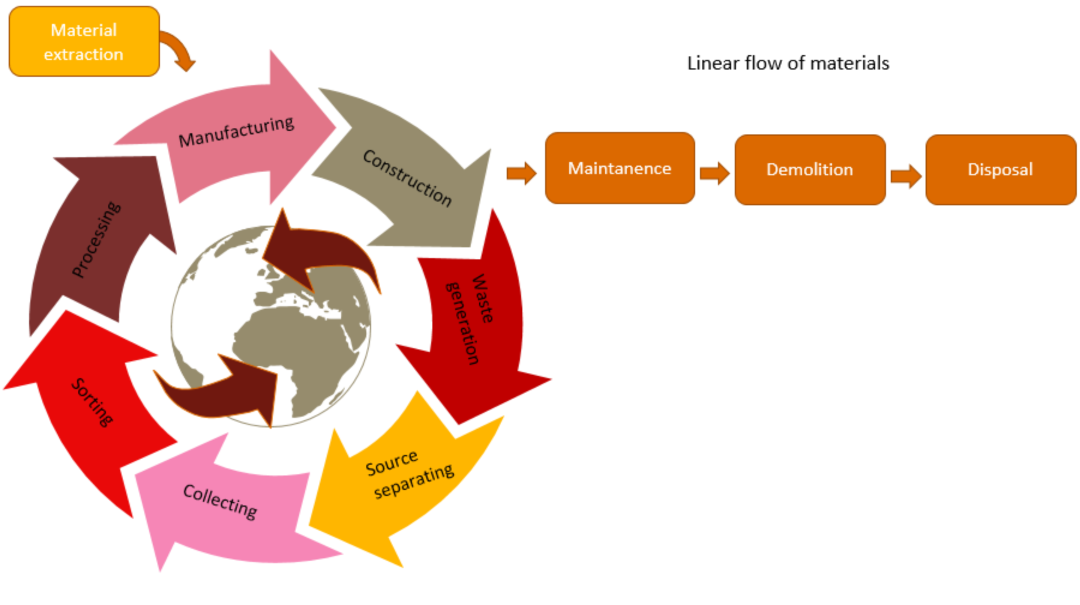
1. Circular economy in the European construction sector

1.1. The role of construction and demolition waste in the circular economy

The circular economy concept refers to the idea of the better and more efficient use of resources and, correspondingly, the reduction of waste. The circular economy represents a shift from the traditional linear flow of materials pattern (Figure 1) of “take-make-consume-dispose” growth model, toward a sustainable system, that aims at reducing the use of virgin resources, generating savings through improving secondary resource use and lowering negative environmental impacts[1].

One of the most resource- and waste-intensive economic activities is construction. The construction sector produced 923 million tonnes of waste in 2016[2], which in terms of volume is the largest waste stream in the EU, representing 30%[3] of all waste generated. **Construction and demolition waste (CDW)** refers to the waste generated from general construction activities and includes concrete, bricks, gypsum, wood, glass, metal, plastic, solvents, asbestos and excavated soil. The recycling and reuse of CDW components has high potential in reducing construction costs and negative environmental impacts, related to the extraction, processing and production of construction materials.

Figure 1: Linear and closed-loop model of CDW



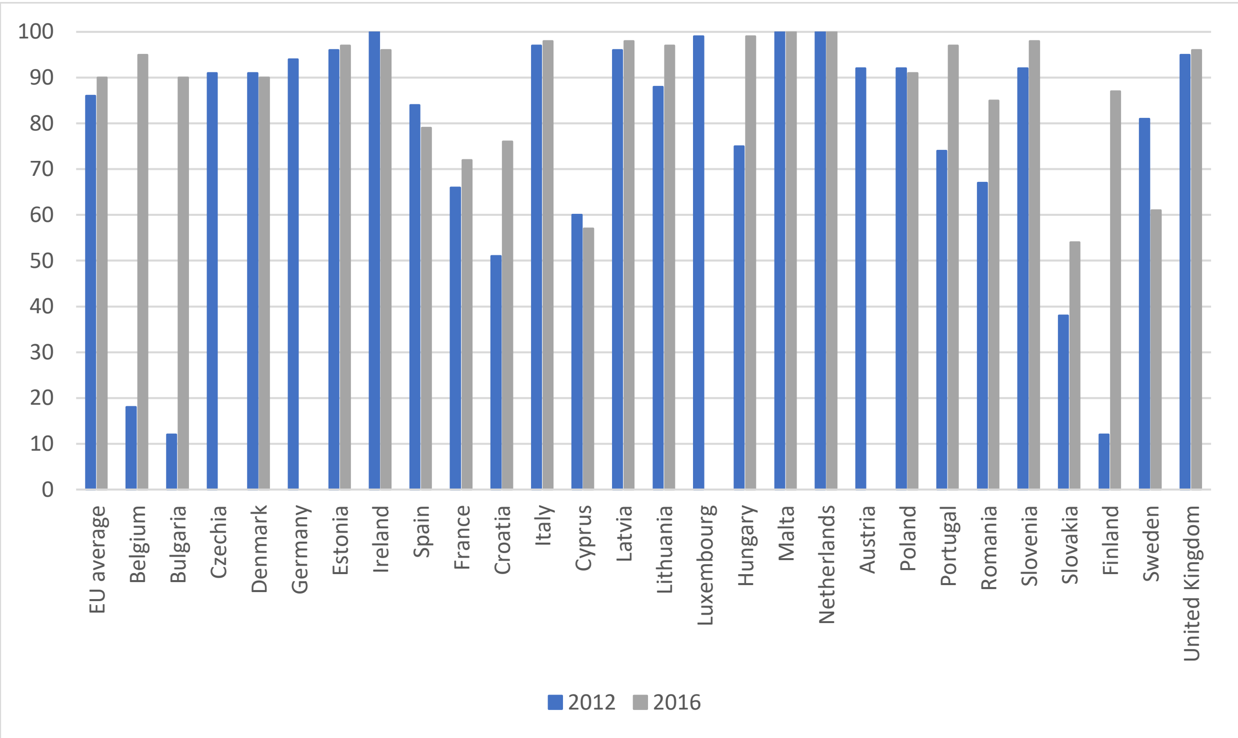
Source: Brennan et al. (2014)[4]

1 European Commission, Towards a circular economy: A zero waste programme for Europe
2 Eurostat 2017, http://appsso.eurostat.ec.europa.eu/nui/show.do?lang=en&dataset=env_wasgen
3 European Commission, Construction and Demolition waste, http://ec.europa.eu/environment/waste/construction_demolition.htm
4 Brennan, J., Ding, G., Wonschik, C.-R., Vessalas, K., A closed-loop system of Construction and Demolition Waste Recycling, The 31st International Symposium on Automation and Robotics in Construction and Mining (ISARC 2014)

1.2. Statistics and data on CDW

The recovery rate of construction and demolition mineral waste (CDW) has been overall increasing in the EU between 2012 and 2016 with some exceptions as in the cases of Denmark, Poland, Spain, Cyprus and Ireland. Although this ratio shows an improvement and a general tendency toward less landfilling and more resources brought back to the value chain, it does not deliver insights on the amounts of CDW recycled as a share of all CDW. In fact, it measures the ratio between the CDW that was subject to recovery, reuse or recycling, including backfilling, against the CDW treated, e.g. landfilled. As backfilling also counts as CDW recovery, the date does not reflect the share that is recycled. Stricter data reporting, differentiating between the alternatives to landfilling can deliver a more accurate idea of the state of CDW and promote the use of waste planning to keep up with regulation. This statistic hence already illustrates the challenge of providing and accessing reliable data in the CDW management and policy. European Commission data estimates the share of recycled CDW to be at only 50% in 2018[5], with the exception of a few Member States, which recycle a higher share. Overall, this shows that applying the concept of circular economy in the construction sector is challenging in practice.

Figure 2: Recovery rate of construction and demolition waste (%)[6]



Source: Eurostat 2018

The current paper aims to give an overview of the transition trends towards a circular economy in the EU construction sector with a focus on CDW. Section 2 provides a state of play presenting the CDW market, its size and main players. Section 3 provides the policy background governing the treatment and management of

5 European Commission, EU Construction and Demolition Waste Protocol and Guidelines, http://ec.europa.eu/growth/content/eu-construction-and-demolition-waste-protocol-0_en

6 This data refers to the percentage of construction and demolition mineral waste recycled, which includes materials such as concrete, bricks, gypsum, wood, glass containing waste etc.

CDW, as well as the CDW priorities identified by the industry. Furthermore, the paper highlights some of the challenges and opportunities in the management of CDW (and more broadly the application of the concept of circular economy in practice in the construction sector) based on public policy and industry case studies. It concludes by highlighting a set of recommendations, looking forward.

2. State of play of CDW in EU MS

2.1. Market size and structure

The CDW recycling market in Europe was worth around EUR 13.8 billion in 2013, and is projected to grow to EUR 17.6 billion[7][8] by 2020. This expected growth is linked to the projected increase in the volume of CDW until 2020 and the demand for alternative solutions and diversion from landfilling[9]. One of the main factors for this are the rising landfill prices, as well as the growth in residential construction activities and space and resource shortages in urban areas across the EU. The relevant **market drivers** in the CDW market are the regulatory environment (see CDW regulations in Section 3), economic instruments, such as landfilling taxes, and consumer demand for secondary materials. Technologies that allow for cutting the costs CDW management on site are also driving the market, as discussed in Section "Innovation and technology initiatives".

One of the main players in the CDW management (see Figure 3**) are demolition contractors. The demolition industry is mostly comprised of SMEs with an average annual turnover of around EUR 1 million, who are active mostly on national and regional level**[10]. However, there are big demolition contractors active on the market as well. Six of the **global top ten ranking[11] of demolition contractors by turnover** are European companies, with Europe accounting for 55.9% of the global revenue in demolition. Three of them are located in the UK, one in the Netherlands, Belgium and Norway. In the Europe top 20 demolition companies, besides from the UK, German and French contractors also appear with high turnover.

[7] Converted to EUR from USD in the original source

[8] Construction&Demolition Recycling, May 2014, C&D recycling markets in Europe forecast to grow, http://www.cdrecycler.com/article/frost-sullivan-report-construction-demolition-market/

[9] Ibidem.

[10] EDA, Industry report 2015

[11] D&RI, Demolition and Recycling international, "Less than the sum of its parts?", Volume 20, Number 3, May-June 2018

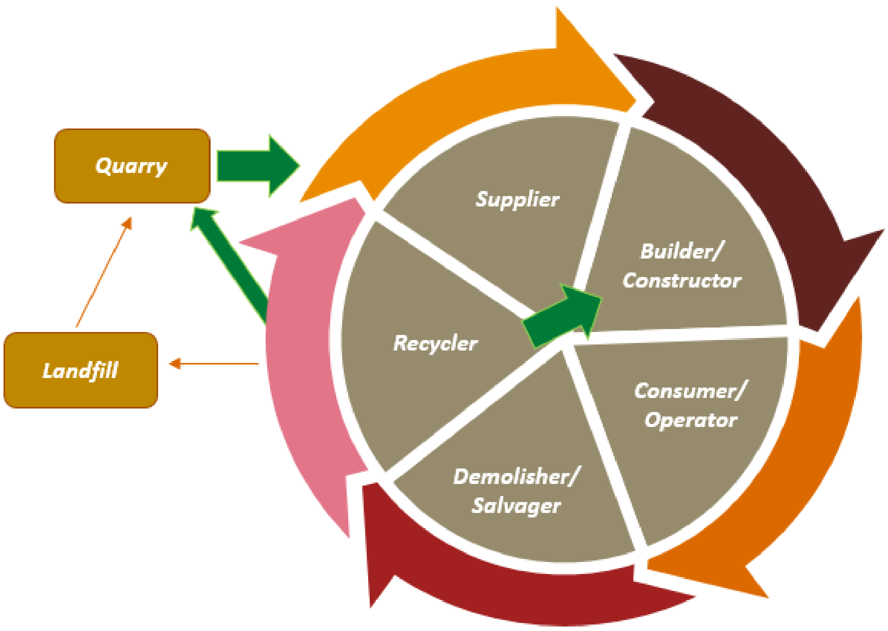
Table 1: Top 10 demolition contractors in the EU for 2017

No.	Company	Country	Turnover (EUR million[12]) 2017
1	Keltbray	UK	343.6
2	Erith Contractors	UK	196.8
3	Beelen Sloopwerken	Netherlands	133.0
4	Wantly SA	Belgium	125.5
5	McGee Group	UK	122.3
6	Freimuth Abbruch und Recycling	Germany	116.5
7	Cardem	France	103. 9
8	Hagedorn Unternehmensgruppe	Germany	102.3
9	Max Wild	Germany	101.2
10	Delete Group	Finland	81.1

Source: Construction&Demolition Recycling, May-June 2018

Hosting most of the world's biggest companies in the sector is significant for CDW activities, as big companies are also investors in technologies and new solutions involving the efficient CDW recovery. However, the CDW value chain involves other actors besides from demolition contractors. Figure 3 presents the CDW Recycling value chain as a circular process with interconnections between recyclers, suppliers of secondary materials and the builders, thus emphasising the responsibility of all actors involved in the process, rather than just demolition contractors. This includes the consumers, as they can drive the demand for secondary materials when the awareness about their benefits is present.

Figure 3: Main actors in CDW Recycling



Brennan et al. (2014)[13]

12 Converted from US dollars from the original ranking

13 Brennan, J., Ding, G., Wonschik, C.-R., Vessalas, K., A closed-loop system of Construction and Demolition Waste Recycling, The 31st International Symposium on Automation and Robotics in Construction and Mining (ISARC 2014)

3. Public policies for CDW management

3.1. CDW regulations

The European Commission has put various policy initiatives in place to stir the construction industry toward circular economy principles. As material recovery rates of CDW are heterogeneous throughout the EU (Figure 2), setting ambitious enough targets for all Member States is a challenge. The implementation of proper management of CDW, leading to higher recovery levels can be facilitated through the adoption of best practices that make clear the benefit of CDW recycling for construction companies and for consumers.

The overarching legislation on waste in the EU is the **Waste Framework Directive 2008/98/EC (WFD)**[14], amended in 2018. WFD encompasses the recovery, recycling and reuse of waste and sets out a target of **70% for CDW recovery by 2020**. WFD also provides **end-of-life criteria on construction waste materials** like iron, steel, aluminium and copper scrap and glass cullets, defining conditions for the reuse of these recyclables.

Additionally, in 2018 the EC adopted the **Circular Economy Package**[15], which provides further legislative proposals on waste, identifying CDW as a key topic and amending regulations on landfilling, packaging and end-of-life criteria for vehicles and electric equipment.

In 2016 EC also published the **EU Construction and Demolition Waste Protocol**[16] to address some of the main hurdles to the recycling and reuse of CDW, such as the quality assurance of the secondary products. The lack of confidence in these materials restricts the demand and influences negatively the development of the recycling infrastructures in the EU. The protocol encompasses five objectives:

1. *Improved waste identification, source separation and collection*
2. *Improved waste logistics*
3. *Improved waste processing*
4. *Quality management*
5. *Policy and framework conditions*

Voluntary by nature, the Protocol provides insights from best management practices and practical guidelines for industry and policy makers. One of the guiding principles of the document is the promotion of waste audits.

Waste audits are an important part of the material recovery process, as they provide information about the nature and amount of materials that can be recycled. Performing waste audits promotes better management and optimisation of the demolition works, as for example they allow for planning in the case of hazardous materials. Public policies differ geographically with the region of Flanders (Belgium) for example banning the landfilling of recyclable waste materials and making waste audits compulsory, similarly to Czech Republic. Regulation on compulsory waste audits are in place also in almost half of the EU-28 countries, however, for example in Spain, despite it being mandatory, it is not widely implemented, due in part to lack of monitoring and controls[17].

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14 https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv:OJ.L_.2018.150.01.0109.01.ENG

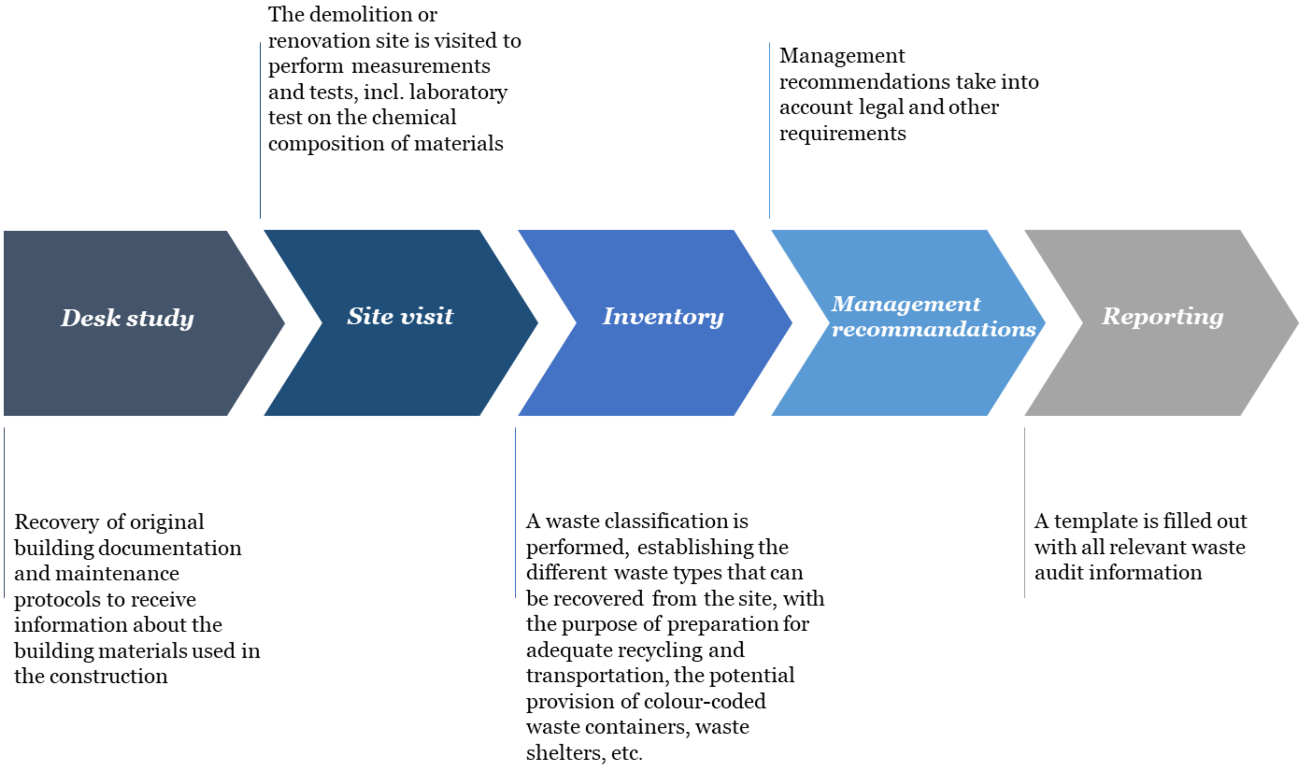
15 http://ec.europa.eu/environment/circular-economy/index_en.htm

16 EU Construction and Demolition Waste Protocol, http://ec.europa.eu/growth/content/eu-construction-and-demolition-waste-protocol-0_en

17 Technical and Economic Study with regard to the Development of Specific Tools and/or Guidelines for Assessment of Construction and Demolition Waste Streams prior to Demolition or Renovation of Building and Infrastructures, Final Report, DG GROW, 2016, https://ec.europa.eu/docsroom/documents/24562/attachments/1/translations/en/renditions/pdf

The EC has put forward guidelines[18] for pre-demolition audit, EU Pre-demolition & Renovation Waste Audits, consisting of recommendations on how to assess resources from demolition materials prior to demolition or renovation works. These recommendations consist of five stages (see Figure 4) designed to deliver quality assurance for the secondary material:

Figure 4: Stages of waste audit

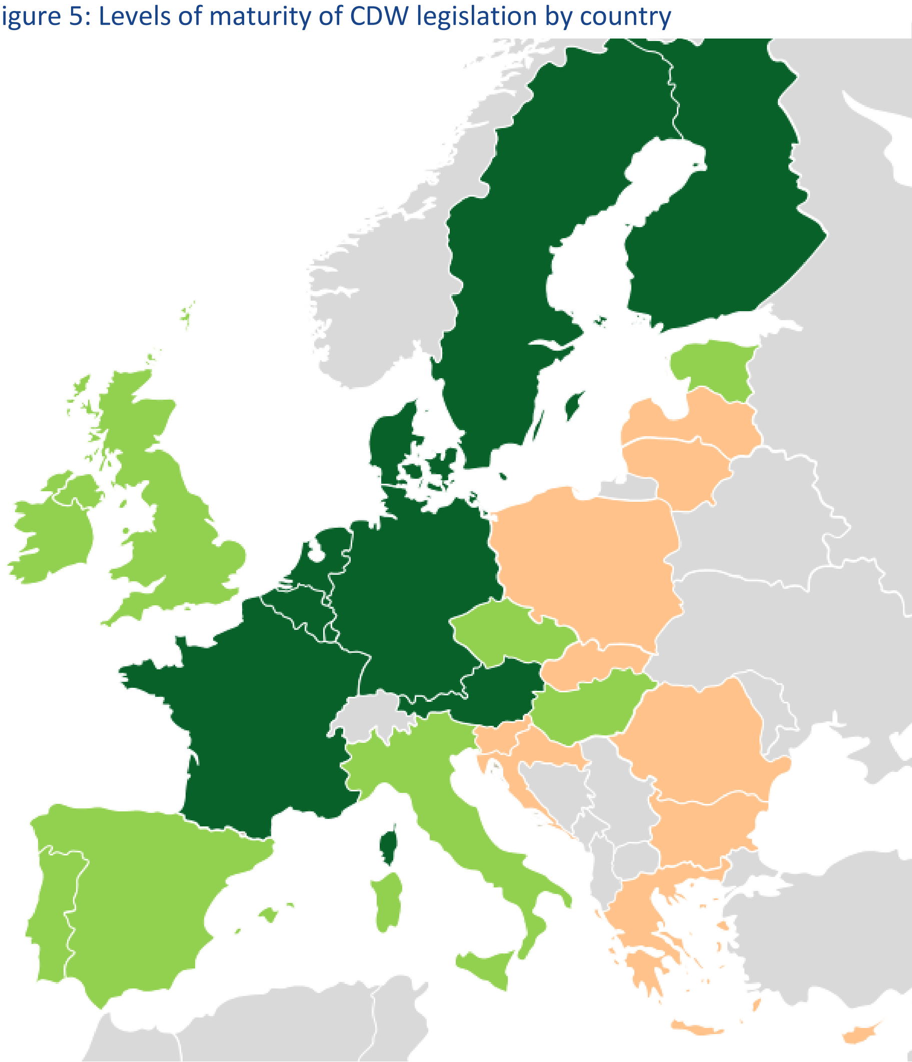


Source: DG GROW 2016

A state of play study groups Member States in categories, according to their "Levels of maturity" in CDW generation and management. These levels represent the level of implementation of the legal and regulatory framework in each country, taking into account the age of relevant CDW legislation, its level of specificity, the level of implementation in terms of effective application and the outlook, in terms of new legislative proposals, initiatives etc. According to these criteria, MS belong to a developing, advanced or mature legislation category:

[18] Ibidem.

Figure 5: Levels of maturity of CDW legislation by country



Developing level	Advanced level	Mature level
WFD transposed into national law, little legal specifications on CDW, low level of enforcement	*Longer tradition in CDW legislation, WFD transposed, more specific legislation, weak enforcement*	*Mature legislation, steps toward future regulation and targets above the WFD requirements, enforcement facilitated with regulations*

Source: EC 2017[19]

This analysis of CDW legislation highlights the need for further development of the regulatory framework at a European level and its reinforcement. Compared to the data in Figure 2, however, it also shows that regulation is not the sole driver of CDW market developments, as in some of the countries with "developing level" of legislation (Latvia, Lithuania, Romania, Croatia and Bulgaria) the CDW recovery rate has been improving since 2014. On the contrary in Sweden, which has a mature level of legislation, the CDW recovery

[19] European Commission, Deloitte Report, Resource Efficient Use of Mixed Wastes Improving management of construction and demolition waste, Final report, 2017

rate has dropped. Reasons for such developments could be found in CDW management and the obstacles connected to it (see Case Study Swedish construction company).

3.2. Public policy case studies

To reach the 2020 policy objectives of achieving 70% recovery of CDW national institutions and agencies have launched projects ranging from raising awareness to providing practical guidelines to companies for the effective CDW management. As seen in Figure 5, policies differ not only in terms of content, objectives and maturity, they can be legally binding or serve as recommendations and guidelines.

Case Study:

CDW in the Scottish Circular Economy Strategy

In 2016, the Scottish government put forward its first circular economy strategy "Making things last". The strategy focuses on waste prevention, identifying the construction sector to be the largest generator of waste, responsible for 50% of all waste in Scotland, also producing more than half of all carbon emissions. The focus of the Scottish strategy lays on building design as the key to waste reduction, not only for new buildings, but also in renovation and refurbishments works. The strategy aims at supporting SMEs to deliver building projects best practices and to build capacity in collaboration with industry and research institutions, such as the Construction Scotland Innovation Centre, thus putting emphasis on the importance of innovation for sustainable CDW management. Primary aggregates and timber resources are the focus of increased recycling of demolition materials. The strategy follows the EU target of 70% recycling and reuse of CDW until 2020. Another emphasis of the circular economy transition is the tracking of waste and the building of an evidence base, including for CDW, for a reliable assessment of achieved results.

In line with the circular economy strategy, waste audits are a recommended as a best practice in the Resource Efficient Scotland programme. Their aim is to be conducted prior to the completion of the project, to prepare for potential change in waste quantities in the final site clean-up. Zero Waste Scotland is an initiative funded by the European Regional Development Fund and the Scottish government offering advice and technical support on circular economy issues with the Resource Efficient Scotland programme. It published Designing Out Construction Waste guidelines built around five principles: waste-efficient procurement, materials optimisation, off-site construction, re-use and recovery and deconstruction and flexibility. The guidelines emphasise the importance of planning for all the building stages and are directed toward SMEs in construction, identifying best practices in work with clients, during the procurement of contractors, aiming to assign responsibility for the waste for all supply chain participants. This addresses problems arising from the absence of contractual agreements on waste with the subcontractors and contractually involves the client, designers, main and sub-contractors of the construction project in regards to the production of waste. The guidelines also address potential language related miscommunication between workers and managers, providing visualisation tools for the staff[20].

[20] Resource efficient Scotland, Best practice guide to improving waste management on construction sites.

4. Industry Initiatives

As for the implementation of public policies throughout the EU, private sector operation models vary depending on their local market characteristics. The price differences between primary and secondary materials, as well as landfilling costs play a role in the profitability of CDW recycling across markets. The current section will look into five types of initiatives:

- *public-private partnerships between industry and public sector organisations,*
- *sustainability labelling as a practice gaining momentum,*
- *construction site practices, which reveal the practical on-the-ground challenges faced on the construction or demolition ground,*
- *concrete production technologies, as the awareness of the impacts of concrete production grow and the key potential for CDW re-use and reduction is seen to be in concrete,*
- *innovation and technology initiatives, focusing on software allowing for better data collection and reporting*

4.1. Public-private partnerships

A growing number of private sector initiatives, often in cooperation with government agencies in the form of public-private partnerships, are putting their focus on concrete. When it comes to the circular economy of building and CDW, **concrete is the most used component and correspondingly the largest part of the generated waste.** Concrete mix is made by a dry part – sand, gravel, crushed stones, and a wet, binding paste part – water and Portland cement. Material engineers are working to create mixtures that reduce the environmental negative impact of cement production, as well as optimise its use and minimise the waste generated from it.

Case Study:

German agency for international cooperation and the Bosnian company Kakanj

A public-private partnership between German owned Bosnian cement producer **Kakanj and the German agency for international cooperation (Gesellschaft für internationale Zusammenarbeit, GIZ)** implements new production methods, adhering to circular economy goals. The German owners **Heidelberg Cement AG and Schwenk KG** serve in a knowledge transfer capacity with technical experts on the ground for a multiannual project aiming to use CDW and other waste materials to **substitute fossil fuels in the concrete production process**. In the first project year, local workers undergo trainings. In the following project years, workers learn waste management techniques in practice from waste collection, separation and processing to its recycling. A batching system is installed for the burning of secondary fuel materials in the testing phase, measuring CO2 emissions. In that phase, secondary materials produced in neighboring Croatia recycling facilities are used, thus building and strengthening regional facility networks for the circular economy. Using secondary material fuels for this project has proved to reduce the CO2 emissions, associated with the production of concrete.

4.2 Sustainability labelling

The German company Heidelberg Cement AG is also one of the founders of the Concrete Sustainability Council, a global private sector certification initiative, which is dedicated to certifying the production of green or sustainable concrete by assessing the entire concrete supply chain. Eight out of the eleven founding organisations are European based associations and companies, incl. the European Concrete Platform (ECP).

Labelling products to certify their sustainability is a trend beyond the construction sector. The European Commission has identified certification systems as a main driver for investments, with DG FISMA currently working on a package of measures following its action plan for sustainable finance. These measures will involve a common classification, or a **sustainable finance taxonomy,** to enable the reliable labelling of financial vehicles and products and thus to facilitate investments into the green economy[21]. These developments signal that in the business of CDW management labels and certifications will become increasingly relevant for financing, and given the impact of concrete production on the environment, in terms of energy usage and considering it is the main component of CDW, focus on its production may continue spreading.

Case study:

Beton Bewust label

The Dutch Association of concrete mortar manufacturers in the Netherlands **(Vereniging van Ondernemingen van Betonmortelfabrikanten in Nederland, VOBN)** is a professional organisation representing companies in the industry. It has introduced the **Concrete Awareness (Beton bewust) label**, a quality certification for concrete production, which since its introduction in 2012 has achieved a 6% CO2 emissions reduction and 28% increase in the use of secondary materials, such as concrete granulate generated from CDW, in concrete from 2014 to 2015. It considers the producers' status on circularity, energy consumption, the use of binding agents for the concrete mixture, the use of raw materials and fuels involved in the production and the average amount of CO2 emitted by m^3 of product[22]. The certification serves as management tool as well, as it allows the comparison between different lines of production. The initiative also aims at raising awareness that the circularity of a product starts from its design.

4.3 Construction site practices

Besides from regulations and economic incentives, the successful management of CDW also comes down to the actual working practices on the construction site. The following case study reveals details of the daily work in the construction process, which can be improved for a smooth transition toward better collection of CDW.

21 https://ec.europa.eu/info/publications/180524-proposal-sustainable-finance_en
22 http://www.gww-bouw.nl/beton-bewust-staat-model-wereldwijd-certificatiesysteem/

Case study:

Swedish construction and property development company NCC

CDW management (CDWM) challenges may range from technological ones to language barriers. The Swedish NCC case shows that the main CDWM practices employed on the construction site are the use of prefabricated components, the use of color-coded waste containers, the sorting, the recycling of waste and just-in-time (JIT) delivery strategy. JIT refers to the concept of lean management; materials are delivered just when they are needed and are not stored on site, unnecessarily occupying space.

Since construction workers on site are international and not necessarily fluent in the construction management language, difficulties in the instructing regarding waste disposal occurred in this case. The construction company solved this by distributing small brochures with information in three languages. Additionally, challenges were a general lack of awareness and of understanding on how to sort the wastes and practical issues such as shortage of space, causing the location of waste containers to be too far from the work location on the construction site. Inadequate space means that there might not be enough space for both recycling equipment and waste containers, which could be the case in densely populated areas. In such cases, noise levels and dusts caused by the recycling works are challenging issues as well. The absence of an agreement with subcontractors, such as electrical subcontractors, on the construction site regarding waste management was identified as a hindrance to adequate CDWM. A recycling company subcontractor was engaged for the collection of the waste, but other subcontractors lack incentives to actively participate in the adequate waste management. Another on site issue was the lack of shelters for waste containers, leaving the CDW exposed to various weather conditions. With certain materials, such as gypsum, this could pose difficulties with the further transportation of the waste, since it absorbs rainwater and becomes heavier to move and manage, which drives up costs of managing.

4.4 Concrete production and usage technologies

New construction methods that avoid the use of concrete, which constitutes the largest component of CDW, have a high impact on the reduction of waste. The off-site manufacturing of 3-D modules, like roofs, block work or external insulation, the substitution of concrete frames with timber or steel, pre-cast or composite panels have a waste reduction potential of up to 90%[23].

The resource-efficient use of concrete and the possibility to deconstruct it and reuse it, besides from being economical and reducing costs, is also important because of concrete production's environmental impact. The production of concrete depends on the extraction of sand and gravel, which has negative environmental impacts as it destabilises riverbeds, putting farming land at higher risk of flooding and leaving coastal communities more vulnerable to storm damage[24]. With sand becoming scarcer and more expensive, illegal sand extraction is taking place, destroying ecosystems. Up to 10% of sand in concrete can be replaced by plastic, without affecting the structural integrity of the material. This has been shown to work by Bath University and Goa Engineering College researchers, in a project using waste plastic to deal with the sand

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23 Galvez-Martos et al. 2018, Construction and Demolition Waste Best Management Practice in Europe. Resources Conservation and Recycling. 136. 10.1016, http://iranarze.ir/wp-content/uploads/2018/10/E9712-IranArze.pdf

24 BBC, The battle to curb our appetite for concrete, https://www.bbc.com/news/business-45893549

shortage in India. In fact, the study, published in the journal for Construction and Building Materials, investigates various types of plastic as replacement for sand, which otherwise accounts for 30% of the concrete mixture[25]. The concrete mix for 3-D printing for example, contains superplasticizers, which help keep the mix creamy, for better buildability and to prevent the clogging of the printer[26]. In fact, companies can use recycled plastic to reinforce concrete, which results in 90% reduction in CO2 in the production process, compared to using traditional steel mesh. **3-D concrete printing of buildings and structures ultimately reduces waste, costs,** and contributes to the optimal use of the resource.

Case Study:

Eindhoven as a 3-D concrete printing hub

The city of **Eindhoven** in the Netherlands aims to become **a 3-D concrete printing hub** for Europe. The technical university of Eindhoven is building the world's first 3-D printed houses, collaborating in the process with a net of local architectural, real estate, engineering and manufacturing companies. The construction company implementing the project, Van Wijnen, uses the method also as a **solution for labour shortages of skilled bricklayers**[27]. The benefits of 3-D concrete printing stem from the high precision of the technology, which makes the exact planning of material usage possible, allowing for up to 40% less utilisation of cement and thus reducing CO2 emissions from the building process[28]. The lower cost of 3-D homes could also have implications for social housing, making it more affordable.

The role of academia in the development of innovative materials is important. University research centres often collaborate with government institutions and private sector companies in thematic clusters. In **Casale sul Sile**, Italy, a group of concrete manufacturing companies is working on producing concrete mix, using less limestone, which reduces the CO2 from the production process by 30% and increasing the pre-prepared concrete walls' insulation by 25%[29]. This on the one hand reduces the amount of the future CDW generated from the pre-prepared structures and on the other hand employs the use of recycled CDW. **Imperial College of London** researchers have succeeded in producing a new type of biodegradable concrete, **Finite**, that is recyclable and can be moulded to be reused over and over again or even dissolved. Compared, concrete recovered from sorted CDW needs to be transported, grounded and remixed in new concrete mixtures. Instead of using sand from riverbeds and beaches like traditional concrete mixtures, the extraction of which inflicts severe damage on the environment, Finite uses desert sand. Desert sand is an abundant resource and because of the fine constitution of the grains due to erosion, it has been thought to not bind well in mixtures. The new method manages that and does not have the negative environmental impact like other sand does, yet delivering a material as strong as concrete[30].

These examples show the importance of research and innovation in material production technologies and their role in the reduction of CDW. Currently the focus of the industry seems to be toward the design of more

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25 University of Bath, Waste plastic in concrete could help support sustainable construction in India, https://www.bath.ac.uk/announcements/waste-plastic-in-concrete-could-help-support-sustainable-construction-in-india/

26 https://all3dp.com/2/concrete-3d-printing-how-to-do-it-and-application/

27 The Guardian, Netherlands to build world's first habitable 3D printed houses, https://www.theguardian.com/artanddesign/2018/jun/06/netherlands-to-build-worlds-first-habitable-3d-printed-houses

28 Dezeen, 2018, https://www.dezeen.com/2018/06/04/eindhoven-university-technology-project-milestone-3d-printed-concrete-houses/

29 https://de.euronews.com/2018/10/08/gruner-beton-umweltfreundlich-und-kostengunstig

30 http://www.materialfinite.com/

sustainable concrete and materials that will facilitate later CDW recovery. In the long term, there is interest for more radical innovations, as in the case of Finite, which also shows that the awareness of the need for as efficient as possible construction and deconstruction is present.

4.5 Innovation and technology initiatives

Another big trend in CDW management is the increasing appetite for data and reliance on data-driven solutions. Real-time monitoring of CDW generated on the job site, as well as automatic compliance checks can provide significant cost savings for contractors.

Case Study:

SMARTWaste Tool

Building Research Establishment (BRE) is a research and consulting company, specialized in the building environment industry. The company launched an online-reporting platform for contractors active in the CDW management **- SMARTWaste, a tool for the estimation of CDW waste using statistical data on waste from previous building projects in the UK.** The tool offers the possibility to monitor waste management plans on site and provides information on how different materials can be managed efficiently or re-used in line with regulations.

This is done by estimating the amounts of each types of waste likely to be generated at a demolition site, and what share of it can be re-used or recycled on site, removed from the site for re-use, recycled or disposed[31]. This can help with data reporting challenges on a larger scale, as well as with facilitating waste audits and the communication between different teams on site. The tool is built on the principle of Building Information Modelling (BIM), but instead of being project oriented, it aims to optimise on the level of the entire sector[32]. The use of common data is important for the improvement of CDW management, as currently contractors have to provide data in different formats to different clients, according to the client preferred software or method. This creates issues with misinterpretations and directs efforts toward data collection, instead of concentrating on using information.

The tool claims to have contributed to savings amounting to EUR 88 million for the contractors using it and 27.2 million tonnes of CDW diverted from landfills.

31 https://www.designingbuildings.co.uk/wiki/BRE_SMARTWaste_online_reporting_platform
32 https://www.designingbuildings.co.uk/wiki/How_data_can_stop_waste

5. Challenges and opportunities in CDW management

The case studies presented show some of the trends and areas that are relevant for CDW management actors in the public and private domain. **Overall, industry actors are very aware of the overarching trend of the sector – sustainability and resource efficiency. Especially big companies and educational institutions, who have the resources to invest in research, actively pursue initiatives and innovation in the management of CDW.** The efforts of the industry are concentrated on innovation technologies, represented in material science and the development of sustainable concrete, the re-use of recycled secondary materials and optimising communication in the construction process. The efforts of the public sector are primarily oriented toward formulating adequate and useful guidelines for companies and toward promoting the benefits of CDW recovery. However, within these pursuits some challenges remain.

5.1. Technology related challenges

Various tools, ensuring the minimisation of waste during construction, support the CDW management. Such tools are waste management plans and guides, waste data collection tools, waste estimation tools, environmental assessment tools and GIS (geographic information system) tools. Research[33] conducted via stakeholder surveys, however, reveals that these tools are not sufficiently integrated into the construction process.

The design process, consisting of concept, developed and technical design, determines the workflow and project software requirements. During the design stage, the building design documents are produced, such as building drawings, materials specification, schedule of work, bill of quantity etc. Studies show that the largest percentage of CDW occurs during this preconstruction phase, because of inadequate planning, which leads to design changes later on, lack of knowledge on alternative materials and dimensional coordination[34]. Awareness raising initiatives tend to stress the importance of design phase, but concrete tools for the integration of all stages and processes are needed to tackle the issue.

5.2. Market related challenges

Low prices of raw materials, combined with limitations in the market for secondary materials pose a challenge for CDW reuse and recycling, as the quantities produced might not be absorbed by the market. In Sweden for example, the low cost of building materials compared to the **expensive labour cost** cause extra volumes of materials to be ordered to prevent construction delays. Such delays would translate into higher costs for contactors, having to pay for workers waiting for materials to be delivered. The unused materials are then often sent to landfills[35]. Increasing taxes on landfills, as well as facilitating waste audits and quality assurance methods are needed to foster market demand for secondary materials.

33 Akinade et al. 2018, Designing out construction waste using BIM technology, Journal of Cleaner Production 180 (2018) 375-385

34 Ibid., p. 376

35 https://www.naturvardsverket.se/upload/miljoarbete-i-samhallet/miljoarbete-i-sverige/avfall/avfallsforebyggande-programmet/Together-gain-rom-non-toxic-resource-efficient-society-2017-05-22.pdf

5.3. Organisational challenges

Among the benefits that BIM technology can deliver to the construction sector is the ability for multidisciplinary collaboration between architect, engineer and construction teams. As the design process is crucial for the reduction of CDW later on, BIM software offers possibilities to optimise this stage and to deliver up to 15% less CDW[36]. This occurs through detection of design errors and information sharing between teams. However, BIM use faces interoperability obstacles, stemming from the varying software needs and expertise between professional teams, impeding the wide exploitation of this technology. Software related skill shortages among professionals would require a larger investment in trainings on the side of architectural, construction and engineering companies in order to implement the method. Most CDW management tools are not widely implemented in BIM. As the case studies suggest, the implementation of technology solutions for the better coordination of all actors involved in the construction and demolition activities, such as BIM or other software tools, can result in substantial savings and CDW recovery.

Furthermore, stakeholder awareness of waste management practices and benefits plays a role in waste generation. This awareness starts at the client level through the whole construction process, including analysis of potential waste during the design phase, setting waste management goals and recovery goals. Explicit responsibilities regarding waste management have to be defined for all subcontractors involved in the building process[37].

Lifecycle assessment is a holistic way of viewing products by considering their overall impact on the environment. This assessment takes into account the emissions, resource-intensity of production, effects on health and the environment that are generated over the entire life cycle of a product from the extraction of the natural resources, through their processing, distribution, use, recovery, re-use and final disposal[38]. This makes lifecycle assessment relevant for specific building stages and mostly used in the construction phase. This approach is inefficient, as the design stage is crucial for limiting the waste generation. Assessment must be made from inception to finish.

Additionally, the efficient sorting, collection and transport of CDW debris necessitates smart management solution to facilitate material recovery. Such solutions must include cooperation between CDW companies and customers and require reliable data on the quality and quantity of C&D waste[39]. Customers' interest impacts waste management practices.

5.4. Regulatory challenges

The legislation level regarding CDW varies across the MS with some having mature legislative frameworks and optimising their circular economies, and others lacking concrete legislation and compliance enforcement. This also involves the lack of economic incentives for recycling, such as landfill taxes and lack of developed recycling local network[40].

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36 http://publications.lib.chalmers.se/records/fulltext/251973/251973.pdf

37 Ibid.

38 EC, Life Cycle Thinking and Assessment for Waste Management, http://ec.europa.eu/environment/waste/publications/pdf/Making_Sust_Consumption.pdf

39 Construction&Demolition Recycling magazine, May 2014, http://www.cdrecycler.com/article/frost-sullivan-report-construction-demolition-market/

40 Workshop "Improving management of construction and demolition waste", Background paper, I

One of the main obstacles for the estimation of CDW is the lack of reliable demolition waste data. Past data mostly refers to unsegregated waste, which has been collected as general waste. Existing tools do not account for detailed material information or building methodology, which makes them inaccurate[41]. The European Demolition Association (EDA) quotes the lack of solid data for the branch as one of the most pressing issues for the industry. Data from the broad construction sector might not be directly applicable to the demolition industry[42]. Initiatives already exist to tackle this issue, for example in the UK, by implementing online-reporting platforms, but practices that are more widespread are still needed. More demanding and detailed reporting criteria on a legislative level could help improve the situation.

41 Akinade et al. 2018, Designing out construction waste using BIM technology, Journal of Cleaner Production 180 (2018) 375-385

42 EDA, Industry Report 2015

6. Outlook

The CDW sector is continuously growing. Both public policy and industry are actively seeking opportunities for better management, regulation, guidelines and practices. **The research of materials solutions in terms of concrete production is a rising trend,** spread across a spectrum of actors from government agencies, such as the German agency for international cooperation (GIZ) in the case of Kakanj, universities and big companies. Concrete use methods are also trending with the prominent example of 3-D concrete printing, which is gaining popularity and the world's first 3-D concrete printed houses are soon to be inhabited in the Netherlands.

The awareness seems to be present, across market participants, that the efficient resource use of CDW and the cost-efficient prevention of waste starts with the design stage. Still, implementation seems to be not as broad, due to organisational and technological challenges.

To measure progress and track performance toward the 2020 targets of 70% CDW recovery, data is a key challenge. Data reporting requirements could benefit from updating and tightening. This in turn could help not only regulatory bodies assess the state of play, but also the industry to more efficiently manage and improve the handling of CDW.

Effective CDW management practices need to be comprised by a mix of measures, regulatory, economic and informational ones. Economic instruments can be designed to motivate private sector market participants to optimise resource use by **diverting from landfills and recycling more**. Such instruments can introduce taxes or levies to the polluter, raise landfill taxes further, as this has been linked to lower landfill use rates.

Besides from raising awareness about reusing traditional materials from CDW, it is as important to **foster research and innovation activities,** that potentially could simplify the recovery of materials in construction by making them easily reusable in the first place, as in the example of the Finite material, discussed above.