

CHAPTER 8:

Construction and demolition

There is a high potential for recycling and reuse of construction and demolition waste, and the UK has made significant progress in this over the past decade. Concepts such as design for manufacture and assembly, building information modelling, and the circular economy are all having a positive impact, but there should be more focus on the whole lifespan of a development. Government needs to work with the sector on long-term strategies that will improve lifetime reuse, remanufacturing, recycling and management of the materials generated in new and existing infrastructure.

Dr David Greenfield, Managing Director, SOENECS Ltd and Chair of the Institution of Civil Engineers (ICE) resource management expert panel

Surplus material from the construction and demolition of buildings and other infrastructure is one of the largest sources of waste in the UK. The European Union defines it as construction and demolition waste (CDW) in the Waste Framework Directive (2008/98/EC)¹. In 2012, the UK generated 200 million tonnes of waste, half of which was generated by construction, including excavation activities².

This chapter will explore the different types of CDW, the use of new techniques and technologies, highlight emerging best practice and explore the progress made over the past decade in the sector achieving a predicted £653 million in savings by 2025 (ref. 3). Based on this evidence, a series of recommendations for developing and implementing long-term strategies will be presented.

What is construction and demolition waste?

CDW consists of numerous materials, including concrete, bricks, gypsum, wood, glass, metals, plastic, solvents, asbestos and excavated soil, many of which can be recycled⁴. The European Union has identified CDW as a priority waste stream, primarily because there is a high potential for recycling and reuse of CDW, as some of its components have a high resource value. In particular, there is a reuse market for aggregates derived from CDW waste, which are typically used in roads, drainage and other construction projects⁵. Construction or demolition projects are part of the complex lifecycle of a built asset, which can span 50 years or more; the phase of that lifecycle determines the source of these wastes (see Table 1).

The highest volumes of wastes arise during the construction and end-of-life phases, but it is important to look at the whole lifecycle of a development to understand where the waste may occur and, more importantly, how it can be reduced, recycled or avoided.

One area that this lifecycle doesn't acknowledge is design. The role of architects in ensuring that waste is designed out (or even considered) is summed up best by Sophie Thomas, Director of Circular Economy at the Royal Society for the encouragement of Arts, Manufactures and Commerce (RSA), who in 2014 stated that "80% of all the environmental costs of a project are determined during the conception and design phase"⁶. The role of design will be explored in the circular economy section of this chapter.

Statistics

The construction sector is currently outperforming many other sectors for recovery of materials. The UK generated an estimated 45.85 million tonnes of construction in 2012. Some 44.80 million tonnes of this was non-hazardous, 38.80 million tonnes of which was recovered. That means the recovery rate from non-hazardous construction and demolition waste in the UK was 86.6%, already 16.5% above the EU 2020 target of 70% (by weight)⁸. For example, construction company Wilmott Dixon says that it reduced waste generation by 38% from 2012 to 2015, through better procurement and use of materials, and sent less than 7% of its waste to landfill over that time⁹.

While these statistics look very good, they

Lifecycle phase	Activity and waste generation
Phase 1: Product phase	Raw materials are obtained and transported to factories for manufacturing. Waste is generated at this stage, but not directly counted towards CDW.
Phase 2: Construction phase	Manufactured materials are transported to the construction site for installation and other on-site work. Wastes generated by both construction and excavation are counted as CDW.
Phase 3: Use phase	Once the building is occupied, waste is generated by maintenance, repair, replacement and refurbishment of equipment, including periodic site activities and replacement of components (which results in more extracting, transporting and manufacturing). Wastes generated at this stage may be included as CDW, if managed by facility management contractors. The wastes generated directly by occupants are, however, often overlooked and not included in CDW, even though it is fundamentally influenced by the design of the construction phase.
Phase 4: End of life	This involves demolishing the building, processing all waste, and transporting it to where it will be reused, incinerated or disposed of in landfill.

Table 1:
Lifecycle and waste generation of a built asset

need to be put into perspective. According to a study by the non-profit Centre for Studies, Research and Actions in Architecture (CERAA), and Rotor, a group studying material flows in industry and construction (both based in Brussels), more than 80% of CDW in Brussels is composed of inert or mixed waste (the latter comprising two or more different materials) (see Table 2)¹⁰. The large proportion of inert and mixed wastes in CDW means that most of the recovery is achieved through energy-from-waste (EfW) processes, or by using it as a secondary aggregate. These statistics are very similar in the UK.

So from a tonnage perspective, the sector does very well. But more work needs to be done to move the hazardous wastes (which include plasterboard, paint cans, concrete, caulk containers, personal protective equipment (PPE), batteries, aerosol cans, chemicals and electronics)¹¹ from construction processes up the waste hierarchy, through recycling, reuse and particularly reduction of waste.

Management of CDW from excavation

In all construction projects, the first job is to prepare the site. In many cases this requires excavation, tunnelling or boring, which generates enormous volumes of material. The industry normally uses an integrated design approach,

using this material to satisfy the fill requirements wherever reasonably practicable. In many cases, this includes reuse of all topsoil and agricultural subsoil as close to the point of generation as possible.

One such project that has the potential to generate approximately 130 million tonnes of excavated material is the proposed HS2 rail project. The project team states that more than 86% of this material will be reused within the project for the construction of engineering and environmental mitigation earthworks¹². HS2 has bold ambitions, many of which are justified: large-scale projects are already delivering this kind of performance, including the other major rail construction effort in the UK, Crossrail (see case study <<Ch8 CS Crossrail>> on pxx). Crossrail shows that there are huge opportunities for the management of excavation wastes, but that careful planning and advanced thinking are required to ensure that social, environmental and economic solutions are achieved.

Management of CDW during construction

On an annual basis, the construction sector is responsible for one-third of all global resource consumption, one-third of global energy consumption, and 12% of all fresh water use. The manufacture of building materials alone

Waste stream	Tonnage (T)	%
Inert	383008	59.4
Mixed	144905	22.5
Asphalt products “13 actors”	10702	1.7
Asphalt products “roads”	30628	4.8
Plastics	7	0
Paper, cardboard	0	0
Metals	25000	3.9
Wood	5450	0.8
Green waste	1500	0.2
Hazardous	41492	6.4
Other construction and demolition waste	1748	0.3
Total	644440	100

Table 2:
Construction waste types, expressed in tons and percentage

consumes about 10% of the global energy supply, and building construction and demolition waste amounts to about 40% of solid waste streams in developed countries¹³. Construction waste is usually made up of materials such as bricks, concrete and wood which are damaged or unused for various reasons during construction. Observational research has shown that 10% to 15% of the materials that go into a building end up as waste¹⁴. There are several approaches to reducing this burden.

I. Design for manufacture and assembly

The construction sector can continue to innovate and increase sustainability, while reducing waste and increasing recycling, by following the principles of ‘design for manufacture and assembly’ (DFMA) (also known as build off-site or lean manufacturing). In the context of the construction industry, DFMA is an approach best described as “improving quality through the application of efficiency, reducing resources required while increasing positive aspects such as health and safety, quality, certainty”¹⁵. DFMA takes a number of forms, but the common factor is the application of factory (or factory-like) conditions to construction projects. Construction waste can be substantially reduced through off-site construction as a

result of the following factors:

- The volume of throughput in a factory ensures that the materials that have been ordered are used in their entirety.
- Small quantities of waste arisings can be reused in the manufacturing process.
- Factory deliveries are invariably made in bulk, so larger orders can be packaged together in a single consignment, as opposed to numerous small orders packaged separately (as would be the case on site).
- Carefully managed scheduling, logistics and handling mean that disposable protection (for transportation) can be reduced or eliminated.

DFMA necessitates the use of building information modelling (BIM), both in the design phase and through the manufacturing, logistics and installation processes (see below). This in turn encourages best practice across the board and a ‘right first time’ ethos, which leads to further resource efficiencies:

- There are more opportunities for continuous improvement in a production-line environment where repetition of tasks is more common.
- The size of orders means delivery vehicles can be consistently filled to capacity.
- Longer-term relationships with local suppliers are possible, due to the permanence of the work base. This allows for economies of scale,

Case Study

Roadmap to resource efficiency

Gilli Hobbs, Strategy Director, Building Research Establishment (BRE)

In 2008, the Building Research Establishment (BRE) led the development of the 'Construction Resources and Waste Roadmap'²⁸, which aimed to present a long-term perspective and vision for improving construction resource use and waste management, in line with government objectives set out in the Waste Strategy for England 2007. A further objective of the roadmap was to consolidate findings from a number of linked projects, including BRE's National Construction Waste Benchmarking project and its Construction Resources and Waste Platform (a Defra-funded programme from 2004 to 2009, which supported construction resource efficiency research, exemplars and best practice guidance).

The roadmap built on work from 2006, outlined in 'Developing a strategic approach to construction waste (20 year strategy draft for comment)²⁷. This presented a number of scenarios for resource use, linked to future trends relevant to the construction sector. With 2016 being a halfway point in that 20-year strategy, it offers an opportunity to evaluate progress.

Back in 2005, the average amount of waste generated while building new homes (calculated using BRE's SMARTWaste monitoring system²⁹) was 17.3 m³ of waste per £100,000 of property value, and 19.2 m³ per 100 m² of constructed floor area. Using these 2005 SMARTWaste-derived benchmarks as a baseline, two options were evaluated – 15% and 50% reduction of waste by 2025.

The SMARTWaste system has evolved greatly over the past 20 years, and is now a widely used web-based environmental reporting system (including measurement of waste, water and energy throughout the construction process). Over the past decade, SMARTWaste has collated data from over 1300 new-build residential sites, and found that the corresponding benchmarks now stand at 12.4 m³ per £100,000 of value and 18.1 m³ per 100 m² of floor area. This amounts to a waste reduction of 28% and 6% respectively,

compared to the previous 2005 benchmarks. The first indicator will have been affected by inflation, so the second is more reliable. This suggests the first option – 15% waste reduction – was more realistic. A more detailed comparison of SMARTWaste benchmarks could offer more insight, for example, isolating all 2005 housing completions and comparing to all 2015 housing completions.

The 15% and 50% reduction scenarios presented in the strategy document assumed a far greater reliance on off-site manufacture than has happened to date. Without a significant transformation in the way dwellings are designed and built, it is unlikely that anything approaching 50% waste reduction could be achieved. Some progress has been made in understanding where waste is arising, especially in site-based practices, and taking practical actions that can lead to incremental reductions in waste generation. Given the current housing shortage, and revitalised interest in industrialised building, it is still reasonable to predict that off-site manufacture will play an increasing role in the provision of new housing⁹.

There has also been a shift towards designing, building and managing facilities in a holistic, lifecycle-based and integrated way, and the development of building information modelling (BIM) is helping to make this a reality. The UK government mandated the use of BIM on publicly procured projects from April 2016, which has spurred efforts to consolidate and standardise information collation and management in the construction process. In the utopian vision of BIM, it will be possible to drive out waste (time, money, materials) throughout the building supply chain and lifecycle. Yet lifecycle assessment (LCA) has played a small role, so far, in promoting resource efficiency, despite much work being undertaken at an EU level³⁰.

BIM was not specifically referred to in the 2006 strategy report, but the need for better



information management in buildings was a key objective. The last 3 years has seen a transformation in the development of standards, tools and capacity building relating to BIM and information management. Around 2 years ago, BRE developed a research objective to use BIM as a vehicle to understand and promote improved resource productivity across the whole lifecycle of buildings. This work is now underway in several projects, including the Horizon 2020 project 'Buildings as Material Banks (BAMB)³¹, which will ultimately develop a BIM software prototype focused on improving reuse potential and transformation capacity of new and existing buildings.

Many other themes from the 2005 report have seen progress in the past 10 years, such as reduction in landfilling of construction and demolition waste, and increasing the proportion of recycled aggregates being produced. Conversely, other areas have stagnated: there has been little progress in achieving a significant focus and targeting of resource efficiency in refurbishment; or the establishment of consolidation centres that can act as stockholders for surplus materials, or as bulking stations for small waste streams.

knowledge sharing and other opportunities for product / process improvements.

- At end-of-life, dismantling or demolition is simpler, allowing a greater percentage of the building's materials and/or components to be preserved.

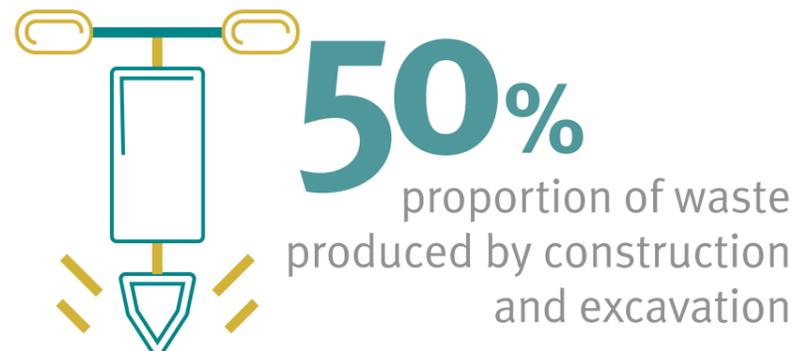
For example, Laing O'Rourke has a 23,000m² offsite manufacturing facility in Steeley, Nottinghamshire. The government has already invested £22 million in the factory, which produces precast wall panels and precast concrete slabs. It takes less than 6 hours from pouring the concrete to loading these components onto the back of a lorry¹⁶, and this offsite manufacturing approach can substantially reduce construction waste (see case study <<Ch8 CS Leadenhall>> on pxx). Despite the huge potential for reducing waste by designing it out, the application of DFMA across the UK is small, due partly to a lack of investment in facilities.

2. Building information modelling (BIM)

The concept of BIM is to construct a building in a virtual environment, prior to constructing it physically. BIM has its roots in computer-aided design and computer-aided manufacturing (CAD/CAM), and uses advanced computer systems to build 3D models of infrastructure and hold large amounts of information about its design, operation and current condition. This virtual building helps stakeholders to work out problems and to simulate and analyse potential design and operational impacts. BIM is typically used right from the design stage of a construction project, to enable the design brief to be tested and the proposed construction solution to be changed at minimum cost¹⁷.

BIM typically models 11 different stages of the construction process:

- Programming of the the lifecycle
- Conceptual design
- Detailed design



- Analysis
- Documentation
- Fabrication
- Construction
- Construction logistics
- Operation and maintenance
- Renovation
- Demolition

BIM has been used to optimise design solutions and avoid clashes, so that issues of buildability are dealt with well before work and spending starts on site¹⁵. One of the main advantages is that the quantities of materials required can be more accurately assessed, meaning wastes can be reduced on site. BIM is already supported by the government: indeed, in 2011, the government embarked with industry on a four year programme for sector modernisation with the key objective of reducing capital costs and the carbon burden from the construction and operation of the built environment by 20%. BIM will enable the interconnected digital design of different elements in a built environment and will extend BIM into the operation of assets over their lifetime¹⁸.

3. Government Soft Landings

In September 2012, the Cabinet Office announced that by 2016 all centrally-funded projects should be delivered in accordance with the Government Soft Landings (GSL) programme. The GSL programme was designed “to champion better outcomes for our built assets during the design and construction stages ... powered by a building information model (BIM) to ensure value is achieved in the operational lifecycle of an asset”¹⁹. The GSL

programme, incorporating level 3 BIM, should allow designers to incorporate waste reduction into the construction, lifetime and dismantling phases. It also stipulates that demolition should not occur.

The GSL is described by the government’s BIM taskforce as a ‘golden thread’, whereby early engagement of the end user and inclusion of a GSL champion on the project team during design and construction through to operational handover is essential. This will allow the project team to set clear targets and measures for:

- Social outcomes: ensuring functionality and effectiveness for user and business requirements.
- Economic outcomes: identifying operational and capital costs early, to reduce costs in construction and operation.
- Environmental outcomes: meeting carbon and sustainability targets, including energy, carbon, water and waste¹⁹.

The BIM Taskforce also suggests that this will allow the project team to “focus on commissioning, handover and training in partnership with users and operators to enable effective operation and early optimisation of asset”. It adds that a post-occupancy evaluation should be embedded in the project plan “to assess performance for at least three years post-completion to establish actual outcomes and lessons learnt”. This should allow for a more considered approach to the generation of construction wastes, and the way that waste is managed, during the operational lifetime of that project.

Case Study

Planning advice for new build flats

Beverley Simonson, London Waste and Recycling Board; Jamie Blake, London Borough of Barnet; Ian Blake, BPP Consulting LLP; and David Greenfield, SOENECS Ltd

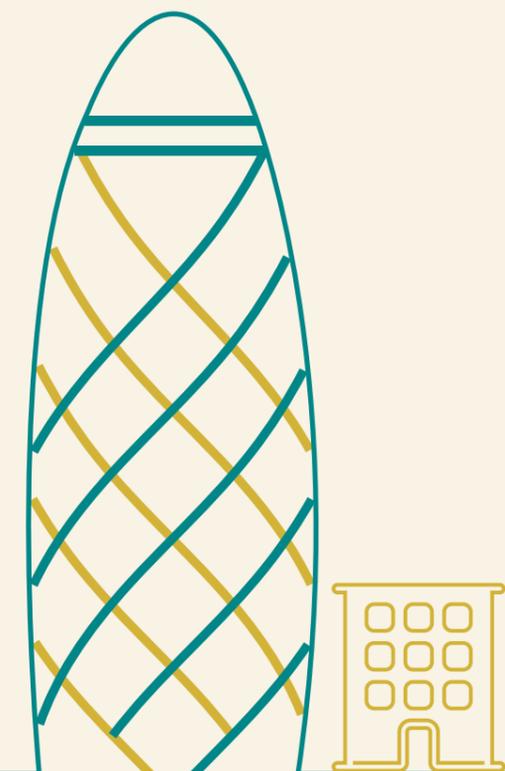
The London Plan²⁰ – the Mayor of London’s development plan for the city – predicts that by 2036 there will be an additional 1,000,000 households living within the greater London area. The vast majority of the required new homes will be medium- to high-density developments, in other words flats. The plan also includes a 50% recycling target for London by 2020. New development is not just constrained to London, and it follows therefore that proper consideration of waste management must form a fundamental part of the design and planning process for all new residential developments. It is essential that such consideration take place early in the planning of new developments, as 80% of all the environmental costs of a project are determined during the conception and design phase.

Given this context, the London Waste and Recycling Board (LWARB) and the London Environment Directors’ Network (LEDNet) commissioned a consultancy partnership formed by BPP Consulting LLP and SOENECS Ltd to develop waste management planning advice for flatted properties. The overall requirement was to prepare a template policy or policies on planning for waste and recycling storage and collection in new-build flatted properties, with the ultimate aim of encouraging the design of waste management that will help London achieve its recycling targets. Two of the outputs from the project were:

- A template waste management policy to be adopted by all London boroughs that required a waste and recycling management strategy for all new developments

■ A template waste and recycling management strategy for developers to complete at pre-application stage. This aimed to ensure that they have considered the five stages of how waste and recycling is managed from within the resident’s home to disposal: occupier separation; occupier storage; collection / bulking; removal / on-site treatment; end destination.

By linking the planning and waste management processes, the intention is that developers will introduce systems that will allow occupants to increase the recycling achieved during the lifetime of buildings, thus reducing costs and increasing environmental performance.



Case Study

The circular economy

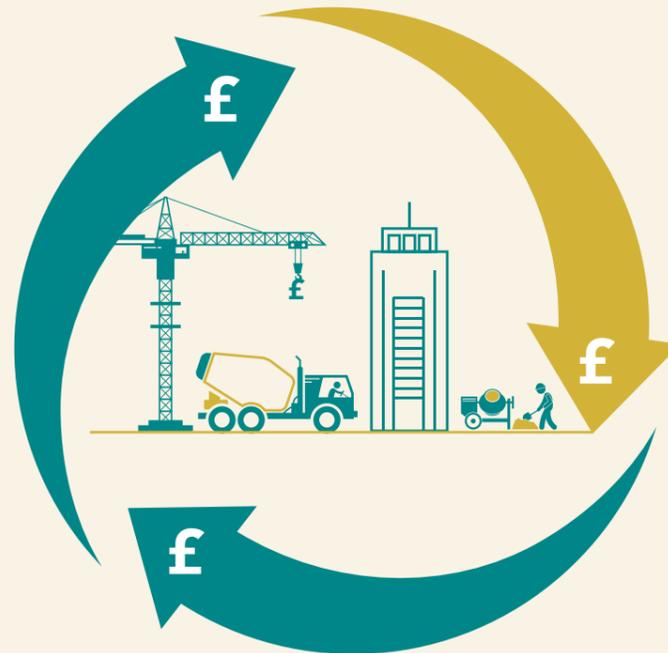
Duncan Baker-Brown, Senior Lecturer at the University of Brighton and Director of BBM Sustainable Design

The concept of the circular economy is only just emerging as an idea, and only beginning to be understood in some sectors of the UK construction industry. But it is gaining some traction. For example, the London Assembly is developing a route map for London's circular economy in partnership with the London Waste and Recycling Board (LWARB), and the Ellen MacArthur Foundation, a non-profit organisation that advocates for the circular economy. In 2015 they published 'London: the circular economy capital'³³, which identifies the built environment as one of its five focus areas. LWARB is now commissioning feasibility studies about how far circular economy principles can be incorporated into the UK construction industry.

Meanwhile, a number of well-informed UK-based architects are independently designing buildings that exemplify circular economy concepts, including ZED Factory, Architype, White Design, and BBM Sustainable Design. Organisations such as the UK Green Building Council and the Building Research Establishment are encouraging discussion of the topic at conferences and attempting to define what it might mean on their websites, but there is not much evidence of actual construction projects inspired by the circular economy.

Europe is further ahead in this area, encouraged perhaps by the establishment in 1987 of the Environment Protection Encouragement Agency (EPEA), based in Hamburg. EPEA was founded by Prof Dr Michael Braungart, one of the two co-authors of 'Cradle to Cradle: Remaking the Way We Make Things'³⁴, a key text in circular economy thinking. The EPEA provides, among other services, 'cradle to cradle' (C2C) training, which has influenced many of Europe's prominent circular economy consultants.

Established firms are also involved. Thomas RAU Architects in Amsterdam focuses on sustainable, closed-loop systems, and claims that it is responsible for inventing concepts well known to C2C converts such as 'material passports' and 'buildings as material banks' (BAMB). They also



developed the 'circular lighting' concept with Philips Lighting, in which Philips leases and takes responsibility for the supply, maintenance and removal of their light fittings.

Design consultancies are actively pursuing working methods that achieve many circular economy goals. Rotor, a group of architects and academics in Brussels, is literally taking apart 'difficult' buildings (from the 1960s and 1970s) one screw at a time, and selling the material for profit. SuperUse Studios from Rotterdam, also architects and academics, are best known for constructing a house (Villa Welpeloo) in 2005 from 60% waste material that was sourced using Google Earth. And in 2014, the University of Brighton opened Europe's first public building made of 90% waste. Built by over 360 construction and design students, it creates 25% more energy than it consumes and serves as a creative design studio open to the public.

Management of CDW during the lifetime of an asset

There is a stream of waste that is often overlooked when considering construction: the impact construction has on the generation of wastes during the operational lifetime of the constructed development. In most cases, this stream could be classified as municipal solid waste or commercial and industrial wastes, as they are a result of usage of the constructed development. The unalterable fact is that the design and construction of a new development has a direct link to the way that wastes are managed during the operational lifetime (see <<Ch8 CS Planning advice>> case study on pxx).

Collecting and processing waste in high-density environments such as cities is difficult and expensive. Design, behaviour-change and technological solutions that enable and encourage households and businesses to adopt more resource efficiency and cost-effective behaviours are being developed and implemented. Recovering mixed and often contaminated materials from a large number of individual properties will always pose challenges, and these are particularly acute in high-density dwellings and offices, where there are three main problems:

- Providing enough space to store recyclable materials, both for the individual dwelling, and to bulk up materials in the building while awaiting collection.
- Securing buy-in from residents and office workers to ensure that materials are allocated to the right containers and put out at the right times.
- Balancing the need for regular pick-ups with the transport and disruption that entails.

In many cases, developers build to sell buildings, not to manage them, so their priorities are the price of construction, meeting regulations, and, crucially, the kudos needed for an effective sale. Sustainability is not yet a kudos factor in any very sophisticated sense, so perceptions of what is 'green' become confused and can amount to 'green bling'.

Management of CDW during the refurbishment phase

The refurbishment stage of the lifecycle produces a multitude of different materials. In the past, much of this was recycled if it was easy; but with the cost of disposal so high, increased waste segregation and philanthropic endeavor reward the innovative. Many companies are changing their approach to maximise the reuse of materials while fulfilling obligations under tough targets set by the BREEAM assessment system (the Building Research Establishment Environmental Assessment Method). This was created to help investors, developers, design and construction teams and occupiers to use natural resources more efficiently²¹.

For example, Encore, an estate management company, has a client whose office refurbishment project was not expected to achieve accreditation to a BREEAM level. By collaborating with their supply chain, Encore was able to successfully complete the project, diverting 100% of the material and sending less than 2% of waste to energy-from-waste processes²².

More can be done to affect design at the appropriate stage, helping the design team to make informed decisions regarding materials reuse without hampering creative design. By connecting all partners in a cooperative effort to make the outputs align to client sustainability goals, the project has been a huge success. This may be an area where Government Soft Landings and BIM can assist further. There are still barriers to being able to fully exploit this approach, but Encore and companies like them are currently researching the potential for even greater collaborative supply chain and waste disposal.

Management of CDW from the end-of-life phases

The demolition waste arising from the end-of-life phase includes insulation, electrical wiring, rebar, wood, soil, concrete and bricks. It also may contain lead, asbestos or different hazardous materials.

Case Study

Crossrail

Lorna Russell, Environmental Assurance Manager, Crossrail Ltd

The construction of Crossrail has generated over 7 million tonnes of excavated material from stations, tunnels, portals and shafts, of which over 98% was beneficially reused. Crossrail specified the destination sites and means of transportation for the material, but also allowed some of the individual contractors to make their own arrangements for beneficial reuse as appropriate. This 'client-led' approach meant that a significant proportion of the material was used to create a landmark nature conservation project at Wallasea Island on the Essex coast. It also reduced the programme risk associated with a potential lack of suitable disposal sites during the main tunnelling and excavation works; enabled the development of infrastructure to transport material by water; and, from the early stages of the project, allocated rail paths to carry more material. Together, this ensured that 80% of the excavated material's journey (measured in tonne km) was made by rail or water.

Crossrail prepared an initial strategy for excavated material alongside the Environmental Statement, which assesses the likely environmental impacts of the project. The

early adoption of a client-led solution enabled us to identify the preferred end-use beneficial reuse destination sites, along with the need for supporting infrastructure (such as transfer stations and wharfs, and early planning of rail paths).

As design works progressed, Crossrail identified the Wallasea Island project as a possible destination site for the excavated material, and entered into a partnership with The Royal Society for the Protection of Birds (RSPB) to support the development of a nature reserve in Essex. To transport material to Wallasea, Crossrail constructed two new transfer stations: the Docklands Transfer Site in Barking, which received material by road from central London stations, shaft and portal excavations; and the Northfleet site in Kent, which received material by rail from the western tunnelling portal. It also developed wharf facilities at Wallasea, the Docklands Transfer Site and Northfleet.

Crossrail awarded a number of contracts for enabling and main construction works that involved the excavation of material. The reuse requirements for the material were incorporated into the contractual Works Information, which ensured that Crossrail's approach was cascaded to the construction contracts. Crossrail also appointed a contractor to operate the Docklands Transfer and Northfleet transfer stations, to transport material to Wallasea Island, and to place the material at the island. In total, just over 3 million tonnes of excavated material was taken to Wallasea Island.

The remaining 4 million tonnes of material went to a number of other beneficial reuse sites (see Map). For example, two alternative sites handled excavated material from early contracts before the preferred site was available; others

took material that was not suitable for disposal at Wallasea. In total, 98% of the material excavated during the construction of Crossrail has been reused to bring new life to nature reserves, recreational facilities, agricultural and industrial land in London and the south-east.



Map: The destinations of Crossrail excavation wastes

1. Wallasea Island: over 3 million tonnes used to create a 1,500-acre wildlife habitat at Wallasea Island in Essex
2. Ockendon: landfill restoration engineering prior to creating a wildlife reserve
3. Pitsea Landfill: supporting restoration of RSPB nature reserve
4. Kingsworth: raise land to allow for construction of a commercial park
5. Goshems Farm: grazing pasture for livestock
6. East Tilbury Quarry: supporting restoration of RSPB wetland nature reserve
7. Ingrebourne: golf course
8. Fairlop Quarry: agricultural use and nature conservation
9. Rainham landfill: landfill restoration
10. Calvert Landfill: landfill restoration



12%

of global water consumption by construction

The desire to offset project costs by maximising the income value of materials recovered from demolition, along with the continued increase in disposal costs and tax, has driven the demolition industry to achieve very high levels of recycling and reuse while minimising disposal to landfill. Demolition waste has long been broken down and used as foundations and sub-bases for new construction, roads and other pavements. This is often referred to as industrial symbiosis, which the Waste and Resources Action Programme (WRAP) defines as an "association between two or more industrial facilities or companies in which the wastes or byproducts of one become the raw materials for another"²³.

There are many applications of this concept. One is the movement towards, and encouragement for, recycling of old concrete as crushed aggregate for new concrete. Another comes from Germany, where calcium sulfate that is available as an industrial by-product is used to make gypsum plaster; by careful factory blending with inert fillers and other constituents. This competes on an equal basis in the UK market place with the familiar pink gypsum plaster that is processed from a natural deposit²⁴.

There are many new companies looking to make this process as simple as possible for demolition contractors. Globechain has created an online platform that connects businesses, charities and people to enable them to reuse unwanted items within a global supply chain network. The aim was to create a way of

providing a waste audit while giving some social impact value for members. One of their case studies shows the benefits for their client, Keepmoat, which reduced its total waste and handling of controlled waste by finding reuse opportunities for items ranging from medical equipment (such as shower seats and grab rails) to electrical products (such as microwaves and fridges), as well as upholstered chairs and furniture. For this project, 0.451 tonnes of material was diverted from landfill with an approximate saving of around 25% of the costs incurred in waste disposal²⁵. While these figures may look low compared to the vast tonnages in the Crossrail project, this is a really important demonstration that many hazardous materials can be moved up the waste hierarchy, rather than going to landfill.

Current strategies and performance

The European Environment Agency (EEA) stated in its 2013 report, 'Managing Municipal Solid Waste', that: "Improved waste management is an essential element in efforts to make Europe more resource efficient. If a country is to generate greater economic returns at lower costs to the environment then it must find ways to extract more value from the resources that it takes from nature, while cutting the burden of emissions and waste."²⁶ The view from Europe matches our own in the UK, and since the turn of the century there have been some very innovative UK programmes, including Pathway to Zero Waste (PTZW), the European Pathway for Zero Waste (EPOW), the creation of the site waste management plans, the introduction of landfill tax and the creation of tools such as BREEAM and Leadership in Energy and Environmental Design (LEED).

This has not happened by accident. One of the key facilitators has been a twenty-year strategy called 'Developing a strategic approach to construction waste'²⁷, which was unveiled in 2006 by Defra in collaboration with the Building Research Establishment (BRE) and AEA Technology (see <<Ch8 CS Roadmap>> case study on pxx). The progress made under that strategy shows that there is some innovation taking place in the sector. But innovation needs to change from the application of good ideas to

a process that can be systematically managed, measured and controlled.

The circular economy

In 1981, Walter Stahel and Geneviève Reday-Mulvey published 'Jobs for Tomorrow: The Potential for Substituting Manpower for Energy'³², in which they sketched their vision of an economy interconnected by loops – cycles of interrelated materials – and its impact on job creation, economic competitiveness, resource savings, and waste prevention. They called this model the 'circular economy'. They highlighted the importance of selling services rather than products, an idea referred to as the "functional service economy" and sometimes put under the wider notion of "performance economy" which also advocates "more localisation of economic activity". Since then, the circular economy has become an increasingly influential concept (see <<Ch8 CS Circular economy>> case study on pxx).

As more evidence is gathered from the growing number of circular economy projects, it should enable more cohesive design and construction. For example, the UK's largest regeneration project, managed by the Old Oak and Park Royal Development Corporation

£653m
predicted savings through increased efficiency by 2025

Case Study

Design for manufacture and assembly at the Leadenhall Building

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At 225m high and 52 storeys, the Leadenhall Building is the tallest structure in the City of London. It was designed by Rogers Stirk Harbour + Partners and Arup, and constructed by Laing O'Rourke for the client, British Land. The distinctive wedge-shaped building has no central core and is stabilised by the expressed exo-skeletal frame.

Using Building Information Modelling (BIM) to enhance the design and facilitate collaboration, Laing O'Rourke worked with the client and design team to maximise the use of 'Design for Manufacture and Assembly' (DFMA). More than 85% of the building (by value) was constructed using components manufactured off-site.

For example, the stair cores – the stairway shaft and walls, with stairs cast inside – were made of precast concrete, rather than traditional, non-structural materials such as plasterboard partitions. This facilitated the early installation of prefabricated mechanical and electrical vertical risers (cavities that carry pipework and wires). Laing O'Rourke also developed a precast lightweight floor slab with grouted joints and precast internal walls and columns. These measures completely eliminated the need for concrete and reinforcement to be prepared on site, normally evident on high-rise buildings. These improvements not only helped prevent waste, but also shortened the programme and reduced the number of workers required to deliver the project.

Compared with other multi-storey, premium London-based office buildings with a shell-and-core design, Leadenhall produced much less construction waste thanks to the use of DFMA principles (see Fig. 1). Construction waste savings began to occur after about four to five months, coinciding with the completion of the groundworks and preliminary works, and the introduction of DFMA structural products.

In addition, the tonnage of construction waste arising per 100m² as a result of using off-site components was 60% less than that from in situ construction processes (see Table 3).



Figure 1: Construction waste generated by off-site and in-situ construction (measured in cubic metres of waste per 100 square metres of gross internal floor area (GIFA))

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	Gross Internal Floor Area (GIFA) (m ²)	Construction Waste (m ³)	Construction Waste (tonnes)	Construction Waste (m ³ /100m ² GIFA)	Construction Waste (tonnes/100m ² GIFA)
Leadenhall Building (off-site)	86,400	12,126	4,864	14.0	5.6
Cannon Place (in situ)	36,200	21,242	5,108	58.6	14.1
Merchant Square (in situ)	29,800	9,557	N/A	32.1	N/A

Table 3: Construction waste metrics

(OPDC), is collaborating with the LWARB to consider how the circular economy can be used as part of the regeneration and urban intensification process to deliver economic growth and jobs while reducing waste, pollution and carbon emissions. The outcomes of this project should give more evidence on the opportunities for the construction and demolition sector.

Conclusions

The chapter has given an overview of the predominant technologies, methods and opportunities arising from a considered approach to strategy, policies and business models for dealing with CDW. These include designing buildings to manage the flow of waste as a utility; BIM; use of circular economy principle; the impact of waste on social spaces within buildings; and self-sufficiency as a result of material management. Based on this evidence, the following recommendations offer a route to continuing the progress made by the construction and demolition sector since the turn of the century.

1. The UK government should continue to promote and use Government Soft Landings and BIM, by specifying that all new infrastructure they commission adopts these frameworks. This should be expanded to the whole public sector.

2. More focus should be placed on the whole lifespan of a development, and how recycling and waste management will be conducted during the operational lifetime to maximise the waste hierarchy and meet local targets
3. The concept of the circular economy, while already reflected in concepts such as BIM, must become intrinsic to new infrastructure developments.

The use of long-term strategies has been proved to give the sector confidence, vision and leadership. Now is the time for further impetus from government.

