

Designing Out Construction Waste

A guide for project design teams



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1 Foreword from Zero Waste Scotland

Constructing a circular economy

The circular economy is one that's sustainable, and as much as possible eliminates waste. It's about developing new business models, designing products more smartly, remanufacturing and reprocessing to create new products from old, and repairing what we can – all to keep products and materials within the economy for as long as possible.

Moving to a circular economy contributes to the Scottish Government's aim of sustainable economic growth as it has the potential to increase productivity and create jobs, while reducing carbon emissions and preserving valuable raw materials. The Government published Scotland's first circular economy strategy, **Making Things Last** in 2016.

Construction is identified as a priority sector within that strategy. Over 4.4 million tonnes of construction waste was produced in Scotland in 2014, making the sector the country's single largest waste producer. Zero Waste Scotland works with organisations in the construction sector to help them design out waste, develop resource efficient products, minimise waste in refurbishment and maximise re-use.

This guide highlights the opportunities to adopt more circular approaches and to design out waste across the entire construction process. Importantly, the guide also highlights the role of good decision-making throughout the entire construction process, and that design is not just decided by the architect, but is informed by many professionals across many disciplines, including project managers, quantity surveyors, mechanical and electrical engineers, facilities managers and other related disciplines involved in designing and building within the industry.



Iain Gulland
Chief Executive
Zero Waste Scotland

2 Introduction – the circular economy in the built environment

Who is this guide for?

This guide is aimed at anyone involved in making decisions at the design stage of construction projects. This could include:

- architects;
- quantity surveyors;
- engineers;
- construction project managers; and
- clients.

In considering the advice given here, you will gain an understanding of the practical considerations and interventions that can be made throughout the design and construction phase of a project to minimise material waste during construction and the lifetime of the resultant building.

After this introduction to the guide and an explanation of the circular economy, **Section 3** presents the five principles of designing out waste, which are key tenets of this concept.

Historically, responsibility for construction waste has generally been placed with contractors. However, effectively designing out waste requires a more collaborative approach with different actions placed on contractors, clients, engineers, architects and designers. Communication between all of these project team members is absolutely crucial to success. **Section 4** of this guide highlights the importance of clear and effective communication between the architect and design team, other members of the project team (such as contractors and engineers) and, most importantly, the client. It emphasises the key points in the design and construction process where communication is vital.

In **Section 5**, the principles of designing out waste are expanded into a series of action points and applied to some general concepts of building design. The practicality and tangible benefits of these action points are evidenced by case studies and real-world examples. The objective of this approach is to provide clear, pragmatic guidance on the opportunities for designing out waste and the benefits of adopting these principles.

In **Section 6**, the action points and recommendations for consideration are mapped against the Royal Institute of British Architects (RIBA) Plan of Work 2013 to illustrate where in the design and construction process they can be applied.

Through this approach, design teams, contractors and clients can all gain insight into and an appreciation of the benefits of considering designing out waste opportunities, and working together as part of a whole project team to make them a reality.

The circular economy

Designing out waste is one of the key tenets of the **circular economy** – a concept inspired by observing the flow of resources in nature. In the living world, there is no landfill for waste materials and resources flow in a cyclical way.

Many sectors, including construction, operate largely within a linear economy model, which assumes resources are abundant and we can make, use and dispose of them without consequences. Policy makers are now looking at more sustainable and restorative models, which will allow resources to flow in a circular way, eliminating waste wherever possible.

In practice, the circular economy is an all-encompassing approach to life and business. Circular economy interventions include developing new business models, smart product design, remanufacturing and reprocessing to create new products from old, and repair – all to keep products and materials within the economy for as long as possible. Applying circular economy ideas means creative and innovative use of new technologies to extend the life of valuable resources, but it will also require a change in attitudes and operating systems.

Zero Waste Scotland is at the forefront of driving Scotland's transition to a circular economy, supporting the implementation of the Scottish Government's circular economy strategy **Making Things Last**.

The strategy highlights four key priority areas for the Scottish Government, one of which is construction and the built environment, which accounts for around 50% of all waste generated in Scotland.



Figure 1. Zero Waste Scotland and the circular economy

Construction, due to its heavy reliance on resources, and with over 100 million tonnes of waste produced annually¹, has a huge potential for circular economy interventions, which in turn can:

- reduce demand for, and waste of, virgin materials;
- help to tackle climate change (by 2050, a more circular economy could reduce carbon emissions by 11 million tonnes a year);
- deliver a more competitive Scottish economy (remanufacturing is already contributing £1.1 billion per year to Scotland's economy and has the potential to grow by a further £620 million by 2020, adding 5,700 new jobs);
- mitigate resource security and scarcity issues; and
- address the subject of corporate social responsibility (CSR).

Traditionally, waste reduction in design and built environment settings was a response to legislation and rising landfill costs. As a result, although materials are diverted from landfill, their value is often degraded, preventing them from re-entering the system (for example, downcycling materials to aggregates for construction fill or recovery as refuse derived fuels (RDF)). With resource scarcity becoming a clear threat to current operating systems, preventing waste at source through design is a priority. As many construction materials are considered to be of low value, any actions aimed at recovery are seen as an added cost. Therefore, the idea of circular economy design should be applied from the inception of any project.

There are several fundamental principles that underpin circular economy thinking. Table 1 demonstrates how these concepts can be applied to the construction and built environment sector, and emerge as opportunities for designing out waste.

Table 1. Circular economy principles and related designing out waste opportunities

Circular economy principles	Example designing out waste opportunities
Prevention	Design for sequential access to relevant services to prevent material damage during maintenance or repair
Share	Allow flexibility within design to acquire unconventional items if necessary and to allow for the potential for material exchange
Life extension	Design to use durable components and fixings
Re-use	Prioritise the sourcing and use of re-used materials
Refurbishment/remanufacture	Consider the use of temporary or relocatable structures
Open-loop recycling	Design to specify the use of recycled materials where possible

¹ Defra. Digest of Waste and Resource Statistics – 2015 Edition

3 Principles of designing out waste

There are five key principles around how to design out waste. As with many ideas within the theory of circular economy, these principles are not discrete, disconnected topics for consideration. Instead, they can all play a part within, and complement, the others. Section 5 of this guide demonstrates how these principles can be applied to recognised concepts of building design.

Design for waste-efficient procurement

This is a facet of the efficient management of the overall construction process. It involves early and ongoing communications between clients, design teams, contractors and sub-contractors, and a review of any specifications that may restrict waste reduction options. If departures from standard specifications are required to enable waste reduction, these are more readily implemented if identified by the design team and discussed with the client and contractor.

Design for materials optimisation

This principle focuses on making the most efficient use of resources without compromising design or quality. Design solutions that lead to a significant reduction in waste generated and costs consider the minimisation of excavation, simplification and standardisation of materials and components, and dimensional coordination.

Design for off-site construction

The concept of industrialised prefabricated building, based on the principle that as much of the work as possible is done in a factory environment, leaving simple assembly operations to take place on site, is not a new one. Off-site construction can result in changes to on-site practice and may require different specialist skills. Therefore, it should be specified early in the design process. Off-site manufactured components should incorporate the principles of designing out waste in their own design.

Design for re-use and recovery

This principle focuses on the whole life cycle of the materials used, extending their life and preparing for recovery. Actions relating to this can involve re-using existing structures on site, sourcing reclaimed products such as roof slates or timber components, excavation arisings (such as using intelligent cut-and-fill methods to minimise waste generation and the need for virgin materials) or crushed demolition materials.

Design for deconstruction and flexibility

Design for flexibility of use and deconstruction, as well as climate adaptation, is a principle focusing on the whole life cycle of the building and is strongly linked to the design for re-use and recovery principle as it allows for materials to be re-used at the end of their life. Examples of this idea can include the use of partitions to allow spaces to be reconfigured or the use of bolts instead of adhesives for deconstruction.

4 Communications

If the ideas and principles of designing out waste are to be successfully applied to any project, effective communication across the project team is absolutely vital. Every team member or stakeholder involved in the design, construction and ongoing management of the project and resultant building should be engaged as early as possible. This will ensure that the importance, benefits and implications of designing out waste are fully understood. Technical team members such as contractors, construction engineers and facilities management teams of the finished building can all bring extremely valuable insight on the practical implications and delivery of any designing out waste opportunities. All team members and stakeholders should be encouraged to raise queries and concerns as soon as they arise. This means they can be addressed and resolved before causing disruptions or barriers to the effective implementation of the designing out waste plan for the project. It is also important to engage as early as possible with the relevant planning, building regulation and other statutory compliance authorities. Communication with these bodies should include discussion of the planned designing out waste strategy and measures.

The key stakeholders to be included in this communications strategy are:

- clients;
- architects;
- quantity surveyors;
- structural engineers;
- civil engineers;
- mechanical and electrical engineers;
- project managers;
- contractors and suppliers; and
- facilities management teams.

All of these parties can form part of the design team, and strong communication between them is fundamental to all design decisions. The most effective way for this to be successfully delivered is for it to be driven by a fully engaged client. Therefore, it is crucial for design teams to engage with clients and communicate the benefits of designing out waste early in any project.

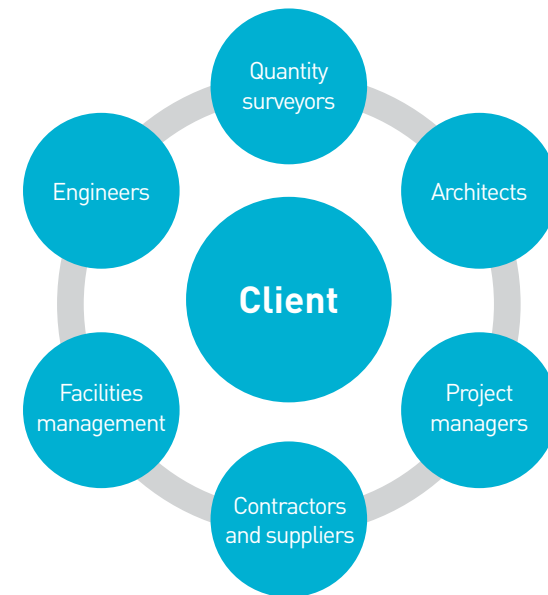


Figure 2. Communication throughout the project team

Engaging with clients

The most important line of communication for the architect or design team is with their client. At a project level, it is critical to secure client support for the objectives of designing out waste. Different types of clients, such as public or private sector clients, may have different key motivations and drivers but the potential benefits of designing out waste can always make a compelling case. These potential benefits include:

- fulfilling overall corporate waste reduction, CSR or environmental targets;
- optimising the future value of the building; and
- minimising future costs (associated with refurbishment works and waste disposal).

A powerful way of engaging with clients on the concepts of designing out waste can be found in Stewart Brand's book 'How Buildings Learn' (Viking, London 1994)

Visualising a building as a series of 'shearing layers' (see Figure 3) can make it easier for the client to understand that, over the lifespan of a building, some elements will be removed and replaced far more frequently than others.

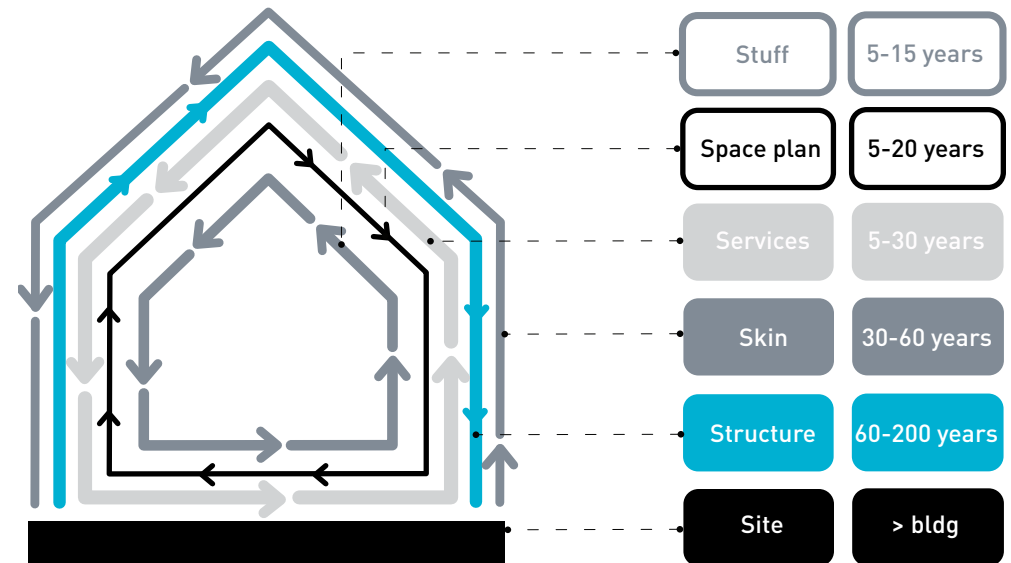


Figure 3. A building as a series of 'shearing layers'

Sketch: John Gilbert Architects based on 'How Buildings Learn', Brand (Viking, London 1994)

Buildings designed with flexibility and strong environmental credentials will be attractive to occupiers and potential investors, adding value and minimising development risks.

In 'The Changing City' (Bulstrode Press, London 1989) Francis Duffy demonstrates the benefit of looking at the long-term costs of building elements over a period of 60 years. Figure 4 clarifies the proportional difference between initial capital costs and the long-term cumulative costs to the building owner and occupants. This can be an influential demonstration of the long-term benefits to be gained by minimising the costs, disruption and waste associated with the inevitable upgrading of buildings.

A building that has demonstrably lower long-term costs will be attractive to all clients, whether they will be retaining ownership and meeting those costs themselves or if they are interested in potential marketable sell-on benefits. Alongside the obvious long-term financial attraction, approaching the project with designing out waste as a priority can also provide a cost-effective way of gaining credits for BREEAM and other accreditation schemes.

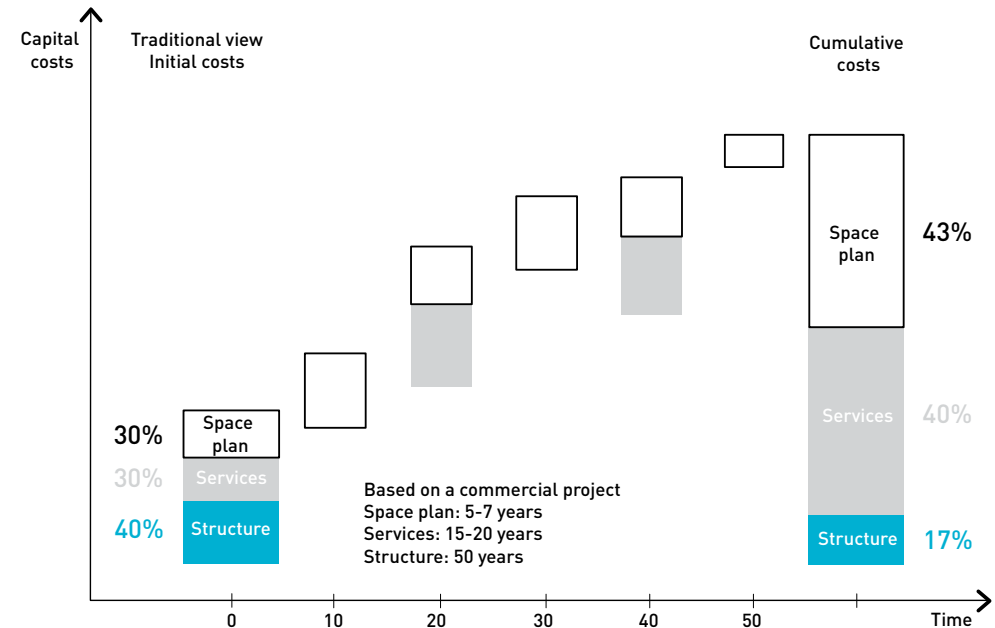


Figure 4. Long-term cumulative building costs

Sketch: John Gilbert Architects based on 'The Changing City', Duffy and Henney (Bulstrode Press, London 1989).

Case study **Model D house**

Architecture and Design Scotland's case study of the Model D house in Pitmanachie near Insh, Aberdeenshire, highlights the benefits of a strong relationship between the client, architect and project team.

The house was designed to demonstrate an affordable building option for rural communities, uses local natural materials and offers a highly adaptable living space.

'The relationship between the architect, client and manufacturer, in this case, was critical in delivering this affordable housing project to the target specification. The two parties did not follow a traditional contractual relationship, but instead recognised the strengths of each throughout the entire process – from concept design through to completion. This was aided by the extensive research that was undertaken during the design stages on various aspects of the house, its design and specification. The house represents the outcome of an innovative approach to developing and delivering low cost, low energy housing.'

More Information

Photograph and design: Gokay Deveci, ARB RIBA FRIAS



Section 6 of this guide maps the recommended measures, interventions and considerations of designing out waste to the RIBA 2013 Plan of Work stages. Figure 5 highlights the key points in that process where clear and unambiguous communications between the architect/design team, the client and other project team members are crucial.

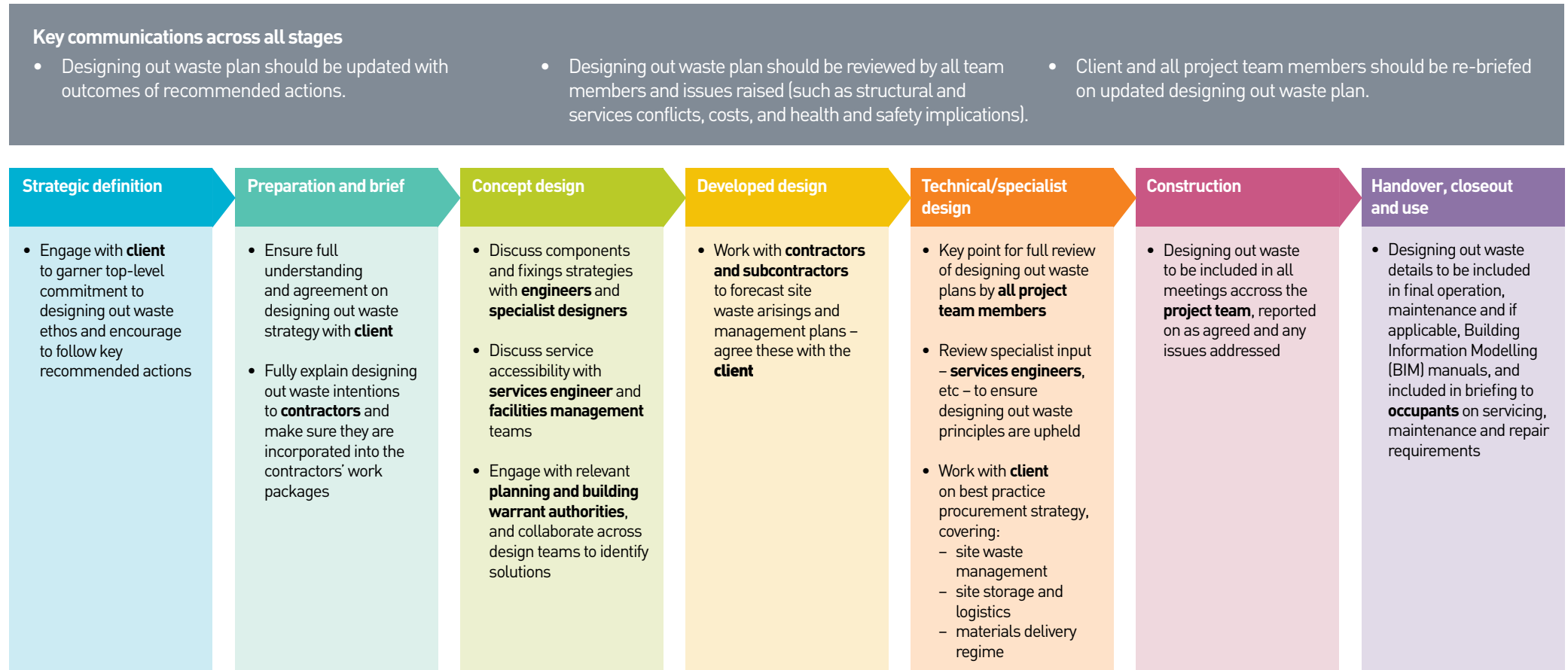


Figure 5. Key communication points

This reproduction and use of the Plan of Work has been granted permission by the Royal Institute of British Architects.

5 Applying the principles to the concepts of building design

5.1 Management/information

The designing out waste principles introduced in Section 3 and their related actions (as described throughout Section 5), need to be set within a management and reporting framework to be implemented effectively. To catalyse a transition to a true circular economy, this management approach will need to be set up in all sectors of the construction industry, from funding and procurement bodies to demolition contractors. At the design stage of a project, the three main groups who can act to implement effective management processes are:

- clients;
- design teams; and
- contractors.

Actions for clients

Establish high-level support for waste prevention

Regardless of the scale of waste reduction, it is clear that when everyone involved is genuinely motivated, and provided with management support during the process, results will be tangibly improved. Motivation can come from many sources, but best results are achieved when the client is enthused and dedicated to achieving waste reduction.

The example here demonstrates what is possible when a client is highly motivated to reduce waste and, while this may well not be replicable on all projects, serves as an exemplar of what is possible.



On this new-build house in Fife, the client installed a dustbin for waste only. No skips were allowed and waste was sorted on a daily or weekly basis. The client diligently separated all arisings taking them to the local council recycling centre, relevant charities or via websites such as Freecycle and Gumtree.

Photograph: Graham Drummond, Passivhaus Associates

Ensure waste reduction clauses are embedded within appointment/contract, briefing and tendering documentation

Establishing targets and reporting structures needs to be supported and complemented by suitable additions or alterations to standard procurement templates in respect of the client organisation's engagement with others involved in the project. In large organisations, this can be complicated by the fact that different departments or individuals are responsible for different contractual arrangements, so a concerted effort to integrate the subject is required.

In construction projects, it can be useful to ensure the information is contained within the documents issued and that a separate briefing exercise, perhaps as part of the tendering process, is undertaken to highlight and explain the aspirations of the client.

Taking this approach gives a legal standing to the targets and will create a binding key performance indicator that gives the client recourse should these targets not be met.

Set waste reduction targets at corporate and project levels along with monitoring and reporting processes

Waste reduction targets need to be made at a corporate level to achieve alignment with all other targets and reporting requirements that the client has committed to. Construction activities will be an important part of these and each project will require its own targets. Thereafter, a robust monitoring and reporting process will need to be implemented to follow progress and achievements against the wider corporate and project-specific targets. Progress needs to be monitored with reporting stages established at the outset.

Identify a 'designing out waste champion'

Identifying a key individual or team explicitly responsible for delivering the savings and benefits will provide impetus to achieve results throughout the process and beyond. An in-house champion or team of champions should be selected, who will be responsible for all reporting to management, communication down the chain of command and for ensuring the integration of the subject across all stakeholders within the organisation. The champion will also be the key liaison person for design teams in construction projects. The benefit to the client of this approach is that there is a single point of contact for all stakeholders, and information and progress can be quickly and easily shared for reporting purposes.

Allow flexibility to acquire unconventional items if necessary

An important principle of designing out waste is that opportunities may arise to acquire materials or components beyond conventional procurement routes. The client may identify certain items or these can be sourced by a contractor working on more than one site at a time. The key is to establish a protocol that allows for this within the contract, and allows for secure and dry storage.

The potential benefits of having an engaged, ambitious client who is willing to set project-specific waste-reduction targets and reporting requirements for the entire project team, are excellently demonstrated by the following case study on a development delivered by the architects at Austin-Smith:Lord for South Lanarkshire College.

Case study South Lanarkshire College

South Lanarkshire College project delivered by Austin-Smith:Lord

South Lanarkshire College set out a brief to design a flexible, low-carbon teaching building with eight classrooms. The project received funding from the European Regional Development Fund and South Lanarkshire Council's Renewable Energy Fund. The College management team decided to aim for a BREEAM 'Outstanding' building, in line with their values and strategic aim 'to promote sustainable behaviours'.

South Lanarkshire College was committed to designing out waste from the inception and partnered with BRE to develop a BREEAM pre-assessment for the project. Austin-Smith:Lord developed a detailed understanding of how the building needed to perform by carrying out several consultations with the client teams and the key stakeholders in the project – from the potential building users to the facilities management and maintenance staff, who are key to the daily operation of the completed building.

Austin-Smith:Lord then worked with project consultants to develop a low-energy-building design, using a fabric-first approach that starts with the creation of a highly thermally efficient building enclosure. As the design developed, issues relating to the building materials to be used were addressed.

This attention to detail proved its benefit at the tender stage. It was stipulated that the contractor must recognise the importance of these issues and would be monitored throughout construction. Any alternative materials or equipment proposed could then be evaluated against environmental and financial criteria.

- Materials efficiency study reports, prepared during the design stage, were issued to the main contractor, CCG (Scotland) Ltd, prior to the build. Several key waste minimisation steps were identified:
 - All excavated material would stay within the campus, being spread on top of the existing bunds formed around the perimeter. Any spare construction materials or sizeable offcuts would be given to the College for use by the construction students.

- Masonry ordered was only just enough for the construction, with any remaining stock being given to the College.
 - The plasterboard supplier operated a leftover materials return procedure, so any waste generated could be incorporated back into the production process.
 - Several skips were made available for specific materials, so that all waste generated on site could be segregated and identified for reUse where possible.
 - Monthly waste analysis reviews, carbon footprint calculations and water use reports were displayed on site for everyone to see.
- Excavated material from the site has been incorporated into landscaped areas around the new building. Topsoil was also re-used by the Horticultural Department located in the adjacent building. This avoided 287 tonnes of waste, approximately 11% of the total weight of material in the project.
- Austin-Smith:Lord chose to specify materials with a high recycled content. The main construction elements targeted were:
 - Concrete used in foundations, ground and first floors (156 tonnes), and concrete blockwork (52 tonnes). The concrete foundations and floor slabs used 40% of ground granulated blast furnace slag (GGBS) into the concrete mix, reducing the use of newly excavated aggregates.
 - Steel frame (9 tonnes). The main steel structure was made off site, with any waste generated being recycled into new steel.
 - Recycled newspaper insulation (5 tonnes).
 - Carpets (5 tonnes).
 - Ceiling tiles (14 tonnes).

By using materials with a high recycled content, the project avoided using approximately 241 tonnes of raw materials, which equates to around 10% of the total weight of materials used in the project.

More information

Actions for design team

Depending on the type of contract and the stage of work, the design team may include contractors and associated engineers, or it may be just a single architect. The opportunities presented here are relevant and adaptable across the possible spectrum of team size and complexity.

Agree project-specific targets, reporting and methodologies

Setting well-defined and realistic targets to minimise project-related waste gives clarity to the aims of the project and can serve to focus efforts across the team towards achieving a shared goal.

The specific targets and reporting requirements may be set by the client as part of their brief or they may be discussed and at an early stage. These may be fixed or flexible, but some form of target, reporting methods and timescales, and associated method statements will usually be required.

Again, the clear communication and definition of these requirements should negate the possibility of any misunderstandings, and ensure the project progresses successfully.

Identify a 'designing out waste champion'

For exactly the same reasons as noted for clients above, it is usually best if one key individual (or team) – the champion – is made explicitly responsible for delivering the savings and benefits discussed. As with the client, the champion is then responsible for all reporting, and will be the key liaison person for the client and contractor. Importantly, the champion should also be responsible for briefing all other members of the design team and ensuring that the subject of designing out waste and the contractual obligations are fully understood across all disciplines and included in all relevant project documentation.

Prepare a deconstruction plan

A deconstruction plan identifies every component of the building and details how they can be located, accessed, repaired and eventually removed if necessary. All elements of the proposed building should be identified on drawings, schedules or digital models and include relevant information such as material characteristics (for example, toxicity), fixings, location and access arrangements. The purpose of the plan is to enable anyone who may work on the building in the future to easily identify how to access, repair, maintain or replace each item without excessive disruption and time. Identifying and prioritising items with a shorter anticipated lifespan or greater maintenance requirement is helpful in this process.

The deconstruction plan is given to the contractor at the start of the construction phase so that the relevant sections can be completed during the build. It will then be given back to the client as part of, or alongside, the health and safety file, and operation and maintenance manuals, etc.

Establish potential re-usable site assets

It can often be the case that a proposed construction site is considered as a blank canvas upon which a new vision, perhaps unrelated to the specifics of what may already exist, can be developed. The value of circular-economy thinking is that everything is considered a potential resource. In this way, the site, as found, may well yield significant resources when considered as a potential source, from whole buildings and landscaping to individual items recovered from demolition.

For example, it has become commonplace to factor in the ability to reuse aggregates within the build programme. Either through utilising waste products from excavation as spoil to level out the site or to produce type 1 aggregate for use on site.

Opportunities such as these should be carefully appraised, including potential risks of re-use (such as toxicity or provenance), and methodologies set up to enable the optimum recovery of assets on site, bearing in mind the potential cost savings achievable.

Prepare a Site Waste Management Plan

While the deconstruction plan addresses the design and long-term maintenance issues of the building, the Site Waste Management Plan (SWMP) addresses the site and construction process. The SWMP is a key document for specifying and improving waste reduction strategies. It should be developed at an early stage of the project by the design team and/or quantity surveyor.

A SWMP should be agreed with the client as part of the design stage, and should:

- detail all of the waste streams and their volumes that are expected to arise from the project site;
- explain how these materials will be managed efficiently and specify how re-use and recycling of materials will be maximised;
- detail the strategy for material movement and disposal; and
- be used as a recording tool for actual waste arisings, movements and disposal, and comparison with project targets.

Many construction contractors and procuring clients will already have SWMP templates. For those that do not have one, an easy-to-use tool is available from Zero Waste Scotland available [here](#). It will help you:

- estimate the waste generated in a project and identify actions to reduce its costs;
- record actual waste movements; and
- review project performance.

Check that all drawings and specification convey waste reduction principles

A specific task of the designing out waste champion is to ensure that the principles established in the plans are constantly and consistently applied across all documentation. This can be challenging as the project team may become increasingly complex and multi-dimensional. Therefore, it is very important that the champion reviews all documents from other design team members, contractors and specialist sub-contractors.



Reporting to client, including cost implications

As part of the general and regular reporting to the client, waste reduction progress should be included in the same way that health and safety issues are generally reported (that is, on an ongoing basis). Cost reporting will be a regular feature of progress meetings and it is important that cost issues related to designing out waste are managed as part of this process.

Actions for contractor

Depending at which stage a contractor becomes involved in a project, and what has already been decided by the client and design team, contractors and certain specialist subcontractors may have input and influence on all of the actions described above. Several of these will lead to outputs relevant across the whole project, but there are two that the main contractor should also implement independently within its own team:

- agree project-specific targets, reporting and methodologies; and
- identify a 'designing out waste champion'.

Applying these measures independently will allow the contractor to ensure that appropriate and effective lines and methods of communication are established with other project team members, and keep the project as a whole on course and meet its wider aims.

Best practice management of deliveries, packaging and storage

An important aspect of designing out waste at source is managing the high levels of packaging that arrive on site. The effective management of this should form part of the SWMP agreed with all project team members, but it is of specific relevance to contractors as they will have the responsibility for delivery of this part of the plan.

In some cases, the packaging is necessary to protect certain vulnerable items from damage, contamination, moisture and weather. However, with suitable storage and transportation arrangements on site, it is usually possible to remove the need for the majority of packaging. Negotiating with suppliers and delivery companies can be helpful in reducing the amount of packaging used. Many items, such as cardboard, can be harmlessly recycled or even composted on site. Another option is to stipulate the use of re-usable packaging that can be returned for continued use (that is, plastic or timber crates rather than cardboard or shrink wrap).

Although, as stated, this element of site waste management will predominantly be the responsibility of contractors, it can be noted as part of the overall project objectives and designers can support the effort through the specification choices made.

The **South Lanarkshire College** case study demonstrates how taking the time early in a project to stipulate best practice site waste management and having strong communication between the design team and on-site contractors, can ensure that waste produced during the construction phase is kept to an absolute minimum.

5.2 Adaptability

The most effective intervention possible to effect genuine waste reduction is to avoid generating it in the first place. The ideas described in this section all consider strategies for prolonging the useful life of a building by allowing for a variety of use or occupation patterns, these strategies can also minimise the amount of waste that is generated as part of any alterations.

Temporary or relocatable structures

In most of the examples and action points suggested in this guide, it is assumed that the majority of the building will remain, while some elements are altered. However, using temporary or relocatable structures is a way of avoiding waste. When the service life is over, the entire structure can be removed and relocated as and when it is next required. In theory, there is no waste whatsoever from its use. Many practical applications of this principle have their roots in traditional forms of nomadic housing or temporary structures – a tent is a good example of this. Adapting those ideas to modern construction is becoming an increasingly popular and viable option.



Relocatable structures can take many forms. Here a partly completed module is craned into position.

Photograph and design: Carbon Dynamic.

The Resource Efficient House case study on [page 27](#) demonstrates the waste minimisation benefits of considering the use of relocatable structures and incorporating a high degree of flexibility within the design.

Flexible layouts

The following three examples involve the spatial arrangement of buildings or spaces with the same goal in mind – anticipating potential future alternative uses and, as far as is possible, adjusting the design to facilitate this. Separating these ideas allows for greater clarity about the specific possibilities available.

Flexible layout 1 – adjacencies

The first example considers the potential alternative arrangements of a building, anticipating a variety of occupation patterns or functions and locating spaces to allow for these alternatives with minimum disruption – and future cost – to the building owner or manager.

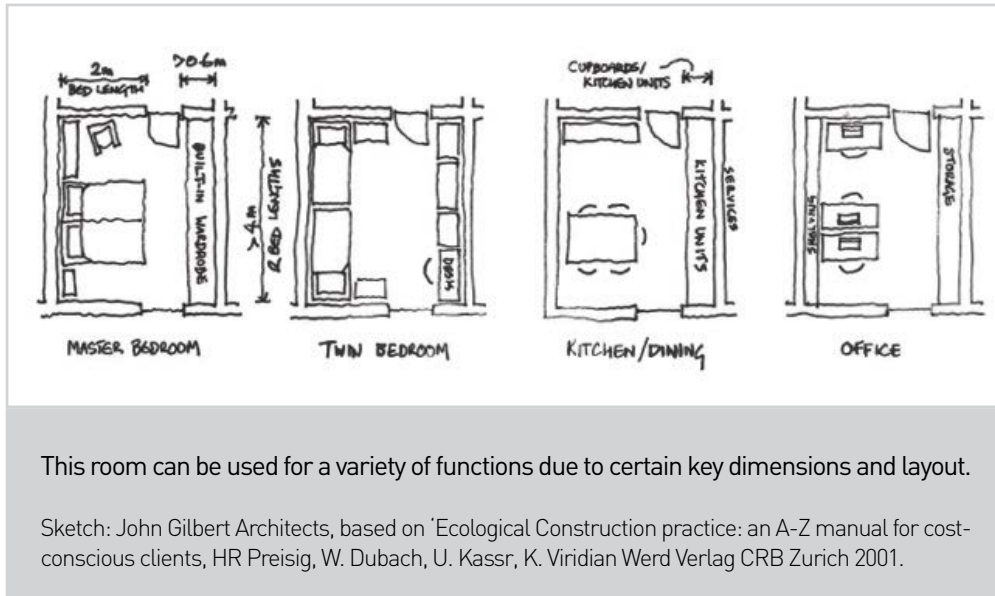


In this Glasgow housing project, the brief called for a degree of flexibility to allow the client to respond to varying occupancy needs over time. The above layout allowed for either 2 x 2-bedroom flats or a 1 x 1-bedroom and 1 x 3-bedroom flat. One room was designed with two doorways, but the design had to respond to fire and acoustic constraints of the regulations.

Design: John Gilbert Architects.

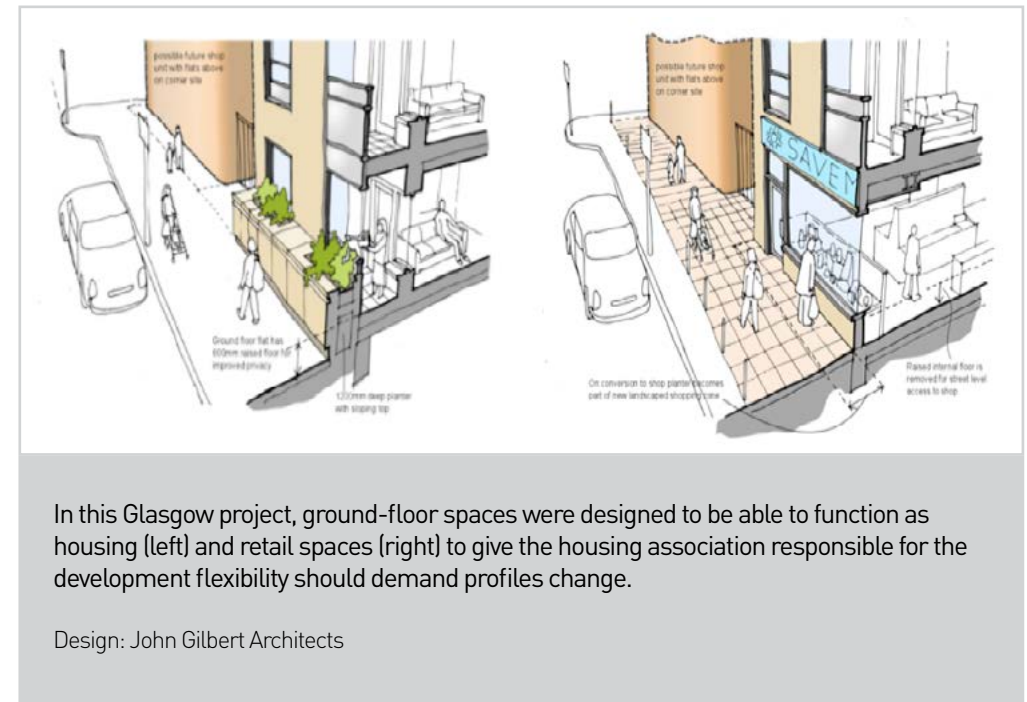
Flexible layout 2 – functional options

Looking at example 1 in greater detail, the diagrams here show how individual rooms can be designed to anticipate a variety of potential uses. Each room can be used as a main (double) bedroom, a children's bedroom (1 or 2 single beds) a dining room or an office. These multi-functional rooms then become the 'building blocks' of the home.



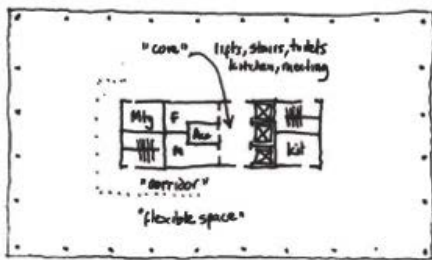
Flexible layout 3 – built-in capacity

The ideas of flexibility can also be applied to sectional considerations as well as plan layouts. Adding height within a storey can offer the potential for different future uses (for example, where additional services are required). Raised floors will allow for alternative underfloor servicing and there are a variety of ceiling systems available that do not necessarily need to look overtly commercial. In domestic buildings, leaving a space that could accommodate a staircase in the future will enable the unused attic to be developed at a later stage.



'Core' layouts

Core layouts stem from a simple observation that, in many building types, the need for certain 'core' services is likely to remain constant, while predicting the precise use of other spaces is less clear. Grouping all of the core services in one place, and 'freeing-up' the residual spaces has led to a number of solutions, all of which allow for a variety of end-uses. This prolongs the useful or economic life of the building, reducing waste generated from alterations and 'future-proofing' the initial investment.

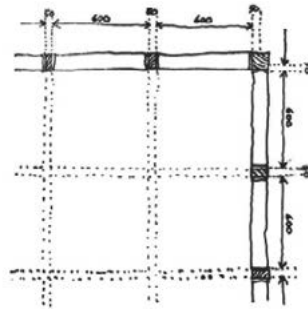


In a typical commercial development, the 'service core' of stairs, lifts, service spaces and toilets is clearly delineated while an inferred 'corridor' provides access to a flexible space that can be developed in any way to suit each user.

Sketch: John Gilbert Architects

Standardised grid/module

Using standardised modules within a project increases the likelihood that any individual piece can, if necessary, be replaced economically with a similarly sized component. In contrast, bespoke items may require standard components to be adjusted to fit. The sketch here shows the tartan grid dimensions of the Walter Segal construction system, which rigorously standardised components to simplify the build process. Using standard components means it may be worthwhile keeping a few spare should they be needed. This can speed up and simplify maintenance and replacement should it become necessary.



Sketch: John Gilbert Architects

Limited structural intrusion

Thinking of ways to minimise the intrusion of structure into the space can help ensure that the building can accommodate alternative uses in the future. Larger beams spanning a longer distance can 'free-up' a space that might be more economically divided by interim columns. Therefore, the additional capital costs have to be balanced against possible future savings.



In this housing development, trusses have been used to span from external wall to external wall leaving the internal spaces free for any desired arrangement of internal partitions. The partitions themselves (shown awaiting erection) can be altered or moved without any risk to the overall structural integrity of the building.

Photograph: Chris Morgan
Design: Locate Architects/John Gilbert Architects

5.3 Layering and access

A fundamental concept of designing out waste is to enable access to components which may need more frequent repair, maintenance or removal, and to do so while minimising disruption to other components around them. Early strategic consideration of these ideas offers huge potential for designers to improve on conventional solutions.

This concept accepts that while the majority of buildings may be able to last centuries, certain components have far shorter lifespans. Depending on the specification of these components, they may be repairable or replaced. While options around this are discussed in the next section, this section is concerned with avoiding damage and waste to adjacent components that are to remain in-situ.

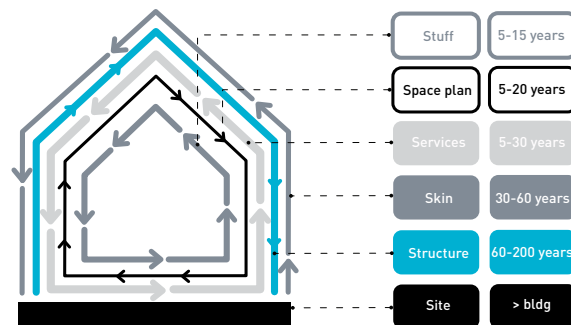
Separation of layers related to lifespan/function

The book 'How Buildings Learn' by Stewart Brand offers a valuable conceptual framework for separating the layers of a building according to their anticipated lifespan, noted in more detail in Section 4. Figure 6 indicates this simplified view of these layers. Each layer performs a different function and those with faster anticipated replacement or repair cycles are placed closer to the surface, allowing access without disruption to longer-lasting elements behind.

This diagram is conceptual only, but the principles expressed can be developed in detail in each part of the building.

Figure 6.
A building as a series of 'shearing layers'

Sketch: John Gilbert Architects based on 'How Buildings Learn', Brand (Viking, London 1994)



Variation in the same layer according to differential wear/weathering

This idea is very similar to that of separation of layers related to lifespan/function, but involves a simpler assessment of the anticipated wear and tear or weathering of a single layer or component.

An example of this is flooring in heavily trafficked areas such as entrances and walkways in offices. The area of flooring just beyond the entrance matting is likely to suffer far more than the area just to the side or near a corner. Anticipating this and allowing for more frequent replacement or maintenance of the worn areas (such as by using carpet tiles, rather than a single carpet sheet) reduces the waste associated with this inevitable wear and tear.

Externally, this concept can be applied equally to differential weathering. For example, external finishes tend to suffer most within the first 150mm above ground level due to splashing from rainfall. Introducing a break and different finish to these areas will allow these to be maintained without the need to replace the whole wall area.



Recognising that replacing carpet tiles in worn out areas can give an uneven look, carpet manufacturer Interface offers tiles with a randomised appearance allowing new insertions into existing layers that do not look out of place.

Photograph: Interface

Sequential access

This involves a simple principle linking back to the layering ideas noted above, whereby the designer ensures that the components most likely to require repair, maintenance or replacement are easiest to reach, either on the surface or by providing access.

This is another point where effective communication is vital – this time between the design team and potential facilities management providers. Collaboration between parties to develop a full understanding of exactly what cabling, pipework and other services may need to be accessed can facilitate the desired design specifications.



Service voids in the wall and floor of this house allow services to be run freely without penetrating the vapour control and airtightness membranes. By locating all main service runs at skirting board level, and by using a cup-and-screw fixing for the skirting boards, most service runs are easily accessible for the lifetime of the building.

Photograph: Chris Morgan
Design: Locate Architects/John Gilbert Architects

Tolerance for access and dismantling

There are many instances where building components are installed in such a way that to remove them would create considerable damage to the component itself or to adjacent materials and finishes, because there is no space or allowance for removal.

When designing components that are likely to require more frequent maintenance, repair or replacement, the principle here is to allow enough room to manoeuvre the item out if necessary and for the repaired or new item to be fitted.



Windows often need maintenance, repair or replacement before the elements around them. Installing the windows with a good space tolerance (20mm shown here) allows them to be more easily accessed and replaced without disturbance to adjacent components. Here the space around the window is filled tightly with natural sheep's wool which remains flexible and does not degrade over time as much as some synthetic materials, nor does it stick to the window like some sprayed foams, maintaining an airtight seal while allowing for easy removal.

Photograph & Design: Gaia Architects

Safe and convenient access

Components that are dangerous or inconvenient to repair or remove will tend to be left longer between maintenance cycles, due to cost or the risks associated with repair.

An example is the Scottish tenement window. This is traditionally accessed from inside, allowing repair, maintenance or replacement safely and easily, regardless of the storey height.

Extending the principle leads to the creation of dedicated service spaces, such as that shown here.

This principle also offers a cautionary note in relation to large-scale, off-site panel erection methods. While off-site construction, as discussed in Section 5.4, can lead to significant savings in cost, time and waste generation, there may be a risk that large components cannot be easily maintained or repaired without, for example, removing the whole panel, necessitating the need for a crane, increased costs and an associated waste of materials. Therefore, the design of off-site manufactured components themselves should incorporate the principles of designing out waste.



Service spaces allow maintenance staff to service, repair and, in some cases, replace whole items without needing to disrupt access to important spaces or damage internal finishes.

Photograph and Design: Gaia Architects

Reduced or 'weaker' chemical or mortar bonds

Modern adhesives and cement-based mortars tend to be very strong. In the majority of cases, these are too strong to enable straightforward separation of bonded components. Where such bonds are necessary, it is worth considering at the design stage if the strength of the bond can be reduced, which remains sufficient for normal use, but allows access and disassembly if necessary. Water soluble adhesives may be preferable to stronger solvent-based alternatives. The most common construction example is of a weak to medium strength lime-based mortar for masonry as used in traditional masonry construction, this allows for easier removal and re-use of stone or brickwork if required.



Carpet manufacturer interface introduced 'TacTiles'. These are small adhesive pads used instead of applying adhesive over the entire substrate. This reduced level of adhesion remains adequate to keep the carpet tiles in place, but allows for simple installation and replacement with less resource use, time, cost and waste.

Photograph: Interface

Minimum number and type of fixings

Reducing the number and type of fixings to be used simplifies operations on site and in the longer term. It means maintenance teams do not need to search for bespoke fixings to replace those removed, standard fixings can be kept on site and repair work can be carried out as intended, so avoiding the need for ad-hoc arrangements.

In this space, the floorboards themselves are held in place by strips that are screwed to the substrate below. By removing some of the screws, sections of flooring can be lifted and replaced easily, so giving access to the services below. A similar detail is used in the ceiling, but the check in the boards is not required.

Photograph & Design: Gaia Architects



5.4 Components

Having looked strategically at how design considerations should avoid the need for components to be disturbed in future, and make access to them easy and safe, it is also important to consider the characteristics of the components themselves. Components in this case are anything that the building or structure is made of (that is, the 'component parts' of the project). These might range from bricks, carpet tiles, and fixings to landscape elements, civil engineering materials, large structural elements, and whole wall or roof sections that are built off site and have to be craned in. The key consideration is to acknowledge that these components will be removed at some point – some much sooner than others – and aim to minimise waste through re-use, repair and recycling.



Unlike solid timber or 'I'-joists, open-web joists like those shown allow services to be run within their depth without the need for notches or holes to be cut within. This removes the need to establish strict 'no-go zones' agreed with the structural engineer or manufacturer, and avoids compromising the joist's integrity and potential for re-use.

Photograph: Graham Drummond, Passivhaus Associates

Whole components

Components that have been damaged in the normal course of their use are far less likely to be easily re-used. A common example of this is timber floor joists and rafters. Rafters are often adapted with 'birdsmouth' notches that are cut for positioning or, in the case of timber joists, with holes drilled to allow services to pass through. Both adaptations mean that future re-use is compromised.

Durable components

To be re-used in whole or part, components need to be sufficiently durable to survive removal, handling, storage, re-working (if necessary) and transporting to another site. This idea is closely linked to suggestions in **Section 5.3** around fixings and bonds used, because even durable and valuable components such as stone can be damaged if they are bedded in mortar that is too strong. Traditional use of stone in a weaker lime mortar allows for easy, and relatively economic, re-use of the stone itself.

Repairable components

A key concept of the circular economy involves the ability to extend the life of a product, so avoiding the need for replacement. The ability of certain components to be repaired is not the same as their durability. Some components are durable, but hard to repair (many plastic components come into this category). Others are inherently less durable, but eminently suitable for repair and, with care, can outlast seemingly more durable items.

One aspect of this concept, which is, in effect, a restating of the idea of the differential wearing of layers, recognises that some components have differential wear-and-tear properties or weathering within themselves. A example is that of a window, where the handles and locking devices may be subject to far greater use and potential damage than the rest of the component. Anticipating this and ensuring that the handles can be easily repaired/replaced will contribute to the longevity of the component overall.

Standardised components

Another way to improve any component's reparability is to standardise it. In general, the more bespoke a component is, the less likely it is to be useful for other applications. Expanding this logic leads to the observation that standardising components as far as possible will maximise the potential for them to be useful elsewhere and to be re-used. It also means that individual components are more likely to be repairable and replaceable during the service life of the whole building or project.

Case study Resource Efficient House

The Resource Efficient House was designed for Zero Waste Scotland by Tigh Grian Ltd and built at the BRE Innovation Park at Ravenscraig, North Lanarkshire. It shows how several of the ideas of designing out waste can be successfully incorporated in a building that has the potential to be cost-effectively replicated in a variety of locations.

The use of off-site modular pod construction allowed the design of:

- a highly adaptable living space;
- a building that could be simply deconstructed and re-used on another site; and
- a building that required only standardised building products without the need for adaptation or off cuts.

The construction of an average three-bedroom home akin to the Resource Efficient House can produce up to 13 tonnes of construction waste...

With careful design, the Resource Efficient House produces less than 4 tonnes of waste.

More information



Standardised tools

As procurement and construction options are diversifying, some components or assemblies may require unique or unusual tools. These will normally be supplied with the components during initial site works, but can easily become lost. This can prejudice ongoing maintenance and repair or removal works. Such assemblies are to be avoided but, if used, it is helpful to order a spare set of tools and ensure that these are safely stored with the operation and maintenance manuals.

Minimum number of components

All other things being equal, components tend to be more economical to re-use if there are fewer component types and a larger volume of each. Thus, it is worth aiming to minimise the variety of component types when designing. Can a component be used for more than one thing? There is a natural limit to the applicability of this in practice. However, where it is possible, it not only makes re-use of components more likely, but simplifies the procurement and construction process.



This tiny building is a composting toilet as part of a Forest School in Ardnamurchan. Apart from the pre-fabricated composting chamber beneath, almost the whole building is built using timber sourced on site. All structure, and internal and external finishes (including the roof) are made from timber. This means almost everything could be sourced and made locally.

Photograph: Chris Morgan
Design: Locate Architects/John Gilbert Architects

Use components that are easy to handle

While construction processes often involve large machinery, the ongoing maintenance and repair of these same components rarely does. Large and heavy components lifted into position as part of the build process cannot usually be lifted out again in the same manner. Thus it is important to consider how components that may need repair or replacement can be safely and cost-effectively handled and manoeuvred throughout their service life.



This competition-winning entry for 'Our Island Home' by Arc Architects features a number of measures to address waste reduction and future flexibility. One is that all components can be lifted by no more than two people. This makes construction and ongoing maintenance or alterations simple in remote areas where large mechanical lifting may not be feasible.

Image and design: Arc Architects

Off-site manufactured components

Manufacturing and assembling components off site, in controlled environments, offers great potential to reduce waste, primarily through greater efficiencies in raw material use. It can also significantly reduce actual installation time, which introduces another cost-saving element to the project.

The many benefits of off-site manufacture are demonstrated in the case studies on the **Resource Efficient House** and **CCG (Scotland) Ltd's** closed frame timber panel system.

Case study CCG (Scotland) Ltd

Off-site manufacturing

Having long been a promoter of construction efficiencies, **CCG (Scotland) Ltd** is at the forefront of off-site manufacturing, in particular the manufacture of timber modular buildings.

Through its subsidiary company, CCG (OSM) Ltd, CCG has developed a timber modular building system that consists of a closed timber frame panel. The system includes:

- main structural frame;
- insulation;
- vapour control layer;
- internal service zones;
- lining board;
- windows;
- doors; and
- external cladding system.

Introducing this system has moved a large proportion of the construction work from site to a controlled factory environment. Within this factory environment there is greater quality control, waste control, and health and safety control.

The capacity for optimisation and cutting of standard building product sizes allows project waste to be minimised at the design stage. This practice also makes it easier to re-use offcut materials within the factory, as opposed to trying to manage an 'offcut' area on site.

An important part of the overall system is the use of acrylic 'brick slips' instead of masonry facing bricks. These offer several advantages, including:

- ease of application to a wall panel;
- reducing transportation costs (as opposed to traditional facing bricks);
- factory-based application removes external weather concerns (so avoiding 'no-build' periods); and
- avoiding wasting facing brick through cuts, damage or surplus materials.

The projects using this system so far have delivered a significant reduction in all waste being removed from sites. The use of the factory-manufactured wall panel, rather than manually handling materials into position on-site, has also led to reduced damage to materials.

CCG (Scotland) Ltd used the closed wall panel system with the brick slip on a project procured by Queens Cross Housing Association to deliver 90 flats and houses in Panmure Street, Glasgow.

Using the key performance indicator for waste control of total weight of waste produced per dwelling, CCG estimates that a good-performing project of similar size and nature would produce around 3 tonnes of waste per dwelling, including all waste removed from site.

The Panmure Street total waste generated per dwelling was 2.2 tonnes. This suggests a 25% reduction from the good practice estimation of waste generated.

This resulted in a cost saving of around £8,000 over a £30,000 waste disposal bill.

If this performance could be repeated throughout all of CCG (Scotland) Ltd's business, it could result in an overall annual saving of £80,000.

Brick slips applied to closed timber frame panel in factory manufacture.



Closed panel system with brick slip facing as used in Queens Cross Housing Association development in Panmure Street, Glasgow.



Avoid composite components

Composite components can save a great deal of time and cost on site since they have the potential to simplify the construction process. However, the issue with composite components, depending on the nature of each part and how they are joined, is that it complicates and, in some cases, prevents the process of re-use, repair, recycling and recovery. In general, the simpler the component – ideally monomeric as opposed to polymeric – the simpler and more cost-effective it is to recover.



The roof construction of this sports centre has been built up in individual layers – internal liner sheet, separating structure and insulation, external sheet – rather than using a composite panel. This increases time on site, but allows each part to be easily separated and maintained or replaced if necessary, and will reduce the ultimate waste stream at the end of the service life of the building.

Photograph and design: Gaia Architects

Avoid coatings

Coatings are used for a variety of reasons, not least to protect and lengthen the service life of materials and components exposed to weather or internal wear and tear. They also have the capacity to brighten up drab surfaces – few people would like to live and work in homes and buildings that had not been painted. As such, the use of coatings is welcome. However, coatings are often complex chemical products and can significantly complicate, and in many cases prevent, the re-use or cost-effective recovery of otherwise straightforward materials. A number of coatings available do not compromise the recovery of the substrate material and these are worth investigation at the design stage.

There is a balance to be struck, but in the interests of reducing waste, significant gains can be achieved by considering each component used and choosing those that do not need to be coated to be durable or attractive.



A new-build house in which all external materials are naturally durable can be left uncoated. A natural slate roof and heartwood of European larch cladding are complemented by aluminium flashings and rainwater goods. Unlike steel, aluminium does not require a coating to be rustproof.

Photograph: Chris Morgan
Design: Locate Architects/John Gilbert Architects

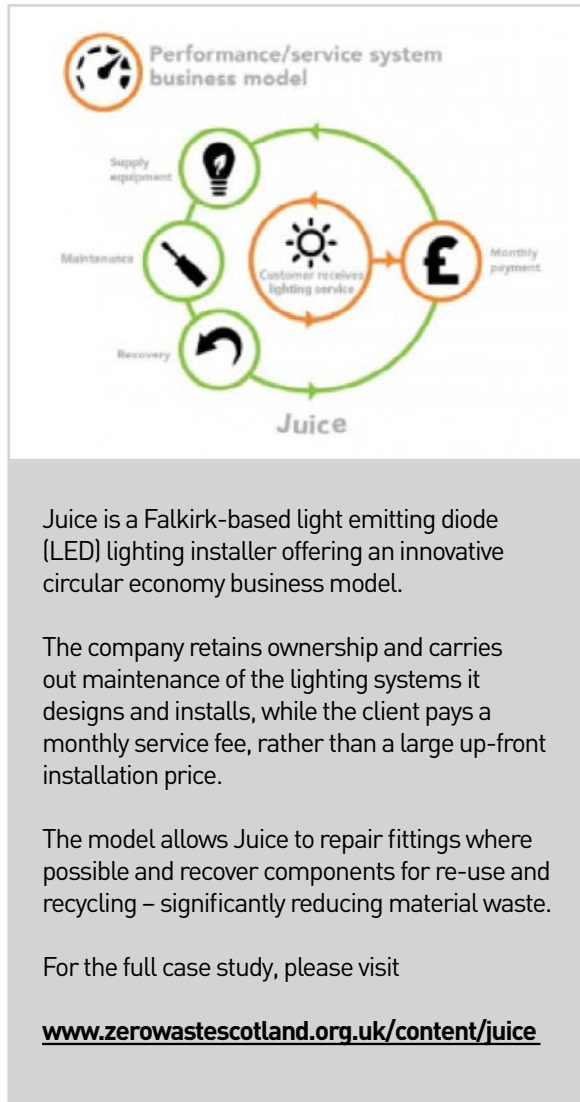
Consider natural materials

Toxicity in building products is more widespread than commonly appreciated and there are many reasons why levels should be reduced for the sake of human and environmental health. However, in the context of waste reduction, the issue is that, as disposal costs rise and options for disposal of toxic materials become fewer, it is likely that future disposal costs will be much higher than at present. Therefore, the use of these materials is a waste stream and cost penalty for future generations.

The solution is to use 'natural' and non-toxic materials wherever possible. The terms 'natural' and 'toxic' are contentious and broadly undefined. However, there is a difference between a simple piece of timber and one impregnated with chemical preservatives and coated with synthetic coatings. Ultimately, the benefit of 'natural' materials is that where all other recovery options fail, it is possible for them to be safely composted, leaving – in effect – a 'zero waste' solution.

Leased components

Several manufacturers and suppliers have improved their own systems and now offer leasing of components, a take-back service for repair or replacement and/or a commitment to recycle materials as part of their own manufacturing process. Working with these manufacturers and suppliers will reduce waste in the long term and, by supporting these companies, a project can help drive the wider industry in this direction. These models can save waste by supporting the take-back service and refurbishment of components and equipment.



Re-used components

Re-using components and materials is preferable to using recycled items mainly because the embodied energy will almost certainly be far lower. However, depending on the items under consideration, re-using components can disrupt the design process since there may be a greater need to adjust the design to suit the component. For example, re-using whole steel structures means the entire building needs to conform to the dimensions of the re-used material. By contrast, the re-use of bricks is unlikely to make much difference to the design process, although there may be implications for the construction process in terms of storage and handling.

Re-using components tends to represent a greater commitment to the cause of waste reduction by all involved in the project. Support from the client for the additional work often required by design team and contractor is necessary.

It should also be noted that not all components can be re-used if there are risks associated with doing so, most commonly involving the potential for residual toxicity in the material itself or in coatings, etc. This can often be the case with soil that has been contaminated. The converse is that re-used materials have the potential to shape the project and give far greater character to a building than conventional materials.



The majority of the materials used in the Bute Recycling Centre were themselves recycled, reclaimed or supplied from sustainable sources. The bricks are a variety of quality seconds that would normally have been scrapped, the roof is 100% recycled aluminium and glass screens used internally were made from local waste in conjunction with an artist.

Photograph: Andrew Lee.
Design: Collective Architecture

Case study **BedZED eco-village**

The BedZED eco-village in Sutton, south London, made extensive use of re-used materials during construction. Designed by ZEDfactory architects and developed by housing association Peabody, it was completed in 2002 with 100 homes ranging from small studio apartments to four-bedroom family homes, and office and community space. Conceived as a zero-fossil-fuel development, BedZED continues to exemplify high ambition in reducing the environmental impact of new build and achieving high all-round sustainability standards.

Maximising the use of re-used materials was prioritised from the earliest design phases and throughout construction. Bioregional, a sustainability charity that was one of the three lead project partners, took responsibility for researching sources of low-impact construction materials with staff dedicated to the task.

- 98 tonnes of reclaimed structural steel used – 95% of the structural steel on the scheme. The sections were retrieved from demolition sites within a 35-mile radius
- Extensive use was made of reclaimed timber, including for floorboards and exterior bollards. More than 50km of 50x100mm and 75x100mm reclaimed timber studwork used in the internal plasterboard partitions. This studwork is neither structural nor exposed to any weathering and was not visible once installed, so it required no sanding, grading or durability treatment. This low specification timber was easy to source economically from reclamation yards and was cheaper than new softwood.
- 279 tonnes of recycled crushed green glass used as bedding for paving slabs, replacing the same quantity of virgin sand.
- 980 tonnes of recycled aggregate made from crushed concrete used in the road sub-base, supplied as a graded product (Type 1 aggregate).

There were ambitions to use reclaimed paving slabs and reclaimed doors throughout the development, but these proved too difficult to realise.

In total, BedZED sourced 3,404 tonnes of reclaimed and recycled materials (including 1,862 tonnes of reclaimed on-site subgrade fill). This amounts to 15% by weight of the total materials used in construction or 7% excluding sub-grade fill.

The use of these reclaimed materials was estimated to reduce BedZED's embodied CO₂ by 4%. All of the measures, except reclaimed steel, resulted in cost savings to the client or the contractor, after factoring in additional staff time spent on sourcing the material. Using reclaimed steel was cost neutral.

More information



Photograph: Tom Chance

Re-usable or compostable wet mixes

Depending on the chemical processes involved, most wet mixes cannot be re-used as mortar or binder. However, most can be ground up to provide aggregate for subsequent mixes. One advantage of clay-based mixes is that they can usually be re-used without detriment to the properties of the mix. Ultimately, too, clay-based mixes can be buried as they represent no risk of pollution and can be safely mixed with other inert materials and placed into the ground.



Clay plaster can be made into a variety of colours and finishes, and has a number of advantages over conventional plasters. It is a natural product with little or almost no embodied energy, contains no harmful additives and has a capacity to regulate internal humidity levels with associated health benefits.

In terms of waste reduction, clay contains no toxic elements and can be safely buried on site and ploughed back into the ground – where it came from.

Photograph and design: Arc Architects /Rebeearth Earth Building

'Non-fixed' components

Throughout history, and across the world, building solutions have been devised which achieve their goal without 'fixings' as such. From igloos to complex Japanese joinery details, it is possible to connect things in many ways which, while being sufficiently robust, allow for more straightforward removal should the need arise. Such solutions are rarely deployed in the current UK construction industry, but remain possible. Floors can be detailed to 'float' with little or no formal fixing and a number of components, such as floor boards, can be 'clicked' into place without the need for glue. Through design or deadweight, certain items can be 'friction fitted' without risk of being dislodged. Small and lightweight items can often be fitted using magnetism, and some forms of secondary glazing can be fitted using magnetic strips, as pictured here.



Polycarbonate sheets can be fixed to windows using magnetic strips. This reduces draughts and saves energy at little cost compared to replacing or upgrading the windows themselves.

Photographs: Glaze & Save Secondary Glazing.

Removable mechanical fixings

As a general rule, mechanical fixings – which can be easily removed – are to be preferred over chemical or other non-removable fixings. In metalworking, bolts and clamps should be preferred over welding and riveting, while in domestic timber construction, screws and bolts again allow for easy removal unlike nailing.



Welded joints are usually stronger than bolted ones but depend greatly on the quality of the weld. Bolted, welded and riveted connections all have benefits and disadvantages. From the perspective of disassembly, bolts (as long as they do not seize or rust) are preferable.

Photograph and design: John Gilbert Architects

6 Application to Royal Incorporation of British Architects (RIBA) plan of work

Careful consideration of all of the suggestions and ideas in Section 5 of this guide can contribute towards a project with as little associated waste as possible. To help architects, design teams and other project members incorporate these considerations and actions into their standard practices and procedures, this section maps them onto the well-defined stages of the RIBA Plan of Work 2013 model.

Plan of work stage	Key actions for clients	Key actions for designers	Key actions for contractors
0 Strategic definition	Set corporate targets for reducing waste.		
	Embed these targets within corporate policy and procedures.		
	Set corresponding requirements/targets for each project.		
	Ensure sufficient measurement/monitoring processes are in place for each project.		
	Report annually on overall corporate performance.		

This reproduction and use of the Plan of Work has been granted permission by the Royal Institute of British Architects.

Plan of work stage	Key actions for clients	Key actions for designers	Key actions for contractors
1 Preparation and brief	Ensure designing out waste-specific clauses (targets/requirements) are embedded within the pre-qualification questionnaire and invitation to tender documentation.	Be prepared to demonstrate best practice/experience in designing out waste principles and delivery as part of tendering/appointment.	Be prepared to demonstrate best practice/experience in designing out waste principles and delivery as part of tendering/appointment.
	Ensure designing out waste specific clauses (targets/requirements) are embedded in all appointment and contract documents.	Agree with client project-specific targets/priorities for designing out waste, agree methodologies as necessary. Plans should include rationale and overall strategies as well as more detailed information.	
	Identify 'designing out waste champion' to lead and report on designing out waste issues.	Identify 'designing out waste champion' to lead and report on designing out waste issues.	Identify 'designing out waste champion' to lead and report on designing out waste issues.
	Designing out waste champion may need to brief design team/others on designing out waste.	Designing out waste champion within design team to brief all members of team on issues, targets and the need to embed these issues into their own design/specifications.	Designing out waste champion within contractor's team to brief all likely personnel/including sub-contractors on issues, targets and the need to embed these issues into their own work packages.
		Carefully assess existing buildings on site to establish extent of fabric to be retained and refurbished. Accurate survey is critical. Ensure proposed design does not compromise ongoing adaptability of existing building.	
		Where buildings are to be demolished, use a pre-demolition audit to quantify materials and/or components that can be recovered. Accurate survey is critical.	
		Assess all site resources to establish extent that can be re-used/recovered/recycled on site and potential design solutions for use in proposed project. Accurate survey is critical.	

Plan of work stage	Key actions for clients	Key actions for designers	Key actions for contractors
1 Preparation and brief		Assess all site resources to establish extent that can be re-used/recovered/recycled on site and potential design solutions for use in proposed project. Accurate survey is critical.	If appointed to design stages, be prepared to engage in all issues raised as part of the design team.
		Check if materials from other projects nearby or being undertaken by client/design team/contractor can be usefully incorporated within the proposed building design.	
		Assess likely impact of designing out waste measures on design, cost and project programme.	
		Report on above to client.	
2 Concept design	Designing out waste champion may need to re-brief design team/others on designing out waste/update on progress.	Identify all on-site and off-site resources that can be incorporated into proposals.	
		Check any testing (for example, with regard to contamination) required in association with above components (including assessment by principal designer).	
		Discuss management/construction issues with client which could impact on designing out waste (for example, use suitable contractors (including demolition contractors).	
		Establish from site surveys potential constraints to construction that could impact on relative benefits/detriments of off-site construction options/materials storage on site/access constraints.	

Plan of work stage	Key actions for clients	Key actions for designers	Key actions for contractors
2 Concept design		Consider all principles outlined under adaptability, layering and access, and agree with client specific ways forward.	
		Consider potential for deployment of temporary or re-locatable structures to offset need for permanent structures.	
		Consider layouts with potential to increase adaptability over time, such as adjacencies and grouping of specific functions.	
		Consider potential to increase longevity of spaces through anticipating alternative uses/additional height.	
		Consider structural solutions which use less material and provide minimal intrusion allowing for long term flexibility in use, self-supporting solutions preferred over interdependent ones.	
		Consider simplicity and standardisation of form/grid/materials.	
		Consider 'core' arrangements that provide all required services but allow greater freedom beyond these 'fixed' areas, such as fire escape stairs, lifts and toilets.	
		Consider access arrangements and relationship with excavation/earth movement to minimise excavation re-modelling and potential removal of spoil.	
		Review foundation and ground-floor design to minimise waste and extend potential lifespan of solutions chosen.	

Plan of work stage	Key actions for clients	Key actions for designers	Key actions for contractors
2 Concept design		Agree with client designed separation of layers in relation to lifespan and function.	
		Consider likely high areas of wear and tear, and identify potential to allow for discrete repair/ maintenance of these areas without impact on adjacent finishes.	
		Consider likely components requiring greater maintenance and review access/safety and tolerances.	
		Where specific items (such as existing steel beams) are to be used/re-used, establish subsequent design requirements (for example, span limitations).	
		Agree with structural engineer explicit fixings strategies to enable deconstruction of components and agree with client.	
		Agree with services engineer explicit strategies for services to minimise waste generation.	
		Assess likely impact of designing out waste measures on design, cost and project programme.	
		Assess likely impact of agreed measures on planning/ building warrant/other statutory compliance (for example, Scottish Environment Protection Agency and Scottish Water), utility providers and neighbours.	
		Report on above to client.	

Plan of work stage	Key actions for clients	Key actions for designers	Key actions for contractors
3 Developed design	Designing out waste champion may wish to re-brief design team/others on designing out waste/update on progress.	Designing out waste strategy should be reviewed by all team members and issues raised (for example, structural/services conflicts, costs, and health and safety implications).	If appointed to design stages, be prepared to engage in all issues raised as part of the design team.
	Client may need to purchase reclaimed materials in advance of, or separate to main contract.	Prepare initial construction/deconstruction plan as basis for understanding construction sequence, to highlight potential problems with deconstruction process and identify impact on waste. Include fixings points for all major items/items likely to require more frequent maintenance cycles.	
		Subsequent to the above, identify (with contractor/sub-contractors if available) likely significant waste arisings and methods for controlling these to minimise waste, costs, emissions, etc. This information can also be put in the health and safety plan, costed and agreed with client.	
		Begin the process of dimensional coordination, establish structural and planning grids in combination with a more detailed knowledge of (standardised) components.	
		Establish floor heights, and structural and services zones to minimise extent of material offcuts, but optimise long-term potential for alteration/adaptation.	
		Use valuable components (worth re-using).	
		Use durable components (capable of being re-used).	
		Use 'whole' components (that is, do not need to be notched, chamfered or altered to work) to optimise change of re-use.	

Plan of work stage	Key actions for clients	Key actions for designers	Key actions for contractors
3 Developed design		Use repairable components (capable of being repaired and re-used).	
		Use standard components as far as possible to minimise waste and increase potential for replacement, etc.	
		Use the minimum number of components to simplify ongoing maintenance and repair issues.	
		Use re-used and recycled materials and components in preference to new.	
		Use natural and/or safely compostable components and materials in preference to man-made options.	
		Use components which are easy to handle to simplify installation and reduce costs and risks associated with access and repair.	
		Avoid using composite materials that cannot be separate – especially adhesive-bonded components.	
		Avoid coatings that will compromise re-use and recycling potential.	
		Avoid toxic materials and coatings that will represent a health risk and future disposal burden.	
		Avoid materials and components with little or no resale, re-use or recovery potential.	
		Prioritise non-fixed components (for example, friction fit and floating floors).	

Plan of work stage	Key actions for clients	Key actions for designers	Key actions for contractors
3 Developed design		Use durable and re-usable fixings.	
		Use a minimum number and type of fixings.	
		Use fixings that are removable (such as screws and bolts) not 'once-only' (such as nails and welds).	
		Use fixings for which simple or standard tools will work.	
		Chemical fixings and wet mixes, where used, should be weaker than the bonded components to allow for re-use of components.	
		Wet mixes where possible to be re-usable/ compostable.	
		Report on above to client.	
4 Technical design/ specialist design	Designing out waste champion may wish to re-brief design team/others on designing out waste/update on progress.	Deconstruction plan, should be reviewed by all team members and issues raised (such as structural and services conflicts, costs, and health and safety implications).	If appointed to design stages, be prepared to engage in all issues raised as part of the design team.
	Client may need to purchase reclaimed materials in advance of, or separate to, main contract.	Detailed designs and specifications must be checked against manufacturer's guidance to avoid conflicts where designing out waste principles have been applied.	
		Preference for suppliers and manufacturers that will lease, repair or take back and recycle components.	
		Preference for suppliers that will adopt best practice packaging options to minimise on-site waste.	

Plan of work stage	Key actions for clients	Key actions for designers	Key actions for contractors
4 Technical design/ specialist design		Standard specification tools and models, such as National Building Specification (NBS) and Building Information Modelling (BIM), should be reviewed to ensure they do not compromise designing out waste principles applied.	
		Where performance specifications are used, ensure these include clauses that adequately control designing out waste aspirations.	
		Where designing out waste principles have been applied and these differ markedly from conventional design, ensure these are highlighted within tendering documentation (for example, together in a separate section towards the front of the document) to avoid these being missed.	
		Review specialist input (such as services layouts) to avoid compromise of the principles applied.	
		Identify solutions to any planning consent conditions as applied to waste.	
		Review all off-site construction detail proposals in terms of detail and process in relation to designing out waste aspirations.	
		Review building warrant requirements in relation to designing out waste aspirations.	
		Designing out waste principles, as agreed, to be included in all tender packages for specialist subcontractors	

Plan of work stage	Key actions for clients	Key actions for designers	Key actions for contractors
4 Technical design/ specialist design		Ensure all designing out waste principles applied are integrated in BIM model and handbook with location, means of disassembly, re-use/recycling notes and any special considerations stated.	
		Agree best practice principles of on-site waste management to be included in tendering documentation for contractor. These should include a SWMP including site storage and logistics, 'just-in-time delivery' regime, a consolidation centre as necessary and careful sequencing plans.	
		Agree with client best practice materials delivery regime to be included in tender documents for contractor.	
		Report on above to client.	
5 Construction	Designing out waste champion should take the opportunity to re-brief design team/contractor on designing out waste aspirations (for example, at the pre-start meeting).	Designing out waste should be included as an item in all meetings, including pre-start meeting to ensure issues are raised and resolved with due consideration with alterations managed and costed, etc.	If appointed to design stages, be prepared to engage in all issues raised as part of the design team.
			Contractor to adhere to all waste management guidelines established including use of specified suppliers, waste minimisation, recycling, reducing over-ordering and packaging aspects.
			Contractor to ensure all sub-contractors adhere to guidelines as above.
			Contractor to ensure all tools necessary for disassembly/instructions and information are made available as required for inclusion within final documentation.

Plan of work stage	Key actions for clients	Key actions for designers	Key actions for contractors
6 and 7 Handover, closeout and use	Client designing out waste champion should brief all occupants on designing out waste aspirations and associated maintenance/repair implications.	Designing out waste issues arising in defects period to be handled as necessary with regard to original aspirations.	Contractor should allow for demonstration of servicing requirements as part of commissioning, to include long-term designing out waste principles as applicable.
	Client should initiate a plan for ongoing reporting and education associated with waste management generally.		

7 References and acknowledgements

This guide has been produced by Ricardo Energy and Environment and John Gilbert Architects on behalf of Zero Waste Scotland.

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