Designing out Waste: A design team guide for civil engineering

LESS WASTE, SHARPER DESIGN
“This guide to designing out waste on civil engineering projects is very timely. It clearly demonstrates the importance of design decisions in the generation of waste on projects, and how this can be significantly reduced by use of established techniques and by working closely with clients and contractors as an integrated project team. Civil engineers have tremendous potential to improve the sustainability of construction by making the best use of resources and minimising waste. I urge designers to make the most of the opportunities presented in this design guide.”

Paul Jowitt, ICE President

The Institution of Civil Engineers has led the way in stressing the importance of sustainability through its Sustainable Development Strategy and Action Plan for Civil Engineering and designing out waste is an important part of this.
Using this guide

Designing out Waste: A design team guide for civil engineering – is presented in two parts:

1. **Design Guide** provides the case for action, the principles of Designing out Waste, and a structured approach to implementing it in civil engineering projects.

2. **Technical Solutions** provides technical information on an extensive series of design solutions and engineering techniques which can be used to improve materials resource efficiency in civil engineering projects.

The sections within Part 1 of this guide are described below, to help you find the relevant information.

- **Section 1.0**
  - **Introduction** – Explains the role of reducing waste in sustainable construction, the scale of construction waste produced in the UK, the types of project that are covered by the design guide and introduces the five key principles for Designing out Waste.

- **Section 2.0**
  - **Case for action** – Presents to the construction industry the drivers for reducing construction waste to landfill and using materials more efficiently. It also demonstrates the close link between reducing waste and reducing the carbon footprint, and how effective planning at the early stages of a project can help this process.

- **Section 3.0**
  - **The five principles of Designing out Waste** – Explains that most design solutions for Designing out Waste fall into just five easy to follow principles.

- **Section 4.0**
  - **Project application of the five Designing out Waste principles** – This section is aligned to the project lifecycle and shows how Designing out Waste can be integrated throughout the different stages in design from feasibility to detailed design, specification and procurement for new construction and maintenance/refurbishment projects. This includes a useful checklist of the key actions that can be implemented at each design stage.

- **Section 5.0**
  - **Designing out Waste process** – Presents a simple three-step process for applying the Designing out Waste principles in projects. This includes a suggested format for a design review workshop to help identify and prioritise design solutions. It can be included as part of the Value Management process on larger projects. On smaller projects, the design guide can be used in conjunction with WRAP’s Designing out Waste tool for Civil Engineering (DoWT-CE) to identify the best opportunities.

- **Appendices** – Information on the Construction Commitments: Halving Waste to Landfill; and drivers for reducing waste, including a summary of CEEQUAL.

Symbols are used throughout the guide to highlight important aspects or provide quick access to useful information. The colours of these will vary, depending on the colour coding of the section. These symbols are described below:

1. Key resources to refer to for further information. Full references and/or web links for these publications and others are provided in footnotes or in the text, and in Appendix C.

2. Key questions to ask yourself to help implement the Designing out Waste principles.
1.0 Introduction

Sustainability has risen rapidly up the construction agenda over the past few years and designers have a key role in helping to deliver projects that are sustainable in terms of their environmental, social and economic impacts. One important aspect of sustainable construction is waste; actions to reduce waste will also generally reduce the carbon footprint of a project. This guidance focuses on the influence design decisions have on construction waste and how waste can be reduced through design.
Waste and resource use has become an issue of increasing importance in construction in recent years. This is being driven by numerous factors including:

- the UK government’s Strategy for Sustainable Construction setting a target of halving the amount of construction, demolition and excavation waste to landfill by 2012 compared to 2008;
- the costs of sending material to landfill and transporting new materials to site continuing to rise, providing a strong economic case;
- the Site Waste Management Plan Regulations, implemented in England in 2008, enforcing requirements to forecast and record waste arisings and record any decision taken on the nature of the project, its design, construction method or materials used in order to minimise the quantity of waste produced on site; and
- clients keen to demonstrate that their construction projects are as sustainable as possible, and many are now setting targets for waste reduction and reuse in construction contracts.

Design decisions to reduce waste and use materials more efficiently can also contribute to gaining points under the Civil Engineering Environmental Quality Assessment and Awards Scheme (CEEQUAL) and can thus be used to demonstrate the environmental quality of a project.

Civil engineering projects usually require large quantities of materials and have the potential to generate large quantities of waste. The biggest opportunities to reduce these occur through decisions made at the design stage, as these determine the approach that will be adopted at the construction stage.

Examples include deciding whether to excavate weak foundation materials and replace them with imported fill or to retain and strengthen the existing materials in-situ by means of geosystems or addition of cementitious materials; or, on a maintenance project, whether to excavate a highway pavement and replace with new asphalt or to recycle it on site using low energy cold recycling techniques. The role of designers in reducing waste is therefore crucial, and this guide provides a practical approach to enable them to successfully implement Designing out Waste in projects.

Waste should not be considered in isolation; it is part of the overall consideration of sustainability in construction, which includes factors such as carbon impact, resource depletion and water use. All of these issues are interlinked and, in general, techniques that reduce waste will also reduce the carbon impact. In many cases, design solutions that reduce waste will also be quicker and offer cost savings compared to conventional solutions.

Whilst some solutions are innovative, many are established and commonly used engineering techniques. Designing out Waste therefore does not require designers to retrain or significantly change their current working practices. Part 2 of this guide presents an extensive range of technical solutions that can achieve reductions in waste, with key references and a summary of their likely effect on cost, programme, recycled content and carbon impact of the project. The technical solutions are mostly well established techniques for which further detailed guidance is available elsewhere.

In developing the approach to Designing out Waste, WRAP worked with design teams on live projects and this led to the development of five key principles that design teams can use during the design process to reduce waste:

- Design for Reuse and Recovery.
- Design for Off Site Construction.
- Design for Materials Optimisation.
- Design for Waste Efficient Procurement.
- Design for Deconstruction and Flexibility.

All opportunities for Designing out Waste fit within these five principles, and they can therefore act as useful prompts when identifying potential technical solutions to ensure that no opportunities are missed. The principles are identical whether the project is civil engineering or building construction, but the focus is different; in civils projects most opportunities occur within Design for Reuse and Recovery and Design for Materials Optimisation. This guide provides full explanation of each principle and how they should be applied throughout the project cycle for new construction and maintenance/refurbishment projects.
It is important that Designing out Waste is considered from an early stage in the project cycle, and that designers follow this through the ground investigation, detailed design, specification and procurement stages, in conjunction with other members of the project team, to ensure that design solutions identified at an early stage are embedded into the project and fully implemented. This is most successfully achieved if a structured approach is used, and this guide presents a simple three-step process for applying the Designing out Waste principles in projects:

1. Identify opportunities for alternative design solutions which reduce materials use and/or waste creation, and prioritise those which will have the biggest impact and are the easiest to implement;
2. Investigate the prioritised solutions further, and quantify the benefits; and
3. Implement the agreed solutions through the technical drawings, specifications, project reports and procurement process, and ensure that they are recorded in the Site Waste Management Plan (SWMP).

The selection of design solutions should be carried out in conjunction with the client, principal contractor and specialist subcontractors where possible. This ensures that considerations of buildability and effect on programme and sequencing of work packages are taken into account, and that all parties buy into the process and understand the need for waste reduction. This can be carried out as part of a formal design review at the preliminary design stage for large projects (for example as part of a Value Engineering process), or less formally for smaller projects. A suggested format for a design review workshop is given in this guide. WRAP has produced a suite of tools to help designers to identify, quantify and record opportunities to Design out Waste.

- The Designing out Waste Tool for Civil Engineering is used at the outline design stage, producing indicative results quickly based on limited project information and helping to inform design decisions.
- The Net Waste Tool is used as the design progresses and further information is available. It provides detailed calculations of waste and recycled content, helping to develop the selected design opportunities.
- The WRAP Site Waste Management Plan Template can be used to record the design decisions made to reduce waste and identify Good and Best practice performance, helping to meet legal requirements and communicate the design decisions to the contractor. WRAP has produced a suite of tools to help designers to identify, quantify and record opportunities to Design out Waste.

The guide presents a simple three-step process for applying the Designing out Waste principles in projects:

**Step 1: Identify**
- The Designing out Waste Tool for Civil Engineering
- The Net Waste Tool
- The WRAP Site Waste Management Plan Template

**Step 2: Investigate**
- Set a mandate in the project for waste reduction and materials resource efficiency, require the designers to create design solutions that minimise waste and ensure they are adopted in the project.
- Understand how design can reduce construction waste, costs and carbon impact on a project, and how contractors can work with the design team to identify and implement the best opportunities.

**Step 3: Implement**
- Highlighted here are the main objectives that will enable project teams to make a difference in Designing out Waste.
- Construction clients: Set a mandate in the project for waste reduction and materials resource efficiency, require the designers to create design solutions that minimise waste and ensure they are adopted in the project.
- Civil engineering covers a wide range of project types; some of the main categories are shown in the table below, but the list given is not exhaustive and categories not shown are not excluded from this guide. The aim is to present the key principles and a structured approach to Designing out Waste that can be applied to all types of civil engineering project. Both new construction and maintenance are included. Buildings, other than piling and foundation aspects, are not included; they are covered by a parallel WRAP publication 'Designing out Waste: a design team guide for buildings'.

### Designers for civil engineering projects:
Understand the principles behind Designing out Waste, the technical solutions available, the importance of considering waste and use of materials from the start of the design process, how the benefits can be quantified and to implement these principles by creating design solutions.

### Contractors:
Understand how design can reduce construction waste, costs and carbon impact on a project, and how contractors can work with the design team to identify and implement the best opportunities.

### Construction clients:
Set a mandate in the project for waste reduction and materials resource efficiency, require the designers to create design solutions that minimise waste and ensure they are adopted in the project.

### Civil engineering project types:

<table>
<thead>
<tr>
<th>Type</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Highways</td>
<td>Tunnels, Development site infrastructure</td>
</tr>
<tr>
<td>Airports</td>
<td>Railways, Flood defence</td>
</tr>
<tr>
<td>Utilities – streetworks</td>
<td>Ports and harbours, Coastal protection</td>
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<tr>
<td>Utilities – infrastructure</td>
<td>Bridges and structures</td>
</tr>
</tbody>
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Note: the project types are described in more detail in Part 2 of this guide.

### Key resources:
- Designing out Waste: a design team guide for buildings
- Designing out Waste Tool for Civil Engineering
- The Net Waste Tool
- The WRAP Site Waste Management Plan Template

1. Both the Designing out Waste tool and the Net Waste Tool are available at www.wrap.org.uk/fmetool
2. Available at www.wrap.org.uk/swmp
3. Available at www.wrap.org.uk/designingoutwaste
The construction industry is the UK’s largest consumer of resources, using over 400 million tonnes of material each year. Out of this an estimated 120 million tonnes of construction demolition and excavation waste is created. More efficient use of materials makes a major contribution to reducing the environmental impacts of construction including reduced demand for landfill and depletion of finite natural resources. It also contributes to the economic efficiency of the sector and of the UK as a whole.
A significant proportion of the environmental impact of construction arises from the use of resources – principally energy, water and materials. Optimising the use of materials and reducing the amount of waste created (called ‘materials resource efficiency’) is a highly effective sustainability strategy and involves a balanced approach through all stages in construction (including demolition). Implementing materials resource efficiency at the design stage is ‘Designing out Waste’.

Figure 1 shows how this can be approached and the white boxes highlight the areas where designers can have a significant impact. As can be seen, measures to improve materials resource efficiency are closely linked with measures to reduce energy.

It is important that designers adopt the ‘waste hierarchy’ (Figure 2) that focuses initially on reducing waste, as this is where potentially the largest impacts can be made. Application of materials resource efficiency will generally lead to the most cost effective and low carbon method of construction. In summary, major improvements in materials resource efficiency are possible and can lead to cost savings by:

- reducing the amount of materials used;
- reducing the quantity of materials being sent to landfill during the construction process by Designing out Waste and by effective site waste management;
- reusing, recycling and recovering waste materials wherever feasible; and
- utilising more recycled materials and mainstream products containing high levels of recycled material.

2.2 Drivers for reducing waste

2.2.1 Reducing waste reduces cost

The cost of disposal of waste to landfill has increased significantly in recent years, partly due to rapid escalation in the landfill tax (£48/tonne for non-hazardous waste in 2010/11). Even inert waste is expensive to dispose of because the number of licensed or permitted landfill sites has decreased significantly since the implementation of the Landfill Directive in the UK in 2001. Although the landfill tax for inert waste is much lower (£2.50/tonne), the large volumes generated on many civil engineering projects and the often long transport distances to suitable licensed or permitted landfills mean that the traditional “dig and dump” approach is no longer economic. Most contractors now aim to retain as many materials on site as possible, and look to their designers to provide solutions that enable this.

2.2.2 Government and regional policies and targets on waste

UK governments have set out to reduce construction waste to landfill for a number of years, for economic and environmental reasons. This has been implemented through a range of initiatives, including:

- a target for halving construction, demolition and excavation waste to landfill by 2012, relative to 2008, adopted in England by the government’s Strategy for Sustainable Construction 2008;
- the Zero Waste Scotland policy goal;
- the Welsh Assembly Government’s plan to move towards becoming a zero waste nation;
- the Site Waste Management Plan Regulations, which became mandatory in England from April 2008; and
- the Strategic Forum’s sector-wide Construction Commitments, which adopt on behalf of the construction sector the sustainability targets of the government’s Strategy for Sustainable Construction.
2.2.3 Reducing waste reduces CO₂

The government’s Strategy for Sustainable Construction also contains targets for the reduction of UK CO₂ emissions, including a target of 15% reduction from construction processes and associated transport by 2012 compared to 2008. The Climate Change Act 2008 sets a target of an 80% reduction in UK emissions of CO₂ by 2050. The Highways Agency introduced a carbon accounting framework in 2008 which includes measurement of CO₂ emissions from all construction and maintenance projects and has introduced targets for reducing greenhouse gas emissions. Local authorities are reporting to Defra on their CO₂ emissions for 2008-09 and will be expected to reduce emissions in the future. Measures that reduce CO₂ from construction will therefore be a high priority in determining the nature of construction operations in the future.

The good news is that measures that reduce waste will in most cases also reduce CO₂ emissions (Figure 1). There is therefore no conflict between Designing out Waste and reducing CO₂. In most cases, the measures will also bring cost savings and in some cases, savings in timescale as well. These synergies are described in more detail in the principles of Designing out Waste in Section 3 and the summary sheets for technical solutions in Part 2 of this guide.

The WRAP CO₂ emissions estimator tool is an Excel based calculation tool which estimates the carbon dioxide saved in selecting different construction techniques and supply alternatives, including the use of primary or recycled and secondary aggregates. It allows the user to compare different options for constructing a road and includes unbound, hydraulically bound, bitumen bound and concrete applications. The tool is available at www.aggregain.org.uk

WRAP is providing the framework to support the construction sector working towards achieving the Construction Commitments: Halving Waste to Landfill. Companies from all parts of the construction sector are encouraged to sign up to a voluntary commitment to demonstrate their intent to take action and measure and report progress. A large number of major civil engineering clients, contractors and designers have already signed up. For more information, refer to Appendix A or visit www.wrap.org.uk/construction

The significant financial gains available from effective waste reduction, together with the wider project and environmental benefits provide a powerful incentive for action.

CASE STUDY:

£16 million was saved by the use of recycled materials in the construction of the M6 Toll Road in the West Midlands. CAMBBA (a joint venture between Carillion, Alfred McAlpine, Balfour Beatty and AMEC) identified sustainable methods for the motorway construction, at the time the largest construction programme in the UK, including extensive processing and re-use of site recovered materials. A range of recycled aggregates were imported from other construction and demolition projects. The programme to reduce site waste to landfill created a saving of some 400,000 heavy lorry trips to the site, giving both CO₂ and cost savings.

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2.3 Waste management regulation

Unprocessed clean excavation materials used on the site of origin are not classed as waste. However, surplus material going off site, as well as surplus/damaged materials, off cuts and packaging are classified as waste and have to be handled in accordance with the relevant regulations on waste management. These impose a Duty of Care on all who handle, store, process or dispose of waste with the aim of preventing harm to human health and/or the environment.

The relevant regulatory authorities are:
- the Scottish Environment Protection Agency www.sepa.org.uk; and
- the Northern Ireland Environment Agency www.ni-environment.gov.uk

Details of the relevant regulations and procedures can be found at the websites of these organisations and also at www.netregs.gov.uk

The use of a cold mix process to recycle the existing pavement of the A38 in Devon reduced the CO₂ emissions from the works from 3,565 tonnes to 1,651 tonnes compared to conventional reconstruction using primary aggregates, and reduced the waste from the project by 11,500 tonnes.

The government’s Strategy for Sustainable Construction also contains targets for the reduction of UK CO₂ emissions, including a target of 15% reduction from construction processes and associated transport by 2012 compared to 2008.

Details of the application of waste regulations to the use of recycled and secondary aggregates are available in the Waste Management Regulations module of AggRegain at www.aggregain.org.uk

Reuse, recycling and recovery of waste is encouraged by the Regulations, but those undertaking such activities need to demonstrate that they are complying with the relevant legislation. Designers need to be aware of these requirements and ensure that sufficient time is allowed to comply with them, e.g. for obtaining licences/permits or exemptions for recycling or recovery activities. This will protect the project from prosecution and help to differentiate them from less competent organisations that are prepared to flout the law.

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For many years, most recycling and recovery operations have been undertaken under a series of exemptions from the Environmental Permitting Regulations (Waste Management Regulations for Scotland and Northern Ireland). These are currently under review for England and Wales and may be replaced by standard permits in the future. The aim is to make the level of regulation appropriate to the degree of risk involved. A number of activities are classed as Low Risk by the Environment Agency and do not have to be reported to them (for projects in England and Wales). A list of these is available on the Environment Agency website. Designers should check the relevant websites to ensure they are aware of the up-to-date position and are compliant with the relevant regulations.

Reuse of excavated material elsewhere on the same site – e.g. cut/fill earthworks – will generally be regarded as not requiring waste management licences/environmental permits or exemptions. However, if the material is sent off site, even for recycling, it becomes a waste and subject to the waste management/environmental permitting regulations. Processing of material on site – e.g. crushing and screening of demolition material – will also be subject to these regulations and require a licence/permit or exemption.

2.3.1 Quality protocols
Materials derived from waste and imported to the site are also covered by the waste management/environmental permitting regulations and will generally be regarded as waste until they have been placed in their final position. This means that the receiving site also has to have the relevant licences/permits or exemptions. However, these are not required if the materials have been produced in accordance with a Quality Protocol developed by the Environment Agency and WRAP.

Quality Protocols require producers of recovered materials to demonstrate that they comply with the relevant standards and that the materials have been fully recovered and are no longer waste. The Quality Protocol for the production of aggregates from inert waste has been available since 2004 and can be downloaded from www.aggregain.org.uk. Versions have been produced for England and Wales, Scotland and Northern Ireland in liaison with the regulatory authorities in each region.

Further protocols are being developed by WRAP and the Environment Agency for a number of other materials, including:
- pulverised fuel ash (pfa) and furnace bottom ash (fba);
- steel slag; and
- tyre derived rubber materials.

These protocols are not endorsed by the Scottish Environment Protection Agency, so will only apply in England, Wales and Northern Ireland.

Blast furnace slag has been deemed to be a by-product rather than a waste and hence does not require a Quality Protocol. Details of the various protocols are available on the Environment Agency website. Designers should ensure that recycled and secondary materials imported to their project are produced in accordance with the relevant protocols. This provides assurance on the quality of the products and means the site does not require a licence/permit or exemption to receive them.

Designers should check the relevant websites to ensure they are aware of the up-to-date position and are compliant with the relevant regulations.

2.3.2 Contaminated land

Particular care has to be taken when dealing with contaminated land, and liaison with the regulatory authorities should take place from as early a stage as possible in the project life cycle. Guidance on the management of land affected by contamination, including model procedures and requirements for contaminated land reports, are available on the Environment Agency website. Guidance on assessing whether materials are classed as waste or not and determining when treated waste can cease to be waste for a particular use is given in ‘The Definition of Waste: Development Industry Code of Practice’ available from the CL:AIRE website www.claire.co.uk.

It will be important for the designer to understand clearly what the regulatory requirements will be for the processing of the contaminated materials, including any emissions to air or water, testing and any long term monitoring and validation, and on how recovery of the materials from waste will be assessed and demonstrated. Materials Management Plans, described in the CL:AIRE Code of Practice, can be a suitable way of demonstrating recovery from waste.

Designers therefore need to be aware of a number of issues relating to waste regulation in order to ensure that the relevant measures are included in the design and programme and communicated to the client, principal contractor and supply chain. This will aid in obtaining planning permission and ensuring the project complies with all the relevant legislation. This will avoid unexpected delays if the relevant licences/permits or exemptions are found not to be in place at a later stage in the project and will ensure the construction does not lead to pollution of the environment and/or harm to human health.

Key resources
- Quality Protocol for the production of aggregates from inert waste
- The Definition of Waste: Development Industry Code of Practice
- www.netregs.gov.uk
- www.aggregain.org.uk
- www.claire.co.uk

2.4 Demonstrating waste reduction

2.4.1 Site Waste Management Plans

One of the legal requirements for a Site Waste Management Plan in England is that, ‘It must record any decision taken before the site waste management plan was drafted on the nature of the project, its design, construction method or materials used in order to achieve the objective set requirements in project procurement contracts; and others that they are contributing to the development of waste policy and its implementation in England and Wales as well as in Scotland and Northern Ireland.’ The WRAP SWMP Template (available at www.wrap.org.uk/swmp) has a section which the design decisions can be recorded and the benefits quantified. This enables the designer to demonstrate to clients and others that they are contributing to corporate policies to reduce waste and, for signatories to the Halving Waste to Landfill Commitment, fulfilling their responsibilities at project level to:
- create design solutions that minimise waste and use resources efficiently;
- set requirements in project procurement processes and engage with the supply chain; and
- measure performance at a project level relative to a corporate baseline.
2.4.2 The Net Waste Tool (NWT) and other WRAP tools

WRAP’s Net Waste Tool (NWT) includes:
- the Designing out Waste Tool for Buildings (DoWT-B).
- the Designing out Waste Tool for Civil Engineering (DoWT-CE).
- the Net Waste Tool – detailed design tool (NWT-D).

The Designing out Waste (DoW) tools assist designers during the preliminary or outline design stages of either buildings or civils projects to estimate the savings in waste, cost, and embodied carbon that can be achieved by using the technical solutions described in Part 2 of this guide. The tool is designed to complement this guide (and the design guide for buildings) and is available at www.wrap.org.uk/nwtool.

For those design solutions that are followed through to the detailed design stage, the Net Waste Tool can be used to calculate the anticipated waste and recycled content. Measures can then be selected to reduce the quantity and cost of waste and increase the recycled content. The Net Waste Tool is also available at www.wrap.org.uk/nwtool.

The WRAP SWMP Template can be used to record the waste prevention and reduction solutions identified, the forecast waste quantities and proposed waste management strategy, and the actual waste produced on site and how it was reused, recycled or otherwise disposed of. It also allows users to review and improve their progress from Standard Practice to Good and Best Practice levels of waste reduction and recovery.

Standard Practice is compliance with legal requirements. Good and Best Practice go beyond this to identify and implement ways to achieve significant reductions in waste, cost savings and improvement in the materials resource efficiency of the project.

The WRAP SWMP Template is available at www.wrap.org.uk/swmp.

The relation between generic project stages and the various WRAP tools is illustrated in Figure 3 and discussed in more detail in Section 4.2.

### Key resources
- Site Waste Management Plans Regulations 2008
- The WRAP SWMP Template
- The Net Waste Tool
- CEEQUAL

For those design solutions that are followed through to the detailed design stage, the Net Waste Tool can be used to calculate the anticipated waste and recycled content. Measures can then be selected to reduce the quantity and cost of waste and increase the recycled content.

2.4.3 CEEQUAL

CEEEQUAL is the Civil Engineering Environmental Quality Assessment and Awards Scheme and can be accessed at www.ceequal.com.

It is a scheme for improving sustainability in civil engineering and public realm projects. It was developed by the Institution of Civil Engineers (ICE) and a wide ranging group of committed industry organisations. It is operated for and by the construction industry with shareholders including ICE, the Construction Industry Research and Information Association (CIRIA), Building Research Establishment (BRE), Civil Engineering Contractors Association (CECA) and Association for Consultancy and Engineering (ACE).

The objective of CEEQUAL is to encourage the attainment of environmental excellence in civil engineering, and therefore to deliver improved environmental and social performance in project specification, design and construction. CEEQUAL uses a points-based assessment system for projects covering a number of topics, including waste minimisation and management. Measures to design out waste can therefore be used to gain points on CEEQUAL and demonstrate the environmental excellence of a project.

More details on CEEQUAL are given in Appendix B.
3.0 The five principles of Designing out Waste

During the design process there are numerous opportunities to reduce waste and this guide provides a systematic approach to identifying and implementing them at project level. It is based on key principles distilled from extensive consultation, research and work carried out by WRAP directly with design teams. The guidance contained in this document is intended to be adapted to suit the specific requirements of each project.
3.1 Introduction

Research carried out by WRAP has identified five basic principles that can be adopted to reduce the waste produced by projects through design:

- **Design for Reuse and Recovery.**
- **Design for Off Site Construction.**
- **Design for Materials Optimisation.**
- **Design for Waste Efficient Procurement.**
- **Design for Deconstruction and Flexibility.**

Some technical solutions through which the principles can be implemented are described in Part 2 of this guide. The principles should be applied as early as possible in the project lifecycle, ideally from the feasibility study stage (Figure 3), as this gives the maximum scope for achieving efficiencies in waste and cost reductions, reductions in embodied carbon and increased recycled content. The principles are applicable to both new construction and maintenance/refurbishment projects (Section 4). They need to be applied throughout the project lifecycle, in particular at the detailed design and procurement stages, to ensure that the potential gains identified during the outline design are achieved during construction. The WRAP SWMP Template can be used to track the development of waste reduction measures and demonstrate the savings to clients, the project team, management and others.

The approach in this guide is to proactively target options to reduce waste, recognising that a few key solutions on each project are likely to achieve significant waste reduction, along with cost savings and other benefits such as reduction in the project’s carbon footprint. These will be different for every project, so it is important to have a process for prioritising these actions, i.e. project ‘Quick Wins’.

The same five key principles are also used in the WRAP design team guide for buildings and this should be referred to for all building elements of a project.

3.2 Design for Reuse and Recovery

This principle has particular relevance to civil engineering projects, which typically use large quantities of materials in earthworks, pavements and structures and can generate large quantities of waste. Design for Reuse and Recovery of materials already on site is fundamental to achieving materials resource efficiency, minimising the quantities of materials that have to be imported to or exported from the site. It is impossible to eliminate the import of materials completely, particularly for elements such as pavements, concrete, steel and drainage. For these elements, however, gains in materials resource efficiency can be made by using materials with high recycled content.

Design for Reuse and Recovery may be split into two subsections:

- Reuse and recycling of materials on site;
- Importing materials with high recycled content.

Under the waste hierarchy (Figure 2), actions under reusing and recycling of materials on site should be considered first, then supplemented by importing materials with high recycled content.

3.2.1 Reuse and recycling of materials on site

A number of generic opportunities are available to enable reuse and recycling of materials on site in civil engineering projects (Table 2). These are well established techniques, supported by technical guidance and standards. They are outlined in the following paragraphs and their application to particular elements is described in more detail in Part 2 – the Technical Solutions part of this guide.

### Table 2. Opportunities for reuse and recycling of materials on site

<table>
<thead>
<tr>
<th>Reuse existing foundations, floor slabs, pavements, structures and drainage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Designing site layout to use existing topography and features</td>
</tr>
<tr>
<td>Balancing cut/fill quantities</td>
</tr>
<tr>
<td>Manufacturing soils on site using PAS 100 compost</td>
</tr>
<tr>
<td>Treating of soils with cementitious agents and use of hydraulically bound materials (HBM)</td>
</tr>
<tr>
<td>Using geosystems to enable use of material on site</td>
</tr>
<tr>
<td>In-situ remediation or encapsulation of contaminated land</td>
</tr>
<tr>
<td>Crushing/screening arisings for use as recycled aggregates</td>
</tr>
<tr>
<td>Cold recycling of pavements</td>
</tr>
</tbody>
</table>

Reusing existing foundations, floor slabs, pavements, structures and drainage

The first question that should be asked when a new development is proposed is, ‘what use can be made of existing structures and materials on site?’ This may be as fundamental as deciding whether an existing structure can be retained and refurbished rather than demolishing it and building a new structure. This opportunity usually relates to buildings and so is an important element within Designing out Waste: a design team guide for buildings; however, similar principles can be applied to other constructed elements such as pavements, foundations, floor slabs, structures and drainage. It is important that this is considered at the feasibility stage, so that the design process can be focused on reuse rather than new construction.
Balance cut/fill quantities

It is a fundamental principle of earthworks that the design should attempt to balance the quantities of cut and fill to minimise the import, export and movement of materials\(^1\). However, there are often reasons why this is not readily achievable; earthworks material may be unsuitable for use as fill or as foundation materials or may be susceptible to deterioration in wet weather. In the past, when landfill and primary aggregates were cheap and readily available, it would often be cheaper to excavate unsuitable materials and import suitable ones than to engineer the materials on site to make them suitable. Questions of liability over contaminated land also often led to a ‘dig and dump’ approach where this was concerned. However, with the rapidly increasing cost of landfill and primary aggregates, the situation has changed so that it is now generally cheaper to retain materials on site wherever possible, which also benefits improving materials resource efficiency.

It is also particularly important to make the best use of topsoil and subsoil available on site. These surface layers which support plant growth are collectively termed ‘soil’ and are vulnerable to damage during construction works. They are also very expensive to import to site. Care should therefore be taken to ensure that a soils audit and survey is undertaken prior to work starting, a plan is made to maximise their reuse and implemented to ensure minimum waste on site. Defra has recently published a Code of Practice for the sustainable use of soils on construction sites\(^2\). Soil in this sense should not be confused with the underlying layers that are used for earthworks purposes, though these are also often termed ‘soil’ (as opposed to ‘rock’).

Manufacture soils on site using PAS 100 compost

Excavated material from shallow depth is often unsuitable for use as fill in embankments and structures, as it may be too wet or have significant organic matter. Provided the materials are not contaminated, however, they can be a useful resource for manufacturing topsoil for the site when mixed with compost complying with PAS100. Similarly, other materials that are unsuitable for reuse as structural fill, such as colliery spoil or poor quality topsoil, can be used for manufacturing soil; materials such as these are often present on regeneration sites and present a challenge for the designer. The use of such materials should be built into the cut/fill balance to ensure they are used effectively, and to ensure that sufficient material for topsoil manufacture is identified. Topsoil is often very scarce on development sites, particularly on brownfield land, and it is important to identify suitable materials for soil manufacture at an early stage, as it is very expensive to import topsoil. Surplus material may also be used for landscaping, and the potential for this should also be identified as early as possible in the project. A WRAP guide to compost specification and use and case studies are available at www.wrap.org.uk/composting.

An example of the use of PAS100 compost is shown on Figure 4.

Treatment of earthworks materials

with cementitious agents and use of hydraulically bound materials (HBM)

Earthworks materials that are too wet for use may be rendered suitable by treatment with binding agents such as lime, cement, pulverised fuel ash (pfa) or ground granulated blastfurnace slag (ggbs). This may be carried out in-situ, to render the soil suitable for use as capping (Figure 5), or by excavating and mixing on site, to enable material to be placed as fill in an adjacent area. This can be particularly useful for developments on sloping ground where material excavated on the upslope side is to be deposited on the downslope side to form a level platform.

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Figure 4. Manufactured soil using compost – Ebbw Vale regeneration
To avoid differential settlement across the site, the fill material must have similar strength to the area of cut, but as the excavated fill is from shallower depth it is likely to be weaker and may need treatment, especially if the soil is fine grained and the work is carried out in winter or wet weather. If secondary materials such as pfa and ggbs can be used instead of cement or lime, the carbon footprint can be significantly reduced. Higher value end uses can be obtained by using larger proportions of binding agents, to give materials with higher strength and stiffness for use as subbase and base layers in pavements and as working platforms. These materials are generically classed as hydraulically bound materials (HBM) and can be used either with existing soils in-situ to create subbase, with arisings of fine grained soils from trench excavations to produce suitable backfill materials, or with coarse recycled or secondary aggregates in a variety of applications. Geosystems comprise soil, an engineered geo-component and engineering input. Geo-component is a generic term referring to an engineered product, often but not always geosynthetic based, used in a geosystem. Geosystems can be used to reinforce existing materials, either in new construction or as repairs to existing slopes and pavements. Use of geosystems can enable thinner layers and steeper slopes to be used in pavements and embankments, reducing the total quantity of materials required. They can also be used in place of concrete and steel, materials with high embodied carbon, to provide low-carbon engineering solutions. WRAP has recently published extensive guidance on geosystems; this is available at www.aggregain.org.uk. Examples of the use of geosystems in slope and soil reinforcement are shown in Figures 7 and 8.

Figure 5. In-situ application of binders to create an HBM

Figure 6. Ex-situ manufacture of an HBM, and placement

Figure 7. Examples of geosystems being used in retaining walls for steep slopes

13 Available at www.wrap.org.uk/construction/how_do_i_reduce_waste/sectors/utilities/utilities_guidance.html
14 Available at www.aggregain.org.uk/opportunities/materials/hydraulically_bound/index.html
In situ remediation or encapsulation of contaminated land

Many brownfield sites contain contaminated soils, which require treatment before the site can be developed. A range of remediation technologies are available, either on site or at adjacent ‘hub’ sites; these include:
- soil washing;
- biodegradation of organic contaminants;
- thermal desorption;
- soil vapour extraction for volatile organics and petroleum;
- chemical methods; and
- stabilisation with cementitious agents to form HBMs and prevent migration of contaminants.

Treatment of groundwater may also be required. Regulatory requirements must be complied with (see Section 2.3), appropriate permits obtained and long term monitoring may also be required in some cases. However, this will generally be cheaper than disposal of large volumes of hazardous waste to landfill.

Crush/screen arisings for use as recycled aggregates

If it is not possible to reuse existing foundations, floor slabs, pavements or structures, they may be demolished or excavated and the resulting materials crushed and screened to produce recycled aggregates for use in the redevelopment of the site or potentially exported to other sites (Figure 9).

Pre-demolition audits and appropriate surveys should be carried out to ensure that the materials are suitable for recycling and to obtain estimates of the quantities available.

The materials must be inert, i.e. clean concrete, brick, masonry, asphalt, rock and soil; contaminated materials must not be included. The ICE Demolition Protocol\(^1\) can be used to quantify the materials available for recycling at the demolition stage and track their use.

The WRAP guide, The efficient use of materials in regeneration projects\(^2\) details a step-by-step approach to the ICE Demolition Protocol and good practice in site waste management planning and achieving higher recycled content.

Three KPIs can be used with the guide and the ICE Demolition Protocol to encourage greater reuse and recycling of material:
- the Demolition Recovery Index (DRI) describes the efficiency of material recovery from demolition;
- the Retained Material (RM) is a measure of the extent of reuse of demolition materials on site; and
- the Recycled (and reclaimed) Content (RC) measures the proportion of recycled (and reclaimed) materials in the new build.

Recycled aggregates should be produced in accordance with the WRAP Quality Protocol for the production of aggregates from inert waste, to ensure a high standard of quality control and aggregates that are no longer waste for use on or off site. In this way, suitable materials for subbase, capping, drainage and backfill to structures can be generated on site rather than being imported, reducing waste to landfill, transport costs and CO\(_2\) emissions. Recycled aggregates may be produced that are not compliant with the Quality Protocol in which case they will remain waste and an exemption or permit will be required for their use on or off site.

If the conditions on site do not permit the processing of materials, e.g. due to lack of space, demolition and excavation materials may be sent to a nearby aggregate recycling plant for processing. In this situation it will not usually be possible (or sensible) to return the same material, processed into recycled aggregate, to the site where it came from. However, the demolition protocol can be used to track the material and confirm that it has been turned into recycled aggregate for sale on the open market. The demolition protocol can also be used to confirm that incoming materials to the site have an equivalent or greater recycled content than could be obtained by processing the material on site.

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1. Available at www.ice.org.uk/knowledge/specialist_waste_board.asp
2. Available at www.wrap.org.uk/construction/tools_and_guidance/regeneration.html
Cold recycling of pavements

Where maintenance of existing roads is required, a range of cold recycling techniques is available to enable the existing pavement materials to be recycled into the new pavement. These techniques can be applied in-situ or by excavating the pavement layers, taking them to an adjacent temporary plant site, mixing and returning to site. The latter approach enables greater consistency to be obtained in the final product, which enables thinner layers to be used to achieve the same level of performance. These techniques can also be applied to airport pavements. Cold recycling techniques greatly reduce the quantities of waste compared to conventional reconstruction of the pavement. They are also generally quicker, cost less and emit less CO₂.

Cold recycling can also be used to take planings from existing road pavements on the site and use them as coarse aggregate in new pavements in other areas of the site. A range of other hot and cold maintenance techniques are available for highway and airport pavements to avoid complete replacement of the existing structure. Ex-situ cold recycling of an asphalt pavement is shown on Figure 10 and the crack-and-seat process for concrete pavements is shown on Figure 11.

3.2.2 Importing materials with high recycled content

In construction, reuse may imply the reuse of existing materials on site (see Section 3.2.1) or the use of ‘new’ construction materials that contain a high level of recycled material (often referred to as ‘recycled content’). There have been major advances in the use of recycled materials in civil engineering projects in recent years (Table 3).

Recycled and secondary aggregates now comprise 25% of the aggregates consumed in the UK and recycled aggregates are permitted in almost all applications for highways in the UK Specification for Highway Works.

CASE STUDY:

In a recent project to widen the M25 between Junctions 12 and 15 and construct a spur road into Heathrow Terminal 5, 90% of the unbound aggregates used were recycled aggregates, with about one third being obtained from existing pavements and soils on site and two thirds from demolition material from the London area.18

Key questions

- Can any elements of the existing site be reused in the new development?
- Can demolition and excavation materials be recycled as aggregates on or off site?
- Can the site layout be adapted to the existing topography to minimise earthworks?
- Can a cut and fill balance be achieved with the ground conditions on site?
- Can unsuitable soils be used for soil manufacture with PAS 100 compost?
- Can unsuitable soils be rendered suitable by stabilisation or geosystems?
- Can contaminated soils be remediated or encapsulated on site?
- Can existing pavements be recycled into new pavements using cold recycling techniques?
All of the materials listed in Table 3, and many other materials with high recycled content, can be obtained with no loss of performance or increase in cost compared to virgin materials. Details are given in the WRAP ‘Recycled content in construction products guide’. Opportunities to use recycled materials in civil engineering are given in the WRAP ‘Quick Wins Guide’ and ‘Reference Manual’ as well as on www.aggregain.org.uk. It may be possible to use reclaimed materials, such as bricks and tiles, on some sites; details of the availability of such materials are given in the WRAP ‘Reclaimed building products guide’.20

Table 3. Opportunities for imported materials with high recycled content

| Using recycled/secondary aggregates in unbound applications |
| Using recycled/secondary aggregates in HBM |
| Using recycled asphalt in new asphalt |
| Using secondary aggregates in asphalt |
| Using PAS100 compost in soils manufacture and landscaping |
| Using recycled steel in piles, safety barriers, decks, rails, structures, etc. |
| Using recycled tyres – tyre bales, shredded tyres in drains, crumb in asphalt, etc. |
| Using recycled plastic in kerbs, railway sleepers, piles, etc. |
| Using high recycled content in pipes, e.g. recycled aggregate in concrete, recycled steel, plastic, etc. |
| Using geosystems with imported_fll to reduce layer thicknesses |

Designers should ensure that they use specifications that do not prohibit the use of materials with high recycled content. The use of materials with high recycled content should be considered from an early stage, as part of the overall project strategy to minimise waste and maximise recycled content.

Use of materials with high recycled content reduces the overall level of waste from construction as it enables materials that might otherwise be disposed of to landfill or exempt sites to be used as high value construction materials. The recycled content has to be balanced against the transport distance; however, if the products or material cannot be sourced locally it may be less sustainable to transport it a long distance to site than to use locally available materials with lower recycled content. This is particularly important for bulk materials such as aggregates, where the most sustainable source will generally be that closest to the site, whether primary or recycled. Designers need to consider the availability of recycled materials at an early stage, especially when setting targets for projects in terms of recycled content or carbon footprint. Guidance is given in the WRAP guide ‘The efficient use of materials in regeneration projects’.19

Recycled aggregates for unbound applications will generally be available in most urban areas in the UK. However, use of recycled aggregates in concrete, although technically possible, may be difficult to achieve as few suppliers produce recycled aggregates of sufficient quality for use in concrete, and few concrete producers are set up to use recycled aggregates. The use of recycled aggregates in hydraulically bound materials can, however, be used in a number of applications including working platforms, road and airport pavements and as trench reinstatement to utility renewal works.

Key questions

- Where can recycled products be used in the design?
- Are recycled products of adequate quality available locally at reasonable cost?
- Is the use of recycled products tracked using the ICE demolition protocol and WRAP guide ‘The efficient use of materials in regeneration projects’?

The latter application can be run as a ‘closed loop’ operation, with arisings from various streetworks being brought to a central depot, processed and sent out either as unbound aggregates or hydraulically bound materials for backfill to other streetworks excavations. Guidance on the use of recycled and secondary aggregates in hydraulically bound materials is available at www.aggregain.org.uk.

ICE Demolition Protocol

The efficient use of materials in regeneration projects

Code of Practice for the sustainable use of soils on construction sites

Sustainable geosystems in civil engineering applications

Hydraulically bound materials incorporating recycled and secondary aggregates

Quality manual for hydraulically bound materials

Quality Protocol for the production of aggregates from inert waste

www.aggregain.org.uk

3.2.3 Impact on programme

It is essential that options for reuse and recovery are considered from the very start of a project in order to inform the design process so that the best options for the site can be identified and implemented. This process has to start at the feasibility stage and will then follow through the rest of the project cycle as shown on Figure 12. It is important that the preliminary and detailed ground investigations and surveys are designed to address the key questions for reuse and recovery, or it may either not be possible to implement these options or the risks involved may be much greater. For example, if it is proposed to use treatment with lime or cement to render wet soils suitable for use as fill or capping, detailed testing should be carried out to determine the optimum mix design and to check for the presence of components that could make the soil unsuitable for this technique, such as organic compounds or sulfates.
Off site construction is one of a group of approaches to more efficient construction sometimes called Modern Methods of Construction that also include prefabrication, improved supply chain management and other approaches. These are extensively used in the buildings sector of construction but are also suitable for a number of applications in civil engineering, including:

- use of prefabricated units such as manholes;
- use of precast components for retaining walls, bridges and other structures;
- use of precast piles rather than cast in-situ; and
- use of precast tunnel segments rather than cast in-situ tunnel linings.

The examples given here all involve concrete; applications where precast concrete can be used in preference to cast in-situ will often save waste and speed the construction work, as it eliminates the need to wait for concrete to gain strength before placing subsequent lifts. This can be particularly important where the programme is tight. Similarly, avoiding having to lay bricks on site by use of prefabricated units may often reduce waste and save time, leading to savings in cost.

The methods of construction should be considered from the early project stages, particularly at the preliminary design stage. By this stage the basic design concept should be sufficiently well established that the method of construction becomes important in achieving the project objectives. The final decisions on method of construction may not be made until the detailed design stage, but it is important that they are discussed at the preliminary design stage so that any possibilities are not excluded.

It is important that all relevant specialists are involved in the discussion about the possible use of off site construction, as this may involve factors beyond the knowledge or experience of the design team.
This is particularly critical for piling, where ground conditions, adjacent structures, limits on noise and vibration, and anticipated loadings (particularly if uplift forces have to be resisted, e.g. for wind turbine foundations) should be considered. Specialist piling contractors should always be involved in such discussions. Similarly in other areas, the relevant specialists should always be involved in the discussions (see Section 3.5 - Design for Waste Efficient Procurement). Integrated project teams allow the open discussion of such ideas at an early stage and help to provide a ‘reality check’ on potential methods of construction. Similar advantages to off site construction can be gained in some cases by constructing components on site in the same way as in a factory and then transporting them to where they will be used, for example tunnel lining segments which can be precast on site or off site and then moved to the tunnel face rather than being cast in-situ. Tunnel linings are often constructed by using shotcrete – quick-setting concrete sprayed directly onto the face – as this is more rapid than using segmental linings. However, the use of shotcrete produces large amounts of waste due to rebound during the spraying process. The use of precast linings can significantly reduce the amount of waste.

Assembly on site is now frequently used as a method of construction for replacement bridges and viaducts. The new structure is built alongside the existing one, which is then demolished and the new structure moved into place as a unit.

The main driver for this method of construction is that it minimises closure or disruption of the road or railway, but it also allows more efficient construction with reduced waste compared to constructing it in stages while keeping the road/railway functioning. The existing structure can then be demolished or dismantled more efficiently, allowing greater recovery and reuse of its materials for future projects. Therefore, the potential to use off site construction should be considered at the preliminary design stage because of its impact on:

- structural design/system selected;
- project timescales;
- coordination with other work packages;
- project buildability; and
- procurement routes.

For smaller scale systems and/or components (e.g. manholes), usually procured through specialist subcontractors, it is likely that the designer will consider these elements suitable for Design for Off Site Construction during later design stages, possibly having identified the most suitable items to be manufactured off site during the preliminary design stage.

### Key questions

- Can any part of the design be manufactured off site?
- Can site activities become a process of assembly rather than construction?

### Key resources

- Current practices and future potential in Modern Methods of Construction

### 3.4 Design for Materials Optimisation

Materials Optimisation means adopting a design approach that focuses on materials resource efficiency so that less material is used in the design (i.e. lean design/ value engineering) and/or less waste is produced in the construction process, without compromising the design concept or required performance. This is subtly different from Design for Reuse and Recovery, which aims to maximise efficient use of materials available on site and maximise the recycled content of imported materials. A number of technical solutions, in particular the use of geosystems, can be used to implement both principles. Various ways in which Design for Materials Optimisation can be applied to civil engineering projects are described below.

A key aspect of Design for Materials Optimisation is the use of various ground improvement techniques to avoid having to excavate soft foundation soils, which may be unable to support the proposed loading from embankments, buildings or structures without excessive settlement or even failure. Various techniques can be used to overcome these problems, including:

- foundation drains to accelerate settlement;
- geosystems to reinforce weak foundation soils;
- vibrocolumns and dynamic consolidation to strengthen the foundation soils;
- lightweight fill to reduce loading; and
- staged construction to allow consolidation of the foundation before construction of the structure or pavement.

### CASE STUDY:

- Tyre bales and lightweight fill are being used on the widening of the A421 between the M1 and Bedford to construct a temporary bypass across a former slurry pit.
- Tyre bales and rock fill are being used to construct 65 km of reinforced access roads for a wind turbine farm in South West Scotland to avoid having to excavate the very soft peat.

Depending on the ground conditions, these techniques may be used in combination to enable construction, e.g. for a highway embankment over soft ground, foundation drains, a reinforcing geosystem at the base of the embankment, lightweight fill and staged construction may all be used. Some of these options are illustrated in Figure 14 and 15. The alternative would be excavation of the soft soils, if not too deep, and replacement with imported free-draining fills and/or construction of the embankment with much shallower side slopes to spread the load. Both options would result in much greater use of materials and would require the disposal of large quantities of unsuitable foundation soils.

Many of the ground improvement techniques described above require the use of a working platform. This provides various opportunities for material optimisation and reuse of materials:

- use unbound recycled aggregates to construct the working platform;
- use recycled aggregates with binders to create a hydraulically bound mixture working platform, which will be stronger than an unbound working platform;
- construct a working platform by treatment of in-situ soils with lime or cement; and
- incorporate the working platform into the final structure as part of the design.

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Guidance produced by WRAP on the use of hydraulically bound materials for working platforms is available at www.aggregain.org.uk.

Also included in Design for Materials Optimisation are innovative ways to reduce the overall material use in structures such as voided slabs in bridges, lightweight aggregate in concrete (especially when derived from a secondary material such as expanded pulverised fuel ash) and use of innovative lightweight materials such as fibre reinforced composites. Reducing the weight of structures reduces the loading, so the structural members and foundations will be thinner and require less cement and reinforcement. Geosystems can also be used to reduce the overall material use on a project by enabling steeper slopes to be constructed without requiring the use of concrete or steel retaining structures or by enabling pavement layers to be thinner.

Design for Materials Optimisation also includes the simplification and standardisation of materials and component choices and the importance of making the design buildable. These aspects are mainly considered at the detailed design stage, but should be borne in mind from the start of the design process. Standard details for most forms of construction are available, e.g. standard drawings for highway construction details are available in Volume 3 of the Manual of Contract Documents for Highway Works.

Simplification and standardisation of materials and component choices will increase the buildability, reduce the amount of rework and allow reuse of formwork. Using standard dimensions will minimise the number of off cuts (e.g. for geosynthetics).

Considerations of buildability are particularly important for design of reinforcement for concrete and for complex geosystems; designs that look suitable on drawings may prove difficult to construct on site, particularly in cramped conditions and bad weather. It is important that designs are checked by experienced practitioners to ensure that they are simple and easy to construct on site. As with the other design principles, involvement of an integrated project team from an early stage will result in designs that are buildable and efficient in terms of materials resource efficiency, cost and programme.

Key questions:
- Can the amount of excavation be avoided by using ground improvement techniques?
- Can the overall use of materials be reduced by use of geosystems?
- Can the working platform (if required) be incorporated in the final structure?
- Can innovative designs or materials be used for structures to reduce material use?
- Can the design, form and layout be simplified without compromising the design concept?
- Can the design be coordinated to avoid/minimise excess cutting and jointing of materials (e.g. pipes and geosynthetics) that generate waste?
- Is there repetition and coordination of the design, to reduce the number of variables and allow for operational refinement (e.g. reusing formwork)?

Key resources:
- Guidance on the use of HBM in working platforms
- Quality manual for hydraulically bound materials
- Sustainable geosystems in civil engineering applications
- www.aggregain.org.uk
3.5 Design for Waste Efficient Procurement

Until relatively recently, designers of civil engineering projects largely regarded waste as ‘a matter for the contractor’. Similarly, the programming and sequencing of work on site was largely left to the contractor, so long as it did not affect health and safety or the satisfactory performance of the finished works. This was largely a function of the traditional forms of contract, which set out clear responsibilities for each party. With the increase in design and build, joint ventures, partnerships and other innovative forms of contract, the designer is now likely to be much more integrated within the project team and able to contribute to initiatives to reduce waste through procurement.

The advantages of integrated project teams, with early contractor involvement, will help in identifying the areas where waste is likely to be generated and the design decisions that can reduce this. This will involve liaison with the principal contractor and specialist subcontractors. At preliminary design stage, this will assist the designer to investigate options that are simple to construct and minimise waste. At the detailed design stage, this can extend to developing the work sequences and material logistics plans that will minimise waste. Programming should ensure work is efficient and does not cause unnecessary waste due to rework. It should also ensure that opportunities to reuse materials are taken, e.g. demolition material from one phase of a project being processed for use as recycled aggregates in another phase. It is important that the contractual arrangements do not prohibit the use of waste minimisation and recovery techniques, e.g. by excluding them from the specification.

During the detailed design stage, designers need to understand how their design choices lead to the generation of waste on site. An example is the selection of mesh size for reinforced concrete, which should be open enough to allow the concrete to be placed and compacted easily while providing the required degree of reinforcement. Similar considerations apply to the specification of geosynthetics. Once this is understood, methods can be applied that can reduce waste through some or a combination of the following:
- design (e.g. designing structural elements which can be constructed efficiently);
- specification (e.g. writing tighter specifications of work procedures to avoid waste and allow the use of recycled materials); and
- contracts (e.g. encouraging early contractor involvement).

One of the most important ways in which procurement can be used to promote waste reduction is by including commitments to reducing waste in contracts throughout the supply chain, including those for designers. Suitable wording for generic clauses for avoiding waste and allowing the use of recycled materials; and contracts (e.g. encouraging early contractor involvement).

Appropriate KPIs and targets for waste can also be included in contracts. The designer should be involved in the setting of these at project level at an early stage, in conjunction with the client and principal contractor (if appointed). Individual clients will often have company-wide KPIs and targets for waste, which can be included directly in the contract documents. While there is a wide range of KPIs relating to construction waste available, the most useful ones are those used for reporting on progress towards Halving Waste to Landfill.

These are available at the WRAP Reporting Portal[^29] and are given below:
- waste to landfill KPI: reduction in ‘tonnes of waste to landfill per unit of construction output’ relative to baseline year;
- waste reduction KPI: reduction in ‘tonnes of waste per unit of construction output’ relative to baseline year;
- waste recovery KPI: percentage of waste diverted from landfill during the last year.

The WRAP SWMP Template will automatically calculate a number of KPIs, which can be compared with targets set before construction starts. A number of KPIs that can be used for highway works, particularly for local authority term maintenance contracts, are given in the WRAP ‘Recycled Roads’ guides[^30].

For designers and consultants who have signed the Halving Waste to Landfill Commitment, one of the actions is ‘Identify for clients and contractors the best opportunities to reduce waste and use more recovered material’. Waste efficient procurement is a way of fulfilling this commitment.

[^28]: Available at [www.wrap.org.uk/procurementrequirements](http://www.wrap.org.uk/procurementrequirements)
[^30]: Available at [www.aggregain.org.uk/recycled_roads](http://www.aggregain.org.uk/recycled_roads)
3.6 Design for Deconstruction and Flexibility

Design for Deconstruction and Flexibility is one of the key principles for designing out waste in buildings. Designers need to consider how materials can be recovered effectively during the life of the building when maintenance and refurbishment is undertaken or when the building comes to the end of its life, and this is discussed in the design team guide for buildings. The principle is also relevant for civil engineering projects, although with a slightly different focus.

Some civil engineering structures, such as pavements and earthworks, cannot be disassembled and reconstructed in the same way as buildings, but there is still a requirement to ensure that they can be maintained, refurbished or extended as required. The construction should not include any materials or components that would make future extension or recycling difficult or impossible. Examples of ‘how not to do it’ include:

- the use of unbound post-tensioned steel in reinforced concrete structures that render it difficult and dangerous to demolish;
- the use until the 1960s of coal tar, a material containing carcinogenic organic compounds, in bituminous pavements; and
- designing underground services such as drainage pipes or water mains without considering future potential lateral connections which may otherwise require rework or major shutdowns.

All these problems can be overcome. It is good practice in the design of current projects to avoid the use of hazardous materials that might cause problems for future recycling. These should be picked up during the design process by CDSHH assessments and the application of the Construction (Design and Management) Regulations 2007. Use of the Regulations will also encourage construction that makes maintenance easy. Future deconstruction or augmentation may still be an important consideration in some cases, possibly to allow widening of a road, bridge or other facility. In this respect, components and elements manufactured using off-site construction [see Section 3.3] are advantageous as they can often be more easily disassembled than cast-in-situ elements, and can potentially be reused in the new construction. This highlights how Design for Deconstruction links directly to Design for Reuse and Recovery. In some cases it may be known at the outset that future expansion is likely. In these cases the design should anticipate the future expansion, both by incorporating measures to make this easier and by avoiding anything that would make it difficult, while ensuring that the design meets the requirements for the current project and does not incur additional cost.

During the preliminary design stages the design will generally not be sufficiently advanced to develop Design for Deconstruction and Flexibility proposals to any great extent. However, it is important at these stages to agree with the client and other consultants that Design for Deconstruction and Flexibility is part of the overall strategy so that all parties are committed to considering it throughout the design process.

Key questions

- Is the design adaptable for potential expansion or alternative use in the future?
- Does the design contain anything that would make it difficult to deconstruct or recycle the structure or element at the end of its life?
- Does the design incorporate reusable/recyclable components and materials?
- Can the components be maintained, upgraded or replaced without creating excessive waste?

Key resources

- CIRIA Report C607 Design for Deconstruction
Waste reduction should be addressed as part of the project sustainability agenda throughout the design process by the application of the five Designing out Waste principles. This section provides practical guidance on their application in relation to generic project stages for new construction and maintenance works, so that the principles can be integrated into processes that you currently use. The five principles should also be used to inform the project Site Waste Management Plan from an early design stage.
and maintenance/refurbishment. These generic design project stages for the two project types are shown in Figures 16 and 17 for new construction and maintenance & refurbishment respectively; the Figures also show the relation of the design project stages to the WRAP project stages for procurement guidance for civil engineering and infrastructure projects and where various WRAP tools can be used in the design process. They also indicate how the five Designing out Waste principles are applied in the various project stages.

Table 4. Key actions for clients and designers

### Key actions for clients

- Set a target for reducing waste to landfill.
- Embed the targets within corporate policy and processes.
- Set corresponding requirements in project procurement (designers’ and contractors’ appointments, tender and contract documentation) and engage with the supply chain.
- Measure performance at a project level relative to a corporate baseline.
- Report annually on overall corporate performance (this particularly applies when clients are signatories to the Construction Commitments: Halving Waste to Landfill).

### Key actions for designers

- Create design solutions that minimise waste and use resources efficiently.
- Identify for clients and contractors the best opportunities to reduce waste and use more recovered material.
- Measure the potential improvement at project level.
- Support design teams in broadening their knowledge of resource efficient design.
- Report annually on overall corporate performance (this particularly applies when designers and consultants are signatories to the Construction Commitments: Halving Waste to Landfill).

4.3 New construction

Most new construction projects of significant size (greater than about £5 million, Highways Agency definition of Major Projects) will follow a series of stages similar to those shown in Figure 16:

- The Feasibility Study will establish the need for the project and identify several options;
- The Preliminary Ground Investigation will provide basic information to allow assessment of the options;
- The Preliminary Design will review the options and produce an outline design for one or more options;
- The Main Ground Investigation will provide the detailed information needed for the design of the chosen option(s);
- The Detailed Design will develop the outline design into the final design to be constructed;
- The chosen design will be built at the Construction stage; and
- The final Project Review will be held once the completed construction has been handed over to the client.

**Definitions**

**New construction**: Construction to build a completely new structure or infrastructure or to significantly upgrade or expand an existing structure or infrastructure. Widening of roads and bridges is included.

**Maintenance & refurbishment**: Construction to enable an existing structure or infrastructure to continue to perform its original function. This includes replacement of utilities, repair of slope failures and reconstruction or resurfacing of road and airport pavements. This may include some upgrading to meet new standards but not a significant increase in capacity.

Figure 16. New construction: project stages and application of Designing out Waste principles

**Figure 16. New construction: project stages and application of Designing out Waste principles**

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32 Available at: [www.wrap.org.uk/procurementrequirements](http://www.wrap.org.uk/procurementrequirements)
Many infrastructure owners and operators, such as the Highways Agency, British Airports Authority and Network Rail, have frameworks and procedures for new construction which follow the generic project stages in Figure 16. For smaller new construction projects, particularly if they involve a repeat of previous types of work, the project cycle may be condensed and some of the early stages omitted or shortened.

For new construction, the Designing out Waste principles need to be applied from the very earliest stages of a project. It is important that they are built into the client’s brief for the designer and the rest of the project team at the start and are not seen as something to be added on at a late stage in the design; by that time, many potential options will have been closed out and the form of the design will be so far advanced that it may not be possible to alter it, or there may be insufficient information or time to properly evaluate new options.

Having established that sustainability and waste reduction are to be key principles for the project, the key stage for many of the Designing out Waste principles is the Preliminary Design Stage. By this time the basic form and purpose of the development will be clear and some information will be available from desk studies, surveys and preliminary investigations of the ground conditions and the condition of existing structures, pavements and services. This stage of the project will often involve making a choice between several options, with the chosen option (or options) taken forward for detailed investigation and design. In order to make an informed choice between the options, it is important that designers apply the Designing out Waste principles to assess which options offer the best potential for overall materials resource efficiency. This will particularly involve the application of Design for Reuse and Recovery, Design for Off Site Construction and Design for Materials Optimisation.

Having carried out the preliminary design and selected one or more options, the next project stage is the main ground investigation and associated surveys. It is vital that this is designed to obtain the necessary information to allow the detailed design of the chosen options. The design team should be involved in monitoring the results as the investigation proceeds, so that adjustments can be made if conditions turn out to be different from those anticipated. The Designing out Waste principles can then be applied during the Detailed Design Stage. At this stage Design for Waste Efficient Procurement becomes more important, as it is essential that the specification embodies the principles of the design and contractual arrangements ensure that these are carried forward into the actual construction. Design for Deconstruction and Flexibility should also be considered at this stage, both to ensure that nothing is included that will be difficult to recycle in the future and, if required, to include positive measure to make future expansion easier. The options selected earlier for Design for Reuse and Recovery, Design for Off Site Construction and Design for Materials Optimisation should be carried forward into the detailed design and resulting specification and procurement.

The actions at each stage are explained in more detail in the following sections. Technical information on specific design solutions and engineering techniques which can be used to improve resource efficiency are given in Part 2.

### 4.3.1 Feasibility stage

Key actions for designers at the feasibility stage are shown in Table 5. At this stage key project parameters are discussed with the client so that the Strategic Brief can be developed. Waste should be considered and the adoption of the Design for Reuse and Recovery, Design for Materials Optimisation and, if required, Design for Deconstruction and Flexibility principles should be addressed as they can influence significantly the design approach. The strategic brief should incorporate requirements for materials resource efficiency. This should not be left as a high-level aspiration but practically applied on the project as the design develops and changes. This will allow the design to include the waste reduction strategy during design development and construction.

#### Feasibility Report

The Feasibility Report should include an assessment of the impact of applying the Designing out Waste principles on the project, including financial implications. These implications should also consider the financial and other benefits, such as reduction in waste to landfill, increase in recycled content, savings in programme and reduction in carbon footprint. At this stage this can be done at a notional level, assessing the barriers, complications, advantages and disadvantages.

The impact of the Designing out Waste principles should be presented to the client as part of the overall project sustainability strategy. If necessary, recommendations for the appointment of any specialist consultants should be made. Once this has been agreed with the client, the design team should continue to develop the client’s requirements document and the design brief including references to the five Designing out Waste principles. The design team should be involved in the preliminary ground investigation to ensure it obtains the necessary information to carry out the preliminary design and choose between different options for the construction.
### Table 5. Key actions for designers at feasibility stage

<table>
<thead>
<tr>
<th>Designing out Waste principles</th>
<th>Key actions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design for Reuse and Recovery</td>
<td>Identify if there are any existing foundations, structures, pavements, floor slabs or services on the site that can be reused or refurbished either in part or wholly to meet the client’s requirements. If not, carry out a pre-demolition audit for any buildings or structures to identify whether the existing materials on site can be recycled into the new construction. Identify whether the proposed site layout can be matched to the existing topography to minimise the amount of earthworks. Identify whether the design is likely to require import or export of materials and if a cut/fill balance can be achieved on site. Identify whether treatment of unsuitable soils is likely to be required and what options might be suitable. Identify whether contaminated land is present and if options are available to remediate it on site. Identify whether imported topsoil is likely to be required; if so, identify whether there are suitable materials for soil manufacture on site as an alternative, and incorporate into the cut/fill balance.</td>
</tr>
<tr>
<td>Design for Materials Optimisation</td>
<td>Identify if ground improvement techniques are likely to be required if weak foundation soils are present.</td>
</tr>
<tr>
<td>Design for Deconstruction and Flexibility</td>
<td>Identify if future expansion or modification of the construction is likely to be required and if measures need to be included in the design to facilitate this.</td>
</tr>
<tr>
<td>General</td>
<td>Develop the requirements for the preliminary ground investigation to enable decisions to be made on the options for Design for Reuse and Recovery and Design for Materials Optimisation. Assess the likely impacts of Design for Reuse and Recovery opportunities on design, cost and project programme. Report findings to the client in the Feasibility Report.</td>
</tr>
</tbody>
</table>

#### 4.3.2 Preliminary design stage

Key actions for designers at this stage are shown in Table 6. The preliminary design offers the best opportunities for the adoption of the five Designing out Waste principles as during this stage the design is developed from preliminary sketch design to concept design. The information from the Feasibility Report should be investigated in detail during this stage in order to assess suitability for practical implementation. The Designing out Waste Tool for Civil Engineering can be used at this stage to give outline quantification of the effect of various options for each element of the design. An outline SWMP should be produced at this stage, detailing the waste reduction related design decisions. When applying the Designing out Waste principles at this stage, the following information should be considered:
- feasibility report;
- design brief;
- preliminary ground investigation (including pre-demolition audit and surveys of the condition of existing infrastructure;
- initial specification information; and
- information from other design team consultants including programme and cost.

### Table 6. Key actions for designers at preliminary design stage

<table>
<thead>
<tr>
<th>Designing out Waste principles</th>
<th>Key actions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design for Reuse and Recovery</td>
<td>Assess existing foundations, structures, pavements, floor slabs or services that will be reused. Assess existing materials that will be recycled for use in the new construction and estimate quantities. Revise site layout and levels to minimise earthworks and need for import or export of materials. Assess suitable materials for soil manufacture. Decide on best options to treat unsuitable soils (stabilisation, HBM, geosystems, etc). Decide on best options for contaminated land (if present) and agree with the regulatory authorities. Review availability of recycled aggregates and other materials in the local area and decide on most sustainable options.</td>
</tr>
<tr>
<td>Design for Off Site Construction</td>
<td>Assess the opportunities for off site construction of key components and the potential impact on design, cost and programme. While conducting the site investigations, identify any site conditions that either facilitate (easy access or use of a local manufacturer) or impede (access/traffic problems, neighbours, air rights issues, buildability e.g. craneage) the use of off site construction. Assess with other consultants and specialist contractors the practicability, benefits and disadvantages of off site construction and alternative on site construction methods. Assess the cost of any testing and certification likely to be required.</td>
</tr>
<tr>
<td>Design for Materials Optimisation</td>
<td>Assess options for ground improvement to be taken forward and discuss practicability, benefits and disadvantages with specialist contractors and the principal contractor. Assess whether working platforms are required and if they can be integrated into the permanent works through discussion with specialist contractors and the principal contractor. Consider use of geosystems to reduce overall material use in pavements, structures and earthworks. Consider structural solutions that use less material and simplify the structural solutions as much as possible. Investigate opportunities to avoid or minimise excavation. Review foundation solutions with specialist contractors to ascertain if options such as rotary or displacement piles can be considered.</td>
</tr>
<tr>
<td>Design for Deconstruction and Flexibility</td>
<td>Assess the implications of Design for Deconstruction and Flexibility to major elements (e.g. pavements and structures). Discuss and agree with the client and design team the implication of materials optimisation methods on the design, functionality, cost and programme.</td>
</tr>
<tr>
<td>Design for Waste Efficient Procurement</td>
<td>Discuss appointment and requirements of demolition contractor with the client to maximise reuse, recovery and recycling. Consider the implications of the design solution on construction activities (e.g. specifications and contracts).</td>
</tr>
<tr>
<td>Design for Deconstruction and Flexibility</td>
<td>Assess the implications of Design for Deconstruction and Flexibility to major elements (e.g. pavements and structures).</td>
</tr>
<tr>
<td>General</td>
<td>Identify requirements for detailed ground investigation and any further surveys or investigations of existing infrastructure. Record design decisions and outline quantities of waste in an outline Site Waste Management Plan and set preliminary KPIs and targets. Assess the likely impacts of Designing out Waste opportunities on design, cost and project programme. Report findings to client in the Preliminary Design Report.</td>
</tr>
</tbody>
</table>
4.3.3 Detailed design stage

This is the stage when a great deal of the design is finalised. Key actions are shown in Table 7. Most of the decisions on the application of Designing out Waste principles will therefore have been made by the end of this stage. The ideas for waste reduction identified in the preliminary design stage should be embedded in the development of the design. As the design is developed, discussions with specialist subcontractors and suppliers should be held as part of Design for Waste Efficient Procurement. Contractors, subcontractors and suppliers should be made aware of the project waste reduction aims and their engagement obtained, either formally (ECO, DBFO, D&B) or informally. Relevant details should be included in initial discussions with them and ultimately included in the tender documentation.

The designer should review all the preliminary design stage inputs with all the other consultants and the principal contractor (depending on the type of contract) and advise the client of any necessary amendments to the cost plan programme and overall design; this should include a review of the project waste strategy. The designer should continue consultations with the planning and environmental regulatory authorities and all other agencies and organisations that affect the project waste strategy.

Actions for all the Designing out Waste principles should be adopted and at the end of this stage an appraisal of the opportunities should be included as part of the Design Report to the client. It is important that the outline SWMP is updated with new information generated from this stage.

**Design Report**
The details of the final design will be contained in the drawings, specifications, schedules of information, Bills of Quantities and the final Design Report, which should explain how the Designing out Waste principles have been applied to the design and the savings in waste, cost, programme and carbon footprint that have been obtained as a result.

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### Table 7: Key actions for designers at detailed design stage

<table>
<thead>
<tr>
<th>Designing out Waste principles</th>
<th>Key actions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Design for Reuse and Recovery</strong></td>
<td>Confirm existing foundations, structures, pavements, floor slabs or services that will be reused and any measures necessary to upgrade them. Confirm existing materials that will be recycled for use in the new construction, where they will be used and measures needed to achieve this. Finalise site layout and levels and quantify import and export of materials. Confirm suitable materials for soil manufacture and details of the process. Confirm options to treat unsuitable soils (stabilisation, HBMs, geosystems, etc.) and consider order of work to minimise delay and rework. Confirm options for contaminated land (if present) and agree methodology, timescale and validation measures with the regulatory authorities and specialist subcontractors. Confirm which recycled aggregates and other materials will be used and where they will be sourced.</td>
</tr>
<tr>
<td><strong>Design for Off Site Construction</strong></td>
<td>Confirm which key components will be constructed using off site construction. Confirm any measures required on site to enable off site construction to be used (e.g. amendments to entrances and exits, requirements for space and height at relevant stages of construction). Identify where small scale components (e.g. manholes) can be manufactured using off site construction. Confirm the requirements and cost of testing and certification.</td>
</tr>
<tr>
<td><strong>Design for Materials Optimisation</strong></td>
<td>Confirm options for ground improvement and order of work to minimise delay and rework. Confirm arrangements for working platforms to maximise use of recycled and secondary aggregates and integrate into the permanent works if possible. Confirm use of geosystems to reduce overall material use in pavements, structures and earthworks. Confirm structural solutions that use less material and simplify the structural solutions as much as possible. Standardise similar elements (e.g. geosystems) so that repeatability of the process leads to manufacturing and installation efficiencies including waste reduction. Confirm foundation solutions with specialist subcontractors to minimise waste consistent with achieving the required performance.</td>
</tr>
<tr>
<td><strong>Design for Waste Efficient Procurement</strong></td>
<td>Embed all of the design options to be pursued into project briefings and procurement. Consider the sequence of work and how this can reduce waste. Identify (in collaboration with the principal contractor and specialist subcontractors) where the remaining potential significant on site waste streams are likely to occur. Determine the procurement routes responsible for the identified waste streams and initiate discussions with potential contractors and/or subcontractors to identify ways to minimise these. Once waste minimisation initiatives during procurement are identified and agreed as practicable, they should be assessed in terms of the impact on cost, programme and design. Agree the adoption of the waste minimisation initiatives with the client and embed them in drawings, specifications and contracts. Identify if there are any special contract conditions that need the input of the client’s legal advisors and, if so, advise the client accordingly and initiate process. When incorporating requirements for waste reduction in procurement documentation, refer to WRAP guidance on model wording for civil engineering and infrastructure projects.</td>
</tr>
<tr>
<td><strong>General</strong></td>
<td>Use WRAP’s Net Waste Tool to identify key ways to reduce waste on the project. Review quantities of waste in the outline Site Waste Management Plan and review KPIs and targets. Assess the likely impacts of Designing out Waste opportunities on design, cost and project programme. Report findings to the client in the Design Report.</td>
</tr>
</tbody>
</table>

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The preliminary design stage may be followed by a stage of statutory proceedings (not shown on Figure 16) which may include public inquiries and obtaining planning permission. The designer should be involved in this phase to ensure that the benefits of applying the Designing out Waste principles are clearly explained to statutory consultees and the planning and environmental regulatory authorities. Demonstrating this is being incorporated in the proposed project can assist a favourable conclusion to the proceedings by being a strong ‘tick in the box’ for sustainability.

Once the statutory proceedings (if required) have been completed, the detailed ground investigation and any further surveys or testing, and for any consultances that may be required with regulatory authorities to implement any of the Designing out Waste principles (e.g. for proposals to remediate contaminated land).
4.3.4 Pre-Construction and Construction

Pre-Construction is the last design stage when the technical design is advanced. Key actions are shown in Table 8. All five principles should have been applied and design solutions selected and frozen in. The designer needs to liaise with the principal contractor and subcontractors at this stage to ensure that they are fully understood and implemented when construction starts. The outline SWMP will usually be handed over to the principal contractor at the start of this stage to form part of the project SWMP. The designer also needs to be available during the construction stage to respond if conditions turn out to be different from anticipated or construction methods do not work as planned.

### Table 8. Key actions for designers at pre-construction and construction stage

<table>
<thead>
<tr>
<th>Project stage</th>
<th>Key actions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-Construction</td>
<td>Include any further waste advice/input from specialist subcontractors and suppliers in drawings, specifications, schedules of information, etc. Identify solutions for any planning consent conditions with regard to waste. Include materials and waste actions information into any relevant applications that are submitted to other agencies including the client’s insurers who also may have a direct interest in design and specifications that affect the project waste minimisation strategy. If off-site construction solutions are adopted, agree procurement route, programme, etc and assemble tender information packages. Develop tender packages for specialist subcontractors and include within the contract specification requirements with regard to waste by means of special clauses, drawings, etc. When incorporating requirements for waste reduction in tender and contract documentation, refer to WRAP guidance on model wording. In consultation with other consultants, assess the impact on cost, programme and design of all developments in the project waste strategy resulting from planning, environmental regulatory requirements and all other consultations, negotiations, etc. Include the above developments in the project waste strategy. Ensure any Design for Deconstruction and Flexibility elements are recorded in the Health and Safety file detailing their location, nature and any special considerations required.</td>
</tr>
<tr>
<td>Construction</td>
<td>Respond to questions on waste from the client, principal contractor and subcontractors.</td>
</tr>
<tr>
<td>Handover and Project Review</td>
<td>Review lessons learned from project with client and contractor and amend practices to minimise waste in for future projects.</td>
</tr>
</tbody>
</table>

4.4 Maintenance and Refurbishment

The procedures shown in Figure 17 apply to maintenance or refurbishment projects of significant size (generally above £250,000). Routine maintenance work does not normally have to go through these procedures, but is dealt with as necessary. Often, a number of small projects for similar work at different locations are joined together into a larger contract for efficiency of procurement. The Designing out Waste principles are still applicable to these small scale works, and the possibilities of moving materials between different sites may offer opportunities for waste reduction that would not be available if the sites were considered individually.

Maintenance work for civil engineering infrastructure is often carried out under framework contracts which run for several years. The designer may be part of the managing agent contractor’s project team, as for the Highways Agency’s strategic road network. Larger maintenance contracts are often procured individually rather than as part of a framework, and in these cases the designer may be part of the principal contractor’s team. In other cases, the designer may be part of the client’s team, such as in-house local authority highways departments.

### Figure 17. Maintenance and refurbishment: project stages and application of Designing out Waste principles
Many infrastructure owners and operators have set targets for waste reduction and recycling as part of their maintenance works. Local authorities have set targets in their highway term maintenance contracts; examples can be found in the ‘Recycled Roads’ guidance on AggRegain.34 As most maintenance work involves excavating existing materials and replacing them with new ones, clients are generally keen on Designing out Waste as this will reduce costs, make the works more efficient, cause less disruption and have a lower carbon footprint than conventional design solutions based on ‘dig and dump’ and replacement with new material. The design team may not be significantly involved in the early project stages for maintenance. The project cycle starts with defects detected during routine inspections, which will be carried out in accordance with set procedures appropriate to the type of infrastructure. The Routine Inspections may be carried out by the design team, or the contractor’s trained personnel with the design team only involved if there is an imminent risk to health and safety or a major issue beyond the competence of the regular inspections.

Investigations will then be carried out, including surveys, cores and boreholes as appropriate. The design team should be involved at this stage, to ensure that adequate information is obtained to enable the Designing out Waste principles to be applied at the next stage – the Assessment of Options and Value Management Stage. This is broadly equivalent to the preliminary design stage for new construction and is the critical stage for applying the Designing out Waste principles, especially Design for Reuse and Recovery and Design for Materials Optimisation which can result in significant reductions in waste, cost savings and reduction in carbon footprint. Most clients have formal procedures for this process, some of which can involve the use of sophisticated whole life cost models. However, these models and procedures may not take sufficient account of waste reduction and other sustainability issues and it is up to the design team to ensure that these factors are given sufficient weight in the decision making process.

As most maintenance work involves excavating existing materials and replacing them with new ones, clients are generally keen on Designing out Waste as this will reduce costs, make the works more efficient, cause less disruption and have a lower carbon footprint than conventional design solutions based on ‘dig and dump’ and replacement with new material.

At the Detailed Design stage Design for Waste Efficient Procurement becomes more important, as it is essential that the specification embodies the principles of the design and contractual arrangements ensure that these are carried forward into the actual construction. Design for Deconstruction and Flexibility should also be considered at this stage, both to ensure that nothing is included that will be difficult to recycle in the future and to include positive measure to make future expansion easier if required. The design team should ensure that the options identified at the previous stage are carried into this stage and the principle of Designing out Waste is communicated to the principal contractor and specialist subcontractors.

The designer should be involved in the Pre-Construction stage to ensure that the design is correctly specified and included in the contractual arrangements during procurement. The designer also needs to be available during the Construction stage, to answer any questions regarding the design or to develop alternative methods if problems are encountered. Finally, the designer should be involved in the Project Review, so that lessons learned can be shared with the whole project team and incorporated in the design of future projects. It is particularly important for designers to get feedback from the contractor on the buildability of the design, where waste was generated and suggestions for improvement.

For effective results, the Designing out Waste principles have to be applied throughout the project cycle. While there will be a focus on specific principles at particular stages, particularly the assessment of options and value management stage, they have to be applied consistently throughout a project if they are to be put into practice. Whatever the contractual arrangements, it is important for the designer to be part of an integrated project team that shares the same goals for the project, and to have access to the experience of the contractor from an early stage in the project as possible.

The actions at each stage are explained in more detail in the following sections.

Technical information on specific design solutions and engineering techniques which can be used to improve resource efficiency are given in Part 2.

4.4.1 Assessment of options and value management

The assessment of options stage is the first that offers significant opportunities to apply the Designing out Waste principles in maintenance projects; in fact, this stage also offers the greatest opportunities to investigate alternative solutions, which are then refined during the value management process until the most effective solution for the particular situation is decided. Opportunities to reduce waste can be included in the assessment, particularly if they also give other benefits such as reduction in costs, programme and carbon footprint. Many technical solutions for maintenance works do yield these benefits as well as reducing waste. Key actions for designers are shown in Table 9.

For any given infrastructure type, the range of options for maintenance will generally be smaller than for new construction; however, many maintenance techniques have been developed in recent years to maximise opportunities for recycling and low carbon technologies, especially for highway and airfield pavements.35 Many of these techniques apply the Design for Reuse and Recovery and Design for Materials Optimisation principles, which are particularly suited to maintenance works. Refurbishment may allow greater opportunities for innovative bespoke solutions to reduce waste, depending on the nature of the project and the client’s requirements.

For effective results, the Designing out Waste principles have to be applied throughout the project cycle.
Table 9. Key actions for designers at assessment of options stage

<table>
<thead>
<tr>
<th>Designing out Waste principles</th>
<th>Key actions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Design for Reuse and Recovery</strong></td>
<td>Identify and assess options for recycling pavements on site, especially those that use cold recycling techniques. Identify and assess opportunities for use of hydraulically bound materials for pavement reconstruction. Identify and assess methods of repair for slope failures using materials on site with geosystems and stabilisation. Identify and assess methods of repair for slope failures using recycled materials imported to site (recycled aggregate, tyre bales, plastic piles, etc.). Check availability of structural materials with high recycled content (steel, precast concrete, drainage pipes, timber, etc.). Review availability of recycled and secondary aggregates in the local area and decide on most sustainable options.</td>
</tr>
<tr>
<td><strong>Design for Off Site Construction</strong></td>
<td>Identify and assess the opportunities for off site construction of key components and the potential impact on design, cost and programme. Identify and assess opportunities for construction of new elements alongside existing structures to continue operation of the asset. Identify any site conditions that either facilitate (easy access or use of a local manufacturer) or impede (access/traffic problems, neighbours, air rights issues, buildability e.g. craneage) the use of off site construction. Identify and assess with other consultants and specialist contractors the practicability, benefits and disadvantages of off site construction and alternative on site construction methods.</td>
</tr>
<tr>
<td><strong>Design for Materials Optimisation</strong></td>
<td>Identify and assess methods of repair for slope failures using vegetation to avoid having to excavate material. Identify and assess opportunities to use geosystems to minimise overall material use in pavements, structures and earthworks. Consider structural solutions that use less material and simplify the structural solutions as much as possible. Investigate opportunities to avoid or minimise excavation. Review foundation solutions with specialist subcontractors to ascertain if options such as rotary or displacement piles can be considered. Discuss and agree with the client and design team the implication of materials optimisation methods on the design, functionality, cost and programme.</td>
</tr>
<tr>
<td><strong>Design for Waste Efficient Procurement</strong></td>
<td>Discuss appointment and requirements of demolition contractor (if required) with the client to maximise reuse, recovery and recycling. Consider the implications of the design solution to construction activities (e.g. specifications and contracts).</td>
</tr>
<tr>
<td><strong>Design for Deconstruction and Flexibility</strong></td>
<td>Assess the implications of Design for Deconstruction and Flexibility to major elements (e.g. pavements and structures).</td>
</tr>
<tr>
<td><strong>General</strong></td>
<td>Identify requirements for further investigation and surveys or investigations of existing infrastructure. Record design decisions and outline quantities of waste in the project Site Waste Management Plan and set preliminary KPIs and targets. Assess the likely impacts of Designing out Waste opportunities on design, cost and project programme. Report findings to the client in the Options Report.</td>
</tr>
</tbody>
</table>

Options Report
The Options Report should include a review of the methods that are available for maintenance or refurbishment of the structure and an assessment of the implications of applying the Designing out Waste principles on the project, including financial implications and impacts on programme. It should also identify any additional work that may be required to implement the Designing out Waste principles and the overall effect on the project.

The output from the assessment process should be an Options Report that includes an assessment of the impact of applying the Designing out Waste principles, including financial and programme implications. The report should include how the Designing out Waste principles can be applied in the design and the benefits that can be obtained in terms of waste reduction, cost savings, increased recycled content, programme savings and reduction in carbon footprint.

When applying the Designing out Waste principles at this stage, the following information should be considered:

- results of inspections and investigations;
- client’s requirements in terms of traffic and structural loadings, lifetime of solution, likely cost and time available for the maintenance work;
- records of construction and maintenance of the existing infrastructure; and
- information from other design consultants, including programme and cost.

The various options identified will be assessed in terms of a number of criteria, including factors such as whole life cost and minimising disruption to the user as well as potential for waste reduction. This may be done through a formal value management process; this can offer opportunities to discuss options for waste reduction in a structured manner involving the entire project team. This process is described in more detail in Section 5.

Design Report
The details of the final design will be contained in the drawings, specification, schedules of information, bills of quantities and the final Design Report, which should explain how the Designing out Waste principles have been applied to the design and the savings in waste, cost, programme and carbon footprint that have been obtained as a result.

Key resources
- CIRIA Report C677 Whole life infrastructure asset management: good practice guide for civil infrastructure
- WRAP’s procurement requirements for reducing waste and using resources efficiently
Use WRAP’s Waste Tool or similar to identify key ways to reduce waste on the project.

Table 10. Key actions for designers at the design stage

<table>
<thead>
<tr>
<th>Designing out Waste principles</th>
<th>Key actions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Design for Reuse and Recovery</strong></td>
<td>Confirm options for recycling pavements on site or using reclaimed asphalt in new asphalt.</td>
</tr>
<tr>
<td></td>
<td>Confirm use of fly ash or ggbs in concrete.</td>
</tr>
<tr>
<td></td>
<td>Confirm use of hydraulically bound materials for pavement reconstruction.</td>
</tr>
<tr>
<td></td>
<td>Confirm methods of repair for slope failures using either materials on site with geosystems and stabilisation or imported recycled materials.</td>
</tr>
<tr>
<td></td>
<td>Confirm use of structural materials with high recycled content (steel, precast concrete, drainage pipes, timber, etc).</td>
</tr>
<tr>
<td></td>
<td>Confirm use of recycled or secondary aggregates from the local area.</td>
</tr>
<tr>
<td><strong>Design for Off Site Construction</strong></td>
<td>Confirm which key components will be constructed using off site construction.</td>
</tr>
<tr>
<td></td>
<td>Confirm construction of new elements alongside existing structures to allow continued operation of the asset.</td>
</tr>
<tr>
<td></td>
<td>Confirm any measures required on site to enable off site construction to be used (e.g. amendments to entrances and exits, requirements for space and height at relevant stages of construction).</td>
</tr>
<tr>
<td></td>
<td>Confirm where small scale components (e.g. manholes) can be manufactured using off site construction.</td>
</tr>
<tr>
<td></td>
<td>Confirm the requirements and cost of testing and certification.</td>
</tr>
<tr>
<td><strong>Design for Materials Optimisation</strong></td>
<td>Confirm repair for slope failures using vegetation to avoid having to excavate material.</td>
</tr>
<tr>
<td></td>
<td>Confirm use of geosystems to minimise overall material use in pavements, structures and earthworks.</td>
</tr>
<tr>
<td></td>
<td>Confirm structural solutions that use less material and simplify the structural solutions as much as possible.</td>
</tr>
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<td></td>
<td>Confirm foundation solutions with specialist subcontractors such as rotary or displacement piles.</td>
</tr>
<tr>
<td></td>
<td>Confirm and agree with the client and design team the implication of materials optimisation methods on the design, functionality, cost and programme.</td>
</tr>
<tr>
<td><strong>Design for Waste Efficient Procurement</strong></td>
<td>Embed all of the design options to be pursued into project briefings and procurement.</td>
</tr>
<tr>
<td></td>
<td>Consider the sequence of work and how this can reduce waste.</td>
</tr>
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<td></td>
<td>Identify (in collaboration with the principal contractor and specialist subcontractors) where the potential significant on site waste streams are likely to occur.</td>
</tr>
<tr>
<td></td>
<td>Determine the procurement routes responsible for the identified waste streams and initiate discussions with potential contractors and/or subcontractors to identify ways to minimise waste.</td>
</tr>
<tr>
<td></td>
<td>Once waste minimisation initiatives during procurement are identified and agreed as practicable, they should be assessed in terms of the impact on cost, programme and design.</td>
</tr>
<tr>
<td></td>
<td>Agree the adoption of the waste reduction initiatives with the client and embed them in drawings, specifications, SWMP and contracts.</td>
</tr>
<tr>
<td></td>
<td>When incorporating requirements for waste reduction in procurement documentation, refer to WRAP guidance on model wording for civil engineering and infrastructure projects.</td>
</tr>
<tr>
<td><strong>Design for Deconstruction and Flexibility</strong></td>
<td>Include specific measures to enable future expansion or upgrading if required.</td>
</tr>
<tr>
<td></td>
<td>Ensure that no materials are used that will be difficult to recycle in the future and record assessment in project Health and Safety file.</td>
</tr>
<tr>
<td><strong>General</strong></td>
<td>Use WRAP’s Waste Tool or similar to identify key ways to reduce waste on the project.</td>
</tr>
<tr>
<td></td>
<td>Revise quantities of waste in the project Site Waste Management Plan and KPIs and targets.</td>
</tr>
<tr>
<td></td>
<td>Assess the likely impacts of Designing out Waste opportunities on design, cost and project programme.</td>
</tr>
<tr>
<td></td>
<td>Report findings to the client in the Design Report.</td>
</tr>
</tbody>
</table>

4.5 Use of WRAP tools

There are a number of WRAP tools that can provide assistance to the designer in applying the Designing out Waste principles to actual projects, both in new construction and maintenance/refurbishment. The most important ones are shown in Figures 16 and 17 and are described briefly below.

The WRAP SWMP Template should be started at the preliminary design/assessment of options stage and used to record design decisions to reduce waste. The initial forecast of waste should be made at the detailed design stage, and should then be revised by the principal contractor at the pre-construction stage.

The principal contractor should then fill out the actual quantities during the construction stage and carry out the post-completion review of actual and estimated quantities. The designer should be involved in the review, so that lesson can be learned for future projects.

The WRAP SWMP Template can also be used to set KPIs and targets for waste and track these throughout the course of the project.

The Designing out Waste Tool for Civil Engineering (DoWT-CE) should be used at the preliminary design/assessment of options stage to investigate the potential applicability of a range of solutions and obtain estimates of the potential reductions in waste, cost savings, increase in recycled content and reduction in carbon impact for each solution. Estimates of the CO2 produced by different options can also be obtained by using the WRAP CO2 emissions estimator tool.20

WRAP’s Net Waste Tool should be used at the detailed design stage to obtain detailed forecasts of waste and the effect of different actions to reduce and recycle waste. It can also be used to obtain estimates of the recycled content of the project and identify ‘quick wins’ to increase this.

For signatories of the Halving Waste to Landfill commitment, the Reporting Portal is used to record the actual figures for waste in relation to construction spend, either for individual projects or for the organisation as a whole. For individual projects, the final figures in the WRAP SWMP Template can be input directly into the Reporting Portal.

A considerable amount of guidance and information on topics such as waste minimisation and management, recycled content, procurement, logistics, individual materials and case studies is available at www.wrap.org.uk/construction and for recycled and secondary aggregates at www.aggregain.org.uk

20 Available at www.aggregain.org.uk/sustainability/try_a_sustainability_tool/co2_emissions
In order to fully explore the opportunities for waste reduction, the design team should implement a process to identify, investigate and implement Designing out Waste opportunities on the project. This section provides a suitable structured process which can be used on all types of project.
5.1 Overview
Section 4 showed how the Designing out Waste principles need to be applied throughout the project cycle in order to achieve the maximum potential savings. It is helpful to have a structured process to ensure this is carried out in a consistent manner, decisions on which options to pursue are recorded, and waste reduction is integrated into the overall design process and not seen as something separate to be added on as an afterthought.

The methods used within each step should be chosen to suit the size and nature of the project, and some methods are described further in Sections 5.3 – 5.5. On large projects in particular, it may be that the design team, client or project may already have an established design review or value management process which can be adapted to incorporate consideration of waste and the application of the Designing out Waste principles. This is discussed further in Section 5.2.

5.2 Value management
Many clients who regularly carry out construction work, including infrastructure owners and operators such as the Highways Agency, Network Rail and British Airports Authority, have established formal procedures for new construction and maintenance work which the design team and other members of the supply chain have to follow. These processes will include reviews of the design at various stages in the project cycle; for projects covered by these processes, the design team should ensure that Designing out Waste is one of the topics considered in the design review process.

Many of these formal processes make use of the technique of value management. This is a style of management particularly dedicated to motivate people, develop skills and promote synergies and innovation with the aim of maximising the overall performance of an organisation. It involves production of a value management plan and opportunities register at the start of the project, which are updated at each stage. Value management studies are carried out at each stage. The format for these will typically comprise:
- briefing and workshop handbook;
- facilitated workshop;
- draft report; and
- debrief and final report.

The design review for waste reduction could be carried out as part of the value management study at the preliminary design stage. The workshop for this stage would normally include representatives of the contractor as well as the design team and client, so ensuring the best combination of stakeholders for optimal evaluation of options. The brief for the facilitated workshop at this stage would include:
- investigate and clarify the detailed functionality of the preferred project option through all component elements of the preliminary design;
- identify various alternative value solutions to achieve required design functionality;
- undertake an initial assessment of the alternative value solutions for technical feasibility, benefits, buildability and ease of implementation against the current design; and
- confirm the value solutions to be taken forward for incorporation into the design.

It is therefore important to ensure that Designing out Waste is set as one of the objectives (or “functions” in value management terminology) at an early stage in the project. This will then be included in the value management process through all the project stages.

This is a style of management particularly dedicated to motivate people, develop skills and promote synergies and innovation with the aim of maximising the overall performance of an organisation.

1. Identify opportunities for alternative design solutions which reduce materials use and/or waste creation, and prioritise those which will have the biggest impact and be easiest to implement;
2. Investigate the prioritised solutions further, and quantify the benefits; and
3. Implement the agreed solutions, ensuring that they are recorded in the Site Waste Management Plan.
5.3 Step 1: Identify
The most appropriate time to commence the Designing out Waste process is during the Option Selection or Preliminary Design stage, prior to the submission of the planning application. By this stage the design will be sufficiently advanced for initial material selection and method of construction to be discussed but still at a stage where options can be considered. At this stage, the potential for change still exceeds the cost and resistance to change [Figure 18].

The purpose of Step 1 is to identify as many potential opportunities as possible to improve materials resource efficiency in the project through the design, and then to rationalise the list by prioritising those which will provide the biggest benefits and be easiest (and most cost efficient) to implement. This approach ensures that no opportunities are missed, and then that time and effort is not spent pursuing insignificant ones.

Identifying potential opportunities usually requires some form of design review. The form that this process takes can vary greatly depending on the size of the project, type of contract and nature of the work, and should be appropriate to the size and nature of the project. For many projects, particularly larger ones (say over £5 million), a facilitated workshop is often a good way to carry out the design review, but this may not be appropriate for small projects or standard work packages. The design team may find it useful to use the Designing out Waste Tool for Civil Engineering to investigate potential options on small projects, or as an initial stage ahead of the formal design review on larger projects.

For traditional style contracts, the design review may involve only the design team and the client. On Design, Build, Finance, Operate (DBFO), Design and Build (D&B) and some framework contracts, it may only involve the design team and the principal contractor. However, the design review will be most effective when it involves all stakeholders: client; design team; principal contractor; and specialist subcontractors. This ensures that all perspectives are included and that the chosen options will be acceptable to the client and the contractors who will have to build them.

5.3.1 Design review workshop
An experienced and impartial facilitator should be appointed several weeks in advance of the workshop. This could be someone within one of the companies but who is not involved in the project, for example a sustainability manager.

The role of the facilitator is to enable attendees to explore opinions and capture ideas in a flexible but structured manner. The workshop structure presented here was developed from working with design teams on live projects, and was found to be successful and robust. However, it can be adapted to suit particular project circumstances if required, for example depending on the size and nature of the project and whether Designing out Waste is considered on its own or as part of an overall review of the design.

The following workshop structure is suggested.

I. Awareness session: overview of the project and the Designing out Waste principles.

II. Creativity session: ideas generation.

III. Reasoning session: ideas prioritisation.

All these stages must be kept separate to ensure the success of the workshop – they are consecutive. It is important that all attendees participate in this exercise to make sure that all opportunities are explored. Experience to date shows that on average between 2 and 3 hours are required for the workshop and it can readily be combined with a scheduled design team meeting.

I. Awareness session
The aim of this session is to clearly establish the scope of the workshop (i.e. it is to determine design opportunities that can reduce waste on the project), and to ensure that all participants in the workshop have a common understanding of the project particulars and constraints (e.g. environmental, severance, community etc) and the Designing out Waste principles.

During this session the facilitator should present the five Designing out Waste principles (supported by case studies showing material, carbon and cost savings) in conjunction with project specific objectives relating to waste. Relevant members of the project team should give an overview of the project, and any preliminary options generated by the design team.

The outcome from this session should be that the team understands the focus of the workshop and is enthusiastic so that they can come up with creative and realistic options to reduce waste through design. This session should not last more than 30 minutes.

II. Creativity session
This session aims to generate ideas focusing on how the design of the project can be developed or even changed to reduce waste. This session should be completely open and inclusive and should create an atmosphere where ideas are generated and stimulated through people thinking ‘outside the box’. Attendees should be encouraged to ‘brainstorm’ for a range of design opportunities in the context of the project that will effectively reduce waste generated in construction. The key question to base discussions should be:

What can you do or influence as a design team to Design out Waste?

The rules for this session are:

- free wheel for ideas, no criticism allowed;
- go for quantity and expand on other’s ideas; and
- write it, shout it, throw it – ideas should be written on note cards or post-its, one idea per card, maximum three lines.
If ideas are not flowing then considering the Designing out Waste principles in turn may help. Alongside, the key questions of the Designing out Waste principles (see section 3) may be useful to help prompt for design opportunities. For all ideas to be explored, it is important that no one feels disenfranchised and all ideas, no matter how improbable, should be collected and assessed along with all the others. This session can last between 45 minutes to one hour.

III. Reasoning session

The design opportunities identified are evaluated so that those selected are based on the criteria of being the easiest to implement and having the greatest beneficial impact. When new ideas in the Creativity session are exhausted the facilitator should collect all note cards/post-its. Design opportunities are then evaluated by the group for their waste reduction potential and feasibility for implementation in terms of cost, programme and quality. Although only a rough initial assessment based mainly on the team’s experience and knowledge of the project, this helps to quickly identify the top opportunities with the greatest impact on waste and most likely to be pursued on the project. The experience of the contractor is particularly valuable in assessing the opportunities. A simple Opportunities Matrix should be used with each idea allocated to one of the four quadrants illustrated in Figure 19 and outlined below.

High/Low impact on waste reduction refers to whether the design opportunity will greatly/_minimally reduce the waste generated during the construction phase.

Easy/Difficult to implement refers to whether the project constraints (cost, programme, procurement method, availability of materials or other economic conditions) permit the implementation of the opportunity on the project.

It is suggested that no more than ten ideas are in Category A.

Once all of the ideas have been applied to the Opportunities Matrix, each of those in Category A should be assigned to an individual who has expertise in the relevant subject (e.g. an opportunity relating to the bridge deck would be allocated to the structural engineer, one relating to sub-base to the highway engineer etc). They will investigate them further as Stage 2 of the Designing out Waste process. Completion dates should also be set to ensure they are progressed. The ideas in Categories B-D should not however be neglected, but reviewed from time-to-time to check whether changes to the project increase their potential for consideration.

5.4 Step 2: Investigate

In Step 2 each of the Category A ideas is investigated fully to ascertain its viability and potential benefits. Aspects to be considered may include the following:

- compliance with standards;
- buildability;
- impact on project objectives;
- impact on project programme;
- risks;
- impact on Health & Safety; and
- opportunities to maximise value and minimise costs and risks.

WRAP has published many technical documents, research papers and case studies which may help with this investigation, particularly on www.aggregain.org.uk. It is also important to quantify the benefits and impact of each design opportunity so that decisions about which ones to pursue further are made objectively based on evidence. Key metrics to quantify are cost savings (including material and disposal cost savings), waste reduction and carbon reduction. Refer to WRAP’s design quantification methodology37 for a suggested approach to this. Also quantify other metrics which are relevant to the project or may help decision making, such as time savings or labour savings.

Using WRAP’s Net Waste Tool38 is an efficient way of quantifying reductions in waste, cost and carbon, and potential increases in recycled content. The reports it produces can be used to support feedback and discussion in subsequent design team meetings. As a result of the investigation and quantification it is likely that some of the Category A ideas will fall away as being not technically feasible or cost effective, for example. The remaining ideas should then be reviewed at a design team meeting, prior to their inclusion in a report of recommendations to the client and principal contractor. This report should be supported with the technical evidence and quantification generated, such as from WRAP’s Net Waste Tool. This report of recommendations may form part of a scheduled stage report.

5.5 Step 3: Implement

Once client approval to proceed with the recommended design opportunities has been obtained, they should be fully worked up into design solutions and frozen into the design. Details of the solutions should also be recorded in a SWMP – either the project SWMP if the principal contractor has started this, or an outline SWMP if they have not.

The WRAP SWMP Template38 contains sections enabling design decisions and quantification to be recorded.

This approach provides an auditable record of how the Designing out Waste principles were applied on the project. This gives greater potential for the design solutions being implemented in the construction stage and resisting any influences for them to be omitted. Recording the quantified benefits also enables the designer to demonstrate that they have delivered cost and other savings to the client/contractor, which can help them to win repeat business with future projects.

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36 Available from www.wrap.org.uk/designingoutwaste
37 Available at www.wrap.org.uk/swmp
38 Available at www.wrap.org.uk/swmp
To promote best practice throughout industry, and to drive this right through the supply chain, WRAP launched the Construction Commitments: Halving Waste to Landfill in October 2008. This supports the Construction Commitments of the Strategic Forum for Construction and focus on the specific target for waste: achieving a 50% reduction of construction, demolition and exaction waste sent to landfill by 2012 (from a 2008 baseline) through waste reduction, reuse and recycling.
APPENDIX A

The Construction Commitments: Halving Waste to Landfill
To promote best practice throughout industry, and to drive this right through the supply chain, WRAP launched the Construction Commitments: Halving Waste to Landfill in October 2008. This supports the Construction Commitments of the Strategic Forum for Construction and focuses on the specific target for waste: achieving a 50% reduction of construction, demolition and excavation waste sent to landfill by 2012 (from a 2008 baseline) through waste reduction, reuse and recycling.

This is a voluntary agreement with signatories from across the supply chain:
- clients;
- contractors;
- designers and consultants;
- manufacturers and suppliers; and
- waste management contractors.

Organisations sign up to the following statement of intent:

“We commit to playing our part in halving the amount of construction, demolition and excavation waste going to landfill by 2012. We will work to adopt and implement standards for good practice in reducing waste, recycling more, and increasing the use of recycled and recovered materials.”

Designers play a key part in meeting this target by responding positively to clients and contractors who are already supporting this campaign. Designers can demonstrate their contribution through consistent measurement and reporting, subject to independent monitoring.

Key actions for designers under the commitment are:
- create design solutions that minimise waste and use resources efficiently;
- identify for clients and contractors the best opportunities to reduce waste and use more recovered material;
- support teams in broadening their knowledge of resource efficient design;
- measure the potential improvements in materials resource efficiency at a project level; and
- report annually on overall corporate performance.

For more information visit
www.wrap.org.uk/construction

APPENDIX B

Drivers for reducing waste

B1 Site Waste Management Plan Regulations 2008

New legislation came into effect in England on 6 April 2008 requiring all construction projects with a contract value in excess of £300,000 to have a Site Waste Management Plan (SWMP), with increased requirements for projects over £500,000. These regulations apply to all projects where construction work began after 1 July 2008. A full copy of the legislation can be obtained from www.opsi.gov.uk

A SWMP is a document that identifies how waste arising during the construction process is to be managed, and ultimately reduced or recycled. This ‘waste’ includes construction, demolition and excavation arisings. The legislation places duties on both the client and the main contractor.

The client is required to... “give reasonable directions to any contractor so far as is necessary to enable the principal contractor to comply with these Regulations.” There are also additional requirements on clients relating to the review of the SWMP and in relation to site security to ensure that waste is not disposed of illegally. Whilst clients will not usually draft the SWMP, they are responsible for ensuring that it is developed, and in accordance with the Legislation.

To be legally compliant, the SWMP should be developed by the principal contractor before starting on site and should include:
- headline information about the project (location, date etc);
- the name of an individual responsible for waste;
- a forecast of the quantity of waste that will be generated, identified by material type;
- a set of clear actions to reduce waste, and to increase the level of recycling; and
- the end destination for each waste stream and the recovery rate that will be achieved.

A critical component of achieving good practice in waste reduction and recovery in construction involves the formulation and implementation of a SWMP at the pre-design stage. While SWMPs are the responsibility of the client and contractor, they determine key waste streams and set targets for waste reduction and, because of this there are advantages in thinking about them at an early design stage. It is essential that the appropriate planning for waste occurs up-front to ensure maximum impact and for key actions to be incorporated and implemented through the SWMP. Key to this is communication through the supply chain, and collaboration between the design team and contractor as early as possible in the design and planning stage.

WRAP have developed extensive guidance and a downloadable Excel based SWMP template, available at www.wrap.org.uk/swmp

B2 Landfill Tax and Aggregates Levy

Reducing construction waste provides a direct reduction of the cost of waste disposal. In addition, finding end destinations other than landfill are also likely to become more cost effective. The SWMP is a key tool in achieving these cost savings.

Limited landfill capacity has led to increased costs of waste disposal. This includes both gate fees and an escalator on Landfill Tax. Additionally, the extraction of quarry materials is subject to an aggregates levy that is ultimately passed on as cost in the price of construction materials and products. Although designers are frequently not directly involved in the cost management of projects, it is important that they are aware of the costs associated with waste in order to assess the benefits of adopting waste reducing design solutions in projects.
The traditional civil engineering approach can be expensive to dispose of large volumes, waste can be surprisingly expensive, licensed to accept such materials is limited and there may be difficulties finding and availability of suitable sites as well as long transport distances increasing increasingly untenable on grounds of cost and requirements for environmental performance (including materials resource efficiency and waste reduction and recovery) on projects. Adopting the principles of good practice waste minimisation and management on projects and measuring performance can demonstrate that these requirements are met.

The assessment consists of a list of questions under a series of headings relating to different environmental aspects of the project. Points are gained by actions that improve the environmental performance of the project. These are generally above that needed to satisfy regulatory requirements. Evidence has to be provided to support the answers. Starting to use CEEQUAL early in a project greatly aids the delivery of evidence and improvements to the project. To aid this it may be helpful to ‘plot’ the CEEQUAL questions against their project programme, showing when the questions need to be considered and when the evidence for each question is likely to become available.

B3 Financial drivers
Waste can be surprisingly expensive, especially on civil engineering projects where the volumes can be very large. Even if the material is classed as inert it will still be expensive to dispose of large volumes, and there may be difficulties finding suitably permitted/licensed sites close to the final destination. If hazardous wastes, such as contaminated soils are encountered it may be very expensive to send them to landfill, as the number of sites permitted/ licensed to accept such materials is limited and may involve long transport distances as well as high gate fees and landfill tax. The traditional civil engineering approach of ‘dig and dump’ for anything unsuitable is increasingly untenable on grounds of cost and availability of suitable sites as well as sustainability.

Reducing construction waste provides a direct reduction of the cost of waste disposal by both volume and value. Finding end destinations other than landfill are also likely to become more cost effective, especially considering the landfill tax escalator. The business risks of not considering waste in construction projects are:
- costs may be higher than expected – particularly with increasing landfill tax;
- landfill capacity is running out, and as availability reduces prices rise; and
- until very recently, materials prices have been outpacing general inflation.

B4 Environmental drivers
There are also strong environmental reasons for reducing waste.
- Reducing waste leads to less landfill space being used. This is particularly relevant since the UK has limited landfill capacity in many areas: around 3-4 years in Scotland and 8 years in Wales. As construction produces around one third of all waste in the UK, all construction professionals have a duty to act.
- Reducing waste has a carbon impact at project level by reducing the embodied energy associated with the manufacture and transport of materials and landfill emissions.

B5 Corporate Social Responsibility (CSR) drivers
Increasingly incorporate sustainability as part of their CSR objectives. Adopting targets and measuring results can demonstrate real performance against corporate responsibility and sustainability policies, meeting the expectations of stakeholders.

B6 Project specific drivers
Construction clients and planning authorities are increasingly setting targets and requirements for environmental performance (including materials resource efficiency and waste reduction and recovery) on projects. Adopting the principles of good practice waste minimisation and management on projects and measuring performance can demonstrate that these requirements are met.

B7 CEEQUAL

CEEEQUAL (the Civil Engineering Environmental Quality Assessment and Awards Scheme) has the aim of improving sustainability in civil engineering and public realm projects. A CEEQUAL Award is increasingly recognised as an indication of a high quality project that makes a significant contribution to environmental and sustainability goals and many public and private sector clients are keen for their projects to achieve this status. Designing out Waste is one of the ways in which the requirements of CEEQUAL can be met.

The objectives of the CEEQUAL scheme are:
- to recognise the attainment of good, very good or excellent environmental and social practice in civil engineering and public realm projects;
- to promote improved sustainability performance in project specification, design and construction; and
- to create a climate of environmental awareness and continuous improvement in the industry.

The current version of CEEQUAL is applicable to any civil engineering work undertaken on a specific site, this could be new build or refurbishment. This includes projects such as railway work, road work, refineries, and roads. The material must not be contaminated or contain greater than 3% total organic carbon.

The Aggregates Levy is currently £2 per tonne for primary aggregates.
8 Material use

8.1 Basic principles

8.1.1 NSO Was a plan that makes recommendations for material use to minimise environmental impact* drawn up?
If No, score 0. If Yes, score 6

8.1.2 NSO Has this plan been implemented?
If No, score 0. If Yes, score 12

*This includes selection of materials on a “reduce, reuse, recycle” approach and of environmental impact (such as the potential for pollutants leaching into the environment, transport impact and design for waste minimisation).

This consideration of the waste hierarchy is at the heart of the philosophy of Designing out Waste and is reflected in Section 4, Project application of the five Designing out Waste principles and Section 5, The Designing out Waste process.

8.2 Minimising material use and waste

8.2.1 NSO Is there evidence that the selection and use of prefabricated units* has been considered on the merit of their environmental benefits?
If No, score 0. If Yes, score 6

8.2.2 NSO Have the outcomes of this consideration been implemented?
If No, score 0. If Yes, score 6

*Consider as prefabricated units any parts or units that can either be constructed on site or prefabricated off site, such as precast concrete panels, units, etc. This does not include earthworks or components that can only be bought as complete units, such as pumps, transformers and other mechanical or electrical equipment etc.

Designing out Waste principle:
■ Design for Off Site Construction.

Technical solutions:
■ Pre-cast manholes, gullies, service ducts and trencheding.
■ Pre-cast concrete rather than cast in-situ.
■ Precast tunnel lining segments on site.
■ Assemble structures on site and move into place.

8.2.3 Has an assessment been made at design stage to ensure optimisation of cut and fill to reduce the quantity of excavated fill to be taken off site?
If No, score 0. If Yes, score 4

8.2.4 What percentage by volume of excavated material that is suitable for reuse has been beneficially reused on site?
Up to 15% reused, score 0
15% - 30% reused, score 2
More than 30 up to 50% reused, score 4
More than 50% up to 90% reused, score 6
More than 90% reused, score 8
100% reuse, score 10

It may appear strange that it is possible to score for beneficial reuse at the design stage, but it is at that stage of a project when clear decisions can and need to be made about maximising reuse, especially as it is rarely possible to amend the design at construction stage to take advantage of any surplus excavation arisings.

Designing out Waste principle:
■ Design for Materials Optimisation.
■ Design for Reuse and Recovery.

Technical Solutions:
■ Balance cut/fill quantities.
■ Lime or cement to dry out wet fill.
■ Treat unsuitable materials for landscaping and soils manufacture.
■ Lime or cement to stabilise soils in-situ for use as capping.
■ Geosynthetic and lime/cement with original soil for slope repairs.
■ Treat existing soil to make HBM subbase/ballast.

The concept of ‘beneficial reuse’ has been extended to include treatments with geosystems or cementitious agents to enable materials to be retained and beneficially used on site. See Section 3.2.1 for more details of options for retaining materials on site for beneficial reuse.

Note: Section numbering relates to the CEEQUAL sections. Sub-sections which are not relevant to Designing out Waste have not been included.
Note: NSO (Not Scope Outable) indicates that the question is mandatory for all projects.
8.3 Responsible sourcing of materials

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<thead>
<tr>
<th>8.3.3 N56</th>
<th>Client</th>
<th>Design</th>
<th>Construct</th>
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<tbody>
<tr>
<td>(a) Have the designer and contractor researched all locally available material sources, including recycled materials?</td>
<td>12</td>
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<tr>
<td>(b) Have the designer and contractor adapted the designs and specifications to allow for their use, where appropriate?</td>
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<tr>
<td>If No, score 0. If Yes, score 4 for (a) and 8 for (b)</td>
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The traditional approach of using standard designs and specifications can lead to the exclusion of acceptable locally sourced material and more sustainable material choices. Good practice of actively seeking sustainable local materials on a site specific basis should be encouraged.

**Designing out Waste principles:**
- Design for Reuse and Recovery.
- Design for Waste Efficient Procurement.

**Technical solutions:**
- Process street works arisings for pipe bedding and trench backfill.
- Recycled aggregates for capping.
- Recycled aggregates for structural backfill.
- Recycled aggregates for slope repairs.
- Recycled/secondary aggregates as unbound subbase.

8.4 Timber
This section is not relevant.

8.5 Using reused and/or recycled materials

<table>
<thead>
<tr>
<th>8.5.1</th>
<th>Client</th>
<th>Design</th>
<th>Construct</th>
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</thead>
<tbody>
<tr>
<td>What percentage by volume of any existing structures, such as roads, tanks, pipework etc, have been retained and used within the project?</td>
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<tr>
<td>Under 25%, score 0</td>
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<tr>
<td>25% to &lt;50%, score 2</td>
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<tr>
<td>50% to &lt;75%, score 4</td>
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<tr>
<td>75% and above, score 6</td>
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Examples for this include reuse of existing foundations, roads, walls, etc, or, for a flood defence project for instance, the re-use of an existing lock structure as part of new flood defence walls (See CIRIA Publication Reuse of Foundations C653 (2007)).

**Designing out Waste principle:**
- Design for Reuse and Recovery.

**Technical solutions:**
- Reuse of piled foundations.
- In-situ hot recycling of asphalt.
- In-situ cold recycling of asphalt.
- On site hot recycling of asphalt.
- Ex-situ cold recycling of asphalt.
- Retexturing asphalt pavement surfacing.
- Crack and seal with overlay for repairs.
- Saw cut and seal with overlay for repairs.
- Cold recycling of concrete and cement bound pavement layers (in-situ and ex-situ).
8.5.2 What percentage by volume of materials (excluding bulk fill and subbase), for use in the permanent works has been specified to be made from reclaimed or recycled material, whether reclaimed from the site or elsewhere?
- Under 5%, score 0
- 5% to <20%, score 2
- 20% to <40%, score 4
- 40% to <60%, score 6
- 60% to <80%, score 8
- 80% to <90%, score 10
- 90% and above, score 12

Examples include reclaimed bricks, elements or components using recycled material such as recycled plastic or reprocessed timber. Recycled materials must satisfy the necessary performance and quality criteria (e.g. plastic piles and kerbs).

Designing out Waste principles:
- Design for Reuse and Recovery.
- Design for Waste Efficient Procurement.

Technical solutions:
- Steel with high recycled content.
- Recycled aggregate in concrete barriers.
- Pfa and ggbs as cement replacement materials.
- Pipes with high recycled content.
- Reclaimed asphalt in base and binder course.
- Reclaimed asphalt in surface course.
- Secondary aggregates in base and binder course.
- Secondary aggregates in surface course.
- Secondary aggregates in cold asphalt mixtures.
- Reclaimed asphalt from other site in cold mixture.
- Recycled aggregate in pavement concrete.
- Secondary aggregates in pavement concrete.
- Railway sleepers: containing recycled aggregate.
- Railway sleepers: recycled plastic.
- Plastic sheet piling.
- Recycled/secondary aggregates in concrete.
- Reclaimed bricks or bricks with high recycled content.

8.6 Minimising use and impacts of hazardous materials
This section is not relevant.
8.7 Durability and maintenance

<table>
<thead>
<tr>
<th>8.7.1</th>
<th>Client</th>
<th>Design</th>
<th>Construct</th>
</tr>
</thead>
<tbody>
<tr>
<td>Is there evidence that durability and low maintenance of structures and components have been actively considered in design and specification? If No, score 0. If Yes, score 6.</td>
<td>6</td>
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</tbody>
</table>

Extending the lifetime of a structure is likely to have considerable environmental benefits as it avoids the environmental impacts associated with later refurbishment or the building of a new structure. In the same way, a low maintenance scheme reduces the environmental impacts relating to maintenance and is also likely to extend the structure’s lifetime.

It is essential that the desired lifespan of a structure is reflected in every detail of a structure. Often durability of a structure is compromised by minor components within it that have a shorter design life than the structure itself and were specified without bearing the overall objective in mind.

Efforts to Design out Waste should never be at the expense of the durability of the structure; a solution that has a shorter design life or requires more frequent maintenance than conventional techniques is not sustainable, however much waste it avoids or how high its recycled content. This is particularly important in pavement engineering, where maintenance requirements are an important part of the design process. Whole life costing can be used to select the most sustainable option. The technical solutions presented in this Design Guide are well established techniques backed up by design guides, specifications and standards, which are referenced in the technical solution sheets. The solutions themselves therefore should not give rise to problems with durability so long as they are properly constructed; it is therefore important to ensure that the contractors are familiar with the techniques and that the workmanship is satisfactory.

Designing out Waste principles:
- Design for Deconstruction and Flexibility.

Technical solutions:
- This is integral to the selection of technical solutions and as such no specific solutions are specified.

8.7.2

Is there evidence that long term planned maintenance has been properly considered in the design process? If No, score 0. If Yes, score 4.

8.8 Future deconstruction or disassembly

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<tr>
<th>8.8.2</th>
<th>Client</th>
<th>Design</th>
<th>Construct</th>
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<tbody>
<tr>
<td>What percentage by volume of components or prefabricated units used can be easily separated on deconstruction/disassembly into material types suitable for recycling? Under 15%, score 0 15% to &lt;30%, score 2 30% to &lt;45%, score 4 45% to &lt;60%, score 6 60% to &lt;75%, score 8 75% to &lt;90%, score 10 90% and above, score 12</td>
<td></td>
<td></td>
<td>12</td>
</tr>
</tbody>
</table>

Examples for suitable material types may include bricks, blocks, stone and concrete, treated and untreated timber, glass, PVC, different types of plastic, metal, paper and cardboard, and components (for example sinks, toilets, radiators).

Designing out Waste principle:
- Design for Deconstruction and Flexibility.

Technical solutions:
- None specified.
9 Waste Management

9.1 Basic principles:

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<th>9.1.2</th>
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<td>NS0</td>
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<td>10</td>
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</table>

Examples of designing for waste minimisation in the works include the use of arisings in works (for instance as engineering fill), use of standard sizes to avoid off-cuts and/or prefabrication where possible, incorporation of the function of temporary works such as shuttering for concrete into elements of the permanent structures.

This is at the heart of the philosophy of Designing out Waste and is reflected in Section 4, Project application of the five Designing out Waste principles and Section 5, The Designing out Waste process.

9.2 Legal and other requirements

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<thead>
<tr>
<th>9.2.1</th>
<th>Client</th>
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This can be demonstrated by use of the WRAP SWMP Template to record design decisions regarding waste.

9.3 Site preparation

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Designing out Waste principle:
- Design for Waste Efficient Procurement.
  This question reflects the basic philosophy of Designing out Waste but does not relate to specific technical solutions.

9.2.4 What percentage by volume of waste from demolition or deconstruction has been taken to landfill?

- If <70%, score 0
- 50% to 70%, score 2
- From 30% and <50%, score 6
- From 10% and <30%, score 10
- If less than 10%, score 14

Designing out Waste principle:
- Design for Reuse and Recovery.

Technical solutions:
- Process demolition material for use on site.
- Send demolition material off site for processing into recycled aggregate.

9.4 On site waste management

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<th>9.4.3(a)</th>
<th>Client</th>
<th>Design</th>
<th>Construct</th>
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</tbody>
</table>

Designing out Waste principle:
- Design for Waste Efficient Procurement.

This question reflects the basic philosophy of Designing out Waste but does not relate to specific technical solutions.
Our vision is a world without waste, where resources are used sustainably.

We work with businesses and individuals to help them reap the benefits of reducing waste, develop sustainable products and use resources in an efficient way.

Find out more at www.wrap.org.uk