Case study: Designing out Waste

Birmingham Schools

A design review of the project to co-locate the Holte, Mayfield and Lozells Schools onto one site in Birmingham identified easy to implement ideas to reduce construction waste on site with the potential to reduce total project costs by £206,784, reduce the amount of waste produced on site by 7271 tonnes and reduce embodied carbon by 1004 tonnes.

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WRAP's 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.

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CAPITA SYMONDS

Front cover photography: Artist's impression of Holte, Mayfield and Lozells School [Archial]

Executive summary

Designing out Waste during the design stage of a construction project presents a significant opportunity to reduce waste from occurring on site, reducing the construction industry's waste burdens and improving the efficiency of material usage. These can provide clear cost savings and reductions in embodied carbon.

Through working with design teams on live projects, WRAP (Waste & Resources Action Programme) has created a series of exemplar case studies which demonstrate the benefits of taking action at the design stage to reduce waste and embodied carbon by making changes that either saved money or were cost neutral based on the five key principles of Designing out Waste:

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

This report describes the work conducted by WRAP with Bovis Lend Lease and Capita Symonds to demonstrate these principles in practice by identifying cost-effective and feasible waste reducing opportunities in the design of a project to co-locate the Holte, Mayfield and Lozells Schools in Birmingham onto one site. The project is part of the Birmingham Building Schools for the Future (BSF) programme.

The Designing out Waste process comprises three stages:

- **Identify** – engagement with the design team in a design review workshop to identify and prioritise opportunities to reduce waste based on the five key principles of Designing out Waste;
- **Investigate** – qualitative and quantitative analysis of prioritised alternative designs compared with the base design, including calculation of cost, waste and carbon savings; and
- **Implement** – selection of solutions to implement into the design and build based on the outcome of this analysis.

The ideas generated at the workshop were evaluated by the design team in terms of their waste reduction potential and their feasibility for implementation on the project. The following ideas generated at the design review workshop were selected as being the most appropriate for quantitative analysis:

- use of demolition material from the existing brick school as drainage material under the new playing field;
- use of steel hoarding that can be reused on future BSF sites;
- use of permanent fencing instead of temporary hoarding; and
- prefabrication of the Mayfield flat, horticultural classroom and caretakers' houses.

A comparative assessment of these four opportunities (i.e. base design versus alternative design) to reduce waste was undertaken to determine the difference in the overall construction cost, quantity of waste, embodied carbon, cost of waste disposal and value of material wasted. The table below summarises the results of this assessment for three of the ideas; the fourth (use of reusable steel hoarding) is omitted because it is being considered further but may be adopted within the BSF programme.

Implementing the three alternative designs would:

- reduce total project costs by £206,784;
- reduce waste created on site by 7271 tonnes;
- reduce embodied carbon by 1004 tonnes;
- reduce waste disposal costs by £169,676;
- reduce the value of materials wasted by £100,069; and
- reduce lorry movements off site by 360.

If adopted, use of reusable steel hoarding on this project and a further three Birmingham BSF sites would provide a further potential cost saving of £263,284, a potential reduction in waste created on site of 393 tonnes and a potential reduction in embodied carbon of 58 tonnes.

The aim is to apply the design review process to all future Birmingham BSF projects.

Results of quantitative analysis of design solutions for the Birmingham Schools project

Design solution	Total project cost saving	Reduction in waste (tonnes)	Reduction in embodied carbon (tonnes) [A]	Reduction in waste disposal costs	Reduction in value of materials wasted
Recycling of demolition material as fill under sports pitches	£167,213	7200	977	£167,213	£67,080
Use of existing fence instead of hoarding	£37,539	60	15.6	£2119	£31,170
Prefabrication of caretakers' houses	£2032	11.4	11.4	£344	£1819
Total	**£206,784**	**7271**	**1004**	**£169,676**	**£100,069**

A: Resulting from reduced materials used and/or reduced waste created. It does not include carbon contributions from transport of materials and waste.

Contents

1.0 Introduction

The construction industry is the biggest user of materials in the UK economy, consuming more than 400 million tonnes of materials each year. It also generates over 120 million tonnes of construction, demolition and excavation waste each year – over a third of all waste – only half of which is currently recycled or reclaimed back into construction.

The WRAP Construction Programme is helping the construction industry cut costs and increase efficiency through the better use of materials and reduction in waste. It aims to set new standards for good and best practice in resource and waste management in the construction industry, and provides free access to tools and knowledge to allow clients, designers and contractors to increase the materials resource efficiency of their projects and to increase industry awareness of the commercial benefits of doing so.

The best opportunities to reduce materials use and waste in construction occur by working at the earliest stages possible in the construction process. Empowering design teams to identify and act upon these opportunities to design out waste is therefore key to achieving the Government's and industry's commitment to Halving Waste to Landfill by 2012.

Decisions made throughout the evolution of a design can have a major impact on the levels of materials used during a project and waste that arises during the physical construction and future demolition. Often these decisions are made based on considerations such as site constraints, client requirements for improved performance or finish, or compliance with Building Regulations but, currently, these considerations rarely include improving materials resource efficiency or reducing waste.

'Designing out Waste' during the design stage presents a major opportunity to prevent the creation of waste on site thus improving resource efficiency, reducing waste to landfill and saving carbon – and reducing project costs. The five key principles of Designing out Waste are:

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

WRAP has worked closely with the construction industry to develop a simple three-step structured process for 'Designing out Waste' to help design teams apply these principles to reduce the amount of construction waste produced through early changes to design, specification and procurement. A guide, *Designing out Waste: A design team guide for buildings*,[1] presenting this Designing out Waste process was published by WRAP in June 2009 and is recognised by RIBA within its CPD Core Curriculum.

This report describes work conducted as part of a WRAP project to work with the design teams of major live construction projects. The WRAP project had four main objectives:

- to identify opportunities to reduce the amount of construction, demolition and excavation waste produced at the outline design stage;
- to positively influence projects by gaining client, contractor and design team buy in to identify and adopt appropriate waste reduction design solutions;
- to gather evidence of the waste, cost and embodied carbon savings as a result of the adopted solutions; and
- to follow and test WRAP's design guidance and Designing out Waste process.

A number of construction projects were selected to be involved in this WRAP project and to produce exemplar case studies. This report summarises the findings of work by Capita Symonds (on behalf of WRAP) conducted with Bovis Lend Lease to identify and investigate opportunities for Designing out Waste on the Birmingham Schools project.

[1] *Available from the WRAP website (www.wrap.org.uk/designingoutwaste)*

1.1 The construction scheme

Under the £2.4 billion Birmingham Building Schools for the Future (BSF) programme, Birmingham City Council Education Department intends to replace the existing Holte Secondary School, Mayfield Special School and Lozells Primary School in Aston with one new school combining all three schools on the same site. Lozells Primary School and Holte Secondary School currently share a campus, working in partnership with Mayfield Special School.

The new school will accommodate approximately 1500 pupils within 16,750m^2 of new and adjusted accommodation. The school is being designed to create a fully integrated educational experience with designated clusters of classrooms provided for each age group with shared facilities such as a sports hall, art, drama and music studio and catering areas. The new development will also provide improved community/out-of-hours facilities and dedicated on site parking.

The existing site houses three separate school buildings, two of which are a prefabricated design from the 1960s. The existing schools sit in the western half of the site and construction works will be phased across the site to reduce disruption to services and ensure the safety of users during the project. On completion of the new building, the existing schools will be demolished and new playing fields and sports facilities will be constructed. Artists' impressions of the new school are shown in Figures 1 and 2.

Figure 1 Aerial view of the new combined school [Archial]

Figure 2 Artist's impression of the new combined school [Archial]

1.2 The project team

Capita Symonds was contracted by WRAP to:

- facilitate the design review workshop (see section 2);
- carry out the subsequent cost, waste and environmental assessments; and
- develop the exemplar case study.

Capita Architecture, one of the UK's largest architectural practices and the architectural brand of Capita Symonds, supported Capita Symonds in developing the exemplar case study.

Holte, Mayfield and Lozells Schools are being built on Birmingham City Council land and funded under the Birmingham BSF programme.

The main contractor for the first phase of the Birmingham BSF is Bovis Lend Lease. The architect is Archial Group.

2.0 Designing out Waste process

The Designing out Waste process devised by WRAP involves three stages:

1. **Identify** alternative design solutions which reduce materials use and/or creation of waste, and **prioritise** those that will have the biggest impact and be easiest to implement. This stage requires some form of design review, and WRAP's Designing out Waste guide presents the format for a facilitated design review workshop which ensures a robust approach involving all the design team.
2. **Investigate** the prioritised solutions further and **quantify** the benefits in terms of reductions in waste, cost and carbon. This enables evidence-based decision-making on which design solutions to implement.
3. **Implement** the agreed solutions in the project through the plans, specifications and contracts. **Record** the solutions in the Site Waste Management Plan to ensure they are fully communicated to the contractor and the quantified benefits are communicated to the client.

Designing out Waste: a design team guide for buildings recommends undertaking the design review workshop during RIBA Stage C.

2.1 Design review workshop

The design review workshop was held on 25 February 2009 at Archial's studio in Birmingham. It was attended by:

- Estelle Herszenhorn – WRAP;
- Michelle Powers – Capita Symonds;
- Chris Hubball – Capita Architecture;
- Elizabeth Randall – Bovis Lend Lease;
- Jonathan Miller – Bovis Lend Lease;
- Jacob Johnson – Bovis Lend Lease;
- John Headden – Bovis Lend Lease;
- Martin Woodhouse – Bovis Lend Lease;
- Danielle Jinks – Bovis Lend Lease;
- Mike Guppy – Archial;
- Martin Rogers – Archial; and
- Jeremy Parker – Fira

The workshop had three separate but consecutive sessions:

- Awareness session – review of Designing out Waste principles and summary of the construction project;
- Creativity session – ideas generation; and
- Reasoning session – ideas classification and prioritisation.

2.1.1 Awareness session

The first session included a brief overview of WRAP's construction programme, materials resource efficiency and the aims of the design review workshop. The design team then gave a short presentation on the Holte, Mayfield and Lozells Schools scheme, highlighting some of the specifications from the design brief and project restrictions.

2.1.2 Creativity session

A brainstorming session was then undertaken where all members of the team were encouraged to suggest ideas of how waste could be prevented or reduced. The aim was to create an atmosphere where ideas were stimulated through people thinking 'outside of the box'. Attendees were encouraged to 'brainstorm' a series of design opportunities that would effectively reduce construction waste in the project. The role of the facilitator was to encourage the design team to have a free flow of ideas, and to identify as many opportunities as possible. All ideas, regardless of feasibility, were recorded.

2.1.3 Reasoning session

Following the brainstorming session, the complete list of ideas was reviewed by the whole team with ideas being sorted into those already incorporated into the design (Table 1) and new ideas that were not incorporated (Table 2).

The ideas were then evaluated by the group for their waste reduction potential and their feasibility for implementation on the project in terms of cost, programme and quality. Although a rough initial assessment, this helped to quickly identify the top opportunities with the greatest impact on waste and the most likely to be pursued on the project. All ideas were prioritised by the team by classifying as either A, B, C or D as per the simple 'opportunity' matrix shown in Figure 3:

- Section A – High impact on waste reduction, easy to implement.
- Section B – High impact on waste reduction, difficult to implement.
- Section C – Low impact on waste reduction, easy to implement.
- Section D – Low impact on waste reduction, difficult to implement.

The facilitator steered the discussion towards selection of those ideas with the greatest potential to minimise waste and applicability to a wide range of construction projects.

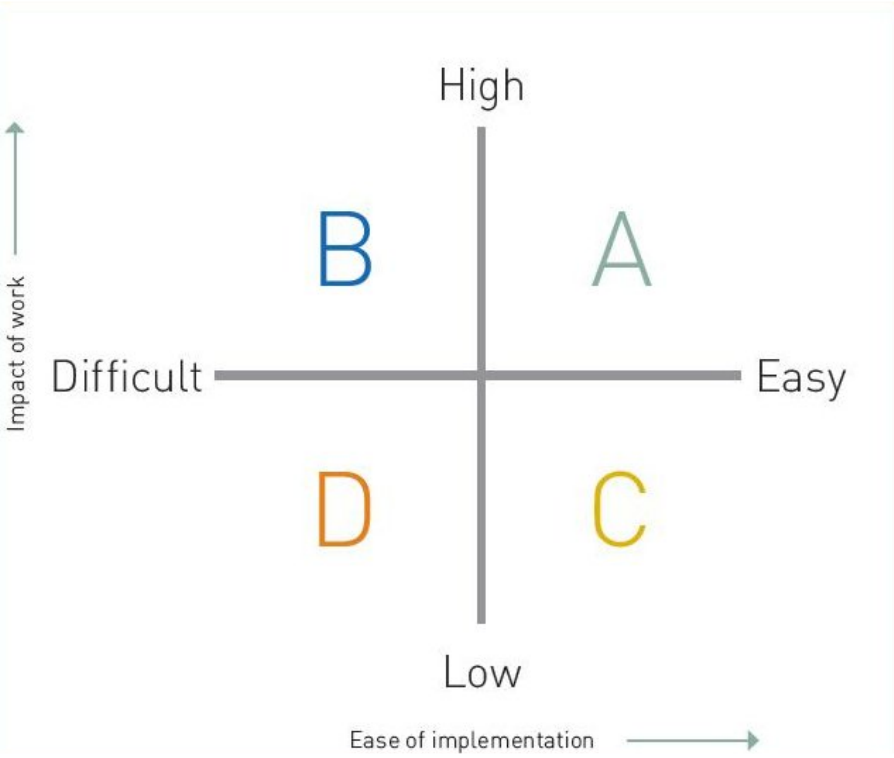

Figure 3 Opportunity matrix used to evaluate waste reduction ideas

Table 1 Ideas already incorporated into the design

Idea	Rating
Recycling of material from the 5m high embankment on the east side of the site in landscaping on the west side.	A
Optimise floor levels for cut and fill balance.	A
Reduce mechanical and electrical (M&E) work through prefabrication of various elements.	B
Precast floors and stairs.	C
Standardisation of internal door sets.	A
Off site manufacture of rainscreen.	A
Simplify external cladding systems – reduce the number of different types and determine the boundaries to maximise efficiency.	A

Idea	Rating
Use tiled carpets and vinyl flooring rather than sheet.	A
Build to standard block dimensions.	A
Standardise cladding and window sizes.	A
Establish early links with the supply chain and Birmingham City Council to establish ease of construction. This applies across the whole of Birmingham BSF.	A

Table 2 Ideas not incorporated into the design

Idea	Rating
Use of demolition material from the existing brick school as fill material under the new playing field.	A
Use of reusable hoarding that can be reused on future BSF sites.	A
Use of permanent fencing instead of temporary hoarding.	A
Prefabrication of the Mayfield flat, horticultural classroom and caretakers' houses.	A
Pre-lagged pipework to reduce insulation waste.	A
Large standard size/shape timber cladding panels.	A
Specifying non-standard plasterboard to reduce offcuts.	A
Reduce materials needed for drainage by use of sustainable drainage system (SUDS).	B
Look at waste management on all Birmingham BSF schools as one project. Standardise and optimise use of materials and waste across all sites.	B
Compost or mulch trees and recycle on this site or elsewhere via a waste contractor.	C
Precast lift shafts.	C
Off site manufacture of toilets next to Lozells classrooms.	C
Prefabricated plant rooms.	C
Use of resin-bonded recycled glass flooring.	D
Reuse current all weather pitch.	D
Use of materials from demolition to form car parking.	D
Construction of permanent road system within the site setup.	D
Use of BubbleDeck® or Omnidec in floor slabs.	D

The team then created a shortlist of their preferred options (Table 3) with the aim of including up to 10 design solutions with those rated 'A' the most preferable, followed by 'B' and 'C', then 'D'.

Table 3 Shortlist of design solutions

Idea	Rating
Use of demolition material from the existing brick school as fill material under the new playing field.	A
Use of reusable hoarding that can be used on future BSF sites.	A
Use of permanent fencing instead of temporary hoarding.	A
Prefabrication of the Mayfield flat, horticultural classroom and caretakers' houses.	A
Pre-lagged pipework to reduce insulation waste.	A
Large standard size/shape timber cladding panels.	A
Specifying non-standard plasterboard to reduce offcuts.	A

Further research and discussion helped to refine and clarify the design solutions on the shortlist to decide on those appropriate for quantitative analysis. The following questions were considered:

- Would the design solution satisfy the client's requirements?
- What would be the likely cost (based on previous experience and industry knowledge of the design team)?
- How practical was the solution (based on previous experience, knowledge of the design team and understanding of site constraints in implementing solutions, e.g. storage of components)?

Based on this discussion, the following conclusions were drawn:

- **Use of demolition material from the existing brick school as fill material under the new playing field.** The staging of works and demolition would only allow recycling of demolition material as fill under the external works. As such the assessment took account of the quantity of fill required under the sports pitches.
- **Use of reusable hoarding that can be reused on future BSF sites.** The project team proposed use of steel hoarding with the expectation that this would be reusable up to three further times.
- **Use of permanent fencing instead of temporary hoarding.** In some areas of the site the existing palisade fencing could be retained instead of use of temporary hoarding. The new fencing cannot be installed early due to the construction site boundaries moving and the likelihood of damage.
- **Prefabrication of the Mayfield flat, horticultural classroom and caretakers' houses.** Two semi-detached houses are to be provided. Although their design was at an early stage, WRAP's Net Waste Tool was used to estimate material quantities and costs for both houses built on site and prefabricated houses.
- **Pre-lagged pipework to reduce insulation waste.** The design was not developed enough to provide accurate estimates of quantities but, as the idea was considered by the design team as being valuable, potential products were investigated.
- **Large standard size/shape timber cladding panels.** The area of the building covered in timber cladding is small and therefore this idea was not considered likely to be cost-effective.
- **Specifying non-standard plasterboard to reduce offcuts.** Following the discussion with the design team, Bovis Lend Lease reported that during subcontractor interviews it had been agreed that all plasterboard would be ordered to size and offcuts would be taken back by the supplier for recycling. This option had therefore already been adopted and was taken off the list for quantitative analysis.

As a result of this selection process, four alternative design opportunities (Table 4) were taken forward to a full quantitative assessment.

Table 4 Ideas selected for quantitative analysis

Base design	Alternative design
Off site disposal of demolition material and import of material for fill under sports pitches.	Recycling of demolition material under sports pitches as fill – no import or disposal.
Use of ply hoarding and disposal upon completion of construction.	Use of steel hoarding that can be reused four times on future Birmingham BSF sites.
Use of ply hoarding and disposal upon completion of construction.	Use of existing fencing instead of temporary hoarding where possible. Replacement with new fencing upon completion of construction.
Site-based 'traditional' construction of two semi-detached caretakers' houses.	Prefabrication of two semi-detached houses.

2.2 Quantitative analysis

Four design ideas were selected at the workshop for quantitative analysis. The impact of the changes was quantified by comparing the original design (base design) with the alternative design as shown in Table 4. A quantitative analysis was undertaken of the potential cost, waste and embodied carbon reductions by changing from the base design to the alternative design.

To provide the most accurate assessment of the actual quantities involved and costs of materials, Capita Symonds cost consultants drew estimates from the latest design drawings and cost plan estimates available at the time of assessment.

2.2.1 Calculate

The first step in the assessment was to calculate:

- **Total construction cost of design** – based on the material composition of the design and the unit rates (including labour, plant and material costs) provided by the surveyor;
- **Quantity of waste created on site** – application of industry material wastage rates (%) to material quantities (m^3) summed to give the volume of waste (m^3) arising from the base design and alternative design. Standard conversion factors applied to convert to mass (tonnes);
- **Cost of waste disposal** – volume of waste (m^3) calculated above multiplied by the unit cost of waste disposal;
- **Value of materials wasted** – material unit rates (£) multiplied by the volume of waste (m^3) to determine the cost.[2] This cost was multiplied by the materials percentage to exclude plant and labour and determine the value of materials wasted (£); and
- **Total embodied carbon** – the sum of the embodied carbon of the materials used for a function in a design and the embodied carbon of the material waste resulting from that design.[3] The savings in the embodied carbon of waste materials was measured by converting the savings in waste materials (m^3) to tonnes of carbon. The Inventory of Carbon & Energy (ICE)[4] developed by researchers at the Department of Mechanical Engineering, University of Bath was used for the conversion.

WRAP's *Net Waste Tool, Guide to Reference Data, Version 1.0* (May 2008)[5] was used to source Good Practice wastage rates, waste disposal costs and materials percentages.

The detailed calculations are presented in Appendix A.

To estimate the quantity of waste diverted from landfill due to the changes in design, recycling/recovery rates would need to be applied to the quantity of waste arising on site. These rates depend on the site waste management strategy chosen for the site, which is usually not fixed at the design stage of the project. WRAP provides guidance on planning and implementing Good Practice site waste minimisation and management projects.[6]

2.2.2 Compare

The second step was to compare for the base design and alternative design of the different ideas on the shortlist:

- total construction cost;
- quantity of waste created on site;
- cost of waste disposal;
- total project cost (total construction cost + cost of waste disposal);

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[2] *The value of materials wasted provides a measure of a component of the total construction cost which is spent but does not form a useful function in the finished building. It also represents a measure of unnecessary depletion of finite natural resources which could be avoided by reducing waste through the alternative design change.*

[3] *These are assessed independently as although a reduction in waste from a design change will also reduce the embodied carbon of the waste impact, the alternative design may itself have a higher embodied carbon than the original design. For example, a design manufactured off site may produce less waste than the traditional in situ solution and thus the embodied carbon impact of waste may be less, but it may use materials with a higher embodied carbon or a more carbon intensive manufacturing process.*

[4] *www.bath.ac.uk/mech-eng/sert/embodied/*

[5] *www.wrap.org.uk/nwtool*

[6] *www.wrap.org.uk/construction/tools_and_guidance/waste_minimisation_and_management/waste_man_guidance.html*

- total embodied carbon; and
- value of materials wasted.

The results of the quantitative analysis of the four waste reducing opportunities are summarised in section 3.

2.3 Selection of solutions

Following the quantitative analysis, the results were presented to the design team, client and contractor, with the aim of pursuing and implementing in the construction project those alternative designs which were shown to reduce waste and to either break even or give cost savings. These are discussed in section 4.

3.0 Cost, waste and carbon reductions from selected solutions

3.1 Recycling of demolition material as fill under sports pitches

The financial impact to the project of recycling the demolition material as fill under the sports pitches would be a saving in the total project cost of £167,213 (Table 5). There would also be environmental benefits in terms of:

- a total reduction in waste created on site of 7200 tonnes; and
- a total reduction in embodied carbon of 977 tonnes.

The saving in waste disposal costs would be £167,213, and the reduction in the value of materials wasted £67,080. Another benefit of there being no waste is that 720 lorry movements would be avoided,[7] resulting in further carbon savings through reduced carbon dioxide (CO_2) emissions.

Table 5 Recycling of demolition material as fill under the sports pitches – results of quantitative analysis

	Base design	Alternative design	Reduction
Total project cost [A]	£234,213	£67,080	£167,213
Waste created on site	7200 tonnes	0 tonnes	7200 tonnes
Embodied carbon in materials	40.8 tonnes	28.8 tonnes	12 tonnes
Embodied carbon in waste [B]	965 tonnes	0 tonnes	965 tonnes
Total embodied carbon	1006 tonnes	28.8 tonnes	977 tonnes
Cost of waste disposal	£167,213	£0	£167,213
Value of materials wasted	£67,080	£0	£67,080

A: Includes cost of waste disposal.

B: Does not include carbon impact of transporting waste or recycling/recovery/disposal method.

3.2 Use of reusable steel hoarding

The project will require 2745m of hoarding of height 2.4 metres. The design team considered that it would be possible to reuse the steel hoarding up to three times (i.e. four uses in total). The use of reusable hoarding gives cost, waste and carbon reductions spread over four sites. In this case it was assumed that steel hoarding could be used four times on Birmingham BSF projects. Table 6 presents the overall savings achieved by reuse of steel hoarding on four sites equal to the size of the Holte, Mayfield and Lozells campus.

[7] *Return trips made by a 20-tonne capacity tipper lorry with a full 20-tonne load.*

Table 6 Using reusable steel hoarding – results of quantitative analysis for four uses

	Base design	Alternative design	Reduction
Total project cost [A]	£604,140	£340,856	£263,284
Waste created on site	1084 tonnes	691 tonnes	393 tonnes
Total embodied carbon [B]	313 tonnes	255 tonnes	58 tonnes
Cost of waste disposal	£48,552	£13,770	£34,782
Value of materials wasted	£277,794	£224,627	£53,167

A: Includes cost of waste disposal.

B: Does not include carbon impact of transporting waste or recycling/recovery/disposal method.

A quarter of the figures in Table 6 can be attributed to the Holte, Mayfield and Lozells project. The financial impact to the project of using reusable steel hoarding instead of plywood hoarding would be a saving in the total project cost of £65,821 (Table 7). There would also be environmental benefits in terms of:

- a total reduction in waste created on site of 98 tonnes; and
- a total reduction in embodied carbon of 14 tonnes.

The saving in waste disposal costs would be £8696 and the reduction in the value of materials wasted £13,292.

In addition, equal savings could be achieved on three further Birmingham BSF projects.

Table 7 Using reusable steel hoarding – results of quantitative analysis for Holte, Mayfield and Lozells project

	Base design	Alternative design	Reduction
Total project cost [A]	£151,035	£85,214	£65,821
Waste created on site	271 tonnes	173 tonnes	98 tonnes
Total embodied carbon [B]	78 tonnes	64 tonnes	14 tonnes
Cost of waste disposal	£12,138	£3442	£8696
Value of materials wasted	£69,448	£56,157	£13,292

A: Includes cost of waste disposal.

B: Does not include carbon impact of transporting waste or recycling/recovery/disposal method.

3.3 Use of existing fence

In some areas of the site the existing fence could be retained to keep the site secure without the need for temporary plywood hoarding. This is estimated at 700m in addition to the 2745m of hoarding considered in section 3.2.

The financial impact of using the existing fence instead of temporary plywood hoarding to site would be would be a saving in the total project cost of £37,539 (Table 8). There would also be environmental benefits in terms of:

- a total reduction in waste created on site of 60 tonnes; and
- a total reduction in embodied carbon of 16 tonnes.

The saving in waste disposal costs would be £2119 and the saving in the value of materials wasted £31,170.

Table 8 Use of existing fence instead of temporary hoarding – results of quantitative analysis

	Base design	Alternative design	Reduction
Total project cost [A]	£41,235	£3696	£37,539
Waste created on site	335 tonnes	275 tonnes	60 tonnes
Total embodied carbon [B]	516 tonnes	500 tonnes	16 tonnes
Cost of waste disposal	£2119	£0	£2119
Value of materials wasted	£31,170	£0	£31,170

A: Includes cost of waste disposal.

B: Does not include carbon impact of transporting waste or recycling/recovery/disposal method.

3.4 Prefabrication of the caretakers' houses

The financial impact to the project of prefabricating the caretakers' houses would be a saving in the total project cost of £2032 (Table 9). There would also be environmental benefits in terms of:

- a total reduction in waste created on site of 11 tonnes; and
- a total reduction in embodied carbon of 11 tonnes.

The saving in waste disposal costs would be £344 and the saving in the value of materials wasted £1819.

In addition, prefabrication of the caretakers' houses would reduce the programme (for this part of the works) and therefore increase flexibility on site.

Table 9 Prefabrication of caretakers' houses – results of quantitative analysis

	Base design	Alternative design	Reduction
Total project cost [A]	£150,425	£148,393	£2032
Waste created on site	12.9 tonnes	1.51 tonnes	11.4 tonnes
Embodied carbon in materials	1494 tonnes	1490 tonnes	3.9 tonnes
Embodied carbon in waste [B]	8.55 tonnes	1.07 tonnes	7.48 tonnes
Total embodied carbon	1502 tonnes	1491 tonnes	11.4 tonnes
Cost of waste disposal	£901	£557	£344
Value of materials wasted	£4054	£2235	£1819

A: Includes cost of waste disposal.

B: Does not include carbon impact of transporting waste or recycling/recovery/disposal method.

4.0 Discussion

4.1 Potential savings

The design team agreed to implement three of the four design ideas assessed:

- use of demolition material as fill under the sports pitches;
- use of permanent fencing instead of temporary hoarding; and
- prefabrication of the caretakers' houses.

The design team supported the idea of using reusable steel hoarding on several Birmingham BSF sites and agreed to consider this idea further. However, at the time of writing it had not received financial approval.

Table 10 shows the significant benefits to the project of implementing the three alternative designs. The figures exclude the savings from reusing steel hoarding as this idea has not been approved for implementation.

The total project cost saving is £206,784 of which £167,676 is due to savings in waste disposal costs. There is also a reduction of £100,069 in the total value of materials wasted.

The environmental benefits are also significant; the reduction in waste created on site is 7271 tonnes and the total reduction in embodied carbon is 1004 tonnes. In addition, there would be 360 fewer lorry movements transporting waste off site and a corresponding reduction in lorry movements importing fill material on site.

If adopted, use of reusable steel hoarding on this project and a further three Birmingham BSF sites would provide:

- a further potential cost saving of £263,284;
- a potential reduction in waste created on site of 393 tonnes; and
- a potential reduction in embodied carbon of 58 tonnes.

Table 10 Potential benefits from the three design solutions

Design solution	Total project cost saving A	Reduction in waste (tonnes)	Reduction in embodied carbon (tonnes) B	Reduction in waste disposal costs	Reduction in value of materials wasted
Recycling of demolition material as fill under sports pitches	£167,213	7200	977	£167,213	£67,080
Use of existing fence instead of hoarding	£37,539	60	15.6	£2119	£31,170
Prefabrication of caretakers' houses	£2032	11.4	11.4	£344	£1,819
Total	**£206,784**	**7271**	**1004**	**£169,676**	**£100,069**

A: Cost of construction + waste disposal cost

B: Total of embodied carbon in materials and waste.

4.2 Pre-lagged pipework

Although the design team considered the use of pre-lagged pipes as having potential to save insulation waste on site, further discussion with suppliers did not identify any known waste savings. The majority of pre-insulated pipes on the market are those designed for outdoor use. The insulation on these pipes is waterproof, allowing pipes to be buried directly into the ground without further protection. The pipes are usually supplied in set lengths of 12m. This means that, should the pipe need to be cut, the resulting offcut creates metal and insulation waste whereas standard piping would just create metal waste. Additionally, when offcuts are discarded, the pre-insulated pipe must go through an additional treatment process to remove the insulation before the metal can be recycled.

Pre-insulated pipe of this type is clearly ideal for its purpose in external use where normal 'internal' types of insulation would not work. For internal use, however, there does not appear to be any waste saving and there could potentially be an increase in waste.

4.3 The Holte, Mayfield and Lozells project as part of the BSF programme

The design review of the Holte, Mayfield and Lozells Schools project considered the project on an individual basis. This was the most practical option as the design teams had not yet been gathered for future BSF projects and therefore firm agreement on taking on board new ideas could not be sought.

Because the project is part of a wider BSF programme, this could potentially have given a greater number of opportunities to reduce waste than on an individual project. Two common reasons for not reusing or recycling waste materials on site are lack of storage space and programming. If there is not space on site to store waste materials for reuse/recycling, then the cost of storage off site often greatly outweighs the financial benefit of reuse/recycling. Similarly, when waste materials could potentially be reused/recycled on other sites under the same management, the programmes of the two sites often would require lengthy and potentially costly storage of materials.

The new Holte, Mayfield and Lozells school is being built within phase 2 of the Birmingham BSF programme, which will deliver 11 schools (both new build and refurbishment). During the design review workshop it was suggested that a central holding site for storage of materials throughout the BSF programme would allow greater reuse/recycling of materials. One example of this is proposed reuse of the steel hoarding. Bovis Lend Lease indicated that this was an option that it would consider discussing with its client.

Appendix A Quantitative analysis results

Recycling of demolition material as fill under sports pitches

- **Base design:** off site disposal of demolition material and import of material for fill under sports pitches.
- **Alternative design:** recycling of demolition material as fill under sports pitches – no import or disposal.

Although the cost of recycling aggregate on site is usually cheaper than imported granular fill, in Table A6 it is assigned an equivalent value as a worst case assessment. As the site demolition material would be used to create the recycled aggregate, it is given the same value in Table A5.

Table A1 Base design – quantification of waste and materials

Material	Quantity (m^3)	Other dimension	Density (tonnes/m^3)	Volume of material (m^3)	Tonnes of material	Wastage rate	Quantity of waste (m^3)	Quantity of waste (tonnes)
Site demolition material	3000	m^3	2.40	3000	7200	100%	3000	7200
Imported granular fill	3000	m^3	1.70	3000	5100	0%	–	–
Total							**3000**	**7200**

Table A2 Alternative design – quantification of waste and materials

Material	Quantity (m^3)	Other dimension	Density (tonnes/m^3)	Volume of material (m^3)	Tonnes of material	Wastage rate	Quantity of waste (m^3)	Quantity of waste (tonnes)
Suitably graded granular fill, from site demolition material (crushed concrete)	3000	m^3	2.40	3000	7200	0%	–	–
Total							**0**	**0**

Table A3 Base design – cost of waste disposal

Material	Unit	Quantity of waste	Bulking factor	Material type	Unit cost of waste disposal (£/m^3)	Total cost of waste disposal
Site demolition material	m^3	3000	0.5	Inert	£28	£167,213.11
Imported granular fill	m^3	0	0.5	Inert	£28	£0
Total						**£167,213.11**

Table A4 Alternative design – cost of waste disposal

Material	Unit	Quantity of waste	Bulking factor	Material type	Unit cost of waste disposal (£/m^3)	Total cost of waste disposal
Suitably graded granular fill, from site demolition material (crushed concrete)	m^3	0	0.5	Inert	£28	£0
Total						**£0**

Table A5 Base design – cost, and value of materials wasted

Material	Quantity (m^3)	Unit rate (£)	Cost	Materials percentage	Value of materials	Wastage rate	Value of wasted materials
Site demolition material	3000	22.36			£67,080	100%	£67,080
Imported granular fill	3000	22.36	£67,080	90%	£60,372	0%	£0
	Cost of base design		**£67,080**	**Total value of wasted materials**			**£67,080**

Table A6 Alternative design – cost, and value of materials wasted

Material	Quantity (m^3)	Unit rate (£)	Cost	Materials percentage	Value of materials	Wastage rate	Value of wasted materials
Suitably graded granular fill, from site demolition material (crushed concrete)	3000	22.36	£67,080	100%	£67,080	0%	£0
	Cost of alternative design		**£67,080**	**Total value of wasted materials**			**£0**

Table A7 Base design – impact on CO_2 emissions

Element	Material	Quantity materials (tonnes)	Quantity of waste (tonnes)	CO_2 equivalents (tonnes)	Material carbon (tonnes)	Waste carbon (tonnes)
Demolition material	Site demolition material	7200	7200	0.134	N/A	964.8
Granular fill to sports pitches	Imported granular fill	5100	0	0.008	40.8	0
Total					**40.8**	**964.8**

Table A8 Alternative design – impact on CO_2 emissions

Element	Material	Quantity materials (tonnes)	Quantity of waste (tonnes)	CO_2 equivalents (tonnes)	Material carbon (tonnes)	Waste carbon (tonnes)
Granular fill to sports pitches	Suitably graded granular fill, from site demolition material (crushed concrete)	7200	0	0.004	28.8	0
Total					**28.8**	**0**

Table A9 Summary

	Base design	Alternative design	Reduction
Cost of design	£67,080	£67,080	£0
Cost of waste disposal	£167,213	£0	£167,213
Total project cost	£234,293	£67,080	£167,213
Total waste arisings	7200 tonnes	0 tonnes	7200 tonnes
Value of wasted material	£67,080	£0	£67,080
Material carbon	40.80 tonnes	28.80 tonnes	12.00 tonnes
Waste carbon	964.80 tonnes	0 tonnes	964.80 tonnes
Total carbon	1005.60 tonnes	28.80 tonnes	976.80 tonnes

Use of reusable steel hoarding instead of ply

- **Base design:** use of ply hoarding and disposal upon completion of construction.
- **Alternative design:** use of steel hoarding that can be reused four times on future Birmingham BSF sites.

To provide a meaningful comparison:

- the calculations for the base design used four times the quantities of materials required for the hoarding at the Holte, Mayfield and Lozells site; and
- the calculations for the alternative design were based on four uses with disposal at the end of the fourth use.
- all materials are disposed of at then end of final use (100% wastage), the steel as zero cost as it has a market value.

The length of fencing required is 2745m.

Table A10 Base design – quantification of waste

Material	Quantity[A]	Unit	Other dimensions			Density (tonnes/m^3)	Volume of material (m^3)	Tonnes of material	Wastage rate	Quantity of waste (m^3)	Quantity of waste (tonnes)
18mm thick plywood; 2.4m high	27,670	m^2	0.018			0.50	498	249.0	100%	498.05	249.03
50mm × 100mm rails (3) to full perimeter	34,587	m	0.05	0.10		0.50	173	86.5	100%	172.94	86.47
150mm × 150mm posts @2m centres; 2.4 high	13,835	m	0.15	0.15		0.50	311	155.6	100%	311.28	155.64
Concrete foundation to posts	5490		0.3	0.30	0.5	2.40	247	592.9	100%	247.05	592.92
Total										**1229.32**	**1084.06**

A: Plywood, rails and post quantities include 5% excess.

Table A11 Alternative design – quantification of waste

Material	Quantity	Unit	Other dimensions			Volume of material (m^3)	Density: fencing (kg/m^2 of fencing); concrete (tonnes/m^3)	Tonnes of material	Wastage rate (%)	Quantity of waste (m^3)	Quantity of waste (tonnes)
Galvanised steel sheets; 2.4m high	6654	m^2	0.01			67 [A]	11.2[A]	75	100	66.54	74.52
Galvanised steel top and bottom rail supports	5545	m	0.025	3.142		11 [A]	1.4 [A]	9	100	10.89	9.32
Galvanised steel support poles	1386		3.5	0.025	3.142	10 [A]	1.4 [A]	9	100	9.53	9.32
Galvanised steel spigots – new on each site	5545		1.5	0.035	3.142	32 [A]	0.7 [A]	5	100	32.01	4.66
Concrete foundation to posts – new on each site	5490		0.3	0.3	0.5	247	2.40	592.9	100	247.05	592.92
Total										**366**	**690.73**

A: Takes into account the profile of the metal. Data provided by the manufacturer.

Table A12 Base design – cost of waste disposal

Material	Unit	Quantity of waste	Bulking factor	Material type	Unit cost of waste disposal (£/m³)	Total cost of waste disposal
18mm thick plywood; 2.4m high	m³	498.05	0.5	Timber	£18	£17,635.87
50mm × 100mm rails (3) to full perimeter	m³	172.94	0.5	Timber	£18	£6,123.78
150mm × 150mm posts @2m centres; 2.4 high	m³	311.28	0.5	Timber	£18	£11,022.48
Concrete foundation to posts	m³	247.05	0.5	Inert	£28	£8,748.00
Total						**£48,552.13**

Table A13 Alternative design – cost of waste disposal

Material	Unit	Quantity of waste	Bulking factor	Material type	Unit cost of waste disposal (£/m³)	Total cost of waste disposal
Galvanised steel sheets; 2.4m high	m³	66.54	0.5	Metal	£0	£0
Galvanised steel top and bottom rail supports	m³	10.89	0.5	Metal	£0	£0
Galvanised steel support poles	m³	9.53	0.5	Metal	£0	£0
Galvanised steel spigots – new on each site	m³	32.01	0.5	Metal	£0	£0
Concrete foundation to posts – new on each site	m³	247.05	0.5	Inert	£28	£13,770
Total						**£13,770**

Table A14 Base design – cost, and value of materials wasted

Material	Quantity (m)	Unit rate (£)	Cost	Materials percentage	Value of materials	Wastage rate	Value of wasted materials
Temporary ply hoarding new to each site (2745m each project)	10980	51	£555,588	50%	£277,794	100%	£277,794
	Cost of base design		**£555,588**	**Total value of wasted materials**			**£277,794**

Table A15 Alternative design – cost, and value of materials wasted

Material	Quantity (m)	Unit rate (£)	Cost	Materials percentage	Value of materials	Wastage rate	Value of wasted materials
Galvanised steel fencing 2.4m high	2745	85	£233,325	88%	£205,875	100%	£205,875
Dismantling and re-erection costs	2745	34	£93,761	20%	£18,752	100%	£18,752
	Cost of alternative design		**£327,086**	**Total value of wasted materials**			**£224,627**

Table A16 Base design – impact on CO_2 emissions

Element	Material	Quantity materials (tonnes)	Quantity of waste (tonnes)	CO_2 equivalents (tonnes)	Material carbon (tonnes)	Waste carbon (tonnes)
Temporary ply hoarding new to each site (2745m each project)	18mm thick plywood; 2.4m high	249.03	249.03	0.48	118.54	118.54
	50mm ×100mm rails (3) to full perimeter	86.47	86.47	0.48	41.16	41.16
	150mm × 150mm posts @2m centres; 2.4m high	155.64	155.64	0.48	74.09	74.09
	Concrete foundation to posts	592.92	592.92	0.13	79.45	79.45
Total					**313.24**	**313.24**

Table A17 Alternative design – impact on CO_2 emissions

Element	Material	Quantity materials (tonnes)	Quantity of waste (tonnes)	CO_2 equivalents (tonnes)	Material carbon (tonnes)	Waste carbon (tonnes)
Galvanised steel; temporary hoarding to be reused on four sites.	Galvanised steel sheets; 2.4m high	74.52	74.52	1.82	135.63	135.63
	Galvanised steel top and bottom rail supports	9.32	9.32	1.82	16.95	16.95
	Galvanised steel support poles	9.32	9.32	1.82	16.95	16.95
	Galvanised steel spigots – new on each site	4.66	4.66	1.82	8.48	8.48
	Concrete foundation to posts – new on each site	592.92	592.92	0.13	77.08	77.08
Total					**255.10**	**255.10**

Table A18 Summary

	Base design	Alternative design	Reduction
Cost of design	£555,588	£327,086	£228,502
Cost of waste disposal	£48,552	£13,770	£34,782
Total project cost	£604,140	£340,856	£263,284
Total waste arisings	1084 tonnes	691 tonnes	393 tonnes
Value of wasted material	£277,794	£224,627	£53,167
Total carbon	313.24 tonnes	255.10 tonnes	58.14 tonnes [A]

A: Total carbon equals materials carbon OR waste carbon as all materials become waste in this short-term use. Summing them would be double counting.

Use of existing fence instead of temporary hoarding

- **Base design:** use of ply hoarding and disposal upon completion of construction.
- **Alternative design:** use of existing fencing instead of temporary hoarding where possible.

Both would be replaced with new fencing upon completion of construction.

Table A19 Base design – quantification of waste

Material	Quantity	Unit	Other dimension (m)			Density (m^3)	Volume of material (m^3)	Tonnes of material	Wastage rate	Quantity of waste (m^3)	Quantity of waste (tonnes)
Palisade fencing (2.5m height)	700	m	2.5	0.02		7.85	35	275	100%	35	275
18mm thick plywood; 2.4m high	735	m	2.4	0.018		0.5	13	6.6	100%	13.23	6.62
50mm × 100mm rails (3) to full perimeter	2205	m	0.05	0.10		0.5	11	5.5	100%	11.03	5.51
150mm × 150mm posts @2m centres; 2.4 high	882	m	0.15	0.15		0.5	20	9.9	100%	19.85	9.92
Concrete foundation to posts	350		0.3	0.3	0.5	2.40	16	37.8	100%	15.75	37.80
Total										**95**	**335**

Table A20 Alternative design – quantification of waste

Material	Quantity	Unit	Other dimension (m)		Density (m^3)	Volume of material (m^3)	Tonnes of material	Wastage rate	Quantity of waste (m^3)	Quantity of waste (tonnes)
Palisade fencing (2.5m height)	700	m	2.5	0.02	7.85	35	275	100%	35	275
Total									**35**	**275**

Table A21 Base design – cost of waste disposal

Material	Quantity of waste	Unit	Bulking factor	Material type	Unit cost of waste disposal (£/m^3)	Total cost of waste disposal
Palisade fencing (2.5m height)	35	m^3	0.5	Metals	£0	£0
18mm thick plywood; 2.4m high	13	m^3	0.5	Timber	£18	£468.47
50mm × 100mm rails (3) to full perimeter	11	m^3	0.5	Timber	£18	£390.39
150mm × 150mm posts @2m centres; 2.4 high	20	m^3	0.5	Timber	£18	£702.71
Concrete foundation to posts	16	m^3	0.5	Timber	£18	£557.70
Total						**£2119.28**

Table A22 Alternative design – cost of waste disposal

Material	Quantity of waste	Unit	Bulking factor	Material type	Unit cost of waste disposal (£/m^3)	Total cost of waste disposal
Palisade fencing (2.5m height)	35	m^3	0.5	Metals	£0	£0
Total						**£0**

Table A23 Base design – value of materials wasted

Material	Quantity (m)	Unit rate (£)	Cost	Materials percentage	Value of materials	Wastage rate	Value of wasted materials
Labour for removal of existing palisade fencing [A]	700	5	£3,696	0%	£0	100%	£0
Installation of new timber fencing	700	51	£35,420	88%	£31,170	100%	£31,169
	Cost of base design		**£39,116**	**Total value of wasted materials**			**£31,169**

A: Waste disposal costs are included in Table A21.

Table A24 Alternative design – value of materials wasted

Material	Quantity (m)	Unit rate (£)	Cost	Materials percentage	Value of materials	Wastage rate	Value of wasted materials
Labour for removal of existing palisade fencing [A]	700	5	£3,696	0%	£0	100%	£0
	Cost of alternative design		**£3,696**	**Total value of wasted materials**			**£0**

A: Waste disposal costs are included in Table A22.

Table A25 Base design – impact on CO_2 emissions

Element	Material	Quantity materials (tonnes)	Quantity of waste (tonnes)	CO_2 equivalents (tonnes)	Waste carbon (tonnes)
Removal and disposal of existing palisade fencing at end of project	Palisade fencing (2.5m height)	274.75	274.75	1.82	500.05
Temporary hoarding (700m)	Timber components	22.05	22.05	0.48	10.50
	Concrete components	37.80	37.80	0.13	5.07
Design Total					**515.61**

Table A26 Alternative design – impact on CO_2 emissions

Element	Material	Quantity materials (tonnes)	Quantity of waste (tonnes)	CO_2 equivalents (tonnes)	Waste carbon (tonnes)
Removal and disposal of existing palisade fencing at end of project	Palisade fencing (2.5m height)	274.75	274.75	1.82	500.05
Total					**500.05**

Table A27 Summary

	Base design	Alternative design	Reduction
Cost of design	£39,116	£3696	£35,420
Cost of waste disposal	£2119	£0	£2119
Total project cost	£41,235	£3696	£37,539
Total waste arisings	335 tonnes	275	60 tonnes
Value of wasted material	£31,170	£0	£31,170
Total carbon	515.61 tonnes	500.05 tonnes	15.56 tonnes [A]

A: Total carbon equals materials carbon OR waste carbon as all materials become waste in this short-term use. Summing them would be double counting.

Prefabrication of caretakers' houses

- **Base design:** site-based 'traditional' construction of two semi-detached caretakers' houses.
- **Alternative design:** prefabrication of two semi-detached houses.

Table A28 Base design – quantification of waste and materials

Material	Quantity	Unit	Other dimension (m)			Density (m^3)	Volume of material (m^3)	Tonnes of material	Wastage rate (%)	Quantity of waste (m^3)	Quantity of waste (tonnes)
b) Steel frame generic (includes columns, beams, bracing and fire protection)	194	m^2	1	1	0.51	7.85	98.94	776.7	0	0	0
b) Concrete precast	96	m^2	1	1	0.15	2.40	14.40	34.6	2	0.29	0.691
b) Concrete precast	96	m^2	1	1	0.05	1.20	4.80	5.8	4	0.19	0.23
d) Steel structure generic	96	m^2	1	1	0.0051	7.85	0.49	3.8	0	0	0
a) Internal stairs (per flight)	2		1.8	4.4	0.15	2.70	2.38	6.4	0	0	0
c) Internal balustrades	2		3	1.1	0.15	0.70	0.99	0.7	0	0	0
d) Insulation	216	m^2	1	1	0.2	0.01	43.20	0.5	15	6.48	0.0778
e) External wall sundries	8		0.27	2.1	0.22	7.85	1.00	7.8	1	0.01	0.0783
e) External wall sundries	8		0.25	0.75	0.22	7.85	0.33	2.6	1	03	0.0259
f) Inner skin	216	m^2	1	1	0.1	0.60	21.60	13.0	20	4.32	2.59
a) Glazing system	24	m^2	1	1	0.04	2.60	0.96	2.5	1	0.01	0.0250
d) External doors single	4		1	2	0.038	3.70	0.30	1.1	5	0.02	0.0562
a) Internal walls	10	m^2	1	1	0.015	0.50	0.15	0.1	10	0.02	075
a) Internal	260	m^2	1	1	0.009	0.60	2.34	1.4	5	0.12	0.070

Material	Quantity	Unit	Other dimension (m)			Density (m^3)	Volume of material (m^3)	Tonnes of material	Wastage rate (%)	Quantity of waste (m^3)	Quantity of waste (tonnes)
walls											
b) Party walls	182	m^2	1	1	0.0125	0.60	2.28	1.4	23	0.51	0.31
b) Party walls	110	m^2				–		–			
b) Single FD30 rated	10		1	2	0.035	1.53	0.70	1.1	5	0.04	0.0536
i) Ironmongery	4		0.101	0.213	0.058	7.85	0.00	0.0	1	0.00005	0.0004
a) Walls	76	m^2	1	1	0.005	2.00	0.38	0.8	8	0.03	0.06
a) Walls	366	m^2	1	1	0.015	1.30	5.49	7.1	5	0.27	0.36
b) Floors	16	m^2	1	1	0.003	1.10	0.05	0.1	5	02	026
b) Floors	138	m^2	1	1	0.015	4.30	2.07	8.9	20	0.41	1.78
c) Ceilings	156	m^2	1	1	0.015	0.70	2.34	1.6	23	0.53	0.37
d) Other floor finishes	156	m	1	0.1	0.01	0.50	0.16	0.1	10	0.02	0.008
d) Other floor finishes	10	m	1	0.025	0.003	7.85	0.00	0.0	1	0.000008	0.0001
b) Worktop	14	m	1	0.6	0.03	3.70	0.25	0.9	1	0.003	0.0093
a) Heating – generic	194	m^2				8.50	19.51	165.8	3	0.59	4.98
d) Light & power	194	m^2				5.60	5.06	28.3	3	0.15	0.85
e) Water installations	194	m^2				9.84			5		
f) Security alarms	194	m^2				1.40	2.47	3.5	3	0.07	0.10
g) Fire alarms	194	m^2				1.40	2.47	3.5	3	0.07	0.10
j) Internal drainage	194	m^2				1.40			5		
a) Toilets	4		0.37	0.735	0.735	2.00	0.80	1.6	3	0.02	0.0480
b) Baths	2		0.8	1.8	0.008	1.40	0.02	0.0	3	0.0007	0.00097
c) Showers	2		1	1	0.004	1.40	0.01	0.0	3	0.0002	0.00034
d) Sinks	6		0.4	0.4	0.005	7.85	0.00	0.0	3	0.0001	0.001
f) White goods	2		0.595	0.872	0.04	7.85	0.04	0.3	3	0.001	0.0098
f) White goods	2		1.7	0.54	0.54	0.15	0.99	0.1	3	0.03	0.004461
Total										**14.20**	**12.90**

Table A29 Alternative design – quantification of waste and materials

Material	Quantity	Unit	Other dimension (m)			Density (m^3)	Volume of material (m^3)	Tonnes of material	Wastage rate (%)	Quantity of waste (m^3)	Quantity of waste (tonnes)
b) Steel frame generic (includes columns, beams, bracing and fire protection)	194	m^2	1	1	0.51	7.85	98.94	777	0	0	0
b) Concrete precast	96	m^2	1	1	0.15	2.40	7.20	0.1	2	0.14	0.002
b) Concrete precast	96	m^2	1	1	0.05	1.20	2.40	0.1	4	0.10	0.002
d) Steel structure generic	96	m^2	1	1	0.0051	7.85	0.49	4	1	0.00	0.04
a) Internal stairs (per flight)	2		1.8	4.4	0.15	2.70	1.19	0.0	0	0	0
c) Internal balustrades	2		3	1.1	0.15	0.7	0.99	0.7	3	0.03	0.02
d) Insulation	216	m^2	1	1	0.2	0.01	43.20	0.5	15	6.48	0.08
f) Inner skin	216	m^2	1	1	0.018	0.5	3.89	2	1	0.04	0.02
a) Glazing system	24	m^2	1	1	0.04	2.6	0.96	2	3	0.03	0.07
d) External doors single	4		1	2	0.038	3.7	0.30	1	3	0.009	0.03
a) Internal walls	10	m^2	1	1	0.015	0.5	0.15	0.08	1	0.002	0.0008
a) Internal walls	260	m^2	1	1	0.0125	0.6	3.25	2.0	1	0.033	0.020
b) Party walls	182	m^2	1	1	0.0125	0.6	2.28	1	1	0.02	0.01
b) Party walls	110	m^2	1	1	0.015	7.59	1.65	13	1	0.02	0.13
b) Single FD30 rated	10		1	2	0.035	1.53	0.70	1	3	0.02	0.03
i) Ironmongery	4		0.101	0.213	0.058	7.85	0.005	0.04	1	0.00005	0.0004
a) Walls	76	m^2	1	1	0.005	2	0.38	0.8	1	0.00	0.008
a) Walls	366	m2	1	1	0.015	1.3	5.49	7	1	0.05	0.07
b) Floors	16	m2	1	1	0.003	1.1	0.05	0.05	1	0.00	0.0005
b) Floors	138	m^2	1	1	0.015	4.3	2.07	9	1	0.02	0.09
c) Ceilings	156	m^2	1	1	0.015	0.7	2.34	2	1	0.02	0.02
d) Other floor finishes	156	m	1	0.1	0.01	0.5	0.16	0.08	1	0.002	0.0008
d) Other floor finishes	10	m	1	0.025	0.003	7.85	0.0008	0.006	1	0.000008	0.00006
b) Worktop	14	m	1	0.6	0.03	3.7	0.25	0.9	1	0.003	0.009
a) Heating – generic	194	m^2					19.51	17.64	3	0.59	0.53
d) Light &	194	m^2					5.06	4.22	3	0.15	0.13

Material	Quantity	Unit	Other dimension (m)			Density (m^3)	Volume of material (m^3)	Tonnes of material	Wastage rate (%)	Quantity of waste (m^3)	Quantity of waste (tonnes)
power											
e) Water installations	194	m^2				9.84			5		
f) Security alarms	194	m^2					2.47	2.96	3	0.07	0.09
g) Fire alarms	194	m^2					2.47	2.96	3	0.07	0.09
j) Internal drainage	194	m^2				1.4			5		
a) Toilets	4		0.37	0.735	0.735	2	0.80	2	1	0.01	0.02
b) Baths	2		0.8	1.8	0.008	1.4	0.02	0.03	1	0.0002	0.0003
c) Showers	2		1	1	0.004	1.4	0.008	0.01	1	0.00008	0.0001
d) Sinks	6		0.4	0.4	0.005	7.85	0.005	0.04	1	0.00005	0.0004
f) White goods	2		0.595	0.872	0.04	7.85	0.04	0.3	1	0.0004	0.003
f) White goods	2		1.7	0.54	0.54	0.15	0.99	0.1	1	0.010	0.001
Total										**8**	**1.51**

Table A30 Base design – cost of waste disposal

Material	Unit	Quantity of waste	Bulking factor	Material type	Unit cost of waste disposal (£/m^3)	Total cost of waste disposal
b) Steel frame generic (includes columns, beams, bracing and fire protection)	m^2	0.00	0.5	Metals (ferrous)	£0	£0
Precast concrete hollow core plank; 150mm thick; grouting - excludes screed	m^2	0.29	0.5	Inert	£28	£16.05
Sand/cement screed; 50mm thick; mesh reinforcement	m^2	0.19	0.5	Mixed	£36	£13.72
Roof structure – pitched – steel	m^2	0.00	0.5	Metals (ferrous)	£0	£0
1000mm wide precast concrete straight staircase; 3000 storey height - excludes balustrades		0.00	0.5	Inert	£28	£0
1100mm high timber balustrade; hardwood handrail; softwood balusters		0.00	0.5	Timber	£18	£0
100mm glasswool quilt or batt insulation	m^2	6.48	0.5	Mixed	£36	£463.16
Lintels to cavity walls; 70–85mm cavity – 1650–2100mm long; including cavity tray		0.01	0.5	Metals (ferrous)	£0	£0
Lintels to cavity walls; 70–85mm cavity – 750–1500mm long; including cavity tray		0.00	0.5	Metals (ferrous)	£0	£0
External walls, inner skin, cavity block construction; inner skin aerated concrete blocks – 100mm	m^2	4.32	0.5	Inert	£28	£240.79
Double glazed windows; aluminium, coated; side/top hung	m^2	0.01	0.5	Mixed	£36	£0.69

Material	Unit	Quantity of waste	Bulking factor	Material type	Unit cost of waste disposal (£/m³)	Total cost of waste disposal
70mm thick × 980mm × 2100mm single uPVC glazed panelled doors; double glazed unit; uPVC frame; excluding ironmongery		0.02	0.5	Mixed	£36	£1.09
19mm × 150mm window boards, MDF, with rounded front edge and ends, decoration	m²	0.02	0.5	Timber	£18	£0.53
One layer 12.5mm wallboard fixed with dabs to blockwork measured separately	m²	0.12	0.65	Plasterboard	£17	£2.98
12.5mm plasterboard, paint finish	m²	0.51	0.65	Plasterboard	£17	£13.04
Metal 70mm C-studs at 600mm staggered centres; 25mm mineral wool insulation between studs	m²	0.00	0.5	Metals (ferrous)	£0	£0
1000mm × 2100mm structural opening single solid core FD30 flush door set; 45mm thick laminate faced door; timber frame; painted finish; butt hinges		0.04	0.5	Timber	£18	£1.24
Mortice locks; five levers		0.00	0.5	Metals (ferrous)	£0	£0
150mm × 150mm ceramic wall tile; plain colour	m²	0.03	0.5	Inert	£28	£1.69
Skim coat plaster on plasterboard, painted	m²	0.27	0.5	Mixed	£36	£19.62
2.5mm thick vinyl sheet safety flooring; non slip	m²	0.00	0.5	Mixed	£36	£0.17
Nylon sheet carpet, natural fibre underlay	m²	0.41	0.5	Mixed	£36	£29.59
12.5mm plasterboard M/F suspended ceiling systems; metal concealed grid and hangers	m²	0.53	0.65	Mixed	£36	£28.95
100mm softwood skirtings, painted	m	0.02	0.5	Timber	£18	£0.55
Stainless steel dividing strips at door thresholds	m	0.00	0.5	Metals (ferrous)	£0	£0
Granite top, stainless steel frame and legs	m	0.00	0.5	Inert	£28	£0.14
Radiator heating system inc heat source houses	m²	0.59	0.5	Mixed	£36	£41.83
Generic light & power – domestic	m²	0.15	0.5	Mixed	£36	£10.85
Hot & cold water service houses	m²	0.00	0.5	Mixed	£36	£0
Generic	m²	0.07	0.5	Mixed	£36	£5.29
Generic	m²	0.07	0.5	Mixed	£36	£5.29
Internal drainage houses	m²	0.00	0.5	Mixed	£36	£0
VC (including waste pipework)		0.02	0.5	Mixed	£36	£1.71
Acrylic (including waste pipework)		0.00	0.5	Inert	£28	£0.04
Acrylic (including waste pipework)		0.00	0.5	Inert	£28	£0.01
Stainless steel (including waste, taps)		0.00	0.5	Metals (ferrous)	£0	£0
Electric oven		0.00	0.5	Mixed	£36	£0.09
Fridge/freezer		0.03	0.5	Mixed	£36	£2.13
Total						**£901.25**

Table A31 Alternative design – cost of waste disposal

Material	Unit	Quantity of waste	Bulking factor	Material type	Unit cost of waste disposal (£/m^3)	Total cost of waste disposal
Steel frame – generic	m^2	0.00	0.5	Metals (ferrous)	£0	£0
Precast concrete hollow core plank; 150mm thick; grouting - excludes screed	m^2	0.14	0.5	Inert	£28	£8.03
Sand/cement screed; 50mm thick; mesh reinforcement	m^2	0.10	0.5	Mixed	£36	£6.86
Roof structure – pitched – steel	m^2	0.00	0.5	Metals (ferrous)	£0	£0
1000mm wide precast concrete straight staircase; 3000 storey height - excludes balustrades		0.00	0.5	Inert	£28	£0
1100mm high timber balustrade; hardwood handrail; softwood balusters		0.03	0.5	Timber	£18	£1.05
100mm glasswool quilt or batt insulation	m^2	6.48	0.5	Mixed	£36	£463.16
Plywood structural sheathing (for timber framing) 18mm	m^2	0.04	0.5	Timber	£18	£1.38
Double glazed windows; aluminium, coated; side/top hung	m^2	0.03	0.5	Mixed	£36	£2.06
70mm thick × 980mm × 2100mm single uPVC glazed panelled doors; double glazed unit; uPVC frame; excluding ironmongery		0.01	0.5	Mixed	£36	£0.65
19mm × 150mm window boards, MDF, with rounded front edge and ends, decoration	m^2	0.00	0.5	Timber	£18	£0.05
Two layers 12.5mm wallboard, one side only, to studwork measured separately	m^2	0.03	0.65	Plasterboard	£17	£0.83
12.5mm plasterboard, paint finish	m^2	0.02	0.65	Plasterboard	£17	£0.58
Metal 70mm C-studs at 600mm staggered centres; 25mm mineral wool insulation between studs	m^2	0.02	0.5	Metals (ferrous)	£0	£0
1000mm × 2100mm structural opening single solid core FD30 flush door set; 45mm thick laminate faced door; timber frame; painted finish; butt hinges		0.02	0.5	Timber	£18	£0.74
Mortice locks; five levers		0.00	0.5	Metals (ferrous)	£0	£0
150mm × 150mm ceramic wall tile; plain colour	m^2	0.00	0.5	Inert	£28	£0.21
Skim coat plaster on plasterboard, painted	m^2	0.05	0.5	Mixed	£36	£3.92
2.5mm thick vinyl sheet safety flooring; non slip	m^2	0.00	0.5	Mixed	£36	£0.03
Nylon sheet carpet, natural fibre underlay	m^2	0.02	0.5	Mixed	£36	£1.48
12.5mm plasterboard M/F suspended ceiling systems; metal concealed grid and hangers	m^2	0.02	0.5	Mixed	£36	£1.67
100mm softwood skirtings, painted	m	0.00	0.5	Timber	£18	£0.06

Material	Unit	Quantity of waste	Bulking factor	Material type	Unit cost of waste disposal (£/m^3)	Total cost of waste disposal
Stainless steel dividing strips at door thresholds	m	0.00	0.5	Metals (ferrous)	£0	£0
Granite top, stainless steel frame and legs	m	0.00	0.5	Inert	£28	£0.14
Radiator heating system inc heat source houses	m^2	0.59	0.5	Mixed	£36	£41.83
Generic light & power – domestic	m^2	0.15	0.5	Mixed	£36	£10.85
Hot & cold water service houses	m^2	0.00	0.5	Mixed	£36	£0
Generic	m^2	0.07	0.5	Mixed	£36	£5.29
Generic	m^2	0.07	0.5	Mixed	£36	£5.29
Internal drainage houses	m^2	0.00	0.5	Mixed	£36	£0
VC (including waste pipework)		0.01	0.5	Mixed	£36	£0.57
Acrylic (including waste pipework)		0.00	0.5	Inert	£28	£0.01
Acrylic (including waste pipework)		0.00	0.5	Inert	£28	£0
Stainless steel (including waste, taps)		0.00	0.5	Metals (ferrous)	£0	£0
Electric oven		0.00	0.5	Mixed	£36	£0.03
Fridge/freezer		0.01	0.5	Mixed	£36	£0.71
Total						**£557.50**

Table A32 Base design – value of materials wasted

Material	Quantity	Unit	Unit rate (£)	Cost	Materials percentage	Value of materials	Wastage rate (%)	Value of wasted materials
b) Steel frame generic (includes columns, beams, bracing and fire protection)	194	m^2	80	£15,520	82%	£12,726	0	£0
Precast concrete hollow core plank; 150mm thick; grouting - excludes screed	96	m^2	43	£4128	60%	£2477	2	£49.54
Sand/cement screed; 50mm thick; mesh reinforcement	96	m^2	17	£1632	42%	£685	4	£27.42
Roof structure – pitched – steel	96	m^2	80	£7680	85%	£6528	0	£0
1000mm wide precast concrete straight staircase; 3000 storey height - excludes balustrades	2		1500	£3000	80%	£2400	0	£0
1100mm high timber balustrade; hardwood handrail; softwood balusters	2		144	£288	60%	£173	0	£0
100mm glasswool quilt	216	m^2	18	£3888	79%	£3072	15	£460.73

Material	Quantity	Unit	Unit rate (£)	Cost	Materials percentage	Value of materials	Wastage rate (%)	Value of wasted materials
or batt insulation								
Lintels to cavity walls; 70 to 85mm cavity - 1650 to 2100mm long; including cavity tray	8		164	£1312	91%	£1194	1	£11.94
Lintels to cavity walls; 70 to 85mm cavity - 750 to 1500mm long; including cavity tray	8		74	£592	90%	£533	1	£5.33
External walls, inner skin, cavity block construction; inner skin aerated concrete blocks – 100mm	216	m^2	21	£4536	51%	£2313	20	£462.67
Double glazed windows; aluminium, coated; side/top hung	24	m^2	341	£8184	60%	£4910	1	£49.10
70mm thick x 980mm x 2100mm single uPVC glazed panelled doors; double glazed unit; uPVC frame; excluding ironmongery	4		1099	£4396	80%	£3517	5	£175.84
19mm x 150mm window boards, MDF, with rounded front edge and ends, decoration	10	m^2	9	£90	52%	£47	10	£4.68
One layer 12.5mm wallboard fixed with dabs to blockwork measured separately	260	m^2	11	£2860	18%	£515	5	£25.74
12.5mm plasterboard, paint finish	182	m^2	14	£2548	60%	£1529	23	£343.98
Metal 70mm C-studs at 600mm staggered centres; 25mm mineral wool insulation between studs	110	m^2	74	£8140	32%	£2605	0	£0
1000mm x 2100mm structural opening single solid core FD30 flush door set; 45mm thick laminate faced door; timber frame; painted finish; butt hinges	10		156	£1560	57%	£889	5	£44.46
Mortice locks; five levers	4		159	£636	60%	£382	1	£3.82
150mm x 150mm ceramic wall tile; plain colour	76	m^2	46	£3496	36%	£1259	8	£100.68

Material	Quantity	Unit	Unit rate (£)	Cost	Materials percentage	Value of materials	Wastage rate (%)	Value of wasted materials
Skim coat plaster on plasterboard, painted	366	m^2	6	£2196	60%	£1318	5	£65.88
2.5mm thick vinyl sheet safety flooring; non slip	16	m^2	20	£320	56%	£179	5	£8.96
Nylon sheet carpet, natural fibre underlay	138	m^2	21	£2898	72%	£2087	20	£417.31
12.5mm plasterboard M/F suspended ceiling systems; metal concealed grid and hangers	156	m^2	36	£5616	34%	£1909	23	£429.62
100mm Softwood skirtings, painted	156	m	12	£1872	33%	£618	10	£61.78
Stainless steel dividing strips at door thresholds	10	m	5	£50	60%	£30	1	£0.30
Granite top, stainless steel frame and legs	14	m	350	£4900	60%	£2940	1	£29.40
Radiator heating system inc heat source houses	194	m^2	85	£16,490	60%	£9894	3	£296.82
Generic light & power – domestic	194	m^2	65	£12,610	60%	£7566	3	£226.98
Hot & cold water service houses	194	m^2	65	£12,610	62%	£7818	5	£390.91
Generic	194	m^2	12	£2328	60%	£1397	3	£41.90
Generic	194	m^2	18	£3492	60%	£2095	3	£62.86
Internal drainage houses	194	m^2	18	£3492	60%	£2095	5	£104.76
VC (including waste pipework)	4		307	£1228	81%	£995	3	£29.84
Acrylic (including waste pipework)	2		221	£442	70%	£309	3	£9.28
Acrylic (including waste pipework)	2		250	£500	60%	£300	3	£9.00
Stainless steel (including waste, taps)	6		499	£2994	86%	£2575	3	£77.25
Electric oven	2		300	£600	100%	£600	3	£18.00
Fridge/freezer	2		200	£400	60%	£240	3	£7.20
	Cost of base design			**£149,524**	**Total value of wasted materials**			**£4054**

Table A33 Alternative design – value of materials wasted

Material	Quantity	Unit	Unit rate (£)	Cost	Materials percentage	Value of materials	Wastage rate (%)	Value of wasted materials
Steel frame – generic	194	m^2	80	£15,520	82%	£12,726	0	£0
Precast concrete hollow core plank; 150mm thick; grouting – excludes screed	96	m^2	43	£4128	60%	£2477	2	£49.54
Sand/cement screed; 50mm thick; mesh reinforcement	96	m^2	17	£1632	42%	£685	4	£27.42
Roof structure – pitched – steel	96	m^2	80	£7680	85%	£6528	1	£65.28
1000mm wide precast concrete straight staircase; 3000 storey height - excludes balustrades	2		1500	£3000	80%	£2400	0	£0
1100mm high timber balustrade; hardwood handrail; softwood balusters	2		144	£288	60%	£173	3	£5.18
100mm glasswool quilt or batt insulation	216	m^2	18	£3888	79%	£3072	15	£460.73
Plywood structural sheathing (for timber framing) 18mm	216	m^2	22	£4752	40%	£1901	1	£19.01
Double glazed windows; aluminium, coated; side/top hung	24	m^2	341	£8184	60%	£4910	3	£147.31
70mm thick × 980mm × 2100mm single uPVC glazed panelled doors; double glazed unit; uPVC frame; excluding ironmongery	4		1099	£4396	80%	£3517	3	£105.50
19mm × 150mm window boards, MDF, with rounded front edge and ends, decoration	10	m^2	9	£90	52%	£47	1	£0.47
Two layers 12.5mm wallboard, one side only, to studwork measured separately	260	m^2	11	£2860	18%	£515	1	£5.15
12.5mm plasterboard, paint finish	182	m^2	14	£2548	60%	£1529	1	£15.29
Metal 70mm C-studs at 600mm staggered centres; 25mm mineral wool insulation between studs	110	m^2	74	£8140	32%	£2605	1	£26.05
1000mm × 2100mm	10		156	£1560	57%	£889	3	£26.68

Material	Quantity	Unit	Unit rate (£)	Cost	Materials percentage	Value of materials	Wastage rate (%)	Value of wasted materials
structural opening single solid core FD30 flush door set; 45mm thick laminate faced door; timber frame; painted finish; butt hinges								
Mortice locks; five levers	4		159	£636	60%	£382	1	£3.82
150mm × 150mm ceramic wall tile; plain colour	76	m^2	46	£3496	36%	£1259	1	£12.59
Skim coat plaster on plasterboard, painted	366	m^2	6	£2196	60%	£1318	1	£13.18
2.5mm thick vinyl sheet safety flooring; non slip	16	m^2	20	£320	56%	£179	1	£1.79
Nylon sheet carpet, natural fibre underlay	138	m^2	21	£2898	72%	£2087	1	£20.87
12.5mm plasterboard M/F suspended ceiling systems; metal concealed grid and hangers	156	m^2	36	£5616	34%	£1909	1	£19.09
100mm Softwood skirtings, painted	156	m	12	£1872	33%	£618	1	£6.18
Stainless steel dividing strips at door thresholds	10	m	5	£50	60%	£30	1	£0.30
Granite top, stainless steel frame and legs	14	m	350	£4900	60%	£2940	1	£29.40
Radiator heating system inc heat source houses	194	m^2	85	£16,490	60%	£9894	3	£296.82
Generic light & power – domestic	194	m^2	65	£12,610	60%	£7566	3	£226.98
Hot & cold water service houses	194	m^2	65	£12,610	62%	£7818	5	£390.91
e) Water installations	194	m^2	12	£2328	60%	£1397	3	£41.90
f) Security alarms	194	m^2	18	£3492	60%	£2095	3	£62.86
Internal drainage houses	194	m^2	18	£3492	60%	£2095	5	£104.76
VC (including waste pipework)	4		307	£1228	81%	£995	1	£9.95
Acrylic (including waste pipework)	2		221	£442	70%	£309	1	£3.09
Acrylic (including waste pipework)	2		250	£500	60%	£300	1	£3.00
Stainless steel (including waste, taps)	6		499	£2994	86%	£2575	1	£25.75
Electric oven	2		300	£600	100%	£600	1	£6.00
Fridge/freezer	2		200	£400	60%	£240	1	£2.40
	Cost of alternative design			**£147,836**	**Total value of wasted materials**			**£2,235**

Table A34 Base design – impact on CO_2 emissions

Material	Quantity materials (tonnes)	Quantity of waste (tonnes)	CO_2 equivalents (tonnes)	Material carbon (tonnes)	Waste carbon (tonnes)
b) Steel frame generic (includes columns, beams, bracing and fire protection)	776.68	0	1.82	1413.56	0
Precast concrete hollow core plank; 150mm thick; grouting - excludes screed	34.56	0.69	0.13	4.63	0.09
Sand/cement screed; 50mm thick; mesh reinforcement	5.76	0.23	0.13	0.77	0.03
Roof structure – pitched – steel	3.84	0	1.82	6.99	0
1000mm wide precast concrete straight staircase; 3000 storey height – excludes balustrades	6.42	0	0.13	0.83	0
1100mm high timber balustrade; hardwood handrail; softwood balusters	0.69	0	0.48	0.33	0
100mm glasswool quilt or batt insulation	0.52	0.08	2.61	1.35	0.20
Lintels to cavity walls; 70–85mm cavity – 1650–2100mm long; including cavity tray	7.83	0.08	1.82	14.26	0.14
Lintels to cavity walls; 70–85mm cavity – 750–1500mm long; including cavity tray	2.59	0.03	1.82	4.71	0.05
External walls, inner skin, cavity block construction; inner skin aerated concrete blocks – 100mm	12.96	2.59	0.20	2.59	0.52
Double glazed windows; aluminium, coated; side/top hung	2.50	0.02	0.77	1.92	0.02
70mm thick × 980mm × 2100mm single uPVC glazed panelled doors; double glazed unit; uPVC frame; excluding ironmongery	1.12	0.06	2.53	2.85	0.14
19mm × 150mm window boards, MDF, with rounded front edge and ends, decoration	0.08	0.01	0.48	0.04	0
one layer 12.5mm wallboard fixed with dabs to blockwork measured separately	1.40	0.07	0.16	0.22	0.01
12.5mm plasterboard, paint finish	1.37	0.31	0.16	0.22	0.05
Metal 70mm C-studs at 600mm staggered centres; 25mm mineral wool insulation between studs	0	0	1.82	0	0
1000mm x 2100mm structural opening single solid core FD30 flush door set; 45mm thick laminate faced door; timber frame; painted finish; butt hinges	1.07	0.05	0.48	0.51	0.03
Mortice locks; five levers	0.04	0	1.82	0.07	0
150mm × 150mm ceramic wall tile; plain colour	0.76	0.06	0.55	0.42	0.03
Skim coat plaster on plasterboard, painted	7.14	0.36	0.16	1.14	0.06
2.5mm thick vinyl sheet safety	0.05	0	3.97	0.21	0.01

Material	Quantity materials (tonnes)	Quantity of waste (tonnes)	CO_2 equivalents (tonnes)	Material carbon (tonnes)	Waste carbon (tonnes)
flooring; non slip					
Nylon sheet carpet, natural fibre underlay	8.90	1.78	3.97	35.34	7.07
12.5mm plasterboard M/F suspended ceiling systems; metal concealed grid and hangers	1.64	0.37	0.16	0.26	0.06
100mm softwood skirtings, painted	0.08	0.01	0.48	0.04	0
Stainless steel dividing strips at door thresholds	0.01	0	1.82	0.01	0
Granite top, stainless steel frame and legs	0.93	0.01	0.02	0.02	0
Radiator heating system inc heat source houses	165.84	4.98		0	0
Generic light & power – domestic	28.34	0.85		0	0
Hot & cold water service houses	0	0		0	0
Generic	3.45	0.10		0	0
Generic	3.45	0.10		0	0
Internal drainage houses	0	0	2.53	0	0
VC (including waste pipework)	1.60	0.05	0.55	0.88	0.03
Acrylic (including waste pipework)	0.03	0	0.55	0.02	0
Acrylic (including waste pipework)	0.01	0	0.55	0.01	0
Stainless steel (including waste, taps)	0.04	0	1.82	0.07	0
Electric oven	0.33	0.01		0	0
Fridge/freezer	0.15	0		0	0
Total				**1494.27**	**8.55**

Table A35 Alternative design – impact on CO_2 emissions

Material	Quantity materials (tonnes)	Quantity of waste (tonnes)	CO_2 equivalents (tonnes)	Material carbon (tonnes)	Waste carbon (tonnes)
Steel frame – generic	776.68	0	1.82	1413.56	0
Precast concrete hollow core plank; 150mm thick; grouting - excludes screed	0.12	0	0.13	0.01	0
Sand/cement screed; 50mm thick; mesh reinforcement	0.06	0	0.13	0.01	0
Roof structure – pitched – steel	3.84	0.04	1.82	6.99	0.07
1000mm wide precast concrete straight staircase; 3000 storey height – excludes balustrades	0	0	0.13	0	0
1100mm high timber balustrade; hardwood handrail; softwood balusters	0.69	0.02	0.48	0.33	0.01
100mm glasswool quilt or batt insulation	0.52	0.08	2.61	1.35	0.20
Plywood structural sheathing (for timber framing) 18mm	1.94	0.02	0.48	0.93	0.01
Double glazed windows; aluminium, coated; side/top hung	2.50	0.07	0.77	1.92	0.06
70mm thick × 980mm × 2100mm single uPVC glazed panelled doors; double glazed unit; uPVC frame; excluding ironmongery	1.12	0.03	2.53	2.85	0.09
19mm × 150mm window boards, MDF, with rounded front edge and ends, decoration	0.08	0	0.48	0.04	0
Two layers 12.5mm wallboard, one side only, to studwork measured separately	1.95	0.02	0.16	0.31	0
12.5mm plasterboard, paint finish	1.37	0.01	0.16	0.22	0
Metal 70mm C-studs at 600mm staggered centres; 25mm mineral wool insulation between studs	12.52	0.13	1.82	22.79	0.23
1000mm × 2100mm structural opening single solid core FD30 flush door set; 45mm thick laminate faced door; timber frame; painted finish; butt hinges	1.07	0.03	0.48	0.51	0.02
Mortice locks; five levers	0.04	0	1.82	0.07	0
150mm × 150mm ceramic wall tile; plain colour	0.76	0.01	0.55	0.42	0
Skim coat plaster on plasterboard, painted	7.14	0.07	0.16	1.14	0.01
2.5mm thick vinyl sheet safety flooring; non slip	0.05	0	3.97	0.21	0
Nylon sheet carpet, natural fibre underlay	8.90	0.09	3.97	35.34	0.35
12.5mm plasterboard M/F suspended ceiling systems; metal concealed grid and hangers	1.64	0.02	0.16	0.26	0
100mm softwood skirtings, painted	0.08	0	0.48	0.04	0

Material	Quantity materials (tonnes)	Quantity of waste (tonnes)	CO_2 equivalents (tonnes)	Material carbon (tonnes)	Waste carbon (tonnes)
Stainless steel dividing strips at door thresholds	0.01	0	1.82	0.01	0
Granite top, stainless steel frame and legs	0.93	0.01	0.02	0.02	0
Radiator heating system inc heat source houses	17.64	0.53		0	0
Generic light & power – domestic	4.22	0.13		0	0
Hot & cold water service houses	0	0		0	0
Generic	2.96	0.09		0	0
Generic	2.96	0.09		0	0
Internal drainage houses	0	0	2.53	0	0
VC (including waste pipework)	1.60	0.02	0.55	0.88	0.01
Acrylic (including waste pipework)	0.03	0	0.55	0.02	0
Acrylic (including waste pipework)	0.01	0	0.55	0.01	0
Stainless steel (including waste, taps)	0.04	0	1.82	0.07	0
Electric oven	0.33	0		0	0
Fridge/freezer	0.15	0		0	0
Total				**1490.30**	**1.07**

Table A36 Summary

	Base design	Alternative design	Reduction
Cost of design	£149,524	£147,836	£1688
Cost of waste disposal	£901	£557	£344
Total project cost	£150,425	£148,393	£2032
Total waste arisings	12.90 tonnes	1.51 tonnes	11.39 tonnes
Value of wasted material	£4054	£2235	£1819
Material carbon	1494.27 tonnes	1490.37 tonnes	3.90 tonnes
Waste carbon	8.55 tonnes	1.07 tonnes	7.48 tonnes
Total carbon	1502.82 tonnes	1491.44 tonnes	11.38 tonnes

Waste & Resources
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