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Defra, Science Directorate, Management Support and Finance Team,
Telephone No. 020 7238 1612
E-mail: research.competitions@defra.gsi.gov.uk

SID 5 Research Project Final Report

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Project identification

1. Defra Project code: WR 0111
2. Project title: Understanding and Predicting Construction Waste
3. Contractor organisation(s): Building Research Establishment Ltd (BRE)
4. Total Defra project costs (agreed fixed price): £ 225,300
5. Project: start date ..... 01 October 2005
   end date ..... 31 October 2008

6. It is Defra's intention to publish this form.
   Please confirm your agreement to do so.....**YES** ☒ **NO** ☐

   (a) When preparing SID 5s contractors should bear in mind that Defra intends that they be made public. They should be written in a clear and concise manner and represent a full account of the research project which someone not closely associated with the project can follow.
   Defra recognises that in a small minority of cases there may be information, such as intellectual property or commercially confidential data, used in or generated by the research project, which should not be disclosed. In these cases, such information should be detailed in a separate annex (not to be published) so that the SID 5 can be placed in the public domain. Where it is impossible to complete the Final Report without including references to any sensitive or confidential data, the information should be included and section (b) completed. NB: only in exceptional circumstances will Defra expect contractors to give a "No" answer.
   In all cases, reasons for withholding information must be fully in line with exemptions under the Environmental Information Regulations or the Freedom of Information Act 2000.

   (b) If you have answered NO, please explain why the Final report should not be released into public domain

Executive Summary

7. The executive summary must not exceed 2 sides in total of A4 and should be understandable to the intelligent non-scientist. It should cover the main objectives, methods and findings of the research, together with any other significant events and options for new work.

Background

The construction industry is defined as a priority sector in the Waste Strategy for England 2007(1). This is largely because the sector consumes large amounts of resources (approximately 380 million tonnes per year) and generates large amounts of waste (approximately 100 million tonnes per year). Therefore there is a significant opportunity for the sector to be more efficient with the resources it uses, including producing less waste and increasing recovery of the remaining waste. However, for the industry to manage its resources and waste better, the old adage 'Before you can manage it, you must measure it first' certainly rings true. At the start of this project there were very limited data relating to the amount and the composition of waste generated by construction projects and how it varied between projects. At a number of levels it was therefore difficult to plan and manage this waste more effectively. Combined with this, England has seen policy related to construction waste become more prominent with the requirements for Site Waste Management Plans (SWMPs) being a key tool for improving resource efficiency. Additionally, a joint industry/Government target has been set to divert 50% of construction waste from landfill by 2012 based on a 2008 baseline.

Objectives and Methodology

The main objective of this research has been to understand and predict construction, demolition and refurbishment waste more effectively though data collection and subsequent analysis with appropriate stakeholder input and to disseminate widely and produce appropriate recommendations. This has involved developing a consistent reporting methodology including national reporting standards for construction waste and providing a web-based system whereby the user (the construction project) enters waste data. The funding has also enabled BRE to analyse data generated from SMARTWaste (a web based tool for measuring and monitoring construction waste) which has been in operation for a number of years. Data have been collected at the construction project level and key performance indicators (KPIs) have been produced on the aggregated data based on the amount and type of waste produced against the gross internal floor area and the cost of the project. Unlike most data collection projects for waste which rely on a survey representing a snapshot in time, this project uses a real time data system collecting data throughout the lifetime of a construction project. This gives the user an added incentive to provide data as the data are produced throughout the lifetime of the construction project including at the various project stages (e.g. groundworks, fit out etc) and updated accordingly, and can therefore be used to enhance performance. Benchmarks and models have been developed based on the data collected which can then be used in a number of ways:

At a construction project level:

- to forecast waste production (requirement under the Site Waste Management Plan Regulations in England) and to set appropriate targets (requirement under the Code for Sustainable Homes)
- to benchmark performance against similar projects and to assist with the reduction and recovery of waste through better understanding of the waste

At a company level:

- to set companywide waste reduction and recovery targets
- to benchmark performance across projects and industry

At a local/regional level:

- data to model the amount and type of waste arising from developments and plans which can then be matched to waste facilities' capacities for dealing with waste resulting in improved resource management planning

At a policymaker level:

- provision of data to use for setting and evaluating evidence-based policy in the area of construction waste and resource efficiency.

Key Outcomes

A number of mechanisms have been used to collect data including the development of a benchmarking website, encouragement of data submission through the use of a paper based template and the analysis of data from BRE's SMARTWaste system. The techniques for data collection are based on the requirements for mandatory data i.e. the basic reporting requirements which include information on the construction project and the waste generated.

Much data have been obtained and analysed as a result of this project (854 construction projects) resulting in performance indicators. Benchmarks have then been produced for the amount and type of waste for various construction projects. These data are shown in both tonnes and volumes and throughout the lifetime of a project. Modelling has been carried out at a local, regional and national level to show the effects of setting policies related to construction waste. At a local level, modelling has also been carried out for construction waste arisings for new developments and this has been mapped against existing and future capacities for waste facilities. Performance can also be measured using standard, good and best practice benchmarks.

The objectives of the original research proposal have mostly been met with the extension of the contract for 6 months to enable the collection of data from more construction sites and therefore the development of robust benchmark figures.

Key Recommendations

The primary recommendation and output of this research is to ensure the use and application of the data that has been collected and analysed both for usage by the construction industry as well as for policy makers. This is to encourage the development of waste reduction activities throughout the construction industry leading to cost savings, improved efficiencies and a reduction in environmental impact. The data collected has been analysed to provide recommendations for waste reduction i.e. where the biggest impacts and gains are.

By using the methodologies presented for predicted and modelling construction waste, policymakers can determine the possible implications from various policy interventions in a quantifiable manner and target key areas for improvement. This can also aid construction companies and projects in terms of setting targets and strategies for waste management.

The data collected can be used by the various parts of the construction supply chain and specific Annexes have been produced to describe how and the associated benefits. For planners using the data can help evaluate the resource management requirements from local plans and developments. Clients can you use the data to set realistic targets for waste reduction within their procurement processes and assess the performance of their contractors. Contractors (both principal and trade) can use the data to forecast waste arisings for Site Waste Management Plans, set appropriate targets and to benchmark their performance and aid in continuous improvement.

Data will continue to be collected and subsequent performance indicators produced through the development of BRE's SMARTWaste Plan (a free web-based Site Waste Management Plan tool); this ensures continuation of the research once funding ceases. As a postscript to this research, as of December 2009, SMARTWaste Plan has over 3,500 projects registered, with 2.46 million tonnes of waste measured.

Project Report to Defra

8. As a guide this report should be no longer than 20 sides of A4. This report is to provide Defra with details of the outputs of the research project for internal purposes; to meet the terms of the contract; and to allow Defra to publish details of the outputs to meet Environmental Information Regulation or Freedom of Information obligations. This short report to Defra does not preclude contractors from also seeking to publish a full, formal scientific report/paper in an appropriate scientific or other journal/publication. Indeed, Defra actively encourages such publications as part of the contract terms. The report to Defra should include:
   - the scientific objectives as set out in the contract;
   - the extent to which the objectives set out in the contract have been met;
   - details of methods used and the results obtained, including statistical analysis (if appropriate);
   - a discussion of the results and their reliability;
   - the main implications of the findings;
   - possible future work; and
   - any action resulting from the research (e.g. IP, Knowledge Transfer).

1. Introduction

The construction industry consumes about 380 million tonnes of resources per year and generates over 100 million tonnes of waste; and is being targeted as a priority sector for action by the Government. Construction waste data provided at a project, company and regional level can help to drive change through the industry.

Many contractors collect waste data – either through systems such as BRE's SMARTWaste, their own systems or from waste contractors. However, there is no consistent approach to collecting waste data at a site level which makes any aggregation and comparison of data virtually impossible. The Site Waste Management Plan Regulations in England (for projects over £300,000), Code for Sustainable Homes, rising landfill costs and an increased interest from clients in sustainability means that measuring and monitoring waste generated by construction projects is and will continue to be increasingly important.

This project aims to bring data, from as many sites/companies as possible, together to form self-updating key performance indicators (KPIs). Minimum reporting requirements were developed in consultation with the industry; industry was then encouraged to submit data. This research has led to a number of KPIs and related benchmarks for the amount and type of waste arising from construction activities and a methodology for carrying out modelling; these indicators and benchmarks are currently updated bi-monthly and will continue to be updated after this project finishes with the development of BRE's free SMARTWaste Plan tool. These data have also been modelled at a regional level and embedded into a number of policy areas. Key recommendations have been made for waste reduction and future policies. Benefits of these data are multi-fold and will assist both Defra, regional and local planners and industry:

For Defra:

- Provide data for forecasting and planning for sustainable waste management policy at a construction project level
- Help to prioritise actions and policies related to construction waste management
- Provide a benchmark for measuring and evaluating performance of policies e.g. Site Waste Management Plan Regulations
- Model possible future scenarios and capacities required for recovery of construction waste.

For Planners:

- Assess development and construction policies in terms of likely amount of waste produced e.g. housing
- Aid in waste planning through assessing existing and future capacities of waste facilities for construction waste
- Set targets and/or provide appropriate guidance for reduction and recovery of waste in planning policies and guidance

For the Construction Industry:

- Provide a means for estimating and forecasting waste
- Setting targets for waste reduction and waste recovery
- Provide information for key waste streams
- Benchmark performance against industry averages

This work has been carried out by BRE with support and involvement from a wide range of stakeholders who have both inputted data and provided recommendations in terms of data analysis; in addition the project has worked closely with policymakers at both a regional and national level to provide data for evidence based policy in relation to construction waste.

The original research has been conducted over a 35 month period between October 2005 and October 2008 and involved the following scientific objectives:

a) develop and define basic reporting requirements for construction, demolition and refurbishment waste. This is reported in Section 2 and the objective was fully met by the development and usage of reporting requirements including mandatory information.

b) collect benchmarking data across all the construction sector on construction, demolition and refurbishment waste in terms of quantity and composition of waste. Remove or improve any erroneous data. This is reported in Section 3 and the objective was met through the development of a benchmarking website and BRE's

SMARTWaste Plan tool; although the data collection period was increased due to delays related to the software/programming. In total over 850 construction projects have been collecting data.

c) convert these data into self updating environmental performance indicators for construction type and sector. This is reported in Section 3 and was partially met in terms of the development of environmental performance indicators for project type; however these were not 'self updating' as manual checks had to be put in place due to the variability of the data.

d) work with contractors, planning and regulatory authorities to use data collected to model and predict waste arisings on a site, company, local, regional and national scale. This objective was met by working with Hertfordshire County Council and industry to model waste; this is reported in Section 4.

e) develop key recommendations for waste reducing activities based upon the data collected and subsequent modelling i.e. where the biggest impacts and gains are. This objective has been met and is reported in Section 5.

f) ensure key stakeholders are bought into the process and input any suitable waste data being collected. This objective was met by holding a stakeholder event where the construction industry provided data.

g) disseminate widely to the construction, resource management and planning sectors. This objective has been met with 3 articles written and 3 events held throughout the project's lifetime. Additionally, information from this project was disseminated through events focusing on Site Waste Management Plans.

The remainder of this report covers each scientific objective, the methodology undertaken and the results obtained with a discussion. Section 7 provides an overview of the findings including opportunities for future work. Seven annexes are attached to this document and are referenced as appropriate.

2. Basic reporting requirements

A key scientific objective was to develop and define basic reporting requirements for construction, demolition and refurbishment waste to ensure that there is consistency in the type and meaning of data collected to allow aggregation and comparison. It also ensured that companies that collected data at a project level could supply information by only requiring common mandatory information. These basic reporting requirements were presented to industry in the form of a discussion paper and an event was held with industry in the Spring of 2006 with over 40 delegates whereby they were asked to provide information on the

- Data they currently collected
- Data that they thought could be collected
- Prioritisation

The basic reporting requirements for collecting waste data at a construction project level adopted for this project, based on industry consultation, are summarised below:

Mandatory data is required for:

- Cost of project
- Floor area of project
- Project address and location
- Type of project e.g. residential, commercial etc
- Length of project (start and anticipated end date)
- Number of employees
- If the project is construction, refurbishment and/or demolition
- Amount of waste produced (tonnes or volumes)
- Types of waste (based on EWC codes or BRE's SMARTWaste categories)

These mandatory data were deemed through consultation with industry to be readily available at a project level and provide consistency for data collection.

In terms of the type of project, standard construction classifications were used and it was agreed to categorise projects as: residential, public buildings, leisure, industrial buildings, healthcare, education, commercial retail, commercial offices and civil engineering. For the waste categories, common EWC codes and existing SMARTWaste categories were used as shown in Table 1.

SMARTWaste Waste categories	EWC code
Canteen/office/ ad-hoc	20 03 01
Ceramics/bricks	17 01 02 17 01 03
Concrete	17 01 01
Electrical equipment	16 02 14
Furniture	20 03 07
Inert	17 01 07
Insulation	17 06 04
Metals	17 04 07
Packaging	15 01 06
Plaster/cement	17 08 02
Plastics	20 01 39
Timber	17 02 01

Table 1: Categories for construction waste

This enables the KPIs to be shown for each project type and the type of construction (i.e. new build, refurbishment) and against key metrics such as the project cost and floor area. This is important as both the project and construction type are likely to have an effect on the amount and type of waste produced e.g. demolition projects are unlikely to produce much packaging waste. The level of mandatory data required is also a manageable amount of data for a construction site to submit and data that should be readily available. The industry consultation also recommended the following additional data to be collected.

- Waste removal costs
- Percentage of waste segregated on-site
- Amount of material recycled on-site
- Amount of material recycled off-site
- Amount of material diverted from landfill
- Annual cost of hazardous waste removal
- Number of man hours worked on project
- Unit sizes (if applicable) e.g. housing

This task progressed well in the first stages of the project with the scientific objective being met through the development of these practical reporting requirements through significant engagement with industry.

3. Collection of benchmarking data and environmental performance indicators

The collection of benchmarking data and the conversion of these data into KPIs was carried out from January 2007 and is continuing beyond the research contract. It was always intended to use systems that benefit the provider of the data and are based on real time and not to use surveys. This is because the project team believed that more data would be obtained if the user (i.e. the project and construction company) also benefit by having their own KPIs which can be used at a project level. Surveys can only provide a snapshot in time and often do not provide the respondent with any immediate benefit whereby a system of data collection throughout the lifetime of a project provides a data profile and has an audit trail; it is also in the interest of the company to provide accurate data if they are to benefit from it. The systems developed encouraged companies to supply data and provide a picture of waste generation throughout a project's lifetime. A number of approaches were undertaken with industry in order to obtain these data:

SMARTWaste system

BRE's main mechanism of collecting construction waste data is through the SMARTWaste system (2) which was first developed approximately 10 years ago. As part of this project, the construction industry (predominately contractors) was encouraged to submit data into this system and data were subsequently analysed. SMARTStart (part of the SMARTWaste system) enables the user to enter information at a project level for construction waste based on a visual assessment of what is in a container based on 14 waste categories; this enables data to be collected in a relatively easy and simple way – which is essential onsite. The data collected are then converted to tonnes using standard EA conversion factors (3). Overall tonnage information can also be added through Waste Transfer Notes. Data are then shown for the amount and type of waste produced and the amount that has been segregated; this is shown at a project and company level.

Figure 1 shows a screenshot of summary data at the project level for SMARTStart. Data are summarised for waste generated to date including the actual volume, the bulk volume and tonnage data (if entered).

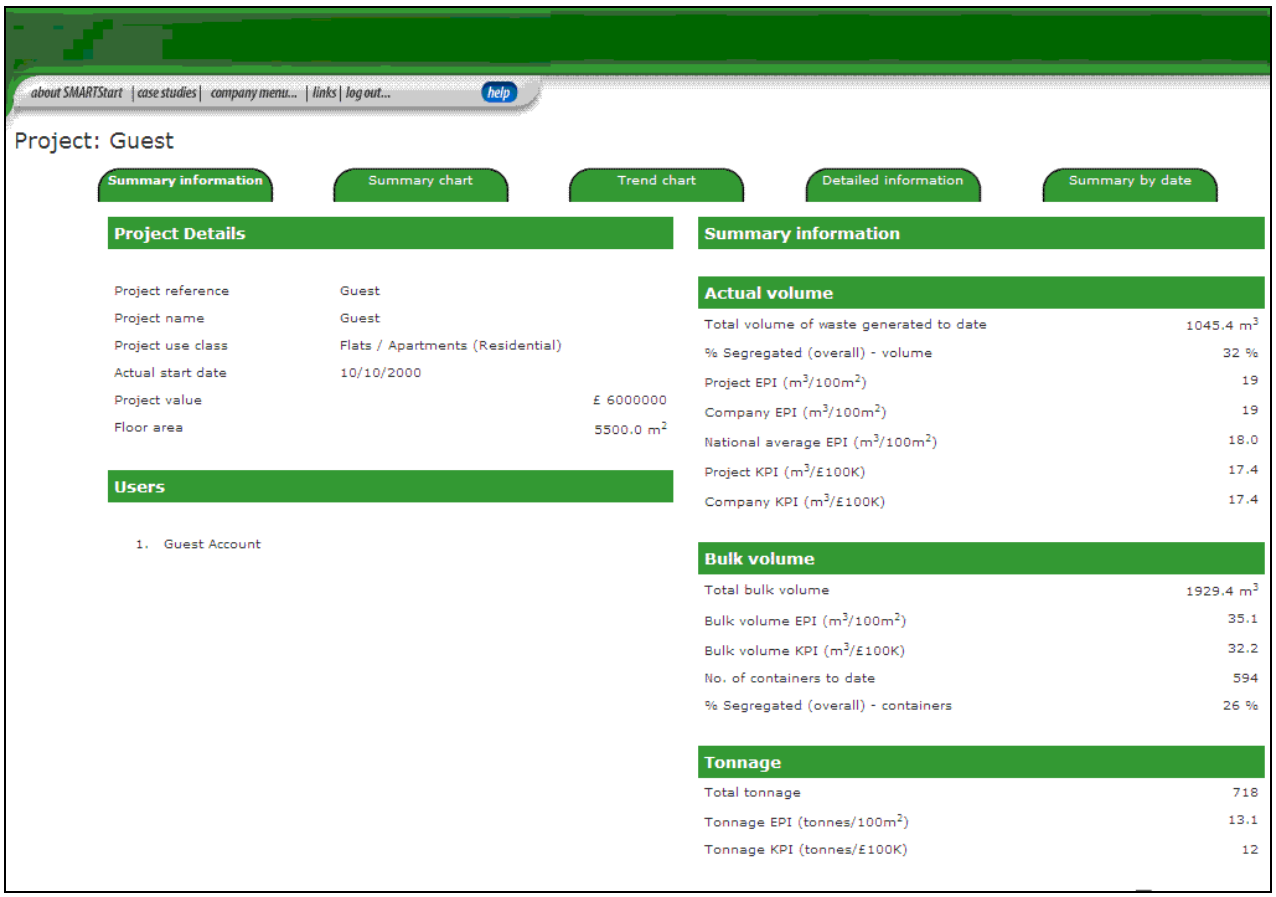

Figure 1: Screenshot of SMARTStart: project summary information

Figure 2 shows how data are added into the SMARTStart system; this form should be filled in for each waste container and when submitted the figures are updated automatically.

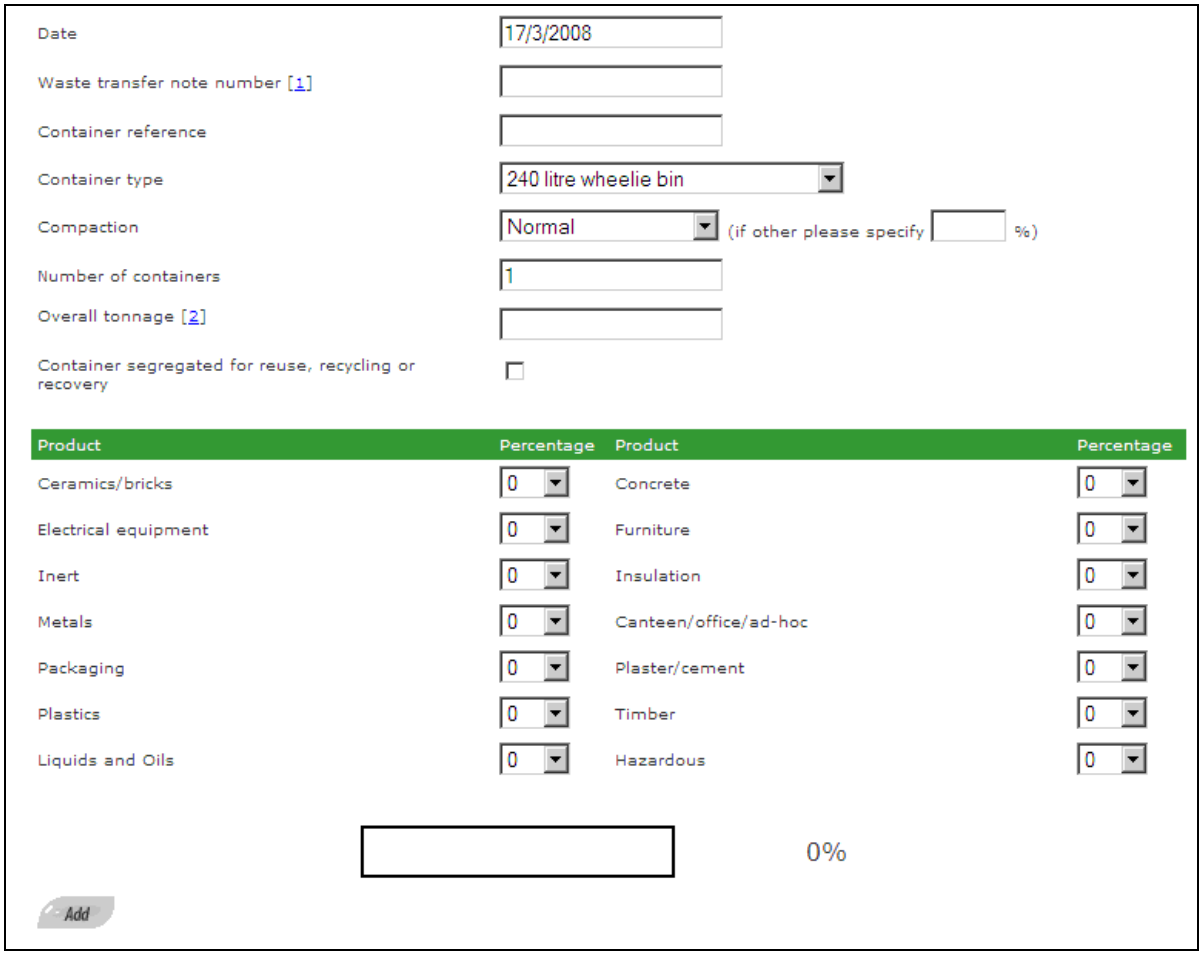

Figure 2: Screenshot of SMARTStart: add data page

Figure 3 shows the detailed information for each waste type. For each waste group information is summarised in terms of the volume of waste generated to date, the tonnages of that material (based on conversion factors), how much has been segregated and the KPIs for that material. This is summarised at both the project and company level.

Summary information | Summary chart | Trend chart | **Detailed information** | Summary by date

Project Performance

	Actual waste (m^3)	Tonnage Lower	Tonnage Upper	Mixed (%)	Segregated (%)	EPI (see key below)	KPI
Ceramics/bricks	251.83	89.05	321.61	47	53	4.58	4.2
Concrete	89.02	98.88	98.88	63	37	1.62	1.48
Electrical equipment	62.15	11.19	14.09	80	20	1.13	1.04
Furniture	27.69	4.85	24.92	94	6	0.5	0.46
Inert	112.03	124.91	167.47	77	23	2.04	1.87
Insulation	78.93	12.38	12.38	96	4	1.44	1.32
Metals	51.7	16.75	69.8	89	11	0.94	0.86
Canteen/office/ad-hoc	52.64	8.56	33.16	97	3	0.96	0.88
Packaging	97.91	20.81	88.12	74	26	1.78	1.63
Plaster/cement	56.56	18.74	26.79	86	14	1.03	0.94
Plastics	53.95	11.71	11.71	45	55	0.98	0.9
Timber	92.18	19.61	39.83	46	54	1.68	1.54
Liquids and Oils	3.22	0	0	100	0	0.06	0.05
Hazardous	15.61	0	0	4	96	0.28	0.26

Figure 3: Screenshot of SMARTStart: detailed information for waste type

Benchmarking Website

A standalone website was created for the project but due to constrained IT resources and conflicting demands this was not developed in the original timescale planned and subsequently delayed some of the data collection.

With Defra's agreement, the contract was varied by extension of the completion date to maintain an adequate period for data gathering, and to import additional data from SMARTWaste.

This website encouraged users to submit information based on the mandatory and additional requirements and enabled users to submit cost and tonne data and use European Waste Catalogue Codes. Data were reported back at both the project and company level. This basically widened the amount of data that could be collected. This benchmarking website has now been incorporated into BRE's free SMARTWaste Plan tool; however it can still be used independently.

Figure 4 shows how information from the benchmarking website is summarised at the company level. Dependant upon the type of data that the user has entered then volume, tonnes and cost KPIs are shown.

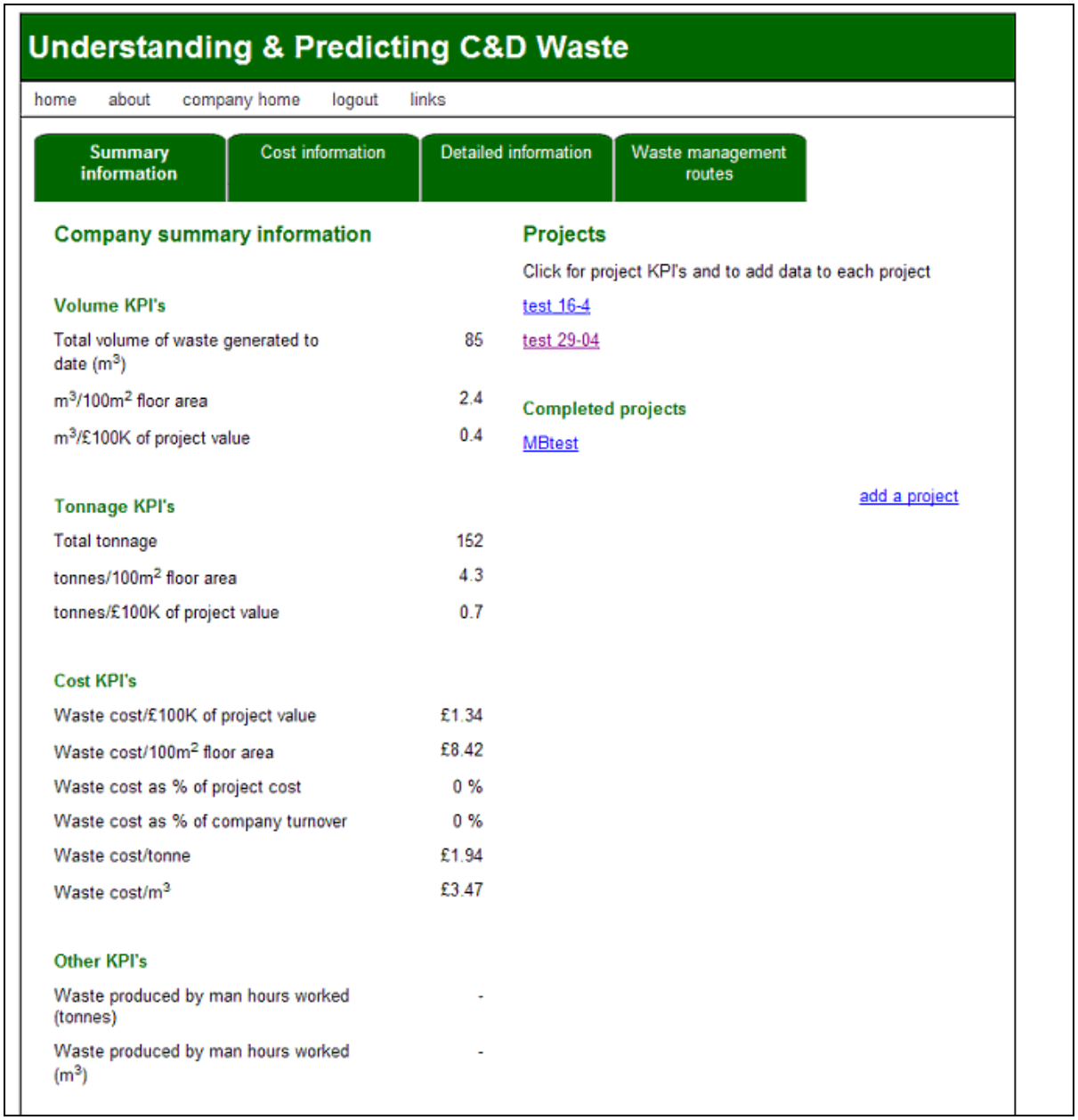

Figure 4: Screenshot of benchmarking website: summary information at the company level

Figure 5 shows information collected that the user can enter at the project level for the waste management routes.

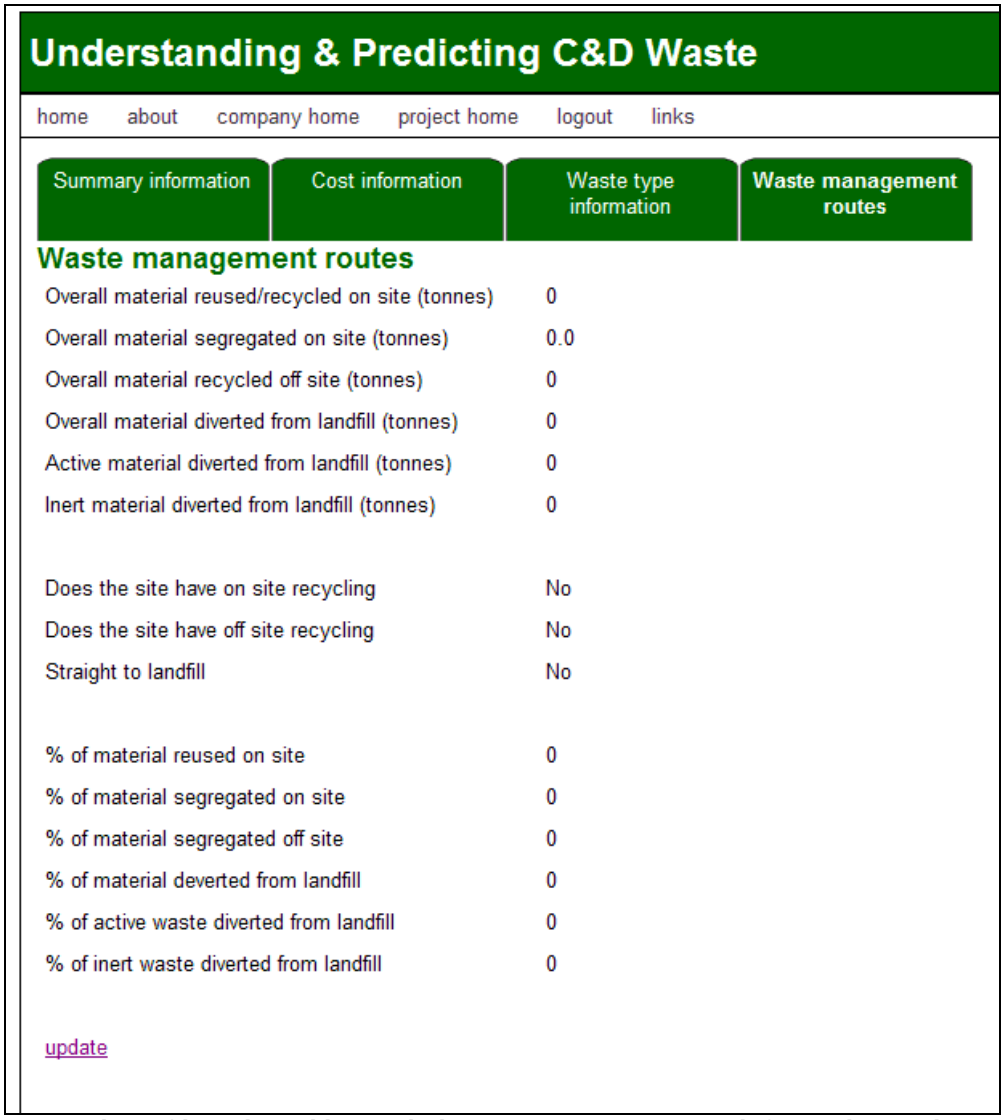

Figure 5: Screenshot of benchmarking website: waste management information at the project level

Manual data

It was realised that not every company would want to put their data on a web-based system. Therefore paper templates were developed based on the mandatory and additional data requirements and these were populated by the company providing information. BRE updated these paper templates for the company and subsequently added them onto the benchmarking website.

As previously mentioned, BRE have now developed SMARTWaste Plan, an online tool for Site Waste Management Plans. The data collection methodology which has been established throughout this project is now being used by this system; which is a benefit beyond the original objectives that the construction industry is using. All of these systems can be viewed and accessed for free at www.smartwaste.co.uk.

A target was set to have 1,000 sites collecting construction waste data as this was felt to provide enough data to produce good quality KPIs and benchmarks. The number of sites collecting through the systems mentioned above as of August 2008 was 1,277. A critical factor affecting the project was the shortening of the time available to collect data via the benchmarking website; meaning that fewer completed projects were available to produce benchmarks from and the quality of the data varied. However this was mitigated within the project by lengthening the data collection period and obtaining data from SMARTWaste. Performance indicators will continue to be produced by BRE on a bi-monthly basis for industry and Government.

The collected data was then aggregated to produce KPIs. Originally it was intended to have automatic self-updating KPIs but this has not yet been possible due to the variability of the quality of data collected which had to be reviewed and adjusted manually with the use of logical and statistical tests which are described below.

The following KPIs have been developed:

- Volume of waste (m^3)/ 100m^2 of gross internal floor area

- Tonnes of waste / 100m^2 of gross internal floor area
- Volume of waste (m^3)/ £100,000 of project value
- Tonnes of waste /£100,000 of project value
- % and amount (volume/tonnes) segregated – this gives an indication of how much material is available for recovery

These KPIs are available by type of construction project and also type of waste, which provides a picture of the waste composition and how it is generated. This is an important consideration, as the composition of the waste is likely to change as the construction project progresses. Currently, KPIs can only be generated for completed projects as projects which are ongoing could skew the dataset. However BRE are currently working on a methodology to enable ongoing projects to be analysed for the KPIs.

Data collected for all completed projects go through a number of logical and statistical tests, to ensure that the data used to produce the KPIs and other data are valid. These are as follows*:*

For the KPI m^3/100m^2:

- The floor area must be greater than 10 m^2.
- The waste volume must be more than 10 m^3 or the data is excluded.
- The volume of waste in m^3 per 100 m^2 floor area must be between 5 and 75.

For the KPI m^3/£100K:

- The project value must be greater than £100.
- The waste volume must be more than 10 m^3 or the data is excluded.
- The volume of waste in m^3 per £100K of project value must be between 5 and 75

Once these logical tests have been applied then the following statistical tests are performed:

- A count of the number of plausible results, the average, standard deviation and median of the results is obtained.
- Limits at a given confidence were calculated using a standard T-table and the basic formula where outlying results are suspected:

  LIMIT (at confidence) value = AVERAGE value + (Standard Deviation x T-table value (fn number of results, confidence level required)).

For example: upper 95% limit = Average value + (std. dev. of data) x (T-table result based on 29 results and 95% confidence) which is 14.2 + (10.5 x1.699) = 32.04 value which is the 95% upper confidence level.

The KPIs have been analysed and are updated at bi-monthly intervals and have been freely available to industry and other interested stakeholders; they are currently accessible from the SMARTWaste website. Table 2 shows the total number of projects, the number of projects collecting data through SMARTStart and the benchmarking website, and the number that have been included and excluded as a result of the statistical tests. Up to August 2008 there were 616 projects completed with 270 of these (44%) passing the logical test. The majority of these are new build projects. There are a number of reasons for this including users only entering data in as test project (i.e. when the waste is less than 10m^3), and where the floor area and project value are not known. Projects that have failed the logical tests have been contacted where appropriate to provide better data. During August 2007, 17 companies were contacted regarding 81 completed projects which did not pass the logical tests. Unfortunately, limited extra data was obtained due to the majority of the projects being more than a year old. It should be noted that a large number of projects (69) were due to complete in December 2007. These projects passed the £/m^2 test but unfortunately for the majority of these projects no waste data were entered. This has added to the number of excluded projects. However, new projects added have been checked monthly to ensure that floor area, project value and waste data are being entered correctly. As of August 2008, there were a further 423 projects registered on SMARTWaste Plan which are actively collecting waste data.

Date	5/4/07	20/6/07	10/10/07	14/2/08	31/8/08
Total number of projects			644	758	854
No. Completed projects	224	303	382	515	616
No. Projects included	87	102	149	213	270
No. Projects excluded £/m^2 (or <10 m^2 floor area)	65	99	110	14	8
No. Projects excluded <10 m^3 waste	18	48	59	172	195
No. Projects excluded, m^3 waste/100m^2 floor area <5 or >75	54	54	64	116	143
% Projects excluded	61%	66%	61%	59%	56%

Table 2: Summary of projects collecting data

Table 3 shows the KPI m^3/100m^2 for analysed projects by project type. The largest data set is for residential, followed by commercial retail, education and commercial offices. Results for project types with 10 datasets or greater are then disseminated. These KPIs are based on new build data for 224 projects.

Project Type	Number of completed projects passing logical tests	Number of companies	Average m^3/100 m^2
Residential	116	21	15.3
Public Buildings	6	5	26.1
Leisure	3	3	12.3
Industrial Buildings	5	5	20
Healthcare	14	8	15
Education	20	11	13.4
Commercial Offices	24	10	20.1
Commercial Retail	27	6	15
Civil Engineering	9	5	24.3
Total	224	74	16.4

Table 3: Average m^3/100m^2 for completed projects by project type

The data have then been divided into quartiles following statistical advice- (where the dataset is large enough) to show standard, good and best practice. The lower quartile has been assigned as ‘best practice’, the next quartile assigned as ‘good practice’ and the top two quartiles assigned as ‘standard practice’. This has been completed for residential, education, commercial retail and offices where the dataset is larger than 10. These can provide benchmarks for the construction industry to start improving its performance and moving from standard to best practice. Figure 6 and Table 4 show standard, good and best performance for residential projects.

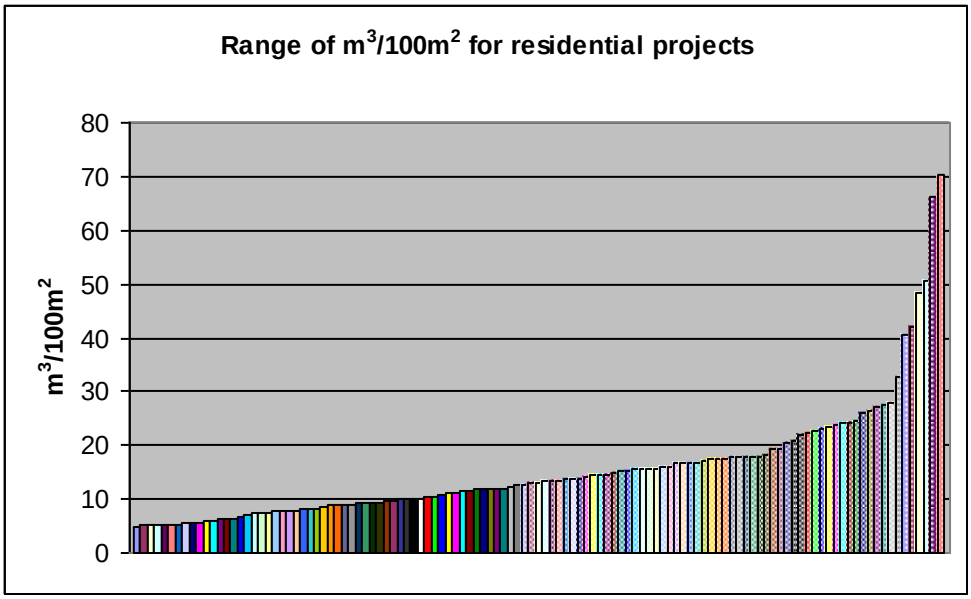

Figure 6: Range of $m^3/100m^2$ for residential projects

Benchmarks for Residential Projects	$m^3/100m^2$	Tonnes/$100m^2$
Best Practice (Lower Quartile)	<9.0	<4.7
Good Practice	9.0 - 12.9	4.7 – 6.7
Standard Practice	>12.9	>6.7

Table 4: Standard, good and best practice values for residential projects

Figure 7 shows the KPIs by waste group for the various project types; there are some variations for instance civil engineering and industrial buildings have a higher proportion of inert waste. This is to be expected as these types of projects usually involve bulk movements of soils and excavation waste and higher usage of recycled aggregates. It is therefore important to provide KPIs for different types of projects to ensure that the KPIs are relevant. More work needs to be undertaken to understand the reasons for the variation between project types.

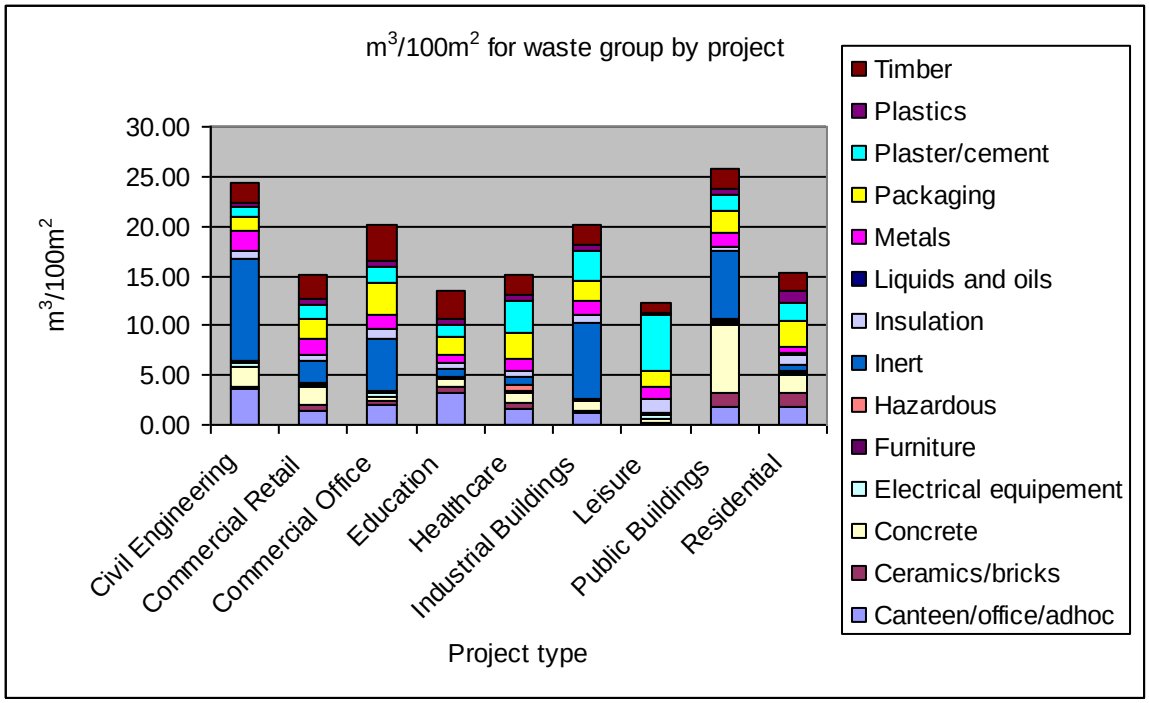

Figure 7: $m^3/100m^2$ for all waste groups for different project types

The percentage waste segregated for different project types has also been calculated for comparison. These results are shown in Table 5 and show that for all project types there is a large variation in the segregation rates. However, the median values do indicate that there is generally more segregation in civil engineering and industrial building projects; this could be due to the larger proportion of inert waste being generated.

	% waste segregated		
	Average	**SD**	**Median**
Residential	17.3	25.1	4.7
Public Buildings	42.7	35.9	40.8
Leisure	0.5	0.9	0
Industrial Buildings	40.7	29.8	23.1
Healthcare	28.4	25.0	7.0
Education	20.5	24.3	10.9
Commercial Offices	36.4	29.8	25.4
Commercial Retail	39.3	37.7	23.2
Civil Engineering	52.9	46.4	31.1

Table 5: Percentage segregation for different project types

A complete analysis of the data collected and description of the methods used is in Annex 1 to this report and is summarised in a presentation (Annex 3). This includes:

- Tonnage KPIs
- Bulk volume KPIs
- Demolition KPIs
- Average segregation rates by waste materials and project types
- KPIs over time
- KPIs by regions
- Breakdown of KPIs by construction type i.e. new build, refurbishment and demolition
- KPIs by waste type

In addition, annexes have been written for each part of the construction supply chain in terms of how these data and the KPIs can be used effectively; these are as follows:

- Annex 4: Policymakers: how the data can be used
- Annex 5: Planners: how the data can be used
- Annex 6: Clients/designer: how the data can be used
- Annex 7: Contractors: how the data can be used

4. Model and prediction of data

The KPIs and benchmarks have been used to model and predict waste arisings from various types of construction projects. For contractors, a benchmarking calculator has been produced which estimates the amount and type of waste produced based on their construction project type and the floor area. These data can be used at a project level or a company level to set targets, strategies and cost for waste management, and are available on BRE's SMARTWaste Plan. The ability to predict waste arisings is critical to reducing these arisings, through moving the industry towards less wasteful building technologies, methods and practices, and to encourage action to be taken before work on site commences.

In terms of planning at a local and regional level, the data can be used at both a micro and a macro level; this is shown in Annex 2. At a micro level the data can be used for local authorities when assessing SWMPs in relation to developments at the planning stage and also for the local authorities own construction activities e.g. highways maintenance. At the macro level the data can be used to model construction waste arisings from future plans and compared with existing and future capacities for waste management facilities.

Research has been carried out with Hertfordshire County Council to model the waste arisings from new housing and other large developments, as shown in Figure 8 at the District level. The East of England Plan Panel Report 2004 (4) (submitted to the Secretary of State June 2006) gives recommendations on the development of housing from 2001 to 2021. These figures can be used together with an assumption of the average floor area per dwelling and the performance indicator of m^3 waste per 100 m^2 of floor area to provide an estimate of the waste arising from the construction of these dwellings. It has been assumed that the average dwelling is 90 m^2 and that 15.3 m^3 of waste is produced per 100 m^2 of floor area for new-build residential projects. This benchmark has been produced from the SMARTWaste system and is based on 116 residential projects completed by the end of August 2008. Figure 9 shows the projection of waste from new housing for Hertfordshire by waste type. BRE continue to work with local authorities to develop a resource planning tool which will be available for all local authorities so this modelling can be replicated elsewhere with relative ease.

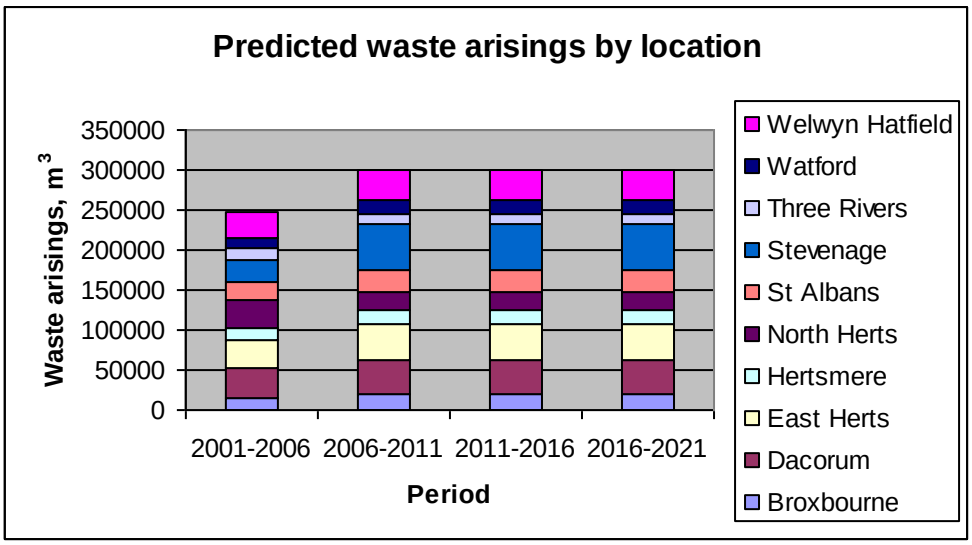

Figure 8: Estimated waste arisings by District for new house building in Hertfordshire

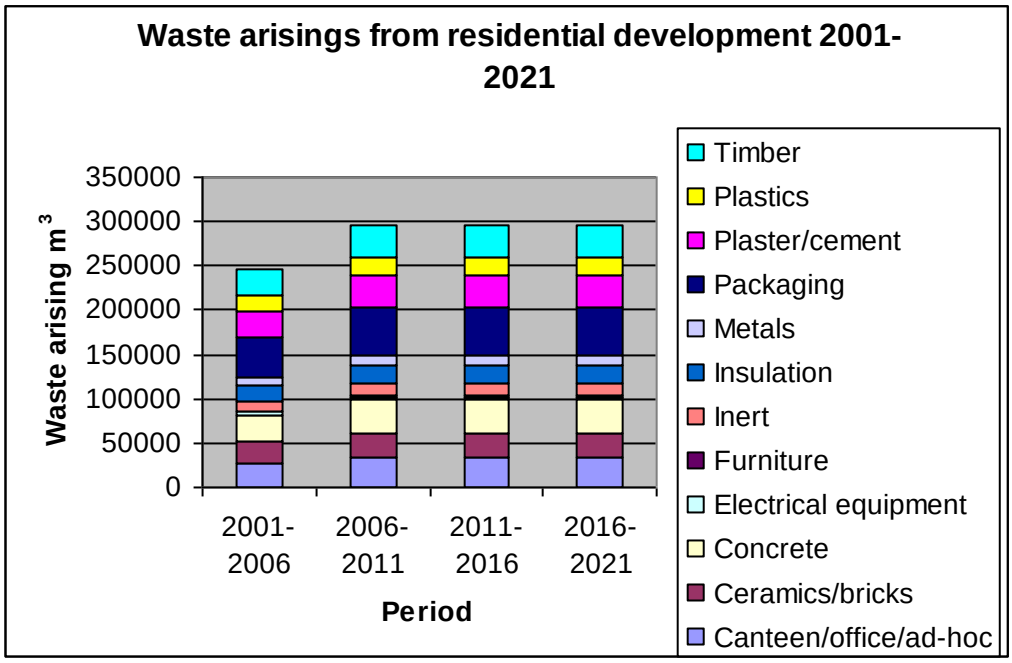

Figure 9: Estimated waste arisings by type for new Housing in Hertfordshire

5. Key recommendations for waste reduction

Key recommendations for waste reduction have been made based on the data collected and subsequent modelling; this is reported on fully in Annex 2. This is intended to help Defra and other organisations target the construction sector in terms of waste reduction. Best practice benchmarks have been applied to a development and show that by moving from 'average' practice to 'best' can reduce the amount of waste by nearly half. As the benchmarks develop overtime it is expected that they will reflect an improvement in waste reduction activities meaning that best practice will move with industry practices. The design and use of materials and onsite practices have an important role to play in waste reduction. In terms of design then designing out waste within the new build/fit out processes by using products/materials that aid waste reduction (e.g. standard sizes, prefabrication, dry trades etc.) will minimise the amount of waste arising. In addition, thought should also be given to the overall design of the building. Designing the building/layout to reduce the overall amount of material resource usage (e.g. by considering floor areas, reduction in number of materials, avoid complex designs and encourage 'straight' lines etc) will minimise waste production. Obviously buildings and systems are not usually designed with the sole purpose to eliminate waste but avoidance of waste can be achieved within an overall design/sustainability framework.

Contractors and subcontractors are critical in terms of waste reduction as they are responsible for the construction of the building and the subsequent waste arising. It is essential for contractors to have an understanding of the type and amount of waste being generated, the cost of the waste and the amount of materials that have actually been used within the build to implement waste reduction, and set an appropriate baseline. Then appropriate targets can be set such as waste prevention targets (applicable to waste from new build/installation); this can be based on either limiting wastage allowances (e.g. % reduction), maximum material purchase or a benchmark figure related to waste generation (with a % reduction related to this). Any targets set should also involve the supply chain and a full understanding in terms of subcontractors and the wastage they generate is required. SWMPs are an effective tool for this.

6. Stakeholder engagement and dissemination

Stakeholder engagement has been a key feature within this research project. The objective of this engagement was to ensure data were being collected and inputted into the project and that the results produced have been

meaningful and useful. Stakeholder engagement has occurred through various means including meetings, events, presentations, articles and face to face meetings. This includes all elements of the supply chain i.e. clients, designers, contractors and waste management companies. In terms of other key stakeholders essential dialogue has taken place with Defra (in terms of the Waste Strategy), Waste Data Strategy and Site Waste Management Plans, BREEAM, CLG and the Code for Sustainable Homes, Constructing Excellence, Environment Agency and various trade bodies such as the Construction Confederation and Major Contractors Group, the National Federation of Demolition Contractors (NFDC) and the Construction Products Association (CPA). This stakeholder engagement has demonstrated successful uses of this research, as follows:

- BREEAM – use of data to set benchmarks for waste generation
- Code for Sustainable Homes – possible use of benchmarks for next major review (2009)
- Input into the Environment Agency Survey on Construction Waste for Wales
- Access to NFDC data on waste arisings and subsequent management of demolition waste
- Working with the CPA in terms of developing a methodology for an indicator on packaging waste
- Discussions with the Construction Confederation to collect data from their members on waste
- Defra – use of data within the Waste Strategy and development of Site Waste Management Plan Regulations.

In terms of dissemination, 3 events have taken place for the construction industry in terms of recruiting companies for data collection and disseminating the benchmarks. These have been attended by over 100 delegates. Over 20 presentations have been given to a variety of audiences and 3 articles have been written for trade journals. A peer-reviewed paper has been submitted and accepted to the Waste and Resource Management Journal.

7. Key recommendations and future opportunities

A number of key recommendations are presented in relation to the collection and analysis of construction waste data:

- Useful data have been obtained for over 200 projects with much more anticipated; this has been achieved by ensuring that there is consistency in the way these data are collected, analysed and reported. It is of paramount importance that any subsequent data collected on construction waste are collected within a consistent framework.
- In terms of encouraging companies to submit data then the systems to collect these should be user friendly and quick to use; most importantly the system should provide data to benefit the companies as well as providing data for this project. The systems set up for this project provide the user with KPIs for their project and company, so providing a key incentive to collect and report data. This is indicated by over 1200 projects registered on the systems.
- Data collected by the waste producer is preferable and provides a buy-in to the project; data should also be collected throughout the lifetime of a project as the waste may significantly change; this fits well with the SWMP Regulations; data can then be used effectively both by industry and Government
- The web-based systems set up allow users to enter as much data as they want in an easy manner and provide a reliable means for working with large datasets. The collection and analysis of these data would not have been possible to such an extent in this project if a paper based survey was used.

By creating and using these data collection and analysis techniques for construction waste, policymakers can determine the implications from various policy interventions in a quantifiable manner. The data can also aid construction companies and projects in terms of setting targets and strategies for waste management and assist with compliance for the SWMP Regulations.

Data will continue to be collected and subsequent KPIs produced through the development of BRE's SMARTWaste Plan. The benchmarking website and the SMARTStart system have now been incorporated into SMARTWaste Plan; although the benchmarking website can still be accessed independently of the new SMARTWaste Plan tool. This has incorporated and developed both the SMARTStart system and the benchmarking website. This ensures continuing benefits from this work following project completion.

Future opportunities to improve data collection provide greater understanding and a better evidence base include:

- Inclusion of more projects using the minimum reporting requirements and subsequently collecting data (Site Waste Management Plans should encourage this)
- Better understanding of the causes of the waste and the extent to which waste can be avoided without having a knock on effect on the construction programme

- Better understanding of the resources used (i.e. benchmarks for resource usage which can be linked to the waste data providing information on wastage rates for key products
- Evaluation of carbon and other environmental impacts of the data collected
- Evaluation of costs of waste, and cost savings resulting from waste avoidance

References to published material

9. This section should be used to record links (hypertext links where possible) or references to other published material generated by, or relating to this project.

References

1. Defra 2007, Waste Strategy for England, May 2007; www.defra.gov.uk/waste
2. For more details on SMARTWaste and the benchmarking website go to: www.smartwaste.co.uk
3. Environment Agency : survey on the arisings of Construction and Demolition waste in Wales 2005-06, published 2008
4. East of England Plan 2004, Examination in Public, Panel Report, June 2006
http://www.gos.gov.uk/goee/docs/193657/193668/East_of_England_Plan_Examin1.pdf

A number of Annexes have been produced to support this report. These are as follows:

Annex 1: Analysis of construction, refurbishment and demolition waste data

Annex 2: Key recommendations and modelling for waste reduction

Annex 3: Presentation on data and findings

Annex 4: Policymakers: how the data can be used

Annex 5: Planners: how the data can be used

Annex 6: Clients/designer: how the data can be used

Annex 7: Contractors: how the data can be used