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Arienir gan Lywodraeth Cynulliad Cymru
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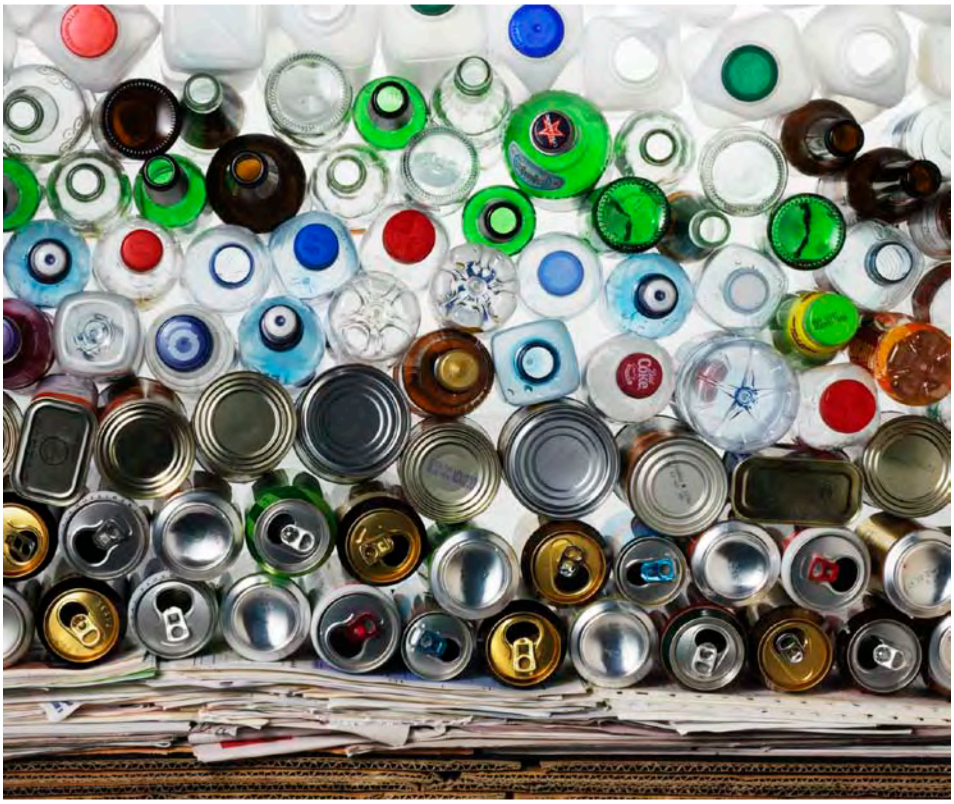
Final Report

Kerbside Collections Options: Wales



This report examines the relative merits of the options that are available to local authorities in Wales for the collection and sorting of dry recyclable materials. The central focus of the work is around the long-running debate on the relative performance of co-mingled, two-stream and kerbside sort dry recycling collection systems in relation to the Welsh Assembly Government's sustainability objectives.

Project code: WAL005-000
Research date: August to December 2010
ISBN: 1-84405-441-1
Date: January 2011

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Front cover photography: Recyclable materials

Executive summary

A key objective of *Towards Zero Waste*, the overarching waste strategy document for Wales, is for 70% of household waste to be recycled by 2025. This objective will be underpinned by statutory recycling targets for individual local authorities. In this context, Eunomia, along with sub-contractors Resource Futures and HCW Consultants, was commissioned by WRAP (Waste & Resources Action Programme) on behalf of the Welsh Assembly Government (WAG) to examine the relative merits of different dry recycling collection systems in relation to WAG's sustainability objectives. The study considered co-mingled, two-stream and kerbside sort collection systems, taking account of the overall financial, environmental and social impacts associated with each collection system. It is WAG's intention that the findings of this research should inform the policy framework within which local authorities will deliver the major changes to their services that will be required in order for 70% recycling to be achieved.

Methodology

The research was carried out in three phases: an initial literature review of previous relevant research; an in-depth study of six Welsh 'case study' recycling schemes (two co-mingled, two two-stream and two kerbside sort) which sought to understand in detail the fate of all material collected from 'doorstep to end destination'; and an all-Wales modelling exercise, in which the impacts of all authorities switching to one or other of the collection systems were compared. This final stage considered impacts in the context of both 'current performance' and the level of 'enhanced performance' likely to be required for the 70% target to be met. Financial and environmental impacts were then brought together by means of a cost-benefit analysis, under which environmental impacts were monetised to allow financial and environmental impacts to be compared on the same basis.

Financial Cost

Where the cost of waste collection and disposal, revenue from the sale of recyclable material and the cost of processing material at a materials recovery facility (MRF) are taken into account, our modelling suggests that rolling out kerbside sort collection across the whole of Wales would result in lower financial cost than either co-mingled or two-stream collection. In the current performance scenario, the difference in cost is relatively small, with co-mingled collection costing £5.5 million (or 4.3%) more per year than kerbside sort and two-stream being £2.7 million (or 2.2%) more expensive than kerbside sort. However, in the enhanced performance scenario, the cost gap is much greater, with co-mingled and two-stream collection costing £25.6 million (or 22%) and £25.8 (or 22.2%) more respectively.

Environmental Cost

Environmental impacts related to collection, MRF/bulking/sorting operations and the treatment and disposal of residual waste and rejected material, as well as the benefits associated with recycling, were analysed for all of the collection options considered. The environmental modelling considered both carbon emissions and air quality impacts, with the projected emissions being monetised for the overall cost-benefit analysis using well established damage cost assumptions. In the current performance scenario, the kerbside sort option performed best in terms of overall carbon emissions, with the two-stream option resulting in a 10.8% greater emission of CO_2 equivalent and co-mingled collection 13.3%. In the enhanced performance scenario, all options delivered a net carbon emission benefit due to the benefit of increased recycling offsetting the combined impact of collection, sorting, transport and disposal. However, again kerbside sorting appears to offer the greatest benefit, contributing a reduction in emissions equivalent to 225,000 tonnes of CO_2 per year. Carbon emissions benefits were calculated as being 24.4% lower for co-mingled collection and 17.6% lower for two-stream collection.

When both carbon emissions and air quality impacts are considered and the projected emissions are monetised, the performance of the options is much closer in the current performance scenario, with the pattern very much following that exhibited by the financial cost results. In this scenario, the overall environmental cost of kerbside sort is lower than the other two options, at £50.6 million per annum. The environmental cost of two-stream collection is only 1.7% greater than kerbside sort, whereas the overall environmental impact of co-mingled collection is 5.5% higher. In the enhanced performance scenario, the relative performance gaps widen considerably, but in the context of a much lower environmental impact for all options, due to the benefit associated with increased recycling and reduced use of landfill.

Social Impacts

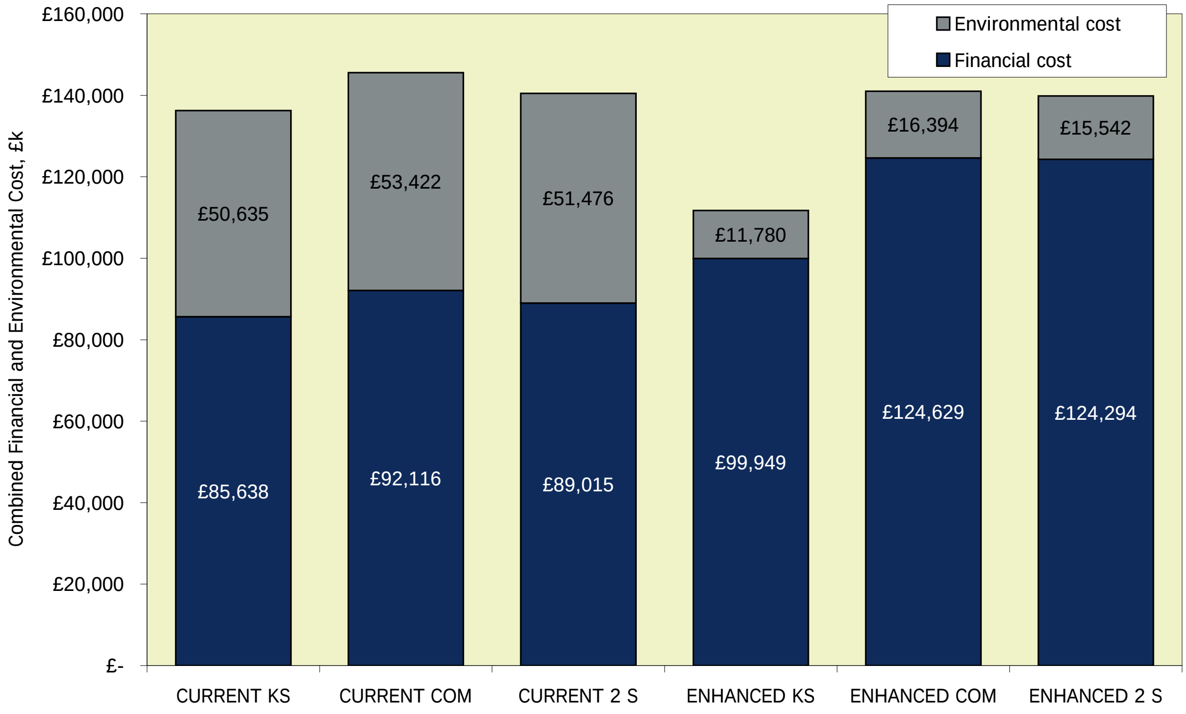
In terms of quantifiable difference in social impact between the options, the primary focus of the study was on employment intensity. Our analysis suggests that the range between the best and worst performing option was quite narrow. More full time equivalent jobs would be created if all Welsh authorities adopted a kerbside sort methodology where current performance is assumed, but in the enhanced performance scenario, more jobs would be created in co-mingled collection, with least being created in kerbside sort. Other impacts considered in the study included health and safety (in respect of both employees and the public), traffic congestion impacts and customer satisfaction. In all of these areas, the limited data available proved inconclusive.

Conclusions

Figure 1 below shows the overall results of the cost-benefit analysis, combining the financial and environmental cost performance of all three options in both current and enhanced performance scenarios. In our analysis, the kerbside sort option consistently outperforms the other two options. In the enhanced performance scenario, the apparent advantages of kerbside sorting are particularly marked, with two-stream only marginally outperforming co-mingled collection against both financial and environmental metrics. At current performance levels, the picture is somewhat different, with all systems more closely matched and two-stream collection performing only marginally less well than kerbside sorting. Key conclusions that can be drawn from the study are:

- Our analysis suggests that co-mingled and two-stream collection systems could be expected to achieve higher yields of collected dry recyclables, relative to kerbside sorting. However, when material rejected at the MRF, by secondary processors and by reprocessors is taken into account, differences in tonnage actually recycled between the systems appear to be marginal.
- Improved environmental outcomes are associated with the typical fates of kerbside sorted material as opposed to co-mingled and two-stream material, both in terms of benefits of recycling and impacts of onward transportation.
- In terms of financial cost, when optimised systems are compared for all options, kerbside sorting does appear to have the potential to offer a lower overall cost.
- The advantages of kerbside sorting appear to increase as recycling performance increases. In turn, the advantage of two-stream over co-mingled collection appears to narrow as performance increases. These results suggest that Welsh local authorities will face a challenge in adapting collection systems that may work well now, but may become increasingly sub-optimal as recycling levels increase towards the 70% target.

Figure 1: Combined Annual Financial and Environmental Cost (£k)



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Glossary

Compositional categories – The classification system used to describe individual materials. The categories used in this project have been derived from various compositional studies.

Contraries – Materials that are sent to a MRF, intermediate processor or reprocessor that are not within the scope of materials desired by that part of the recycling chain. At the primary MRF stage, contraries will only comprise non-target materials. However, at subsequent stages of the chain, contraries may include target material that has been miss-sorted into the wrong product stream.

Cross-contamination – The miss-sorting of target material into the wrong product stream.

Intermediate processors – Facilities that sort material subsequent to the primary MRF process but before the reprocessing stage.

MRF – A materials recovery facility or 'MRF' is a facility at which components of a mixed waste stream, in this case primarily either co-mingled or two-stream collected dry recyclables, are extracted by the use of mechanical and manual separation techniques.

Primary MRF(s) – The first sorting location(s) for co-mingled and two-stream systems and the first point of bulking and sorting of plastics and cans for some kerbside sort systems.

Process loss – Any material(s) collected from the MRF/ bulking facility within a product stream, but not reprocessed into a new product. This excludes material rejected for residual disposal at the Primary MRF.

Process loss rate – The amount of material(s) collected but not reprocessed into a new product, divided by the amount of material collected from the MRF/ bulking facility as a product.

Product/product streams – Materials that are shipped as a specific post MRF/bulking facility product or grade. Each has an assumed composition which includes various components, some of which are specified by onward reprocessors and some of which are contrary items. Some products have the same name as compositional categories such as News and Pams. The News and Pams Product will contain News and Pams, but will also contain other compositional categories such as Grey and White Board.

Reject rate – This term is used in this report to describe the material sent for residual disposal from the Primary MRF(s) and is equivalent to the reject rate methodology required for WasteDataFlow reporting.

RCV – Refuse collection vehicle.

RIDDOR – Reporting of Injuries, Diseases and Dangerous Occurrences Regulations.

Target material – The materials that are targeted by a collection system for ultimate recycling.

Acknowledgements

Particular thanks are due to the six case study authorities for providing data, attending meetings to discuss their services with us and for showing us around the facilities related to their collection services. This entailed a significant commitment of officer time and effort for which we are grateful. Thanks also to the Technical Advisory Group for their input into the project and to the MRF operators and reprocessors for taking the time to speak to us, providing access to sites for primary research and observation and for providing valuable information to support our understanding of the flow of materials from the point of collection to the end destination.

1.0 Introduction

This report has been commissioned by WRAP (Waste & Resources Action Programme) on behalf of the Welsh Assembly Government (WAG) to examine the relative merits of the options that are available to local authorities in Wales for the collection and sorting of dry recyclable materials. The central aim of the work has been to inform the long-running debate on the relative performance of co-mingled, two-stream and kerbside sort dry recycling collection systems in relation to WAG's sustainability objectives. In addition, it is also important to highlight the underlying context for this work. *Towards Zero Waste*, the national waste strategy for Wales, sets a target of 70% for household waste recycling by 2025. Legislation that will establish statutory targets for local authorities to ensure that this national target is met is currently being finalised and it is hoped that findings from this study will contribute towards efforts by WAG and Welsh local authorities to achieve these objectives.

The project as a whole was split into three key phases as follows:

- Phase 1: a desk-based study to evaluate secondary evidence from data and publicly available reports on the comparative performance of dry recycling collection systems, including in relation to the health and safety performance of the systems;
- Phase 2: primary research to determine the financial and environmental costs of the dry recycling systems in six case study authorities in Wales which cover the range of kerbside collection systems; and
- Phase 3: application of the evidence and understanding obtained in Phase 1 and Phase 2 to model whole system costs and performance for all Welsh authorities and to draw together the findings of all three Phases.

This report pulls together the findings from all three phases of this work. It firstly summarises our findings from Phase 1 and describes the methodology used and conclusions drawn from Phase 2, identifying those key concepts which helped to inform the Phase 3 modelling. The report then presents the difference in financial, environmental and social impacts that we have calculated would be the result if each of three dry recycling collection systems was to be rolled out across the whole of Wales, looking at the impacts based on both current performance across Wales, and of the move towards the 70% recycling target.

2.0 Project Aims

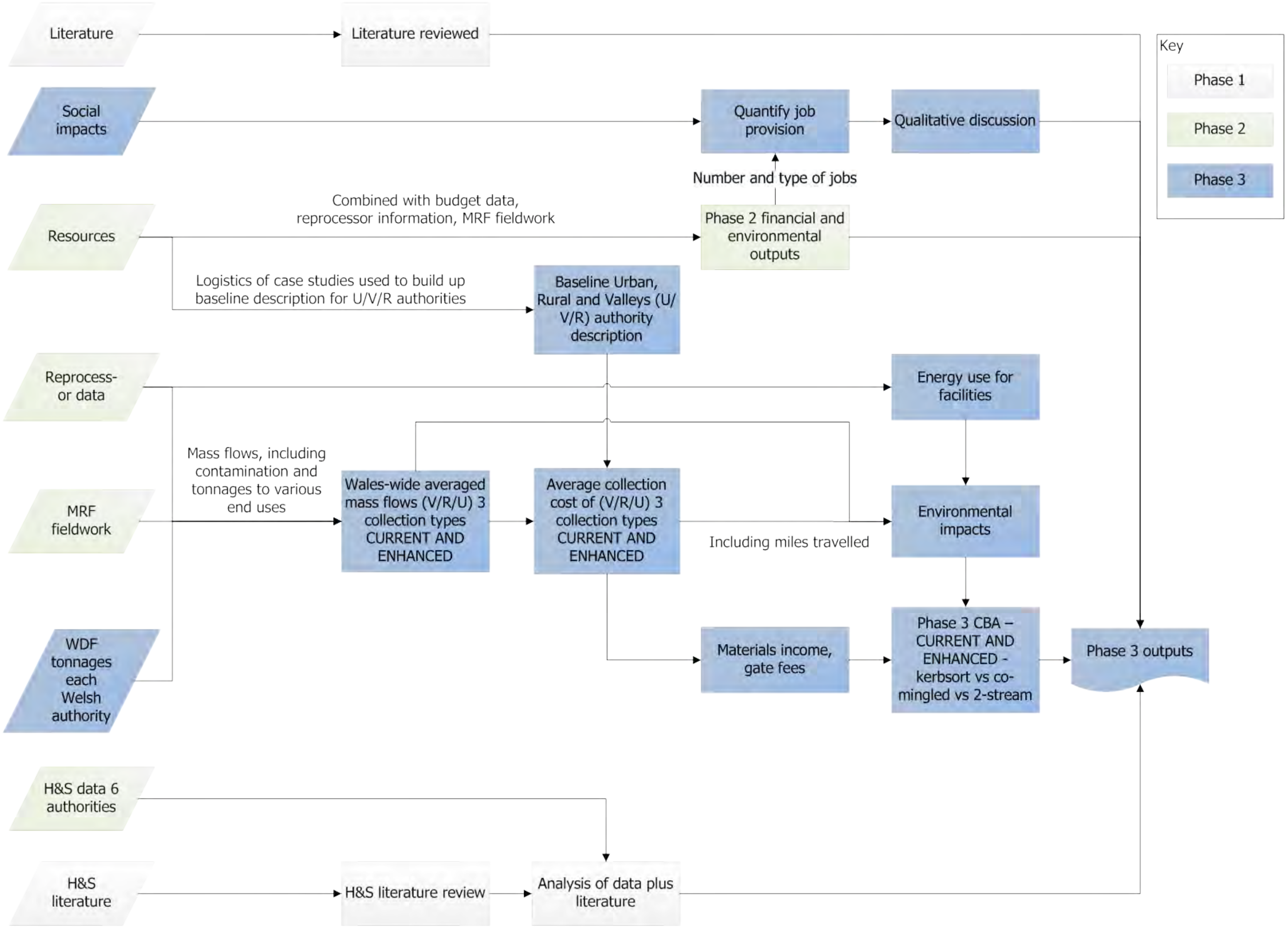
The overall aim of this study was to identify with greater certainty which of following options for collecting dry recyclables perform relatively better or worse in relation to WAG's sustainability objectives:

- sorting materials at the kerbside;
- two-stream collection, with material separated into two streams at the point of collection, with further sorting at a materials recovery facility (MRF) required; or
- single-stream co-mingled collection of materials with sorting at a MRF.

3.0 Methodology

The methodology employed is summarised in this section. Further details of the specific methodologies employed in each stage of the analysis are provided later in the report. An in-depth explanation of assumptions and methodology is set out in the separate *Technical Annex*. As described above, the project was delivered as three phases of work. Phase 1 was centred on critically reviewing published reports related to the comparative performance of dry recycling collection systems, including differential health and safety performance of such systems. Phase 2 involved undertaking a 'doorstep to destination' analysis of six case study authorities: two kerbside sort schemes, two co-mingled schemes and two two-stream schemes operating in Wales, to determine the financial and environmental costs of each approach and to develop appropriate metrics to compare the social impacts of the different approaches to collecting recyclables. This work provided insight into the fate of particular products, including material rejected for residual disposal at primary MRFs used by Welsh authorities, as well as process losses from intermediate and final reprocessors of particular products. Phase 2 also provided the project team with a detailed understanding of some of the key local factors that can influence system costs.

Figure 2: Schematic of Overall Project Approach



The findings from the first two phases were subsequently used to help to determine the methodology for calculating the financial, environmental and social impacts that would be incurred if each of the three dry recycling systems was to be rolled out across the whole of Wales. Two scenarios were examined; the first, hereafter termed the '**current performance**' scenario, involved calculating the costs and benefits associated with the Wales-wide implementation of each of the dry recycling collection systems based on current levels of recycling performance across each authority. The second, hereafter referred to as the '**enhanced performance**' scenario, looked at the Wales-wide costs and benefits based upon the 70% recycling target. Modelling was based on averaged mass flows for urban, rural and valleys authorities (using WasteDataFlow data, the findings from Phase 2 and other reference data as applicable). The collection costs were then calculated based on the typical characteristics associated with these three authority types (informed by the findings from Phase 2). Environmental impacts were also calculated based on the mass flows for each authority. The key elements involved in the overall project approach are summarised in Figure 2.

4.0 Phase 1: Literature Review

The objectives of Phase 1 were to provide some contextual commentary on the current state of understanding of the comparative performance of collection systems and to inform the primary research and analysis to be undertaken in Phases 2 and 3 of the project.

4.1 Methodology

Several studies were identified by WRAP, WAG and the project team as being potentially useful starting points in informing the debate as to the relative merits of different dry recycling collection systems. In undertaking a critical review of this available literature, consideration was given to the following:

- The underlying data sources upon which the research relied, and the credibility of these.
- The methodological approach to the analysis of the data, and the robustness of this, including consideration of issues such as:
    - the appropriateness of scheme classification and analysis, with particular regard to the extent of objective comparability between collection systems;
    - material capture rates;
    - fate of materials;
    - methods for determining resource requirements including vehicle selections, crewing numbers, unit costs and methods of dealing with overheads and financing; and
    - whether the analysis has adequately accounted for all the components of the system that should have been considered.

Through this evaluation, the key findings of relevance to this study were identified, along with any limitations to existing studies which needed to be considered as part of this work. The literature reviews were undertaken following a standardised structure, to ensure consistency of analysis and reporting. Details of each review are presented in full in the *Technical Annex*.

4.2 Collection Systems

A summary of the key findings from the reviews relating to the impact of different dry recycling systems on waste flows and system costs and benefits are presented in the remainder of this section.

4.2.1 Studies Reviewed

The following studies were reviewed within this part of the project. In most cases, a published report was available. Where this was not the case, the material reviewed is described in square brackets.

- WYG (2010) *Review of Kerbside Recycling Collection Schemes Operated by Local Authorities,* Amended Version May 2010.
- ADAS (2007) *Energy Audit of the Kerbside Recycling Services: The London Borough of Camden.*

- Hyder Consulting (2008) *Carbon Assessment: Commingled and Source Segregated Collection Systems, Milton Keynes Council* [presentation only].
- WRAP (2008) *Kerbside Recycling: Indicative Costs and Performance*, June 2008.
- WRAP (2008) *Kerbside Recycling: Indicative Costs and Performance. Technical Annex*, June 2008.
- WRAP (2009) *Kerbside Recycling in Wales,* Summary Report for WAG March 2009.
- WRAP (2009) *Kerbside Recycling in Wales: Indicative Financial Costs,* Report for WAG March 2009.
- WRAP (2009) *Kerbside Recycling in Wales: Environmental Costs*, Report for WAG March 2009 (Research Conducted by ERM).
- Resource Futures (2010) *Analysis of Kerbside Dry Recycling Performance in the UK 2008/09*, Summary Report for WRAP June 2010.
- Entec (2003) *Assessment of Quality Arising from Existing Paper Collection Methods against European Recovered Paper Grades listed in BS EN 643*, Report for WRAP October 2003.

4.2.2 Key Findings

The reports reviewed divide to some extent between those setting out to specifically examine the relative merits of different collection systems versus those that are more general in nature but consider issues of relevance to this debate in the course of meeting wider study objectives. In the summaries that follow, we begin on the former category, with the reader directed to the *Technical Annex* for a more in depth discussion of all reports, including those of less direct relevance to the debate.

The WYG (2010) review of recycling collection schemes sets out to challenge the presumption in favour of kerbside sorting that WYG suggest is promoted by various recent publications and campaigns. The review concludes that co-mingled collection generally performs better in terms of material yield than kerbside sort, with WYG's 'adjusted for rejects' analysis of 2008/09 WasteDataFlow data suggesting that authorities with co-mingled schemes collect 25% more material on average than those with kerbside sort schemes. The study suggests that co-mingled schemes could be expected to generate a maximum material yield of 304Kg per household per annum (accounting for contamination), whereas kerbside sort schemes could only be expected to achieve 244Kg (where both schemes targeted the same 'main five' materials). In terms of cost, WYG base their analysis primarily on recent actual procurements and as such, the main data source is somewhat anecdotal. They conclude that either collection system is capable of being cheaper than the other, depending on variables such MRF gate fee, MRF location and material revenues. However, the point is made that where avoided disposal savings are taken into account alongside net cost of collection and processing, co-mingled collection offers an additional advantage, in that it diverts additional material from residual waste. Whilst the WYG report does not claim to offer the last word on the debate, its drafting does imply a conclusion that co-mingled collection is, overall, probably a better option for most authorities. This is somewhat problematic, because:

- Although analysis of WasteDataFlow data does reveal that co-mingled schemes generally generate higher yields of recyclables than kerbside sort schemes, this does not prove that it is co-mingled collection (or solely co-mingled collection) that explains the difference in yields. For example, there is a well understood correlation between recycling performance and socio-economic characteristics, with more economically deprived areas generally achieving lower recycling performance. More prosperous areas are also more likely to use wheeled bins for kerbside collection and the best performing co-mingled schemes are disproportionately operated using wheeled bins. As this example demonstrates, the causes of relative performance in terms of recyclate yield are varied and complex. It is only by carrying out a multi-factorial regression analysis that the significance of different factors can be identified in isolation from one another. WYG imply that a differential in recyclate yield performance of 25% could, on average, be expected in favour of co-mingled collection. However, based on the regression analysis carried out for this project using 2008/09 WasteDataFlow data, we are of the view that the performance differential that can be attributed directly to the use of co-mingled collection is somewhat lower (with yields expected to be between 10.5% and 18.3% lower for kerbside sort schemes).
- The treatment of material collected but not recycled (i.e. material rejected at the primary MRF and process loss following initial sorting) is dealt with in a somewhat superficial and sometimes opaque manner. The terms

‘MRF reject’ and ‘contamination’ are used interchangeably, although they have different meanings. There appears to be an assumption that it is only ‘contamination’ (i.e. non-target material) that is rejected at MRFs, even though it is clearly the case that target recyclables are often well represented in MRF rejects. Equally, the miss-sorting of target material leading to cross-contamination of product streams and the impact of different sorts of contamination (comprised of both non-target material and target material cross-contamination) on product stream quality are not considered in the analysis. The report is also unclear as to the precise methodology of adjusting for rejected material in the analysis of WasteDataFlow data. Overall, these issues lead to a lack of clarity as to the robustness of the analysis of waste flows and a concern that the study focuses on ‘material sent for recycling’ at the expense of consideration of ‘material actually recycled’.

The WYG study definitely contributes something to the debate and is a substantial achievement, given that it was partially self-funded. However, perhaps due to the limited resources available for the study, the conclusions presented are too often supported either by analysis that presents correlation as causation or evidence that is primarily anecdotal. We understand that WYG will be updating the report based on 2009/10 WasteDataFlow data and would suggest that expanding the statistical investigation to include regression analysis, increasing the transparency of the methodology used and ensuring that conclusions drawn are more directly supported by the evidence (or qualified where the evidence is unclear).

The ADAS (2007) energy and performance audit of Camden’s recycling schemes (both before and after the switch from kerbside sort to co-mingled collection) concluded that the ‘carbon footprint’ of the co-mingled service was significantly lower than the kerbside sort scheme, unless MRF energy consumption was taken into account, in which case the order of results reversed. Although it does not make such a claim directly, the ADAS study is often cited as demonstrating the high importance of MRF energy use in determining the relative environmental performance of collection systems. However, the study boundary of ‘haulage to the M25’ excludes impacts such as recycling benefits, disposal impacts and wider transport impacts. Limiting the study boundary to impacts associated with local logistics and sorting limits the extent to which it is possible to draw overall conclusions. The selection of metrics used to compare collection systems also results in a somewhat distorted picture being presented. Fundamentally, although the ADAS study includes some interesting analysis (including the use of an assumed MRF energy cost per tonne that is considerably in excess of other sources), it does not add directly to our understanding of the overall relative merits of collection systems or the relative importance of MRF energy consumption in determining which collection system offers the best environmental performance.

The Hyder (2008) study for Milton Keynes Council entailed a modelling exercise comparing the Council’s existing co-mingled system (using primary data) and a kerbside sort system based on ‘realistic, but hypothetical parameters’. As far as we are aware, a report of the study has never been published, but a set of PowerPoint presentation slides dated September 2008 summarising the study has been obtained by the project team. Since the study sought to directly examine the relative merits of kerbside sort and co-mingled collection systems, we have reviewed the available information, although clearly the depth of the review is more limited than in other cases where study reports are available.

The main findings were that the existing co-mingled system produced a carbon footprint of 21.6 kg CO_2/tonne against 30.0 kg CO_2/tonne for the hypothetical kerbside sort system. The explanation for these findings was that due to a reduced yield compared to co-mingled, the kerbside sort system required a greater number of miles to be driven per tonne of material collected. A comparison is made with ADAS (2007) Camden considered above. The Milton Keynes MRF is claimed to be 38.6% more efficient than that assumed in the ADAS study, with Hyder concluding that the use of a more energy efficient MRF is a key factor in the apparently contradictory findings relative to the ADAS study. However, as with the ADAS study, the boundaries of the analysis appear to be quite limited, since all studies that we are aware of that consider fate of material (in terms of recycling benefits and disposal impacts) conclude that relative to these variables, MRF energy efficiency (or otherwise) is of marginal importance in the overall analysis. In addition to the apparent narrow focus of the study, it also appears that it was assumed that glass would be collected on a separate pass from other recyclables by both kerbside sort and co-mingled systems, but that in the case of co-mingled, this would be combined with the refuse pass (by using a pod/RCV vehicle), leading to a low marginal impact of glass collection for the co-mingled option. It would seem more likely that glass would be collected on the same pass as other recyclables in the kerbside sort scenario, which would significantly reduce the relative impact of glass collection. Equally, the assumption that both the co-mingled RCV and the kerbside sort collection vehicle would have identical fuel consumption characteristics (which we consider to be unlikely) helps to explain the significant advantage that the study suggests co-mingled collection appears to offer.

The WRAP (2008) *Indicative Costs and Performance* study is a modelling-based analysis of a wide range of collection systems based on kerbside sorting and single and two-stream co-mingled collection. The study draws on analysis of material yields from WasteDataFlow data for 2005/06 and 2006/07, which is obviously somewhat out of date now. Whilst the report makes clear the limitations of this kind of generic modelling based analysis, we would make the following observations:

- The WasteDataFlow analysis leads the study to assume in the cost and performance modelling that there is no significant difference in material yield between scenarios related to whether they are based on co-mingled collection, two-stream collection or kerbside sort. Our regression analysis of more recent WasteDataFlow data suggests that collection system type is a statistically significant factor in determining performance, albeit a less significant factor than several others.
- The study treats contamination and MRF residue by way of an overall contamination rate assumption. No direct account taken for cross-contamination of target material or target material ending up in the MRF reject stream. This may have resulted in an understatement of overall material loss throughout the reprocessing chain.
- A significant contributor to the overall finding that kerbside sort is likely to result in a lower net collection cost than co-mingled options is the selection of material revenue assumptions (in the case of kerbside sort) and gate fee assumptions (in the case of co-mingled options). Although both sets of assumptions are based on credible primary research into market prices, the approach used does lead to a potential issue regarding comparability. The MRF gate fees assumed (co-mingled: £21/tonne without glass, £28/tonne with glass; two-stream: net income of £7/tonne) were derived from WRAP's annual survey of gate fees, which obtains information on contracts of various vintages (including long-term contracts) and is likely to include some gate fees for MRFs that are contracted on a very different basis to that assumed in the collection costs study (e.g. 'processing only' contracts, where material revenue stays with the council). The material revenue assumptions for kerbside sort schemes are based on data from WRAP's Materials Pricing Report (MPR) for the first quarter of 2008. It seems likely, therefore, that the gate fee data source reflected the cost of different types of contracts let at different times in the past, whereas the MPR data reflected more up-to-date market conditions, probably quite heavily driven by the spot market. In our view, evidence from more recent MRF procurements suggests that although both the material revenue and gate fee assumptions seemed relatively conservative, the gate fees used were probably a little high relative to the material values assumed. For this reason, in this study we have developed a dynamic model which takes material value assumptions (from the same database as is used for kerbside sort material values) into account in calculating the assumed MRF gate fees.

In 2009, WRAP carried out a similar study for WAG, which sought to identify the likely relative cost and performance of different collection systems in Wales. This work was coupled with a further study, commissioned by WRAP but carried out by ERM, in which the environmental costs of the same collection options were modelled. These studies together effectively constituted the first comprehensive attempt to establish the relative merits of collection systems on a financial and environmental performance basis and as such they are a forerunner of this study. In terms of results, the reports concluded that collection systems could be broadly ranked in terms of cost and environmental performance with kerbside sort the best performer, followed by two-stream collection and then single-stream co-mingled collection.

The cost and performance element of the project was based directly on the methodology used in WRAP's 2008 *Indicative Costs and Performance* study and as such has similar strengths and weaknesses, as discussed above. In the environmental modelling, key determining factors were the end destinations of some recyclables (and their relative impact in terms of recycling benefit) and the impact of disposal of residual wastes. Given the very similar capture rates assumed for kerbside sort and co-mingled systems, it could be argued that kerbside sorting was credited (quite reasonably) with generally relatively better outcomes in terms of fates of recyclables, but that co-mingled and two-stream options were not adequately credited with the decreased residual waste yields in the collection system, which could also reasonably be expected. This shortcoming is explainable by the vintage of data used in evaluating the difference in yields between schemes, the relatively unsophisticated approach used to deal with 'contamination' and the ongoing uncertainty as to the extent to which yield difference between collection systems is a real phenomenon. Another key factor in the environmental modelling related to the treatment of textiles. The assumptions used both in terms of material capture (i.e. that only kerbside sort would target textiles, which seems reasonable, but also that it would do so very successfully, which is less certain) and the relatively high benefit assumed to accrue for each tonne of textiles recycled or reused (based on a widely used data source) made a notable contribution to the overall finding that kerbside sorting resulted in significantly improved environmental benefits of recycling relative to other collection systems.

4.3 Health and Safety

The key findings identified in examining those reports relating to the potential health and safety performance of different dry recycling collection systems are discussed in this section.

4.3.1 Reports Reviewed

- Bomel (2004) *Mapping Health and Safety Standards in the UK Waste Industry,* (Sudbury Suffolk: HSE books), Report no RR240.
- Bomel (2009) *Update to Mapping Health and Safety Standards in the UK Waste Industry*, Report for HSE.
- CRN (2006) *UK Health and Safety Survey*, completed Spring 2005.
- Davis, R. Ll, Hollett, N. and Watson, H. (2006) *A Health and Safety Study of Kerbside Recycling Schemes using Boxes and Bags*, CHERE (Centre for Health and Environmental Research and Expertise) and Cylch.
- HCW Consultants (unpublished) *Box Weight Data*, Report for WRAP 2006.
- HCW Consultants (2006) *WRAP Time Study Data on Average Kerbside Recycling Weights*, Report for WRAP.
- HSE 16 (11/08) *Reducing "kerbside" glass collection noise risks in the waste and recycling industry.*
- Hoare Lea Acoustics (currently in draft) *Noise Exposure in Glass Collections for Recycling*, Report for WRAP.
- HSL (2006) *Manual Handling in Kerbside Collection and Sorting of Recyclables HSL/2006/25*, HSL, Sheffield.
- HSL (2008) *Collecting, Transfer, Treatment and Processing Household Waste and Recyclables (Research Report 609)*, Report for HSE, DEFRA, SG and WAG.
- Morris Low Associates (2010) *An Assessment of the Health and Safety Costs and Benefits of Manual vs. Automated Waste Collections with Reference to Solid Waste and Recoverable Resources Industry Injury Causation (#3726),* Report for Wasteminz Health and Safety Sector Group.
- Pinder, A. D. J. and Milnes, E. (2002) *Manual Handling in Refuse Collection:* (Sheffield: Health and Safety Laboratory), Report No. HSL Internal Report ERG/02/07.

4.3.2 Key Findings

Data from the Bomel study in 2004 and its update in 2009 relied on the Reporting of Injuries, Diseases and Dangerous Occurrences Regulations (RIDDOR) which is based on standard industry coding (SIC). It was not possible therefore to isolate accident rates for the different industries that fall under this coding, or between refuse collection and recycling operations or even between different methods of collection within these elements of the industry. The conclusions of these studies are thus limited to generic findings; for example, the accident rates for the SIC code within which waste is categorised were 4.5, 11 and 3.3 times above the national rate for overall accidents, fatal injuries and major injuries respectively. The situation is best summed up by the authors themselves: "Further work is required to survey Local Authorities in the UK to gain a better understanding of how many workers they employ in the waste sector, what those workers do and why such a large number of accidents are occurring". One could not make a persuasive case that the situation has changed since this was written.

In 2002, HSL carried out research and a literature review of manual handling in refuse collection and recommended that refuse collections should be carried out using wheeled bins rather than sacks and that this should also apply to recycling operations. However, the research only looked at one recycling operation that was using wheeled bins already and it seems that the recommendation was an extrapolation of their observations of residual waste being collected. In 2006, HSL reported on its research into manual handling in kerbside collection and sorting of recyclables to investigate musculoskeletal disorders and suggest control measures to reduce risk of occurrence. The report recommended a whole range of improvements that could be made to box and vehicle designs that designers, manufacturers and buyers should take into account under the Provision and Use of Work Equipment Regulations (PUWER) 1998.

IN 2006, HCW and WRAP compiled data on the weights of kerbside recycling boxes based on pure streams of materials in order to compare them with HSL's lab weights. It was found, unsurprisingly, that box volume is directly proportional to the weight that the box can contain and that all weights in 40, 44 and 55 litre boxes were within the 20kg filter for males, but that weights of paper and glass in 44 and 55 litre boxes were above the 13kg filter for females. In addition, WRAP asked HCW to compile data they had collected on box weights based on time study measurements (41 study days and 231 observed collection hours). This data demonstrated that mean box weight varied from 3.3kg to 10.93 kg depending upon the scheme in question, with the upper limit falling within the filters for both women and men.

In 2008, HSL investigated the collection, transfer and treatment of household waste and recyclables; an Excel tool was developed as part of this work in order that operators could make comparisons between different operational set ups and their likely health and safety performance. Comments from trial users made suggestions for improvement of the tool. The report was careful to note that the tool should not be used to 'outlaw' any particular system or for it to be used instead of risk assessment. Much of the findings in the report were suggested for adoption in future guidance for the industry.[1]

Studies from New Zealand in 2008 and 2010 seem to be the first studies that show a clear difference in health and safety statistics for different methods of collection. The data indicates that in New Zealand collections using a wheeled bin (via an automated bin collection system) are less hazardous than bag or loose collection methods. However, it is difficult to establish how this data compares to operations in Wales; the methods are not directly comparable to Wales or the UK, as automated bin collection is not common here, and there is insufficient data with which to compare operations in New Zealand with those in Wales.

In 2008 HSE published guidance which addressed the issue of noise in kerbside glass collection. This followed the identification of this issue as a problem and some consequent field work undertaken by HSL. It was found that noise levels in vehicles with side loading troughs and some stillage vehicles were very high. The guidance gave advice regarding typical anticipated noise levels for vehicle types and clarified the requirements of the "Control of Noise at Work Regulations 2005".

WRAP subsequently commissioned additional research into noise exposure when collecting glass in 21 kerbside recycling operations. The purpose of this additional work was to measure noise levels in systems not covered by the original work and to test the latest vehicle designs. Co-mingled collections were found to be at the boundary of the lower exposure action value (EAV), with co-mingled two-stream found to be slightly above this value, and the use of slave bins resulted in significant risk of exposure to the upper EAV. All stillages had the potential to exceed the upper EAV, with one significantly exceeding it. Stillages with noise reduction measures installed were within the upper and lower EAVs. As this report is still in draft form, the reader is directed to the WRAP website to await publication in 2011.

There clearly remain significant problems regarding noise for the kerbside sorting of glass using side loading troughs and older stillage vehicle designs. Newer vehicle designs have reduced noise levels but are still at or above the lower exposure action value. Rear end loading compaction vehicles used for co-mingled or two stream collections also have potential problems as does, in some cases, refuse collection. Noise remains a significant all round problem for the industry that needs to be addressed by vehicle and system design improvements.

There has been much debate in the industry about the relative merits of kerbside sort, two-stream and co-mingled collections in terms of whether one system is inherently 'safer' or 'healthier' than another. Statements that one system is safer than another are often missing the point, as a holistic approach is required when managing risks.

The question that needs to be asked is 'can the risks in any given system be managed?' This would provide a better point of view from which to assess the specific recycling system. Regardless of the operational systems that an organisation has in place, proper application of control measures required by law or provided for in

[1] *Such guidance can be found at: http://www.hse.gov.uk/waste/wish.htm*

approved codes of practice as well as industry specific guidance (such as that provided for in the WISH forum guidance) can reduce risks to levels that are acceptable in terms of being reasonably practicable (see the *Technical Annex* for further guidance on this issue).

Future studies looking at manual handling operations in waste and recycling collections should ensure that schemes are fully understood and fully described so that data can be meaningfully examined and valid conclusions can be drawn. Methodologies of sampling for such studies should be established which ensure sampling is both representative of the population and/or sub populations being sampled (i.e. of sufficient size) and that such a methodology should also describe how sampling can be shown to be random and free from intentional or unintentional bias. Future studies should seek to illustrate any causal (rather than simply correlated) connection between musculoskeletal disorders and manual handling in the different refuse and recycling operations and the effects that changes to poor practices observed in many studies can have on any such relationships. Many of the studies carried out have witnessed poor practice, but as the CHERE (2006) study (conducted on behalf of Cylch) has noted, these poor practices can be properly managed. This study sought to identify the occupational health issues for kerbside recycling schemes and concluded that there were no significant risks in using boxes and bags that could not be effectively managed and controlled.

The search for an answer to the question of whether one form of recycling is inherently safer than another in terms of manual handling remains elusive. Current UK studies do not provide sufficient detail for any valid conclusions to be reached. RIDDOR derived data is too generic to use for such comparisons and other studies suffer from limited sample sizes and do not present sufficient information for the reader to make valid comparisons with other systems. Future studies need to be more robust in the sampling of their data and in the publishing of their raw data for such work be taken as statistically significant.

4.4 Literature Review: Overall Conclusions

The most striking conclusion that can be drawn from the review of reports focused on the cost and performance issued associated with collection systems is the fact that this study appears to be the first concerted and well resourced attempt to bring all of the key issues within scope. Whilst various earlier studies have looked at a part of the jigsaw, none provides a holistic enough approach to really provide confidence that an overall conclusion can be drawn as to which (if any) collection systems could be expected to generally perform better than others. In refining the methodology used for Phases 2 and 3, we have drawn to some extent on all of the studies considered in the review, if only in some cases to identify potential pitfalls to be avoided.

Regarding the health and safety literature, the position is broadly similar, with no overall conclusions to be drawn other than that further (and perhaps more focused) research is required. Whilst it is clearly the case that health and safety performance varies between individual schemes, the data is simply not there to even begin to prove a link to different broad collection system options. However, health and safety is clearly an area where strong opinions exist on all sides of the debate. As such, given the direct duty of care that local authorities have as operators of services (and employers of operational workforces where services are delivered in-house), health and safety is likely to remain a pivotal issue in the debate until much clearer evidence becomes available.

5.0 Phase 2: Case Study Authorities

In order to inform the approach to the Wales-wide cost-benefit analysis for the different dry recycling systems, this phase of work examined in detail the waste flows from the point of collection to end destination for six case study authorities across Wales. The financial and environmental costs associated with those waste flows were then calculated to provide an overall cost-benefit analysis of each case study. In addition, appropriate metrics were also determined to compare the social aspects of the different approaches to collecting dry recyclables. The overall purpose of Phase 2 was to establish a greater understanding of the 'doorstep to end destination' flow of materials and associated costs, effectively providing 'real-life' examples to inform the modelling required for the Wales-wide Phase 3 analysis.

The six case study authorities selected to be subjects of this research were chosen based on the following criteria:

- selected authorities had to be willing volunteers, prepared to cooperate with the study and to contribute officer time to assisting with the research;

- two authorities were required to represent each dry recycling system: two kerbside sort, two two-stream and two co-mingled systems;
- ideally, the six should include two urban, two rural and two valleys authorities, to represent the differences in between authorities with regard to factors such as collection logistics; and
- ideally, no two authorities should have the same MRF arrangements (to maximise the research potential for the project regarding the ways that different MRFs operate and the financial and environmental impacts of MRF operations).

A Technical Advisory Group was established, comprising of a shortlist of potential case study authorities, alongside representatives from WAG, WRAP and the Welsh Local Government Association. The first meeting of this group considered a number of configurations of case study authorities and the following six authorities were subsequently invited to participate in the study:

- Cardiff Council;
- Gwynedd Council;
- Monmouthshire County Council;
- Newport City Council;
- Pembrokeshire County Council; and
- Rhondda Cynon Taf (RCT) County Borough Council.

5.1 Methodology

Full details of the methodology employed for Phase 2 of this study can be found in the *Technical Annex*, with the results of the case study analyses to be published in a separate report. Essentially, the approach to the case studies involved the following key steps.

Initial Site Visit
An initial site visit to each authority was undertaken to observe the flow of materials from the point of collection through the MRF and/or bulking facility, ready to be hauled to various reprocessors.

Finance and Resources Questionnaire
Each authority was requested to provide budget/financial out-turn information and data on the resources employed to deliver the core collection services (dry recycling, refuse and organic waste collections). Given the significant change in service seen in each of the case study authorities over the most recent financial out-turn period (2009/10), five of the six authorities provided their most up-to-date budgets for 2010/11 for analysis, with one authority providing their 2009/10 financial out-turns for analysis. The budgets and financial out-turns were then analysed to determine the costs of the dry recycling and residual waste collection services and to identify any limitations to the direct comparability of costs between authorities.

Financial Modelling
The cost calculations and cost apportionment methods identified above were then harmonised between services and authorities, to ensure costs were as directly comparable as possible. Refuse costs were included alongside dry recycling costs because of the related avoided disposal environmental benefits that result from increased recycling of materials. Organic costs were excluded, with appropriate adjustments made to other service provider costs where required, as not all authorities currently collect both garden and food waste, and due to the added complication of most of the case study authorities being only part way through roll-outs of separate food waste collections. The key cost elements harmonised across the authorities were:

1. The removal of any materials income associated with bring sites, except for Pembrokeshire where, unlike the other case study authorities, glass is collected in bring sites rather than at the kerbside. Costs of glass collection and the associated materials income was treated as if it formed part of the overall kerbside collection costs for Pembrokeshire.
2. The annualising of containment costs.
3. Adjustments were made where other materials are co-collected with dry recycling / residual waste.
4. Adjustments were also made to ensure that back-office costs were not included in front-line service costs.

5 MRF and bulking depot capital costs were added to the overall costs for the two authorities who had these facilities paid for by European funding.
6 Treatment and disposal costs were calculated based on the tonnage collected at kerbside and gate fees provided by each authority.

However, no adjustments were made to the materials income obtained (£ per tonne) by each authority, to variations in salaries, to facility operating costs or to variations in MRF costs (including gate fees paid). Hence the financial costs obtained must be considered in light of these variations.

Health and Safety Questionnaire
Each authority was also requested to provide data for the three year period from April 2007 to March 2010 relating to health and safety for both the collection of dry recyclables at the kerbside and the handling and sorting of dry recyclables either at a bulking depot or MRF. Data requests included information on RIDDOR reports, actual accidents and near miss reports.

Social Metrics
The social metrics to be analysed for each of the case studies were discussed with and agreed by the Technical Advisory Group. Importantly, it was noted that while the methodological approach to incorporating environmental costs and benefits using monetised damage costs in the framework of cost-benefit analysis (CBA) is well established and widely accepted, there is no such consensus on the approach to social impacts. Although data was provided on factors such as employment as part of the resource information request to each authority, analysis of the potential social impacts of the dry recycling schemes was thus undertaken separately to the CBA; as such it is presented as part of the wider overall results in Section 6.2.5, rather than as part of the Phase 2 results.

Mass Flow Modelling
Mass flow models were produced for each case study authority to demonstrate the fates determined for various material streams and to quantify the flow of materials from kerbside collection to those fates.

1 <u>Primary waste analysis:</u> sampling was undertaken at the 'back door' of three MRFs – the Cardiff MRF and the two MRFs used by Pembrokeshire County Council. Sampling was focused on those areas where the biggest gaps in information were found to exist in respect to the quality of material produced in the MRF.
2 <u>Process models:</u> a process model was derived for each MRF and bulking facility used by the case study authorities, to help determine the product streams resulting from this initial processing. These models were based on information provided by the MRFs and bulking facilities themselves, as well as that derived from the initial site visits and primary sampling of material.
3 <u>Reprocessor research:</u> for each product stream derived either through the MRF or bulking facility at each authority, we attempted to establish how the product was subsequently reprocessed up to the ultimate end destination and including any merchants or intermediate reprocessors involved along the way. As far as possible, the fate of all collected materials was established for each material, including process loss to various disposal routes. Interviews were undertaken with merchants, intermediate processors and reprocessors to inform this research. Little hard compositional data was obtained, although information was provided on material quality and established processes. Estimates of process losses were derived mainly from onward facility mass balances.
4 <u>Waste flow models:</u> We started with WasteDataFlow (WDF) tonnages for 2009/10 and then estimated the arisings of different components for each product stream through applying compositional profiles for each stream to the relevant WDF tonnage. These profiles were based on our findings from a combination of the MRF sampling in Cardiff and Pembrokeshire and from previous research. We then applied our findings from the reprocessor research to each product stream to determine the overall fate of material for each authority, including any process losses along the way. Where insufficient data was available, for example on the proportional breakdown of subcomponents (for example of different types of paper), we used reference data to address the data gaps where possible (particularly through the WR0119 Review of Municipal Waste Component Analysis project carried out for Defra).

Environmental Modelling
The climate change and air quality impacts associated with the flow of materials from each authority were calculated, with an external cost applied (in financial terms) to those impacts. The impacts of the major air pollutants – oxides of nitrogen (NOx), oxides of sulphur (SOx), particulate matter (PM) and volatile organic compounds (VOCs) – are attributed an external monetary value which measures the extent of the damage to health associated with the quantity of pollutant being released into the air. Impacts associated with the emission

of greenhouse gases are calculated on the basis of the cost of mitigating the effects of climate change. In both cases impacts can be estimated on a £ per tonne basis, with a higher figure thus representing greater damages. The methodology applied here is widely used in impact assessments carried out by UK governments.

Our methodology for assessing the environmental impacts accounts for emissions from the following:

1. Those resulting from the collection and transportation of both dry recyclate and residual waste (this includes the shipping of recyclate overseas for reprocessing).
2. Impacts associated with sorting and transfer facilities.
3. Avoided emissions resulting from the re-processing of recyclate.
4. Impacts associated with the rejected material throughout the collection, sorting and reprocessing cycle.
5. Impacts associated with the treatment and disposal of residual waste. This includes a consideration of avoided emissions resulting from the generation of energy by incineration facilities.

Cost-Benefit Analysis

In order to undertake a cost-benefit analysis for each case study authority, the external cost associated with the environmental impact of each system was then combined together with the financial cost of operating that service. The overall output of the process provides a total net financial plus environmental cost of the service, as well as a cost per household and a cost per tonne of dry recycling collected.

Health and Safety

Each of the case study authorities provided data relating to health and safety for both the collection of dry recyclables at the kerbside and the handling and sorting of dry recyclables either at a bulking depot or MRF. Details of the data provided can be found in the *Technical Annex*.

5.2 Case Studies: Overall Conclusions

A separate, stand-alone report will be published setting out the results of the analysis of the six case study authorities. For the purposes of this report, we can conclude that examining the six case study authorities in detail has enabled us to gain insight into:

- the flow of dry recycling materials and the associated environmental costs from the point of collection through to the end destination in six Welsh authorities; and
- the financial costs for the initial collection and sorting of those dry recycling.

Much of this information has been used directly to inform the assumptions made in the Phase 3 modelling, especially that relating to the fate of material. However, as anticipated at the start of the project, the Phase 2 research was not well suited to drawing conclusions regarding the relative performance of collection systems overall. There are a number of obvious reasons for this.

Firstly, it is important to recognise that the six case studies undertaken relate to six very different authorities; they cover urban, rural and valleys areas, provide different dry recycling collection systems, have varied residual waste and organic waste collection systems, and approach resourcing in different ways in order to deliver their front-line services. Alongside the key variations in urban-rural classification and dry recycling collection system employed, the case studies comprise three weekly and three fortnightly residual waste systems (using a combination of sacks and wheeled bins), as well as a number of organic waste collection configurations. Several of the authorities share vehicles and crew between service areas, whereas others operate the services separately, and Newport alone provides its dry recycling service through a contractor.

In addition, a key observation derived from our initial visits and information requests was that the two-stream case study examples are not what would be considered conventional two-stream collection systems. The systems in Monmouthshire and RCT might be considered two-stream from a resident's perspective, as they are asked place fibres in one bag and containers in another bag. However, when collected, the two streams of waste are then co-mingled in the back of a single chamber RCV and are taken to a single-stream MRF for sorting. In addition, in RCT the dry recycling waste is also co-collected with garden waste, adding a further departure from the conventional two-stream system, and increased potential contamination in the MRF system for RCT.

Although the costs for collection and sorting of dry recycling were found to vary quite significantly between the case studies, this variation could not be attributed to variation in collection system type. The urban authorities were found to have the lowest collection costs, probably driven in part by the collection frequency for Cardiff, with this being the only authority not to collect dry recycling on a weekly basis. A number of additional factors also made it difficult to directly compare system costs, including variations in materials income received, MRF gate fees or operating costs incurred, unit labour cost variations and relative efficiency of collection services.

Regarding the environmental performance of the dry recycling systems, there was again no apparent pattern in greenhouse gas or air quality emissions according to the collection system employed. Each case study authority scheme will be likely to include a number of sub-optimal components, including those relating to collection productivity (related in part to technology) and the fate of materials, making them difficult to compare. The benefits of dry recycling outweighed any increase in emissions resulting from the collection and processing of dry recycling material, and it is this which most significantly influenced overall environmental performance of the dry recycling system.

There was less variation in financial costs for the residual waste system, with cost differences driven primarily by disposal costs incurred rather than by differences in collection costs. Differences in the overall environmental performance of the combined dry recycling and residual waste collections were primarily driven by the impacts associated with disposing of residual waste; therefore, those authorities that collected more residual waste per household were the worst overall environmental performers.

It was also difficult to draw any conclusions in relation to differential health and safety performance of the different dry recycling systems from the data obtained from the authorities. Given that health and safety data is only reported at a high level for most authorities, and is primarily based on RIDDOR sub-coding, data on the differences between methods will be likely to remain elusive.

The work undertaken in Phase 2 thus illustrates the limitations in comparing dry recycling systems employed by a small sample of real authorities. Although it provides insight into some of the factors that may be driving the overall differential in financial and environmental costs, it is difficult to unpick local differences such as productivity levels, salaries, gate fees paid, and whether materials are going to the optimal end destination, from any cost differential that might be associated with the dry recycling system *per se.* Hence, it is not surprising that no meaningful pattern has emerged as to which is the highest performing collection system. Nonetheless, Phase 2 did provide both data and qualitative information that were invaluable in modelling the all-Wales waste flows for Phase 3, and the general logistics involved in operating services for urban, rural and valleys authorities formed a basis from which the Phase 3 financial and environmental performance have subsequently been determined.

6.0 Phase 3: All-Wales Models

In order to inform the debate that is taking place around the Welsh Assembly Government's interest in moving towards a more harmonised approach to kerbside dry recycling collections across Wales, the remaining part of this study looked at how the three dry recycling collection systems (kerbside sort, two-stream and co-mingled) might be expected to perform if they were rolled out across all 22 local authorities in Wales. Essentially, this involved undertaking a series of modelling exercises, based on WasteDataFlow data for each authority and shaped according to the findings from the Phase 2 case studies and other reference data where applicable. The financial and environmental costs of each system were then calculated based on the mass flows for each authority. Modelling the costs and benefits associated with three harmonised Wales-wide collection systems enabled clear differentiation between the impacts of the different systems.

Two scenarios were considered as part of the Wales-wide cost-benefit analysis of the three dry recycling systems:

- **current performance model**: the collection method is 'switched' at the current level of recycling performance being achieved by each authority across Wales. Local authorities remain on their current recycling and residual waste collection frequencies and simply switch dry recycling collection system type where the system in question is not the current system used by the authority to deliver their dry recycling service; and
- **enhanced performance model**: the collection method is switched at enhanced recycling performance levels, in the context of authorities in Wales meeting the Towards Zero Waste (TZW) 70% recycling target. All authorities are modelled as providing weekly recycling collections and fortnightly residual waste collections,

with performance sufficient to achieve the 70% recycling target once other waste streams are taken into account.

6.1 Methodology

This section summarises the methodology that has been used to determine the potential financial, environmental and social impacts associated with implementing a Wales-wide kerbside sort, two-stream or co-mingled dry recycling collection system:

- It first describes how the waste flows were derived for each authority across Wales, followed by the modelling applied to determine the financial and environmental impacts associated with each collection system. In contrast to the Phase 2 work, all parts of the kerbside collection system were included in Phase 3 (i.e. residual waste, dry recycling and organic waste collections). Organic waste collections will be particularly important in the context of the enhanced performance model and meeting the 70% recycling target.
- It then describes the financial and environmental cost modelling used to determine the overall costs and benefits associated with each scenario and each dry recycling system. Supporting details of the methodology employed for Phase 3 can be found in the *Technical Annex*.

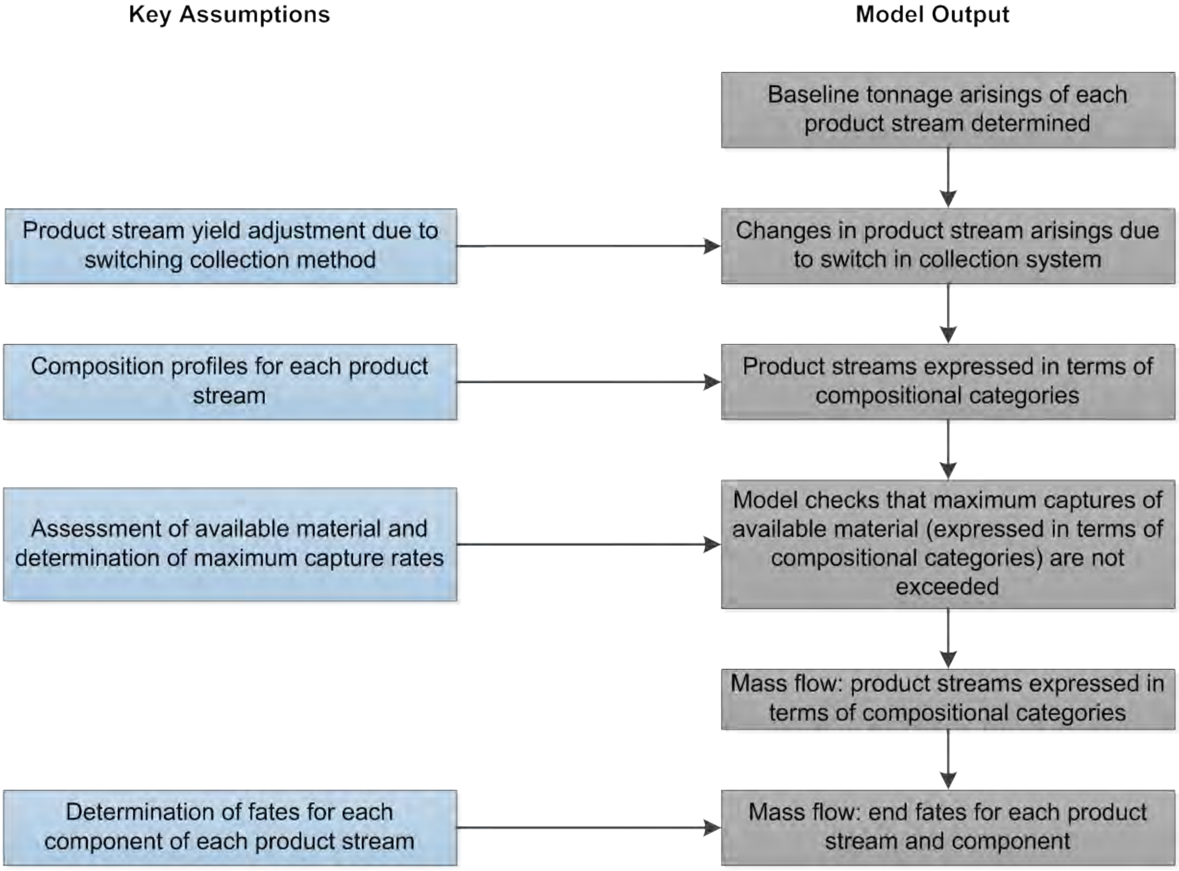
It should be noted that the social impacts associated with the three dry recycling systems are not as amenable to inclusion within a monetised approach, and there is currently no consensus on the approach to modelling social impacts in the framework of cost-benefit analysis. As such, social impacts are discussed separately to the cost-benefit analysis outputs from Phase 3, drawing data from the modelling where applicable.

6.1.1 Waste Flow Models

For Phase 3 of the project the flows of materials in kerbside collection systems were modelled across all authorities in Wales. The purpose of the modelling was to predict the waste flows that would occur if all authorities in Wales were to switch to a particular collection method, i.e. kerbside sort, co-mingled or two-stream. The mass flow modelling methodology and the key assumptions applied are described in greater detail in the *Technical Annex*.

Two sets of mass flows were modelled – one for the current performance scenario and one for the enhanced performance scenario. There are many common elements for each of these modelling exercises. The general approach is illustrated in Figure 3.

Figure 3: General Structure of the Phase 3 Mass Flow Models.



The implication of this approach is that the composition of the kerbside dry recycling bin is inferred from the composition of various product streams. The compositional profiles of product streams have been largely determined from analyses carried out at sorting depots or MRFs, as obtained or referenced in Phase 2 of this project. This approach has been taken because these compositional profiles (of product streams at the sorting depot or MRF stage) provide by far the best data available for Welsh authorities.

It is known from evidence on the characteristics of collection systems that yields tend to vary for kerbside sort and co-mingled systems. In view of this, the waste flow models perform an adjustment where an authority switches between kerbside sort and co-mingled collection methods. The net result of applying this approach is that kerbside sort systems achieve lower yields, but the concentration of non-target material set out by the householder is also lower in comparison to co-mingled collection systems. The yield adjustments and the evidence base for these adjustments are discussed in detail in the *Technical Annex*.

Having determined the tonnage arisings of product streams for each authority (with the product streams recalculated if that authority has experienced a switch, for example from kerbside sort to single stream co-mingled), the model then calculates the composition (by material) of each of the product streams. For example, we have a product stream called "News and Pams", but from fieldwork carried out during Phase 2 of this project, and other evidence, we know that this stream does not consist of only newspapers and magazines, and that other materials can be expected to arise within that stream. Therefore composition profiles are applied to each product stream, in order to express the arisings of various components according to the compositional categories used in this study.

Since the model predicts changes in material flows for switches between collection systems, it is necessary for the model to check that the new mass flows after switches do not exceed the material available within the kerbside system. The model makes any adjustments required within the waste flows for each authority to ensure that capture rates do not exceed the realistically available material.

The model then produces mass flows for the end fates of each material. The fate of each component within each product stream has been separately determined within the model. The list of fates included in the model is based on the findings of the Phase 2 research and is as follows:

- recycling (with different types of recycling considered for some materials, i.e. for fibre the fates *Newsprint*, *Soft Mix* and *OCC Packaging* are included);

- landfill;
- energy from waste incineration; and
- combustion without energy recovery (i.e. combustible materials burnt off during metal smelting processes, with no energy recovery attempted in the process).

Key assumptions underpinning the mass flow models are described in the *Technical Annex*.

6.1.2 Cost Models

This section summarises the approach taken to establishing the costs associated with both the collection and treatment of waste for the two scenarios and across the three dry recycling collection system options.

6.1.2.1 Collection Cost Model

Eunomia's proprietary waste collection model, Hermes, has been used to investigate the cost of different collection options for all authorities in Wales. Hermes is a sophisticated spreadsheet-based model that allows a wide range of authority-specific and collection-specific variables to be modelled. The optimisation of these variables allows us to build scenarios to accurately reflect local circumstances. The main output of the model is the collection cost and in this case also the quantity of fuel used, which provides an input for the subsequent environmental modelling (Section 6.2.2) and cost-benefit (Section 6.2.3) analyses. The specific details of how Hermes works and the assumptions made are summarised in the *Technical Annex*.

In order to calibrate the model to the local collection dynamics, the approach firstly required that the resources and logistics involved in the existing services be captured as accurately as possible within a 'baseline' model. As well as ensuring that the model is representative of the local collection characteristics, this provides a foundation upon which alternative options are built and evaluated. Under each future scenario, the model subsequently calculates the staffing and vehicle requirements.

The key reason for modelling a baseline in this project was to establish geographical descriptors to calculate the resource requirements for each authority in the future options. The important descriptors are:

- time and distance between rounds and depots
- time and distance between rounds and tips
- time at the tip
- time and distance between tips and depots
- time and distance spent driving forward (i.e. between houses) whilst on the collection round

Three of the case study authorities were used as 'baseline authorities', representing the three authority types:

1. Newport for urban authorities;
2. Pembrokeshire for rural authorities; and
3. RCT for valley authorities.

All services currently provided by these three authorities were modelled (i.e. recycling, residual, food and garden where applicable). The resulting numbers of vehicles, miles driven per year, and collection costs were a good match with the financial data provided by these three authorities. We are therefore confident that the geographical descriptors in the model broadly reflect the current circumstances in Wales, and these have been used in the two modelling scenarios discussed below.

All 22 Welsh authorities were classified and modelled according to their authority type (urban, rural and valley), as well as their dry recycling collection system (kerbside sort, co-mingled and two-stream). In both the modelling scenarios, the authority geography was based on the timing assumptions for the three (valley, rural and urban) baseline models, and mass flows were taken from the kerbside mass flow modelling (Section 6.1.1). The collection modelling for these two options provides a collection cost per household, which is then multiplied by the number of households in each authority and summed to give a total cost for Wales.

Current Performance Collection Model

To model the cost of waste collection in Wales at current recycling rates, authorities were grouped together based on their authority type, their dry recycling system and their current recycling and residual frequencies. For example, the group of valley authorities with weekly two-stream recycling and weekly residual collections contains two authorities: Merthyr Tydfil and RCT. All modelling groups are listed in Table 1.

In order to ensure that all switches that occur in the modelling scenarios are covered, Table 1 contains some groups where no authorities currently provide that collection service. For example, no valley authority currently collects both co-mingled recycling and residual waste weekly. However, this group is still modelled, because in the current performance model when all of Wales switches to co-mingled, Neath Port Talbot, Merthyr Tydfil and RCT will move into this group. The result is 24 models to represent the three collection systems for all 22 authorities.

Table 1: Current Recycling Systems Operated by Authorities in Wales

Authority Type	Recycling		Residual	Authorities
	System	Frequency	Frequency	
Valleys	Kerbside Sort	Weekly	Weekly	Neath Port Talbot
			Fortnightly	Bridgend, Torfaen
	Two-Stream	Weekly	Weekly	Merthyr Tydfil, RCT
			Fortnightly	Blaenau Gwent
	Co-mingled	Weekly	Weekly	None
			Fortnightly	Caerphilly
Rural	Kerbside Sort	Weekly	Weekly	None
			Fortnightly	Gwynedd, Anglesey
		Fortnightly	Fortnightly	The Vale of Glamorgan, Conwy
	Two-Stream	Weekly	Weekly	Monmouthshire, Powys
			Fortnightly	None
		Fortnightly	Fortnightly	None
	Co-mingled	Weekly	Weekly	Pembrokeshire
			Fortnightly	Ceredigion
		Fortnightly	Fortnightly	Carmarthenshire, Denbighshire
Urban	Kerbside Sort	Weekly	Fortnightly	Newport, Wrexham
		Fortnightly	Weekly	Flintshire
			Fortnightly	None
	Two-Stream	Weekly	Fortnightly	None
		Fortnightly	Weekly	None
			Fortnightly	Swansea
	Co-mingled	Weekly	Fortnightly	None
		Fortnightly	Weekly	Cardiff
			Fortnightly	None

Details of the assumptions applied for containment, vehicles and crew are all provided in the *Technical Annex*. In general, kerbside sort systems were modelled as having boxes and re-usable sacks for containment, with collection on a stillage vehicle. Co-mingled and two-stream systems were both modelled as having single-use sacks for containment, and with collections on RCVs and split-back RCVs respectively.

In the current performance model, the collection of garden and food waste is dealt with outside of the Hermes model in order to better tailor the service to what is being provided in each authority.

Enhanced Performance Collection Model

To model the future cost of waste collection in Wales at enhanced recycling rates, authorities were grouped together based on their authority type (valley, rural and urban) and their dry recycling system (kerbside sort, two-stream and co-mingled), resulting in nine collection models. In the enhanced performance model, food waste is collected weekly on the same pass as the dry recycling for all three dry recycling systems, and the residual waste and the garden waste service are each modelled on a separate pass.

6.1.2.2 Other Cost Modelling

Residual and organic waste treatment costs are shown in Table 2. The costs were developed in previous modelling carried out for the WAG by Eunomia.[2]

Table 2: Residual and Organic Waste Treatment and Disposal Costs

	Financial cost of waste treatment, £ / tonne
Landfill (including tax)	£88.68
Incineration – electricity only (used in current performance)	£92.80
Incineration – CHP (used in enhanced performance)	£116.51
Windrow composting	£21.31
In-vessel composting	£42.92
Anaerobic digestion (with CHP)	£59.61
Notes 1. Costs are presented in real terms.	

MRF processing costs and kerbside sort depot costs have been calculated using individual facility models. The material income for all collection systems has been calculated using unit values that are predominately based on a two-year average from WRAP's Material Pricing Report (MPR). These values are multiplied by the product streams predicted from the material mass flow modelling and then are divided by the total dry recycling material collected to give a net basket value. The net basket value includes disposal of MRF rejects. The impact of the MRF processing costs and material incomes is shown in the tables below.

Table 3: MRF Processing Costs and Material Incomes (Current Performance Scenario)

	Sorting Cost Per Tonne	**Material Income (Net Basket Value/Tonne)**	**Inferred Gate Fee**
Co-mingled	£78.03	£51.64	£26.96
Two Stream	£63.67	£59.69	£5.43

Table 4: MRF Processing Costs and Material Incomes (Enhanced Performance Scenario)

	Sorting Cost Per Tonne	**Material Income (Net Basket Value/Tonne)**	**Inferred Gate Fee**
Co-mingled	£84.78	£72.14	£16.60
Two Stream	£64.19	£65.28	-£8.77

Table 5: Sorting and Bulking Costs (Kerbside Sort)

	Sorting Cost Per Tonne (Current)	**Sorting Cost Per Tonne (Enhanced)**	**Material Income (Net Basket Value/Tonne)**
Plastics and cans	£143.59	£67.67	£73.66
Other dry recyclables	£15.45	£11.58	£89.19

6.1.3 Environmental Model

Our methodology for assessing the environmental impacts accounts for emissions from the following:

- Those resulting from the collection and transportation of both dry recyclate and residual waste (this includes the shipping of recyclate overseas for reprocessing).

[2] *Eunomia (2009) Environmental Performance and Cost Effectiveness of Residual Waste Treatment Technologies, Report for the Welsh Assembly Government, February 2009*

- Impacts associated with sorting and transfer facilities.
- Avoided emissions resulting from the reprocessing of recyclate.
- Impacts associated with the rejected material throughout the collection, sorting and reprocessing cycle.
- Impacts associated with the collection and treatment of source-separated organic wastes[3].
- Impacts associated with the treatment and disposal of residual waste. This includes a consideration of avoided emissions resulting from the generation of energy by incineration facilities.

The model structure is presented diagrammatically in Figure 4.

Environmental impacts were based on those associated with air pollution only – impacts to soil and water were not considered. The impacts associated with air pollution are much better understood than those of soil and water pollution. Climate change impacts were monetised using the methodology recently developed by the UK Government in the central case. The methodology is summarised in Table 6. Sensitivity analysis subsequently considered the application of a single value for the carbon impacts in line with other approaches used elsewhere in Europe – this approach applies a cost of £28 per tonne for all carbon emissions irrespective of their source.

Table 6: Valuation of Climate Change Impacts – UK Government Methodology (June 2010)

Description		Impact, £ per tonne CO_2	
		Current (2010)	Enhanced (2020)
Traded	Emissions covered by the EU-ETS – principally electricity generation and large industrial facilities. Also includes overseas manufacturing and re-processing facilities (i.e. including the benefits from recycling).[1]	£14	£16
Non-traded	All other emissions	£52	£59
Notes 1. This aspect of the methodology differs from earlier versions of the guidance where benefits from recycling were monetised using the shadow price of carbon (valued in 2009 at £28).			

Source: DECC (2009) Carbon Valuation in UK Policy Appraisal: A Revised Approach. Climate Change Economics, Department of Energy and Climate Change, July 2009

For the climate change impacts we considered results both excluding and including the biogenic CO_2 emissions. Whilst the exclusion of the biogenic CO_2 impacts is typical when a lifecycle assessment (LCA) approach is taken in this type of analysis, analyses undertaken using the cost-benefit framework typically include these emissions. We present results excluding the biogenic CO_2 in the central case, with sensitivity analysis undertaken to consider any variation in the results that would occur as a consequence of the inclusion of this impact. The rationale for the inclusion of these impacts is discussed in more detail in the *Technical Annex*. Air pollution impacts were monetised using the UK-specific damage costs taken from the Clean Air for Europe (CAFE) programme.[4] The dataset includes both the impact of pollution originating in the UK on European air quality as well as damage costs for pollution occurring in the oceans – this is required when considering emissions associated with shipping recyclate overseas.

The following impacts were assumed to be associated with the intermediate facilities used to treat the recyclate collected at the kerbside prior to subsequent reprocessing:

- we assumed energy use at the MRF to be 35 kWh of electricity per tonne of material treated and 2 litres of diesel per tonne; and

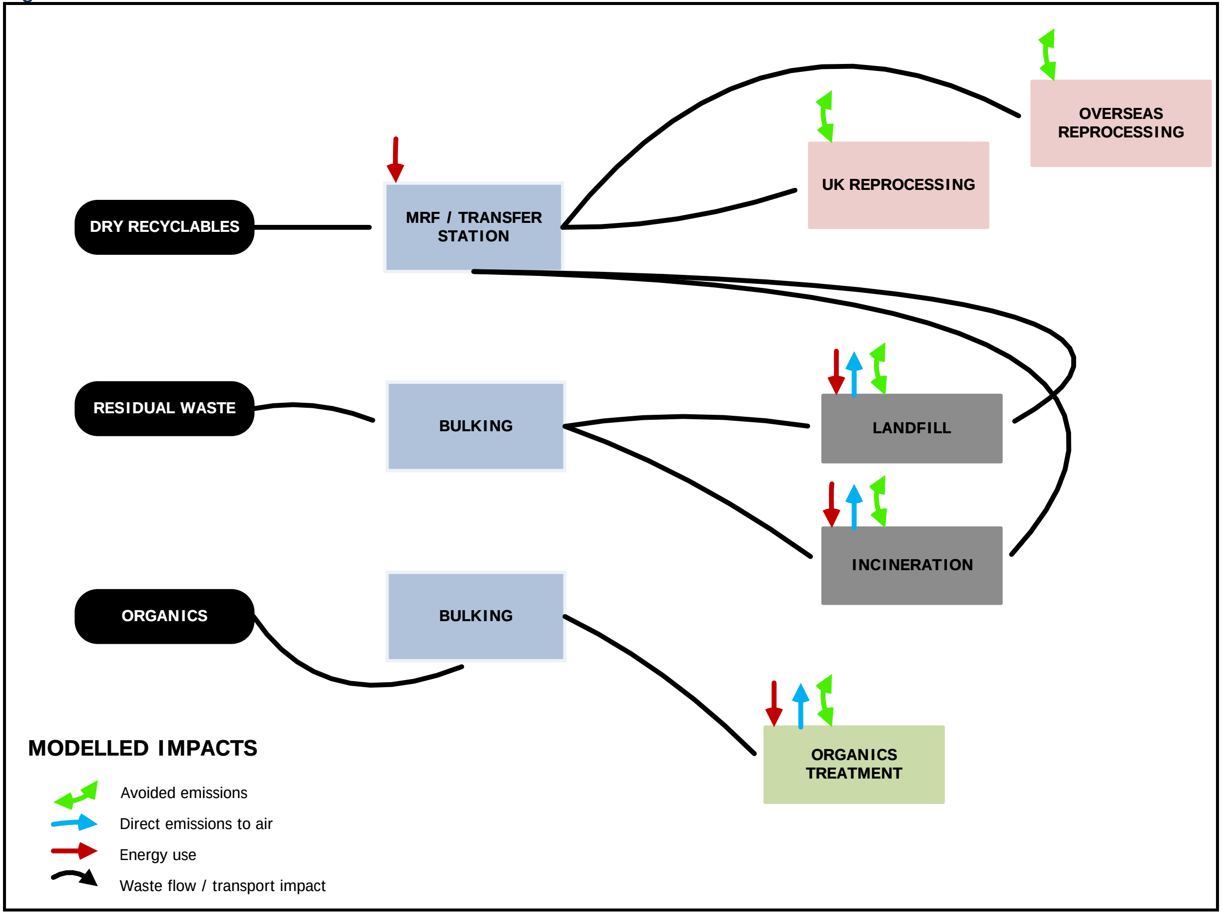
[3] *These impacts were excluded in Phase 2 of the study as most of the case study authorities are currently part way through rollouts of separate food waste collections.*

[4] *M. Holland and P. Watkiss (2002)* Benefits Table Database: Estimates of the Marginal External Costs of Air Pollution in Europe, *Database Prepared for European Commission DG Environment; AEAT Environment (2005)* Damages per tonne Emission of $PM_{2.5}$, NH_3, SO_2, NO_x and VOCs from Each EU25 Member State (excluding Cyprus) and Surrounding Seas, *Report to DG Environment of the European Commission, March 2005*

- energy requirements for the treatment of recyclate at a transfer station were assumed to be 4 kWh of electricity and 1 litre of diesel.

In both cases our estimates have been developed based on data provided by currently operating facilities obtained through the course of this project, and supplemented, in the case of the MRF data, by that available within WRATE. In the current performance scenarios, emissions associated with waste collection were modelled assuming that vehicles achieve the Euro 4 emissions standard; where the enhanced performance scenarios were concerned, vehicles were assumed to meet the Euro 5 standard.[5] Emissions associated with shipping were modelled based on data provided by Maersk.[6]

Figure 4: Structure of the Environmental Model



The environmental benefits associated with reprocessing the recycled material were largely based on data provided by WRATE, as no better data could be obtained through the reprocessors contacted as part of Phase 2 of the study. A number of other literature sources exist aside from WRATE, but in many cases the underlying data contained within them is less recent and is not necessarily appropriate to current practices occurring in Wales. It is acknowledged however that considerable uncertainty surrounds the calculation of these benefits, and that it is an area where more primary research is required. This is discussed in more detail in the *Technical Annex*. Although WRATE provides data on both the climate change and air quality impacts associated with recycling, our model considers only the impacts associated with climate change, as the impacts on air quality (both positive and negative) are likely to happen outside Wales in many cases.

Impacts associated with the treatment of source-separated organic material were modelled using Eunomia's in-house model, originally developed for WRAP in 2006 and recently revised as part of work undertaken on behalf of the European Commission in 2009.[7] Residual waste impacts were similarly modelled using Eunomia's in-house

[5] *See http://www.dieselnet.com/standards/eu/hd.php*

[6] *Maersk Line (2007) Constant Care for the Environment*

[7] *Eunomia / Arcadis (2009) Assessment of the Options to Improve the Management of Bio-waste in the European Union, Final Report to European Commission DG Environment, November 2009*

model which considers impacts associated with both landfill and incineration facilities. Similar impacts were also attributed to the material that results from process loss through the recycling systems, based on the mass flow model outlined in Section 6.1.1. In all cases impacts were attributed on a tonnage basis for each of the compositional categories previously described in Section 6.1.1. The proportion of the residual waste stream sent to incineration in the current scenarios is 18%. In the future scenarios, however, the proportion rises to 95%, in line with the WAG's future waste treatment strategy.

The part of the model used to determine the impacts associated with the landfilling of material has been developed by Eunomia over many years using data from a wide range of sources, including both peer reviewed literature sources as well as data from regulators and site operators where appropriate. The most recent version of the model has been informed by a project carried out by Eunomia in association with Hans Oonk (a former advisor to the IPCC) that offered recommendations to Defra with regard to improvements that might be made to the MelMod landfill model which is used for the UK's annual submission to the IPCC.[8]

Eunomia's model of the behaviour of landfill assumes a more substantial environmental impact associated with the landfilling of residual waste than many other similar models, such as GasSim (the model used to assess the impact of landfill in WRATE) or MelMod for two principal reasons:

- Eunomia's model assumes that a greater degradation of the material occurs as the decay of the non-cellulose and lignin fractions – fats, proteins and sugars – is also included. Much of the impact of landfill in the other models is based on the behaviour of paper products in landfill, which have been much more widely studied than other waste components such as food waste. However food waste, in particular, accounts for a significant proportion of the UK residual waste stream, and also contains significant quantities of the three readily degradable elements previously indicated. Methane emissions from landfill are therefore higher where the behaviour of these additional elements of the residual stream is taken into account – as is the case in our model.
- We assume a landfill gas capture rate of 50% over the lifetime of the landfill, which is assumed to be 150 years. We further assume that more of the gas escapes during the initial years after the material is landfilled, as the landfill cells will not be permanently covered at this stage, and that less escapes once the permanent cover has been applied (thereby further increasing the impact associated with landfilling the more readily degradable materials such as food waste). In contrast, GasSim and MelMod both assume that the capture of landfill gas over the lifetime of the landfill is 75%.

The residual waste model uses differing assumptions for the performance of incineration facilities for the different scenarios considered in the analysis with respect to their energy generation:

- For the current scenarios, we assumed the same performance as used in the Phase 2 models, i.e., facilities were assumed to generate only electricity at a gross generation efficiency of 24%. This assumption is based on a review of the recently published annual reports of 15 UK facilities, with the assumption being at the upper end of the range of efficiencies indicated by the reports for facilities generating only electricity;[9]
- For the enhanced scenarios, we assumed that facilities operate in CHP mode, generating both electricity and heat at efficiencies of 13% and 47% respectively, in line with the aspirational generation efficiencies recently indicated by WAG for future energy from waste facilities.[10]

In both cases, we have assumed that the electricity generated by incinerators offsets the production of electricity that would otherwise have been generated using combined cycle gas turbine (CCGT) plant in line with UK

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[8] Eunomia (2010) Inventory Improvement Project – UK Landfill Methane Emissions Model, Report to Defra (as yet unpublished)

[9] Reports available from http://www.ukwin.org.uk

[10] This requires facilities to reach a total system generation efficiency of 60% where both heat and electricity efficiencies are combined (efficiencies are expressed as a ratio of usable energy out / total energy in). The efficiency of electricity generation is in this case un-weighted when the two are taken together – this differs from the Recovery formula proposed in Schedule 1 to the Revised EU Waste Framework Directive where the electricity generation efficiencies are weighted. Our assumptions are in line with those proposed in the recent technical feasibility assessment undertaken on behalf of WAG – see: AEA (2009) Modelling of Impacts for Selected Residual Waste Plant Options Using WRATE, Final Report for WAG, September 2009

government guidance.[11] Where heat generation is concerned, this has been assumed to offset that from industrial and domestic gas boilers. Our model considers both the climate change and air quality impacts associated with this avoided generation based on data from the ecoinvent database.[12]

In the case of the direct air quality impacts, we assumed that the incinerators meet the requirements of the Waste Incineration Directive (WID) with respect to the pollution abatement equipment installed. Where damage costs have been used to assess the air quality impacts, much of the impact is associated with emissions of oxides of nitrogen (NOx). All UK facilities abate this type of impact through the use of Selective Non-Catalytic Reduction techniques, which allow the facility to meet the requirements of the WID, but not to significantly exceed them.

6.1.4 Cost-Benefit Analysis

As was the case with the Phase 2 assessments, the methodology used within our assessment of the performance of each recycling, organic waste and residual waste collection / treatment system combined the external cost associated with the environmental impact of each system together with the financial cost of operating that service. In economics, an external cost – also known as an externality – arises when the social or economic activities of one group of persons has an impact on another group and when that impact is not fully accounted for or compensated for (in financial terms), by the first group.

Particularly in the case of waste treatment facilities, our experience indicates that it is the climate change and local health impacts of these plant that cause most concern for local residents and the wider community. Eunomia's preferred approach is therefore to apply monetary values or external costs to both the climate change and air quality impacts.

As with the Phase 2 cost-benefit analysis, the impacts of the major air pollutants have been attributed an external monetary value which measures the extent of the damage to health associated with the quantity of pollutant being released into the air. Impacts associated with the emission of greenhouse gases were calculated on the basis of the cost of mitigating the effects of climate change. Air quality impacts were calculated based on the external costs of key air pollutants known to have a local or regional impact.[13] In both cases impacts were estimated on a £ per tonne basis, with a higher figure thus representing greater damages. The methodology described is widely used in impact assessments carried out by UK governments.

With regard to the financial costs, we excluded both the impact of fuel duty and landfill tax from the final totals that combine the financial and environmental costs. The duty and the tax are intended to offset some or all of the environmental impact associated with the pollution from road transport and landfilling waste. Both types of pollution were separately accounted for in the consideration of environmental damages; thus the duty and the tax are excluded from the financial costs to avoid double-counting this part of the impact.

Sensitivity analysis was also undertaken to consider the impact of the following modified assumptions on the results:

- the inclusion of the biogenic CO_2 emissions in our assessment of the environmental impacts – in the central case, these were excluded from the analysis, as is typically the case where a life-cycle assessment approach is employed;
- the application of a single value when monetising the climate change impacts in the cost-benefit assessment, as opposed to the two-tiered approach currently recommended by the UK Government in this type of analysis; and;
- the application of a higher MRF gate fee under the enhanced performance scenarios.

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[11] See, for example: DECC (2009) Carbon Valuation in UK Policy Appraisal: A Revised Approach. Climate Change Economics, Department of Energy and Climate Change, July 2009

[12] Available from http://ecoinvent.ch

[13] These external costs include those associated with days lost to ill-health, and costs resulting from hospital admissions, etc.

6.2 Results

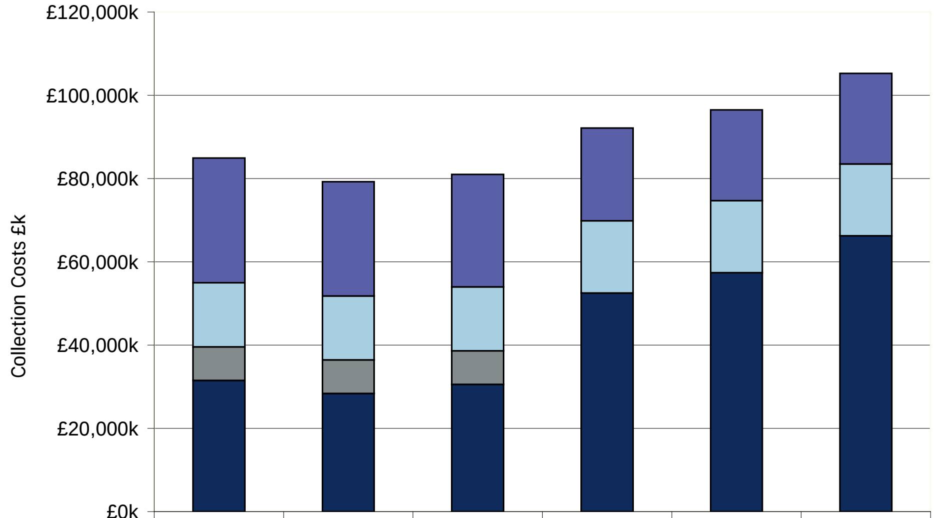
This section presents the results from the Phase 3 modelling which looked at how the three dry recycling collection systems (kerbside sort, two-stream and co-mingled) might be expected to perform if they were rolled out across all 22 local authorities in Wales. The results are presented for both the current performance scenario, which is based on current tonnages of dry recycling, organics and residual waste collected in each authority, and the enhanced scenario, where the recycling performance is sufficient to achieve the 70% recycling target.

6.2.1 Financial Performance

The modelled collection costs for all passes are presented in Figure 5, and are shown net of material income and MRF/depot processing costs in Figure 6. The following should be noted when examining the results:

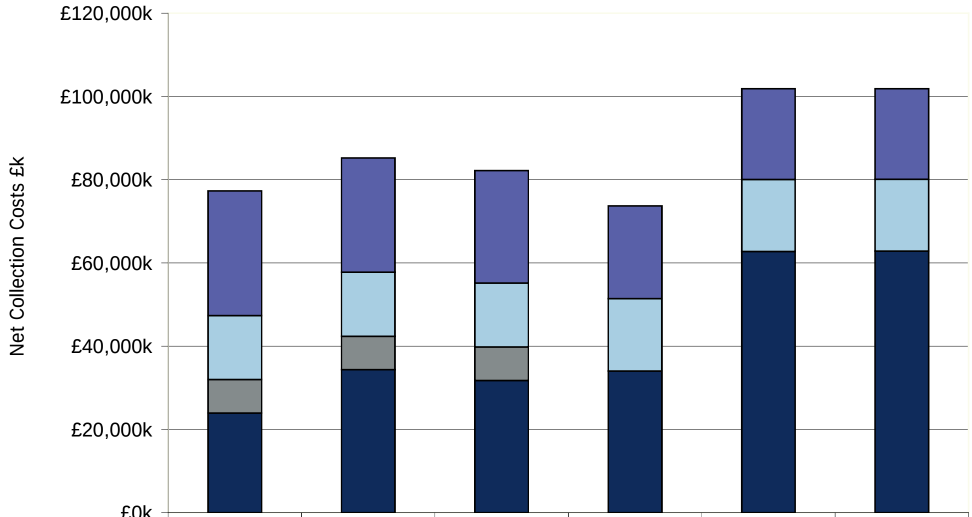
- dry recycling collection costs are very similar between co-mingled and two-stream systems in the current performance model. This is due to loading times and set-out rates being assumed to be the same and because, with captures of material being low relative to the enhanced performance scenario, vehicle payload and volume constraint is also a relatively insignificant factor;
- without taking into account material income and processing costs, the dry recycling collection costs for kerbside sort are higher than the other systems in the current performance model, reflecting the larger numbers of vehicles and collection staff required for this system. However, in the enhanced performance model, the cost of collection in the two-stream system is higher than the other two collection systems. This is primarily due to productivity being reduced in the two-stream option due to capacity issues with the three compartment "one pass" RCVs required to collect two dry recycling streams and food waste;
- when including material income and processing costs, kerbside sort becomes significantly cheaper than the co-mingled and two-stream options, particularly in the enhanced model. Processing costs are significantly lower in the kerbside sort option and this option does not produce some of the lower quality product streams which attract lower material values, hence the overall income is also higher for the kerbside sort system than the other two collection systems;
- dry recycling collection costs increase with all collection systems for the enhanced performance model when compared to the current performance model. This is partly due to the inclusion of weekly food waste collections (which are included as 'recycling costs', as food waste is assumed to be collected on the same pass as dry recyclables), but is also due to higher levels of participation, set-out and substantially higher levels of material capture; and
- when compared to the current performance model, the refuse collection costs in the enhanced performance model are substantially lower; this is mostly reflecting the switch by some authorities to fortnightly collections and to a lesser extent the lower volumes of refuse being set-out.

Figure 5: Collection Costs for All Authorities (excluding material income and MRF/depot processing costs)



	CURRENT KS	CURRENT COM	CURRENT 2 S	ENHANCED KS	ENHANCED COM	ENHANCED 2 S
Residual	£29,952,010	£27,456,721	£27,003,904	£22,268,927	£21,811,830	£21,753,101
Garden waste	£15,380,473	£15,380,473	£15,380,473	£17,371,796	£17,274,152	£17,230,842
Food waste (current)	£8,036,256	£8,036,256	£8,036,256	£0	£0	£0
Dry recycling (& food in enhanced)	£31,537,262	£28,387,698	£30,573,762	£52,488,713	£57,396,902	£66,279,063

Figure 6: Collection Costs Net of Material Income and Processing Costs



	CURRENT KS	CURRENT COM	CURRENT 2 S	ENHANCED KS	ENHANCED COM	ENHANCED 2 S
Residual	£29,952,010	£27,456,721	£27,003,904	£22,268,927	£21,811,830	£21,753,101
Garden waste	£15,380,473	£15,380,473	£15,380,473	£17,371,796	£17,274,152	£17,230,842
Food waste (current)	£8,036,256	£8,036,256	£8,036,256	£0	£0	£0
Dry recycling (& food in enhanced)	£23,947,552	£34,350,966	£31,762,047	£34,050,572	£62,767,555	£62,866,873

Table 7 provides a breakdown of the overall financial cost of each option, including treatment costs for each waste stream. These costs are presented prior to their adjustment for landfill tax and fuel duty and are therefore higher than the costs that form part of the combined results in Section 6.2.3.

The table confirms that residual collection and treatment costs are highest for the kerbside sort system and lowest for the two-stream system under both current and enhanced recycling performance. However, the cost of providing the recycling collection and treatment services is considerably lower for the kerbside sort system, resulting in a lower overall financial cost for this option. Although the amount of residual waste reduces significantly in the enhanced scenarios, the corresponding decrease in the financial costs associated with waste treatment is relatively modest. This is a consequence of the relatively high financial cost associated with treating the waste at incineration facilities operating in CHP mode – the main treatment method for most of the residual waste under the enhanced scenario.

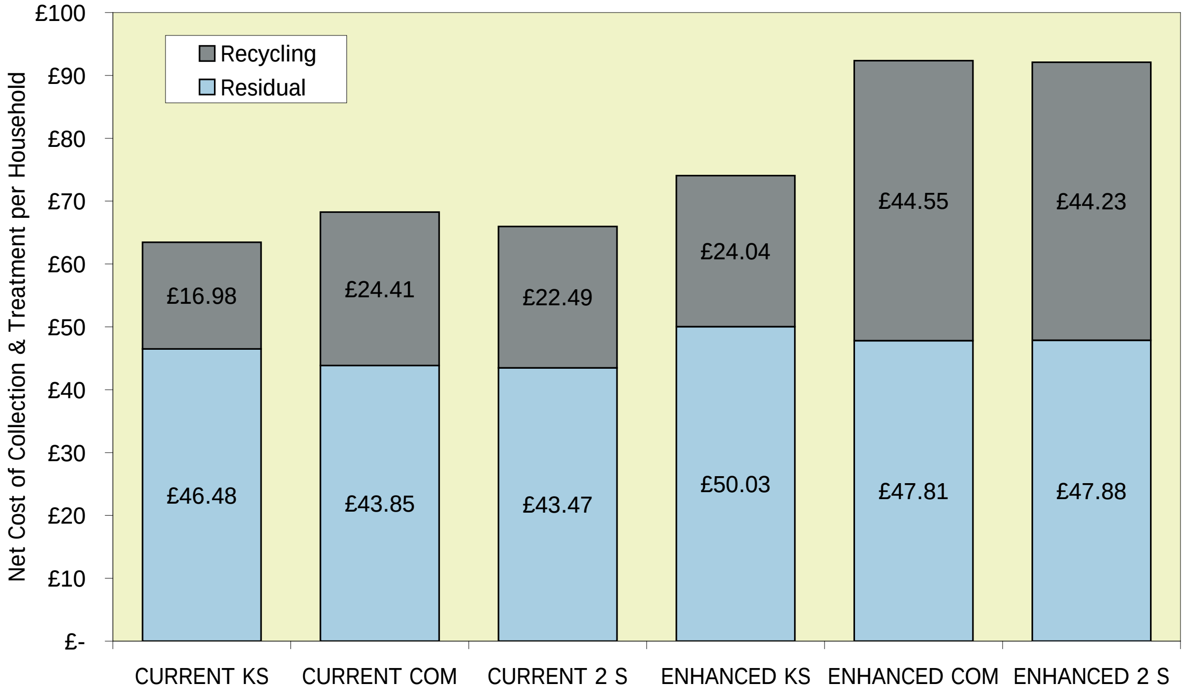
Figure 7 indicates the cost per household of each option, with the cost data again presented prior to adjustment for landfill tax and fuel duty.

Table 7: Breakdown of Financial Costs (£k)

		Residual	Recycling	Food	Garden	TOTAL
Current KS	Collection	£29,952	£23,948	£0	£0	£53,900
	Treatment	£61,647	£0	£1,092	£3,399	£66,139
	TOTAL	**£91,599**	**£23,948**	**£1,092**	**£3,399**	**£120,039**
Current COM	Collection	£27,457	£34,351	£0	£0	£61,808
	Treatment	£59,213	£0	£1,092	£3,399	£63,705
	TOTAL	**£86,670**	**£34,351**	**£1,092**	**£3,399**	**£125,512**
Current 2 S	Collection	£27,004	£31,762	£0	£0	£58,766
	Treatment	£59,432	£0	£1,092	£3,399	£63,924
	TOTAL	**£86,436**	**£31,762**	**£1,092**	**£3,399**	**£122,689**
Enhanced KS	Collection	£22,269	£34,051	£0	£0	£56,319
	Treatment	£47,265	£0	£9,556	£3,225	£60,045
	TOTAL	**£69,534**	**£34,051**	**£9,556**	**£3,225**	**£116,365**
Enhanced COM	Collection	£21,812	£62,768	£0	£0	£84,579
	Treatment	£44,624	£0	£9,556	£3,225	£57,405
	TOTAL	**£66,436**	**£62,768**	**£9,556**	**£3,225**	**£141,984**
Enhanced 2 S	Collection	£21,753	£62,867	£0	£0	£84,620
	Treatment	£44,788	£0	£9,556	£3,225	£57,569
	TOTAL	**£66,541**	**£62,867**	**£9,556**	**£3,225**	**£142,189**

Notes
1. The cost of treating recyclate at MRFs and transfer stations is included within the cost of collection.

Figure 7: Cost per Household per Year of Residual and Recycling Collection and Treatment Services



6.2.2 Environmental Results

Figure 8 provides a breakdown of the environmental damages resulting from the different collection system models. Results are presented excluding the biogenic CO_2 emissions, but including the air quality damages.

As was the case in the Phase 2 reports, under current recycling performance, impacts are dominated by those associated with the treatment of residual waste. When greenhouse gas emissions are valued using the UK Government's current methodology, the climate change benefits associated with recycling materials are relatively small in comparison to the residual waste treatment and disposal impacts. In addition, no air pollution benefit is attributed to the recovery of materials for recycling, as a considerable proportion of both primary production and re-processing is assumed to occur overseas without any impact on Welsh air quality.

Residual waste impacts decrease significantly under the enhanced performance options. In addition to the increase in recycling, less waste is assumed to be landfilled under these options (due to the introduction of new incineration capacity), further decreasing the relative impact of this part of the waste treatment and collection system. In contrast, the enhanced performance options show a relative increase in the importance of transport related impacts, including those associated with the transportation of material overseas for re-processing.

Although the kerbside sort options result in greater residual waste damages, these options result in a lower impact associated with the treatment of rejected material from the recycling process, and greater benefits from recycling. The combined impact is such that the environmental performance of the kerbside sort system is somewhat better under both current and enhanced performance scenarios than the co-mingled and two-stream systems.

Figure 8: Environmental Damage Costs / Year (excluding biogenic CO_2 emissions but including air quality impacts)

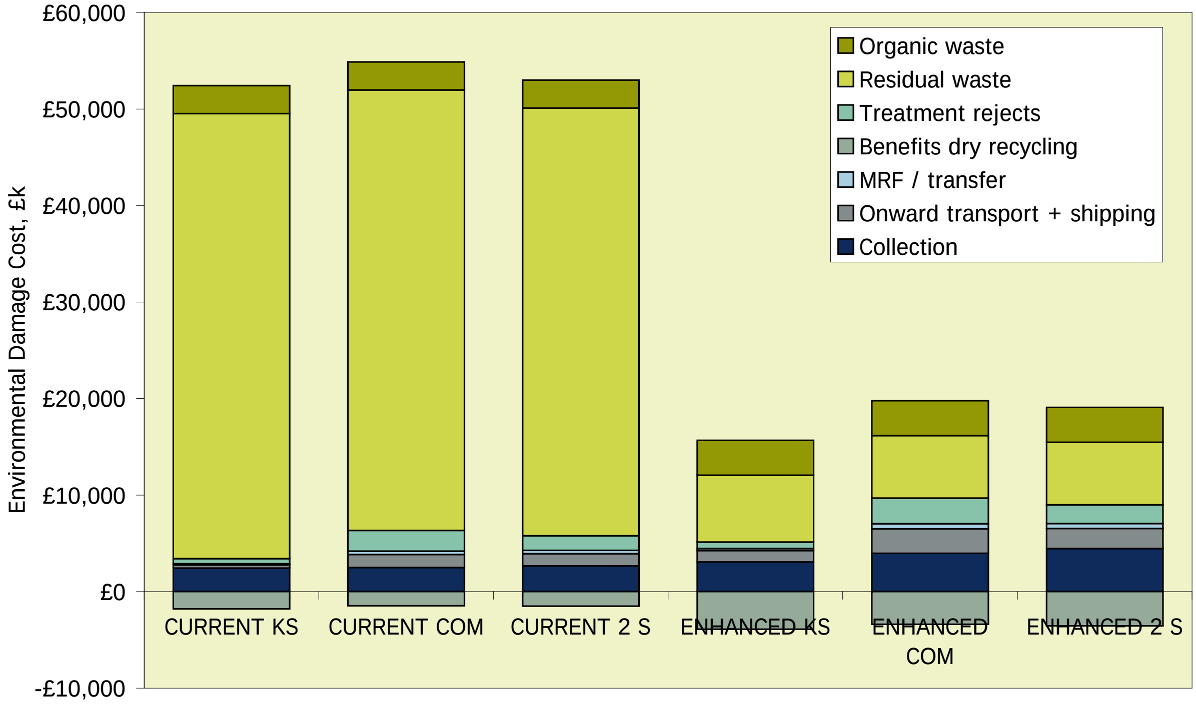


Figure 9 presents a breakdown of the climate change impacts of each option with the greenhouse gas emissions shown in tonnes of CO_2 equivalent. The results are shown excluding the biogenic CO_2 emissions. When the results are presented in this way, the benefit associated with recycling becomes relatively more significant than that seen in the results presented in Figure 8. This is as a result of the lower weighting applied to the climate change benefits associated with recycling in the costs presented in Figure 8, as well as the exclusion of the air quality impacts which, as discussed above, are not applied to the recovery of materials for recycling.

The expression of results in this way leads to a very small residual waste impact under the enhanced performance scenario. The scenario assumes that 95% of the residual waste stream is incinerated, and that these facilities operate in CHP mode with the recovery of significant quantities of heat. Since biogenic CO_2 emissions are excluded from the analysis, the total environmental impact associated with treating residual waste is considerably reduced where air quality impacts are also excluded from the analysis. It should be noted that organics treatment is associated with net negative emissions from the perspective of the climate change impacts where biogenic CO_2 emissions are excluded, although this part of the waste system also contributes to the air pollution impacts (impacts thus appear above the line in Figure 8).

Figure 9: Breakdown of Climate Change Emissions (tonnes of CO_2 equivalent per year)

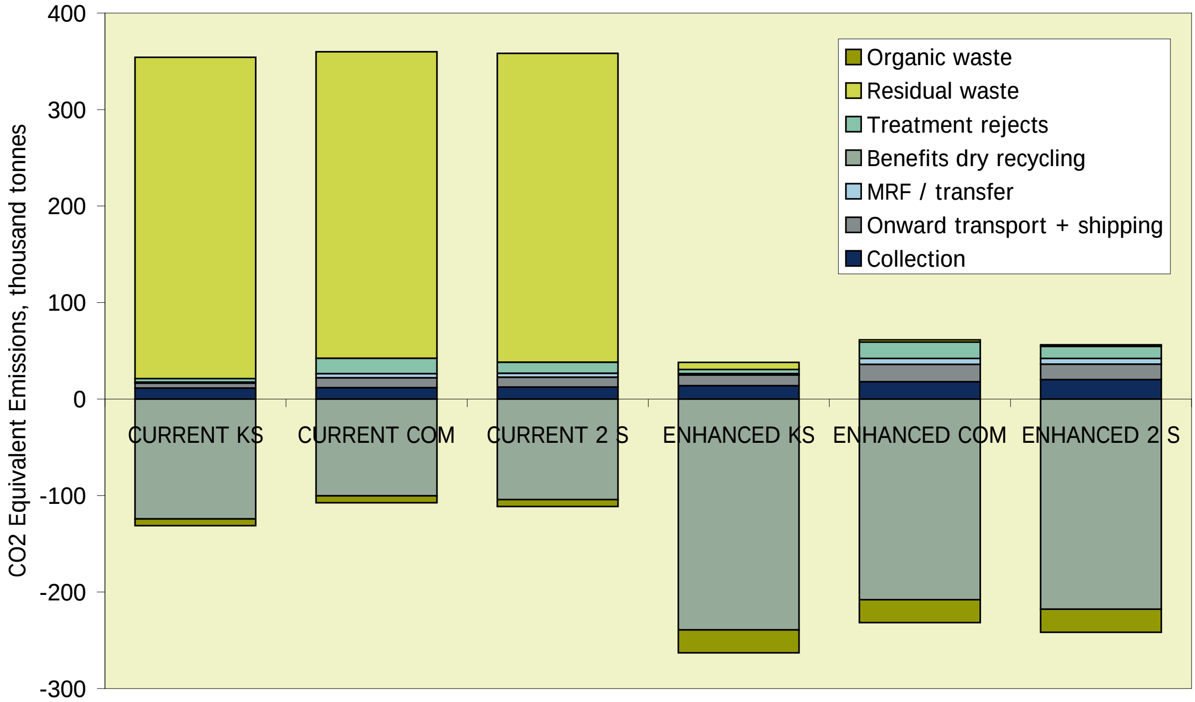


Table 8 and Table 9 present the data provided in Figure 8 and Figure 9 in tabulated form, and include the total (net) environmental impact in each case. Table 9 confirms that when biogenic CO_2 emissions are excluded from the analysis, the enhanced performance options result in a net negative impact with regard to the climate change emissions.

Figure 10 shows the amount of material assumed to be *collected* per household under each of the options. This confirms that the total amount collected under the co-mingled and two-stream options is greater than that collected from the kerbside sort system. Although more material is collected in these two systems, both are assumed to result in a greater proportion of the material being lost at various stages of the process, resulting in lower benefits associated with recycling and a greater contribution to the environmental damages through the treatment of these lost materials. This is particularly the case where the results include the air quality impacts, as these results also include the contribution to the environmental impact associated with the air quality damages from the incineration of the rejected material. The co-mingled systems also result in a greater proportion of the paper collected being re-processed into packaging materials rather than newsprint, the former being associated with a lower environmental benefit than the latter.

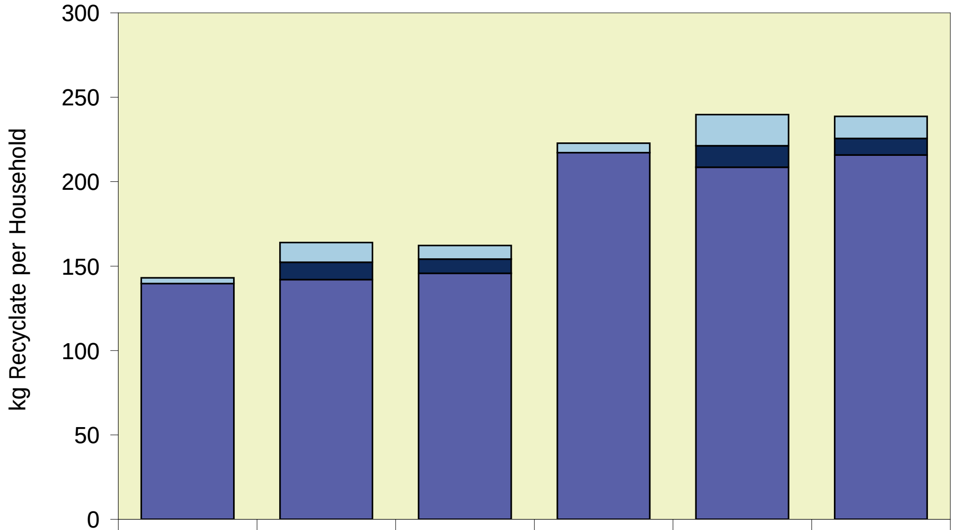
Table 8: Breakdown of Environmental Damage Costs £k per Year (excluding biogenic CO_2 emissions but including air quality impacts)

	Environmental Damage Cost – climate change and air quality impacts (excluding biogenic CO_2 emissions)							
	Collection	Onward transport	MRF / transfer	Benefits of dry recycling	Treatment of rejects	Residual waste	Organics	*TOTAL*
CURRENT KS	£2,445,323	£321,207	£129,321	-£1,789,349	£513,848	£46,119,115	£2,895,982	*£50,635,447*
CURRENT COM	£2,504,713	£1,338,583	£346,191	-£1,453,966	£2,147,186	£45,643,263	£2,895,982	*£53,421,951*
CURRENT 2 S	£2,665,476	£1,267,157	£342,460	-£1,508,089	£1,523,007	£44,289,911	£2,895,982	*£51,475,904*
ENHANCED KS	£3,067,637	£1,180,418	£209,060	-£3,885,622	£681,843	£6,917,730	£3,608,859	*£11,779,926*
ENHANCED COM	£3,972,900	£2,539,613	£526,121	-£3,384,099	£2,647,631	£6,483,067	£3,608,859	*£16,394,093*
ENHANCED 2 S	£4,460,859	£2,079,137	£523,810	-£3,541,253	£1,926,329	£6,484,558	£3,608,859	*£15,542,299*

Table 9: Breakdown of Climate Change Emissions per Year (tonnes CO_2 equivalent)

	Climate change emissions, tonnes CO_2 equivalent (excluding biogenic CO_2 emissions)							
	Collection	Onward transport	MRF / transfer	Benefits of dry recycling	Treatment of rejects	Residual waste	Organics	*TOTAL*
CURRENT KS	11,488	5,154	928	-124,302	3,580	333,033	-6,989	222,892
CURRENT COM	11,767	10,388	4,141	-100,374	16,022	317,587	-6,989	252,543
CURRENT 2 S	12,522	10,100	4,097	-104,255	11,442	320,144	-6,989	247,061
ENHANCED KS	13,953	10,962	1,446	-239,224	4,383	7,188	-23,803	-225,094
ENHANCED COM	18,070	17,931	6,058	-207,875	17,062	2,322	-23,803	-170,236
ENHANCED 2 S	20,290	15,824	6,031	-217,788	12,429	1,592	-23,803	-185,426

Figure 10: Total Material Collected in the Dry Recycling System per Household per Year (kg/hh/annum)



	CURRENT KS	CURRENT COM	CURRENT 2 S	ENHANCED KS	ENHANCED COM	ENHANCED 2 S
Process Loss (kg/hh)	3	12	8	6	18	13
Rejects (kg/hh)	0	10	8	0	13	10
Recycled Material (kg/hh)	140	142	146	217	209	216

6.2.3 Overall Results

Figure 11 presents the combined annual financial and environmental cost of each option. The environmental damages exclude the impact of biogenic CO_2 emissions, but include damages associated with air pollution. Financial costs are presented having been adjusted for landfill tax and fuel duty impacts in order to avoid double-counting impacts, which are also separately accounted for within the environmental damages.

The combined results confirm that the kerbside sort system is the best performing overall option in both the current and enhanced performance scenarios. The co-mingled system performs the worst of the three types of system in both the current and enhanced performance scenarios. The better overall performance of the kerbside sort system is largely driven by its lower financial cost in comparison to that of the co-mingled and two-stream options, although the system also outperforms the other options with regard to the environmental impact, but to a lesser extent.

Environmental impacts decrease significantly in the enhanced performance scenario, such that financial impacts dominate the results to a greater extent. The decrease in environmental impact largely results from the significant decrease in residual waste impacts, as well as an increase in the environmental benefits associated with recycling.

Figure 12 presents the combined financial and environmental costs of each option as given in Figure 11, but excluding the impacts associated with air quality impacts. The relative performance of each option remains unchanged where these impacts are excluded. The exclusion of the air quality impacts has a more significant impact on the enhanced performance scenarios – in these scenarios, more waste is treated through incineration which has a greater impact on air quality.

Figure 11: Combined Financial and Environmental Cost per Year (financial costs adjusted for landfill tax and fuel duty)

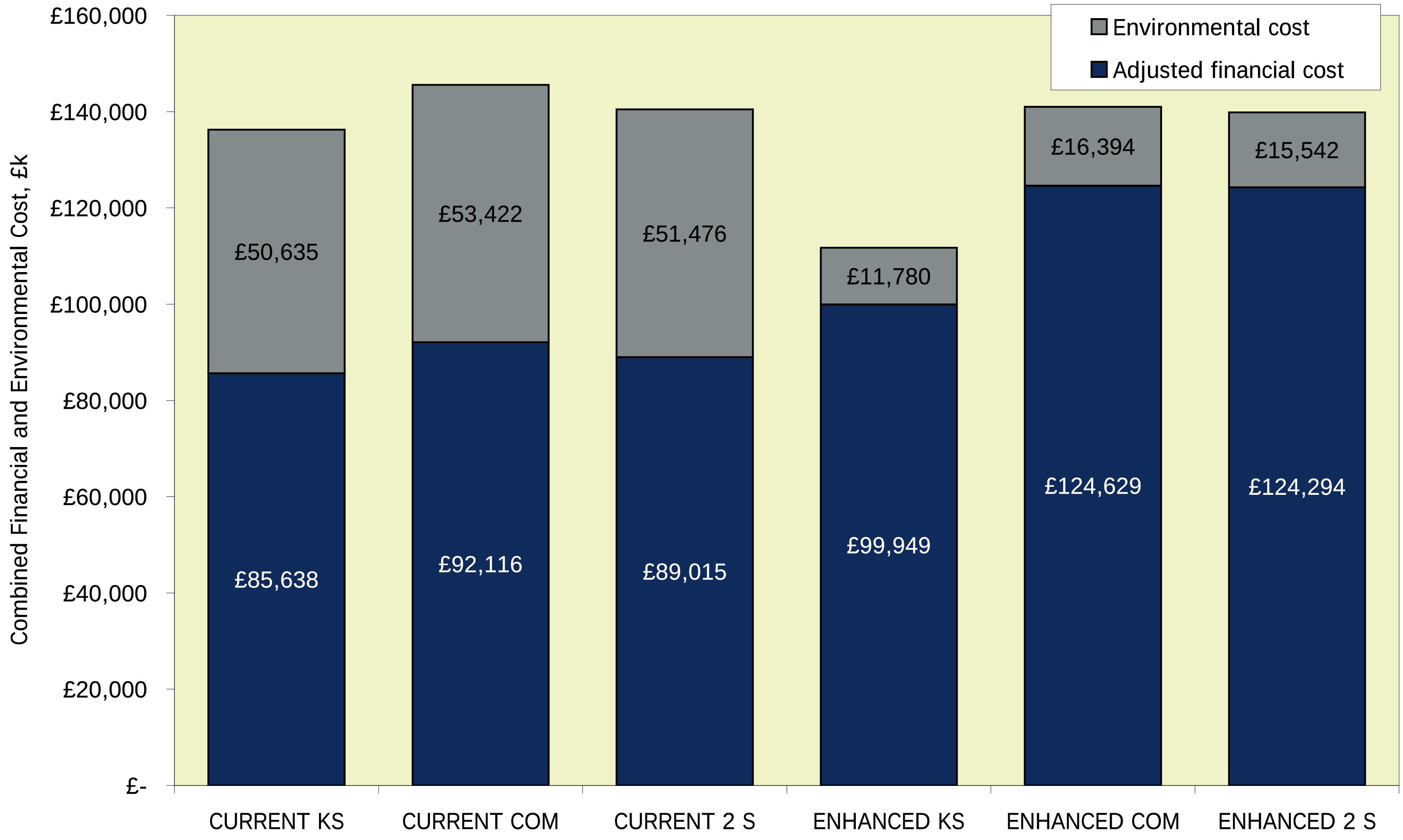
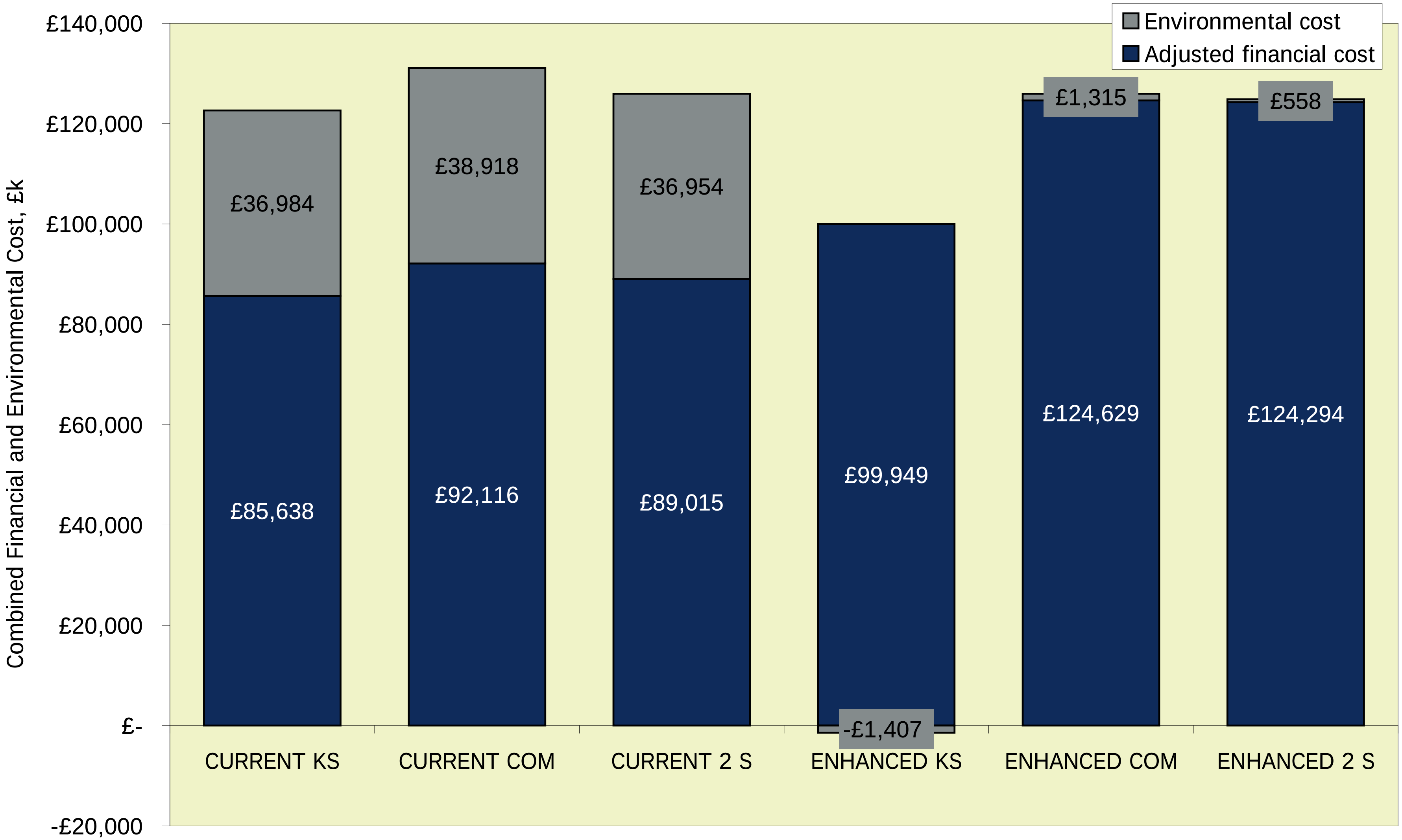


Figure 12: Combined Financial and Environmental Cost per Year Excluding Air Quality Impacts



6.2.4 Sensitivity Analysis

This section presents the sensitivity analysis that has been undertaken on the cost-benefit analysis for both the current and enhanced performance scenarios.

Figure 13 presents combined financial and environmental damage costs, with the environmental cost including the impact of the biogenic CO_2 emissions. The inclusion of these impacts improves the relative performance of the co-mingled and two-stream options with regard to environmental impacts such that the two-stream option becomes, by a small margin, the best performer with regard to its environmental damage cost in the current performance scenario. This improvement in performance results from:

- The greater relative impact associated with residual waste treatment for the kerbside sort option, because biogenic CO_2 emissions from landfill are now included in the damage costs. This has a greater impact on the kerbside sort options as more residual waste is disposed of via landfill.
- An increase in the environmental benefit associated with the recycling of paper and card into packaging materials, resulting from the inclusion of avoided emissions associated with a reduced requirement for wood energy in this type of reprocessing. A greater proportion of the fibre produced by co-mingled and two-stream recycling systems is reprocessed in this way in comparison to the kerbside sort system (the latter system results in the greater production of newsprint from the collected fibre where the majority of the impact relates to avoided electrical energy which is more likely to be generated from fossil energy sources). As a consequence, the inclusion of these emissions improves the environmental benefit associated with recycling from the co-mingled and two-stream systems relative to that of the kerbside sort system.

The improvement in environmental performance is not, however, sufficient to change the overall ranking of the options where the combined financial and environmental cost is considered. In the enhanced performance scenario, the improvements in environmental performance of two-stream and co-mingled collection are not enough to offset the considerable advantages of kerbside sorting in terms of collection, onward transport and the treatment and disposal of rejected material, as well as the better overall benefit of recycling. As such, although the performance gap is closed somewhat, kerbside sorting still outperforms the other two options by a significant margin with regard to overall environmental impacts.

Figure 14 presents the combined financial and environmental damage costs with the latter calculated using a single cost of carbon of £28 per tonne for the climate change impacts, based on the previous shadow cost of carbon (used in the UK Government's previous methodology for evaluating the climate change impacts). The environmental damage costs include the air quality impacts but exclude the biogenic CO_2 emissions. When results are calculated in this way, the overall impact associated with the environmental damages is significantly reduced as a consequence of both the lower damages associated with methane emissions from landfill, and a relative increase in the environmental benefits associated with recycling. Combined financial and environmental costs are thus dominated by the financial impacts to an even greater extent, widening the differential between the kerbside sort system and the other two options.

Figure 15 presents results where an increased gate fee for the single stream and the two-stream MRFs is assumed. The gate fee is modelled as increasing from an average of £16.60 per tonne (the throughput-weighted average of the £4.18/tonne gate fees assumed for large urban MRFs and the £43.36/tonne assumed for the smaller, rural MRFs) to £25.00 per tonne in the single stream MRF and from -£8.77 per tonne to -£0.37 per tonne in the two-stream MRF. This sensitivity analysis was carried out to reflect a set of gate fee assumptions more similar to those used by WRAP in previous studies, as well as more closely reflecting gate fees or processing costs currently incurred by authorities in Wales, which tend to be much higher than those assumed in our central scenario. As would be expected, this sensitivity also results in an increase in the differential in performance between the kerbside sort system and the co-mingled and two stream systems.

Figure 13: Combined Financial and Environmental Cost per Year Including Biogenic CO_2 Emissions

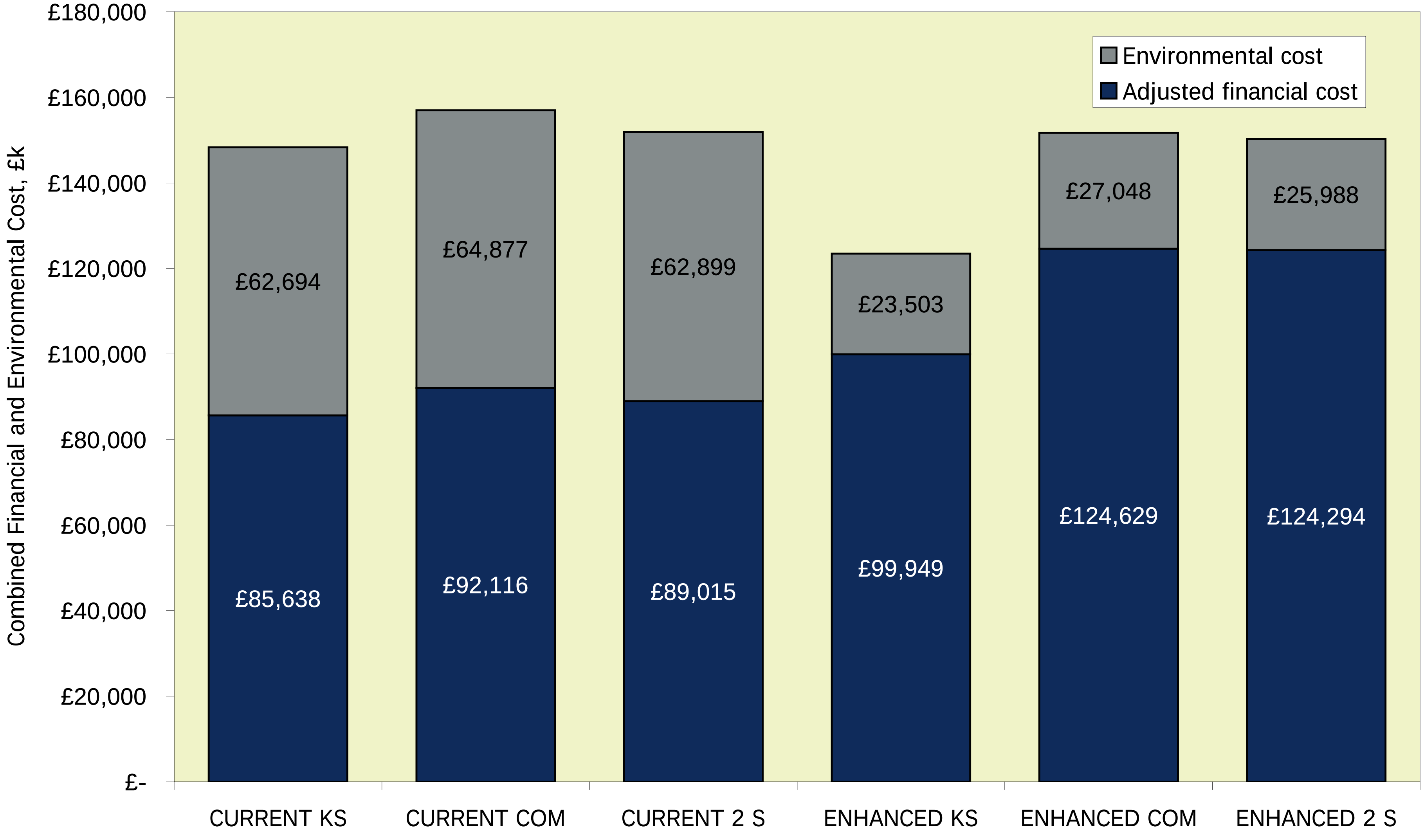


Figure 14: Combined Financial and Environmental Damage Cost Per Year Using a Flat Cost of Carbon

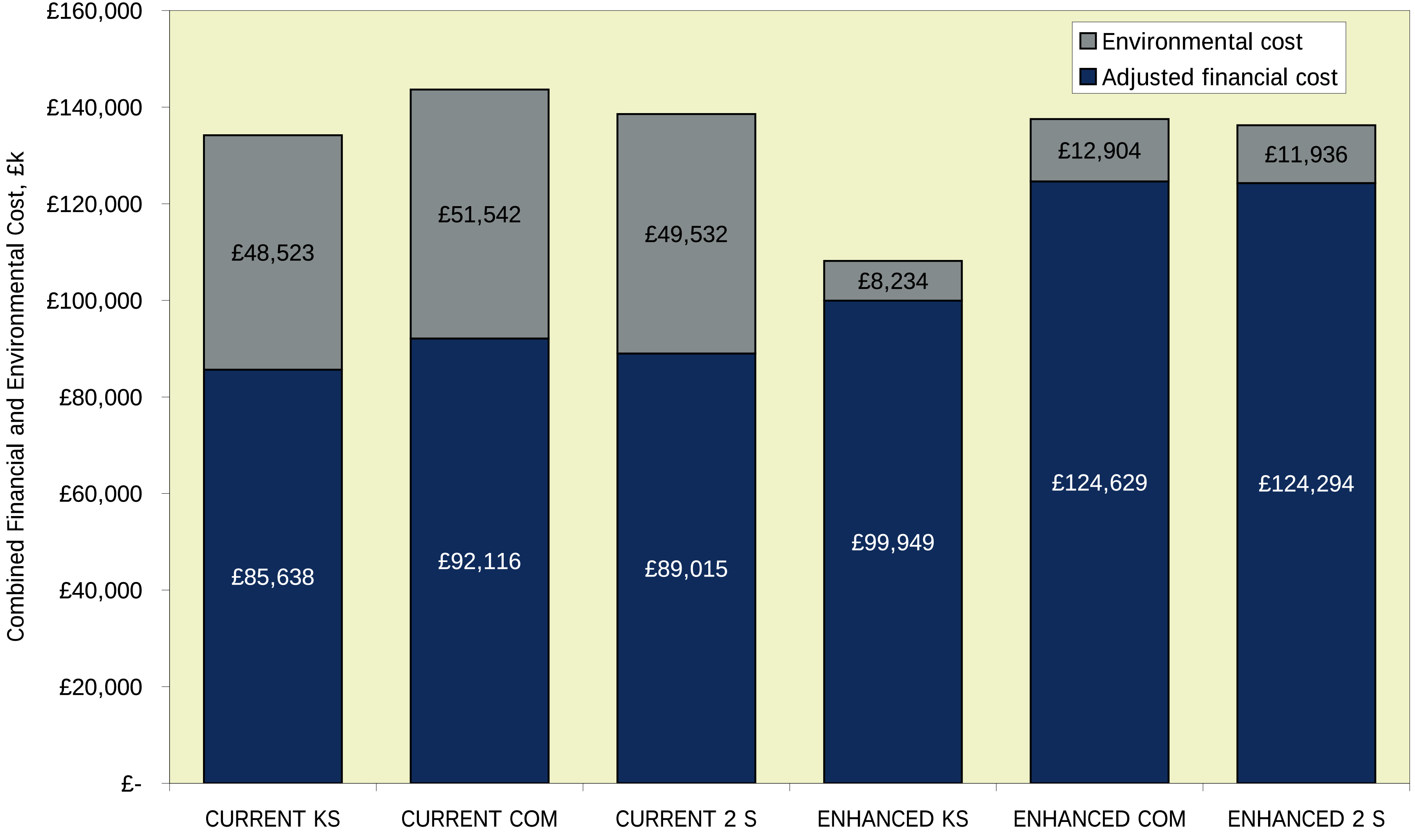
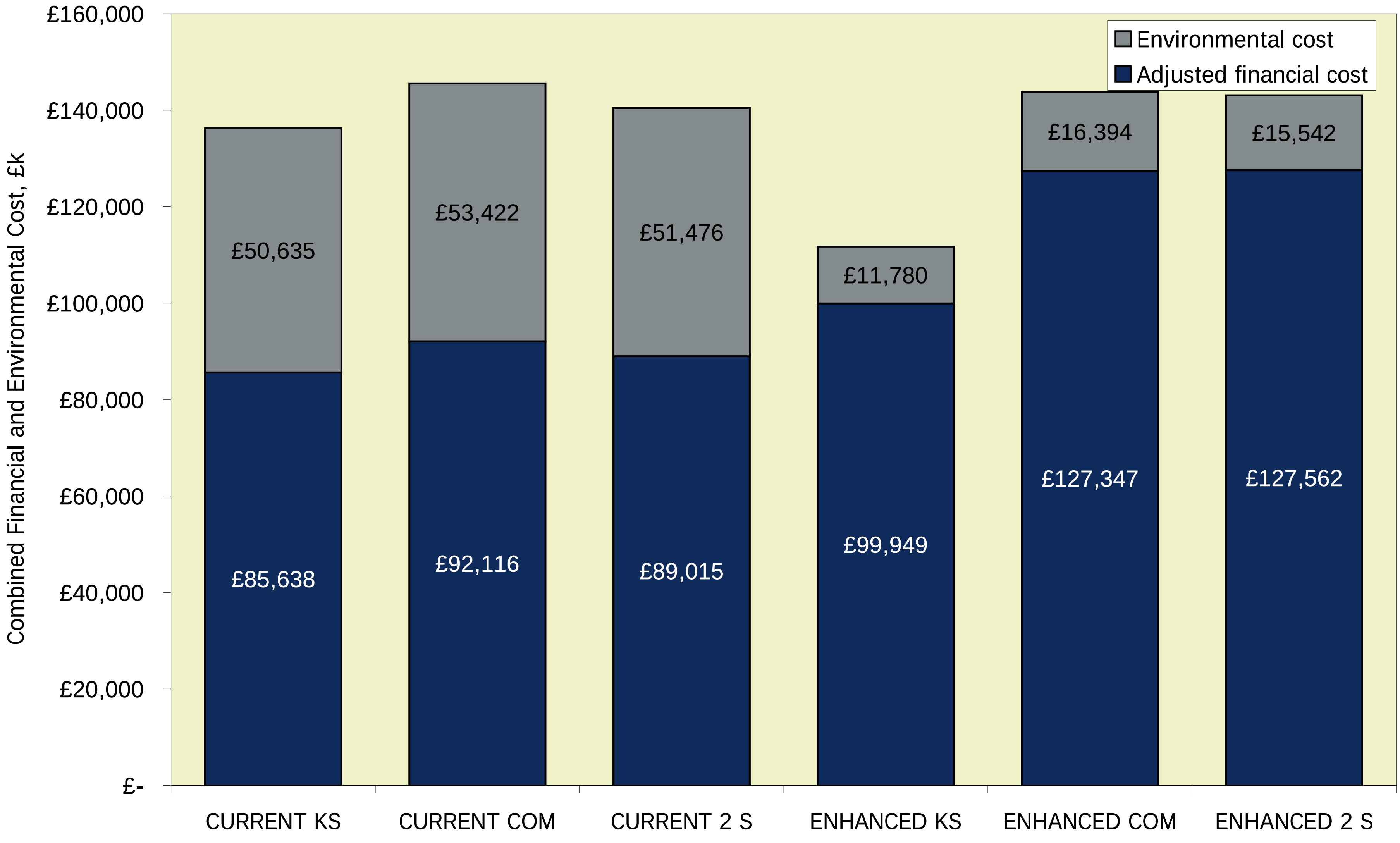


Figure 15: Combined Financial and Environmental Damage Costs per Year Using Higher MRF Gate Fee



6.2.5 Social Impacts

Increasingly, importance is being placed on consideration of the social costs and benefits associated with alternative management routes for waste. While the methodological approach to incorporating environmental costs and benefits using monetised damage costs in the framework of cost-benefit analysis is well established and widely accepted, there is no such consensus on the approach to social impacts.

One recent study undertaken for Defra used the Social Return on Investment (SROI) methodology to try and integrate the environmental, economic and social impacts associated with a number of case studies of third sector involvement in waste management[14]. The report demonstrates that the SROI is effective at ensuring that all the stakeholders who may benefit from a specific activity are identified, but in so doing, the approach can involve double counting. In one example of this, the approach counts as benefits:

- avoided landfill tax; plus
- avoided greenhouse gas impacts of landfill; plus
- reduced external environmental impacts of landfill.

In addition, it is stated in the report that 'it is not possible to directly compare the SROI ratios generated for the case study projects as they describe value generated in different activities and different contexts'. This method would not, therefore, be acceptable if seeking to compare alternative collection routes. For this, it is necessary to use an approach, such as cost-benefit analysis, which does not bias the analysis in favour of one or other of the approaches under consideration.

However, even though social impacts are not always so amenable to inclusion within a monetised approach, this does not mean that such impacts do not exist or are not valid. Our approach, therefore, is to discuss the social impacts, and present relevant data alongside cost and environmental data, but without seeking to place a monetary value on these impacts.

There are a number of different social impacts that may arise from the way in which waste is collected. These may include:

- the nature of the employment, i.e. total levels, the location, and whether full or part time, directly employed or via an agency and whether work is predominantly indoors or outdoors;
- the way in which collection vehicles may affect traffic flow under differing approaches, possibly causing congestion; and
- public attitudes to the different collection systems.

Increased employment is intuitively of social value to the individual employed, the local authority area, and to Wales and the UK as a whole through increasing the tax base. However, attributing any kind of monetary value to employment is not a straightforward matter. Guidance has been sought from the Welsh Assembly Government economists on whether there is a particular monetary value that might be used in assessments looking at employment and job creation and whether this varies by location. Guidance was also sought on the use of multiplier effects. However, the response was that there are no such values or indeed distributional weights applied in WAG analysis, and that the more appropriate way to deal with employment and other social impacts is as we have proposed, through a narrative approach.[15] It is worth noting that the costs of employment will already be incorporated within the cost-benefit analysis for both Phase 2 and Phase 3 of this study, alongside the other financial costs.

Total employment in the Phase 3 Wales-wide modelling for both the current performance and enhanced performance scenarios is shown in Table 10. In the current performance scenario, the kerbside sort system is the most employment-intensive system, requiring 3.6% more full time equivalent (FTE) staff than the co-mingled

[14] *Defra (2009) Benefits of Third Sector Involvement in Waste Management, Defra Waste and Resources R&D project WR0506*

[15] *Personal communication with Andrew Hobden, WAG Economist, 19th November 2010.*

system and 6.7% FTE more than the two-stream system. The higher employment intensity in the kerbside sort system was reflected in the higher collection cost of kerbside sort when material income and MRF/depot processing costs are not included in the overall cost of the system, as discussed in Section 6.2.1. In the enhanced performance scenario, the picture is different, with the co-mingled system becoming the most, and the kerbside sort system the least employee-intensive of the three systems, requiring 12% less FTE versus co-mingled collection.

Table 10: Employment Intensity under Wales-Wide Current and Enhanced Performance Scenarios

	Current Performance			Enhanced Performance		
	Co-mingled	Two-stream	Kerbside sort	Co-mingled	Two-stream	Kerbside sort
Collection Staff - Drivers	152	152	296	275	297	523
Collection Staff - Crew	240	240	358	712	771	645
MRF Operatives	281	259	44	416	320	66
Total staff required	673	651	698	1,403	1,388	1,234

Based on the Phase 2 case study authorities, a qualitative distinction might also be made between the proportion in permanent posts and those with temporary contracts. The breakdown of those on temporary and permanent contracts for each of the authorities is shown in Table 11. Note that no split in permanent and temporary FTEs was provided for one of the MRF operations which is privately-run rather than authority-owned.

Table 11: Percentage of Permanent and Temporary Staff Employed in Dry Recycling Collection and Processing by Authority

	Cardiff	Newport	Monmouthshire	RCT	Pembrokeshire	Gwynedd
Drivers and Crew						
Permanent	67%	100%	100%	60%	80%	100%
Temporary	33%	0%	0%	40%	20%	0%
MRF Operatives						
Permanent	16%	N/A	10%	60%	Unknown	100%
Temporary	84%	N/A	90%	40%	Unknown	0%
Notes: 1. The split for Monmouthshire is based on information supplied by SCA that all operatives employed directly on sorting duties are agency temps. We have then assumed that 90% of MRF operatives are employed on such duties.						

This analysis suggests a propensity for a greater proportion of workers to be employed on a temporary basis in MRFs relative to on collection rounds. However, it is clearly possible for high proportions of staff to be employed on a temporary basis on rounds and on a permanent basis in MRFs, so from this small sample it is not really possible to draw general conclusions.

A distinction might also be made between the number of staff working indoors in MRFs, and those working outdoors either collecting waste or located outside at a depot or MRF. The social impact of this will depend on the individual involved, with outdoor work being seen by some as more attractive and vice versa. Based on the information provided in Phase 2, the approximate percentage split between outdoor and indoor employment is shown for each authority in Table 12. In the two kerbside sort systems, the majority of employment is outdoors, whereas in the two-stream and co-mingled systems, there is a more even split between working indoors and outdoors.

Table 12: Percentage Split between Indoor and Outdoor Employment in Dry Recycling Collection by Authority

	Cardiff	Newport	Monmouthshire	RCT	Pembrokeshire	Gwynedd
Indoor (MRF)	57%	5%	39%	53%	44%	11%
Outdoor (driver/crew)	43%	95%	61%	47%	56%	89%
Notes: 1. The split for Newport is estimated, based on an assumption of some indoor sorting of plastics and cans.						

Another potential impact is that relating to traffic congestion from alternative collection methods. The Department for Transport uses an approach based on the value of travel time savings to evaluate the potential benefits from road schemes in the expectation that they will reduce travel time, which is taken to be unproductive time[16]. Following this approach, different values of time are used based on whether travel is undertaken within working time, or outside, with working time having the greater value. While such an approach could theoretically be applied to consideration of the alternative collection routes, the data requirements would be considerable. It would be necessary to know how the impacts of collection on traffic congestion might vary between alternative systems, and to know how many people might have their journey times increased, and by how long, and indeed the proportion of road users who might be travelling during working hours. Accordingly, this analysis presents a description of the collection requirements in terms of how the vehicles are operated rather than seeking such data on impacts.

The different kerbside dry recycling collections have varying characteristics regarding the speed of collections and therefore resources required to complete the collections. These characteristics are likely to generate differences in the amount each system contributes to traffic congestion. The contribution that collection vehicles make to congestion probably occurs in two distinct ways: firstly, vehicles moving to and from areas of work and travelling at normal road speed add to the total number of vehicles on the road. Secondly, vehicles collecting down streets may in some circumstances contribute to congestion both due to their increased contribution to the number of vehicles on the road, but also in some circumstances (e.g. narrow streets) according to how quickly they can load from each household. In co-mingled and two stream collections, when compared to kerbside sort collections, the collection of material from each household is relatively quick and therefore fewer collection vehicles are required. Typically a co-mingled collection may utilise 60% or less of the number of vehicles required for a kerbside sort scheme, in part as a result of speedier loading times. They should, therefore, contribute less to overall congestion, although the extent of this has not, as far as we are aware, been accurately quantified in any previous studies.

To date, there is no concrete evidence as to whether customers prefer a particular dry recycling system. As the Welsh authorities will already be well aware, accumulating a large pool of information on customer satisfaction is a difficult process. The analysis that has been done in relation to switches between different dry recycling systems in terms of customer perception has typically involved too small a sample, or too poor a representation of socio-economic groups, to enable the authorities undertaking analysis of customer satisfaction to draw any robust conclusions as to the extent of impact associated with collection system type. Generally, these comparisons have shown an increase in public satisfaction when major changes are made to services, with such changes usually coinciding with an increase in the range of materials collected. As there have been very few authorities who have switched from co-mingled collection to kerbside sorting, the anecdotal evidence that does exist generally relates to switches in the opposite direction. From the more empirical evidence available, it appears that the key factors in determining public satisfaction with waste management systems are that adequate, convenient volume is made available *overall* and that a wide range of materials is accepted for recycling.[17]

Regarding the public acceptability of the three dry recycling systems, anecdotal evidence seems to suggest that customer perceptions of the system are most influenced by the nature of the current system in place (i.e.

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[16] *DfT (2009) Values of Time and Operating Costs, Transport Analysis Guidance Unit 3.5.6, April 2009. Available at http://www.dft.gov.uk/webtag/documents/expert/pdf/unit3.5.6.pdf*

[17] *For example, in the largest survey on this issue, NOP interviewed 3,506 people about their waste services in October 2006 and February 2007, finding no significant difference in satisfaction between collection systems, with the highest levels of satisfaction being reported for schemes that included comprehensive recycling and organic waste collection services.*

residents generally feel positive about the system they currently have and express concerns about any significant planned change) and how well it is run (e.g. the number of missed collections), by containment type and by the range of materials that the authority will collect at the kerbside. Different containment types will suit different housing types; residents of back-to-back terraces will perhaps be less keen on having a number of wheeled bins, than they would be on having one or several boxes. In contrast, those individuals with a large drive might prefer a wheeled bin versus having to carry several boxes to the end of their driveway. Though in theory it would be ideal to have multiple containment types available to customers, in practice authorities have to make decisions as to which type of containment suits the majority of their customers and which type of containment will thus be likely to be acceptable. In the case of the Phase 3 modelling, both the boxes (kerbside sort) and bags (co-mingled, two-stream) will be relatively easy to store, but will require carrying to the edge of the householder's property as required. Fundamentally, the key to the successful acceptance of the system will be to ensure that there is sufficient capacity provided to each customer in order to capture as much material as possible in the dry recycling system, that the authorities offer a wide-ranging collection of recyclable materials at the kerbside, and that a smooth roll-out of any service change is delivered alongside clear communications.

The potential social impacts associated with the three dry recycling systems can be summarised as follows:

- Employment intensity – under the current performance scenario, it might be argued that the kerbside sort system is more advantageous, as it provides the highest employment at the lowest overall financial and environmental cost. However, under the enhanced performance scenario, the ranking in terms of employment intensity shifts in favour of co-mingled collection.
- Case study data – it is difficult to draw any conclusions from the data provided by the case study authorities either in terms of the ratio of permanent to temporary jobs provided, apart from observing that use of temporary labour may be more prevalent in MRF operations than in on-street collection operations. Although the kerbside sort system results in a greater proportion of outdoor working than the other two systems, it is difficult to say whether this is a positive or negative impact, as it will depend on individual preference and the working conditions in the indoor spaces.
- Traffic congestion – it seems reasonable to conclude that kerbside sort systems will tend to be more likely to contribute to increased traffic congestion versus the other two options, in part due to the larger number of vehicles required and in part due to slower pick-up times. However, beyond the anecdotal evidence available to any operators of waste collection services that being stuck behind collection vehicles can be very frustrating, it is not possible to effectively quantify the impact of this issue based on the data available.
- Customer satisfaction – there is no concrete evidence as to which dry recycling system is preferred by householders. Customer satisfaction surveys typically produce small sample sets and are not representative of all the socio-economic groups in an area. Satisfaction will be driven by factors such as:
  - what system is already in place and how well the current system is run;
  - how smoothly any roll-out of new services is delivered and communicated;
  - the containment type offered, whether this is the most relevant type for a particular householder's housing circumstances and whether enough capacity has been supplied; and
  - the range of materials that are collected.

7.0 Discussion and Conclusions

This study has, in our view, succeeded in shedding greater light on the complex issues associated with collection system choice. We have succeeded in gaining an improved understanding of material fates that could reasonably be assumed to be 'typical' of different collection systems through the thorough investigation of six case study authorities. We have applied this more sophisticated understanding alongside the knowledge and experience of the project team and Technical Advisory Group to build a holistic model of financial and environmental impacts that might be expected were all Welsh local authorities to switch to one or other of the three collection systems examined. However, it is also acknowledged that, as a modelling-based exercise driven by assumptions, the results of Phase 3 cannot *prove* that one collection system is universally better than another. The extent to which the study can contribute positively to the development of policy in this area ultimately depends on the amount of confidence that the methodology and assumptions used can inspire. Before going on to consider what can reasonably be concluded from the results, it is therefore worthwhile considering some of the methodological issues associated with a study of this kind. The issues highlighted here are discussed in greater detail in the *Technical Annex*.

7.1 Limitations of the Study

As with any modelling-based exercise, the quality of the output is most heavily influenced by the quality of the key inputs, the assumptions made and the modelling methodology used. Phases 1 and 2 of this project allowed us to bring together knowledge and information accumulated in previous studies and to supplement this with primary research on material fates, which helped to fill key gaps in our understanding following the literature review.

Whilst we are broadly happy that our appreciation of material fates likely to typify different collection systems is much improved as a result of Phase 2, we were not as successful in obtaining data from some sources as we had anticipated. At the inception of the study, we had hoped that reprocessors would provide a useful source of large-sample data on material quality. In fact, we ended up having to combine relatively small amounts of hard reprocessor data with anecdotal information from reprocessors and large amounts of 'back of MRF' product stream composition data in order to derive our assumptions for the latter stages of the reprocessing cycle. In particular, we were surprised by the limited extent to which weight-based analysis of product streams appeared to be carried out by intermediate processors and reprocessors. It is likely that in some cases private sector organisations considered the data we requested to be commercially sensitive in nature and probably in other cases some were simply not inclined to apply resources to assisting with the study. However, of the 27 intermediate processors and reprocessors used by the six case study authorities, 21 did cooperate to some extent (with four of the remainder being Chinese and Indonesian paper manufacturers). As a result, we have been left with the impression that, in the case of most of these organisations, maintaining a consistent and accurate picture of input material and product stream quality is not essential to their businesses. Although our understanding of the issues that are most important in driving the environmental performance of different material fates has improved significantly as a result of this study, there is no doubt that further research has the potential to add significantly to the picture. In particular, we were least successful in obtaining a detailed understanding of the practices of the Chinese and Indonesian paper reprocessors used by some of the case study authorities and as such have made assumptions based on the practices of European paper mills. Although in themselves these limitations are not significant to the overall order of results, gaining a more sophisticated understand of ultimate fates would help to improve the accuracy of this kind of modelling.

In addition to the limitations in available data on certain reprocessor processes and the impact of contrary material presence on these, there is a lack of 'fit for purpose' data on the environmental benefits of recycling. Whilst the data available is well suited to strategic level analysis (for example, 'should this material be recycled or not?') it is often not adequately precise to allow reliable differentiation between the different product streams typically produced by different collection systems. We had expected to be able to locate reliable data sources that would, for example, allow us to differentiate between different paper packaging products or textile reuse and recycling fates, but in fact we ended up reverting primarily to data used in WRATE. This was most often because more sophisticated data simply could not be obtained, but was sometimes due to the lack of clarity as to the precise definitions of materials and processes used. To some extent, this seems to be as a result of a lack of good fit between academic study and the real market in terms of how materials and product streams are classified. In any event, although considerable effort was applied to our research into new data sources on environmental benefits of recycling, we have been left drawing the conclusion that data at the level of precision required to more fully understand the subtle differences in material fate associated with collection system difference is not readily available for most materials. Again, this is an area that would merit further research, in particular given the increasing media and public interest in the fate of recyclables and the economic and environmental benefits (or otherwise) of recycling.

In terms of the financial cost analysis undertaken in Phase 3, as with any modelling exercise of this nature it cannot be expected to provide a picture of likely costs of the level of accuracy required to, for instance, set a budget for an individual collection service. However, we are happy that it does have the internal consistency required to allow an objective (if desk-based) comparison of the collection options to be made. In particular, the approach of modelling MRF processing costs and material revenues, as opposed to simply selecting an assumed gate fee for co-mingled and two-stream collection and a separate set of material revenue assumptions for kerbside sorting has attempted to address a common flaw in previous studies that have sought to compare collection options. It is important to note, though, that we have not modelled the collection costs at the individual authority level, but have modelled the three collection systems for three 'baseline' authorities (one urban, one valley and one rural), the results of which have been extrapolated to cover the other authorities within these groups. Whilst this methodology is able to provide a reasonably accurate picture of relative costs of the systems at the Wales-wide level, it is not intended to be accurate at the individual authority level.

Although considerable resources have been applied to investigating the potential social impacts and health and safety implications of the different collection systems, the scope of the study has left us reliant to a great extent on data available from pre-existing sources and in neither case has this data been adequate to allow us to provide a clear picture. Regarding social impacts, this is to some extent inherent in the subjective nature of some of the variables involved. For example, it is not possible to objectively determine whether more or less 'outdoor working' is desirable. This is ultimately a matter of personal preference, in which individuals will take account of the precise nature of the working environment and employment conditions before being able to pass judgement on a particular case. However, regarding issues such as public attitude to different collection systems, it may be possible to add to the current (almost entirely anecdotal) evidence base. Again, though, attitudes are likely to be driven by many factors not directly associated with the collection system itself (for example, general attitude towards the council, or issues to do with precise service design or quality of delivery). As such, the research methodology required to get close to the bottom of which overall systems (if any) are 'generally preferred' would be far from straightforward and probably quite costly to deliver.

Regarding health and safety, although the situation is characterised by shortcomings in the data, it does seem to us that the issues concerned are important enough to warrant a more systematic examination than has previously been attempted. It should be possible (with clear objectives established and resourcing secured) for a research methodology to be established that seeks to objectively understand the factors that are most important in giving rise to risk of accident and injury. It seems likely that some of these factors relate to collection system design, but that others relate to working practices that are unrelated to specific collection systems. Much as the debate within the waste management industry regarding collection system characteristics and their implications for health and safety has been intense and lengthy, we seem to be no nearer to a clear evidence base upon which consensus could be based than was the case when that debate began. What is most important is that an understanding is reached at to the key factors driving the industry's continuing poor health and safety record. The sometimes polarised debate regarding collection systems, with some participants focused on supporting their own position rather than the overall picture, appears to be a barrier to such an objective understanding being obtained. It is the responsibility of all in the industry, alongside Government and regulators, to ensure that such barriers are broken down.

7.2 Comments on Methodology and Assumptions

The primary objective of this study was to identify whether one or other of the collection systems examined could be shown to 'perform better than the others' in relation to WAG's sustainable development objectives. In order to come to a conclusion as to whether this has been achieved, it is necessary to question whether the methodology and assumptions have generally biased the analysis in favour of or against particular options. Enthusiastic readers will be able to obtain a more sophisticated view for themselves by reviewing the *Technical Annex*, which provides a detailed explanation of the approach taken and includes further commentary on methodological and data issues. Here, we provide a brief summary of the key areas where such bias might be expected to have the greatest impact on the results and describe the approach taken in the study.

7.2.1 Waste Flows

This study has been very data intensive and size and complexity of the waste flow datasets has presented significant methodological challenges. However, we do feel that we have addressed the fundamental questions of difference between the collection systems adequately in the Phase 3 models:

- We have sought to address the complex issues around the extent to which collection system choice *per se* is a driver of variation in material captured for recycling in the collection system. Various previous studies, several of which we considered within Phase 1, have arrived at contradictory conclusions on these issues, with some concluding that co-mingled collection generates higher yields in the recycling collection system and others concluding that there is no significant difference. The multi-factorial regression analysis that supports our ‘yield differential’ assumptions represents, as far as we are aware, the first comprehensive attempt to strip out all of the other factors that drive yield performance difference, allowing an objective ‘impact of collection system choice only’ coefficient to be identified. Essentially, this statistical analysis shows (with a high degree of explanatory power) that dry recycling collection yields can be expected to be between 10.5% and 18.3% lower for kerbside sort schemes (with the variation dependant on frequency of kerbside sort collection) relative to co-mingled schemes, all else being equal. However, it is worthwhile noting the following:

- The regression analysis is based on WasteDataFlow data for 2008/09 and its findings have therefore been applied directly in the current performance scenarios. However, in the enhanced performance scenarios, yield differentials have been reduced. This is because, with all options achieving capture rates required to deliver the *Towards Zero Waste* target, it has been assumed that some of the factors driving variation in yield at current performance levels would be addressed. This seems logical, as WAG and Welsh local authorities will have to achieve a significant step change in public behaviour generally, perhaps driven by a policy framework enhanced to further incentivise recycling, if the 70% target is to be met. However, although we have maintained a yield differential, this assumption could not be described as statistically robust, as we do not have a dataset of ‘70% performing’ authorities to analyse. In our view, equally strong arguments could be made that we have maintained too much of a differential as that we have maintained too little of it in the enhanced performance scenario and as such, we are content that the approach taken has been reasonable.
- In any event, it seems likely that any bias in the base regression analysis conclusions is in favour of co-mingled collection. This is because the analysis compares authorities that collect the ‘main five’ dry recyclables (paper, glass, plastics, metal packaging and card). However, it is clear from a more in-depth analysis of the schemes classified in each collection system group that kerbside sort schemes generally target a narrower range of some materials (due in part to containment and vehicle constraints) relative to co-mingled schemes. This is particularly the case with card and plastics, with kerbside sort schemes more commonly restricting card (by size or type) and plastics (targeting bottles only). This means that a part of the yield differential revealed in the regression analysis probably relates to ‘extent to which each material is targeted’ and so it could reasonably be expected that kerbside sort schemes would, all else being equal, actually achieve a slightly lower differential if exactly the same materials were targeted by both systems. This is becoming increasingly possible following recent innovations in kerbside sort vehicles and collection containers.
- We have assumed very similar yields for the co-mingled and two-stream collection systems, as both are assumed to be based on weekly collection using disposable sacks, meaning that customer behaviour is likely to be similar in both cases. However, it should be noted that the regression analysis did not differentiate between co-mingled and two-stream collection and that bin-based co-mingled schemes were heavily represented in the dataset used (which might be expected to perform differently to sack-based schemes). Equally, the dataset accounts for containment volume in kerbside sort schemes in a somewhat crude way, not differentiating between schemes operating on the same frequency that have very different levels of containment provision. This may have resulted in an overstatement of the yield difference that can be entirely attributed to collection system, as optimised ‘high capacity’ kerbside sort systems may actually deliver performance that is more similar to that of co-mingled or two-stream collection. These shortcomings could not be addressed due to the limitations of the dataset available, which is primarily limited by the schemes actually operated in different parts of the UK.

- We have brought into play a fairly sophisticated classification system for material following collection, based on the categories of quantity collected (as discussed immediately above), material rejected at the primary MRF and process losses occurring after sorting at the primary MRF. Based on information supplied by the Phase 2 MRFs and reprocessors, combined with the best available product stream compositional data, we have developed a set of assumptions as to the fate of all material collected, whether that be target or non-target material and whether it is rejected at the MRF or later in the reprocessing chain, either as a result of being non-target for the collection system or being a miss-sorted target material. These assumptions will not be perfect, but they are supported by real process or composition data where available and logical extrapolation where not. Most importantly, in our view, the approach to applying the evidence is internally consistent, which gives us a high degree of confidence in the combined effect of the assumptions made. Our general approach has been to make assumptions that reflect optimised systems and material fates. So, for example, we have applied MRF reject rates that are well below those applied in other studies (and that applied as the WasteDataFlow default) because we have assumed relatively optimised MRF operation.

7.2.2 Financial Costs

Regarding financial cost, in both the current and enhanced performance scenarios, as is the case with material fates we have assumed that schemes are what one would broadly consider to be ‘optimised’. We took the view that this was the best way to eliminate bias that can be associated with cost modelling when the ‘best approach’ to one option is compared against a sub-optimal approach to another. However, an important issue to note is that for both the co-mingled and two-stream collection systems in the enhanced performance scenario, collection of recyclables was assumed to be weekly. Our original intention was to model these systems using fortnightly collection, but we received a strong steer from the Technical Advisory Group that there was a general preference for the use of sacks as collection containers in Wales. The consensus view of the Group was that fortnightly collection would not be compatible with collection in sacks, primarily due to the implications for domestic storage capacity (especially in the enhanced performance scenario). Although this is a logical constraint to place on these systems, from a collection cost perspective it does negate one of the legitimate advantages of co-mingled collection (i.e. that collection frequency can be reduced without significantly constraining containment volume). The project was not able to resource a full sensitivity analysis of this issue due to the large amount of additional modelling that would have been required, but a rough analysis suggested that a switch to fortnightly collection would substantially (but not fully) close the financial cost gap between kerbside sort and co-mingled collection.

As discussed above, we have sought to address the issue of comparability of gate fee assumptions with material value assumptions by integrating both sets of factors into one model. This means that when the material revenue assumption per tonne of, for example, soft mixed paper is increased, the ‘gate fee equivalent’ (i.e. sorting cost plus material revenue) reduces. This has allowed us to calibrate both material revenue assumptions (applied to all collection systems) and ‘gate fee equivalent’ calculations to ensure that, in effect, the same point in the materials market cycle is being considered for all options. This has led to gate fee assumptions in our central scenarios that are much lower than those assumed in several previous studies, but which, in our view, better match current market conditions. In order to demonstrate the implications of higher gate fees actually being obtained by Welsh local authorities (although still below the average gate fees or equivalents currently paid in Wales), we have carried out a sensitivity analysis based on higher gate fees, with is presented in 6.2.4 above.

In general, there are clearly issues with simplifying the collection options available by narrowing the selection down to three and readers will have to judge for themselves, based on the information contained in the *Technical Annex*, whether or not we have met our objective of using ‘optimised but realistic’ assumptions for modelling the cost of each collection system.

7.2.3 Environmental Costs

As discussed above, issues abound with regard to environmental impact assumptions, with, in the context of this study, particular issues encountered when considering the environmental benefits of recycling. In terms of the factors that have been most significant in driving the order of results, the following is worthy of note:

- The impact of collection was a significant factor in the enhanced performance scenario, with both co-mingled and two-stream collection incurring greater impacts associated with collection operations. In particular, two-stream collection lost ground on the other two systems in the enhanced scenario due to rounds being increasingly constrained by volume limitations due to the assumed use of a split-back RCV with a food pod. We are of the view, based on both modelling and observation of real schemes, that the relative inflexibility of this type of vehicle is likely to become an issue for some authorities as performance approaches that required to deliver 70% recycling. It should be noted that the relative low impact of kerbside sort is due primarily to the assumed use of 'double-decker' modern stillage vehicles, which have significantly lower fuel consumption characteristics compared to both RCVs and 'side loading trough' type kerbside sort vehicles. So, although a significantly larger number of vehicles are required for kerbside sort, overall emissions are lower.
- The impact of onward transportation was a significant factor in both scenarios, due primarily to the assumptions applied regarding the proportion of different product streams that would be expected to be exported to East Asia for reprocessing. Although the impacts associated with shipping of material were discounted significantly to account for back-loading and the fact that air quality emissions at sea wouldn't result in equivalent damage costs to those on land, shipping impacts were significant. Although the assumptions used reflect the pattern of the market currently, it is clearly possible (and not uncommon) for kerbside sorted material to be exported to China and for larger proportions of co-mingled material to be reprocessed in Europe. However, we consider the assumptions made to be reasonable in a medium-term context.
- The differential performance in terms of benefit of recycling was of relatively moderate significance in both scenarios. Although kerbside sort performed better overall, this was not a major driver of monetised environmental benefit in the overall scheme of things (although it was relatively more significant in the sensitivity scenario based on a flat rate for carbon emissions). The key materials that contributed to an improved outcome for kerbside sort were glass (due to closed-loop recycling being assumed) and paper, with a larger proportion of news and pams assumed to feed into a newsprint end use, as opposed to a packaging end use. In addition, kerbside sort benefitted from the recycling of textiles in the enhanced performance scenario (as well as incurring the environmental cost of collecting them), as following discussion with the Technical Advisory Group it was decided that textiles could not realistically be collected on a large scale in co-mingled and two-stream schemes. Indeed, the capture rate assumed for textiles in the kerbside sort option was kept low (relative to other materials), with the assumption being that a 'non-kerbside' solution would have to be developed to compliment all collection systems if Wales is to reach 70% recycling and reuse.
- The environmental impact of the treatment and disposal of rejects and process losses was a significant factor, particularly in the enhanced performance scenario. In the waste flow models, fates were assigned to all materials in all product streams and although all collection systems generated process losses, these were greatest in co-mingled collection, followed by two-stream. As most process losses (as opposed to MRF rejects) were assumed to go to landfill (based on our Phase 2 findings) these impacts were quite significant.
- Finally, the impact of residual waste disposal (i.e. waste collected from households as residual) was also a significant factor in favour of co-mingled and two-stream collection, due to the higher yields they were assumed to achieve within their recycling collection systems. However, the impact of residual disposal was tempered somewhat in the enhanced performance scenario, due to the assumption that residual waste would be incinerated with energy recovered via CHP, in line with WAG objectives. This meant that, in the enhanced scenario, the impact of disposing of rejects and process losses was a more significant driver of the overall results than the impact of residual waste disposal.

7.3 Conclusions

It clearly must be acknowledged that a project such as this is not likely to 'put to bed' a debate so long-standing and often polarised as that between supporters of co-mingled and kerbside sort collection. However, it does bring together thinking and evidence accumulated over a long period and supplements this with new data on the fates of materials that are likely to typify the different collection systems. It suffers the limitations associated with all modelling-based analyses, but does draw logically on a large amount of data from real schemes. Overall, we hope that readers and policy makers will agree that the assumptions and methodology used have been reasonable and have not biased the analysis in favour of one collection system or another.

In our analysis, the kerbside sort option consistently out performs the other two options, with the only exception being in the case of environmental cost in the current performance sensitivity scenario where biogenic carbon emissions are included within the analysis, where two-stream performs marginally better than kerbside sort. In the enhanced performance scenario, the apparent advantages of kerbside sorting are particularly marked, with two-stream only marginally outperforming co-mingled collection against both financial and environmental metrics in the central scenario. At current performance levels, the picture is somewhat different, with all systems more closely matched and two-stream collection performing only marginally less well than kerbside sort.

Where the cost of waste collection and disposal, revenue from the sale of recyclable material and the cost of processing material at a MRF are taken into account, our modelling suggests that rolling out kerbside sort collection across the whole of Wales would result in lower financial cost than either co-mingled or two-stream collection. In the current performance scenario, the difference in cost is relatively small, with co-mingled collection costing £5.2 million (or 4.3%) more per year than kerbside sort and two-stream being only marginally (less than 1%) more expensive than kerbside sort. However, in the enhanced performance scenario, the cost gap is much greater, with co-mingled and two-stream collection costing 22% (or £25.2 million) and 21.4% (or £24.6 million) more respectively.

The environmental modelling considered both carbon emissions and air quality impacts, with the projected emissions being monetised for the overall cost-benefit analysis using well established damage cost assumptions. In the current performance scenario, kerbside sort performed best in terms of overall carbon emissions, with two-stream resulting in a 9.6% greater emission of CO_2 equivalent and co-mingled collection 13.9%. In the enhanced performance scenario, all options delivered a net carbon emission benefit due to the benefit of increased recycling offsetting the combined impact of collection, sorting, transport and disposal. However, again kerbside sorting appears to offer the greatest benefit, contributing a reduction in emissions equivalent to 226,000 tonnes of CO_2 per year. Carbon emissions benefits were calculated as being 25% lower for co-mingled collection and 18.3% lower for two-stream collection in the central scenario.

When both carbon emissions and air quality impacts were considered and the projected emissions monetised, the performance of the options was much closer in the current performance scenario, with the pattern very much following that exhibited by the financial cost results. In this scenario, the overall environmental cost of kerbside sort was lower than the other two options, at £50.6 million per annum. The environmental cost of two-stream collection was only 0.9% greater than kerbside sort, whereas the overall environmental impact of co-mingled collection was 5.8% higher. In the enhanced performance scenario, the relative performance gaps widen considerably, but in the context of a much lower environmental impact for all options, due to the benefit associated with increased recycling.

In terms of quantifiable difference in social impact between the options, the primary focus of the study was on employment intensity. Our analysis suggests that more full time equivalent jobs would be created if all Welsh authorities adopted a kerbside sort methodology where current performance is assumed, but in the enhanced performance scenario, more jobs would be created in two-stream collection. Co-mingled collection ranked in second place for job creation in both scenarios, but in both cases the range from best to worst performing was quite narrow. In terms of employment and the other potential social impacts considered, no pattern emerged that would contribute substantially to differentiating between the systems, although some qualitative differences clearly do exist between them. Social impacts are far from straightforward to quantify and compare on a like-for-like basis with financial and environmental considerations and, as such, we would conclude that considerable further study would be required to obtain a significantly clearer overall picture.

Again, the picture regarding relative health and safety implications was inconclusive. In our view, this area clearly does warrant further study, alongside potential reform of the reporting requirements by employers in the waste management industry. It is possible that a major study of collection system specific health and safety issues could lead to clearer conclusions being drawn, but we would be concerned that this could be a distraction from the overall need for our understanding of the key risk factors in waste collection to be improved. In our view, any such study should have a wider scope, considering working practice issues such as 'task and finish' and risk management practice alongside collection system variables. However, it is clearly also important that the duty of care of local authorities as employers and commissioners of services is acknowledged and that, in the absence of clear generic evidence one way or the other regarding collection systems, risk assessments for specific systems in specific areas will be factored in to local decision making processes.

In the context of the *Towards Zero Waste* 70% target, a number of interesting and potentially important observations can be made:

- The apparent advantages of kerbside sorting when considered in financial and environmental terms appear to increase as recycling performance increases. In turn, the advantage of two-stream collection over co-mingled collection appears likely to narrow as performance increases. These results, even if not completely accurate, suggest that Welsh local authorities will face a challenge in adapting collection systems that may work well now, but may become increasingly sub-optimal as recycling levels increase towards the 70% target.
- One strategic challenge thrown up by the study is the need to focus some effort on textiles recycling and reuse, beyond simply assuming that conventional kerbside collection and bring systems will deliver the kinds of capture rates (and significant associated environmental benefits) likely to be required for the 70% target to be obtained. Achieving high levels of capture of the textiles currently finding their way into residual waste is likely to require a multi-pronged and innovative set of strategies, potentially involving partnerships with textile recyclers and charities, rather than traditional, local authority led collection systems. This seems likely to be all the more important in a situation where co-mingled collection continues to be used by a significant proportion of Welsh authorities.

Although our collection cost modelling is clearly imperfect, not least because it relies to an extent on extrapolation, it presents a sharp disparity with, for example, the results of current collection cost analysis carried out by the Welsh Local Government Association. We are confident that our models are accurate enough to demonstrate that there is considerable room for further optimisation and improvements in efficiency and productivity in Welsh waste collection systems. It seems essential that WAG works collaboratively with local government in Wales to deliver the kinds of collection systems that are capable of delivering cost efficient, high performance in the face of the short to medium-term constriction in resources likely to be faced by local authorities.

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