Creating markets for recycled resources

R&D Report: Glass

Increasing collection and recycling of post consumer domestic window waste

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Glossary

Bar length - A length of window frame, commonly one of the outside edges.

Beading – A length of material used to hold glass in a window frame. As the frame is not constructed with the glass inside, the frame is designed to have a separate backing. The glass is put in place and the beading is used to seal the reverse side of the frame holding the glass in place.

Coning sample – A three dimensional cone shaped sample method.

Crittall – A specific steel window material. Crittall is also a brand name.

Deconstruction – Breaking down of a window into the different materials and parts

Extrusion – The method used to manufacture PVC-U profiles.

Fitters – Also referred to as installation operators, fitting teams and fitting crews

Galvanised steel – Steel that has been coated with a layer of zinc metal.

Gasket – A rubber shock seal used to secure glass into PVC-U windows and hold it firmly in place.

Jazz –.Common term used for non white PVC-U profiles

Long life post consumer windows – Waste windows coming out of a property after a period of usage.

Mastic – A silicone based material used to secure windows into wall cavities.

Material ratchet – A strong material strap with a ratchet attached, used for holding items in place.

MRF – Material recovery facility

Material Reprocessor – This phrase refers the party involved in the conversion of one processed material to another.

New build – Phrase used to describe the construction of new buildings.

Occurrence – For project context, occurrence relates to the frequency of window type arisings in the sample population

Post consumer – In most case, to window fabricators, post-consumer windows are windows that have been sold to a customer whether it has been used or not. See short and long life post consumer windows.

PPE – Personal Protective Equipment i.e. high visibility vest, goggles, gloves etc.

Profile – The cross section of a bar length of a window frame.

PVC-U – Un-plasticized polyvinyl chloride, the main plastic used in window manufacture.

Ratchet – A mechanism consisting of a pawl that engages the sloping teeth of a wheel or bar, permitting motion in one direction only.

Reverse logistics – A business term for operating a return or take-back system.

Short life post consumer windows – Windows sold to customers but not installed and returned for various reasons, e.g. mis-sized or death of customer.

Spatial pyramid – A method of applying a pyramid shape to choose sample areas in a pile of material.

Transom mullion – Also known as crucibars, this refers to the cross structure of the window. These lengths of material separate glass panes in a window and are the housing and support structures for window casements.

Window waste producer/Site operator – The party involved in producing window waste materials i.e window replacement or installation companies.

Window waste processor – The party involved in deconstructing windows, segregating and possibly size reduction of the different materials.

Executive Summary

The aim of this project was to undertake trials in order to understand the practical, technical and economic viability of collecting, processing and re-processing post consumer window waste. This report presents findings that industry can use to facilitate increased window waste recovery for recycling. The information generated by this report can also be used by the Waste and Resources Action Programme (WRAP) to familiarise itself with the opportunities, barriers and concerns with regards to recovering window waste for recycling and assist industry.

Industrial project partners played an active and important role in the project, including access to sites, collection and analysis of samples and provision of data and information. The project benefited from vital information from key project partners in terms of sharing their experiences and economical requirements of the various activities involving the processing of window waste.

The methodology undertaken included several key tasks:

- Designing a programme of 4 trial scenarios and collecting data from these trials in a harmonised form for final analysis on the technical, practical and economic feasibility of recovery window waste for recycling
- Presenting window waste composition and averages of the different window material types and styles in order to develop a prognosis tool for waste producers and processors to estimate the amount of material available to recover for recycling
- Developing 3 economic models analysing the feasibility of the trials.
- Analysis of the post consumer flat glass waste collected during the trial and facilitated the incorporation of that material into a fibre glass insulation production line.

The key findings of the project were:

- The majority of window waste is disposed direct to landfill or via a waste transfer station where superficial segregation is undertaken. This is not cost effective for the window waste producers.
- The total potential revenue from recovering the different window types varied from £0.24 for timber windows, £3.96 for metal and £4.10 for a PVC-U window.
- The economic modelling gives a threshold for when it becomes viable to recover window waste, depending on the collection system. This varies from 63 to 79 windows with landfill savings of £50 to £104.
- Health and safety issues are paramount in all activities involving the collection, processing and re-processing of window waste. These issues can be effectively managed by developing risk assessments and method statements.
- Data collected from a sample of 2,317 windows and 198 window parts showed that an average timber window weighs 29kg, an average PVC-U window weighs 39kg and an average window weighs 30.4kg. A 40 yard skip of window waste contains approximately 141.8 generic windows. Composition of window waste produced from client sites were 73% timber windows, 11% PVC-U windows, 11% metal windows and 3% composites. With regard to skip waste, 24% was general waste including composite windows, 66% timber windows and the remaining 10% PVC-U; metal windows do not usually go into a skip.
- The post consumer flat glass collected was reprocessed by Viridor Glass Recycling to meet the specifications of British Gypsum Isover; in total 42 tonnes of post consumer flat glass waste was used in the manufacture of fibre glass insulation, incurring no additional costs to the manufacturer or deviating from their usual routine.
- Dealing with timber window waste remains problematic as there is a lack of consensus on the hazardous nature of the waste and its acceptability for reprocessing, which can vary depending on the reprocessor.
- At least 5 different types of PVC-U material can be obtained from a PVC-U window. As the established market for post consumer PVC-U is largely clean, white profiles, it is recommended that one container be provided for all clean, white profiles while providing another container for mixed PVC-U materials.

Key recommendations include:

- There is requirement to work with the float glass re-melt industry to research into the feasibility of ultimately returning post consumer flat glass back into the production of flat glass.
- Subsidized or free consultancy, on opportunities to adopt any of the models trialled, should be made available for window replacement and waste management companies to seek advice and guidance on a company by company basis.

Contents

Acknowledgements

This work would not have been possible without the collaboration, cooperation and dedication from a range of Industrial Partners, BRE colleagues and representatives of the British Plastics Federation. Without the will from the industry to induce change and move forward, this project would not have been as successful as it has been. Similarly, the support and guidance given by Andy Dawe and Michelle O'Riley at WRAP during the project was greatly appreciated. The partners to the project were crucial to the successes herein and special thanks go to the various staff at BRE and the following companies:

Anglian Windows

Bowater Windows

British Plastics Federation

COSTdown

EB Enterprise

Ecoplas

Glass Technology Services

HW Plastics, Mansells

SIMS Recycling

Viridor Glass Recycling.

Introduction

This project was undertaken on behalf of the Waste and Resources Action Programme (WRAP). The project came about as a result of a previous WRAP funded BRE project. The former project identified sources of waste flat glass, timber profile and PVC-U profile from the demolition and replacement window industry that were suitable for collection, processing and recycling into new products. The key recommendation to WRAP, in that project was that industry should be given some assistance in establishing a network of collection, storage and processing facilities for post-consumer flat glass waste.

The aim of this project was to undertake trials in order to understand the practical, technical and economic viability of collecting, sorting, processing and re-processing of window waste. The idea is that information generated can be used by industry to facilitate increased window waste recovery for recycling.

The objectives of this project were to:

- Provide a framework of variable methodologies for increasing the collecting, sorting, processing and re-processing of flat glass and framing materials arising from post use domestic windows using data, information, good and better practice gathered from a series of practical trials across the UK.

- Design, manage and undertake five parallel practical trials in the UK using a selection of large and small companies across the supply chain that use complimentary as well as diverse methods of collection, sorting, processing, re-processing and disposing of waste flat glass and framing materials.

- Develop a harmonised, practical and cost-effective quality control protocol for identifying, recording and monitoring the quality of flat glass and framing materials being collected, sorted and processed from the practical trials.

- Identify, audit, document, assess and report on the technical, practical, commercial and economic viability of the variable methodologies and indicate how the framework can be promoted, accelerated and exploited by industry using a good practice tool kit.

BRE achieved the above through a series of tasks and they were:

- Designed a programme of 4 trial scenarios and bringing together a strong partnership of key stakeholders in the activities of collection, processing and re-processing of window waste materials.
- Co-ordinated and managed the 4 trial scenarios of 3 phases
- Collected data from the trials in a harmonised form for final analysis on the technical, practical and economic feasibility of recovery window waste for recycling.
- Held workshops after each phase of the trials (3 workshops) to facilitate good and better practice that can be adopted on the next trial phase and for the production of a good practice guide
- Developed an onsite quality control plan for identifying the quality of PVC-U materials and glass recovered for re-processing
- Presented window waste composition and averages of the different window material types and styles and developing a for waste producers and processors to estimate the amount of material available to recover for recycling
- Developed 3 economic models looking at how to make each model economically viable.
- Investigated current markets and opportunities for PVC-U and timber window waste
- Analysed post consumer flat glass waste collected during the trial and facilitated the incorporation of that material into a fibre glass insulation production line.
- Develop a good practice guide through consultation with the industry.

Parallel Programme of Trials

Methodology

The trials were conducted simultaneously, running in parallel with each other over three phases of the project. At the end of each phase, a workshop was held where key partners assembled to discuss the trials to date and share information and experiences to enhance the next phase. The trials shared a few commonalities in the nature of the partners' contributions. In general, partners operated either one or a combination of four key roles:

- Window Waste Producers/Site Operators (SO)
- Window Waste Collection (WC)
- Window Waste Processors (WP)
- Material Reprocessors (MR)

Data collection sheets were developed, for individual project partners, to aid in the collection of relevant data. Modifications to the data collection sheets were made during the trial and in some cases project partners were allowed to collect the required data by using existing company data collection methodology. Frequent site visits to trial sites were conducted to process map current practices, interview site operators, investigate good and better practices, collect data and conduct interviews with upper management.

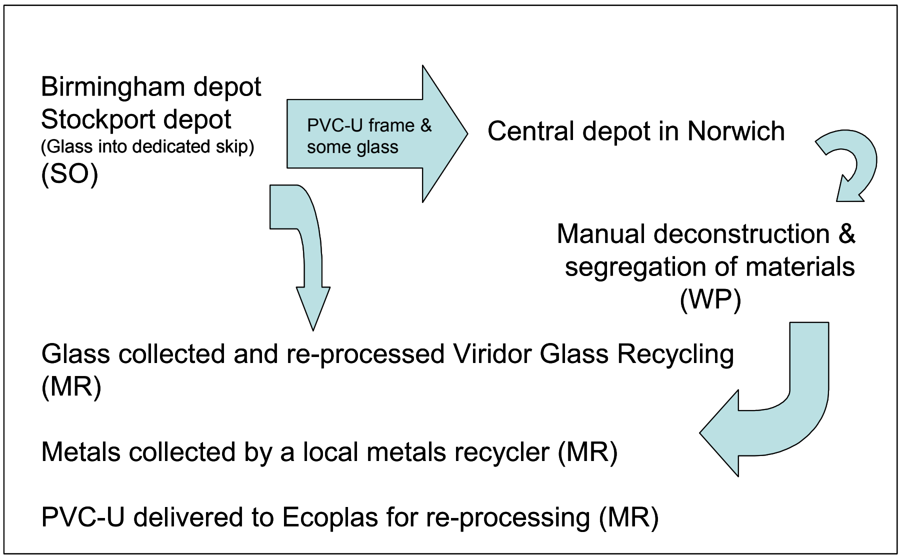
Glass skips were provided by Viridor Glass Recycling, a national glass recycler, at all trial sites and collected when full. All glass collected were transported to Viridor Glass Recycling's depot in Peterborough providing an audit trail. Twenty samples of glass were collected from all trial sites including the Peterborough site. These samples were delivered to Glass Technology Services for analysis. At the end of the trials, all glass was transported back to Viridor Glass Recycling's main site in St Helens for batch testing and re-processing. The re-processed post consumer flat glass waste was then delivered to British Gypsum Isover, a fibreglass insulation manufacturer, to be incorporated back into their manufacturing process.

Trial 1. Reverse Logistics

Employees remove windows and return waste to a central depot

The reverse logistics/take back scheme was conducted to collect post use window waste from installation depots (replacement window company) and delivered to central window fabrication site for deconstruction and removal of fixings. The separated glass and framing materials is then collected and transported by/to relevant material reprocessing companies. The locations of area depots in trial 1 include Birmingham and Stockport and the central depot was situated in Norwich. Figure 1 describes the flow of activities and materials.

Figure 1. Reverse Logistics



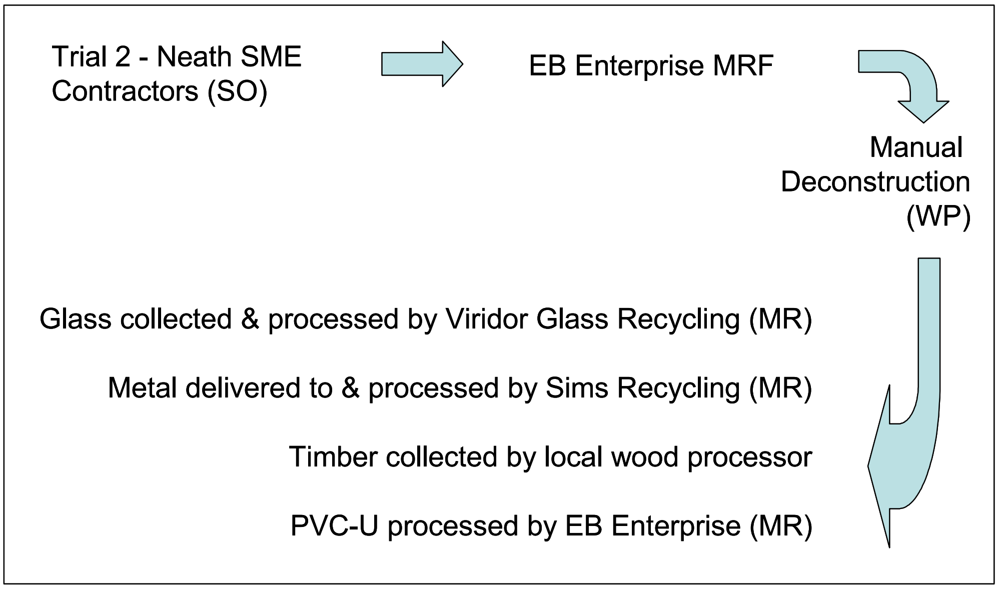
The key partners for Trial 1 were Anglian Windows, Ecoplas and Viridor Glass Recycling. For the purpose of the trials Anglian supplied three working depots operating a take-back scheme. Stockport and Birmingham are window replacement depots facilitating the company's employed fitters. Unavoidable glass waste removed onsite were returned by the fitters from installation jobs and placed in the glass skips provided by Viridor Glass Recycling at the Birmingham and Stockport depots. No deconstruction was conducted on these sites. No unnecessary glass was removed from metal or timber windows. Metal window waste was taken by local merchants and the remaining timber window waste was disposed of into general 40 yard waste skips. PVC-U windows, including short life window wastes, containing some glass were transported back to the Norwich site for deglazing and deconstruction. Glass skips were also provided at the Norwich depot and are collected on demand. The processed PVC-U was delivered in bar lengths to Ecoplas, a specialist PVC-U reprocessor for reprocessing into granulate. The PVC-U granulates wee then sold back to Anglian to be incorporated back into their manufacturing process.

Trial 2. Collection Point System

SME contractors removes windows and return window waste to a central collection site.

A collection point (a specialist window waste material recovery facility run by EB Enterprise) was utilised by small and medium sized (SME) independent replacement window contractors, of Bowater Windows, to deliver their window waste for processing. Figure 2 shows the flow of activities and materials in this trial.

Figure 2. Collection Point Scheme



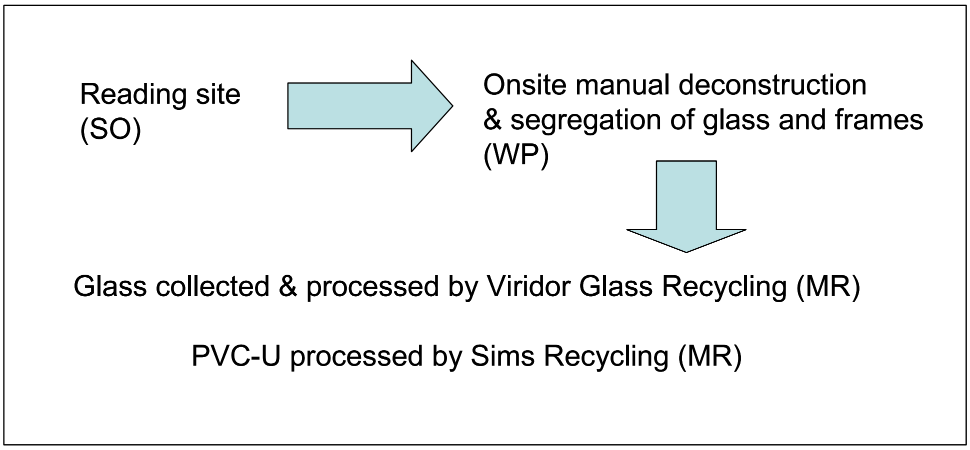
Key partners for Trial 2 were Bowater Windows, EB Enterprise and Viridor Glass Recycling. For the purpose of the trials, Bowater window replacement contractors delivered their window waste to a central collection point situated a couple of miles away from the Bowater installation depot in Neath. EB Enterprise then deconstructed the windows manually segregating as many materials as possible. Glass waste was removed by Viridor Glass Recycling, metals were collected and re-processed by Sims Recycling who supplied their own skip and haulage, and similarly, timber was collected and re-processed by a local wood reprocessor. PVC-U waste was re-processed on site by Welsh Plastics, owned by EB Enterprise. Welsh Plastics' market includes UK, Europe and South East Asia.

Trial 3a & 3b. Onsite Segregation

Deconstruction of window waste on project site in a secured compound.

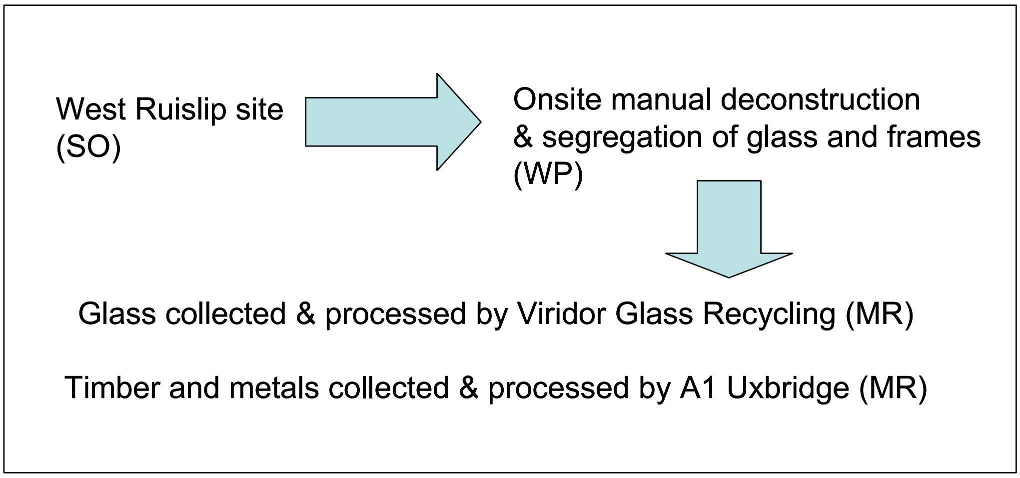
This trial involves the delivery of window waste, by window replacement teams from refurbishment projects, to a secured compound onsite for deconstruction. Window wastes were manually deconstructed on site by dedicated staff and segregated materials stored in dedicated skips to be collected by material reprocessors. The location of trial 3a (figure 3) is at Reading and 3b (figure 4) at West Ruislip, London.

Figure 3. Onsite segregation at a big refurbishment project on trial 3a



The key project partners, for trial 3a, include HW Plastics, Viridor Glass Recycling and Sims Recycling. The Reading site is a PFI (Private Finance Initiative) refurbishment project managed by Wates Construction. The window replacement contractor, Dorwins, was replacing mainly PVC-U windows in this project. The windows were removed within 5 miles of the centrally located deconstruction compound. The waste management contractor was BKP. Post consumer window wastes were delivered by Dorwins' window replacement team to the allocated compound onsite, where dedicated staff monitored waste management activities and deconstruct windows for material segregation. The glass removed was placed into a skip provided by Viridor Glass Recycling. The segregated PVC-U frame waste was delivered by BKP to Sims Recycling in Stratford for mechanical re-processing. Cutting equipment and corner crackers were trialled in a volume reduction exercise.

Figure 4. Onsite segregation at a small refurbishment project on trial 3b



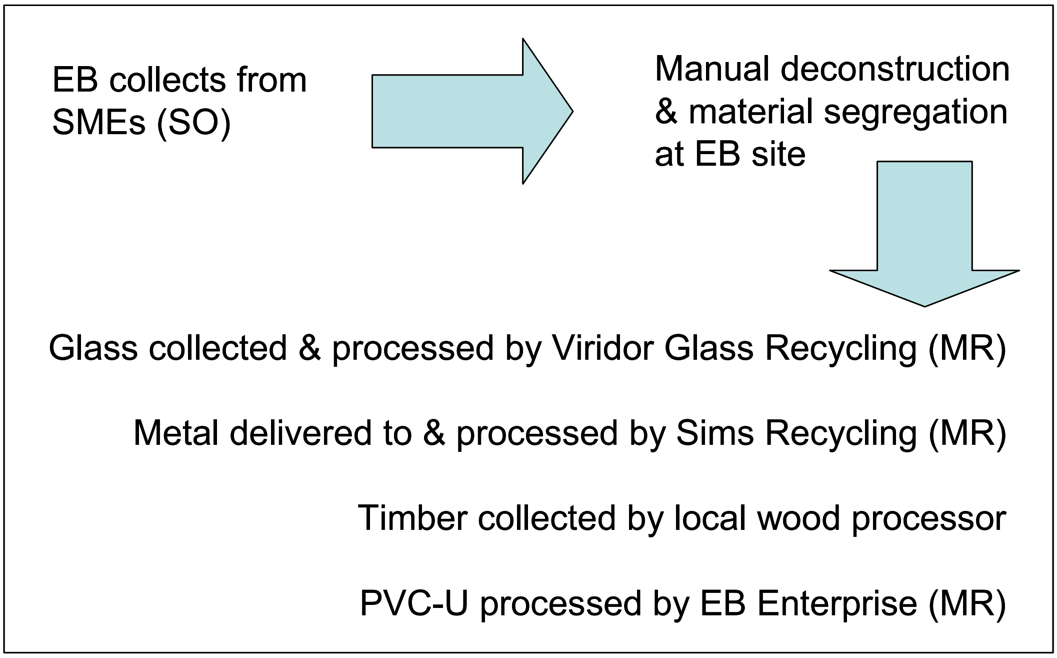
Key project partners for trial 3b were Mansells Construction and Viridor Glass Recycling. The site in West Ruislip was a small refurbishment and a new build construction project. The window waste was generated and deconstructed on the construction site and was processed by a dedicated labourer supplied by Mansells. As this was a small refurbishment project, window waste was stored until the number of windows to be processed was deemed enough work for one full day before any processing of window waste was conducted. All window waste produced was timber with double glazing units. Timber window waste was placed together with other timber waste generated onsite, similarly with metal wastes. The timber and metal skips were removed by Al Uxbridge (owners of a nearby waste transfer station) to be delivered to relevant material reprocessors. The glass was collected by Viridor Glass Recycling.

Trial 4. Collection Round System

A dedicated van picks up window waste from SMEs en route and brings it back to specialist site for deconstruction

Window wastes were put aside by 5 SMEs to be collected by EB Enterprise on a collection round (figure 5). This trial was limited to collecting a few windows from each participating SME contractors due to the lack of storage space at their installation depots. This lack of space was mainly due to the fact that the trial was running concurrent with their existing waste management services. The data collected from this trial was supplemented by data collected from an earlier, larger scale trial conducted by EB Enterprise themselves, prior to the start of this project.

Figure 5. Collection Round Scheme



The key project partners in trial 4 were EB Enterprise and Viridor Glass Recycling. EB Enterprise supplied a transport network, collecting window waste from 5 local SMEs. These materials were collected by a contracted van driver and delivered to EB Enterprises in Neath. The window wastes were deconstructed onsite and materials segregated as per trial 2. EB's waste flat glass was collected by Viridor Glass Recycling, the metals collected by Sims Recycling, timber collected by a local reprocessor and the PVC-U re-processed on site by EB Enterprise.

Data Collection and Analysis

Data collection was conducted using select methodologies to identify, audit, document, assess and report on the technical, practical and economic viability of the five practical trials in a harmonised form so that the information could be used by industry. BRE used a range of data collection sheets, questionnaire survey, interview sheets, site visit reports and process mapping to record information on the collection, processing and re-processing of flat glass and framing materials from the trials. Project partners working on the trials were asked to record information and data either through data collection sheets provided or using current company specific data collection methodology.

Personal interviews, with both site operators and upper management, were conducted to chart current practice and to investigate good and better practice. Specific cost details from the project partners and the associated companies was also gathered to build-up an overall picture of the costs involved in the entire process of replacing windows and dealing with window waste. Interviews were designed to supplement other aspects of data gathering to give a more complete view of the processes involved. Although data collection sheets, interview sheets etc were developed, they served as guidelines as to what types of information were required to be collected. All data collected including commercially confidential information has been delivered to WRAP. This report does not include information deemed confidential by project partners.

Site visits were conducted to process map activities on site both at the macro and micro level. These visits were conducted to identify common practice including examples of good practice contributing to the good practice guide. The macro mapping process consisted of recording the overall activities on the site associated with the trial. This involved identifying the individual processes and identifying how these worked in conjunction with each other. The micro mapping process focused on the individual activities in more detail, recording timings, throughputs and associated issues as well as health and safety aspects to produce a concise working model of each process.

Daily data collection sheets were developed to acquire details on various aspects of post-consumer windows being removed by window installers. These were supplied to the relevant project partner to review and tailored to better facilitate ease and accuracy of information gathering. These sheets were completed by window fitters on a daily basis. An example copy of the Window Waste Producer daily collection sheet can be found in the appendices. Other daily data collection sheets were designed by individual project partners to record process throughputs. These include window processing, specifically manual and machinery processing. All data collection sheets were collected and data analysed by BRE.

Trial Findings

Window Wastes

The window replacement industry generates waste at many different points of the supply chain. In this project, window wastes refer to short life and long life post consumer windows (see glossary for definitions) and not manufacturing waste i.e. post industrial waste. Window frames are tailor made to suit the customer. They are "made-to-measure" making them impractical to reuse, hence recycling being the more feasible best practicable environmental option (BPEO).

At the installation site (customers' property), a fitter team will remove the protective packaging consisting of plastic covering, rubber glass protectors and sometimes cardboard necessary to protect the window on its journey. While the window is fitted, the installation process will generate waste other than the packaging materials such as mastic cartridges, PVC-U off cuts, sometimes masonry and plaster and various assorted waste (boxes of nails, screws, raw plugs, tissues, drinks containers etc). All this waste is removed from the customers' home and transported by the fitters in their van back to their depot where it is disposed of. The majority of all waste generated by the window replacement industry comprises of the replaced windows themselves. It is this window waste material that this project concentrate on. Replaced or "post-consumer" windows can comprise of timber, PVC-U, aluminium, Crittall steel or a variation of composite materials (a combination of two of more materials).

Flat glass window waste – Glass in a window may be coloured, patterned, leaded, Georgian wired, Georgian bar, reinforced, laminated, toughened, and single or double glazed. If the window is double glazed, the volume of flat glass waste will be doubled. Double glazing units (DGU) does not simply comprise of glass. The two pieces of glass are held together in an aluminium casement, held together by strong binding tapes and adhesives. The DGU frame is designed with a series of breather holes between the two glass panes, which allows moisture to be drawn out of the unit into the casement which is filled with silica gel to prevent the glass from misting-up.

Timber windows may be made of various types of hardwoods or softwoods each with its own unique properties. The wood may be painted, treated or any number of combinations of processes used to preserve and protect the wood when it was initially installed and possible additional applications during its life span. Timber windows will have fixtures (such as handles) and fittings (such as brackets), these are usually metal and can be made from brass to aluminium depending on the age of the window. Some modern fixtures may be laminated metals. A timber beading is used to fasten the glass into the frame. The beading and glass is held together in place by nails and sometimes mastic or stronger adhesive and sometimes a security tape. Security tape is designed so it cannot be easily removed. This tape is very strong and makes it very difficult to separate the glass from the frame.

PVC-U windows consist of PVC-U profiles and include aluminium or a galvanised steel reinforcement bar inside the profile. This is held in place by a series of screws. The frame also has fixtures and fittings that can be made from a variety of materials similar to those used on timber frames. Glass held in a PVC-U window is secured in place with a rubber gasket and fastened into the frame by a PVC beading. This beading has a rubber layer that holds the glass in place under pressure.

Metal windows are either cast steel, Crittall or aluminium constructs. These are usually composed of a single material or combination of two or three materials. As metals recycling have been a long established trade, metal window wastes seem to be less of an issue. Most metal window wastes disappear on appearance at disposal sites due to long established unofficial agreement, usually between the waste producer and the local entrepreneurial individual. Composite windows are made from a combination of materials, these are usually metal and PVC-U, but can, on rare occasions, consist of other combinations. Aluminium frames are the more common of these lesser used materials, aluminium frames are screwed together and often contain security tape.

When considering long life window waste and contaminants, one must take into consideration that the post-consumer product has been removed from a wall cavity. When the frame was first installed it will have been fixed in place using cement, mastics, foams/fillers and various adhesives depending on what was necessary or available at the time of installation. It must also be noted that during the life of the window it may gather other materials that, when removed, will constitute a significant contaminant in terms of recycling. These may be due to refurbishment by homeowners e.g. bathroom and kitchen refurbishments which may require tiling to the window frame or painting of the PVC-U frames on the inside to match lounge colours etc.

Industry Roles and Processes

This section describes the different roles played by the project partners. Each role have been investigated to look at the issues (e.g. health and safety), activities, barriers and opportunities involved in recovering window waste for recycling. Roles covered include waste production by SMEs, waste production by reverse logistics, window waste collection and window waste processing.

Window Waste Production by SMEs

Fitters (frequently referred to as installation operators, crews or teams) removes the window waste from customers' homes, store them temporarily in their vans and then transport them back to their offloading point. This offloading point is usually the installation depot where they can pick up the new windows for their next job at the same time.

The two peak times of waste material movements are identified as usually either early morning or late afternoon/early evening. During the main working day there will be very little or no window waste being received. Any consideration given to segregation activity planning must take this into account. An opportunity exists here for part time segregators, possibly expanding the role of yard or warehouse personnel to involve helping the fitters unload and segregate.

Storage of materials for transport from a job site is often something not given much consideration by installation staff. More often than not they are in a rush to get to the installation depot, offload the window waste, reload new windows and finish for the working day. All forms of encouragement by the window manufacturers or window replacement companies will be required to gain cooperation by the ground staff, with regards to window waste segregation.

The other offloading point, other than the installation depots, identified in this project is EB's specialist window waste recovery facility. This is a unique operation and offloading point but the opportunities and health and safety implications are the same from a fitter's point of view.

Waste Disposal Costs

40 yard skips with gantries for access are commonly provided at installation depots. These are general skips sent directly to landfills or sent to waste transfer stations for superficial material recovery before sending to landfill. The skips are usually replaced daily depending on the depot size. Companies are currently charged per lift, per skip plus per tonnage costs. The cost of the current waste disposal option mentioned above, discovered in this project, is averaging at about £130 per 40 yarder per day. An installation centre replacing two 40 yarders per day in a 21 day month, pays about £5,460 per month in waste disposal cost. An important factor to consider when looking at these costs is that, according to project partners participating in the trials, on average of ten 40 yarders paid per year is flytipping waste. This equates to paying approximately £1,300 (not including tonnages) to dispose of someone elses waste.

The EB method described in Trial 2, where window waste was off-loaded directly onto the EB site reduces flytipping incidences leading to an immediate direct saving of £1,300 depending on the cost structure. Due to commercial confidentiality, the price structure of EB Enterprise will not be disclosed in this report but interviews with EB Enterprise and Bowater Windows has shown that a savings of up to 8% - 10% in disposal cost can be achieved in the Trial 2 Collection Point and Trial 4 Collection Round Scheme.

Health & Safety Issues

There are significant health and safety issues involved with waste window materials, glass in particular. It is never a good idea to have installation staff deglazing a window unnecessarily on site. In certain processes of window removal, deglazing might be necessary to gain access to the frame. These glass panes are usually removed whole and then require storage for transport. For most DGUs, the health and safety issues are not as predominant as it involves removal of the whole DGU unit. Current windows being replaced, however, are mainly single glazed windows and single glass panes break easily in transit. It is advisable that a system be put in place to store and transport glass. One possible solution tested in Trial 3a was to have a tailor-made box in which the glass could be stacked and contained. The design of the box must be well thought out to suit working and vehicle conditions. Another possibility, not trialled, would be to sandwich the panes between two sheets of plywood and ratchet them together. This keeps the glass protected, separated and immobilised so that if the glass does break, it is kept snug and tight between the plywood pieces.

Opportunities and Barriers

To encourage fitters to aid in the separation of materials, there must be some sort of incentive for them or at least not be significantly inconvenienced. Recycling incentives or savings in reduction in disposal costs passed down and shared by all parties involved in the process would encourage better waste management by on the ground staff.

Encouraging fitters to keep materials separated for transport from the job site to the depot is difficult. Fitters want to unload as fast as possible, yard staff wants to get the materials separated as fast as possible. If they can be encouraged to work together, then it will be in the fitters' interests to keep materials clean and separate for transportation. By having the fitters assist the yard staff to segregate and the yard staff assisting the fitters to unload, this will help keep materials clean and help both parties perform their tasks more efficiently. EB staff has found that certain fitters would be more cooperative than others, putting the different type of material waste in the right place. The cooperative fitters can be identified by the state of their vans. It has been observed that fitters with a clean and tidy van tend to get in and offload quicker as their waste has more or less been segregated at source i.e. customers' property. An untidy and dirty van owner typically spends longer time sorting the waste within the van at the disposal site in order to be able to place segregated waste in the required areas. Generally, a tidy van will have general waste and sweepings in a waste bucket while an untidy van will have waste strewn all over the van and will need to tidy up before leaving the offloading point.

A well organised, clean van is essential. One of the biggest contaminants during transport is dust sheets used to protect customers' property. As these cannot be shaken out on site, they are gathered up with all the dust and dirt from the job site and taken back to the depot to be emptied there. If there is no proper storage area for these then they must sit in the back of the van. As these sheets are the last thing removed from the site, they are often placed on top of the window waste just before the van leaves site. These sheets are often covered with bits of fresh mastic sealant from the new window installation which can be transferred directly onto the window waste creating an artificial, but significant contamination of material. A designated area to contain dust sheets during transportation after a job is recommended.

Window Waste Production Using Reverse Logistics

Unlike the Bowater Window scheme where contracted SMEs are the producers of window waste, Anglian have arguably better control over schemes introduced as they deal with employees. The overall reverse logistics process is incentivised at the regional depots. They receive a payment directly from the PVC-U reprocessor depending on the quality and amount of material they return to their main depot. This, coupled with a reduction in the regional depot's disposal costs is the driver for a successful scheme. This system will work better if the incentives are noticeably passed down the chain so that everyone involved in the process benefits, especially the fitters.

This system already works for short life, pre-installation, windows. As the network is already in place Anglian is currently trialling the recovery of long life post consumer window wastes. The Birmingham and Stockport depots were used in trials for this project. If the central depot develops the ability to deal with timber, then the only waste that would need to be disposed of at the regional depots would be the glass removed during window extraction and general waste.

This trial showed that contamination is a significant barrier to the recovery of window waste materials. Most PVC-U reprocessors will not accept contaminated material. It is simply too costly to clean it to the required standards. Viridor Glass Recycling will not accept glass skips with certain contaminants as it would be more cost effective for them to dispose of contaminated glass skips to landfill directly than to risk their clients' delicate re-processing machinery. For this system to work, the glass waste will need to be free from contaminants at installation depots. PVC-U frame waste will need to be well deconstructed and segregated before transportation to Ecoplas from the Norwich site. The vital need for the materials to be free from contaminants in this trial is based on the fact that the materials recovered will need to be sold at a reasonable market price to reprocessors in order to fund the scheme but also with the goal to capitalise on the activity. As this is a unique operation within Anglian, a cost model has been developed to reflect the feasibility of such a scheme without the paraphernalia of being a PVC-U window fabricating company relying on post industrial materials to aid the recycling scheme.

Health & Safety Issues

Heath and safety issues remain the same for fitters transporting window waste to installation depots (see H&S section under Window Waste Production by SMEs). The main health and safety issue for reverse logistics of transporting window waste in a trailer once again is glass. Transporting glass like this requires all frames in the trailer to be securely stored to the point of immobilising them to prevent glass breakage where glass still sits in the frame. These can be fastened to brackets in the trailer and secured by a material ratchet. Transporting post consumer glass not in their frames in this manner would require the trailers to be fitted with significant hardware to store the glass, possibly a similar plywood system to that suggested for window fitters or a solid container.

Barriers and Opportunities

The main barrier discovered is making staff segregate waste at the installation depots. The PVC-U processing at the Norwich site is under controlled circumstances and materials are segregated into different grades to the satisfaction of Ecoplas specifications. The main issue lie in keeping materials clean at the installation depots. At the beginning of the trial, the glass skip provided was contaminated by general waste e.g. sealant tubes and drink cans. It was deemed a waste of effort to keep convincing fitters offloading the window waste to segregate the material into the proper skips.

The main issues with providing a glass skip at the installation depot were mainly the security of the skip and as mentioned guaranteeing the quality of the glass separation at the depots. Without precise instructions from the glass reprocessor, it was difficult to educate the yard staff and fitters as to what can and cannot go in the skip. Without some form of monitoring or quality control it is hard to enforce procedures. There is the added problem that if the skip is left without a lid or in a non secured compound, trespassers may contaminate the load. This may be malicious in the form of fly-tipping or innocent with someone delivering material to the site and not having been informed that the skip is for glass alone. Fly tipping impacts can be reduced by holding the skip in a secured compound, or supplying a lockable lid. Informing fitters of site procedures and visual assistance in the form of clear signs can help prevent innocent contamination.

A few measures were put in place parallel to each other to combat the problem. No specific measure was identified as improving the quality of segregated glass but they were all deemed as contributing factors. The new measures include:

- Fitters were instructed to leave DGUs and whole glass panes against the wall to be collected and handled by dedicated staff.
- The yardman in charge of helping the fitters load their new windows was assigned to help fitters offload and to place waste glass into the glass skip.
- The glass skip was placed a distance away from the general skip making it inconvenient for fitters to use it as a general waste skip.
- The glass skip was fitted with a lid and locks providing access only to the yardman.
- Signage was put up depicting what could and could not be put into the glass skip

This was not as big an issue for the Bowater Window trial as the fitters were assisted and guided by EB staff on a specialist site and mainly EB staff conducted the material segregation.

Window Waste Processing

This section looks at issues concerning H&S, barrier and opportunities and equipments trialled where appropriate. There are, as discovered by the project, various methods and circumstances involved in the processing of window waste. Deconstruction processes investigate in this project were:

1. Manual deconstruction on a construction site
2. Manual deconstruction on a specialist site
3. Manual deconstruction on a temporary site
4. Manual and mechanised deconstruction on a specialist site
5. Mechanised PVC-U frame deconstruction on a research site

Site visits were conducted, by BRE, for process mapping and to investigate good and better practice. Matrices of deconstruction methodology for deconstructing a PVC-U and a timber can be found in the matrices.

1. Manual Deconstruction on a Construction Site

Mansells Construction is the main contractor for a refurbishment and new build construction project at the RAF West Ruislip site. They were approached by BRE and agreed to participate in trialling deconstruction of the timber windows from their site, for the project. A labourer was assigned to deconstruct post consumer timber windows. The windows were generated at a slower pace then anticipated. To maximise efficiency and productivity, the windows were stored in a secured compound until a full day's worth of deconstruction activity was accrued (figure 6 & 7). Method statements were developed by Mansells to manage risks involved in the deconstruction of timber windows on a construction site. A summary of the deconstruction process can be seen in table 1.

Figure 6. Dedicated deconstruction area on a construction site

Figure 7. Deconstruction in progress

Table 1. Deconstruction process on a construction site

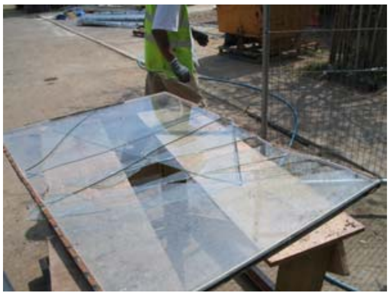
Action	Equipment Used	Description
Prepare area	N/A	Area is setup, bench put in place, tools and PPE delivered from site stores and glass skip fencing opened
Place window on bench	N/A	Window is moved from stockpile to deconstruction area
Remove beadings	Lump Hammer/ Guarded Chisel	Remove 4 beadings, these beadings are then placed into a wood skip
Remove locking bar and casement fixings	Lump Hammer	These are removed and placed in a receptacle to be put into a metal skip
Cut through the bottom bar length	Hand Saw	Cut halfway through the frame each time to expose the joints
Remove bottom bar length	Lump Hammer/ Guarded Chisel	Once joint is severed, knock the bar length out of its joints
Tap off the rest of the frame	Lump Hammer/ Guarded Chisel	Loosen the frame from the glass, lever the frame if necessary. Other 3 bar lengths are removed intact
Glass free and skipped	N/A	Once the frame is removed, the glass is left on the bench. This is then carried whole to the glass skip
Frame Skipped	N/A	Bar lengths are placed in wood skip
Tidy-up (if necessary)	Yard Brush/Shovel	Sweep up any broken glass and material, this is disposed of in general waste skip

Health & Safety Issues

- Manual Handling: For the purpose of this trial, the deconstructors were supplied with specialist gloves and Kevlar sleeves in addition to the regular PPE (eye protection, high visibility body wear, hard hat, optional ear protection and steel plated and toe capped boots). The gloves selected needed a non-slip coating for grip and had to be suitably cut, slash, pierce and abrasion resistant while not impairing manual dexterity. The selected gloves were fully compliant with BSEN388 cut resistance standards, the Kevlar sleeves were elbow-length.

- A guarded chisel was used to protect the workers hands.
- The frames being deconstructed were old DGUs glazed with non toughened flat glass. When the glass breaks during deconstruction (figure 8) the shards are very large. These shards are held in the aluminium spacer by a strong adhesive which is very flexible making them very dangerous and mobile. When this occurs, it is necessary for two people to move the glass from the bench to the skip. This was done with great care.

Figure 8. Broken glass issue



- Moving the frames from the storage area to the deconstruction area. Even though the frames were stored close by, they had to be lifted from a pile onto the bench. This pile gets lower every time a window is removed until it reaches the level of the pallet on which they were stored. These windows were sometimes in excess of 50kg and required two staff to be involved in this exercise.
- Moving the glass from the bench to the skip. Some of the DGUs were large and heavy, and the skip level is over waist height. For such large units, two staff were necessary to lift the glass up and over the skip safely.
- There was an associated issue with moving glass in that it may break while being moved. To minimise risk it was suggested that the pane should be carried by two staff, one at each end, and the glass be carried horizontally rather than vertically.

Barriers & Opportunities

- The main barrier is heath and safety issues but these can be overcome by trialling and developing method statements. There are always risks involved at a construction site or recycling facility. Depending on the level of risk and the activities involved, risks may not always be eliminated but can be managed.
- Considerations should be given to working in a sheltered area. This will eliminate dictation of work schedule by weather conditions.
- Opportunities to avoid minimise void space. The timber from the windows is placed into the timber skip in the form it is removed from the frame. This means that often there are three bar lengths still attached together. In some cases the whole wooden frame may be completely intact. If the windows were reduced to bar lengths, this would minimise void space in the timber skip.
- Contamination barrier. The glass is often heavily contaminated with putty or sealant (figure 9). If this issue can be resolved, the quality of the glass would significantly improve. Some sort of scraper or knife could potentially be used to remove this material.

Figure 9. Glass contamination

- The glass is placed into the glass skip with the aluminium spacer casings still attached. Due to the hazardous nature of the activity, the project partner involved was not willing to consider removing these casements. Again, if these casings could be removed safely, the cullet quality would improve significantly.
- Timber frames are often contaminated by nails. These may not be suitable for timber recyclers who do not have the facility to deal with this type of contamination.

- Broken glass on the ground is lost to general waste skips so as not to contaminate the rest of the cullet. If this glass could be isolated, there is a possibility that it could be kept in the recycling loop. This may be achievable by using a solid top workbench that is larger than any of the windows being deconstructed so any broken glass is kept on the table. Other possibilities may include deconstructing over a container or a sheet. It has been stated by Viridor Glass Recycling that glass lost to sweepings are so negligible in the grand scheme of things that it is not worth recuperating considering the risk of incorporating ceramics and stones into their re-processing system.

This trial shows that deconstruction of timber windows on a construction site is not an issue as long as health and safety issues are taken seriously and method statements adhered to. The deconstruction process becomes more efficient as the staff get acquainted with the activity. The deconstruction process reduced an average timber window to its component parts in just over 6 minutes. If the timber frame were rotten, it comes apart much easier and can be deconstructed in under 5 minutes. When glass breaks during deconstruction the process can take up to 12 minutes to segregate materials safely.

On refurbishment projects on a construction site, as oppose to dedicated window replacement projects, material waste is produced by many different trades, and if segregated, are placed into communal segregated skips. This makes quality control a more difficult task. Also, it was not possible to affirm that any reduction in disposal cost was due to a specific waste i.e. timber frame waste as oppose to timber fencings or dimensional timber.

2. Manual Deconstruction on a Specialist Site

The unique business of EB Enterprise was brought to BRE attention by Bowater Windows in an earlier WRAP funded flat glass project. EB Enterprise is a privately funded MRF specialising in the recovery of window waste in Neath, South Wales. Bowater Windows have been delivering their window waste to EB Enterprise for the past 2 years. Window wastes are off-loaded by Bowater Window contractors, with the help of EB site operators, to maximise efficiency and delivery of lesser contaminated materials for re-processing.

The site is specially catered to deconstructing waste windows (figure 10). There are space, facilities, equipment and tools available on the EB site that although is most efficient and safe when deconstructing windows, their process might not be replicable in other sites or situations i.e. a construction site.

Figure 10. Glass segregation on a specialist site

The EB site provides skips for glass, metal, timber, rubble and PVC-U as well as a general waste skip. Waste windows are deconstructed; segregated materials are cleaned if necessary and stored appropriately (figure 11).

Figure 11. Prime quality post consumer window flat glass waste

Table 2. Summary table of glass processing methodology for all window types on a specialist site

Action	Equipment Used	Description
Prepare area	Yard brush/ Shovel/ Forklift/ Tipper-Skip	Small tipper skips emptied of general waste using forklift. Working area is swept and deconstruction tools fetched.
Remove fittings/fixtures	Screwdriver/ Lump hammer	Fixtures and fittings removed and stored in buckets.
Place window in the skip	N/A	Window or DGU's placed into the skip from stockpile.
Break glass out of frame	"Basher"- A length of hardwood.	Glass is smashed out of the frame over a tipper skip at a level below waist height.
Remove remaining glass	Long-nosed pliers / Claw hammer	Glass shards remaining in the frame are removed.
Segregate frame materials	Screwdriver	Timber frames broken to bar lengths and placed into stills. Metal frames unscrewed. Solid metal frames stacked and stored whole.
Tidy-up area	Yard brush/ Shovel	Clean up any materials spilt.

Table 3. Summary table of PVC-U frame waste processing methodology in a specialist site

Action	Equipment Used	Description
Prepare area	Yard brush	Area is only used for PVC-U frame deconstruction, never needs more than a quick sweeping.
Remove fittings/fixtures	Screwdriver/ Lump hammer	Fixtures and fittings removed and stored in buckets.
Remove beading	Screwdriver	Beadings levered off to allow access to the glass.
Remove gasket	Screwdriver & Claw Hammer	Gasket removed, comes away with no effort on DGU frames, and may require levering on single glazed.
Remove glass	N/A	Glass pane removed whole and taken to the main deconstruction area.
Remove transom mullion	Hand-held electrical saw	Saw used to cut transom mullions out of the frame.
Break the frame	N/A	Frame smashed on the ground on its corners to break the weld.
Gain access to reinforcement bars	Bench mounted reciprocating saw	Weld cut away from the main bar length if necessary to expose the reinforcement bar.
Remove holding screws	Power screwdriver	Remove the screws which hold the reinforcement bar in place.
Remove reinforcement bar	Long nosed pliers	Reinforcement bar tapped out of the frame on the edge of a bench. Difficult bars removed using pliers.
Store reinforcement bars	N/A	Metal bars stored in a skip.
Size reduce bar lengths	Bench mounted reciprocating saw	Cut PVC-U bar lengths into manageable lengths and stored in a still.
Tidy-up (if necessary)	Yard brush	Area may require a sweep to clean up screws or PVC-U shards.

Health & Safety Issues

- Glass removal is a hazard. This method employs a small "tipper skip" into which the glass is broken. The level of this skip is well below waist height to minimise flying glass shards.
- BSEN388 cut resistance standard gloves with a grip coating were used, as were Kevlar sleeves, tinted eyewear, steel toecap and plated boots and high visibility PPE. The workers were wearing short-sleeved tops so any shards of glass would not be held in the folds of the top to minimise any risks of getting cut later on.
- Special note should be made to the choice of eyewear. As a lot of the glass being deconstructed can sometimes be toughened and therefore shatter into the working skip, the glare on a sunny day can be almost blinding. This is why tinted eyewear is necessary. Such glare and light refraction from small particles of glass is a hazard in itself and possibly a concern for epileptics.

- The implements used to remove the glass ("Glass Bashers") are lengths of hardwood timber window profiles identified by the staff as usable. These have splinter potential, however, the gloves in use negate this risk.
- Glass dust rises from the skip when excessive amounts of glass is broken, this dust does not appear to rise above waist level, but there could possibly be breathing hazard issues associated with this. It is unclear how the strength of wind may effect this risk, whether the wind would disperse this dust, or mobilise it more to increase the chances on inhalation. In this instance, some sort of a face mask would be required.
- Deconstruction is conducted outside but is suitable for wet weather due to the choice of method used and the selection of PPE. The deconstruction area is also flood lit for any early morning or evening work necessary.
- When a window is delivered and it is so large that the removal of the glass from the frame can be dangerous. The method employed is for the window installation personnel delivering the materials to use their suction grips to remove the glass and place it directly into the larger glass skip rather than the smaller tipper skip.

Barriers & Opportunities:

A suitable yard must be kept clean at all times. A dirty yard encourages bad practices. If the yard is kept clean and the staffs take pride in their yard, it is more likely that fitters utilising the site will follow suit. A dirty yard may also lead to vehicle damage e.g. punctures and probable health and safety issues.

Apart from location and road access to the collection site, it is necessary for the site to be designed in such a way as to be able to facilitate the amount of traffic visiting the site. If the site is catering for 20 fitter crews and their vans, then the facilities must be able to cope with all 20 vans at the same time as they will occasionally all show up at the same time.

Having to queue and wait to be unloaded may cause fitters to simply dump their waste in the nearest convenient area of the yard. While this may on occasions be acceptable, it is certainly not ideal as it involves double handling of waste and the chances of material contamination increases. Consideration must also be given to access at peak times, if there is not enough room for a van to turnaround and leave the site, the first van into the depot may become trapped by the other vans arriving after them. If fitters are seriously inconvenienced by a collection point depot then there will be less chance of them complying with the system in place, this could lead to an unorganised, inefficient and chaotic site.

There are two distinct scales upon which this system may be built upon, by company and by industry. Company level collection point schemes can be tailored to the needs of individual depots with feasibility dependent on the installation centre's net profit (i.e. volume of waste produced), the area's best practicable environmental options (BPEO) and material reprocessors available within a certain radius in distance. The company might deem it advantageous to locate a waste collection point at the installation depot yard depending on space, or within close proximity of the installation depot. A dedicated member of staff can be employed to deconstruct the window wastes onsite and individual materials sold directly to material reprocessors instead of having a waste management contractor as middleman. This will not only reduce disposal costs for the company but can possibly be an income generating activity.

Industry level collection points would be duplicated EB sites strategically placed all over the UK catering to window waste producing companies within a given radius. These sites would ideally be located in window waste generation hotspots with good access and infrastructure.

3. Manual Deconstruction on a Temporary Site.

A big scale Private Finance Initiative (PFI) refurbishment project in Reading with an ambitious recycling target of up to 60% was introduced to the project by the British Plastics Federation. This trial (Trial 3a) involved providing the Reading project with a glass skip, a PVC-U skip and a dedicated staff for the deconstruction of PVC-U window waste. The Reading site had set up a secured waste management compound where different material skips were available to provide opportunities for recycling by the different contractors working with the different parts of the project. The main parties involved in this trial were Dorwins, a window replacement company and BKP, a waste management company. The staff dedicated to monitoring waste management activities onsite was to deconstruct waste windows during less peak times i.e. while fitters and other trades men were onsite at work. Power tools and PPE were supplied by the project to aid the deconstruction process. Prototype corner cutting equipment and corner crackers were trialled (figure 12 & 13).

Figure 12. Corner cutter trialled for volume reduction

Figure 13. Use of cordless power tools to aid deconstruction onsite

Table 4. Summary table of PVC-U frame waste processing

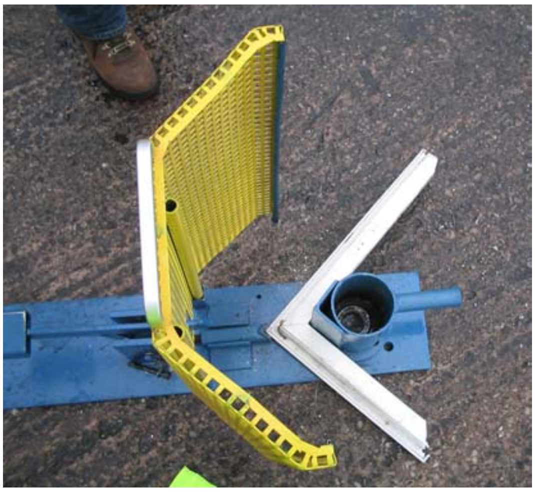
Action	Equipment Used	Description
Prep area	N/A	Fetch equipment from store area.
Remove gaskets	Putty knife	Gaskets removed and stored.
Remove beadings	Putty knife	Beadings levered off and stored.
Remove glass	N/A	Glass comes free once beading and gasket has been released. Stored in glass skip.
Remove sashes	Power screwdriver	Unscrew fixing screws from frame.
Remove sash fixings	Power screwdriver	Unscrew fixing screws from sash.
Remove handles/hinges	Lump hammer	Knock the fixings off.
Break sash corners	Corner cracker	Applied direct pressure to the weld in a sharp cracking motion.
Break frame corners	Corner cracker	Applied direct pressure to the weld in a sharp cracking motion.
Remove fixing screws	Power screwdriver	Removal of screws which hold the reinforcement bar in the PVC-U bar.
Remove reinforcement bars	Long nosed pliers	Reinforcement bars tapped out on edge of skip. Difficult bars pulled out using pliers.
Store materials	N/A	PVC-U and metal in dedicated skips.
Tidy area	Yard brush	Area must be kept clean, deliveries at all times.

Equipment trialled

PVC-U Weld exploiting channelled energy machine ("Corner Cracker")

This piece of machinery was created with the specific intention that it be able to separate PVC-U window frames at the corners, thus enabling access to the internal reinforcement bars and leaving the PVC-U in individual bar lengths suitable for storage. This piece of machinery is manually operated by a foot pedal. The corner of a PVC-U window frame is placed on the cracking angle, then lined up with the opposing groove that will transfer the pressure from the foot pedal. When the pedal is struck, it swings an angled bar into the outside of the frames corner, passing the force through the join of the frame and shattering the weld.

Figure 14. Corner Cracker Prototype



Strengths

This tool is heavily built (it takes two people to move it) and very strong in its construction. The cracking action is very simple and any damage to the machine should be easily repairable. The guard cage is there to protect the deconstructors legs and to stop pieces of weld flying off.

Weaknesses

The design is not perfect and could be improved, it is only a prototype constructed for the project task in its current form. The cracker has an issue where the broken bar lengths sometimes fly off up to 5 ft in a random direction, using a clamp on both the angled bar lengths should rectify this. Complex frame constructions can sometimes leave the cracker unable to easily be positioned. The activation of the cracker requires an awkward manual handling activity. It can be done in number of different ways, but none are ideal and could cause RSI's. Also the foot pedal needs some sort of non-slip coating for use in wet conditions as currently it is a slick metal plate.

Potential

The issues with the cracker could be rectified and modified by mounting a similar system on a bench and have a piston powered cracking action instead of manually activated. This would make it easy to incorporate clamps, remove the RSI issue and increase the overall efficiency of the activity.

Zylogix Joint Cutter Prototype ("Cutting Machine")

The Zylogix Joint Cutter (figure 15) was created with the intention of dissecting PVC-U window frames at both the corners and the transom mullion frame joints. The cutter is a vertically positioned portable tool which is operated by fixing the frame portion to be cut between the holding plate and the blade. The blade is then lowered using a pumping action on the ratcheted lever. Each "pump" lowers the cutting blade, the ratchet teeth then lock and the next "pump" lowers the blade again. This continues until either the blade encounters a reinforcement bar, or the frame is cleaved in two. Once the cut has been made, the pump handle direction can be reversed (pushed away from the body past the holding handle) to release the ratchet.

Figure 15. Zylogix Joint Cutter Prototype

Strengths

The cutter action allows the worker to remain upright while performing the cutting. The machine is robust and portable.The cutter can dissect a frame with minimal repositioning. There is no issue with flying debris as the cutting action is not sharp, but slow and methodical.

Weaknesses

The cutting blade is easily blunted. The blade is also unable to cut through tougher PVC-U frames and reinforcement bars. When the blade is blunt it compresses the profile rather than cutting it. During operation, if the cutter encounters something that impedes the blade, it stops and the handle action causes the machine to rock and lose its balance.
PVC-U bar lengths cut with the machine usually end up being warped at the end. This makes the removal of reinforcement bars difficult. The blade can become imbedded in the profile if it is over a certain depth and the profile is not totally cleaved by the blade. The pumping action, although conducted in an upright position, does require an unusual back movement that might be considered strenuous to the back.

Potential

The cutting machine is a good basic concept. If the base-plate was widened to improve its stability then the machine would possibly function better. The blade may need to be redesigned to be sharper. The existing blade material blunts relatively easily and so needs sharpening or replacing frequently. Investigation should be conducted to look into the possibility of replacing the blade with a more resistant material.

Health & Safety Issues:

BSEN388 cut resistance standard gloves with a grip coating were used, as were Kevlar sleeves, protective eyewear, steel toecap and plated boots and high visibility PPE. The deconstructor also used a peaked cap to keep the sun out of his eyes. The tool used to crack the PVC-U corners is a spring loaded corner cracker that is activated by sharply striking a foot peddle. The body angle required to use this tool is possibly a cause for concern as it requires the worker to be "hunched" over the tool. Of concern also is the working height employed to use the cracking tool which works at ground level and requires the deconstructor to reposition the tool for every corner "crack". The frequency of corner breaks could also be of concern, as it could lead to Repetitive Strain Injuries (RSI's) due to the number of concurrent cracking motions required for some frames. Each corner crack is preceded by a bending action to reposition the frame. Each crack takes an average of 20 seconds including the repositioning action. This method employed constantly for 20+ actions could be a concern with the person bending and straightening rapidly. This could be remedied by having a second person repositioning the frame. The method employed to remove frame fixtures such as handles by bashing them with a hammer is an issue. The method employed requires the hammer to be swung at the handle to generate significant force to knock it off the frame. This could be dangerous if the deconstructor is working around another person as there is a potential for one person to lose control of the hammer. This could possibly be remedied by employing a different method of fixture removal such as using a guarded chisel to better direct the hammers force.

The deconstruction area is a temporary site on a refurbishment project and as such is on a housing estate with residents living close by. Glass skips must be covered and the whole area must be in a secure compound to prevent trespassers gaining access. At all times when the compound is active, there needs to be someone present to ensure only authorised personnel gain access to the site. Even though this site is temporary, it needs to be equally as secure as a permanent site, if not more so.

Barriers & Opportunities

The majority of the processes employed can be achieved by one person. However it would be prudent to have a second person available for certain aspects of the work, essentially the frame lifting and repositioning. The area is a temporary compound and has no all-weather working area. As the site is only temporary, no permanent structure is cost-effective. Some sort of portable shed may be advisable so it can be moved from site-to-site where there is window deconstruction in progress. The area can only be operated during daylight hours as there is no artificial lighting in place, this may be of concern in winter months when it will impair the times during which deconstruction can be conducted. Drivers delivering materials to this site are often in a rush to unload and get back to their next job, or go home. These are sometimes self-employed personnel or agency staff who do not work directly for the company and therefore are not inherently interested in segregation. By labelling all the skips and ensuring that the deconstructor stops work when materials are delivered to help them unload, they can encourage the others to put the right materials in the correct skips. If the deconstructor helps the others, they will often be more receptive to helping as it is in their interests to get unloaded as fast as they can. One material that is not commonly considered for recycling is the rubber gaskets removed from the windows. These are potentially a high value material. As this compound is left unattended overnight in a residential area, there is the potential for fly tipping. Ensuring the compound is locked and all skips are covered will reduce the chances of fly tipping and keep the materials clean in the event of a fly tipping incident. Employing a security may be a practice worth considering if the compound contains expensive plant equipment. Substantial contamination is a barrier to material recovery (figure 16), some form of tool could be employed to remove foams, mastics or cements from the frames. By employing a dedicated segregator to sort materials as they arrive, then deconstruct frames when nothing is being delivered, the employee's efficiency can be increased.

Figure 16. Foam contamination

One of the main barriers involved the complexity of relationships in such a large project. Due to the fact that there were too many decision making parties involved, delays in work programme and the trials were not uncommon. This trial was not able to commence until the third phase of this project's trial schedule. But the project was able to collect preliminary data on the deconstruction process.

4. Manual and Mechanised Deconstruction on a Specialist Site

Anglian Windows was approached in the later part of a former WRAP funded flat glass project, when BRE found out about their recycling system and similar work already established by the company. Anglian Windows operates a unique network that uses reverse logistics to return their post consumer PVC-U window waste to their recycling centre in Norwich where their waste windows are deconstructed. As new windows are delivered to installation depots in Birmingham and Stockport, PVC-U window frames with some glass are transported back to Norwich. Already successful with manual deconstruction of PVC-U window waste, Anglian Windows was ready for advancement to the next step of mechanical deconstruction increasing the throughput of PVC-U frame waste sent for re-processing by Ecoplas. This project helped fund the lease of machinery used in Trial 1 with modifications made by Anglian.

Figure 17. Dedicated area for processing PVC-U frame window waste

Table 5. Summary table of manual & mechanical PVC-U frame waste processing methodology

Action	Equipment Used	Description
Material delivered to deconstruction bay	Drop-drive 40yd trailer	Trailer containing materials delivered to deconstruction bay.
Trailer opened and material sorted	N/A	Once the trailer is opened, the deconstructor must organise the frames inside.
Remove beadings	Putty knife, screwdriver and claw hammer	Don Carlos knife inserted into the joint of the beading, then prised off. Tougher beadings require hammer and screwdriver.
Remove gaskets	Putty knife	Gaskets come free when DGU's are removed, knife sometimes required to remove them from single glazed frames
Remove glass	N/A	Glass removed whole and placed into glass skip next to the bay.
Remove fixtures/fittings	Power screwdriver	Reusable fixtures and fittings removed and stored according to type. Good quality new fixtures from returned frames are reused on site.
Store frames and transport to main deconstruction area	Window racking trolley & plant loader	Once the glass and fixtures are removed, the frames are stored in a racking, then towed to the main deconstruction area.
Remove remaining fixtures	Power screwdriver/Putty knife	Any fixtures not suitable for reuse are removed at the first working area.
Remove reinforcement bar retaining screws	Power screwdriver	Retaining screws that hold the reinforcement bars in place are removed.
Remove any contamination	Putty knife	Any mastic or foam contamination is removed. Frame is essentials stripped of all external materials.
Dissect frame corners	Frame mounted reciprocating saw with turning frame	The frames are then cut at each corner to leave them in bar lengths.
Dissect transom mullion	Frame mounted reciprocating saw with turning frame	Transom mullion are cut out of the frame along the bar lengths.
Cut difficult frames	Hand-held power saw	Some frames are too tough or too awkward for the bench saw, these are moved to a special caged area to be sliced up using a high powered hand held saw.
Remove reinforcement bars	N/A	Reinforcement bars slide out of the sliced frame bar lengths. Bars are placed in a skip according to material type, aluminium of galvanised steel.
Separate frames according to grade	Pallecon (Ecoplas containers)	Different grades of materials separated and placed into designated pallecons.
Size reduce PVC-U	Bench mounted saw	PVC-U bar lengths are sliced up into short lengths to maximise space in the transportation cages.

Equipment Trialled

<u>Bench Mounted Frame Saw</u>

This is an adapted mounted reciprocating circular saw (figure 18). The basic saw has been used as the central point of the structure and a supporting frame has been constructed around it. The frame is designed to accommodate any size of PVC-U window so that the frame can be easily manipulated, positioning it for cutting is not awkward. The operator positions the corner accordingly then uses a foot pedal to activate the saw. The foot pedal sets a cutting sequence into motion, first the frame is clamped, then the reciprocating saw is activated and cuts the corned in one fluid motion returning to rest in its guarded housing. The frame is now safe to be repositioned for the next incision. For removal of transom mullion on a reinforced area, the saw cuts halfway through the frame on either side of the reinforcement bar and the bar length is slid off the reinforcement (this sometimes takes four cuts).

Figure 18. Specialist bench saw used for processing PVC-U frame window waste

Strengths

The saw is capable of a very fast throughput, the corner cuts are clean which makes the removal of reinforcement bars very easy. The operator can perform additional tasks while the saw is running its cutting sequence, this sequence takes approximately 4 seconds during which an efficient operator will use this time to dispose of the last cut bar length into the awaiting palecon or knock out the reinforcement bar of the previous bar length. The saw can completely dissect a PVC-U frame including the transom mullion. The working height of the saw is excellent and the operator has a good working surface.

Weaknesses

The saw struggles when it is called upon to slice through transom mullion reinforcement bars in a fully reinforced frame. Sometimes the saw cannot get through enough to allow the PVC-U bar to be slid off easily. When this happens the frame is cut up as much as is possible and the remainder moved to another area for a stronger metal saw to finish the job. The saw blade needs replacing from time to time. Usually once every 2-3 weeks depending on the saw's usage. Lifting large former conservatory windows onto the bench can sometimes require 2 people, although this isn't necessarily a major issue, it does interrupt the throughput significantly. The set-up of the area means that the operator is cutting in front of himself, then turning 180^{o} to sort the PVC-U and reinforcement bars into the palecons, then turning another 180^{o} back top the saw. This continuous repetition of movement could cause spinal injury if performed incorrectly.

Potential

The saw is a good concept. It is very fast, very efficient and incredibly reliable. Its health and safety provisions have been very well thought out, the bench height and design is ergonomically sound. The blade is reciprocating and has a guard to prevent injury to the operator and the foot pedal is well positioned. The only real flaw is in the blade in that it cannot deal with strong metal reinforcement bars, however, this is a minor point.

Health & Safety Issues

- BSEN388 cut resistance standard gloves with a grip coating were used, as were Kevlar sleeves, protective eyewear, steel toecap and plated boots and high visibility PPE. Ear defenders and disposable ear plugs were used in the main deconstruction area due to the excessive noise of metal movements and machinery.
- Deconstruction delivery bay is built on a scaffold so it is at the height of the rear of the trailer. This scaffold must be checked regularly.

- Broken glass and spilt materials falling under the scaffold cannot be safely removed until the scaffold is removed. Working under this scaffold is very difficult and very hazardous due to it being very cramped. The scaffold is designed to hold a large amount of weight and as such the underneath is dense with poles.
- Some portion of the deconstruction bay work is conducted inside the trailer, primarily when it is raining as the area has no fixed covered area. As this is not a large bay, there is no red/green light set-up so a driver cannot know if the trailer is ok to remove. A red light would indicate that the trailer is either open or that there is someone working inside, green would mean the trailer was empty and closed.
- To one side of the scaffold there is a glass skip which the deconstructor puts glass removed from frames into. The area next to this skip needs to be barriered so as to ensure anyone walking past is at a safe distance from flying glass shards. The bay does have a barrier to prevent anyone on the bay falling into the skip.
- Transferring large glass panes into the skip may be a difficulty for one person as it may need to be lowered rather than dropped due to its size. Lifting such a pane over the safety barrier on the bay may prove difficult. For this, two workers may be necessary or even an alternative storage method for larger glass panes.
- The specialist deconstruction area is built in a concrete workshop, and is electrically lit so deconstruction is possible in all weathers.
- The frame mounted reciprocating saw is operated by a foot peddle. The frame is positioned and once in place the peddle activates a set of clamps that holds the frame in place, the saw then cuts the frame and once the saw has stopped the clamps release. All window frames are turned per cut at a comfortable height on the saw frame.
- The deconstruction bay does not have a suitable working height for the person removing fixings, perhaps some form of bench may be advisable, possibly a portable bench that can be moved to adapt to different situations as the space on the platform is limited.

Barriers & Opportunities

- With the transportation system already in place, it may be possible for materials other than PVC-U to be recycled using this method. Value of other products may be a barrier to this if the cost of haulage is greater than the value gained from recycling the materials.
- Deglazing other window types may prove difficult, the current system does not cater for any glass other than that easily removed from PVC-U frames.
- Glass cullet quality is directly related to its value. From this process, much of the glass is in the form of DGU's. If there was a system implemented to remove the glass from the aluminium frame, this could increase the value of the glass to a recycler.
- The frame mounted saw has an average output capability of over 40 frames per hour during constant, uninterrupted usage, depending on the type of frames. During an 8 hour working day with realistic breaks, troublesome frames, non-constant supply of frames and other duties taken into consideration, 120-150 frames per day is not unrealistic.
- Deconstruction time on the bay depends on the type of window delivered, for a normal 3 casement PVC-U window the time would be under 5 minutes. For a difficult composite frame there is no realistic estimation.

5 . Mechanised PVC-U Window Deconstruction on a Research Site

An adapted mechanical method designed for dealing with metal containing wastes utilised for processing PVC-U windows on an EAWML 48205 operating site.

PVC-U frames were delivered to Sims Recycling to trial their existing equipment meant for processing fridge and freezers (figure 19). Whole PVC-U frames were fed into the machine whole. The idea was to find a processing method that is capable of handling very high throughputs. The results were less successful as segregated white PVC-U materials from the end of the processing line was very much discoloured, lowering its market value. There is need for more modification and research into this processing method.

Figure 19. Mechanised material segregation

Table 6. Summary table of Methodology for Mechanical Material separation on a dedicated site

Action	Equipment Used	Description
Window waste size reduced	Pre-shredder/ Grab crane	Window waste fed into the pre-shredder from above by a grab crane. Frames shredded.
Material fed into granulator	Shovel loader	Material exits the pre-shredder underneath and is shovelled into the hopper of the granulator.
Material granulated	Granulator	Material passes through the rotor and static blades of the granulator and passes out the bottom of the machine through a grate set to 18mm.
Material raised to separation level	Conveyor belt	Material that exits the base of the granulator is carried up a belt to the material separation area.
Ferrous metal removal	Over-band magnet	Ferrous metal repelled by over-band magnet into a storage bay underneath the separation area
Material prepared for eddy current	Shaker table	Material falls onto lower belt and is fed over a shaker table to even out the material.
Non ferrous metal removed	Eddy currrent	Material is passed through an eddy current that repels non ferrous material into a storage bay underneath the separation area
PVC-U removed	Grate	PVC-U and the remaining material is then fed into a dedicated bay.
Material movement	Shovel loader	Material is stored in the bay until full, then removed by a shovel loader

Health & Safety Issues

The only H&S issues would be with the site operation. This is a specialist mechanised system and is located in a depot specialising in material processing. Existing site risk assessments/method statements would apply. However, as processing window wastes is currently an experiment, site protocols, procedures, risks assessments and method statements might need to be adapted if or when the system is to be modified to take glazed window waste.

Barriers & Opportunities

The Pre-Shredder used for this system has a 3cm gap between the blades. If a bar length is passed through vertically then the majority of the bar length may evade the shredder. If the frames were fed through whole this would not be a problem. A shredder with closer-set blades could handle bar lengths, however the closer the blades are set, the slower the throughput rate.

The system was used to process PVC-U windows. It could handle timber easily, but not a combination of the two. The machinery is currently not capable of separating PVC-U from timber. For this method to work, the windows must be of a uniform material, otherwise the end result will be a contaminated material with no outlet or commercial value. This system would be appropriate for aluminium and steel frames; the material would be further sorted as ferrous and non ferrous.

The system processed deglazed PVC-U windows for the purposes of the trial. If the windows were sill glazed the system could be adapted to deal with the glass. At the end of this system the glass and PVC-U would end up in the same bay. By adding a third process, a Wilfley Table or Water Table, the glass and PVC-U could be separated. This table is capable of a throughput of 1 ½ tonnes per hour.

PVC-U is a lightweight material; the granulator used was designed for a waste with a much higher metal content. Due to this the PVC-U effectively bounces around inside the granulator and is not forced through the base blade over the grate. Due to this, the material took eight times longer than usual to process at this stage. The granulator could be modified using a compression plate to generate a down force on the material, pushing it through the base blade and through the grate.

This system as it stands processed 2.1 tonnes of PVC-U window waste in 8 hours. Of the material delivered to Sims Recycling in a skip supposedly meant for window waste, 448kg of it was rubble contamination. There is need to educate the industry in what can and cannot be placed into skips.

Between the pre-shredding and granulation process 92kg of material was "lost", most likely through spillage on the yard floor.

The end product was considered too contaminated by metals to be safely fed back into a manufacturing process. Mechanised deconstruction was considered in this project in order to deal with high volumes of window waste. The current trial shows that more work needs to be done as it is currently not a viable or feasible option.

Window Waste Collection

Most of the project partners will have participated in the role of window waste collection and transportation in some form or another i.e. transportation of post consumer window waste, processed materials etc.

Window Fitters: Segregation at Installation Depot

These are the fitters who remove the frames from customers' homes, store them temporarily in their vans and then transport them back to their off-loading point. This offloading point is usually the main depot where they will drop off their waste windows and pick up the new windows for their next job at the same time (see window waste production section).

Fitters usually work in one of two ways. Either they drop off their waste window material in the morning after the previous day's job and then pick up the windows for the job on that day, or they drop off their waste at the end of the day before going home and pick up the new windows early next morning. So when it comes to segregation of window waste materials haulage and labour is offset by their current practice.

Reverse Logistics

The take-back scheme works for integrated companies where certain materials of value, in this case PVC-U frames, are collected from regional installation centres and bought back to a centralised location to be deconstructed and material segregated. This has been termed "Reverse Logistics" and allows Anglian to transport window waste materials back to their main depot. This system was mainly designed for pre-installation materials (defective windows, cancelled orders, mis-size etc) so that fixtures and fittings can be removed and reused on new products and short life PVC-U window material can be deconstructed and transported to a reprocessor, resulting in the re-processed material incorporated back into the Anglian window manufacturing process. This process allows the drivers delivering new windows on route to return with goods to the main Norwich depot.

This system explored in Trial 1 involves a drop-drive trailer delivering new windows to installation depots and retrieving post consumers windows ready for transportation back to Norwich. This system allows for good quality segregated post consumer material to be recovered as the Norwich recycling site is a specialist deconstruction site. Additionally there is provision for recovering the glass returned to site in the returned frames. This glass is removed from the frames and placed in a skip to be collected by the glass reprocessor. The cleaner the segregated materials are, the better the chances of self funding or even opportunity for capitalisation of the scheme.

Collection Point System

This method involves window fitters delivering their window waste to a designated centralised location after the job is complete rather than taking it back to their installation depot. The collection site is a designated material processor where all delivered material is unloaded by the fitters with the assistance of site staff who will segregate the waste.

The cost of waste transportation for fitters is currently budgeted and imbedded in the costings infrastructure of the business. Whether it would deviate much from the budgeted costs depends on whether the waste is to be dropped of at the installation depot where new windows are being loaded or the distance to the site where waste is to be off-loaded. In the case of Bowater contractors in trial 2, the EB site is only a couple of miles away from the installation depot making the transportation costs of offloading window waste there insignificant.

There are a few issues associated with this system, primarily its location. For a system such as this to function it must be easily accessible to fitters and be in a central location. Fitters may not wish to travel excessive distance to deposit their window waste at such a site. Consideration has to be given to the fact that they may travel over 100 miles in a working day and are not paid by the hour or by distance covered. They are understandably not keen to travel several miles extra past their depot just to off-load their waste before returning past their depots to get home.

Collection Round System

This system is similar to the collection point scheme, with addition of a specialist haulage company picking up window waste at various installation depots en route. A possible system to facilitate installation depots not in the immediate vicinity of a specialist window waste recovery facility may use their installation depots as the collection points storing or racking waste windows awaiting pick up by specialist haulage provided or arranged by the specialist window waste recovery facility. The installation depots can stockpile their daily waste window materials in, for example, a window holding rack to be collected daily or a drop-drive trailer as used by Anglian Windows in their reverse logistics scheme, to be collected once the trailer is full and can be transported in bulk. This may be advantageous for out of the way depots. There are also possibilities and opportunities for groups of SMEs, which do not produce enough volumes of window waste to make recycling economically feasible, to agree on a collection point in order to consolidate effort to fill a trailer for pick up. Containerised system where skips of window waste are to be collected from installation depots are discouraged as this full windows thrown into skips will create a lot of void spaces plus the jumble of window frames and broken glass will make retrieving materials uncontaminated a very difficult task.

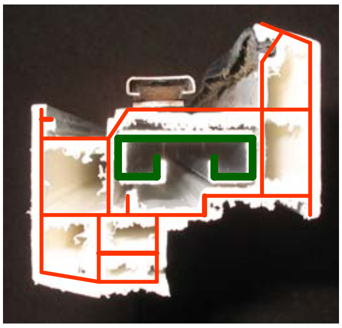
Window Waste Composition, Volumes and Material Data

The purpose of this chapter is to establish actual composition volumes and weights of window types, styles, and composition of material types within the different window types. This is firstly, in order to facilitate the development of an economic model for the different trial scenarios and as a secondary objective to develop a prognosis tool to give window waste producers and processors an estimation of how much of the window waste materials can be potentially recovered for diversion from landfill. This chapter presents some average figures of window waste used in the chapter on economic modelling.

Methodology

Conversion rates were generated using data collected during the trials including various individual waste window occurrences (see glossary). Window type data, from 2,317 windows, including material type, style, dimensions and glazing information was collected by fitters using daily data collection sheets provided by BRE. Onsite data collection of volume, mass and weight, of 198 parts of different window types, was conducted by BRE staff (figure 20). These data contributed to establishing average percentage volumes and weights of window types and compositions.

Figure 20. Measuring material volume without including the void space



Metal windows have not been included in this section due to lack of product availability during sampling over the duration of the trials. It has confirmed, by this project, that metal recycling is a well established trade and metal frame windows have managed to stay out of general skips for as long as any installation depot managers can remember. Data collected and results presented are of timber and PVC-U window only. Weights of metal fixtures and fittings have been provided by Anglian Windows and used for all window types as there was consensus by other project partners that fixtures and fittings from PVC-U and timber windows do not differ significantly.

Occurrences in the sampling fraction produced 73% of timber window, 11% of PVC-U window, 11% of metal windows and 5% of composite windows.

Window types refer to the different types of window i.e. PVC-U or timber window. Window style refers to the number of casements in a window. Window style occurrences of fixed (0), one casement (1), two casements (2) and three casements (3) are shown in the table below. Fixed, in this instance refer to windows with no casements and 1 pane of glass. Limits were set for to use three casement windows as the maximum window size as only a few larger windows were among the total sampling population making it insignificant and uncommon.

Table 7 . Occurrences of the different casement windows in the sampling population

Breakdown of Each Pane Type (by no of casements)	Timber	PVC	Metal	Combined	Timber in T&PVC only	PVC in T&PVC only
All	73	11	11	4	86.9	13.1
1	72	12	12	2	85.7	14.3
2	66	11	12	10	85.7	14.3
3	60	16	13	9	78.9	21.1

Single pane glazing and double glazing units have also been taken into consideration in the calculations by occurrences and window types and styles.

Averages

Although the exercise to establish weights, volumes and composition of window waste was to facilitate the development of economic models and the window waste material prognosis tool, data in this chapter can be used to affirm or discredit industry figures commonly plucked out of the air. It is not uncommon to hear people from the domestic window replacement companies claim that timber and PVC-U windows weigh approximately the same at about 20kg. The results from this project prove incorrect. The deduction by industry, that the proportion of glass in PVC-U is higher than the glass proportion in timber due to double glazing units in PVC-U window, has been confirmed as correct.

The legend below should be used in conjunction with tables in this section

Breakdown of materials
Coated Steel = Screws and bolts
SS Aus/FE = Lock/Keep/Screws + Stay/screws
Zinc casting = Handle material/lock + keep parts plus frame and vent components
Aluminium = Sealed unit spacer tube

Tables 8 – 17 are source tables that show weight and percentage composition of the different materials in the different styles of the different windows types. Table 10, shows values used when developing the economic models in the next chapter.

Table 8 All fixed and 1 casement PVC-U window

	Mass (g)	**Mass (%)**
PVC	10465.49	41
R/F (Frmvcals)	681.3675	2.7
Glass	11055.12	43.3
Coated Steel	157.6	0.6
SS Aus/FE	681.76	2.7
Zinc Casting	1093.6	4.3
Rubber gasket	1329.032	5.2
Aluminium	66.65735	0.3
Timber frame	0	0
Total	**25530.62**	**100%**

Table 9 All fixed, 1 and 2 casement PVC-U windows

	Mass (g)	Mass (%)
PVC	14251.01	41.1
R/F (Frmvcals)	1391.71	4
Glass	13707.89	39.5
Coated Steel	227.929	0.7
SS Aus/FE	985.9954	2.8
Zinc Casting	1581.619	4.6
Rubber gasket	2416.327	7
Aluminium	101.6886	0.3
Timber frame	0	0
Total	**34664.17**	**100**

Table 10. All fixed, 1, 2 & 3 casement PVC-U windows

	Mass (g)	Mass (%)
PVC	22397.65	39
R/F (Frmvcals)	1186.39	2.1
Glass	24943.6	44
Coated Steel	332.93	0.6
SS Aus/FE	1440.218	2.55
Zinc Casting	2310.23	4.1
Rubber gasket	3514.155	6.2
Aluminium	185.8253	0.33
Timber frame	0	0
Total	**56311**	**100**

Table 11. All fixed and 1 casement timber window

	Mass (g)	Mass (%)
PVC	0	0
R/F (Frmvcals)	0	0
Glass	5438.18	30
Coated Steel	135.142	0.7
SS Aus/FE	584.6092	3.2
Zinc Casting	937.762	5.2
Rubber gasket	0	0
Aluminium	0	0
Timber frame	11001.16	60.9
Total	**18096.86**	**100**

Table 12. All fixed, 1 & 2 casement timber window

	Mass (g)	Mass (%)
PVC	0	0
R/F (Frmvcals)	0	0
Glass	8715.615	30.4
Coated Steel	191.287	0.7
SS Aus/FE	827.4862	2.9
Zinc Casting	1327.357	4.6
Rubber gasket	0	0
Aluminium	0	0
Timber frame	17568.52	61.4
Total	**28630.27**	**100**

Table 13. All fixed, 1, 2 & 3 casement timber window

	Mass (g)	Mass (%)
PVC	0	0
R/F (Frmvcals)	0	0
Glass	10708.68	25
Coated Steel	375.679	0.9
SS Aus/FE	1625.145	3.9
Zinc Casting	2606.869	6.2
Rubber gasket	0	0
Aluminium	0	0
Timber frame	26779.24	63.6
Total	**42095.62**	**100**

Table 14. All fixed and 1 casement generic window

	Mass (g)	Mass (%)
PVC	1495.069618	7.8
R/F (Frmvcals)	97.33821749	0.5
Glass	6240.59938	32.6
Coated Steel	138.3502857	0.7
SS Aus/FE	598.4878857	3.1
Zinc Casting	960.0245714	5
Rubber gasket	189.861665	1
Aluminium	9.52247902	0.05
Timber frame	9429.56874	49.25
Total	**19158.82284**	**100**

Table 15. All fixed, 1 & 2 casement generic window

	Mass (g)	Mass (%)
PVC	2035.858558	6.8
R/F (Frmvcals)	198.8156594	0.6
Glass	9428.79742	32
Coated Steel	196.5215714	0.7
SS Aus/FE	850.1303714	2.9
Zinc Casting	1363.680143	4.6
Rubber gasket	345.1895181	1.2
Aluminium	14.52694288	0.1
Timber frame	15058.73117	51.1
Total	**29492.25135**	**100**

Table 16. All fixed, 1, 2 & 3 casement generic window

	Mass (g)	Mass (%)
PVC	4715.293908	10.1
R/F (Frmvcals)	249.7662763	0.5
Glass	13705.50757	29.2
Coated Steel	366.6792105	0.78
SS Aus/FE	1586.213316	3.39
Zinc Casting	2544.418684	5.42
Rubber gasket	739.8221103	1.58
Aluminium	39.12111836	0.08
Timber frame	22953.63616	49
Total	**46900.45835**	**100**

Table 17. Average 1, 2 and 3 casement windows

	Timber Mass (g)	Timber Mass(%)	PVC-U Mass(g)	PVC-U Mass (%)	Generic Mass(g)	Generic (%)
PVC	0	0	15856.42988	40.5	2219.900183	7.3
R/F (Frmvcals)	0	0	1190.098454	3	166.6137836	0.5
Glass	8393.192706	28.9	16435.693	42	9519.142748	31.3
Coated Steel	215.8135	0.7	244.31349	0.6	219.8034986	0.7
SS Aus/FE	933.5851	3.2	1056.872874	2.7	950.8453884	3.1
Zinc Casting	1497.5485	5.2	1695.31239	4.3	1525.235445	5
Rubber gasket	0	0	2517.237868	6.4	352.4133015	1.2
Aluminium	0	0	119.0819973	0.3	16.67147962	0.1
Timber frame	17965.84584	61.9	0	0	15450.62742	50.8
Total	**29005.98564**	**100**	**39115.03995**	**100**	**30421.25325**	**100**

The main purpose of these tables is to facilitate the development of the economic models based on the different trials of the project. The many tables provided in this section demonstrates the variability of window types and styles making calculations for an average PVC-U, average timber and generic window (proportioned by occurrences) necessary.

Table 17 above shows the calculated average timber and PVC-U window by percentage and weight composition.

Composition material included in a timber window is glass, timber and metal fixtures and fittings. 62% of an average timber window is timber and the next major material is glass at 29%. Unlike PVC-U window with reinforcement bars, the metal proportion of a timber window comes mainly from fittings and fixtures and makes up 9% of the window. The average timber window weighs 29kg.

PVC-U contains a larger metal fraction due to reinforcement bars encased in its profile, which is not present in a timber frame window. On average, fixtures and fitting in an average PVC-U window weighs more than fixtures and fittings in an average timber window. In general, the glass weight (42%) proportion is equal with the PVC-U weight (40.5%) proportion of an average PVC-U window. An average PVC-U window weighs about 10kg more than a timber window making the average weight 39kg.

A generic window i.e. average of the occurrence of window styles and types from the sampling population, weighs about 30.4kg. The weight of a generic window is more similar to the weight of an average timber window than an average PVC-U window as timber windows comprise 73% of the sampled occurrences, whereas PVC-U only accounted for 11%.

Prognosis Tool

A simple excel spreadsheet have been developed to give waste producers and processors help estimating the amount of material available to recover for recycling. The spread sheet is available, together with this report, for downloading and would be made available on the WRAP Glass website http://www.wrap.org.uk/materials/glass/flatglass/ . A more comprehensive tool has been developed to estimate materials by window types and styles but the user interface have yet to be decided. Anyone interested in this tool should check the website above regularly for updates.

Table 18 show the prognosis tool. Enter the length and height of the window type in millimetres and put in the number of windows there are for recovery and the results will be presented (table 19). Only one window type can be entered at a time. If the window type is unknown, use the generic window column and the calculations will be based on data collected on averages of PVC-U and timber window according to occurrences in the sampling population.

Table 18. Prognosis Tool

Enter Window Dimensions Here
Only one column to be filled

		Timber	PVC	Generic
Window Length L	**mm**		1500	
Window Height H	**mm**		1200	

Enter the No. of Windows (Nw) here

No of windows =	**70**

The results will show the amount of materials available for recycling in weight (grams). The break down of materials include PVC-U, reinforcement bars, glass, mixed metal fixtures and fittings, aluminium from spacer bars and timber. Example of 70 PVC-U windows with the dimensions of 1.5m by 1.2m has been used in Table 18. The resulting breakdown of materials can be found in Table 19.

Table 19. Prognosis tool results table

RESULTS	
Weight(g) for all Nw windows	
PVC	1216142
R/F (Frmvcals)	85394
Glass	1524240
Coated Steel	23781
SS Aus/FE	102874
Zinc Casting	165018
Rubber gasket	192660
Aluminium	9077
Timber frame	0
Total Weight(g)	3319184

Economic Modelling of Trial Scenarios

A key objective is to provide an economic model and feasibility study for the recovery of window waste from the key scenarios of the trials. The models assess the financial benefits i.e. costs and revenue involved in waste collection and processing. Three key trial scenarios had been accessed, using their current throughput and activities to identify and estimate, based on real data received from the project partners, the costs and revenues of each trial to develop a feasible model that can be reproduced by interested parties.

The 3 models and their set boundaries will be based on:

Trial 1 - Reverse Logistics Scheme

- Throughput of windows processed has been deemed commercially confidential
- A trial uses a manual labour and modified mechanical equipment combination system and powered tools where possible
- Number of staff required per day is 1.5

This model is a unique system developed by Anglian Windows for company use. The reason for inclusion in this modelling is to assess the viability of this system as a standalone activity without being a vertically integrated company i.e. a company that fabricates transports and installs their own products, or have the advantages of supplementing recovered post consumer materials with post industrial materials.

Trial 2 - Collection Point Scheme

- Throughput of windows processed has been deemed commercially confidential
- This system uses manual labour and powered tools
- Number of staff required per day is 2

This collection point scheme is also a unique system as EB Enterprise is the only well established window waste specialist in the country. EB Enterprise also processes post industrial materials. This activity has been excluded in order to look at the viability of recovering post consumer window waste for recycling.

Trial 4 - Collection Round Scheme

- Throughput of windows processed has been deemed commercially confidential
- This system uses manual labour and powered tools
- Number of staff required per day is 2.5

EB Enterprise aided in trialling the collection round scheme by providing a small scale operation of collecting window waste from a few established customers. The idea is to compare the advantages of being able to offer haulage as oppose to Trial 2, where the window wastes are dropped off. By offering haulage, the client base and volume throughput can be increased.

Trial 3a & b will have similar economics and feasibility as trial 2 as they have the same concept of a collection point scheme. We were unable to conduct a specific economic feasibility study for these 2 trials as not enough segregated materials were collected during the trials to enable full cost data sets to be obtained.

Methodology

Cost data was requested from project partners on labour, haulage, vehicle and machinery hire and maintenance, machinery depreciation costs, property rental, reprocessing and disposal to landfill etc. Different project partners produced varied sets of cost data due to their individual and sometimes overlapping roles in the project. These cost data sets have been divided into 4 categories namely, haulage, overhead and disposal to landfill, in order to enable scenario comparison. Cost data used were costs pertaining to collection and processing of post consumer materials only. For example, it cost £8/hr to sort a box of PVC-U materials into grades and the box consist of 50% post-industrial and 50% post consumer product. Only £4 will be considered under labour costs as only half the time spent has been on post consumer materials. Costs within the above mentioned categories were broken down proportionately into activities accordingly. For example, for glass removal from window frames as an activity, all costs pertaining to this activity are gathered i.e. labour cost, equipment costs and overall overheads was proportioned accordingly to get the share for this activity.

BRE process mapping exercises generated throughput rates for window processing required to develop the economic model. Interviews with the individual project partners were also conducted to generate further cost details. Cost data considered commercially confidential is not included in this report.

Assumptions and Set Boundaries

The following are assumptions and set boundaries when developing the 3 models:

- Average number of windows in a 40 yard skip is 141.8, with each generic window weighing 30.4kg
- Benefits is revenue minus the cost
- Cost of processing generic windows have been used instead of the cost of processing the individual window type i.e. PVC-U, timber etc, as it was not feasible within the scope of the project to investigate in detail certain integrated processing activities.
- Every 8 hour working day consist of 6 hours productivity
- Figures used are based on a 1 tonne window waste material, which in turn is based on the window material type waste occurrence in a sampling of 2000 windows.
- For the revenue of an individual window, the composition used is 24% general waste including composite windows, 61.32% timber, 9.24% PVC-U and 9.24% metal. This is due to the fact that one will have better control of the window materials coming in i.e. potential revenue previously lost to local scrap metal dealers can now be obtained
- Ground staff labour cost per hour is based at £8
- Landfill gate fees (including landfill tax of £15/tonne) is based at £35/tonne
- Landfill cost savings are based on the proportion of window waste in a skip. Cost of landfilling general waste and composite will still remain the same.
- Metal reinforcement bars are contained within PVC-U frames hence it cannot be recorded by occurrence during BRE site visits. An assumption has been made on reinforcement bars consisting of 50% aluminium and 50% steel.
- Occurrences from sampling over 2000 windows show waste production composition to be of 73% timber windows, 11% PVC-U, 11% metals and 5% composites. But since metal windows are often diverted before reaching disposal points at the installation depots the 40 yard skip composition is based on no metal windows being present. The skip waste composition has been established to be 66% timber windows, 10% PVC-U windows, 24% general waste including composite windows.
- One month consist of 21 working days
- Revenues of materials used are the estimated current market price obtainable for materials in their current processed form and not reprocessed form. This means that reprocessing costs have not been taken into consideration.
- Revenue is specific to different company circumstances and as such varies from case to case. Hence, an indicative revenue value from current markets for individual materials was used instead of scenario specific revenue values. This is for the purpose of illustrating the benefit of processing window waste regardless of local market situation.
- Revenue used was based on a generic window. The revenue calculations, of a generic window, were based on potential revenues from a PVC-U and a timber window, which is based on occurrences from the sampling population.
- Waste producer costs have not been considered as the costs of offloading window waste at the window installation depots are considered similar to offloading at a specialist site.
- Weights, volumes and compositions of metal windows have been derived from previous BRE pre-demolition audits. Sampling size involved 168 metal windows of 16 different sizes. Material weight of reinforcement bars has been expressed as a ratio (2.9:1) of steel in proportion to aluminium considering upper and lower density types of each

material. A 50/50 proportion of the mix has been assumed due to the fact that during sampling, metal reinforcement bars are contained within PVC-U frames hence it cannot be recorded by occurrence.

- Weights, volumes and compositions, of PVC-U and timber windows, have been taken from data collected during the trial (see chapter on material data)
- Where haulage is included in the cost, the calculation will be based on a radius distance of within 50 miles

Recovery versus Landfill Disposal

For the purpose of investigating the feasibility of window waste recovery, real data from project partners had been used. Their throughputs, cost, revenue, benefits and landfill cost savings of the individual project partners' trials are commercially confidential. This section shows the revenues that can be derived from a 40 yard skip of window waste and the number of windows required to be processed to make window waste recovery feasible and better yet, financially beneficial.

Table 20, 21 and 22 shows the potential revenue and the landfill cost savings from materials in a PVC-U window, a timber window and a metal window. The revenue calculated is without costs.

Table 20 Potential revenue from materials in a 1 PVC-U window

	PVC-U	**Mixed Metals**	**R/F Steel**	**R/F Alu.**	**Glass**
1 PVC-U Window (kg)	15.86	3.11	0.89	0.31	16.44
Value per tonne of material (£)	150.00	40.00	70.00	600.00	5.00
Revenue (£)	**2.38**	**0.12**	**0.06**	**0.18**	**0.08**
Landfill savings (£)	0.55	0.11	0.03	0.01	0.58

Total revenue per PVC-U window : £2.82
Landfill cost savings per PVC-U window : £1.28
Total potential revenue per PVC-U window : £4.10

Table 21. Potential revenue from materials in a 1 timber window

	Timber	**Mixed Metals**	**Glass**
1 Timber Window (kg)	17.97	2.65	8.4
Value per tonne of material (£)	0.00	40.00	5.00
Revenue (£)	**0.00**	**0.11**	**0.04**
Landfill savings (£)	0.27	0.09	0.29

Note: Landfill savings based on landfill gate fees of £35/tonne minus £20/tonne recycling charge

Total revenue per timber window : £0.15
Landfill cost savings per timber window : £0.09
Total potential revenue per timber window : £0.24

Table 22. Potential revenue from materials in a 1 metal window

	Mixed Metals	**Steel Frame**	**Alu. Frame**	**Glass**
1 Metal Window (kg)	2.71	10.41	3.6	9.52
Value per tonne of material (£)	40.00	70.00	600.00	5.00
Revenue (£)	**0.11**	**0.73**	**2.15**	**0.05**
Landfill savings (£)	0.09	0.36	0.13	0.33

Total revenue per metal window	: £3.04
Landfill cost savings per metal window	: £0.92
Total potential revenue per metal window	: £3.96

Note that cost to the specific trials are considered commercially confidential (CC) and has in this case been excluded from the tables. Benefits specific to the trials have also been calculated using project partner throughput which is also commercially confidential. Table 23 below shows figures calculated for a generic window according to occurrences in the sampling population.

Table 23. Figures used to calculate benefits of recovering a window versus landfill disposal for the 3 models

Cost of disposing 1 window in skip (£)	Revenue of recovering 1 window (£)	Cost of recovering 1 window (£)	Landfill cost savings of recovering 1 window (£)	Benefit Of recovering 1 window (£)
- 1.03	0.76	CC	0.73	CC

The 3 models below shows the benefits of recovering a window in a 40 yard skip as opposed to disposal to landfill in the different models. This demonstrates, for the purpose of interested parties, the costs, revenues and cost savings involved in the different methods of recovery. This allows companies to assess the effort required in the different models relevant to them. The different models depict the throughput required to make recovery of window waste economically viable.

Model 1. Reverse Logistics

The basis for using the reverse logistics model is when one has to deliver some form of goods and at the same time retrieve window waste for recovery so that the vehicle does not return empty. This method of reverse logistics proves to be financially not feasible as a standalone process. There are two possible opportunities to make this model a viable option. Firstly, for waste producers, by being a vertically integrated company, like Anglian Windows, with opportunities to incorporate recovered post consumer PVC-U material into current fabrication processes, therefore reducing the cost of purchasing virgin materials. Secondly, this model is viable as an option for both waste producers and waste management operators. By processing 78.8 windows per day, this will realise a cost neutral +/- £0 value and a landfill cost savings of £57.70 per month. Processing more than 78.8 windows per day in this manner will begin to generate financial benefit.

Table 24. Feasibility threshold for the Reverse Logistic Model

No. of windows	Benefits	Landfill Cost Savings	Total Benefits
78.8	+/- 0	57.50	57.70
141.8	47.90	103.51	151.39

If a waste producer generates more than 3.18 tonnes (76% waste windows and 24% general waste) of window waste per day or if a waste management operator receives more than 3.18 tonnes of window waste per day, it will be financially beneficial to recover the materials for processing.

Model 2. Collection Point Scheme

This collection point system was modelled on a specialist window waste processor and is viable as an option for both waste producers and waste management operators as long as the throughput of windows processed exceeds 63 windows a day. Table 25 shows the model calculations based on a lower throughput but nevertheless achieved a landfill cost savings of 31%. If 63 windows per day are processed, the landfill cost savings will mount up to £45.99 per month.

Table 25. Feasibility threshold for the Collection Point Model

No. of windows	Benefits	Landfill Cost Savings	Total Benefits
63	+/- 0	45.99	45.99
141.8	59.90	103.51	161.41

If a waste producer generates more than 2.55 tonnes (76% waste windows and 24% general waste) of window waste per day or if a waste management operator receives more than 2.55 tonnes of window waste per day, it will be financially beneficial to recover the materials for processing.

Model 3. Collection Round Scheme

This system is an adaptation of the collection point model whereby haulage services were provided, to access feasibility. In order to make it financially viable, the throughput that Table 26 is based on has to be increased. The minimum throughput of windows processed to achieve a cost neutral value is 69 per day (6 windows more than the collection point system). This will at the same time realise a landfill cost savings of up to £50.37.

This system has potential from both a waste management operator and waste producer point of view. There are opportunities for waste producers to amalgamate a collection point system at their installation depot with a collection. The collection round can be provided as service to local small volume waste producers offering them opportunities to recycle their waste and at the same time, supplement a existing collection point scheme to increase their volumes of window waste achieving the necessary throughput to make it cost neutral and where possible financially beneficial.

The haulage service cost can be recovered through integrating the cost into service quotes i.e. collection charges.

Table 26. Feasibility threshold for the Collection Round Model

No. of windows	Benefits	Landfill Cost Savings	Total Benefits
69	+/- 0	50.37	50.37
141.8	55.33	53.14	161.41

If a waste producer generates more than 2.79 tonnes (76% waste windows and 24% general waste) of window waste per day or if a waste management operator receives more than 2.79 tonnes of window waste per day, it will be financially beneficial to recover the materials for processing.

To Recover or Not to Recover: That is the Question

The models presented gives different companies the idea of throughput required when implementing such a process. Cost details collected from the different trials were excluded due to commercial confidentiality. Due to the fact that threshold throughputs were given, the trial specific costs, unique to the project partners, are relatively unimportant. As costs are commercially confidential, a sliding scale of £1.80 - £4.80 per window can be used as the indicative cost. It is understandable to think that the difference in the upper and lower scale of cost given is vast, which is why stress is further put on the usage of threshold throughputs instead.

The reverse logistics scenario, although currently unique, will be suitable for companies in similar position as Anglian Windows, where there are opportunities for window fabricators with their installation depots to implement a reverse logistics scheme to recover their PVC-U waste for processing back at headquarters. The collection point scheme has huge potential for waste management facilities, window installation companies and large window refurbishment projects to replicate. The collection round scheme is most suitable for waste management companies where services, to collect window waste from installation depots, can be offered. This scheme can also be adopted by installation centres pooling together enough quantities of window waste from a group of small companies or depots in the vicinity to make processing economically feasible, if not financially beneficial.

Window waste producers, where the opportunity arises, who decide to use window waste specialists will most definitely have cost savings. Investigations into trial 2 and 4 show that it is economically viable for a window waste specialist to quote clients prices about 8% - 10% below landfill disposal cost. The tables provided in this chapter could help give waste producers a benchmark figure when negotiating waste management costs. An important point to remember when using waste contractors is to ensure the availability of an audit trail i.e. make sure that materials claimed to be recycled are really being recycled.

The answer to recover or not to recover window waste for processing is YES:

- If adopting the reverse logistics model and will be processing at least 3.18 tonnes of window waste per day
- If adopting the collection point model and will be processing at least 2.55 tonnes of window waste per day
- If adopting the collection round model and will be processing at least 2.79 tonnes of window waste per day.

Flat Glass Waste Sample Analysis

Methodology

Part of this project was to undertake the following tasks in order to determine the quality and specification of flat glass waste recovered to assess their suitability for their end market application, in this case fibre glass insulation. The following were tasks set for the Glass Technology Services (GTS)

- Sieve analysis and separation; quantify particle size distribution and non glass inclusions for 20 glass samples recovered from the various trials.
- XRF analysis of any of the sieved fraction for all 20 glass samples recovered from the various trials (analysis of the glass fraction)

The samples collected from the trials were delivered to GTS on the following dates with the following codes:

05/07/04	**30/07/04**	**02/09/04**
WGP01	WGP06	WGP15
WGP02	WGP07	WGP16
WGP03	WGP08	WGP17
WGP04	WGP09	WGP18
WGP05	WGP10	WGP19
	WGP11	WGP20
	WGP12	
	WGP13	
	WGP14	

The samples delivered were approximately 5 kg, they were then coned and quartered to produce a 1 kg sample. The sample procedure shown below was adopted. Also it should be noted that the particle size was a function of the original sampling, whereby the waste glass was placed in a metal container and manually broken until all the pieces were small enough to fit into the storage container.

<u>Glass Sampling Methodology by BRE</u>

Glass sampling was conducted using two methodologies, the first was a method designed to collect samples on trial sites, and the second was a method for collection from the central glass bay at Peterborough.

On-site sampling was conducted using an aluminium sampling container. Glass was removed from the site skip (only when the glass level inside the skip was sufficient to allow safe access) by placing it into the sampling container. This container was then placed into an aluminium box with a securable lid. This box was then closed and the lid secured before being lifted either onto a suitable work bench or most appropriate flat surface (sometimes floor level). The glass was then size-reduced by smashing it using a heavy tool inserted through a hole in the lid of the box (in this case a flat headed crow-bar). Once the glass was size reduced, a 5kg sample was placed in a plastic sample container and labelled accordingly.

Figure 21. On-Site glass sampling tools

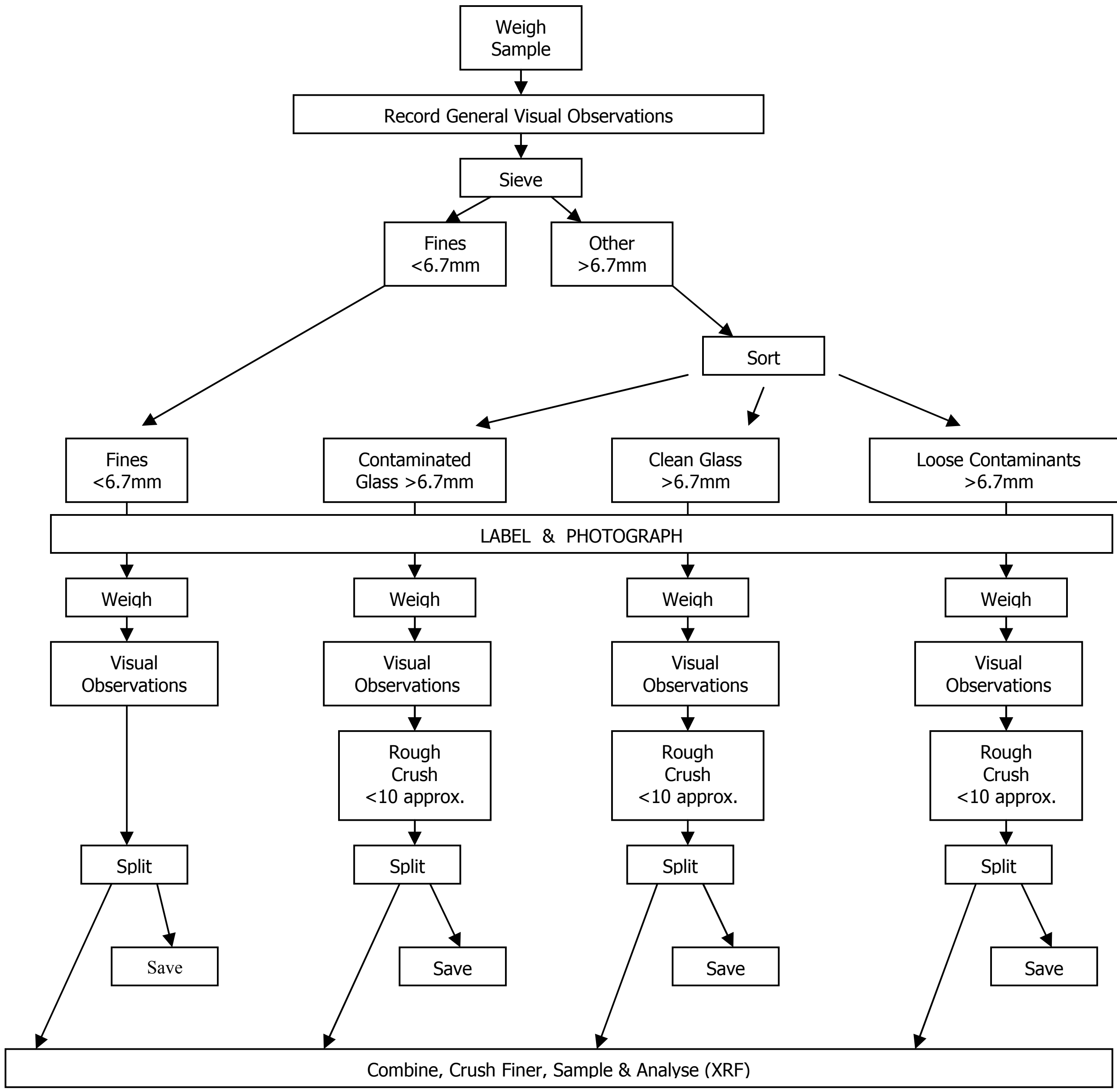
Sampling from the Peterborough bay was conducted using a spatial pyramid selection system to identify location to be sampled and a coning sampling system to sample the material.

For the cone sampling (Figure 23), 100kg is removed from the collection pile and built up into a cone on a clean plywood surface. The cone is then quartered to 4 piles of 25kg and one of these piles is then quartered to give 4 piles of slightly over 5kg. This material is then size reduced and placed in a plastic sampling container and labelled accordingly.

Figure 23. Coning Sample conducted at Viridor Peterborough.

Figure 22, on the next page, depict the methodology GTS used for analysis of the samples received.

Figure 22. GTS methodology of analysing post consumer glass samples



Results and Conclusion of Trial Samples Analysis

The appearance and analysis of the samples indicates that they all came from modern float glass. In some cases, the glass was toughened. All the samples received contained to lesser or greater extent contamination.

Samples WGP01 & WGP03 was toughened glass with little cross contamination. Sample WGP02 was a mixed selection of glass including wired and leaded, which is reflected in the slight composition variation, including a slight increase in the lead content. Samples WGP04, WGP05 & WGP06 were from double glazed units with metal edging and sealant materials. All the other samples appeared to be from various types of window frames including wooden frames with putty seals. Characteristics of the individual samples collected during the trial can be found in the indices.

Summary of the sampling results from the 20 samples can be found in the appendices section.

The loss on ignition (LOI) is an indicator of the level of organic material in the waste, the results show that most samples had a measurable organic below 1%. However, WGP04 had a LOI of 7.87% and during the procedure, noxious fumes were emitted. Fumes were emitted from all of the samples during LOI.

The analysis of the glass samples indicates that glass collected contained contamination that would decrease the value and the number of opportunities for recycling. An incentive scheme and training to encourage good practice needs to be adopted and then further assessment to assess the effective of the good practice would be required.

Closing the Loop

Flat Glass Window Waste

The 100 tonnes waste flat glass collected from the trials, bulked up at the Peterborough bay, was sent to Viridor Glass Recycling headquarters in St Helens for reprocessing. The results were first considered devastating. From the glass tipped onto the ground, serious contaminations were discovered. The audit trail was rendered not usable as the contaminated skip loads were passed unwittingly. This was because only visual, top layer of the skip quality control was allowed due to heath and safety reasons, contaminations below the top layer of glass was not detected. Discussions with Viridor Glass Recycling and a few other project partners gave some indication as to where the contaminated loads could have come from. It took only a load to contaminate the 100 tonne of otherwise acceptable glass reducing the recyclable fraction to about 42 tonnes. Data sheet provided by Viridor Glass Recycling on the reprocessing of the 100 tonnes of flat glass from the trials can be found in the Appendices.

It was thought appropriate, at the beginning of the project, to use the waste to make a product which itself has a positive environmental benefit during its 50 year predicted useful life. Using flat glass waste significantly reduces the energy required to melt the glass, estimated by British Gypsum Isover as 3 kwh for each percent of flat glass added.

The 42 tonnes of flat glass cullet, of BGI specification, was delivered to BGI on 23rd September 2004. BRE and project partners were invited to the BGI compound on 24th September to view the process and the over 5000 rolls of fibreglass insulation produced from the post consumer flat glass waste collected during the project.

Quality and Specification

The quality of the waste glass is the most important criteria with much of management time and money being invested in good-housekeeping procedures and auditing. Viridor Glass Recycling and trial experience indicated that some window installation companies may not be prepared to police their skips properly to ensure only glass of the correct type goes into them, a particular problem for smaller businesses with limited resources. Once a skip is contaminated beyond economic recovery (specifications specific to the different reprocessors), there is no alternative but to send the skip to landfill in order to avoid further contamination of existing glass stocks. Particular cross contamination problems can occur within the wheeled bin collection system where cullet is deposited en masse in a bulk tipper vehicle. Cross contamination from poor quality cullet batches is thus exacerbated and can result in mass cullet contamination. Obviously, differing markets require different grades of glass feedstock but a good rule of thumb is to aim high as good quality cullet is always in demand and tends to command better prices in the marketplace. The UK is currently swamped with low quality, low value cullet and the situation looks likely to continue into the foreseeable future. Contamination with general construction waste is generally not accepted within the flat glass recycling industry and post consumer glass cullet generation offers adequate opportunities for such contamination to occur. It will therefore require extreme vigilance on the part of fitters and processors to ensure such contamination does not occur if the subsequent glass generated is to have a sensible market value, quality control will be paramount. This has been proven by EB Enterprise where premium quality post consumer glass waste has been collected during the trials. Under controlled circumstances, it is possible to recover post consumer flat glass waste of reasonably high quality.

Segregated glass skips **must not** contain any inert waste e.g. ceramics, concrete or masonry (Figure 22). Specifications produced by Viridor Glass Recycling are as below:

- Clean Glass – no contamination of any kind accepted (A1 & A2 quality in flowchart)
- Mixed glass – frosted, pattern, double glaze units (DGU), laminate and wired

End Markets

The demand for good quality clear cullet for use in glass re-melt markets currently exceeds the supply available from post production sources. This situation is historically consistent and has been magnified by the relatively recent construction within the UK of two additional float glass factories. Beyond this recent increase in re-melt capacity, capacity linked demand within the UK re-melt sector is broadly static and unlikely to rise significantly within the foreseeable future. The situation regarding lesser grades of mixed flat glass is however less positive. Several re-melt markets which would historically be major consumers of heavily reprocessed secondary flat glass grades have come under increasing price competition from the attempted dumping of excess container glass stocks into these markets. It is generally accepted within the industry that flat glass cullet tends to be of a better and more consistent quality than equivalent container glass cullet. It also enjoys enhanced ease of melting within the furnace on account of its generally lower levels of body pigmentation. These facts notwithstanding, container cullet enjoys a supply side fiscal driver mechanism (the Packaging Recovery Note) which gives this material a large arbitrary price advantage over equivalent flat glass cullet. Currently the supply/demand situation for lower grade flat glass cullet is finely balanced, The trend however is towards increasing downward pressure on prices driven primarily by PRN fuelled container glass cullet dumping.

Post consumer derived flat glass is in most ways identical to other forms of flat glass cullet with one or two caveats, namely, it will not be practical to expect the same degree of product traceability as that enjoyed by pre consumer flat glass cullet and there is an increased risk of contamination with construction waste due to actions associated with the window removal phase of operations. These factors notwithstanding, it has been proved that a recycling pathway utilising re-melt is perfectly practical providing commercial factors are satisfied. The fibreglass industry seems particularly suitable for the use of post consumer flat glass as it is fairly tolerant of the variations in glass colour likely to be encountered in flat glass and can be considered a partially closed loop pathway with both products being firmly placed within the building products market sector. Post consumer flat glass could also be utilised to a limited extent within the container re-melt sector as a top up material for those manufacturers struggling to source adequate flint cullet stocks. The use of post consumer flat glass in the flat glass re-melt sector is more problematical due to the nature of that particular production process but should not be dismissed. Further investigations would need to be conducted in conjunction with the flat glass manufacturers before a definitive answer to this particular challenge can be attempted. Bespoke and capital intensive reprocessing techniques would be almost inevitable to temper market fears in this area. As for markets outside the re-melt sectors, those markets already in existence tend to be for limited quantities and/or low value. Obviously low quality, low value markets are quite feasible on a technical basis but whether they will provide the revenue stream or economies of scale needed to produce real, sustainable and commercial viability remains to be seen.

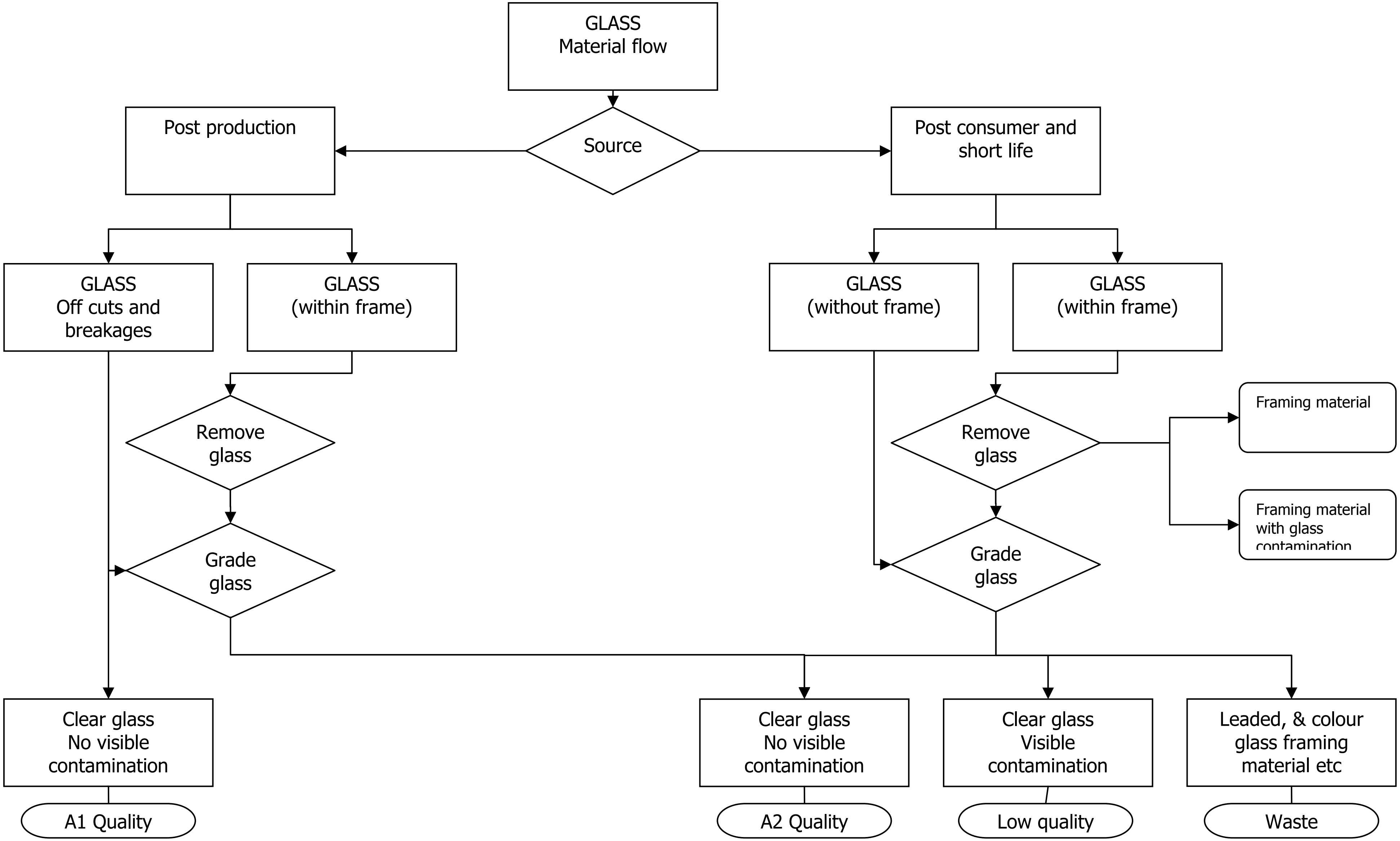
Supply, Demand and Conflicting Markets

Over the last few years the UK has seen a steady increase in the arisings of both recovered flat glass and container glass. In addition to this, substantial infrastructure has been deployed by the glass recycling industry with the result that a considerable quantity of post consumer automotive glass is now being generated primarily from the vehicle windscreen replacement industry. With the prospect of new supply streams of both end of life vehicle (ELV) and Waste Electrical and Electronic Equipment (WEEE) glass imminent and further increases in the supply of container glass cullet due to the deployment of kerbside collection infrastructure, the question of where all this glass will go is becoming more pressing. What seems to be particularly obvious is the fact that the PRN fiscal driver system is beginning to have significant effects within the re-melt markets which were unforeseen on its introduction. Instead of ever increasing the quantities of container glass recycled by the satisfying of existing insatiable market demand and the stimulation of new markets it is increasingly apparent that its secondary effect is that of material displacement. By singling out this arbitrary conceptual glass stream for preferential treatment less efficient, poorer quality glass streams will steadily displace the incumbent materials from existing supply/demand arrangements arrived at, through natural selection for best value economic equilibrium, thus dialling in poor commercial and environmental fitness into the UK economy. This is the natural result of the one sided application of a supply side driven fiscal driver to the problem of market expansion. The introduction of further supply side subsidies aimed at levelling the playing field will only compound the problem as it will pit driver against driver, subsidy against subsidy and will doubtless lead to a lucrative brokering industry draining yet more resources from the coal face. Sustainable market development must be largely demand driven with supply side pressure playing a supporting role in smoothing the process through intelligent and targeted incentives where appropriate.

Barriers and Opportunities

The recovery, processing, reprocessing and marketing of post consumer sourced window glass is perfectly feasible with the caveat that commercial factors are satisfied and it is chiefly the satisfying of these factors which presents the main barrier to the rapid establishment of a sustainable window recycling network within the UK. Technologies are already available and being utilised within various sectors of the recycling industries and would seem to be capable of adaptation to post consumer flat glass reprocessing. However, if the justified concerns of the flat glass re-melt industries are to be satisfied, the development of such technologies will have to be undertaken with the support of glass manufacturers to ensure a genuine fit for purpose solution. The next issue to raise its head subsequent to the adoption of a mutually agreed reprocessing methodology will be that of economies of scale. Expensive reprocessing facilities need to be fed with a commercially viable volume of material to generate the revenue levels needed to justify the up front capital investment. At present, such a volume of feedstock is not generated in the UK and what is generated is spread over a wide ranging geographical area. It would seem to be probable therefore that an initial period of poor commercial returns will be inevitable whilst the slow business of collection infrastructure deployment is undertaken. It should be noted that the rolling out of significant levels of collection infrastructure prior to reaching consensus on final product specifications, reprocessing methodologies and quality control protocols whilst expedient may be risky. The next significant barrier is that presented by the current situation of sales market instability, no commercial party will be willing to invest in post consumer glass recycling when the future security of sales markets is so precarious. Whilst the flat glass re-melt markets should be a fairly safe for the long term reuse of flat glass cullet, the secondary markets of fibreglass and container glass re-melt have no real obligation to the uptake of flat glass cullet of any variety. It all comes down to pricing in these markets and the pressures associated with PRN qualification have already been adequately covered elsewhere. Collection logistical costs should also be borne in mind, unless the model of specialist regional deconstruction facilities is embraced then the cost effective collection of post consumer flat glass may prove challenging. The adoption of an appropriate regional approach to window deconstruction will simplify collection networks whilst simultaneously dialling in economies of scale.

Figure 24. Glass Quality Flowchart



PVC-U Window Waste

BRE research on a previous WRAP funded project "Research into Waste Glass, Window and Door Frames from the Demolition and Replacement Window Industries" in 2003 showed that 6% of the 6 million windows replaced annually are PVC-U. The majority of replacement windows are PVC-U and in general, the majority of timber window waste coming out will gradually be replaced with PVC-U window waste. Waste composition from data collected during this project shows that 11% of windows currently coming out are PVC-U windows.

Quality and Specification

At the recycler, low and particularly medium grade material can be upgraded using colour separation. PVC-U reprocessors are very particular that bar lengths that arrive meet their specification of absolutely no metals. This is why it is important, during the processing stage, to deconstruct the PVC-U window and segregate as many materials as possible. The cleaner the PVC-U bar lengths to the reprocessor, the higher the value.

Mechanised PVC-U window deconstruction trialled by metal recyclers have proven that much more work and investment is still required. This method was trialled to investigate opportunities to deal with large quantities of PVC-U windows generated, where manual deconstruction might not be as efficient. The intention was to feed whole windows in at one end with clean segregated materials produced at the other end. However, to process unclean or mixed materials is a costly process and the value added to the recyclate can be less than the extra processing costs. In these instances it can be better to provide the material into a low-grade application.

PVC-U can be sorted into many different grades (see photographic glossary included in the index). The ultimate deconstruction and segregating process will produce the following main grades:

- White hollow profile free from contaminants
- White hollow profile with contaminants e.g. sealants
- Brown hollow profiles
- Co-extruded profiles
- Foam profiles

It has been questioned about how realistic it is to segregate such a number of materials onsite. This level of segregation will be space and container demanding. The scale of the project may influence the decision on the degree of deconstruction and segregation. It will not be an issue for specialist window waste processors to adopt this level of segregation as this will only increase their potential material value. It would, however be difficult for window replacement companies to establish such a set up in their yard. The flowchart in Figure 25 has been developed to give guidance to these companies on what can realistically be achieved in their position. There has been indecisiveness when contemplating the position of contaminated white profiles, whether they belong in material type 1 (see Figure 25) with clean white profiles or not. The decision to place it in material type 2 (see Figure 2) is due to the fact that PVC-U re-processing technologies have very low tolerances to contaminations. From a reprocessors point of view it should be material type 2 but from a specialist processor there is possibility and potential to clean the contaminated white profile and put it in a material type container. From a window replacement company, with restricted ability to segregate thoroughly, it is safer for them to place such materials in a material type 2 container.

End Markets for Re-processed PVC-U Window Materials

PVC windows are a potential source of plastic, metal and rubber materials. PVC waste should be segregated into clean white (Material type 1), for which there are several outlets. Contaminated, non white and contaminated jazz (Material type 2) currently has very few customers, but it has been used to make pipes, road cones, concrete replacement products etc. Gasket material can be one of several polymers and has been used for horse gallops. For material types see Figure 25.

Table 27 below shows potential market area and value for re-processed material type 1 and material type 2. There has been debate about whether materials type 2, excluding hollow profiles have any separate use or can they be mixed together for, e.g. concrete substitution. Bar lengths from processors to re-processors have known to fetch anything from £100 - £200 per tonne.

Table 27. PVC-U Material Type

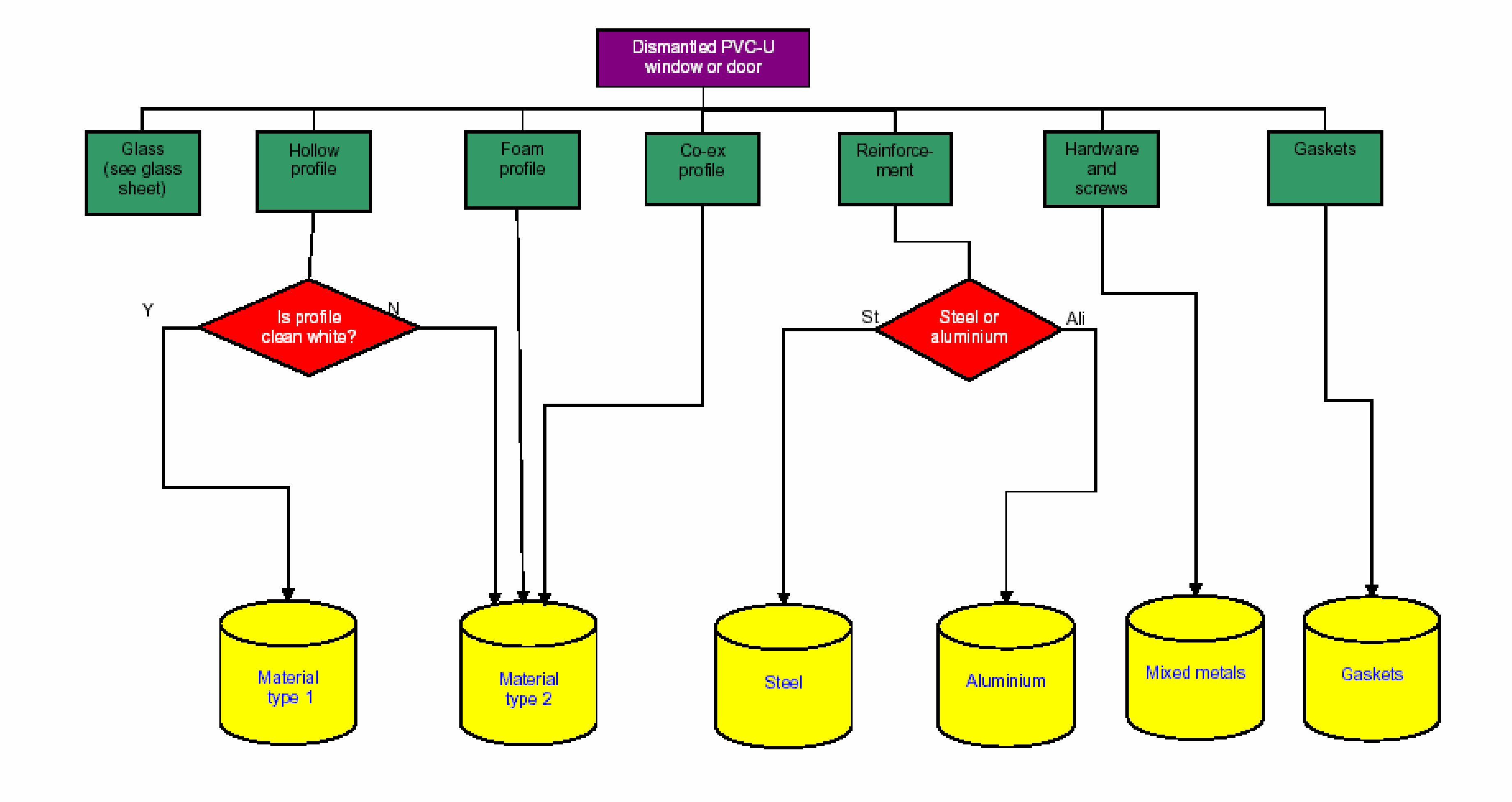
Material	Market area	Potential Value (£ per tonne)
PVC-U Material Type 1	Cavity closures, coextrusion profile	400
PVC-U Material Type 2 – hollow profiles	Pipes, conduit	250
PVC-U Material Type 2	Road cones, traffic barrier, polymer concrete	50-70

Table 28 shows potential for the more difficult materials such as gaskets and foamed material.

Table 28 Other materials

Description	Comment	Potential Value
Melt Processable Flexible Gaskets (TPEs)	All gaskets made from TPEs.	Potentially high
Cellular PVC-U (PVCU-E) (All offcuts and post consumer cellular foam)	-	Potentially medium - high

Figure 25. PVC-U Window Material Quality Flowchart



Timber Window Waste

Recycling wood waste can be complicated due to the introduction of the hazardous waste regulations. Recyclers contacted were adamant that treated wood waste is unacceptable but were unable to clarify if timber window frames were classified as treated wood waste. The most common answer to this question seems to be "it depends if the window is treated with hazardous material". This leads to another question of how to identify what windows have been treated by hazardous material or not. BRE is still conducting investigations into this matter.

Current practice shows that segregated timber frame waste is being accepted by some wood recyclers and not by others. BRE experience on auditing waste management facilities shows that timber waste arriving at different waste facilities are segregated in accordance to the specifications provided by the preferred wood recyclers. There are waste facilities that segregate up to 85% of their timber waste as the specifications from their wood recycler allows them to put aside all types of timber and timber like products. While other facilities segregate only 30% of their timber waste as they only pick out clean wood like dimensional timbers, pallets and such. The recommendation here is to find out from each individual wood recycler within a radius of a site if they will take window frame waste. As long as the answer is yes, as stated in the schedule of acceptable wood waste shown below, all timber frame waste should be able to be received by the wood recycler. The key here is that, as long as there is no agreed guidance on how to identify if a timber has been treated with substances that may be deemed as hazardous, the wood recycler will also have the same difficulties to a certain degree. It is always safer to double check when a wood recycler agrees to accept window waste, to make sure they are aware that almost all timber window frames are treated or coated in one way or another.

From the wood recyclers' point of view, they are in a very difficult position. With no definite guidance from the EA on hazardous waste definitions and with pressure from the hazardous waste regulations, they have the difficult decision to make on whether they can take window frame waste or not. This could contribute to the fact that there are some wood recyclers who would officially say that they operate a strict policy of no treated wood waste but are known to be willing to receive certain wood waste contaminated by treated wood waste.

The below is a list provided by a wood recycler on what can and cannot be accept. One will find it contradictory to the strict utterance that treated timber waste will not be accepted.

<u>Acceptable wood waste</u>

- All soft and hard wood waste
- Pallets
- Offcuts/boxes/packing cases
- Plywood
- Fencing
- Floorboards
- Plain chipboard
- Joists
- Window frames with glass and double glazing seal removed
- All material accepted with metallic contamination.

<u>Unacceptable wood waste</u>

- Treated material of any nature
- Medium density board
- Hardboard
- Melamine and laminated material
- Foliage, twigs and leaves
- Railway sleepers
- Telegraph poles

This note following the list was included: "These items are not negotiable. Charges will be made for any contamination and loads may be rejected".

End Markets

There will always be charges when disposing of timber window waste due to limited end markets. Wood waste has low bulk density and therefore to keep costs to a sensible level it must be transported in large [40 or often 55 cubic yard] bulks and lifted weekly. Current average recycling charges are about £20 £25 per tonne as oppose to landfill charges of £35 per tonne.

There are currently not many choices for the end market of timber window waste. For clean and untreated timber, the end markets are better. Clean timber can be used for animal bedding, compost, cat litter and chipboard manufacture amongst others. End markets provided by most waste facilities and wood recyclers BRE and project partners spoke to, that accepts timber window waste, named only the board mill as their end market for timber waste. There is much need for investigation into new recycled products using timber window waste. BRE is in discussion with industry partners to trial using timber window wastes as a fill to produce recycled building products.

Conclusion

Minimum recovery of window waste is occurring in England and Wales currently. Window waste producers are in general disposing their window waste in one to two 40 yard skips, sending them directly to landfill (if one is present in the near vicinity) or re-routing them to waste transfer stations where very superficial segregation is conducted. This current practice is not cost efficient. Current practice could be altered to get direct savings from fly tipping costs and indirect savings on labour costs from not operating on the 40 yard skips with gantries system.

Health and safety (H&S) issues are predominant in all activities involving the collection, processing and re-processing of window waste. These issues can be managed by developing risk assessments and method statements.

Process mapping of the different trials show that there are variable methodologies of deconstruction suited to different requirements and situations. Several deconstruction methodologies have been presented in this report to show interested parties what they entail. A general deconstruction methodology for timber and PVCU window has been provided in the appendices, in the form of matrices, for guidance. One common lesson learnt was that power tools (including cordless) and machinery are essential. It helps alleviate manual fatigue and increases efficiency and throughput of windows processed.

Data collected from a sample of 2,317 windows and 198 window parts showed that an average timber window weighs 29kg, an average PVC-U window weighs 39kg and an average window weighs 30.4kg. A 40 yard skip of window waste contains approximately 141.8 generic windows. Composition of window waste produced from client sites were 73% timber windows, 11% PVC-U windows, 11% metal windows and 3% composites. With regard to skip waste, 24% was general waste including composite windows, 66% timber windows and the remaining 10% PVC-U; metal windows do not usually go into a skip.

The potential revenue from a metal window is £3.04, the potential value from a single PVC-U window is £2.82 and the potential revenue from a timber window is £0.15. The total potential revenue from recovering the different window types including, landfill cost savings, varied from £3.96 for metal, £4.10 for a PVC-U window and £0.24 for timber windows.

Adopting the different models of recovering window waste for recycling will need to meet a threshold number of windows to make it economically viable. The different models investigated will require to process different number of windows per day to achieve a cost neutral figure. The reverse logistics model requires at least 78.8 windows to be processed per day to remain cost neutral and achieve a landfill cost savings of £57.70. The collection point model requires at least 63 windows to be processed per day to remain cost neutral and achieve a landfill cost savings of £45.99. The collection round model requires at least 69 windows to be processed per day to remain cost neutral and achieve a landfill cost savings of £50.37.

This project showed that it is possible to recover post consumer flat glass waste for re-processing although flat glass waste from secured and vigilantly controlled sites are preferable. These sites are able to produce good enough quality glass, requiring less re-processing effort, for use in higher value products. There are vital lessons to learn from the reduction of the collected 100 tones of waste flat glass from trials to 42 usable tonnes, due to contamination. This shows that just one badly contaminated load can ruin the whole batch. There needs to be better quality control procedure to ensure contaminated loads do not get through. Viridor Glass Recycling's qualities controls have so far been more customers orientated than load specific.

The post consumer flat glass collected was reprocessed by Viridor Glass Recycling to meet the specifications of British Gypsum Isover; in total 42 tonnes of post consumer flat glass waste was used in the manufacture of fibre glass insulation, incurring no additional costs to the manufacturer or deviating from their usual routine. The specification of flat glass re-processed per tonne for 42 tonnes of 0mm to 6.5mm sized fraction was 122 grams for organic contamination, 5 grams for inorganic contamination, 45 grams for non ferrous metals and 10 grams of ferrous metals.

Dealing with timber window waste remains problematic as there is a lack of consensus on the hazardous nature of the waste and its acceptability for reprocessing, which can vary depending on the reprocessor.

There is potential to obtain at least 5 different grades/types of PVC-U material from a PVC-U window. From a segregation onsite point of view, it would require too much time and space to achieve that degree of segregation, unless on a specialist site. Since the more established market for post consumer PVC-U seems to be sourcing mainly clean, white profiles, it is recommended that one container be provided for all clean, white profiles while providing another container for mixed PVC-U materials.

Recommendations

Recommendations have been compiled by information acquired and lessons learnt from the project and workshop held during the Glass Conference at BRE. Overall key recommendations are presented. Recommendations have also been broken down into the different roles stakeholders play in the industry.

Recommendations

- Subsidized or free consultancy should be made available for window replacement companies to seek advice and guidance on a company by company basis. This consultancy could be in the form of a help-point via the WRAP glass website or an enquiries number. Consultancy, on opportunities to adopt any of the models trialled, can also be in the form of a half day site visits, where current practices and processing opportunities can be assessed and feasibility calculated.
- There is need for investment into developing better equipment and machinery to increase the throughput of processing window waste. The economic feasibility study has proven that the higher the throughput of windows processed the better chances of a bigger return. This would be incentive for starting up specialist facilities or expanding current waste management businesses into processing window waste.
- There is requirement to work with the float glass re-melt industry to research into the feasibility of ultimately returning post consumer flat glass back into the production of flat glass. There are big issues in a project like this that needs ironing out, there is need for investment into machinery that will give the re melt industry post consumer of the required specification, there is need to develop quality control methodology and protocols to the satisfaction of the re-melt industry, there is a need to trial run a batch of good quality post consumer flat glass waste into the production line of a float glass production line etc.
- There is need for investment into establishing specialist window waste facilities. A key point made by major window replacement companies in this project is that the will to recover window waste for recycling is there but the lack of local specialist facility like EB Enterprise hinders better practice.
- There is need to research the collection round scheme to develop collection systems that can bring the waste windows back to the processing site whole. Trial 4 in this project trialled the model using a van limiting the number of windows that can be picked up. A van was used in order to retrieve whole waste windows. A containerised system, as explained in the report, is not feasible as it produces too contaminated a load of window waste to be worth processing, If this collection round using the white van can be scaled up to using possible an arctic trailer, the number of trips made within a 50 mile radius would decrease, the customer base will increase, the number of window replacement companies with new opportunities to divert their window waste from landfill increases together with the number of windows going through the facility.
- Experience from the Netherlands show that there is the possibility of incorporating a fee onto new windows funding the recovery of the post consumer waste. This concept aligns itself with the producer responsibility principle. Opinions from the industry, on this issue were that the recovery fees added will be negligible in the overall costs for the customer. Dissemination of project findings is required. This report has produced some vital results and opportunities available to the industry should be widely spread. Some form of a mobile awareness raising programme can be adopted to raise awareness of the opportunities to recovery window waste for processing and the benefits this entails. This mobile programme can be in the form of a slide presentation, Q&A session, video presentation, good practice guide distribution and possibly a live deconstruction demonstration.
- Investment and research will be required to find outlets for timber waste windows. Actively research into current and potential market to find fresh outlets instead of relying on a direct route to board mills.
- Markets for all grades of post consumer PVC-U granulates are currently available in the UK, Europe and internationally. Industry secrecy and commercial confidentiality prevents a reprocessor from knowing another reprocessor’s market stifling the growth of the post consumer PVC-U market. A UK and Europe wide market research project should be commissioned to establish actual companies looking and open to obtaining all grades of post consumer PVC-U materials.
- Current waste management facilities should be encouraged to investigate opportunities to recovery energy onsite from the timber window waste to cover the facilities own energy usage and to sell excessive electricity to energy companies that are required by law to purchase any excess energy the site produces.

Window Waste Producers

- At the highest end of the waste hierarchy is reduction of waste before reusing, recycling or recovery for energy. Vertically integrated companies including window fabricators should incorporate the deconstruction concept and design windows that are easier to deconstruct for material segregation. According to Bowater Windows, the fabrication sector is moving in another direction and are currently very keen on the idea of integrated window parts reducing labouring but making deconstruction and re-processing more difficult.

- Corporate window waste management strategies should be developed especially for window replacement companies with installation depots around the UK. Waste management budgets are currently allocated to the different depots according to net income from windows installed; this gives depot managers an excuse to not encourage better practices as long as their disposal costs are within the set budget.

- The good practice guide developed by this project should be made freely available to all depot managers. Awareness, guidance and assistance should be provided to depot managers enlightening them to the opportunities available to improve current practices. The ground staff level good practice leaflets in the good practice guide document should be made available to all ground staff. Where possible, they should be included in the corporate installation manuals provided. Good practices should be highlighted during induction of all new installation staff.

- For depot managers or small window replacement establishments, current waste management practices should be revisited to compare with findings from this report. This report and the good practice guide can give guidance and present opportunities for the recovery of window waste that can help the company achieve significant landfill cost savings and possible opportunities to obtain revenues from recovered window waste materials. Just as important, there are opportunities to induce change making ground staff more efficient, reducing fly tipping, health and safety risks and injury to staff. If reluctant to engage in processing activities, companies can encourage the preferred waste contractor to take over the responsibility as it can be financially beneficial to them. This gives the companies a chance at having their waste diverted from landfill and at the same time demand lower waste management costs.

Window Waste Processors

- Aim for a higher degree of deconstruction and segregation of window waste materials as this increases the opportunity for achieving higher revenues for the recovered materials.

- Research and trial new technologies that will help raise the throughput of window wastes being processed. The higher the throughput the better the financial benefits (dependant on initial investments and extra costs incurred)

- Investment into equipment to get better quality and less contaminated materials for reprocessing will be required.

- Collection services, within a 50 mile radius, should be provided to increase customer base and window waste throughput.

Material Reprocessors

- The materials investigated, including glass and PVC-U, have so far been re-processed by machinery and equipment that was developed to deal with less contaminated materials. Investment into modification or new equipment will be needed to target known contaminants or negatively characteristics of the post consumer materials, in order to cope with these materials better and get a better end product for incorporation back into production lines.

- Quality control procedures have to be tighter especially with post consumer flat glass. It has shown that just one bad load of glass can reduce the end product by more than 50%. There is need to overcome heath and safety issue in order to ensure material from the bottom of the skip is checked.

- Research into higher value recycling, e.g. post consumer flat glass waste back into float glass production. In order to ensure a stable demand for post consumer flat glass, we need to source a market that is reliant on flat glass alone with no possibilities of substituting it with bottle or any other glass.

Appendices

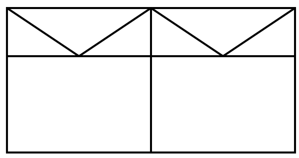
Bowater Windows Daily Data Collection Sheet

Project Details

Name of person completing this sheet	
Location (Installation address)	
Date	
Skip number	
Distance travelled from installation address to EB Enterprise	

Daily Product Data:

This will record the raw data for the type, design and sizes of windows and doors that were removed each day (please use a separate sheet if needed).

Separation Raw Data	**How many**	**Material Type T – Timber M – Metal P – PVC-U**			**Size in millimetres (length x height)**	**What type of glazing S – Single D - Double**		**Window Types (Please draw)**
EXAMPLE (Window)	*2*	*T*	*M*	*P*	*2221 x 1250*	*S*	*D*	
Window 1		T	M	P		S	D	
Window 2		T	M	P		S	D	
Window 3		T	M	P		S	D	
Window 4		T	M	P		S	D	

PVC-U Window Deconstruction Methodology

Product	Material	Separation Methodology	Storage	Quality Specific	Health and Safety
Gasket		Levered/scraped off with an appropriate tool, such as a screwdriver, Filler Knife or Don Carlos knife.	Cut into even lengths if appropriate to maximise space in removal receptacle. If possible, use some form of size reduction machinery.	Different composition of gasket material a potential barrier to recycling.	Working with a sharp tool requires the appropriate safety measures. Also working area needs to be properly managed.
Beading	PVC-U	Levered off with an appropriate tool, such as a screwdriver, guarded chisel, Filler Knife or Don Carlos knife. Tool must have a sharp, flat end. May require a lump hammer to prise the beadings apart.	Either cut to fit the storage receptacle, or store lengthways in a racking. For the purposes of size reduction, a chipping machine is advantageous.	Most beading is composed of two different materials, plastic and rubber.	Working with a sharp tool requires the appropriate safety measures.
PVC-U Frame	PVC-U	Break the frame at the corners either using a mounted saw with a frame/fastening clamps to hold the bar in place, pressurised cracker that exploits the weakness of the weld at the corner. Frames need to be broken into straight lengths to allow access to reinforcement bars. The cleaner the break, the easier it is to gain access to the reinforcement bar.	Either cut to fit the storage receptacle, or store lengthways in a racking. For the purposes of size reduction, a chipping machine is advantageous. Remove Transom Mullion and Reinforcement bars for size and weight reduction as well as material segregation.	Contaminants such as mastics and other fillers/cements may need to be removed as well as other general dirt.	Training for the usage of machinery and safety equipment specific to that apparatus is essential.
PVC-U Crucibar (Transom Mullion)	PVC-U	Use a mounted saw with a frame/fastening clamps to hold the bar in place. If a bench mounted saw is not feasible then a hand-held version may be used, however, this may entail extra protective equipment to be supplied. The crucibar weld is the weak point and may be exploited by applying pressure or force to break the crucibar's welds with the main bar length.	Crucibars should be reduced to straight lengths as a minimum to maximise storage space in the receptacle. For the purposes of size reduction, a chipping machine or mounted saw are advantageous.	General quality of the material may require cleaning of some form prior to reprocessing.	Training for the usage of machinery and safety equipment specific to that apparatus is essential.
Fixtures and Fittings	Various	All fixtures and fittings such as hinges, locks, brackets, screws removed using standard tools (screwdriver, hammer, guarded chisel etc) . Also remove any plastic wraps and labels with scraping tool or peel where possible.	Separate good quality fittings from misorders/unused frames for reuse. Poor quality fittings store separately. Labels/wraps dispose of appropriately. All fittings should ideally be stored in covered area or a covered receptacle.	Good quality and unused fixtures and fittings separated from those either used or of poor quality. If fixtures conform to current industry standards, they should be kept separate again for possible reuse.	Must be compliant to general Health and Safety practices. Also working area needs to be properly managed.
Reinforcement bars	Steel or Aluminium	Remove fastening screws if necessary and, where possible, slide out the bar. If the bar is secured in another manner it may be necessary to crack the PVC-U frame lengthways if appropriate or use a specialised chipping machine and chip both materials together, then separate.	Cut into even lengths if appropriate to reduce wasted space in removal receptacle. A covered skip is recommended to prevent water contaminating the metal.	If any of the metal is contaminated, then some form of cleaning or decontamination may be necessary.	Safety equipment specific to the job is essential..
DGU	Glass	Comes free once beading and gaskets are removed. Removed as a single unit intact where possible. Single glazed units removed similarly, but more care must be taken as they are a lot less robust and break easier.	Stored whole in specialist glass receptacle.	DGU's conforming to the latest industry specifications can possibly be reused.	Proper glass handling equipment required. Slash and Puncture resistant gloves, Kevlar arm protectors, PPE, tinted visor, steel toecap work boots.

Timber Window Deconstruction Methodology

Product	Material	Separation Methodology	Storage	Quality Specific	Health and Safety
Timber Frame	Wood	Use a mounted saw or manual saw to dissect the frame into straight lengths once the glass has been removed. If timber is jointed, it may be possible to cut half-way though the corner with a hand saw and knock the bar length out with a lump hammer, exploiting the joints. If the frame has wooden beadings, it may be necessary to remove these with a guarded chisel and lump hammer. Tap the chisel into the join and lever the beading off. Frame bar lengths and beadings in particular may contain nails, removal of these may be necessary if the material is to be stored whole and not chipped. If using chipping machines that cannot handle nails, then they must be manually removed.	Cut timber lengths to size so they fit the storage receptacle or further size-reduce them using a wood chipper. This material should be stored in a covered receptacle or covered area to prevent water infiltration and potential leaching of contaminants.	Timber frames can be contaminated with a vast range of preservatives, fillers, cements, paints, solvents. The presence of nails may be an issue if the final market requires whole bar lengths.	Training for the usage of machinery and safety equipment specific to that apparatus is essential. Also working area needs to be properly managed. Potential for leachate generation and correct storage of potentially hazardous contaminants must be considered. Timber has issues with splinters and nails, proper handling training may be necessary dependant on the nature of the timber.
Fixtures and Fittings	Various, mainly metal	Most fixtures can be removed with a standard tool (screwdriver), those that cannot may require a guarded chisel and lump hammer, or even a manual saw in certain circumstances. Weak casement fixings may be snapped-off manually.	Good quality and unused fixtures and fittings separated from those either used or of poor quality especially if there are some which conform to current industry standards. Fixtures from timber windows must be treated similarly to the timber itself in terms of contaminant control and stored appropriately.	Good quality and unused fixtures and fittings separated from those either used or of poor quality. If fixtures conform to current industry standards, they should be separated for possible reuse. Some timber fixtures are subject to the same contaminants as the frames.	Must be compliant to general Health and Safety practices. Also working area needs to be properly managed. Potential for leachate generation as with timber frames. Fixtures may have been painted with lead-based paints and a variety of combinations of preservatives, ensure proper breathing apparatus is available for any work on such frames.
Glazing	Glass	Remove entire glass sheet intact if possible over a suitable receptacle in case the glass breaks. Practical methods mainly choose the direct approach of laying the window over a receptacle at waist height or on the floor of a receptacle and smashing out the glass with a hammer or large pole-type implement. Glass shards remaining in the frame removed using pliers/hammer. For jointed timber frames, it may prove more practicable to remove one bar length, then “knock-off” the remaining three lengths from the glass with a block (wooden) and lump hammer (dependant on the presence of sealants holding the frame together). So the glass pane comes away whole.	Store in a covered receptacle designated for glass. Lockable cover necessary for safety, protection from rain and to discourage fly tipping. Covers supremely important if skip is not held in a secure compound.	Glass contaminants may require removal. Mastics, fillers, adhesives, solvents need to be cleaned. Other contaminants such as lead strips from leaded glass and reinforcement wire from safety glass may need to be removed.	Slash and Puncture resistant gloves, Kevlar arm protectors, PPE, tinted visor, steel toecap work boots. Must be compliant to general Health and Safety practices. Due to the nature of light refraction from broken glass (particularly shattered toughened glass), any person suffering from epilepsy may not be suitable. Also tinted eye-wear is suggested to prevent eye damage and attention lapses that may result. At any point where glass is broken consideration must be given to glass dust, appropriate breathing apparatus may be necessary where applicable.

Summary table of sampling results collected during the trial (WGP01 – WGP10)

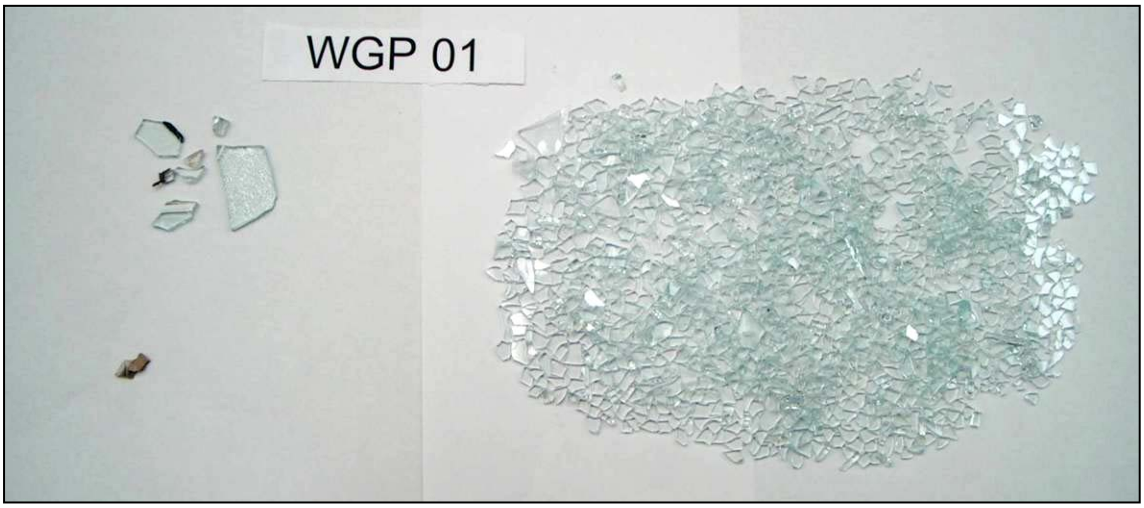
		WGP02	WGP03	WG	WGP05	WGP06	WGP07	WGP08	WGP09	WGP10
SiO_2	72.02	72.39	71.79	72.37	72.10	71.87	72.26	72.31	71.51	72.58
Al_2O_3	0.71	1.00	1.10	1.08	1.05	1.08	1.05	1.08	1.07	1.01
Fe_2O_3	0.09	0.10	0.12	0.11	0.11	0.11	0.10	0.11	0.10	0.10
CaO	9.02	8.74	8.46	8.44	8.44	8.40	8.52	8.37	8.56	8.41
MgO	3.91	3.84	3.95	3.95	4.05	3.95	3.89	4.03	4.28	3.96
Na_2O	13.91	13.22	13.69	13.43	13.43	13.69	13.31	13.24	13.91	13.13
K_2O	0.09	0.47	0.65	0.39	0.57	0.64	0.59	0.61	0.30	0.56
TiO_2	0.05	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.03	0.04
ZrO_2									0.01	
SO_3	0.19	0.19	0.20	0.19	0.20	0.20	0.22	0.20	0.23	0.20
Cr_2O_3	0.0002	0.0002	0.0003							
Pb	0.0017	0.0027	0.0012	0.0014	0.0021	0.0012	0.0014	0.0030	0.0014	0.0011
Cd	0.0008	0.0009	0.0011	0.0009	0.0010	0.0012	0.0011	0.0011	0.0012	0.0011
LOI	0.03%	0.87%	0.16%	7.87%	0.23%	1.23%	0.05%	0.35%	0.67%	0.02%

Summary table of sampling results collected during the trial (WGP11 – WGP20)

	W	W	W	W	W	W	W	W	W	W
SiO_2	72.31	72.06	72.07	71.94	72.22	72.16	71.97	72.11	72.14	72.27
Al_2O_3	1.03	1.02	0.99	0.96	1.08	1.03	1.10	0.93	1.04	1.07
Fe_2O_3	0.11	0.10	0.10	0.10	0.11	0.11	0.12	0.10	0.11	0.11
CaO	8.51	8.59	8.67	8.87	8.56	8.59	8.58	8.66	8.60	8.46
MgO	3.94	4.01	4.00	3.88	3.87	3.96	3.85	3.89	3.92	3.89
Na_2O	13.22	13.49	13.49	13.55	13.36	13.38	13.56	13.64	13.46	13.43
K_2O	0.60	0.47	0.43	0.44	0.54	0.51	0.54	0.40	0.48	0.51
TiO_2	0.04	0.05	0.04	0.04	0.04	0.04	0.04	0.05	0.04	0.04
ZrO_2										
SO_3	0.24	0.21	0.20	0.21	0.20	0.21	0.22	0.22	0.20	0.21
Cr_2O_3										
Pb	0.0012	0.0016	0.0014	0.0017	0.0015	0.0016	0.0016	0.0020	0.0016	0.0017
Cd	0.0011	0.0009	0.0011	0.0011	0.0011	0.0011	0.0011	0.0011	0.0010	0.0011
LOI	0.22%	0.78%	0.13%	1.07%	0.48%	1.06%	0.89%	0.96%	0.34%	0.63%

Sampling results of the individual samples

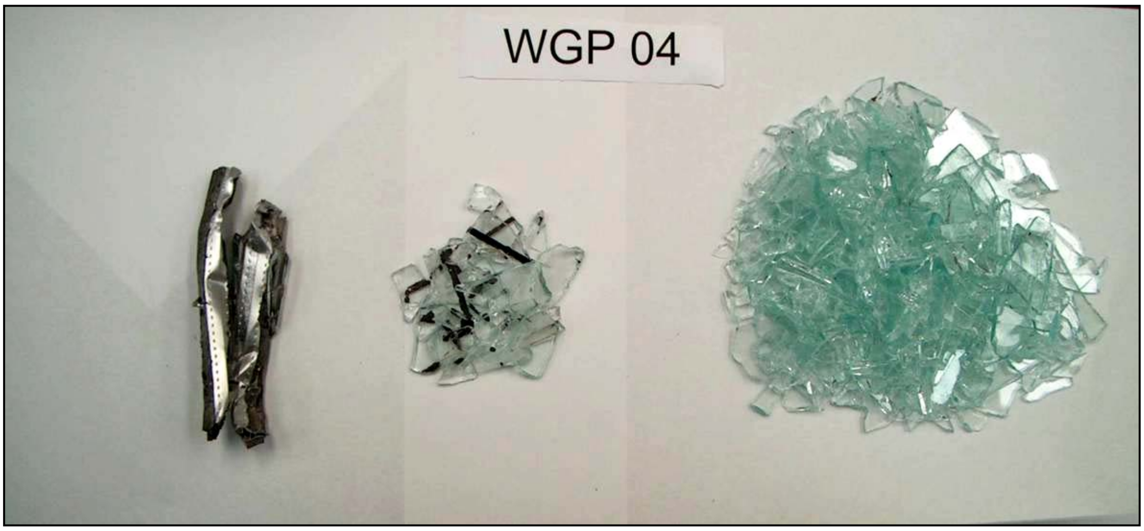
Sample	WGP01	
Sample mass	1027 g	LOI – 0.03%
General Observation		Mainly toughened glass approximately 4 mm thick. Little visual contamination or glass dust. Some sealant along edges of some glass fragments.
Size Fractions	**% Fraction**	**Comments**
Fines <6mm	56.30%	Characteristic "dice" <6mm from toughened glass failure. Only a small amount of fine glass dust.
Visually contaminated glass >6mm	1.65%	Edge sealant on some glass particles.
Visually "clean" glass >6mm	41.90%	Mixture of larger characteristic "dice" from toughened glass failure. Clean with little visible surface dust.
Loose contaminants >6mm	0.15%	Pieces of sealant and paper.



Sample	**WGP02**	
Sample mass	1020 g	LOI – 0.87%
General Observation		Mixture of patterned, wired, leaded and flat glass including glass with wallpaper backing.
Size Fractions	**% Fraction**	
Fines <6mm	7.11%	Glass dust.
Organic contaminated glass >6mm	47.39%	Pattern glass backed with wallpaper
Metallic contaminated glass >6mm	15.79%	Wired glass and leaded glass including partially attached strips of lead
Visually "clean" glass >6mm	29.60%	Flat glass with some surface dust.
Organic contamination >6mm	0.12%	Mainly wallpaper

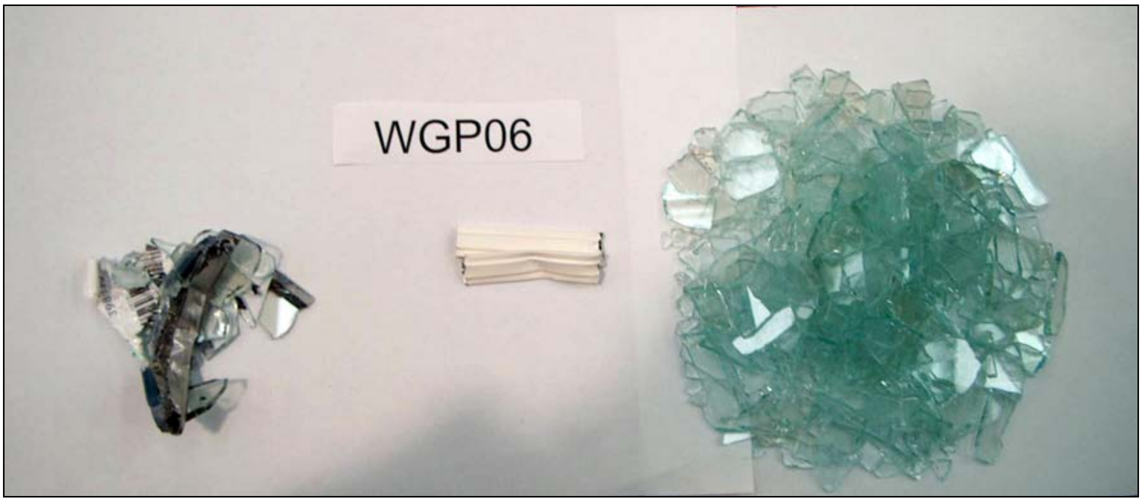
Sample	**WGP03**	
Sample mass	1068 g	LOI – 0.16%
General Observation		Mainly toughened glass approximately 4 mm thick. Little visual contamination or glass dust. Some sealant along edges of some glass fragments and paper labels.
Size Fractions	**% Fr**	**Comments**
Fines <6mm	55.21%	Glass dust.
Contaminated glass >6mm	3.85%	Edge sealant on some glass particles and a large paper label.
Visually "clean" glass >6mm	29.60%	Mixture of larger characteristic "dice" from toughened glass failure. Clean with little visible surface dust.

Sample	**WGP04**	
Sample mass	1039 g	LOI – 7.87% (noxious fumes)
General Observation		Flat glass from DG units with metal edging and sealants.
ize Fractions	**% Fraction**	
Fines <6mm	12.41%	Fine glass particles including a large portion of glass dust.
Contaminated glass >6mm	9.24%	Glass with organic sealant
Visually “clean” glass >6mm	73.58%	Shards of glass with some glass dust.
Loose contaminants >6mm	4.77%	Metal edging.



Sample	WGP05	
Sample mass	1178 g	LOI – 0.23%
General Observation		Flat glass from DG units with metal edging and sealants.
Size Fractions	**% Fraction**	**Comments**
Fines <6mm	11.97%	Fine glass particles including a large portion of glass dust.
Contaminated glass >6mm	10.97%	Glass with organic sealant and paper labels.
Visually “clean” glass >6mm	76.11%	Shards of glass with some glass dust.
Organic contamination >6mm	0.08%	Paper labels.
Metallic contamination >6mm	0.87%	Metal edging.

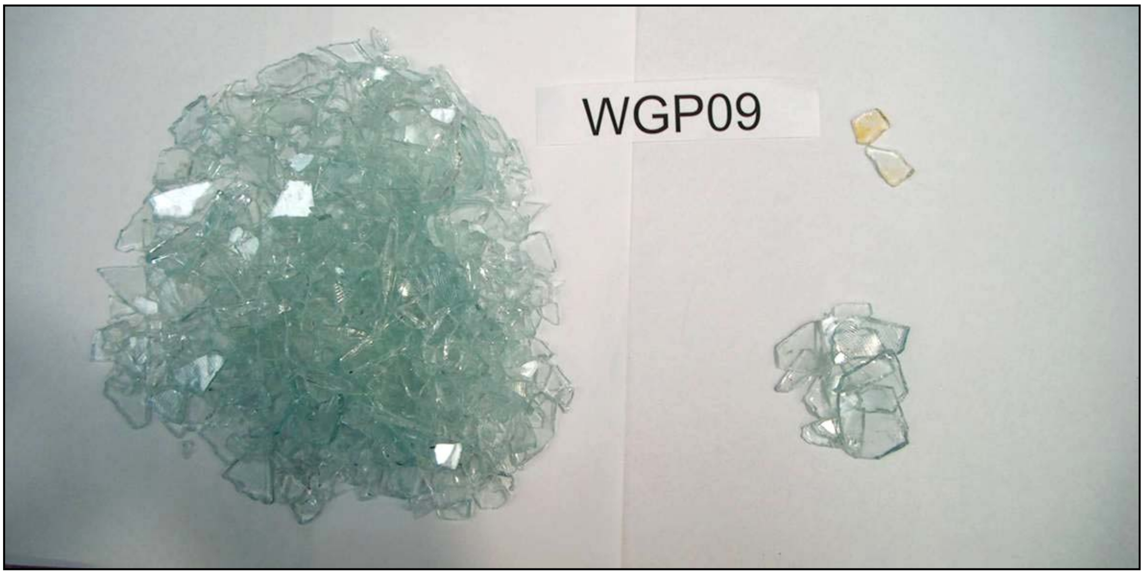
Sample	**WGP06**	
Sample mass	1185g	LOI – 1.23%
General Observation		Flat glass from DG units with metal edging sealants and paper labels.
Size Fractions	**% Fraction**	**Comments**
Fines <6mm	2.68%	Fine glass particles including a large portion of glass dust.
Contaminated glass >6mm	7.80%	Glass with organic sealant and paper labels.
Visually "clean" glass >6mm	88.77%	Shards of glass with some glass dust.
Metallic contamination >6mm	0.75%	Metal edging.



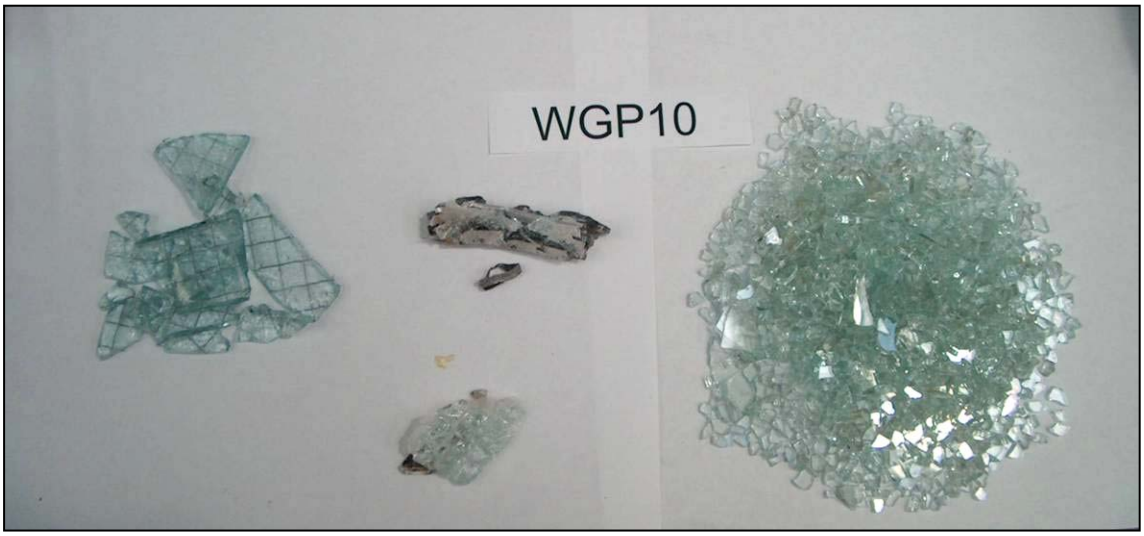
Sample	**WGP07**	
Sample mass	1011g	LOI – 0.05%
General Observation		Flat glass with very little visible contamination.
Size Fractions	**% Fraction**	**Comments**
Fines <6mm	3.19%	Glass dust.
Contaminated glass >6mm	8.38%	Glass with organic sealant.
Visually “clean” glass >6mm	88.43%	Shards of glass with some glass dust.

Sample	**WGP08**	
Sample mass	1148g	LOI – 0.35%
General Observation		A mixture of flat glass with colour and heavily contaminated glass.
Size Fractions	**% Fraction**	**Comments**
Fines <6mm	8.00%	Glass dust of various colours including inorganic and organic contamination.
Contaminated glass >6mm	18.31%	Glass with organic sealant, paper labels and putty.
Visually "clean" glass >6mm	68.22%	Shards of glass with some glass dust.
Contamination >6mm	1.78%	Mixture of sealants, paper and putty.
Coloured glass >6mm	3.69%	Coloured mainly blue and light green.

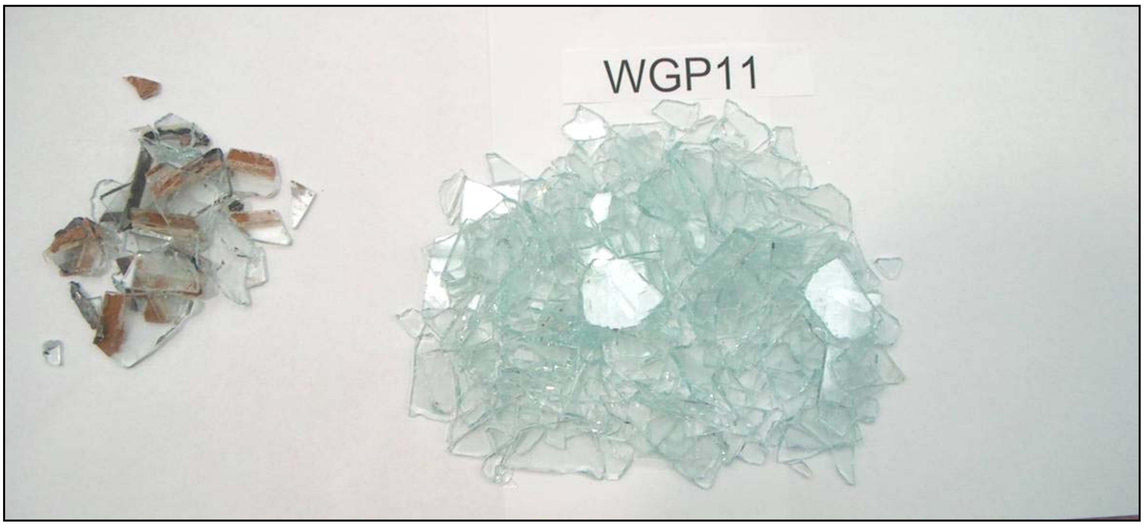
Sample	**WGP09**	
Sample mass	1063g	LOI – 0.67%
General Observation		Flat glass with very little visible contamination accept some coloured glass.
Size Fractions	**% Fraction**	**Comments**
Fines <6mm	11.60%	Fine glass particles including a large portion of glass dust.
Contaminated glass >6mm	4.66%	Glass with organic sealant
Visually "clean" glass >6mm	83.34%	Shards of glass with some glass dust.
Yellow coloured glass >6mm	4.77%	Yellow coloured glass, no other visible contaminates.



Sample	WGP10	
Sample mass	1158 g	LOI – 0.02%
General Observation		Mix of flat, wired and laminated glass.
Size Fractions	**% Fraction**	**Comments**
Fines <6mm	29.49%	Fine glass particles including a large portion of glass dust with various organic and inorganic contaminates.
Contaminated glass >6mm	2.36%	Glass with organic sealant and paper labels.
Visually “clean” glass >6mm	52.93%	Shards of glass with some glass dust.
Wired glass >6mm	12.08%	Large pieces of wired glass
Contamination >6mm	3.14%	Metal edging and sealants.



Sample	**WGP11**	
Sample mass	1045 g	LOI – 0.22%
General Observation		Mainly flat glass with sealant contamination.
Size Fractions	**% Fraction**	**Comments**
Fines <6mm	0.40%	Fine glass particles.
Contaminated glass >6mm	14.30%	Glass with organic sealant.
Visually "clean" glass >6mm	85.30%	Shards of glass with some glass dust.



Sample	**WGP12**	
Sample mass	1158 g	LOI – 0.78%
General Observation		Mix of flat, wired and laminated glass. Including numerous contaminates.
Size Fractions	**% Fraction**	**Comments**
Fines <6mm	17.57%	Fine glass particles including a large portion of glass dust with various organic and inorganic contaminates.
Contaminated glass >6mm	9.78%	Glass with organic sealant and paper labels.
Visually "clean" glass >6mm	65.60%	Shards of glass with some glass and contamination dust on the glass surfaces.
Wired glass >6mm	5.37%	Large pieces of wired glass
Metallic contamination >6mm	1.04%	Metal edging and sealants.
Ceramic (inorganic) contamination >6mm	0.64%	Ceramic contamination.

Sample	**WGP13**	
Sample mass	1104 g	LOI – 0.13%
General Observation		Mainly flat glass with sealant contamination.
Size Fractions	**% Fraction**	**Comments**
Fines <6mm	1.77%	Fine glass particles.
Contaminated glass >6mm	10.18%	Glass with organic sealant.
Visually "clean" glass >6mm	88.05%	Shards of glass with some glass dust. Including a piece of textured glass.

Sample	W	
Sample mass	1183 g	LOI – 1.07%
General Observation		Mix of flat, wired and laminated glass. Including numerous contaminates.
Size Fractions	**% Fr**	**Comments**
Fines <6mm	20.32%	Fine glass particles including a large portion of glass dust with various organic and inorganic contaminates.
Contaminated glass >6mm	1.51%	Glass with organic sealant and inorganic contaminates (putty).
Visually "clean" glass >6mm	75.61%	Shards of glass with some glass and contamination dust on the glass surfaces.
Wired glass >6mm	2.10%	Large pieces of wired glass
Inorganic contamination >6mm	0.44%	Ceramic contamination.
Organic contamination >6mm	0.02%	Sealant materials.

Sample	WGP15	
Sample mass	1035 g	LOI – 0.48 %
General Observation		Mix of flat, wired and coloured glass. Including numerous contaminates.
	% Fraction	Comments
Fines <6mm	17.30%	Fine glass particles including a large portion of glass dust with various organic and inorganic contaminates.
Contaminated glass >6mm	5.75%	Glass with organic sealant and inorganic contaminates (putty).
Visually "clean" glass >6mm	75.04%	Shards of glass with some glass and contamination dust on the glass surfaces.
Wired glass >6mm	58.49%	Large pieces of wired glass
Coloured glass>6mm	0.32%	Coloured glass.
Contamination >6mm	1.62%	Putty material.

Sample	**WGP16**	
Sample mass	1058 g	LOI – 1.06 %
General Observation		Mix of flat and coloured glass. Including numerous contaminates.
Size Fractions	**% Fraction**	**Comments**
Fines <6mm	5.47%	Fine glass particles including a large portion of glass dust.
Visually "clean" glass >6mm	91.88%	Shards of glass with some glass and contamination dust on the glass surfaces.
Coloured glass>6mm	0.24%	Coloured glass.
Contamination >6mm	2.41%	Putty material and other sealing materials.

Sample	**WGP17**	
Sample mass	1112 g	LOI – 0.89 %
General Observation		Mix of flat and coloured glass. Including numerous contaminates.
Size Fractions	**% Fraction**	**Comments**
Fines <6mm	4.29%	Fine glass particles including a large portion of glass dust.
Visually "clean" glass >6mm	93.26%	Shards of glass with some glass and contamination dust on the glass surfaces.
Coloured glass>6mm	2.18%	Coloured glass.
Contamination >6mm	0.27%	Putty material and other sealing materials.

Sample	**WGP18**	
Sample mass	1150 g	LOI – 0.96 %
General Observation		Mix of flat and coloured glass. Including numerous contaminates.
Size Fractions	**% Fraction**	**Comments**
Fines <6mm	17.28%	Fine glass particles including a large portion of glass dust with various organic and inorganic contaminates.
Visually "clean" glass >6mm	78.66%	Shards of glass with some glass and contamination dust on the glass surfaces.
Contaminated glass >6mm	0.25%	Glass with sealant materials.
Coloured glass>6mm	1.24%	Coloured glass.
Contamination >6mm	2.17%	Putty material and other sealant materials.
Metallic contamination >6mm	0.40%	Screws.

Sample	**WGP19**	
Sample mass	1045 g	LOI – 0.34 %
General Observation		Flat glass with putty sealant materials.
Size Fractions	**% Fraction**	**Comments**
Fines <6mm	6.68%	Fine glass particles including a large portion of glass dust with various organic and inorganic contaminates.
Visually "clean" glass >6mm	88.10%	Shards of glass with some glass and contamination dust on the glass surfaces.
Contaminated glass >6mm	2.91%	Glass with putty and other sealant materials.
Contamination >6mm	2.31%	Putty material and other sealant materials.

Sample	**WGP20**	
Sample mass	1029 g	LOI – 0.63 %
General Observation		Mix of flat including putty and other sealant materials.
Size Fractions	**% Fraction**	**Comments**
Fines <6mm	7.76%	Fine glass particles including a large portion of glass dust with various organic and inorganic contaminates.
Visually "clean" glass >6mm	85.39%	Shards of glass with some glass and contamination dust on the glass surfaces.
Contaminated glass >6mm	3.53%	Glass with sealant materials.
Contamination >6mm	3.32%	Putty material and other sealant materials.

Data sheet of re-processing of flat glass waste collected during the trials

Collection data:

Total tonnage collected by the end of the project : 102.34 tonnes
Total tonnage rejected upon receipt of skips : 9.40 tonnes
Nett tonnage transferred for reprocessing : 92.94 tonnes

After mass sieving at St.Helens

Fraction 1 - 0mm-16mm : 30 tonnes total.
Organic contamination : 2166 grams per tonne
Inorganic contamination : 2851 grams per tonne
Non ferrous metal : 437 grams per tonne
Ferrous metal : traces*

Action taken: Rejected to fine reject glass bay due to excessive inorganic (stone etc.) contamination. Particles too small for supplementary optical sorting

Fraction 2 - 16mm- 25mm : 38 tonnes total.
Fraction 3 - 25mm- 60mm : 14 tonnes total.

Due to difficulties with testing at these particle sizes, the samples were amalgamated, crushed and then sampled and tested.

Organic contamination : 6268 grams per tonne
Inorganic contamination : 4178 grams per tonne
Non ferrous metal : 3569 grams per tonne
Ferrous metal : traces*

Action taken: Attempted basic reprocessing but product far too contaminated for use by BGI (end market). Glass subsequently sent for secondary reprocessing using electronic optical sorting and metal decontamination to improve contamination profile.

Fraction 4 - 60mm+ : 10 tonnes total

Action taken: Due to the highly contaminated nature of this fraction, frame materials, masonry etc. it was decided to attempt no further reprocessing and landfill the fraction in its entirety.

After Secondary Optical sorting at St.Helens

Size fraction - 16mm-60mm : 42 tonnes total
Organic contamination : 2734 grams per tonne
Inorganic contamination : traces*
Non ferrous metal : 950 grams per tonne**
Ferrous metal : traces*

Action taken: Product sent for final reprocessing and crushing

* traces: where no contamination was found during the sampling and testing process but where the presence of said contaminant was likely but sporadic

** The remaining presence of a high level of non ferrous metal contamination is due to the fact that the non ferrous fraction of the BRE glass contained an unusually high level of lead (Pb) which is by far the most difficult to remove of the non ferrous metals.

After final reprocessing at St.Helens

Size fraction – 0mm - 6.5mm : Tonnage not measured, presumed to be 42 tonnes as per previous paragraph as losses here should be minimal.
Organic contamination : 122 grams per tonne
Inorganic contamination : 5 grams per tonne
Non ferrous metal : 45 grams per tonne
Ferrous metal : 10 grams per tonne

Action taken: Delivered into BGI 23/9/04