

Flat Glass Recycling in Scotland

Assessment of Market Opportunities



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Report prepared by
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Executive Summary

Flat glass can arise from a wide variety of waste streams and sources. As the majority of flat glass is lime glass it can be processed to meet a variety of end market specifications.

In Scotland it is estimated that approximately 319,533 tonnes of flat glass arise in the waste stream each year; however only 19,013 tonnes of this is currently recovered. This would indicate that there are significant opportunities to increase the volume of flat glass recovered from the waste stream.

However it must be noted that the vast majority of this material arises from the construction and demolition sector, which continue to largely dispose of their waste to landfill. Flat glass recovery from this sector largely consists of the glass being collected amongst other C&D wastes and ending up as secondary aggregates.

The sources of glass and associated contaminants can play a significant role in determining the end markets available to a particular material. However with alternative markets continuing to be developed in Scotland and the UK, there is increasing opportunity to economically recover this flexible resource.

The volume of flat glass looks like likely to increase in the coming years with the introduction of local authority recycling targets, End-of Life Vehicles Directive trend towards utilizing greater volumes of glass in the building sector. The greatest challenge for the industry will be to economically recover this valuable resource.

Work which could make a significant impact on volumes of glass recovered includes:

- Survey of local authority civic amenity sites to determine potential for implementing facilities to allow for the collection of flat glass
- Survey of local authority building maintenance departments to determine the volume of flat glass they replace through their public buildings as well as council housing. Also to determine what happens with the glass and what the scope is for recycling it.
- Review of current research on pulling flat glass from the C&D waste stream with the aim of identifying focussed pilot projects aimed at pulling greater volumes of flat glass from the waste stream

Introduction

Flat glass is widely utilised by many industries and due to its inherent physical and chemical properties can be recycled into a wide variety of end markets, recovering a valuable resource which may otherwise end up being landfilled.

This report aims to identify the potential sources of flat glass in Scotland and the volume arising from each. The condition of these materials when recovered can significantly affect the possible disposable / recovery route available to that particular material. The report highlights some of the main factors which influence a material's acceptability into these markets.

The introduction of the Packaging Regulations and associated Packaging Recovery Notes (PRN) was introduced to the UK to encourage the recovery of packaging materials from the waste stream, placing particular emphasis on producer responsibility. The potential revenue generated from PRN's has helped reprocessors to develop their operations and support the collection infrastructure.

However as flat glass cullet now competes with container cullet on many fronts and markets without such financial drivers it remains at an economic disadvantage. Demand for flat glass cullet may potentially drop as increasing volumes of container glass; particularly flint glass is pulled from the waste stream. Also, the advance in processing technologies enabling greater contaminants to be removed will also enable greater utilisation of container cullet in markets which otherwise may only use the cleanest sources of cullet regardless of associated PRN revenue.

The logistical problem of collecting the glass due to the sheer topography of Scotland also poses particular problems. The collection of this awkward material can prove uneconomic in some cases and the challenge remains for collectors to penetrate these sparse sources both effectively and economically.

In recent years the topic of market development has never been far from conversations regarding recycling. This is particularly so regarding flat glass cullet. With there being an increasing desire to use container cullet by end markets rather than flat cullet, there has never been a time where market development has been so crucial to flat glass recycling, particularly higher value markets which can sustain the collection infrastructure. Remade Scotland and the UK Market Development Network as a whole are working on a number of fronts to address many of these issues and to ensure there are viable end markets for all types of glass recovered from the waste stream.

This report aims to give an overview of the market and how it is developing. Ever-changing market conditions dictate that those involved in the industry need to react and adapt to this constantly changing market.

Production of Flat Glass

The worldwide flat glass market is principally dominated by five major groups, namely Asahi (Japan), Pilkington (UK), Saint-Gobain (France), PPG Industries (USA) and Guardian Industries (USA).

The flat glass sector is the second largest in the EU glass industry, and represents approximately 22% of the total glass production. The sector employs approximately 12,500 people in the manufacturing stages, and a further 90,000 are employed in the processing of the glass into end markets¹.

At present there are two flat glass manufacturers in the UK, namely Pilkingtons and St.Gobain which produce approximately 700,000 tonnes of flat glass each year. The American company Guardian are currently building a new facility in Goole, Yorkshire which is due go into production in early 2004. It is estimated the plant will produce approximately 250,000 tonnes of float glass per annum.

Flat glass, like container glass is made from soda lime glass, which principally comprises of silica sand (SiO_2), soda ash (Na_2CO_3) and limestone (CaCO_3).

Flat glass is used in a wide variety of applications such as glazing, transport, horticulture and decorative applications.

There are two methods of manufacturing flat glass in the UK, namely the float glass method and the rolled method.

Float glass – this process was developed by Pilkington Brothers PLC in 1959, and has since become the principal method for producing flat glass world wide.

Float glass accounts for approximately 95% of flat glass production and is predominantly used in the construction and automotive industries. Construction accounts for approximately 80% of this consumption with the remainder being predominantly utilised by the automotive industry.

The float glass method works by feeding molten glass from the furnace onto a bath of molten tin in a continuous ribbon. Since the glass and tin do not mix the surface between the two materials is completely flat. The ribbon then leaves the bath and is cooled until the surfaces are sufficiently solid enough to be safely lifted onto a system of conveyor rollers. The ribbon will then pass through an annealing lehr where it is cooled under controlled conditions until it reaches room temperature. The glass then goes to a cutting stage where it is cut to the desired shape and size. A large modern float glass plant can produce up to 5000 tonnes of glass per week and will operate continuously all year round².

Rolled glass – this process is used in the manufacturing of patterned or wired glass and accounts for approximately 5% of the sector output.

This method works by feeding a continuous stream of molten glass between water cooled rollers. Patterned glass is made in a single pass process, with the bottom roller engraved with the desired pattern and the top roller smooth. The thickness of the glass can be controlled by simply adjusting the gap between the rollers. Wired glass is made in a double pass process.

¹ Standing Committee of the European Glass industries website: www.cpierglass.be/main.html

² British Glass - Making Glass: www.britglass.co.uk

Flat Glass Waste Arisings

At present there is a lack of accurate data regarding flat glass waste arisings throughout the industry, which is in part due to availability of quantitative data at a company level; however it is also because information regarding flat glass production also tends to relate to area rather than weight. Flat glass can also have a life span of several years before needing replaced and therefore production figures often do not relate to disposal rates.

The vast majority of waste flat glass arises principally from secondary flat glass manufacturing, the construction industry and the End-of-Life Vehicles (ELVs) sector.

Figure 1: Flat Glass Arisings

Secondary Processing

The glass manufacturing industry in the UK is largely based in the north of England and to a lesser extent, the Scottish central belt.

However approximately 20,000 tonnes per annum arise from widespread secondary glass processing and glass merchants in Scotland. This principally arises from off-cuts and breakages¹.

This has encouraged flat glass collectors in Scotland to try and develop markets more local to sources of glass arisings. They have also sought to minimize the transportation costs inherent in collecting from long distances.



Auto Industry

The auto industry uses both toughened and laminated glass for use in vehicles. Toughened glass is easy to remove from vehicles once it shatters; however laminated glass through its very nature does not shatter and needs to be removed manually, which can be both time consuming and costly.

It is estimated that the average motor vehicle contains approximately 30kg (~3%) of glass².

Therefore with approximately 1.9 million vehicles being scrapped each year in the UK, this equates a potential 60,000 tonnes of waste flat glass arising per annum, with additional sources of waste glass arising through the replacement windscreen sector.

A report by the Transport Research Laboratory (TRL) produced on behalf of SEPA, estimated that the total number of ELVs arising in Scotland during 1999 was approximately 134,433 vehicles, potentially generating approximately 4033 tonnes of waste flat glass per annum. These vehicles came from three main sources:

Premature ELVs from insurance companies (11%)

Old ELVs, abandoned and recovered (4%)

Old ELVs from private owners and retailers (85%)

TRL estimate that approximately 10% of an ELVs weight is recovered by dismantling, 16% by scrapping with 6% being disposed to landfill. The remaining 68% of the vehicle enters one of the 4 shredding facilities in Scotland. Of the 90,000 tonnes of ELVs shredded annually in Scotland, an estimated 75% is recovered as ferrous and non-ferrous metal with the remaining 25% being landfilled³.

¹ Interview with Rob Nicol, Berryman, 26th January 04

² Automotive Consortium on Recycling and Dismantling (ACORD) Annual Report 1998

³ SEPA Web-site: www.sepa.org.uk/nws/education/vehicles.pdf

The volume of waste glass arising from this sector appears small compared to the total volume of waste flat glass arisings in the UK. However field studies conducted by the Consortium for Automotive Recycling (CARE), suggest that in practice even this level of recovery is unlikely to be achieved. Complete recovery assumes that an ELV will retain its full complement of glass and that it is all recoverable. Often vehicles are damaged and / or the glass has been sold on as parts. Also, a high percentage of glass can be lost while the ELV is in transit or where the only basic glass recovery processes are employed.

In September 2000 the UK adopted the End-of-Life Vehicles Directive, which will require each Member State to reuse or recycle 80%, and recover 85% of ELVs (by weight) by January 2006. A second set of targets requires them to reuse or recycle 85% and recover 95% by 2015. Recovery encompasses both recycling and energy recovery. This will have a huge impact on the volume of ELV glass arising both in Scotland and the UK as a whole.

At present there are a large number of ELV facilities operating in Scotland, including 105 dismantlers, 208 scrap yards and 58 metal recyclers¹. However, the implementation of the ELV Directive which introduces stricter environmental controls, may lead to a reduction in the number of processing facilities available in the future, as some operators may find it uneconomical to invest both the time and money required to become an authorised treatment facility. The new rules mean that the 'de-pollution' of vehicles is required before recycling.

The new regulations mean that producers will be responsible for the costs of collecting and treating vehicles with a negative value put on the market after July 2002. However the cost of delivering an ELV to an authorised facility will still have to be met by the last owner.

Glass will play its part in meeting the directive targets and is specifically identified as one of the materials that must be recovered, as will other materials such as plastics which are not currently recovered during the shredding process.

There is significant scope for recycling glass since it is a material which can be easily identified and removed. The major issues associated with recovering glass from an ELV are the time and costs involved at the dismantling facilities, and the inherent low value of the resultant material. This type of dismantling recovery system on an EU-wide scale may ultimately prove prohibitively expensive, particularly if there is a lack of end markets for the glass.

Also, the logistics in collecting relatively small volumes of glass from widely dispersed dismantlers, particularly in Scotland may negate any environmental benefits gained from the recycling process.

After removal from the vehicle the glass is processed to produce cullet. In the cullet processing plant the ELV glass is crushed and refined through a series of magnets and jets to remove contaminants present.

Figure 2 shows that once the collection infrastructure is established for this type of waste flat arising it is possible to feed the processed glass into a variety of markets.

Flat glass which is sourced from the auto windscreen replacement sector (approximately 1,500 tonnes per annum in Scotland²) will also go through a similar route to that of glass from a dismantler. If adequate education is in place and quality control measures are implemented the quality of glass from these sources can be of a standard sufficient to meet specifications for a variety of markets once treated at the cullet processor stage.

Guidance released by the Environment Agency and the Scottish Environment Protection Agency (SEPA) has stated that if glass is intended to be recycled as cullet that the large panes should be removed from the vehicle before the vehicle is shredded, however if it is to be recycled as a secondary aggregate then it may be left in the vehicle.

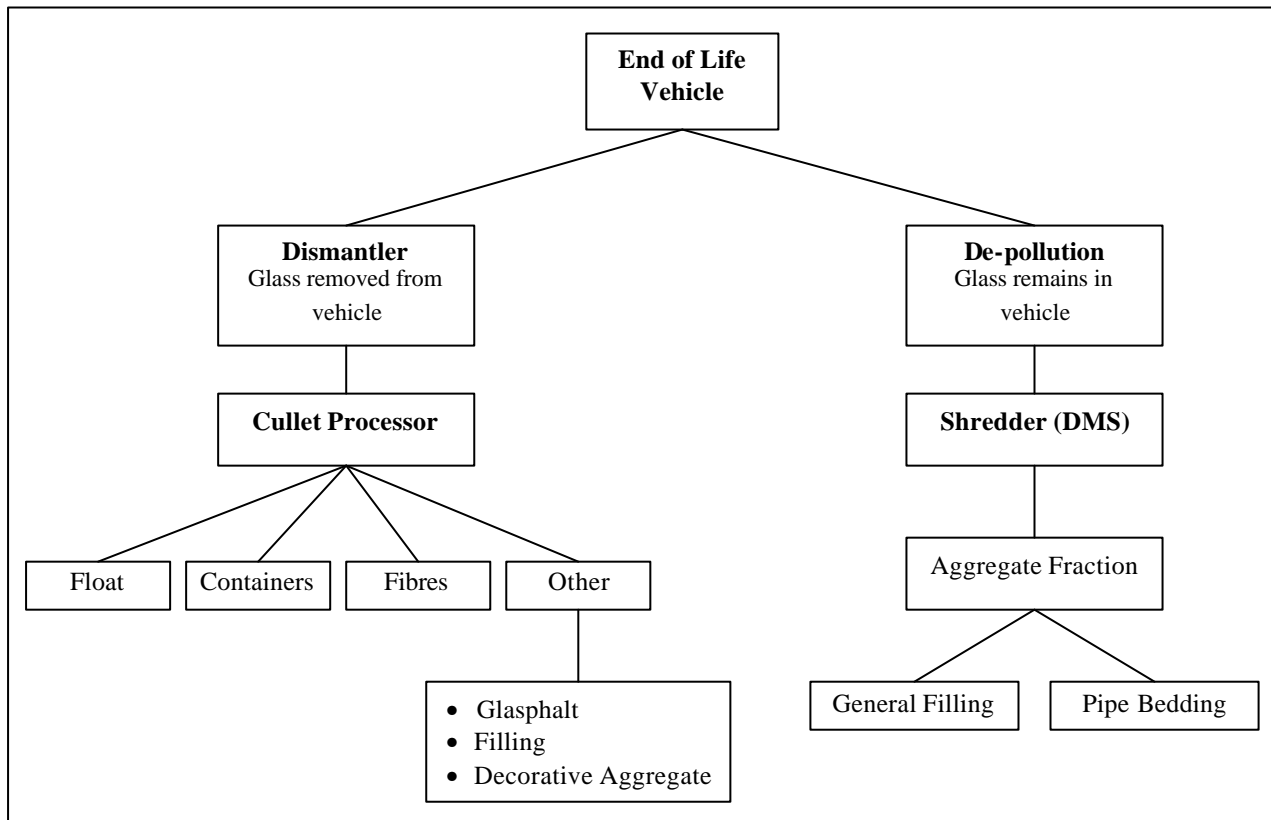
¹ SEPA Web-site: www.sepa.org.uk/nws/education/vehicles.pdf

² This has been estimated as 10% of the UK figure

Remade Scotland in November 2003 carried out a sample survey which involved contacting all auto windscreen companies in Glasgow to determine how they dispose of their waste flat glass arisings. The survey found that the size of company varied dramatically from ones which only replace 2-3 windscreens a day to companies which replace up to 500 per week. Approximately 60% the companies questioned indicated that their waste flat glass was recycled. The remaining 40% who do not currently recycle indicated that their waste was collected by waste management companies for disposal. They were unaware of options for recycling their waste flat glass.

This would indicate that there remains a significant volume of waste flat glass in Scotland which is relatively easy to pull from the waste stream, provided it can be collected and recycled cost effectively.

Figure 2: Possible Recycling Routes¹



Building Sector

The Building Research Establishment Ltd (BRE) has estimated that construction and demolition (C&D) waste contains approximately 3 - 6% of flat glass. The total UK C&D waste arisings are 72.5 million tonnes per annum which implies that the total flat glass arising from this source is between 2.2 and 4.4 million tonnes per annum in the UK.

A report by the EnviroCentre produced on behalf of SEPA in 2002 estimates that 6.28 million tonnes of C&D waste were produced in Scotland. This would imply that there are between 190,000 and 380,000 tonnes of flat glass arising from this waste stream in Scotland per annum.

At present the recycling of flat glass from C&D sources in the UK is minimal as refurbishment and demolition contractors will often ignore the glass fraction, leading to it ultimately becoming mixed with other materials and ending up in landfill.

¹ European Association of Flat Glass Manufacturers: Statement on ELV Glazing, www.gepvp.org

Historically the volume of glass used in buildings has grown, with a change from single to double or even triple glazing. New trends are also encouraging greater volumes of glazing to be used by the building sector.

Technical barriers to recycling this source of flat glass are based primarily on glass type and composition. For example wired or laminated glass is more problematic to recycle than pure rolled or float glass.

Another difficulty in recycling in this sector is collecting both the glass and glazing frames. The domestic and commercial replacement window sectors will often return complete windows to a reprocessing plant. With commercial windows, particularly those on demolition sites, it is less clear whether glass alone or entire windows are reclaimed from site for processing or whether glass can be broken down at site. Many of these barriers will need to be overcome to improve the economics and achieve greater separation and recycling rates

The replacement sector in this industry can also generate considerable volumes of waste flat glass and has seen trends change to replacing single with double glazing which can have a life expectancy of up to 50 years. The trend to furnish buildings with increasingly large glazed areas and the increase in replacement of double glazed units will inevitably lead to increasing volumes of waste flat glass arising from the demolition and replacement window sectors. This increase in waste, coupled with the increasing disposal costs will prove a significant burden to the industry and will require other disposal routes such as recycling to be developed (provided markets can be developed which can support the collection infrastructure).

The introduction of new fiscal and regulatory drivers being introduced are also placing more responsibility on the producers of waste, making them responsible for ensuring that their waste is recovered for reuse and / or recycling. The European PVC industry, and the window frame sector represented by the European Plastics Converters (EuPC) has a voluntary commitment to resource efficiency, and aims to recycle half of the collectable window profile waste by 2005, with a target by 2003. Contamination of the flat glass and associated window and door profiles is perceived to be one of the key barriers to recycling architectural glass, especially into higher value applications. There is a clear need to identify methods of minimising contamination at the removal, transportation and management level.

One of the main difficulties in flat glass recycling is utilising PVB laminated glass and wired glass, which needs additional processing. The PVB laminate layer is removed by using crushing and screening systems. Magnetic systems are employed to remove the metal fraction from wired glass¹.

At present there are approximately 7,000 – 8,000 window replacement companies spread throughout the UK. In the UK during 2001 the domestic sector alone replaced 6.7 million window units, generating approximately 90,000 tonnes of waste flat glass. This volume of waste glass is expected to increase significantly in the coming years, particularly as the replacement of double glazed units becomes more popular.²

The waste flat glass generated by this sector will usually be collected in mixed containers with other waste materials; often rubble and is either disposed to landfill or recycled as a secondary aggregate.

¹ IWM Wastes Management Journal, September 2002, Glass – A Resource For The Future by James Hurley (BRE)

² WRAP: Research into Waste Glass, Window and Door Frames from the Demolition and Replacement Window Industries, may 2003, Written by BRE on behalf of WRAP

Existing Flow of Glass from Replacement & Demolition Sectors

Table 1: Types of Waste Management Options¹

	Reuse	Recycle	Combusted	Landfill
Flat Glass	9.3 %	21.2 %	0.0 %	69.6 %
Timber	23.8 %	14.5 %	4.6 %	57.1 %
PVC-U	37.8 %	3.3 %	0.0 %	58.9 %

Existing Flow of Glass from Replacement & Demolition Sectors

Table 1 shows the findings of a survey conducted by BRE on behalf of WRAP looking at waste arisings in the window replacement and demolition sectors. The table clearly shows that at present the majority of flat glass and profiles from the demolition and replacement window sector continue to be sent to landfill as transport as labour costs can often make recycling cost prohibitive. Also, until the cost of landfill rises significantly enough to make recycling a more attractive option, vast volumes of flat glass will continue to be sent to landfill.

The survey also highlighted that only 19% of the respondents stated that more than 80% of their flat glass waste was segregated. This indicates there is a need for continued education programmes and closer working relationships between waste flat glass generators and collectors.

The construction industry in the UK continues to remain buoyant with marginal growth expected, particularly through the house building sector. This trend will continue to see demand for increased volumes of flat glass from the manufacturing sector which will ultimately end up in the waste stream.

Antique & Art Glass

There is already an established market in the UK for antique and art glass. Although there is no recognised industry trade body at present there are approximately 11 companies in Scotland registered with SALVO (independent body representing the reclamation sector) and approximately 100 UK wide.

This is a highly specialist market with much of the material being unique, as the majority art glass cannot be manufactured again due to it becoming a dying trade with traditional skills being lost.

Recovery of this type of flat glass has become popular and in many cases will be reused rather than recycled.

Although there no accurate figures estimating the volume of art glass which is recovered, it is assumed this type of flat glass does not substantially affect the overall recycling figures for flat glass.

¹ WRAP: Research into Waste Glass, Window and Door Frames from the Demolition and Replacement Window Industries, may 2003, Written by BRE on behalf of WRAP

Summary of Flat Glass Arisings & Recycling Levels

Table 2 shows the approximate levels of flat glass potentially available within the waste stream both within Scotland and the UK as a whole.

Table 2: Summary of Flat Glass Arisings & Recycling Levels

Source	Scotland (Potential) T/yr	Scotland (Actual Recycled) T/yr	UK (Potential) T/yr	UK (Actual Recycled) T/yr
Vehicles Scrap	4,033	1,613	60,000	8,000
Replacement	1,500	900 (~60 %)	15,000	12,000
Building C & D	190,000 – 380,000	Minimal	2.2 – 4.4 M T	Minimal
Replacement	9,000 (10% of UK)	1,800 (~20 %)	90,000	~ 27,000
Secondary Glass Processing	20,000	15,000	250,000	175,000 – 200,000
TOTAL	224,533 – 414,533	19,313	3,715,000	234,500

The table shows that there are approximately 319,533 tonnes of flat glass available from Scottish waste arisings per annum. However the vast majority of this (~285,000 tonnes) arises from the construction and demolition sector, which is often collected and ultimately disposed amongst other building materials, therefore very little recovery of this fraction currently takes place. This will continue until either better mechanisms for recovery are introduced by the building sector or the cost of disposal rises, making recovery of materials a more viable option.

Of the remaining 34,033 tonnes arising in Scotland currently 19,013 tonnes are recovered, representing a 51% recycling rate.

There is a particularly low level of recovery from the scrap vehicle sector; however the introduction of the End-of-Life Vehicles Directive will inevitably lead to a greater level of recovery. There is also a low level of recovery from the building replacement sector, although trends towards utilizing double and triple glazed units will ultimately lead to greater volumes of flat glass arising from this source which may make recovery an increasingly viable option.

It can be seen that although there is a significant volume of flat glass currently being recovered, there is still remains a lot of scope to vastly improve the level of recovery both in Scotland and the UK.

Recycling of Flat Glass

General

The recovery and re-utilisation of flat glass scrap and off-cuts from the manufacturing sector is well established in the UK, however traditionally the only significant example of post-consumer flat glass recycling in the UK has been from vehicle windscreen replacement, which is estimated to produce approximately 15,000 tonnes per annum in the UK¹.

It is estimated that approximately 223,500 tonnes of flat glass are recycled per annum in the UK.

Currently almost all recycled flat glass goes back to primary glass manufacturing and the fibre glass industry²:

Flat glass	70,000 tonnes / year
Container	60,000 tonnes / year
Fibre glass	50,000 tonnes / year

Figure 3: Processed Flat Glass



Glass Manufacturing

Recycling flat glass back into flat or container glass remains one of the main outlets for recycling flat glass and can generate a variety of environmental and cost benefits, as well as offering a 'closed-loop' recycling option. Possible benefits include:

- Reduced melting temperature and energy required
- Reduced quarrying
- Reduced atmospheric pollution
- Reduced batch costs

As stated above, at present the flat glass manufacturers utilise approximately 70,000 tonnes per annum of process scrap (e.g. off-cuts from glaziers). These factories produce significant quantities of in-house cullet which is suitable for processing back into the furnace.

The disparity in specifications for each of these glass markets greatly influences the scope for utilising flat glass in these

markets.

Float glass for example by its very nature is produced to a very high specification and as such is extremely sensitive to even the slightest contamination. Tables 2 & 3 highlight the main problems and risks to float glass quality if not controlled. The main problem with recycled glass as a feedstock is contamination.

¹ Recycling World Magazine (online) <http://www.tecweb.com/wlibrary/>

² WRAP: Recycled Glass Market Study & Standards Review, 2003 Update

Table 3: Main Problem Areas Associated with Cullet Usage¹

Potential Problem Areas	Risk to Float Quality if Not Controlled
Cullet from glass of different compositions (different chemical makeup) e.g. automotive glass from several manufacturers, bottle glass and glass from tableware or ovenware	Ream in the glass which appears as distortion. Note: Ream is simply a region of glass within the product, which has a composition different from the average.
Clear and tinted glass i.e. iron level	Glass colour and solar control properties
Contamination issues (metal attachments, adhesives, glass printing, heating and antenna wires, plastic from laminated glass)	Inclusions, bubbles, ream knots, colour variation

Table 4: Examples of the Effect of Contamination²

Type of Contamination	Effect
Aluminium	Silicon inclusions and major bubble outbreak
Refractory particles Examples include: Chromite >0.2mm Carborundum >0.5mm	Inclusions (small particles not detectable)
Silicon Carbide	Major bubble outbreak
Carbon	Affects melting and foaming causing inclusions and bubbles. Also colour

The contamination issues detailed above can potentially cause a loss of up to a week in flat glass production due to quality failure, ultimately leading to the batch being rejected.

It is estimated that a typical float plant can use up to 20% of cullet in a batch, however due to quality and cost this material is normally sourced from the companies own downstream processing plants.

A typical cullet specification for float glass is shown in Table 5. Examples of specifications for containers and fibreglass, which are less severe, are also shown.

¹ European Association of Flat Glass Manufacturers – Statement on ELV Glazing (Recycling of End-of Life Vehicle Glazing)

² European Association of Flat Glass Manufacturers – Statement on ELV Glazing (Recycling of End-of Life Vehicle Glazing)

Table 5: Max Permissible Levels of Contamination¹

Contamination Types	Particle Weight / Size	Float max allowed g/t	Fibreglass max allowed g/t	Containers max allowed g/t
Ferrous Metal	>0.5g	None (2 if <0.5g)	65	50
Non-Ferrous Metal	>0.1g	None (0.5 if <0.1g)	24	20
Refractory Materials	>0.2mm	None	250	20
Organic Substances	>2g	None (45 if <2g)	120	3000

It can be seen from the table above that the specification for float glass is far stricter than that for fibreglass and glass container markets.

The quality issues associated with recycling back into the flat glass manufacturing sector, currently restricts this market to only approximately 70,000 tonnes per annum in the UK.

When recycling flat glass cullet is into the container manufacturing sector, which as things stand the majority goes to Rockware; the quality requirements are similar to those for container cullet.

Commercially flat glass is at a disadvantage compared to container glass, as container glass is financially more attractive due to PRN revenue. Therefore it is likely that the use of flat glass in these markets may remain static or even decline if increased volumes of good quality container cullet can be sourced.

Also, technically flat glass has limited opportunities in the container market due to the high iron content of flat glass, as it has the tendency to cause a slight greenish tinge in colour and therefore is best suited to lower value glass containers.

Table 6: Relative Maximum Seed Count Allowances²

Glass Type	Relative Maximum Seed Count
Float	1
Rolled Plate	7
Container	10,650
‘E’ Glass (reinforcement fibre)	25,000
Insulation Glass Fibre	50,000

Table 6 gives the relative maximum ‘seed count’ for various types of glass. The seed count is a composite value indicating the number and size of gas bubbles entrained in the finished product.

The chemical composition is extremely critical for float glass production and the composition of the cullet must precisely match the glass composition in the furnace, which means that at best, flat glass

¹ European Association of Flat Glass Manufacturers – Statement on ELV Glazing (Recycling of End-of Life Vehicle Glazing)

² WRAP: Recycled Glass Market Study & Standards Review, March 2002

manufacturers will only recycle material that originates from their own downstream processing plants where they can be certain of the composition.

A report published by the Waste and Resources Action Programme in 2002 indicated that Pilkington considered the risks of using external flat glass in their float glass production lines as too high, although they were willing to use it in their rolled flat glass. They also indicated that they could utilise more cullet in this line if they could source sufficiently good quality cullet at a reasonable price.

St.Gobain do use a small amount of recycled flat glass but this only comes from their own downstream processing facilities and they would not consider using glass from any other source.

WRAP estimates that given these two companies already recycle an estimated 50,000 tonnes per annum between them, and that there is only scope for up to an extra 20,000 tonnes per annum recycling capacity remaining from these end users.

At this time cullet from ELV sources is not used. The contamination levels from any post-consumer flat glass product are considered too high to make recycling economically viable at present; with Pilkington estimating that it would be both costly and labour intensive to process glass from ELV and C& D sources to meet their purity requirements.

Significant levels of contamination arise particularly from and rear windscreens. There are also technical problems with processing automotive glass. The methods used to fix non-movable glazing into the bodies of cars have been changing. The trend has moved away from the 'gasket sealing' technique, and now a 'direct bonding' method is used, which glues the glazing into place. This makes it difficult to remove the glass in one piece and can also lead to problems with adhesive contamination for the cullet. Also, the plastic laminate interlayer makes the front windscreen difficult and expensive to remove and process.

Regardless of contamination issues, the recovery of these sources of glass will prove difficult. Manually recovering glass from ELVs is a labour and energy intensive activity.

The logistical difficulty in collecting glass from the wide distribution of ELV dismantling facilities in the UK could alone prove costly and problematic.

Even if the sorting issues were overcome, the logistics of collection and transporting the material would be daunting. For example, if approximately 1.9 million ELVs are being dismantled at 4000 separate locations. Assuming each dismantler might potentially handle 475 vehicles per annum. Recovering approximately 50% by mass (taking into account some sales as replacement parts and some breakage during vehicle transportation) and assuming that each vehicle initially contains 30kg of glass on average, each dismantler might produce 7 tonnes of waste glass annually, with contamination likely.

Figure 4: Flat Glass Reprocessing Facility

One approach could involve developing collection vehicles; similar to those used in kerbside collection schemes to collect recyclable household waste (similar to the Dutch system for the collection of ELV materials).

Another possibility stemming from research carried out by metal recycler Mayer Parry suggests separating the glass fraction after it has been shredded. Analysis revealed a glass content of about 18.5%. If we extrapolate this figure, about 12% of the glass entering the shredder is currently being recovered and recycled¹.



¹ Recycling World Magazine (online) <http://www.tecweb.com/wlibrary/>

Other Markets

Glass Fibre

The fibre glass market in Scotland is dominated by Superglass, which can utilise an estimated 40,000 tonnes of flat glass. However due to this demand glass will often be hauled up from sources in England.

Superglass operate a conventional fuel-fired furnace which allows them to use either plate or container cullet. However, technically the glass fibre industry prefers to utilise flat glass due to lower contamination levels. Ceramic contamination is of particular concern.

Figure 5: Close Up of Processed Cullet



However the attraction of using container glass with the associated PRN revenue coupled with improvements in processing techniques may see this market switch to container cullet in the coming years.

In the UK glass fibre manufacturers utilize approximately 50,000 tonnes of plate cullet each year. All three major manufacturers of this product in the UK are current purchasers of plate cullet. The quality requirements of this industry are similar to those of float glass with one notable exception. They are less sensitive to feedstock colour, provided that the colour is consistent. Contamination by stones, ceramic glasses and other high temperature melting materials can also

cause production problems.

Decorative Aggregates

Flat glass has begun to find its way into the decorative aggregate market and is an ideal feedstock due to it often being perceived as a cleaner feedstock compared with container cullet. It also does not have the as high an organic contamination content, so readily associated with container cullet.

Essex based Windmill Aggregates has been utilising flat glass along with container glass to produce a new type of gravel called 'Crystaleis'. The product has received wide coverage through gardening programmes and show gardens at Chelsea, Hampton Court and BBC Gardeners World Live. Pulverizing the glass ensures that sharp edges are removed and that it is safe for handling.

Northern Cullet (which is also part of the Potters Europe Group) also supplies a decorative aggregate called 'Decogem', which can be used in a variety of garden and home applications.

This is considered a relatively high-value market and as such can be cost effective without surplus revenue generated from utilising container cullet. Also, the loss in PRN revenue can often be saved through reduced processing to remove organic residues.

This market is in its infancy stages and the consumption is still low; however with these products now receiving considerable exposure through garden and home shows coupled with increasing availability this market is set to grow in the coming years.

Blast Cleaning Abrasives

Flat glass can be used to manufacture glass grit for blast cleaning as well as being used to produce glass bead.

Glass grits are currently being produced using container cullet simply due to the PRN revenue implications previously discussed. However, flat glass cullet due to its associated low contamination, is being used to produce glass beads by Potters Ballotini. The beads are used in a variety of industrial metal preparation applications such as peening, cleaning, finishing and deburring.

Highway Safety Marking Spheres

Potters Ballotini manufacture glass spheres, similar to the ones they produce for blast cleaning, using flat glass cullet, which can be used with a variety of binders, water-based paint, epoxy thermoplastic, polyester, PMMA and polyurethane.

This is then used for highway safety markings. The inclusion of glass spheres, help provide excellent durability and night time reflectivity.

Construction Aggregates

At present the only flat glass which ends up being utilised by this market is when it comes out the construction and demolition sector and is mixed with other waste materials deemed suitable to be processed as secondary aggregates.

Also, as ELV shredding facilities come online in the UK the aggregate proportion may end up being used as general fill material or pipe bedding.

The UK / Scottish Situation

At present there are two principal companies which collect and recycle flat glass in Scotland and the UK as a whole, namely Berryman and Viridor-Richardson.

They both collect waste flat glass from a variety of sources which include glass manufacturers, glass merchants, replacement sector, and end of life sources.

Flat glass is normally collected in either a clean skip or a mixed skip. The clean skip containing high quality low contaminated glass will often be collected for free, whereas a mixed skip will contain glass which has a higher level of contamination, and which has often not been separated from frames and fixings. Companies can expect to pay up to £70 or £80 to have the material collected.

Case Study

Local authorities are increasingly prepared to recycle flat glass as they see it as a way to boost their recycling figures and reduce landfill costs. For example, in Oxfordshire they estimate they may be able to collect 100 tonnes of flat glass annually. Each skip load weighing up to nine tonnes is collected by Viridor-Richardson and costs the local authority approximately £45; however this is off-set by a reduction in waste and subsequent landfill costs.

The council are finding that the volume of DIY-based waste that people are disposing of is increasing, which may be due to people beginning to tackle bigger projects themselves or whether builders or window replacement companies are refusing to handle the waste is difficult to gauge. If it is the latter then this is really a trade waste which is finding its way into the household waste stream.

As with the rest of the UK, in Scotland the majority of off-cuts from manufacturing of flat glass in the UK will end up in one of the glass manufacturing sectors.

The replacement sector still sends the majority of its waste flat glass to landfill.

Viridor-Richardson

At the moment Viridor-Richardson are the largest waste flat glass collector and recycler in Scotland, collecting approximately 15,000 tonnes per annum. Their main processing centre is strategically based in Wishaw, which is in the heart of the central belt in Scotland.

Viridor-Richardson try to work with producers of waste flat glass to try and educate them and ensure adequate quality control measures are implemented. This has a two fold benefit, firstly Viridor-Richardson can be sure they're receiving good 'clean' sources of material, but secondly and just as important is that if they can identify the exact source of glass they can help match that to a particular end market.

This has enabled Viridor-Richardson manage a range of almost 30 grades of flat glass, each with varying chemical composition and degree of contamination.

By implementing such working practices Viridor-Richardson can optimise the commercial value of the glass by matching it to the best available end market.

Viridor-Richardson has an exclusive arrangement in Scotland to supply Superglass (Stirling), a major supplier of mineral wool insulation products. During periods of high demand they even haul glass up from down south.

In the rest of the UK they supply flat glass cullet to companies such as Pilkington and Rockware. They have been working with Pilkington long-term and are beginning to see significant quantities of cullet going into their rolled glass production facility in St.Helens. Rockware is the one remaining glass container manufacturer that continues to accept flat glass; however this may change if greater volumes of container glass can be sourced by them in the coming years due to the potential PRN revenue associated with container cullet.

Berryman

Berryman currently collect approximately 400 to 430 tonnes of flat glass per month (mainly from from glass merchants, window replacement companies) in Scotland, which equates to them potentially collecting over 5000 tonnes of flat glass per annum in Scotland. Berryman currently does not have any reprocessing capacity in Scotland, however they hope to develop reprocessing facilities in the coming years and develop their flat glass collection infrastructure.

At present the majority presently goes to their South Kirkby plant for reprocessing. The majority of this glass will then be sold onto Rockware Glass for re-melt and will continue to do so until they switch to using container cullet. They also supply material to the glass fibre industry.

They also supply Potters Ballotini Ltd, which use the glass to manufacture glass beads, which can be found in applications such as in road safety markings as they not only enhance the reflectivity of the markings but also improve their durability. These beads can also be used in industrial cleaning applications with the beads being used peening, cleaning, finishing and deburring metal surfaces.

Often if the material is 'clean' it will be uplifted free of charge. However if there is acceptable contamination there will be a charge. Berryman tries to 'clean' at source by education, working closely with suppliers and separation.

Berryman also supplies material to Northern Cullet (which is also part of the Potters Europe Group) which supply glass grain to a variety of industrial applications. They also supply a decorative aggregate called 'Decogem' which can be used in a variety of garden and home applications.

Although Berryman supply flat glass cullet to a variety of end markets, they welcome the opportunity to look at other markets and opportunities to further develop their portfolio of end markets.

Berryman estimate that deeper penetration of the construction and demolition market will happen in coming years, however this will require investment in new technologies to ensure optimum contamination removal.

They also estimate that the industry will see increased volumes of waste flat glass arising from the replacement sector.

Berryman have the capability to process most types of flat glass (reinforced, laminated, heated windscreens), however heat treated glass can be problematic depending on the end market and as such will normally be removed upon identification.

They perceive Landfill Tax, Education, Transportation Costs and lack of PRN revenue as the main barriers to expanding flat glass recycling in Scotland.

Conclusion & Recommendations

This report has demonstrated that there is an active effort to recover and recycle flat glass in Scotland with markets being developed in parallel.

The overall waste flat glass arising in the UK is approximately 315,000 tonnes per annum; however much of this material is C & D waste, which at present predominantly ends up in landfill. A minimal amount of this will end up being recycled as a secondary aggregate, although currently this is not common practice.

There are approximately 19,000 tonnes of waste flat glass collected in Scotland per annum, with the majority being recycled in Scotland. The remainder is sent down south for reprocessing and supply to the glass manufacturers or other niche markets previously discussed.

This represents a low level of recovery, however if you take the C & D waste out of the equation as at the present time remains difficult and costly to remove, only approximately 35,000 tonnes per annum remain available to recover of which approximately two thirds (19,313 tonnes) is currently recycled.

During detailed interviews with both flat glass collectors in Scotland, they highlighted transportation costs as one of the main barriers to increasing the recovery of waste flat glass in Scotland. This problem arises largely from the glass manufacturing industry being based mainly in the North of England and the central belt of Scotland, whereas flat glass though its very nature is widely used throughout the UK. For example, Superglass, the main user of flat glass cullet in Scotland is based in the central belt, which can make collecting in the more remote and rural parts of Scotland cost prohibitive.

They also felt the current situation with the PRN system, which economically disadvantages flat glass cullet compared to container cullet, will continue to burden the flat glass recycling industry, particularly as these two materials now often compete for the same end markets.

With the introduction of the ELV Directive and trends in the building sector to use greater volumes of glass, there may be a significant increase in the volume of flat glass entering the waste stream in coming years; however to ensure greater recovery, a number of initiatives should be employed such as focused education programmes at all stages of the materials life-cycle.

Education (working closely with the sources of glass) was an issue collectors felt was particularly important to help ensure a good clean source of material, required by end market specifications. This is imperative to sustain viability of a collection service. Both organisations indicated that historically they have been trying to work closely with all their suppliers to minimise the risk of contamination. This remains an on-going programme.

Other drivers such as the increasing cost of landfill, the Pollution Prevention and Control (Scotland) Regulations 2000 and the Climate Change Levy are also contributing to increasing the desirability to pull flat glass from the waste stream.

However, although there are regulatory mechanisms in place which encourage waste flat glass recovery, further drivers / legislation which dictates that recovery must take place needs to be introduced to significantly increase the recovery of waste flat glass.

Another option may be to review the production of flat glass products to manufacture them with ease of recovery incorporated at the design stage.

It is clear from these meetings that both organisations are keen to increase the volume of waste flat glass they collect, provided end markets make it economically viable.

As new markets continue to develop and the glass manufacturing industry continues to improve reprocessing systems, the capacity to utilise flat glass in the UK should continue to grow. However

without financial mechanisms in place to support the collection of this material, flat glass will continue to lose out due to the premium paid for container cullet.

As with most materials, market development is seen as one of the most important mechanisms to supporting the recovery of waste flat glass. However, particular emphasis must be placed on higher value markets which can support the collection infrastructure. Both recyclers indicated that if higher value markets were available they could justify increasing their workforce to enable them actively source greater volumes of material. They would also be able to continue and expand education programmes.

With local authorities now having recycling targets, many are targeting the heavier materials found in the waste stream such as glass. Oxfordshire is one such council who are in partnership with Viridor-Richardson to collect flat glass from their CA sites. Opportunities such as these are beginning to arise with other local authorities; however in order to make these schemes effective, site operators must be made aware of the issues regarding flat glass recycling, and at some sites separate the glass from the surrounds to reduce issues with contamination.

Waste from the replacement sector such as increasing DIY waste, perhaps due to people taking on larger jobs themselves and some replacement companies refusing to handle waste in order to avoid becoming a registered waste carrier, indicates that the collection of waste flat glass from CA sites can often generate significant volumes of flat glass. This type of collection service offers the opportunity to easily recover a waste which may otherwise have ended up being consigned to landfill, and also contributing towards local authority recycling targets. Greater penetration of this source could be a positive way to further improve recovery rates predominantly from the building replacement sector.

Both organisations interviewed agreed that there is scope for greater penetration of organisations which handle both small and large volumes of glass from replacement activities such as local authorities and building window replacement companies.

To partially address this issue the Waste and Resources Action Programme (WRAP) in September 03 announced an invitation for suitably qualified candidates to tender for 'Increasing collection and recycling of post consumer domestic window waste'. This has been introduced to develop and test methodologies to increase the collection and recycling of flat glass and framing materials arising from post-use domestic windows. This work will help optimise the recovery of glass from this waste stream which is likely to produce increasing volumes of waste flat glass in the coming years.

This report has identified some of the main factors influencing the flat glass recycling market in Scotland. It has also identified areas where further work may increase the volumes recovered; however other areas of research which may also yield recovery of glass such as a survey of large organisations such as local authorities building maintenance / construction works departments where they have a responsibility for replacing relatively high volumes of windows both in council buildings and council housing schemes.

Due to the unique topography of the Scottish landscape, further research should also include analysis of the transportation infrastructure compared to the widely dispersed sources of glass arisings. This would indicate the volumes of glass which would be required from a source in order to make a collection service viable from that particular source.

Greater effort must also be made to engage the C&D sector, to further penetrate this vastly untapped resource of flat glass which is currently either landfilled or used as secondary aggregates. However until the cost of disposal rises significantly or other fiscal drivers are put in place, these practices will remain largely unchanged. Due to the significant volume of glass remaining in the C&D sector, research which can directly assess ways which this material may be recovered should be undertaken to tap into this vast potential resource.

It is clear that with end markets continue to be developed, there is significant capacity available to increase the volume of flat glass recovered from the waste stream and with focussed activities which can further penetrate the waste streams, such as those mentioned in this report, greater volumes of flat glass can cost effectively be pulled from the waste stream to feed into several end markets.