

# Flat Glass

A technical report on the production of processed cullet from waste flat glass.



## Executive summary

### Background

The Business Resource Efficiency and Waste (BREW) Waste Protocols Project aims to produce Quality Protocols on various waste streams that will:

- define the point of full recovery from a waste back into a product or material that can be reused by the business or industry or sold into other markets; or
- define when wastes are recovered to a state where the Environment Agency considers that their use is acceptable in accordance with its low risk regulatory principles; or
- confirm to the business community what legal obligations remain to control the reuse of the treated waste material.

The project board asked a Technical Advisory Group (TAG) to consider the feasibility of producing a Quality Protocol that would enable the point of recovery of waste flat glass to be moved closer to the point of production.

### Methodology

The TAG brought together representatives from the Environment Agency, Waste & Resources Action Programme (WRAP) and industry. Its remit was to produce a technical report setting out the processes involved in producing cullet from waste flat glass, describing the markets into which cullet can be sold and making recommendations as to the possible development of a Quality Protocol. In doing so, the TAG:

- identified and quantified the major markets and appropriate end uses for waste flat glass;
- identified the current legislative framework that governs the production, handling, storage, transportation and use of waste flat glass;
- reviewed available standards and specifications;
- assessed relative risks to human health and the environment from the use of waste flat glass cullet and identified, where necessary, mitigation methods; and
- proposed routes forward for each of the major markets so that certain end uses may be regarded as fully recovered where strictly defined conditions are met.

### Findings

The TAG's findings are summarised below.

- Flat glass cullet is inert. There is no risk to human health or the environment in any end use providing permit conditions are met (where applicable) and appropriate health and safety measures are taken when handling the material. The only potential risk that may arise is if the cullet contains contaminants harmful to human health or the environment.
- Flat glass cullet is generally used as a substitute for silica and other more harmful substances, e.g. copper slag.
- Flat glass cullet can be processed to achieve a number of standards and different specifications.
- Flat glass cullet can be used to produce materials and products in the following markets:
  - flat glass;
  - container glass;
  - fibre glass; and
  - alternative markets.
- These markets are active and healthy. Therefore, processed cullet produced for these markets is highly likely to be used.
- The production of aggregates is covered by the WRAP Quality Protocol for production aggregates from inert waste. If flat glass is processed to produce aggregates in accordance with these Quality Protocols, it will not normally be considered waste. Therefore, the TAG considered this process to be outside its remit.
- Good quality control and training of staff is essential if the flat glass is to be segregated correctly to enable it to be processed to meet the specification required.
- When flat glass cullet is produced for a particular market and meets a specified standard appropriate for that market, the TAG's view is that the cullet replaces virgin material at that point and can be considered to be fully recovered.

### Recommendations

The TAG recommended that a Quality Protocol be produced setting out the steps necessary to recover flat glass waste into a product. This Quality Protocol should include:

- recognised end uses;
- publicly available standards and specifications that can be met;
- details of the record-keeping necessary to demonstrate that a specification has been met and material has been sold to a market for use;
- inspection of loads before and after processing in line with an appropriate specification.

Essential checks should include:

- loss on ignition;
  - particle size distribution;
  - ferrous metal content;
  - non-ferrous metal content; and
  - inorganic content.
- a requirement to keep all documentation for a minimum of three months.

The TAG also recommended that the Quality Protocol require good practice for collection that would enable the end user specification to be met.

A publicly available specification is not currently available for container glass, glass bead, foam glass, paint filler and fibre glass. Therefore it is suggested by the Environment Agency that industry should be invited to produce or supply a publicly available specification for these markets as part of the consultation on the Quality Protocol. If appropriate standards can be agreed these end uses can be added to the proposed Quality Protocol.

# 1. Introduction

- 1.1 The Waste Protocols Project is a joint Environment Agency and Waste & Resources Action Programme (WRAP) initiative funded by the Department for Environment, Food and Rural Affairs (Defra) Business Resource Efficiency and Waste (BREW) Programme.
- 1.2 Uncertainty over the point at which 'waste' is fully recovered and ceases to be waste has meant that some materials have continued to be controlled under the EU Waste Framework Directive and, in some cases, disposed of to landfill. To provide more certainty, to stop materials being landfilled unnecessarily and to increase the use of waste as a resource, we have set up the Waste Protocols Project.
- 1.3 Depending on the circumstances of the sector concerned, the project seeks to achieve one or more of the following outcomes:
  - to produce a Quality Protocol defining the point at which waste may become a non-waste product or material that can be either reused by business or industry, or supplied into other markets, enabling recovered products to be used without the need for waste regulation controls;
  - to produce a statement, in accordance with the Environment Agency's low risk regulatory policy,<sup>1</sup> indicating that the use of the waste is considered to be such low risk that it would not normally be in the public interest to take enforcement action for failure to obtain a waste management licence; and
  - to produce a statement that confirms to the business community what legal obligations they must comply with to use the treated waste material.
- 1.4 Flat glass is one of the waste streams addressed during the first year of the BREW Waste Protocols Project. A Technical Advisory Group (TAG) was set up to bring together representatives from the Environment Agency, WRAP and industry. Appendix A contains a list of TAG members and Appendix B gives its terms of reference.
- 1.5 In order for waste flat glass to be considered as having ceased to be waste, it needs to be demonstrated that the material has been fully recovered and that there is no further need for waste regulatory controls.
- 1.6 The TAG therefore looked at a number of issues considered of particular relevance in order to identify the point where the waste:
  - presents the same or lower risk as a virgin material to human health and the environment;
  - can meet a defined standard/specification and requires no further processing; and
  - has a market and therefore certainty of use.
- 1.7 The objectives of this report are to:
  - describe the progress of the TAG on this topic;
  - set out the TAG's findings; and
  - provide recommendations to the project board and the Environment Agency on what steps are needed to meet one of the three accepted project outcomes as stated above.
- 1.8 The TAG set out to:
  - identify the major markets and therefore end uses for flat glass cullet;
  - identify the current legislative framework that governs the production, handling, storage, transportation and use of flat glass cullet;
  - review available standards and specifications;
  - assess relative risks to human health and the environment from the use of flat glass, and mitigation methods; and
  - propose routes forward for each of the major markets so that certain end uses may be regarded as fully recovered where strictly defined conditions are met.

1 See <http://www.environment-agency.gov.uk/subjects/waste/1416460/1334460/1098094/>

## 2. Cullet collection

### 2.1 Grades of cullet

- 2.1.1 Typically, flat glass cullet is collected at source in dedicated skips/bins provided by the cullet processor/collector. Three separate grades of cullet are collected:
- **Clear cullet** consists of standard flat glass only, usually from off-cuts. Although suitable for use in all markets, it is generally used in flat glass manufacture which requires the highest quality material.
  - **Mixed cullet** consists of a mixture of glass types (sealed window units, laminated glass, mirrored glass, tinted glass, printed glass, old glass from wooden frames). It is not used in flat glass manufacture, but processed mixed cullet can be used for other glass manufacture. Any mixed cullet that is too contaminated for glass manufacture (i.e. cannot achieve the specification due to, for example, large quantities of mirrored glass) is diverted for aggregate use where this is possible.
  - **Laminate** consists of laminated standard flat glass, either from manufacturing off-cuts or from post-consumer units of safety glass, bomb-proof glass with surface film and windscreens.

### 2.2 Collection infrastructure

- 2.2.1 An infrastructure exists in the UK with companies involved in different operational aspects. Two companies dominate the collection and processing of flat glass cullet from waste flat glass, largely for the flat glass market. Three other companies collect and process smaller volumes of flat glass cullet for alternative markets.
- 2.2.2 In addition, a flat glass manufacturer collects a large volume of clear flat glass cullet directly from its own customers using reverse haul logistics.
- 2.2.3 Some smaller companies collect and segregate window waste for supply to a cullet processor or direct to a flat glass manufacturer.

## 3. Sources of waste flat glass

3.1 The various sources of waste flat glass in the UK are indicated below.

### 3.2 Flat glass manufacture

3.2.1 Waste glass is generated during glass production, usually from production off-cuts and glass produced during the transition phase of product changes. The waste remains within the factory and is generally 100 per cent recycled. If the cullet arises due to a contamination issue, it is not suitable for remelting within flat glass production and is diverted to other markets such as the manufacture of container glass, glass bead or glass sand/grain.

### 3.3 Window manufacture

3.3.1 The majority of external cullet used in flat glass manufacture is sourced from window manufacturers. As flat glass manufacture requires the highest quality cullet, it is important that contamination is kept to a minimum. This is achieved by:

- collecting glass at the cutting table;
- staff training; and
- site auditing.

3.3.2 A site will usually collect two separate streams of cullet – mixed and clear. The clear stream originates from manufacturing off-cuts and the mixed stream from reject sealed units. If the site uses safety glass, a laminate stream may also be collected.

### 3.4 Domestic window waste

3.4.1 In some cases, post-consumer windows are recovered from site by the window fitter and returned to base. Here the glass or sealed unit is removed from the frame and collected in a dedicated skip. This practice is subsidised by the collection of PVC-U frames for the Recovinyl scheme.<sup>2</sup>

### 3.5 Car windscreen manufacture

3.5.1 There are three car windscreen manufacturers in the UK. Each manufacturer collects production off-cuts and rejected windscreens for recycling.

### 3.6 Replacement windscreen companies

3.6.1 Replacement windscreen companies collect old windscreens in dedicated skips for recycling. This practice considerably reduces the companies' waste disposal costs.

### 3.7 End-of-life vehicles

3.7.1 Around two million end-of-life vehicles (ELVs) arise in the UK each year. On average, each vehicle contains approximately 3 per cent glass by weight. The End of Life Vehicle Directive sets out recycling for ELVs (Table 1).

**Table 1 Summary of ELV Directive recycling targets**

Deadline	Reuse and recovery	Reuse and recycling
No later than 1 January 2006	85% (for vehicles produced after 1 January 1980) 75% for vehicles produced before 1 January 1980	80% (for vehicles produced after 1 January 1980) 70% for vehicles produced before 1 January 1980
No later than 1 January 2015	95% (for all ELVs)	85% (for all ELVs)

2 See <http://www.recovinyl.com>

- 3.7.2 Two types of glass are used by the automotive industry – toughened and laminated:
- Toughened glass is easy to remove from vehicles after shattering. However, it needs to be recovered carefully to avoid contamination.
  - Laminated glass does not shatter and needs to be removed manually, which is time-consuming. It requires further processing at an additional cost.
- 3.7.3 The CARE report (Brinkler 2004) estimated that, at its current value, it was uneconomical to recover ELV glass using current methods. In the UK, the majority of ELV glass is sent to landfill and only a small proportion is recycled.

### 3.8 Construction and demolition (C&D) waste

- 3.8.1 Each year some 90 million tonnes of C&D waste is generated in the UK; 594,000 tonnes of this is flat glass.
- 3.8.2 Flat glass cullet from this source is too contaminated to process for flat glass and it requires considerable processing before it can be used for other glass manufacture. At the moment, site practice is not to segregate waste flat glass from C&D waste. As a result the material is normally processed for use in aggregates.
- 3.8.3 Corporate social responsibility means there is now a drive to increase recycling of glass from this sector, back into glass. WRAP is leading efforts to encourage this practice.
- 3.8.4 The introduction of mandatory Site Waste Management Plans in England and Wales for all construction projects over £250,000 in April 2008 is likely to result in an increase in the amount of flat glass recycled from the C&D sector.

## 4. Key markets for recovered flat glass

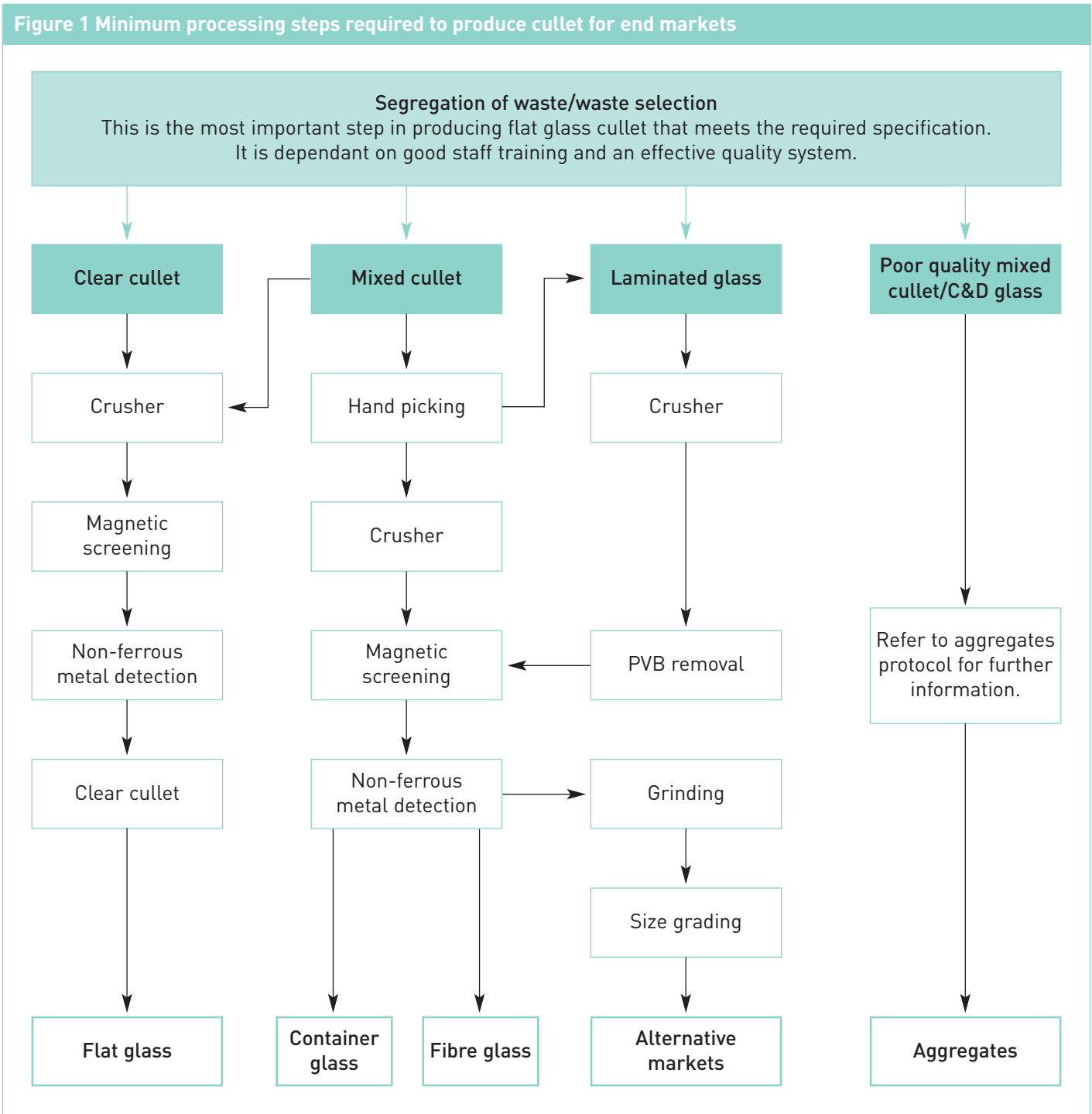
- 4.1 Flat glass is infinitely recyclable and can be used in a wide range of markets. Of these, remelting glass to form new glass products has the greatest environmental benefit. This is because:
- less energy is required to remelt glass than to melt the raw materials (this reduces the fuel required and thus carbon dioxide emissions);
  - it reduces the volume of raw materials required, saving valuable natural resources and minimising quarrying activity (there is also a reduction in emissions of carbon dioxide from batch materials); and
  - it reduces the volume of waste going to landfill.
- 4.2 The key potential markets for flat glass waste are:
- flat glass (100,000 tonnes per year);
  - container glass (80,000 tonnes per year);
  - fibre glass (50,000 tonnes per year); and
  - alternative markets.
- 4.3 Alternative markets typically include:
- aggregates;
  - glass beads;
  - foam glass;
  - abrasives;
  - bricks and ceramics;
  - water filtration;
  - sports turf; and
  - paint filler.
- 4.4 The production of aggregates from waste flat glass is covered by the WRAP Quality Protocol for the production of aggregates from inert waste.<sup>3</sup> If aggregate is produced from waste flat glass in accordance with the Quality Protocol it is not normally considered waste. Production of aggregates using waste flat glass is therefore not considered further in this report.
- 4.5 Further detail on these markets can be found in Appendix C.

3 See [http://www.aggregain.org.uk/quality/quality\\_protocols/](http://www.aggregain.org.uk/quality/quality_protocols/)

## 5. Cullet processing

- 5.1 The degree of processing required depends on the level of contamination and the end market. The minimum processing steps required to produce cullet for each end use are summarised in Figure 1.
- 5.2 The main methods of contamination removal are:
- **Hand picking.** The uncrushed cullet is passed along a conveyer belt and any visible contaminants are removed by hand.
  - **Magnetic screening.** This removes ferrous metal contamination from the cullet. A range of separation technologies is available using either electromagnets or permanent magnets.
  - **Non-ferrous metal detection.** Metals such as brass, stainless steel and lead in the cullet stream are detected using an eddy current system. Once detected, the metal is removed using a mechanical gate or pneumatic blast.
  - **Polyvinyl butyral (PVB) removal.** PVB is removed by an air blower once it has been separated from the glass by crushing.
- Additional processing steps may be employed (e.g. optical recognition and pyro-ceramic detection) that are unique to the processor.
- 5.2 If processed cullet is to meet the end market specification, correct segregation at source is crucial. This relies on good staff training and having an effective quality management system in place.
- 5.3 The BREW Waste Protocols Project identified a need for a good practice guide for the supply of cullet to flat glass manufacturers. This guide, funded by the project, has been produced following consultation with UK glass manufacturers and cullet processors (BREW 2007a). The guide will be available via the Environment Agency and WRAP websites.
- 5.4 The cullet processor should:
- have procedures in place to ensure all inputs are suitable for processing for the particular intended end use; and
  - test outputs for compliance with the specification for the end use.

Figure 1 Minimum processing steps required to produce cullet for end markets



## 6. Existing flat glass cullet specifications and standards

### 6.1 Flat glass manufacture

6.1.1 The BREW Waste Protocols Project has developed a specification for flat glass cullet for use in flat glass manufacture following consultation with UK glass manufacturers and cullet processors (BREW 2007b). This publicly available specification will be available via the Environment Agency and WRAP websites.

### 6.2 Other glass manufacture

6.2.1 PAS 102: 2004 (WRAP 2004b) gives specifications for container glass cullet for use in alternative markets. The TAG agreed that PAS 102 can also be applicable to flat glass because:

- the majority of the specification deals with particle size; and
- flat glass is of similar composition to container glass.

6.2.2 Table 2 summarises the publicly available specifications for alternative markets. Where no specification is available, the minimum processing steps are detailed.

Market	Specification/standard
Glass bead	No publicly available specification currently available. Ground and dried on-site to meet the company's size specification.
Brick and ceramics	PAS 102: 2004 Sections 4 and 5
Sports turf	PAS 102: 2004 Section 6
Water filtration	PAS 102: 2004 Section 7
Abrasive	PAS 102: 2004 Section 8 and ISO 11127*
Flat glass	BREW Waste Protocols Project, 2007 <i>Specification for flat glass cullet waste used in flat glass manufacture</i> #
Container glass	No publicly available specification currently available.
Foam glass	No publicly available specification currently available. Normally involves fine grinding to a particle size of 100 µm.
Paint filler	No publicly available specification currently available. Normally involves fine grinding to a particle size of 0.2–0.4µm†
Fibre glass	No publicly available specification currently available.

\* ISO 1993  
 # BREW 2007b  
 † WRAP 2004a

6.3.3 Individual glass manufacturers' specifications may differ from those in Table 2 (e.g. they may make them more stringent for operational reasons); these are also acceptable.

6.3.4 A publicly available specification is not currently available for container glass, glass bead, foam glass, paint filler and fibre glass. Without such specifications, the TAG was unable to determine:

- the minimum level of processing that should be undertaken; and
- appropriate levels of contamination removal.

- 6.3.5 Table 3 gives a summary of specifications that are used for the use of flat glass cullet in fibre and container glass manufacture. These are currently not publicly available and therefore it is not known whether these are acceptable industry-wide specifications that can be met and used to ensure material quality.

Table 3 Specifications for flat glass cullet used in fibre and container glass manufacture (g/tonne)			
Component	Fibre glass*	Fibre glass#	Container glass#
Ferrous metals	65	50	50
Non-ferrous metals	24	20	20
Inorganics	120	30	20
Organics	250	120	3,000
Size	<10 mm		
Moisture	<2%		
* GEPVP 2005a			
# WRAP 2004a			

- 6.3.6 This issue could be raised during the consultation stage of the Quality Protocol, giving industry the opportunity to either produce a publicly available specification or make current specifications publicly available.

## 7. Risk assessment

- 7.1 Flat glass is classed as a soda lime silica glass. Table 4 shows the typical chemical composition range.

Analyte	Percentage by weight	
	Minimum	Maximum
SiO <sub>2</sub>	70.0	73.0
Al <sub>2</sub> O <sub>3</sub>	-	1.5
MgO	3.5	4.5
CaO	8.0	9.7
Na <sub>2</sub> O + K <sub>2</sub> O	13.4	14.6
Fe <sub>2</sub> O <sub>3</sub>	-	0.2

- 7.2 The environmental risk of using flat glass cullet in different markets is summarised in Table 5.
- 7.3 As the majority of cullet is simply remelted to form a new glass product of similar composition, there is no environmental risk associated with its use. For all other markets where the glass is replacing a different material, its inert nature means that there is no additional risk in its use.
- 7.4 If flat glass is used in applications such as for sand substitute where there is a potential for dust, end users are advised to follow the general handling and dust guidance available from HSE.<sup>4</sup> This is the same as the good practice considered necessary for virgin glass.

Table 5 Risk assessment for the use of flat glass cullet in different end markets

Application/use	Hazardous event and potential pathway	Receptor(s)	Risk before mitigation			Mitigation measures required	Risk after mitigation		
			H	M	L		H	M	L
<b>All markets</b>	If the waste is not segregated correctly before processing, the cullet produced will not meet the specification for the end market and may contain contaminants harmful to the environment.	Air Groundwater Aquatic habitats Terrestrial habitats Flora & fauna Humans		✓		Full staff training Environmental management system Input controls			✓
<b>Glass manufacture</b> – flat – container – fibre – beads – foam	No additional hazard as the chemical composition is the same as the end product.				✓				✓
<b>Aggregate</b> – bound – unbound	Leaching of contaminants into the terrestrial or aquatic environment via surface run-off or groundwater transportation has been shown to be insignificant.	Groundwater Aquatic habitats Terrestrial habitats Flora & fauna Humans			✓	Glass is classified as an inert material under the EU Landfill Directive. This means that it will not undergo any significant physical or chemical transformations, and that the total leachability and ecotoxicity of the leachate is insignificant and will not endanger the quality of surface water and/or groundwater. No mitigation proposed.			✓
	Release of glass dust during use.	Air Terrestrial habitats Flora & fauna Humans			✓	No additional measures required above those already in place for handling aggregates.			✓
<b>Abrasive</b>	Release of glass dust during use.	Air Terrestrial habitats Flora & fauna Humans			✓	No additional measures required above those already in place for using existing materials such as copper slag.			✓
<b>Bricks and ceramics</b>	Release of glass dust during use.	Air Terrestrial habitats Flora & Fauna Humans			✓	No additional measures required above those already in place for using existing materials.			✓

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Table 5 Risk assessment for the use of flat glass cullet in different end markets continued

Application/use	Hazardous event and potential pathway	Receptor(s)	Risk before mitigation			Mitigation measures required	Risk after mitigation		
			H	M	L		H	M	L
<b>Water filtration</b>	Leaching of contaminants into the aquatic environment has been shown to be insignificant.	Groundwater Aquatic habitats Terrestrial habitats Flora & Fauna Humans			✓	Glass is classified as an inert material under the EU Landfill Directive. This means that it will not undergo any significant physical or chemical transformations, and that the total leachability and ecotoxicity of the leachate is insignificant and will not endanger the quality of surface water and/or groundwater. No mitigation proposed.			✓
<b>Sports turf</b>	Leaching of contaminants into the terrestrial or aquatic environment via surface run-off or groundwater transportation has been shown to be insignificant.	Groundwater Aquatic habitats Terrestrial habitats Flora & Fauna Humans			✓	Glass is classified as an inert material under the EU Landfill Directive. This means that it will not undergo any significant physical or chemical transformations, and that the total leachability and ecotoxicity of the leachate is insignificant and will not endanger the quality of surface water and/or groundwater. No mitigation proposed.			✓
	Release of glass dust during use.	Air Terrestrial habitats Flora & Fauna Humans			✓	No additional measures required above those already in place for handling aggregates.			✓
<b>Paint filler</b>	Release of glass dust during manufacture	Air Terrestrial habitats Flora & Fauna Humans			✓	No additional measures required above those already in place for using existing materials.			✓

## 8. Legislation

8.1 The current legislative controls applying to the transportation, storage, processing and delivery of flat glass cullet are summarised in Table 6.

Table 6 Summary of legislative controls on flat glass cullet		
Activity	Current legislative control	Current approach
Delivery of flat glass cullet to the reprocessing site	Flat glass cullet delivered for processing is waste and it must be handled according to the waste Duty of Care in the Environmental Protection Act 1990 and the Environmental Protection (Duty of Care) Regulations 1991. The cullet must be transported by a person who is registered as a waste carrier.	Normal regulatory controls apply.
Storage of flat glass cullet for recovery	The storage of flat glass cullet prior to processing requires a waste management licence under the Environmental Protection Act 1990 unless the activity is exempt from licensing under the Waste Management Licensing Regulations 1994 Schedule 3. Paragraphs 17 or 18 of this Schedule are exemptions that can apply if the conditions of those paragraphs are met.	The Environment Agency has adopted a Low Risk Regulatory Position* on: the sorting of uncontaminated glass pending its collection for recovery; and the sorting and deconstruction of waste windows and doors for the purpose of recovery.  No such low risk position applies in Scotland or Northern Ireland where normal regulatory controls apply.
Processing of cullet to meet the specification required by its destined market (see Section 5).	The treatment of waste requires a waste management licence under the Environmental Protection Act 1990 unless it is exempt from licensing under the Waste Management Licensing Regulations 1994, Schedule 3. Paragraph 11 of this Schedule is an exemption that can apply if the conditions of that paragraph are met.	Normal regulatory controls apply.
Delivery of processed flat glass cullet to the end user	At present, processed cullet is still considered to be a waste and it must be handled according to the waste Duty of Care in the Environmental Protection (Duty of Care) Regulations 1991. The processed cullet must be transported by a person who is registered as a waste carrier.	At present, normal regulatory controls apply until the cullet is reincorporated into its final use product/application.

\* Appendix A, Environment Agency 2007

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**Table 6 Summary of legislative controls on flat glass cullet** continued

Activity	Current legislative control	Current approach
Storage of processed cullet at the glass manufacturing site	At present, processed flat glass cullet is considered to be waste and its storage requires a waste management licence under the Environmental Protection Act 1990 unless the activity is exempt from licensing under the Waste Management Licensing Regulations 1994, Schedule 3. Paragraph 1A of this Schedule (storage of waste glass on a regulated glass manufacture site) is an exemption that can apply if the conditions of that paragraph are met.	Normal regulatory controls apply.
Glass manufacture	The process is regulated under the Pollution Prevention and Control Regulations 2000, Section 3.3 of Schedule 1. All glass manufacturing sites with a melting capacity greater than 20 tonnes/day require an IPPC operating permit. This covers all container, flat and fibre glass producers.	Normal regulatory controls apply.

## 9. Findings and recommendations

### 9.1 Findings

9.1.1 Flat glass is inert. There is no risk to human health or the environment in any end use providing:

- permit conditions are met (where applicable); and
- appropriate health and safety measures are taken when handling the material.

9.1.2 Flat glass is generally used as a substitute for silica and other more harmful substances (e.g. copper slag).

9.1.3 Flat glass can be processed to achieve a number of standards and different specifications.

9.1.4 Flat glass cullet can be used to produce materials and products in the following markets:

- flat glass;
- container glass;
- fibre glass;
- aggregates<sup>5</sup>; and
- alternative markets.

Therefore it can demonstrate certainty of use.

9.1.5 Good quality control and training of staff are essential if the glass is to be segregated correctly to enable it to be processed to meet the specification.

9.1.6 Once the specification for the target end market is reached, the cullet is handled in the same way as virgin material. Therefore it is considered that:

- the product containing the flat glass cullet meets a specification;
- the environmental hazard is low; and
- the product is certain to be used.

### 9.2 Recommendations

9.2.1 The TAG recommended that a Quality Protocol be produced that sets out the steps necessary to recover flat glass waste into a product.

9.2.2 The Quality Protocol should include:

- types of end uses;
- reference to achievable standards and specifications;
- details of the record-keeping necessary to demonstrate that a specification has been met and material has been sold to a market for use;
- inspection of loads before and after processing in line with the appropriate specification. Essential checks should include:
  - loss on ignition;
  - particle size distribution;
  - ferrous metal content;
  - non-ferrous metal content; and
  - inorganic content;
 and
  - a requirement to keep all documentation for a minimum of three months.

9.2.3 The TAG also recommended that the Quality Protocol require good practice for collection that would enable the end user specification to be met.

9.2.4 A publicly available specification is not currently available for container glass, glass bead, foam glass, paint filler and fibre glass. It is therefore suggested that industry should be invited to produce or supply a publicly available specification for these markets as part of the consultation on the Quality Protocol.

<sup>5</sup> The production of aggregates is covered by WRAP Quality Protocols for the production of aggregates from inert waste. If glass is processed in accordance with these Quality Protocols, it will not normally be considered waste. Therefore the TAG considered this end use to be outside its remit.

## 10. References and bibliography

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## Appendix A Technical Advisory Group (TAG) membership

Organisation	Representative	Type of member
BREW Waste Protocols Project Team	Suzanne Laidlaw	Attending
	Michelle Steer	Attending
	Dominic O'Neill	Attending
	Sarah Clayton	Attending
Environment Agency	Clare McCallan	Correspondence
	Kathryn Harriss	Correspondence
Environment Agency Wales	Rebecca Favager	Correspondence
WRAP	Andy Dawe	Attending
British Glass	Dave Dalton	Attending
	Mark Pudner	Attending
	John Stockdale	Correspondence
Glass & Glazing Federation	Ian Chisholm	Attending
CERAM Building Technology	Andrew Smith	Attending
BRE	Caroline Weeks	Attending
	Gilli Hobbs	Correspondence
Veolia	Sabrina Rubio	Attending
SEPA	John Harris	Correspondence
Guardian	Neil Vincent	Attending
Viridor	Nick Davison	Attending

## Appendix B Terms of Reference

### 1. Mission Statement

To produce a Quality Protocol, recognised by (and produced with the support of) industry, that defines when flat glass waste has been reprocessed to such a level that it is considered to be fully recovered and no longer subject to the requirements of the regulatory waste regime.

If this is not achievable, the Quality Protocol will provide guidance to business that will:

- define when flat glass waste is recovered to a state where the Environment Agency considers that its use is acceptable in accordance with its low risk regulatory principles; or
- confirm to the business community what legal obligations remain to control the reuse of the treated waste material.

### 2. Desired outcomes/outputs

The Technical Advisory Group (TAG) will produce a technical report that will identify and establish:

- which end products the Quality Protocol should address;
- whether there are any existing standards and specifications for each end product;
- whether the material can be collected and reprocessed to meet existing standards and specifications;
- where existing standards and specifications do not exist, to identify alternatives and/or to scope out a project for producing a new standard or specification;
- potential environmental and human health impacts and mitigation methods;
- costs and benefits of the different end uses (with the aid of project economist); and
- a standard terminology.

### 3. Limitations

- The point at which flat glass waste has been fully recovered may not be possible to define. If the point of full recovery cannot be defined, the TAG will refer this matter to the Environment Agency for it to produce guidance on when waste regulatory controls apply.
- For the purposes of this TAG, the Environment Agency must be satisfied with the point at which flat glass waste has been fully recovered.
- Where specifications and standards do not exist and are required, financial or time implications may result in delays to the TAG's work.

## Appendix C Market analysis for flat glass

### C.1 Flat glass manufacturing

- C.1.1 There are three UK flat glass manufacturers in the UK producing approximately 750,000 tonnes of flat glass each year<sup>6</sup>.
- C.1.2 The consultation responses and research suggest that flat glass manufacturers use between 0 per cent and 30 per cent recycled flat glass cullet in their production process. Of this, the proportion of externally sourced cullet varies from as little as 10 per cent to as much as 60 per cent. Contamination is the main constraint on increases in the percentage of cullet sourced externally.
- C.1.3 The three flat glass manufacturers have different policies with regards to the use of external cullet. These are summarised below:
- No external cullet is used for flat glass manufacture.
  - External cullet used is from window manufacturers in the form of off-cuts. It is processed for use on-site.
  - External cullet used is supplied by cullet processors.
- C.1.4 Externally sourced cullet comes from known sources such as a manufacturer's own customers. Manufacturers will not, in most cases, consider using glass from other source such as merchants due to the risk of contamination.
- C.1.5 One manufacturer expressed some optimism about the use of flat glass cullet in float production and has recently increased the target quantities to be used in 2007 by almost 30 per cent because of the advantages this offers. These advantages include:
- cost savings compared with using only virgin raw materials;
  - energy savings (over raw material use), in particular helping to meet the manufacturer's Climate Change Agreement (CCA) targets;
  - the resulting increase in furnace life; and
  - benefits relating to marketing and sales of increasing the recycled content of the final product.
- C.1.6 For flat glass manufacturers, the choice between flat glass and virgin raw materials is based on price. Price is taken as a function of raw materials, energy savings, CCA commitments, furnace life, carbon trading on EU Emissions Trading Scheme II (EU ETS II), etc.
- C.1.7 If more flat glass of sufficient quality and at a competitive price could be supplied, then it would certainly be used.
- C.1.8 The flat glass manufacturers use some of the clear off-cuts from window and car windscreen manufacturers. The flat glass from this source represents the premium quality material in the market for cullet. Some is rejected and, along with mixed cullet derived from rejected sealed units, is offered to container glass and fibre glass manufacturers.

### C.2 Fibre glass manufacturing

- C.2.1 There are three main glass fibre manufacturers in the UK. Typically glass fibre contains up to 25 per cent recycled flat glass cullet.
- C.2.2 The total use of cullet in fibre glass manufacturing increased by 50 per cent over the previous two years to around 150,000 tonnes in 2005<sup>7</sup>. However, the majority of this increase was container glass. Earlier quality concerns over the use of container glass have been overcome and fibre glass manufacturers have registered as reprocessors under the Packaging Waste Regulations to gain revenue from Packaging Recovery Notes (PRNs).<sup>8</sup>

<sup>6</sup> Glass Technology Services, 2007 *Technical Report on the Production of Cullet from Waste Flat Glass*.

<sup>7</sup> WRAP, 2006 *Assessment of the Quantity of Flat Glass being Collected for Recycling and the Processing Infrastructure in place in the UK - Year 2 Report*.

<sup>8</sup> Communication with Andy Dawe, WRAP.

- C.2.3 It is estimated that up to 50,000 tonnes of the total cullet used in fibre glass manufacturing in UK each year is flat glass cullet<sup>6</sup>. Fibre glass manufacturers use mixed colour container glass cullet because they do not want to pay the higher price for clear cullet. There is an excess of mixed colour waste container glass in the UK primarily due to significant imports of green and brown wine bottles. The majority of container glass production in the UK is of clear glass and so requires clear glass cullet. Thus there is plenty of mixed colour container glass cullet available for fibre glass manufacturers.
- C.2.4 Technically, flat glass cullet has two main advantages over container cullet for fibre glass manufacture<sup>6</sup>:
- It provides a cheap source of magnesium oxide (MgO), which is important for glass fibre manufacture.
  - It has less pyro-ceramic contamination. Fragments of pyro-ceramic melt at a higher temperature than glass; hence they do not melt in the furnace and block the small holes in the spinners which form the fibres.
- C.2.5 The consultation responses suggest that, technically, the optimum is to mix quantities of flat and container glass within the glass fibre/ wool production process. Market prices drive the exact quantities used. The availability of PRNs for container glass often makes it economically favourable.
- C.2.6 Of the fibre glass manufacturers consulted, one company stated that the value of PRNs had resulted in a fall in the percentage of flat glass used in its process. Another company pointed out that, even though the use of flat glass shows an upwards trend, a technical plateau had been reached in its use and thus proportionally the use of flat glass cullet was unlikely to increase in the future.
- C.3 Container glass manufacturing**
- C.3.1 The six container glass manufacturers in the UK operate 30 furnaces across 13 sites<sup>6</sup>. Container glass manufacturers can use both flat and container glass cullet.
- C.3.2 Flat glass cullet is generally used for flint glass and sometimes amber. The batch recipe requires adjustment to accommodate its high iron content, which affects the colour quality. Flat glass cullet is only used to produce lower specification products such as milk bottles.
- C.3.3 Historically only one manufacturer has used flat glass cullet to produce container glass. Table C1 shows the wide variation in the use of flat glass cullet over the past four years. The consultation responses suggest that this is due to a number of reasons including:
- the availability of flint and amber container cullet; and
  - the fact that flat glass has a high iron content and is not suitable for some processes.

**Table C1 Flat glass cullet used in container glass manufacture (tonnes/year)**

Year	Amount
2003	110,000
2004	100,000
2005	55,000
2006	80,000

Source: Glass Technology Services 2007 (Reference 2)

- C.3.4 Price information about cullet is regarded as confidential, but the consultation suggests that the price of flat glass cullet is around £25–35 per tonne irrespective of the production process considered. It was suggested that container cullet costs around £40–42 per tonne. But if the value of the PRNs is taken into account, the cost of container glass falls significantly. (The price of glass PRNs was £22–27 for April 2007 and £25–27 for May 2007.<sup>9</sup>) So despite a technical preference for flat glass cullet over container glass, the competitive price of container glass cullet means that flat glass cullet is not used as widely.
- C.3.5 There is a shortage of clear glass cullet and an excess of coloured container glass cullet in the UK. Clear container furnaces could take at least another 300,000 tonnes per year if the quality was high enough.<sup>10</sup> If more flat glass cullet could be supplied to the market, then it would certainly be used. The shortage of clear glass cullet does not currently translate into higher prices sufficient to drive the supply of flat glass cullet.

## C.4 Alternative markets

### C.4.1 Aggregate

Flat glass cullet rejected by flat glass manufacturers, container glass manufacturers and fibre glass manufacturers can be used as an aggregate. Currently 23 per cent of UK aggregates production is from recycled sources, though the exact contribution of glass to this figure is unknown<sup>11</sup>.

Glass can be used as either an unbound aggregate or combined with bitumen. Most glass cullet used is container glass due to its PRN advantage.

### C.4.2 Glass beads

Two companies currently manufacture glass beads in the UK. Melting 100 per cent clear glass cullet produces glass beads. Container cullet is the preferred feedstock due to the associated PRN advantage, but some flat glass cullet is used due to the shortage of quality clear container cullet. The amount of glass cullet used could be around 25,000 tonnes per year,<sup>12</sup> of which most is flat glass.

### C.4.3 Foam glass

No flat glass is currently used in foam glass manufacture in the UK, although this application is expected to develop.

### C.4.4 Abrasives

Several companies currently manufacture abrasives from recycled glass. These are usually produced using container glass rather than flat glass, although flat glass is also suitable.

### C.4.5 Bricks and ceramics

Only a small amount of flat glass has been used in trials. Flat glass cullet is not currently used on a commercial scale and most of the work carried out has focused on container glass.

### C.4.6 Water filtration

A very small amount of flat glass has been used for water filtration media on a trial basis. Container glass is mainly used.

### C.4.7 Sports turf

Trials by WRAP have shown that cullet can be used in sports turf applications<sup>13</sup>. This work has focussed on container glass, although flat glass should be equally suitable.

<sup>9</sup> <http://www.letsrecycle.com/prices/prnPrices.jsp>

<sup>10</sup> Communication with consultancy

<sup>11</sup> Quarry Products Association, 2005 *Sustainable Development. Building our Strategy*. Available from: [http://www.qpa.org/downloads/sust\\_devA4.pdf](http://www.qpa.org/downloads/sust_devA4.pdf) [Accessed 4 September 2007].

<sup>12</sup> Communication with the Technical Advisory Group

<sup>13</sup> WRAP, 2005 *The Use of Glass Derived Sands in the Sports Turf Industry – Ongoing Monitoring of Trials*. Available from: [http://www.wrap.org.uk/downloads/Sports\\_Turf\\_Research\\_Institute.e7e84771.pdf](http://www.wrap.org.uk/downloads/Sports_Turf_Research_Institute.e7e84771.pdf) [Accessed 4 September 2007].

## Appendix D Definitions

Term	Description
Flat glass	Soda lime silica glass manufactured in a planar form.
Contamination	Material present in cullet which is not flat glass.
Cullet	General term used for waste glass.
Internal cullet	Waste glass generated during production of flat glass.
External cullet	Waste glass generated from outside the glass manufacturing facility.
Clear cullet	Waste glass consisting of standard off-cuts of glass only.
Mixed cullet	Waste glass usually consisting of a mixture of sealed units, mirrored glass, laminated glass, wired glass, tinted glass and glass from post-consumer windows.
Float glass	Flat glass produced by the float glass process. Molten glass leaving the furnace is poured onto one end of a molten tin bath. The glass floats on the tin and levels out as it spreads along the bath, giving a smooth face to both sides. The glass cools and slowly solidifies as it travels over the molten tin and leaves the tin bath in a continuous ribbon.
Rolled plate glass	Flat glass (usually patterned) produced by passing molten glass between two moving rollers. The pattern is impressed upon the sheet by a printing roller, which is brought down upon the glass as it leaves the main rolls while still soft.
Container glass	Glass jars and bottles used for packaging food and drinks.
Fibre glass (insulation)	Glass fibres usually bound together with an organic binder to produce rolls of thick blanket for use as building insulation.
Laminated glass	Two or more layers of float glass bonded to an intermediate layer of PVB plastic film. Laminated glass is used in car windscreens and for safety glazing.
PRN	Packaging waste recovery notes, generated by accredited reprocessors for recycling packaging waste. They have a market value and are sold to businesses that produce packaging waste to enable them to demonstrate compliance with the packaging waste regulations.
PVB	Polyvinyl butyral film used in the manufacture of laminated glass.
Sealed unit	Double or triple glazed unit used in PVC-U windows.
Sports turf	Glass used as a substitute for sand in the construction and treatment of sports pitches and golf courses.
Water filtration media	Material which water is filtered through to remove impurities. Flat glass can be used as a substitute for sand but is only suitable for waste water treatment.

**Waste & Resources  
Action Programme**

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