

Small Scale Glass Recycling Technology

Review of Available Process Equipment



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Report prepared by
Remade Scotland

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Executive Summary

In the drive to divert waste materials from landfill, glass although not biologically active is often an obvious choice for recycling as it is both bulky and heavy. It is also well established in the public mind as being recyclable. Yet in remote rural areas the tonnages diverted are often very small and the consequential costs of collecting and transporting segregated glass can often be prohibitive. However it is possible to process glass into a range of products which can be used locally and this report reviews the extremely small-scale technologies available.

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1 Glass Processing

As various alternatives exist for processing glass, perhaps the most important criteria in selecting crushing equipment is matching the best technology with the feedstock to produce the desired end product, whilst minimising both capital and operating costs.

In its simplest form glass crushing is the process of feeding glass into a machine that typically with the use of rotating hammers, discs, and/or bars reduces the size of the glass feedstock. Depending on the system adopted this can result in the crushed glass having either a sharp or a smooth profile.

Glass processing is similar in many respects to processing traditional aggregates, with a few critical exceptions. Firstly, glass is extremely lightweight compared to other minerals and tends to bounce upon impact rather than simply break. Secondly, glass shatters into fines which are angular to sub-angular and extremely abrasive. These fines can potentially have an adverse affect on the bearings and other sensitive sections of traditional aggregates crushing equipment, causing equipment damage.

Particle size is one of the most important criteria to end markets and can be adjusted in many technologies by changing the space between the discs and bars or by altering the throughput speed. Others achieve specific size reduction by continuous circulation of the cullet until it achieves the specified size. This is an important factor when deciding if the system will process glass to meet one principal end market or several. It is also important to identify equipment which can cope with the unique characteristics recycled glass possesses and the challenges it brings.

2 Output Options

2.1 Aggregate

It is estimated that around 200 million tonnes of aggregates are extracted every year in the UK, consisting mainly of sand, gravel and crushed rock.

If an aggregate is required, it is likely to be regulated by either a British or European Standard. In the case of road construction, the Highways Agency lays down standards in its publication, 'Specification for Highway Works' which all materials must conform to. General fill materials tend to only require to conform to 'performance-based' specifications – i.e. as long as the material meets the required physical and chemical properties, the actual material is not restricted.

However, many standards are highly specific for the type of material e.g. BS 882 (the standard for concrete aggregates only specifies natural sand and gravel, whereas the newer European Standard BS EN 12620 does not specify the type of aggregate. In the UK, around 140,000 tonnes of recycled glass is used as aggregate with the potential to significantly increase this. There are, unfortunately, a number of barriers to achieving this growth:

- ◆ Material-specific standards will require amendment to include glass.

- ◆ Lack of accepted standards for glass in terms of its physical and chemical properties.
- ◆ Glass fragments (>5mm) have a tendency to flake, which may obviously affect its final applications. Smaller fractions to replace sand and gravel should be better options.
- ◆ The ‘Alkali-Silica Reaction’ (ASR) may occur when glass is mixed with cement in concrete, weakening the concrete over time. This is thought to be due to gel formation on the surface of large particles of glass. However, there is also evidence that the addition of very fine glass particles (<600µm) can actually increase the strength of the finished concrete.

2.2 Pipe Bedding

Glass aggregate has been used for drainage and pipe-bedding in the United States for over 10 years now. As it is primarily composed of silica, its drainage properties are similar to sands and gravels. The majority of land in the Argyll islands could be categorised as peaty soil. Drainage would be effective as long as the glass is covered with a layer of clean stone to prevent migration of soil into the drain, thereby preventing clogging.¹ Although this application is low value, it may be the most economical option for on-island use of glass in the islands. The limiting factor would be the profile of the cullet used - for if sharp, the cullet would require to be well covered (over 300mm) to ensure there will be no injuries to humans or animals.

2.3 Sand

There has been much research on the applications of glass sand² which can be used in water filtration, abrasives and sports grounds. However, the small quantities involved and the level of processing required to bring the product to the required specification may discount these as economically viable options for the islands. However sand of a lower quality could be used for bedding slabs or drainage.

2.4 Other Alternatives

There may be the possibility of producing high value artefacts if a local artist is interested in producing glass or glazed products. On the Island of Arran, the Arran Recycling Community Organisation (ARCO) is considering this at present and intends to invest in an electric kiln for this purpose.

2.5 Background issues

There is a potential problem which may arise in the future, regarding the classifications of “recycled product” and “waste”. At the moment there are no issues in producing cullet for pipe bedding or aggregate from glass diverted from the waste stream. However, there is a substantial grey area in defining when a waste ceases to be – this problem has already arisen in the case of green compost which does not achieve PAS100 standards and is therefore still defined as a “controlled waste” with limited applications. If the opinion of SEPA swings towards cullet being classified as a feedstock for the remelt sector, rather than a product, then applications in remote rural areas would be severely limited.

¹ *Guide to the practical use of post-consumer glass in rural areas.* Department for Sustainable Communities/Comhairle nan Eilean Siar. September 2003

² *PAS 102 Specification for processed glass for selected end markets.* WRAP/BSI 2004

3 Factors Affecting Choice of Technologies

Several factors will influence the decision regarding any type of technology:

3.1 Capital Cost

The cost of purchasing and running any type of machinery may prove prohibitive. The mobile units such as the *Allubucket* range from £7,000 to £40,000 and cone crushers with all the associated equipment would be considerably more.

Shetland & Western Isles

Shetland and the Western Isles have invested in heavy-duty crushers and process plants to recycle their glass collections. Equipment used includes:

- Hopper
- Primary breaker
- Heavy duty pulverizer
- Contaminant removal screen
- Dryer
- Enclosed tier sieve
- Dust extractor
- Bagging equipment

3.2 Maintenance Costs

As glass is a brittle, dense, abrasive material, it tends to wear down moving parts of crushing machinery at a fairly fast rate. Different equipment can cope with varying amounts of glass throughput before wearing out moving parts. Replacement hammers can therefore prove to be costly as they have found in Arran where the hammers have to be replaced after only 20 tonnes of processing.

3.3 Cullet Size and Potential Uses

As the equipment may require to be driven using an integrated motor or external engine, the efficiency in reducing cullet size is directly related to the speed of the motor. If a tractor engine is used to power the crusher, then the cullet size will not be reduced to a suitable level to be used as aggregate and the only potential uses are for road foundations or deep drainage/pipe bedding (as in the Western Isles). This problem has also occurred in the Orkneys where they are using the Council's cone crusher as a secondary process to reduce aggregate size.

3.4 Low Volume of Recyclate generated

The capacity of most technologies far exceeds the volume of recyclate generated in remote rural areas, therefore the machinery would only be used for a very short period of time.

3.5 Quality of output - liquid & paper content?

The level of contamination in the containers prior to crushing may also play a part in the decision-making process. For certain applications, the product may have to be particularly clean e.g. concrete-making. In this case, investment in relatively expensive washing equipment which would add to the capital and running costs of the project would be required.

At the moment, there is little or no regulation on the quality of cullet being used for drainage aggregate/sand substitute applications and no reports were found of adverse environmental effects caused by the small amounts of biodegradable materials which would adhere to jars and bottles.

3.6 Operational and Health and Safety Issues

It is crucial that the chosen technology is both easy and safe to use for the operatives. Although a technology outlined underneath is not designed for glass crushing, it is being used in a few island groups for this purpose.

There has been some concern in the past regarding the risk of silicosis arising from glass dust. Remade Scotland looked at this potential problem³ finding that dust produced from glass crushing contains amorphous silica rather than crystalline and therefore poses no appreciable risk as far as the development of silicosis and other respiratory diseases are concerned. The closed system glass compactors with integrated buckets will also reduce the volume of dust released into the atmosphere.

The handling of cullet will require gloves to prevent cuts and abrasions.

4 Technology Options

Valpak, under the auspices of WRAP, undertook a study of glass compactors in Glasgow pubs and nightclubs⁴. The average glass recycle for a nightclub in Glasgow was 0.67 tonnes/night, giving an average of 245 tonnes/annum – often typical in remote rural areas. The cullet could be used for deep drainage (as it tends to be fairly large and sharp in profile) or the reduced volume could be transported off the islands for recycling.

Given these limitations the following represent the main technology options available:

1. Sharp-profile Cullet Production

- ◆ Silipaktor
- ◆ Medium-volume Crusher
- ◆ Tractor-driven
 - Arboreater
 - Allu Bucket

2. Smooth-profile Cullet Production

- ◆ Jarshire BC 1000
- ◆ Medium-volume Crusher
- ◆ Use of existing on island equipment
- ◆ Excavator-driven
 - Allu Bucket

³ www.remade.org.uk/Glass/glass_documents/Abrasive%20Fact%20Sheet.pdf

⁴ *Glass Collection from Licensed Premises – Glasgow*. Andrew McCaffery and Duncan Simpson (Valpak Ltd) WRAP, 2005.

4.1 Sharp-profile Cullet Production

4.1.1 *Silipaktor*

The *Silipaktor* has the capacity to reduce the volume of glass bottles to a cullet of approximately 20% of the original.

- ◆ *Multifeed?* Bottles can be poured in, dozens at a time, or singly.
- ◆ *Size of the Silipaktor.* The footprint is 750mm x 750mm; total height – 1,780mm; feed height – 1,660mm; from the back of the machine to the front of feed – 870mm.
- ◆ *What are the measurements of the bins?* 820mm deep, 660mm wide and 1,020mm high.
- ◆ *Weight?* Without the bin, 180kgs.
- ◆ *How much does each bin weigh empty?* 70kgs.
- ◆ *How much does each bin weigh when full?* About 360kgs.
- ◆ *What is the capacity of each bin?* Total capacity is 280 litres; so as not to overfill bins, it is prudent to fill only 90% thus “working” capacity is about 250 litres.
- ◆ *How much glass does each bin hold?* 290kgs of cullet: this equates to about 650 x 750 ml wine bottles or over five 240 litre bins of uncompacted glass containers and more than that contained in one 1,100 litre wheelie-bin.
- ◆ *What sort of access is necessary?* A service lift or reasonably flat walkway because of the weight of the bins; stairs are unsuitable.
- ◆ *What’s to stop the Silipaktor spraying bits of glass everywhere?* It only works with a bin in place – the automatic cutout operates if the bin is removed; and, when operating, the unit is in effect sealed so negligible dust escapes.
- ◆ *Does the Silipaktor meet EU safety standards?* Yes – it is CE marked to meet both the Electro Magnetic Compatibility (EMC) Directive and the Machinery Directive.
- ◆ *How much noise does the Silipaktor make?* With motor running but no bottles being compacted – 77.4 dBA; with bottles being compacted – by operative’s position 96.1 dBA, 2m from operative’s position 90.1 dBA, 4m from operative’s position 88.2 dBA, 10m from operative’s position 86.5 dBA.
- ◆ *What protective clothing should operators wear?* Operators should wear gloves, ear / eye protectors etc.
- ◆ *Are there any other health & safety issues?* As glass is 99.9% free of crystalline silica (which is a leading cause of silicosis) the material is, to all intents and purposes, harmless.
- ◆ *How is the bin moved?* It is on wheels and, in spite of the weight, is easily manoeuvred.
- ◆ *If the bin is on wheels, what’s to stop it “running off”?* It has a “dead man’s handle”.



- ◆ *What are the power requirements for the machine?* Standard 13 Amp, 240 Volt, single-phase plug adjacent to the unit (motor is only 750 Watts, comparable to domestic washing machine).
- ◆ *What size are the glass particles produced by the **Silipaktor**?* 88% measure 10mm or more in diameter

Indicative Costs

Capital Investment per Unit (including delivery	£3,995
Installation, Commissioning, Training	£200 (plus travelling, accommodation costs)
Maintenance – flails should last for approximately 100 tonnes	£200 labour and parts (plus travelling, accommodation costs)

Contact Details:

Glass Compaction Services Ltd.,
1 Farnham Road, Guildford,
Surrey, GU2 4RG

01483 549076

www.glasscompactionservices.co.uk

4.2 Crushing to Smooth-profile Cullet

4.2.1 *Arboreater*

Arbor Eater Brushwood Chippers Ltd produce a range of equipment which was originally designed for the shredding of woody material but has been found to be effective in a range of applications including glass crushing. The product information is largely relevant to organics and there appears to be no technical data on its application with glass (perhaps due to the small amount of people using it for this purpose). It works using a hammer and as can be seen below, the wear on these should be a matter of concern for anyone contemplating using this technology for glass crushing.

Indicative Costs

Capital Investment per Unit (Bio 600)	£15,000 – 20,000
Installation	No associated costs
Maintenance - New hammers after 20 tonnes	£400

Contact Details:

Arbor Eater Brushwood Chippers Ltd.,
Unit 5 Firsland Park Estate,
Henfield Road,
Albourne,
Hassocks, BN6 9JJ
01273 493180

Operational Experiences from other Island Users

Arran

Arran has been using an Arboreater Bio 600 to produce glass cullet for several years. Although this technology was designed for woodchipping, it can be adapted for glass crushing. However, due to the properties of the resultant cullet, there is significant amount of wear on the machinery. Several sizes of cullet are produced which up until now have all been used for pipe bedding. The acquisition of a grader/sorter has allowed different sizes of cullet to be separated. Whilst the coarser cullet will continue to be used for pipe bedding, the Arran Recycling Community Organisation (ARCO) intends to invest in an electric kiln to make high value glass artefacts to be sold on the island.



ARCO currently process around 150 – 200 tonnes of glass per annum on the island, and find this piece of equipment satisfactory for Arran's needs, as it is also used in the winter to shred cardboard for animal bedding. However, the glass is extremely hard on the hammers and they require to be replaced after only 20 tonnes of processing. ARCO are now using second-hand hammers which have reduced maintenance costs from £400 to approximately £250 per replacement.

Scilly Isles

On the main island of St. Mary's there are eight recycle bins for glass that return glass to a machine used to bulk break into small shards that can then be screened mechanically and used as blinding in foundations for building works and around land drainage pipes etc. The local council are instigating a programme on each of the smaller islands where the intention is to use Arboreaters in order to produce material for use in the maintenance and upkeep of the concrete roads on each island without the need for shipping materials back and forth.

Neville Gardner, Chief Technical Officer, ngardner@scilly.gov.uk

Alderney

Alderney in the Channel Islands is also using an Arboreater for glass volume reduction and sharp cullet production. No report on the effectiveness of the equipment was available.

4.2.2 Allu Bucket

The Allu Bucket is a screener/crusher accessory for hydraulic loaders, such as wheel loaders, excavators and backhoes, which is attached to the base machine by an adapter or a quick coupler.

The screener/crusher consists of a frame (bucket design) without a back plate, onto which 2-4 screening and crushing drums with bearings have been mounted. All the



drums rotate in the same direction. The hydraulic power from the base machine is transferred via hydraulic hoses to the hydraulic motor of the screener/crusher. The hydraulic motor then transfers the power to the drums via chains and chain wheels. The screened and crushed material flows through the crushing and screening drums when the blades scoop the material through the drums.

The processed material falls on the pile by gravity and the force of the rotating drums. Big fragments are left in the bucket, which are easily placed in their own pile.

The average size of the processed material is determined by the type of drums used, the type of counter blade used, the rotation speed of the drums and possible accessories like blades, screens and crushing bars. Worn out blades also have an effect of the particle size.

The screener/crusher requires two-way hydraulics. The rotating direction is always the same, but the hydraulics have the possibility to reverse so that any material blocking the drums can be loosened. The rotating direction of the drums and the rotating speed (300 rpm recommended for best result) are controlled by the operator.

The processing bucket is an accessory for hydraulic loaders such as wheel loaders, excavators and backhoes, which is attached to the base machine by an adapter or a quick coupler.

ALLU Processor Series Guide

The following outlines some important considerations when matching an ALLU with the host machine and application:

- ◆ Match the correct ALLU model to machine by weight classification.
- ◆ Host machine must have auxiliary bi-directional hydraulics (i.e. 3rd valve hydraulics) to operate the ALLU forward & reverse. A case drain line is also required (most times this will need to be added) as a safety relief directly to hydraulic tank if possible.
- ◆ Hydraulic flows provided to the ALLU must not exceed the specifications as listed in the brochure or hydraulic charts for the specific ALLU model.

- ◆ What is the desired application? The ALLU is an effective machine mounted attachment for doing a rough screening, reducing and crushing of many materials, aeration, and for mixing and blending. One person & one machine can typically amount to large savings compared with other alternatives.
- ◆ What material sizing is acceptable to the application and process? Use the biggest size possible for best production and to avoid clogging, especially in heavy and sticky material like clay soils.

SML light, vs. SM standard vs. the SMH heavy duty? Size of the machine and hydraulics may dictate what is available as a match.

Indicative Cost

Prices range from £7,000 upwards. Cullet size and profile is dependent on the rotational speed of the host machine. The manufacturers recommend the use of an excavator rather than a tractor for this purpose.

Contact Details

Ideachip UK Ltd.,
17 Victoria Road,
Holywood,
Co. Down,
N. Ireland BT18 9BA
02890 428 822
www.allu.net

Operational Experiences from other Island Users

Orkney Islands

“In Orkney we invested in an 'Allu bucket' which we use to initially crush the collected bottles and jars. The resulting material is then put through a cone crusher. The cone crusher is the existing one which is used in the Council's quarry. The resulting product is used as an aggregate substitute in concrete products.”

Unfortunately, Orkney have not been able to achieve a high enough torque with their Allu Bucket due to underpowering by using a tractor. This has necessitated the addition of a cone crusher.

Maria Cuthbertson
Waste Reduction Officer
Orkney Islands Council
Telephone 01856 873535 ext. 2315
maria.cuthbertson@orkney.gov.uk

4.2.3 Jarshire

Jarshire produce two models of glass crusher which may be of use in the islands; the Jarshire BC1000 and BC4000. These were designed for bars/clubs where the tonnage of glass produced in an average club in Glasgow is equivalent to approximately 245T/yr.

These products produce a smooth cullet of between 1 and 6 mm which, because of its size and profile, may be useful in remote rural areas.

However, the BC1000 requires to be fed one bottle at a time, whereas the BC4000 is fed through a hopper. The crusher works by a flail chain mechanism and is powered by mains electricity.



Indicative Costs

Jarshire BC1000

£2,900

Jarshire BC4000

£4,900

Replacement of flail chain after 100 tonnes

Approx. £200 plus travelling, accommodation costs

Contact Details

Jarshire Ltd.,
Levels House,
Bristol Way, Stoke Gardens,
Slough, SL 1 3QE
01753 825122
www.jarshire.com

4.3 Use of existing Quarry Operations

As glass can be readily crushed in existing quarry equipment it is worth considering this as a process route if available and if the tonnages generated are adequate.

Operational Experiences from other Island Users

Arran

There have been problems with using existing quarry equipment on Arran when sharp-profile cullet appeared in aggregate sold for domestic use. This was the main driver for ARCO to develop its own mode of glass recycling. There has also been concern that running a crusher for glass then changing back to stone may cause contamination of the resultant stone aggregate.

Isle of Man

Domestic mixed colour glass recycling banks are provided for the collection of clean glass bottles and jars, which recover annually around 900 tonnes. The Isle of Man government is trying to encourage an on-island recycling industry. To this end they have negotiated a contract with the Ballaharra Quarry, St Johns, where the glass is crushed and used to make patio paviours, or as a replacement aggregate (i.e. as an alternative to sand). A gate fee is charged.

Commercial glass arising from pubs, hotels and restaurants – around 740 tpa – is collected for recycling via private recycling schemes. All commercial glass collected is exported to the UK for recycling, where it is treated and made into recycled glass products (e.g. new bottles, drinking glasses). This is delivered by a local operator who bulks up and ships to St Helens. The cost of shipment and receipts for glass is approximately cost neutral. The profit is made from servicing the glass banks from hotels etc. There is currently a disposal charge for all commercial waste which makes it more favourable to recycle.

Stephanie.Gray@dlge.gov.im

www.im-recycling.com

4.4 Crushing of glass prior to shipping from Remote Rural Areas

Where there are no potential outlets for locally processed glass, it may still be worth considering crushing glass to reduce its volume. Most glass crushers are likely to be able to achieve a volume reduction of around 80%, which may then allow for reduced transport costs. However this will depend on the requirements of the final market – for instance the remelt sector often prefers to receive glass in bottle form.

5 Conclusions

From an environmental sustainability perspective the best environmental option would be to use the existing technologies available in quarries, if the quarry operators can be persuaded to process the cullet at a reasonable rate and the product could be used locally. However the volumes of glass available may not make this an economic possibility and the purchase of a small scale glass compactor for use in remote rural areas could offer a local environmentally sustainable solution.

There are a number of small scale glass processing technologies available which can produce a useable cullet and which are readily available.