LAYMAN'S REPORT

LIFE PROJECT: FLAT TO FLAT (LIFE12ENV/BE/000214)

Demonstration of an innovative fine crushing method for glass and alternative cullet in flat glass production

Duration of the project: 1 July 2013 to 31 December 2017

With the contribution of the LIFE financial instrument of the European Community

AGC GLASS UNLIMITED

Maltha

Vlakglas Recycling Nederland

Table of Contents

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Vlakglas Recycling Nederland

Executive summary

The Flat to Flat project is co-funded by the EU Life+ programme and was launched on 01/07/2013. Flat to Flat is an AGC Glass Europe project. The partners involved are AGC Glass France, Maltha Group BV, Maltha Glasrecycling Nederland BV, Maltha Glasrecyclage Belgium BVBA, and Vlakglas Recycling Nederland (VRN). The aim is to cut the environmental impact of flat glass production (CO_2 emissions, energy, raw materials) through the development and validation of an innovative method for recycling and up-cycling glass and other waste materials in the production of flat glass.

The first chapter of this Layman's report contains a description of the project's environmental challenges, the project partners and the main objectives tackled by the Flat to Flat project. In the second chapter the proposed innovative technology and the related benefits are detailed. The third chapter gives a summary of the project's results and achievements. The fourth and last chapter is dedicated to the long-term benefits of the project and to the transferability and replicability of its results.

Market changes in the requirements for clear glass, together with increases in the price levels for all cullet sources to be recycled since the start of the project, have put serious pressure on the final delivery of the project. However, the drawbacks (in terms of business considerations) do not weigh up against the successes achieved by the project:

- The identification of new and alternative cullet flows, and an assessment of their recycling potential, has delivered a broader and deeper understanding of cullet's value chain.
- Improved logistics and even more efficient waste management at cullet collection points have been implemented. This drastically reduces the pollution risk of cullet downstream in the cullet recycling value chain, and reduces the number of cullet transports and, therefore, CO_2 emissions.
- Demonstration of technical feasibility of large-scale cullet crushing. Fine cullet within the narrow and strict specifications required by the flat glass industry has been delivered. Controlling the amount of very fine cullet powder, in particular, has proved to be something of a challenge.
- All critical handling issues of fine cullet in glass production were identified and the technical aspects were tackled.
- Transferability of the technology from flat glass crushing to bottle glass crushing.

Each of these successes has paved the way for the upcycling of cullet flows, which had not previously been considered, towards the highest standards required by the flat glass industry. The increased availability of cullet means more of it can be consumed, thus substantially cutting CO_2 levels in a world facing global warming challenges. It also allows the development of new business models for the bottle glass industry. Here, too, the aim is to upcycle cullet flows, reducing the use of raw materials and cutting CO_2 emissions through the use of more cullet.

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1. Introduction

Environmental challenge

Glass is a key element for many industries. In 2006, the world market for flat glass was estimated at around 42 million tonnes. Growth in demand for flat glass has generally outpaced real GDP growth for the past 20 years. The production of glass, however, requires high levels of energy and raw materials, and leads to the emission of a range of pollutants. The energy currently required to produce one tonne of glass amounts to 6-7 GJ whereas the theoretical minimum energy level required would be 2-3 GJ – the energy necessary for the materials in the glass composition to melt.

Furthermore, the fraction of recycled cullet – or glass waste – used accounts for just 30% of total glass production . For quality control reasons, flat glass producers only reuse internal cullet (production losses and glass with faults) plus some industrial cullet (from subsidiaries and recyclers). In addition, glass production entails the emission of atmospheric pollutants (e.g. CO_2, SOx, NOx) and the use of large quantities of water and raw materials (sand, minerals and metals).

The LIFE FLAT to FLAT project (**LIFE12 ENV/BE/ 000214**), however, demonstrated an innovative processing technique by which the glass industry can use cullet containing a thousand times more ceramics, stone and porcelain than before – i.e. it can come from sources that could not previously be used by the glass industry. Recycled cullet is mixed with raw materials to reach the desired quantities. Glass is heavy en you need a lot of transport movements to transport For the process to be cost-effective and in order to minimise the CO_2 emission, distance between the collection points and the recycler must be as close to each other as possible. This is not always possible, therefor VRN tries to transport as much as possible by vessel. The project aims to cut the environmental impact of flat glass production using the float technique. This involves the use of recycled glass/other waste (end of life flat and bottle glass and alternative industrial waste). The recycled materials introduced into this project come from sources that could not previously be used by the glass industry, due to their adverse impact on glass quality and on the production process.

Together with Maltha, VRN and AGC cover the entire lifecycle of glass (“cradle to cradle”), allowing to demonstrate the technique, but also to define the infrastructure needed to operate it. As well as a significant reduction in the use of raw materials, this cuts energy consumption and CO_2 emissions. Therefore, the project has a positive impact in terms of limiting climate change.

Another environmental challenge to take into consideration is the impact of collecting the flat glass waste and having it transported to the recycler. VRN has set up a national system in the Netherlands for the collection and recycling of flat glass waste. During the LIFE Flat to Flat project, VRN supplied a small quantity of cullet for test purposes. The system of collection is intended for everyone who works with waste glass: painters, glaziers, demolition companies, contractors, glass suppliers, glass processors, glass manufacturers, waste parks and so on. It brings together all of the parties needed to ensure effective cooperation: the companies involved in supplying glass, the collection network, and the recycling companies. The cullet was collected at Dutch collection sources selected by Vlakglas Recycling Nederland. The selection criteria included location, quality of cullet, average quantity of cullet per source, etc.

During the project, VRN carried out evaluations to continuously improve the environmental impact of the logistics involved, in relation to the collection of cullet at the various collection points. The aim was to cut CO_2 emissions to the bare minimum during the logistic phase of flat glass

waste transportation. An optimized logistics system ensures less transport movements and therefore also a reduction of CO_2 emissions per tonne of flat glass waste transported.

Objective and expected results

Objectives

This Flat to Flat project was intended to develop and validate an innovative method for recycling and up-cycling glass and other waste materials in the production of flat glass. This goal has been achieved through an innovative crushing technology that allows the consumption of recycled cullet by the glass producers to be expanded. As a result, cullet consumption could be increased to more than 50% of the total amount of the raw materials introduced in the glass furnace. The innovative processing technique will also make it possible to use cullet that contains 1,000 times more ceramic, stone, and porcelain (CSP) than before. The project covers the entire glass lifecycle. In addition to demonstrating the technique, it has also identified and organized new cullet flows.

Expected results

The project's general environmental objectives (for flat glass production) are as follows:

- up-cycling cullet flows, which are currently not taken into consideration;
- replacing up to 25% of raw materials by recycled/upcycled waste;
- 5% cut in energy consumption;
- 12% cut in CO_2 emissions.

Cullet requires less energy to be melted and replaces carbonated raw materials. And as the amount of glass made from recycled cullet is exactly the same as the amount of recycled cullet introduced in the furnace, no losses occur. The aspiration of this project is to achieve a perfect life cycle.

Project coordinator and partners introduce themselves

Project coordinator –AGC Glass Europe

Based in Louvain-la-Neuve (Belgium), AGC Glass Europe produces, processes and distributes flat glass for the construction sector (external glazing and interior decorative glass), the automotive sector (original and replacement glass) and the solar sector. It is the European branch of AGC Glass, the world's largest producer of flat glass.

Its baseline "Glass Unlimited" reflects the potential of:

- glass as a material to meet a growing variety of needs (comfort, energy control, health and safety, aesthetics, sustainability);
- innovation in products and processes, derived from continuous research in advanced glass technology;
- over 100 sites throughout Europe, from Spain to Russia;
- a worldwide marketing network;
- a 16,000-strong workforce focused on the customer.

Head quarter of AGC Glass Europe at Louvain-La-Neuve, Belgium

Project partners

AGC Glass France

AGC Glass France, a member of the AGC Group, is the group's largest flat glass plant in France. Its headquarters and main industrial plant are located in Boussois, 250 km north of Paris, close to the border with Belgium. AGC Glass France produces and processes flat glass, mainly for architectural applications. Its aim is not only to boost production volumes, but also to maintain the high quality of products and services it offers to customers. This aspiration reflects the need for continuous investment in new technologies. Since 2008, many different

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innovations have been introduced in order to reduce its ecological footprint. One such innovation is oxy-combustion, and furnace 1 at Boussois is the first in Europe to be fitted with this technology.

Maltha Groep BV

Maltha Groep BV is the leading glass recycling company in Europe. Every year, Maltha processes around 1.5 million tonnes of glass waste received from companies, members of the public and local authorities into new, high-quality raw materials for use in the manufacture of new products. Maltha's history stretches back almost 100 years. From a local player in the Dutch town of Schiedam, Maltha grew to become the leading glass recycler in Europe. The company currently operates eight specialised processing sites in five European countries (the Netherlands, Belgium, France, Portugal and Hungary).

Maltha works closely with collection companies and recycling schemes throughout Europe. The collected glass is purified at Maltha, using advanced methods. It is then reprocessed into various types of glass cullet that fully comply with the specifications of customers in the flat glass, packaging glass and glass wool industries. Maltha is also closely involved in many innovation projects. Maltha Groep BV, the holding company, supplies expertise in engineering and design, project management, networking and dissemination. The Maltha plants at Heijningen (Maltha Glasrecycling Nederland BV) and Lommel (Maltha Glasrecyclage België BVBA) – which are also partners in the Flat to Flat-project – are two of the group's specialised production units.

Vlakglas Recycling Nederland (VRN)

VRN, which was founded in 2002, is a foundation founded by the Dutch double glazing industry and by trading companies in the Netherlands.

The VRN collection system has a network of more than 400 collection points, where all types of sheet glass waste (with the exception of car windscreens, special types of heat resistant glass and ceramic glass) can be handed in. This glass waste is then collected, recycled (by a recycling company such as Maltha Glasrecycling) and re-used in the glass industry. The Dutch government has given its support by permitting a recycling fee to be charged on insulating glass that is produced in or imported into the Netherlands. This fee covers most of the subsequent collection and recycling costs. The Dutch ' system for collecting and recycling flat glass waste is unique and is considered to be 'good practice' in Europe. It currently exists only in the Netherlands. The cullet that VRN collects is recycled and re-used in the flat glass, packaging and glass wool industries.

The idea behind the separate collection and recycling of sheet glass is the 'cradle-to-cradle' philosophy: the principle that, after use, materials should be fully recyclable for use in other products. Our aim, and with the C2C philosophy in mind, is to have as much flat glass recycled into the flat glass industry as possible. The VRN system supports the circular economy.

2. The innovative technology

The LIFE FLAT to FLAT project (**LIFE12 ENV/BE/ 000214**), focused on making new sources of cullet available for the glass industry. This cullet contains a thousand times more ceramic, stone and porcelain than the material currently being used, which would make it incompatible with today's production specifications.

The innovative aspect of the new approach was that it took the cullet's full value chain into consideration, from sourcing to end use in the furnace, while complying with the high standards required by the flat glass industry.

VRN set up a system to closely monitor and implement pertinent traceability of the cullet source.

Maltha monitored any incoming pollutants and developed a controlled crushing process, including drying, sieving and de-ironing, to deliver cullet within the given specifications.

AGC used melting tests to assess the various types of pollutants encountered throughout the value chain. The goal was to define new limits and to optimize the value chain itself.

The cullet collector received continuous feedback from end users and handlers. This proved to be essential in terms of optimizing the cullet value chain and of minimizing the amount of pollution in the original cullet source.

Cullet handling was done with the most care as it was proven to be critical for crushing efficiency and for storage.

3. Main project activities and achievements

Quality control of the collected cullet at collection points

As mentioned above, monitoring the quality of the collected cullet proved to be an essential step in the cullet flow.

During the project, VRN supplied batches of cullet for testing. This cullet was divided into the following three categories (based on its origins):

- Combi Flat 1 – originating from glass companies and glaziers. This can either be glass from renovation projects or very clean cutting waste.
- Combi Flat 2 – originating only from renovation and demolition projects.
- Combi Flat 3 – originating from waste parks.

VRN regularly visited its collection points to visually inspect the quality of glass collection, storage and handling. Those monitoring visits also presented an ideal opportunity to check and discuss the fill level of the containers, which helped to optimize collection times, thus minimizing transport frequencies.

VRN invested a lot of energy in sharing information on quality requirements. To motivate collection points to optimize and improve the quality of the collected waste glass, an ORCIV certification system was created. This ORCIV certification gives credit to the public collection points monitored by VRN. This certification made it possible to achieve further increases in the quality of the flat glass waste collected. Companies nowadays place more importance in their operations' sustainability. ORCIV enables companies to demonstrate that they are participating in the sustainable waste management system. VRN wants to guarantee that a certified collection point ensures that visitors and employees of this collection point deposit the supplied flat glass waste safely and that the quality of the flat glass waste complies with its stipulated quality requirements. Random audits will be carried out annually. The audits will be performed by an independent auditor's office, which will also be responsible for certification.

Achievements in the environmental impact of the logistic part of flat glass waste collection

VRN took various actions in an attempt to minimise CO_2 emissions during transport of the cullet.

Regular meetings with the subcontracted transport company helped achieve a reduction in CO_2 emissions. During these meetings, the following points and aims were discussed:

- Realizing the transport of collection of cullet in time without any delays.
- Optimizing the transport routes in order to be able to take the shortest route.
- Looking at the different types of transport used during cullet container transport (i.e. by truck, tipper semi-trailer or by ship).
- Creating a special programme tool for the collection points to control their container fill level.
- Developing a CO_2 reduction calculator on the VRN website that enables people to type in the weight of the cullet they have collected and see how much CO_2 reduction they achieved by using VRN's system. To develop the CO_2 reduction calculator, VRN commissioned TNO to carry out an LCA study of the VRN collection system.

The above efforts and activities helped VRN win the Lean and Green second Star Award in 2017 for its logistic system.

Crushing and handling

The main challenge in crushing and handling the cullet was to meet the specifications set by flat glass producers.

The crushing of glass is already a mature technology and various techniques exist, such as roll mill, bullet crushing, and crushing bars. However, most techniques are designed to crush the cullet as finely as possible. Unfortunately, fine powder is easily blown all over the furnace by the fierce flames used to melt the raw material. The glass powder sticks to refractive stones within the furnace. As they are not

designed for this type of contact, they experience heavy corrosion.

Filterinstallation of crusherline

To avoid such adverse effects, precise specifications for cullet grain size are used. The challenge then is to optimize crushing parameters to avoid producing too much fine cullet, which would then have to be sieved off. Maltha fine-tuned its crushing parameters, using its many years of crushing experience to avoid the overproduction of fine particles.

Another crushing-related challenge involves using the right alloys for the crushing parts that are in contact with the glass. It is well known that the flat glass industry prohibits the use of stainless steel where this might come into contact with cullet. Alternatives, like carbon steel, have poor wear resistances which would create heavy iron pollution in the cullet. This would lead to undesirable glass coloration. Maltha therefore put considerable effort into using the right alloy, one that combined high wear resistance and compatibility with glass production. In addition, a crushing process was used in which glass was crushed on glass.

Silobuilding for crushed cullet

In addition to the right crusher settings, careful handling of the cullet prior to crushing proved to be essential in obtaining the required type of crushed cullet. Dry storage and additional drying before crushing were needed to obtain the requisite grain size in the crusher. Following the crusher process, dry storage is critical until the cullet is loaded into the furnace. Humid cullet evolves over time in glass concrete. If this happens in storage silos, complex and costly maintenance is required to remove the glass blocks. Special covers for the incoming cullet (before crushing) was therefore needed. Large silos were built for the final storage stage of the crushed cullet.

Covered storage

Evaluation of meltability of pollutants in glass

Optimizing the entire value chain is only possible if pollution levels are continuously monitored. Specific melting tests were developed to estimate the meltability of the various pollutants that had been identified. These tests were based on melting time and on a knowledge of temperatures in the flat glass furnaces.

The results led to the establishment of new rules in the quality criteria applied to incoming and outgoing cullet from recyclers. The new technology allows restrictions on Ceramics, Stones and Porcelain, and some metal pollutants, to be eased. This allows less restrictive rules to be imposed on glass collection and recycling. And it makes it possible to use the finest fraction of the crushed glass, which cannot be sorted optically as the grain size is too small. As all potential poluants will melt, this finest fraction can be considered as a premium product.

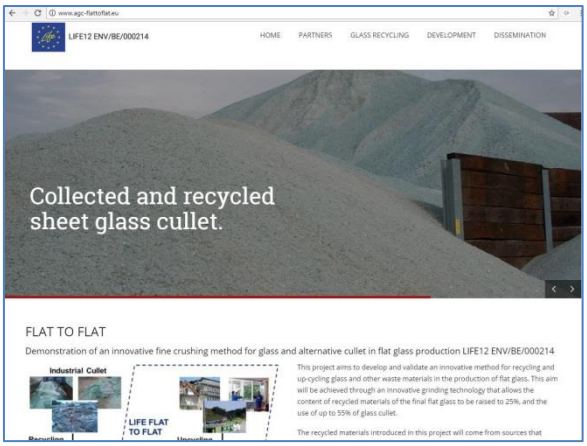
Quality melting test showing that stones in cullet remains after melting and even be the source of glass breakages.

Quality melting tests showing that crushing the cullet at smaller grain size will erode more the steel crusher. During the erosion, more steel particles will be released in the cullet, coloring the glass intensively after melting the cullet.

Dissemination activities and achievements

The project involved various dissemination activities, such as:

- the project website www.agc-flattoflat.eu
- publication of articles (national and international magazines)
- fairs and exhibitions
- presentations at meetings
- conferences and seminars
- networking with other LIFE projects
- creation and dissemination of banners and other promotion material.



Website

Extensive information about the project was provided to numerous stakeholders, including collection points, public authorities, universities and public schools, demolition companies, GBO (Dutch Glass Branch Organisation) members, etc.

Many requests for information came from students and local environmental federations launching studies into the circular economy of glass. This established that there is a fundamental need for this Life project.

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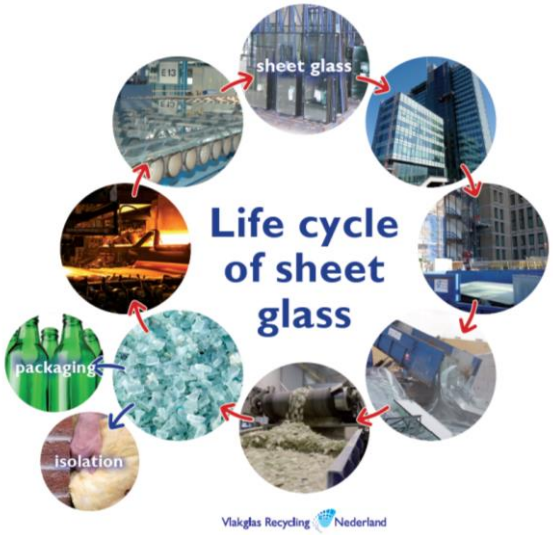
4. Long-term benefits of project and subsequent steps

Long-term environmental benefits

This project has numerous long-term benefits. Tests have shown that crushing technology can easily be transferred from flat glass cullet production to bottle glass cullet. This market is even bigger than the flat glass market, so the potential amount raw material and the global CO_2 savings would be even greater enhancing the environmental benefit of this technology.



The project has also shown that a well-organized flat glass waste collection system, optimized logistics routes and effective monitoring of container fill levels help to reduce CO_2 emissions during transport.

Small-scale tests have also demonstrated that efficient crushing would allow the cullet to be up-cycled into the value chain. Cullet that was previously rejected by the flat glass industry would now become accessible. This still needs to be demonstrated on a larger scale, but all intermediate evaluations were conclusive in this regard. Larger scale tests have been successfully conducted for hollow glass.

Increasing the amount of cullet has a positive impact, cutting energy and raw material use in line with the specified targets:

- up-cycling cullet flows which are currently not taken into consideration;
- replacing up to 25% of raw materials by recycled/ upcycled waste;
- 5% cut in energy consumption;
- 12% cut in CO_2 emissions.

As cullet can be indefinitely recycled without quality loss , the benefits for global warming are undeniable.

Another benefit is the creation and re-enforcement of the circular economy, where glass recycling has yet to be fully implemented or where it needs to be reinforced.

Economic benefits

The economic benefits of the project can be calculated in various ways. The replacement of raw material by more recycled cullet produces immediate energy and raw material savings. If the amount of energy consumed in furnaces is maintained at the same level, higher amounts of cullet will boost glass production per time unit. This means that production capacity can be increased without requiring modifications in the design of the furnace. So production facilities will be able to maintain their activities in an growing market where there is competition from overseas products. And finally, there will be a reduction in the environmental cost, in relation CO_2 and exhaust fume management.

Market changes in the requirements for clear glass, together with increases in the price levels for all cullet sources to be recycled since the start of the project, have put serious pressure on the final delivery of the project. This produced some economic drawbacks with regard to the short and mid-term deployment of this technology in the flat glass industry.

On the other hand, the constraints on hollow glass producers are less strict than the flat glass product criteria. They should benefit from this technology in the short term. Maltha has completed a successful trial involving the use of powder in a packaging glass furnace, together with one of the biggest bottle makers in the world.

Replicability and transferability

Crushing technology is essentially based on accessible technology which makes it highly replicable. And the technological efforts involved in producing high quality crushed cullet for the flat glass industry can immediately be transferred to the bottle glass (hollow glass) industry. This would also boost CO_2, raw material and energy savings, as well as glass production capacity.

In order to facilitate and ensure widespread replication and transfer of the innovative technology, the LIFE Flat to Flat project coordinator and partners will continue to perform intensive dissemination activities to promote the positive environmental benefits of the technology.

This will be done through several activities, including:

- project website (www.agc-flattoflat.eu);
- networking.

VRN has shown that their collection system in the Netherlands is effective and that the costs of containers, collection and other activities can be largely covered by the recycling fee (EPR). Although each country has its own laws, infrastructure etc., a system like VRN's could theoretically be replicated in other countries, so that flat glass waste would be collected for recycling and not end up in a landfill.

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