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Economic study on recycling of building glass in Europe

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Table of Contents

Table of Figures

Aknowledgements

The production of this study could have not been possible without the constent support from various influential stakeholders within the glass industry, interviewed during this two-phase one-of-a-kind study. As centralised information about building glass recycling in Europe was not assembled previous to this study, it is important to point out that the validity of content, data, and insight outlned in this report were possible thanks to the involvement of these stakeholders and their willingness to provide information that was beyond the capacity of Eurostat data.

The report in its entirity was sumbitted for scruitiny by these industry stakeholders. Furthermore, each of the six case studies outlined were particularily assessed and validated from national stakeholders from concerned Member States, followed by consecutive revisions to insure clarity and validity.

With these words in mind, we would particularily like to acknowledge the following dedicated stakeholders:

Country	Stakeholder	Type of organisation
France	Saint Gobain Glass	Flat glass producer
	AGC Glass Europe	Flat glass producer
	Revalo	Flat glass and PVC joinery treatment company
	Paprec	Treatment & waste management company
	Lapeyre	Joinery producer and distributer
	Fédération des Chambres Syndicales des Industries du Verre	Federation
Italy	Eurovetro SRL	Flat and hollow glass producer
	CoVeRe	National recycling association
	Saint Gobain Glass	Flat glass producer
Netherlands	Vlakglas Recycling Nederland	Independent flat glass compliance scheme
	Maltha recycling	Glass treatment company
Poland	Polish Glass Manufacturers Federation	Federation
	Saint Gobain Glass	Flat glass producer
United Kingdom	British Glass Manufacturers' Confederation	Glass federation
	Glass and Glazing Federation GGF	Glass federation
	NSG Group	Flat glass producer
	Berrymans	Flat glass treatment company
	Construction Products Association	Association for construction product manufacturers

Country	Stakeholder	Type of organisation
	GTS	Consulting firm specialised in building glass recycling
Germany	BV Glas (Germany)	Flat glass producer
	Saint Gobain Glass	Flat glass producer
	Bundesverband Flachglas	Federation
	Rewindo GmbH	Association of plastic profile manufacturers
	Reiling	Flat glass treatment company
	Local treatment company in Dortmund	Flat glass treatment company
EU-wide associations	European association of glass recyclers (FERVER)	European association of glass recyclers
	FEVE (container glass)	Association of European manufacturers of glass packaging containers and machine-made glass tableware
	ESGA	European Special Glass Association
	CEWEP	Confederation of European Waste-to-Energy Plants

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Executive Summary

Glass for Europe has commissioned Deloitte Sustainability to carry out the present study with two objectives:

1. Quantify the available quantities of building glass waste (windows, glazing and other flat glass products) from construction, demolition and building renovation in the EU-28 (Phase I); and

2. Compare the economic costs and benefits as well as the environmental impacts of three recycling scenarios for C&D glass waste (Phase II): recovery into flat glass, recovery into other types of glass (especially hollow glass), or recovery with other C&D waste.

This study is the first of its kind: it is based on a rigorous methodology, a thorough data research, extensive interviews with relevant stakeholders and some assumptions to quantify the annual quantities of building glass waste arising in Europe where before there were only rough estimates.

Instead of a guesstimate, Phase I presents results that depend above all on statistical data. Figure 4 and

Figure *5* illustrate the methods used to calculate – both for residential and tertiary sectors – glass waste originating from building renovation and demolition sites.

It has often been acknowledged that most of the end-of-life building glass originates from the replacement stage (distributors, installers) as well as at the demolition stage, and not during the construction phase of a building.[1] Therefore, the construction phase has not been taken into account in the scope of the study.

Quantification of building glass waste

The Phase I results show that the **total glass waste arising from renovation and demolition of buildings in the EU-28 in 2013** approached about **1.5 Mt**, of which 58% originates from the residential sector and 42% from the tertiary sector. This total glass waste figure is 20% more than the tonnage previously considered by glass manufacturers as being of C&D (construction & demolition) glass waste, i.e. 1.2 Mt[1].

Glass waste from RENOVATION *(83% of total waste arisings)* *(tonnes)*		**Glass waste from DEMOLITION** *(17% of total waste arisings)* *(tonnes)*		**Total building glass waste arisings in the EU-28** *(tonnes)*
1 279 882		**260 822**		**1 540 704**
Residential sector	Tertiary sector	Residential sector	Tertiary sector	
825 676	**454 206**	**64 808**	**196 014**	

In 2003, a study of the European Commission had advanced that glass represents about 0.66% of C&D waste.[2] As the estimates of C&D waste generated in the EU range from 510 to 970 Mt per year,[3] some might go so far as to say that quantities of end-of-life glass originating from this source range

[1] Recycling of end-of-life building glass - Glass for Europe, June 2013.
[2] External environmental effects related to the life cycle of products and services, European Commission, DG Environment, 2003
[3] Thematic Strategy on the Prevention & Recycling of Waste, Commission staff working document, 2011.

from 3.4 to 6.4 Mt per year[4]. Yet, that reasoning is a very big step. Indeed, 40% only of C&D waste comes from buildings, and the rest from Public Works, which is out of scope.

Six case studies on building glass waste collection and treatment

Beyond the fact that this innovative study is the first to quantify building glass waste in the EU-28, it also **identifies the existing initiatives and business models in the field of building glass waste collection and treatment in six European Member States** (Phase I): France, Germany, Italy, the Netherlands, Poland, and the United Kingdom. Six countries where the variety of climate (has an impact on the type of architectural glass used), population density, economic context, size (has an impact on distances travelled), etc., play a role in the type of collection and treatment schemes that are set up locally, regionally or at a national scale. Each of the case studies provide feedbacks from manufacturers, national trade and professional associations, and treatment companies committed to these issues, and potentially involved in the field – on a small or wide scale – to improve flat glass collection, treatment, and cullet incorporation.

The second phase of the study **(Phase II)** evaluates and compares potential scenarios for recovering C&D glass waste within the EU-28 in order to determine the economic and environmental costs and benefits of:

- Recovery within the flat glass industry (closed loop recycling) (option 1);
- Recovery within the glass industry (including other glass sectors than flat glass) (option 2), or
- Recovery with other C&D waste, i.e. business-as-usual scenario with 40% recovery and 60% landfilling (option 3).

Significant environmental benefits of more building glass waste recycling

From an environmental point of view, when considering carbon emissions, avoided waste going to landfill and raw material savings, options 1 and 2 provide significant environmental benefits compared to option 3 (see table below). In particular:

- Regardless of the origin of the building glass waste (renovation versus demolition) and of the recycling route chosen (flat glass making versus other glass sectors), **global benefits in terms of overall CO_2 emissions savings reach in average 260 kg CO_2 eq /t** when recovery with other C&D waste has a net cost of 4 kg CO_2 eq /t.
- **The proper recycling of all building glass waste, i.e. options 1 and 2, compared to the business-as-usual scenario could avoid 925.000 tonnes of landfilled waste every year and could save around 1.23 million tonnes of primary raw materials annually (of which 873.000 tonnes of sand).**

It appears from this study that option 2 (recycling in all glass sectors) provides slightly higher benefits than option 1 (closed loop recycling in flat glass sector only), in terms of overall CO_2 emissions savings (- 5%). This is due to the shorter transport distances, which were assumed for the purpose of the study, because all other benefits are equivalent. This suggests that recycling in the closest nearby glass factory should be preferred to maximize environmental benefits, regardless of the glass subsector. Additionally, within each option, CO_2 emission savings are higher when glass waste originates from light renovations of residential buildings / houses than large renovations or demolition. Furthermore, environmental benefits in terms of avoided waste and raw material savings are higher in the sector of renovation than demolition (because of the difference in current waste quantities arising from both sectors).

[4] According to Eurostat there was around 330 Mt tonnes of C& D waste generated in 2010.

Table 1: Synthesis of environmental benefits of the different options

Benefits	Origin of glass	Option 1	Option 2	Option 3
Avoided waste going to landfills	Glass waste from renovation	~ 1.28 million tonnes		~ 512 000 tonnes
	Glass waste from demolition	~ 261 000 tonnes		~ 104 000 tonnes
	Total avoided glass waste	**~ 1.54 million tonnes**		**~ 616 000 tonnes**
Raw material savings	Glass waste from renovation	~ 1.54 million tonnes		~ 614 000 tonnes
	Glass waste from demolition	~ 313 000 tonnes		~ 125 000 tonnes
	Total raw material savings	**~ 1.85 million tonnes**		**~ 740 000 tonnes**
Balance between CO2 emissions and savings	Glass waste originating from light renovations of residential buildings/ houses	**-255** kg CO_2 eq /t	**-269** kg CO_2 eq /t	**4 kg CO2 eq /t**
	Glass waste originating from large renovation or demolition sites	**-247** kg CO_2 eq /t	**-261** kg CO_2 eq /t	

An economic balance yet to be found

From an economic perspective, **the implementation of building glass waste recycling, be it option 1 or 2, would involve higher costs than option 3 or the business-as-usual scenario.** However, results are given at an EU scale and based on many assumptions because of a lack of available data and confidentiality issues, so they should be considered with care.

These findings points to the fact that **the economic balance of building glass recycling in glass making is not attained under current conditions**. From a purely economic modelling thinking, the cost gap could be reduced, through:

- the sale of cullet (glass makers from all sectors are likely to be willing to use more glass cullet in their manufacturing processes and already pay a certain price to access good quality cullet);
- the optimisation of transport costs (especially through reverse logistics);
- adapting landfilling prices
- scaling-up flat glass collection and sorting facilities and practices to bring down costs

- finding another source of revenue, e.g. through an Extended Producer Responsibility (EPR) system.

It was not within the scope of this work to evaluate the impacts of all above options, be it in economic or in practical terms. These options may not all necessarily prove cost-efficient or practically implementable once fully researched. This could be the topic of a separate piece of work.

Figure 1: Overview of total costs for each option and relevant sectors

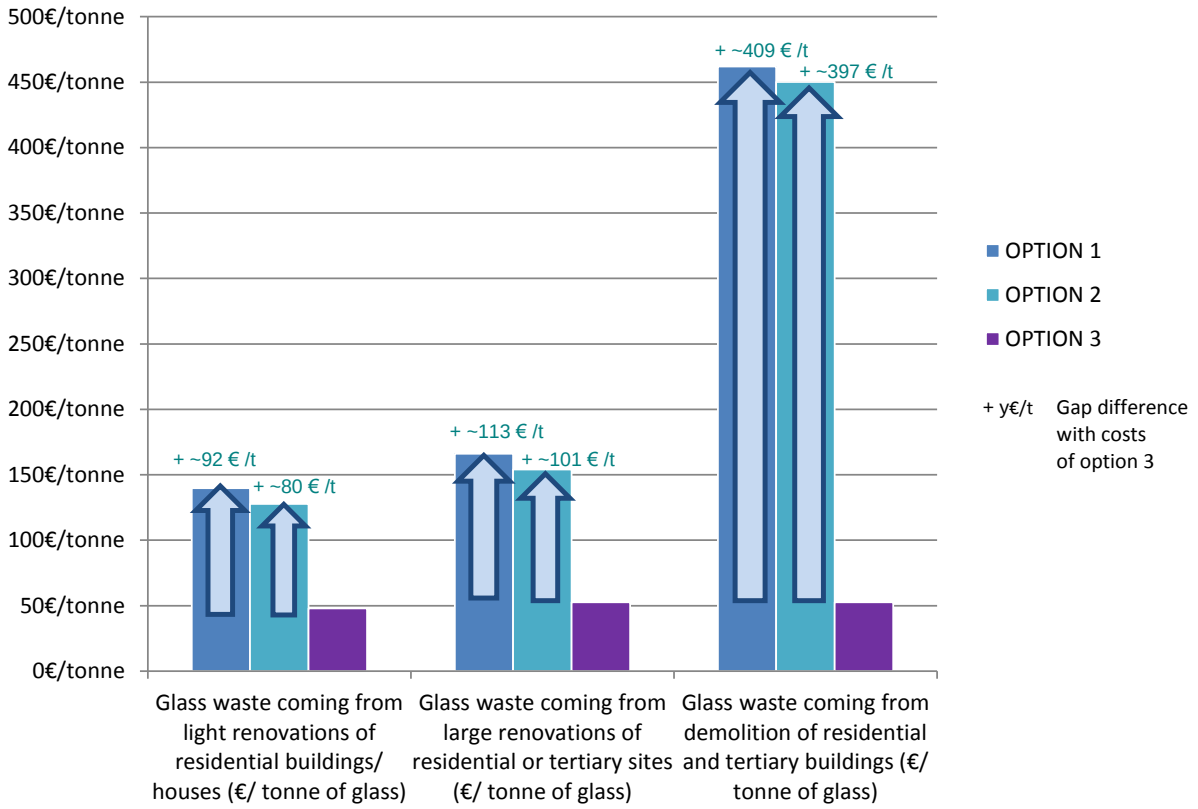


Figure 2: Overview of the distribution of costs per option and sector[5]

A stronger case for glass originating from building renovation

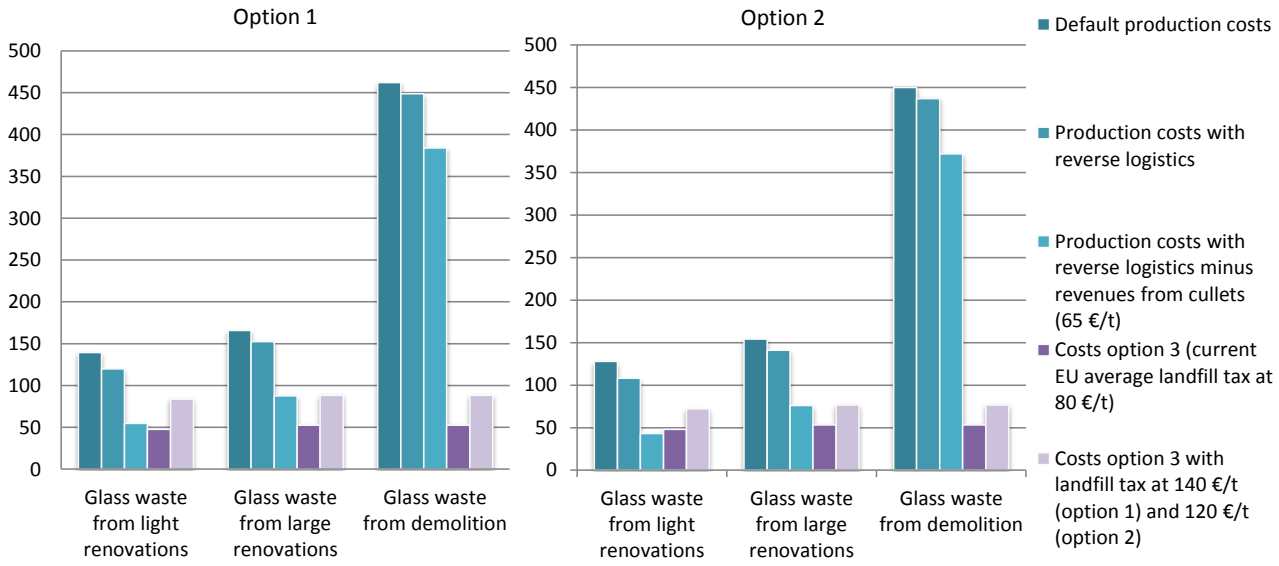
In the case of light and large renovations, the recycling routes could become competitive with some adaptations. The cost gap is much lower in the case of renovation (+/- 100 €/t) than for demolition (+/-400 €/t) and a big part of this gap could be covered by cullet sales. Further cost reductions could be achieved in the case of light and large renovations through the combination of optimisation of transport through reverse logistics and increase of landfill taxes (stand-alone actions would remain insufficient and/or unrealistic), as shown in the figure below. There, default production

[5] In the case of renovations, the cost of dismantling windows is not included in the cost of 'producing cullet' because window installers / carpenters dismantle windows in any case, would there be a specific collection and recycling system or not.
In the case of demolition, dismantling costs are included because dismantling induces a higher manpower cost in case it has been planned to collect separately old windows in view of recycling.
The overall costs of option 3 for light renovations only include the costs of landfilling (80€ /tonne of glass in average in the EU-28), as transport costs are born by window installers / carpenters.

costs are represented along with savings allowed by the implementation of reverse logistics, its combination with the revenues of cullet (EU average of 65 €/ tonne, and/or the implementation of higher landfill taxes (e.g. 120 to 140 €/ tonne instead of EU average of 80 €/ tonne)..

In the case of glass waste arising from the demolition sector, however, dismantling costs create a very marked difference with option 3, which cannot be bridged trough aforementioned actions. A solution to address these costs would be for instance to attribute the cost of dismantling windows not only to the glass recycling sector but also to selective demolition of buildings as well as in other industries involved in recycling other materials used for windows (e.g. PVC and aluminium frames). A further solution would be to introduce selective demolition requirements towards the owners of the demolition site.

Figure 3: Production costs for options 1 and 2 and difference with option 3 if applying reverse logistics and/or additional revenues from cullet



Local infrastructures are key to building glass recycling

The study shows quite clearly how both the environmental benefits and the economic balance are heavily affected by **transport distances**. Alongside transport, **the quality of the infrastructure to collect and sort waste glass adequately** is paramount to minimize treatment needs and thus achieve the necessary economic balance.

Regarding infrastructures, the study of the six pilot countries bring to light the variety in building renovation or demolition practices, the different involvement of professionals as well as the diversity in the collection and treatment schemes linked to the proximity (or not) of glass treatment plants and glass makers ready to use cullet.

These findings suggest that **initiatives on building glass waste recycling may be better developped at local / regional level** compared to any EU-wide system. Nevertheless, when setting the general regulatory framework on recycling objectives, landfilling and waste management, EU authorities could create the momentum and conditions for an economic case to be found, allowing local / regional initiatives to flourish.

Figure 4: method of calculation used for quantifying building glass waste originating from building renovations

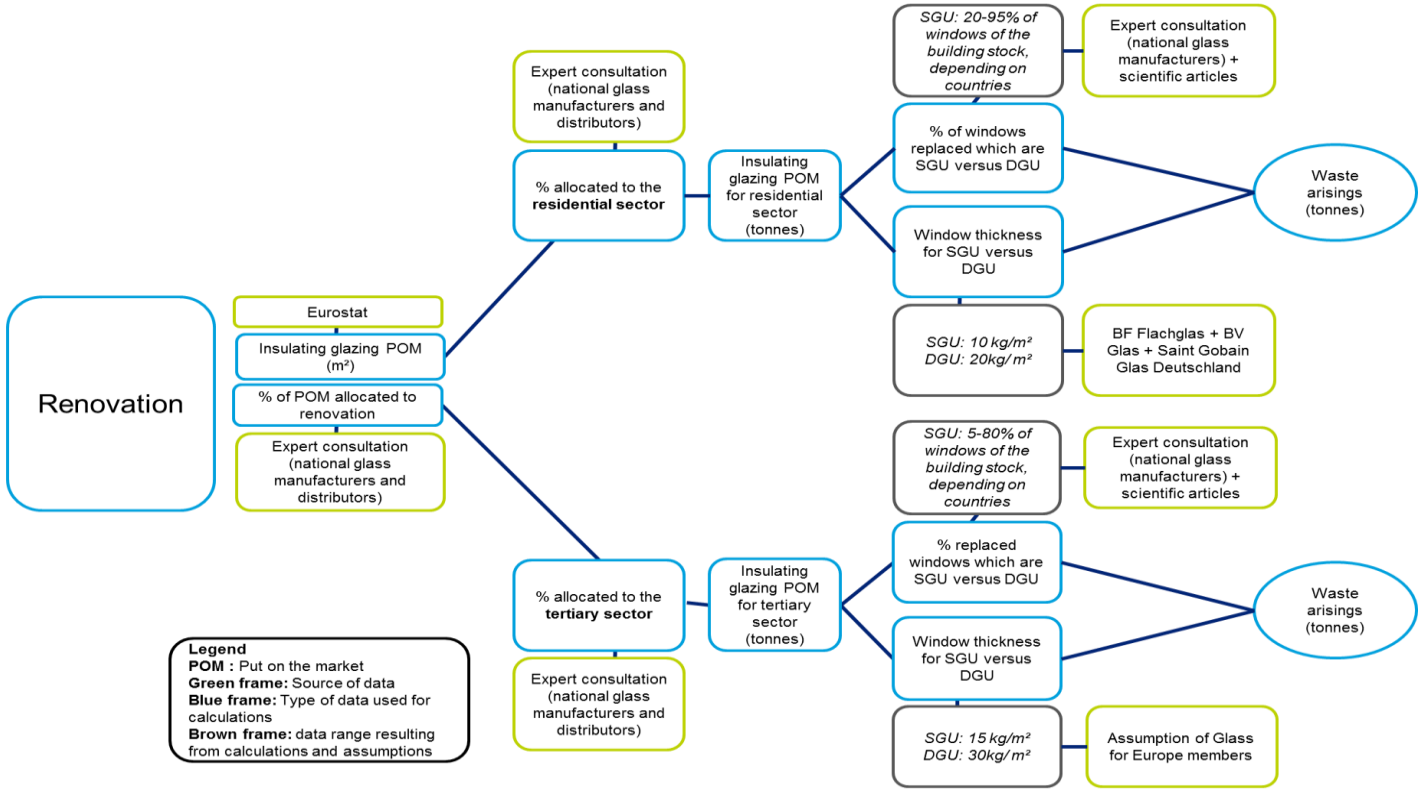
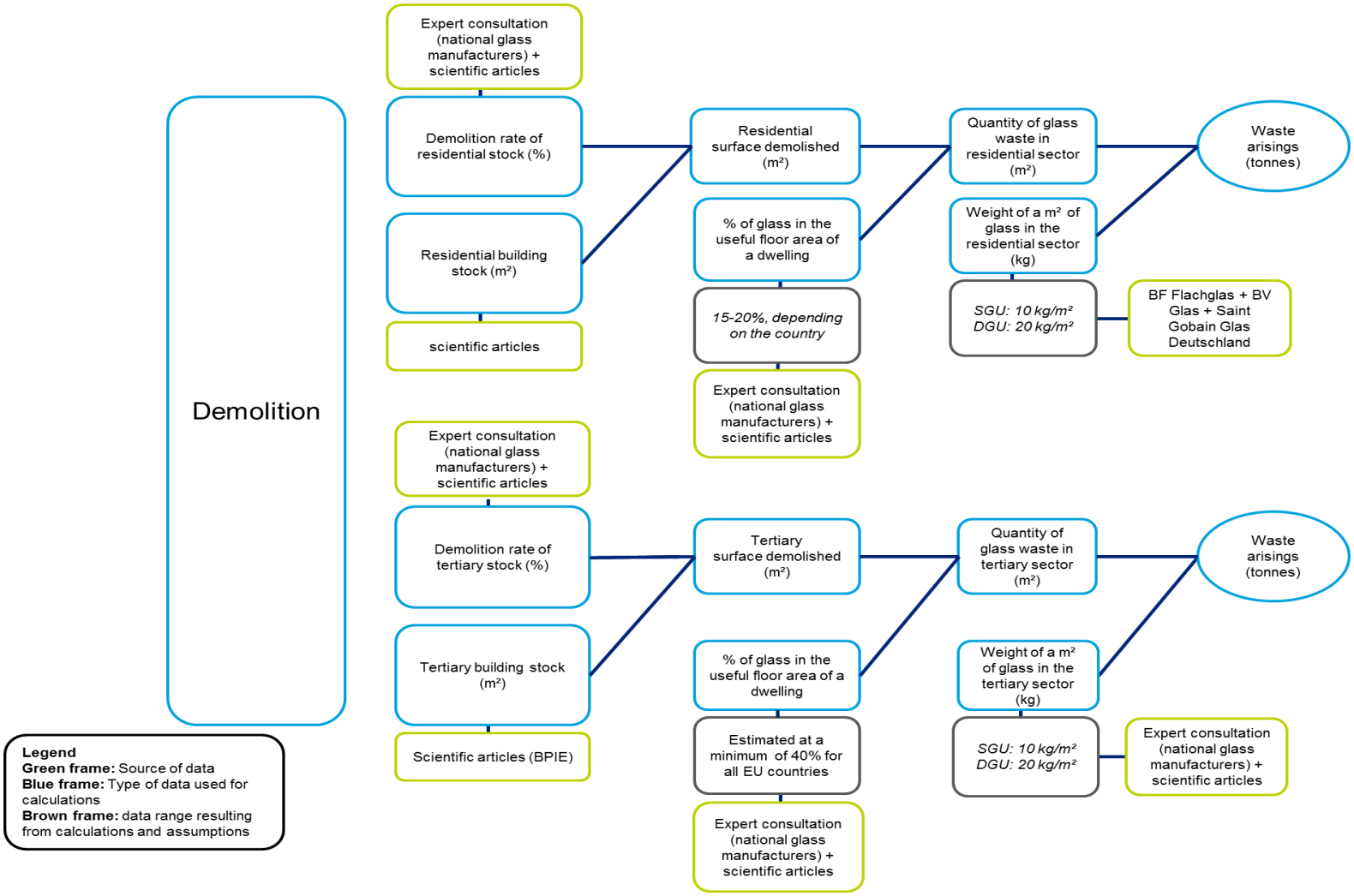


Figure 5: method of calculation used for quantifying building glass waste originating from building demolitions



Introduction & background

Objective of the study

The goal of this study is twofold:

1. Quantify the available quantities of building glass waste (windows, glazing and other flat glass products) from construction, demolition and building renovation in Europe, through the lens of six European Member State benchmark case studies.
2. Compare the economic costs and benefits as well as the environmental impacts of three recycling scenarios for C&D glass waste (**Phase II**): recovery into flat glass, recovery into other types of glass (especially hollow glass), or recovery with other C&D waste

Chapter 1 consists of six case studies conducted in EU member states that cover diverse economic realities, in particular in terms of construction activities, flat glass waste generation, and geography (size, climate, etc.). The selected countries are France, Germany, Italy, the Netherlands, Poland, and the United Kingdom. Each case study consists in an overview of the flat glass waste generated by the demolition and renovation of buildings, and identifies the existing collection and treatment schemes – or the lack thereof – in regards to the end-of-life building glass generated in each of these countries.

Chapter 2 provides an estimation of the building glass waste quantity generated at the EU-28 scale.

Chapter 3 evaluates and compares potential scenarios for recovering C&D glass waste within the EU-28, in order to determine the economic and environmental costs and benefits of each recycling route for C&D glass waste.

Note: Data unavailability and confidentiality proved to be a challenge to conduct the present study. All figures relating to quantities of building glass waste originating from demolition and renovation are to be considered with precaution, as they are estimations based on various hypotheses made along the study. The sensitivity of the results is assessed throughout the report.

Background elements on building glass

In the construction sector, flat glass (also called sheet glass, glass pane, or plate glass) is a type of glass commonly used for windows, glass doors, transparent walls, roof lights and mirrors. Flat glass contrasts with hollow glass (also known as container or packaging glass) and fiberglass (also known as glass wool, used for thermal insulation and optical communication).The construction sector mainly uses flat glass made by the float process. About 3% of rolled plate glass is also used. Float glass can be processed in many ways, either laminated, coated, silvered, toughened, etc. Rolled plate may have wire pieces within it.

In the late 1940s, the concept of double-glazing[6] to enhance thermal insulation began to develop, but its real growth in Western Europe came about in the wake of the energy crisis in the 1970s. In Western and Northern Europe, the actual penetration of double paned glass overall is about 80%.[7]

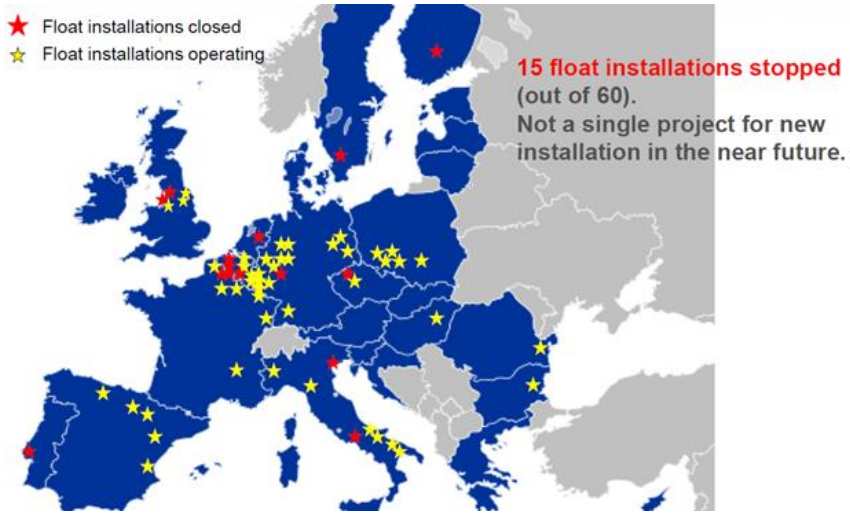
Regarding building glass frames and sashes, they may consist of wood, aluminium, PVC, or steel. The late 1980's and early 90's was characterised with a rise of PVC frames. Today, a growing number of composite window frames (consisting of a combination of aluminium/timber, aluminium/PVC, etc.) are sold on the European market.

Economics of the flat glass sector in Europe

In 2008, flat glass accounted for roughly a third of total EU glass production while the flat glass sector reached a production capacity of about 12 Mt of float glass. At that time, building products accounted for 80% to 85% of the flat glass market, i.e. the production of flat glass for construction could go up to 10 Mt. Demand for flat glass construction products has increased with the architectural and engineering trend towards greater use of glass in building facades. However, it is particularly sensitive to economic cycles because of its high dependency on the building and automotive industries.

In December 2013, out of the 60 float lines located across 16 countries in the EU, 15 have closed, thus 45 float lines were in operation in the EU (Figure 6). To FERVER's belief, in the coming years, it is probable that more float lines will continue to close in Western Europe and instead move their way over to Eastern Europe[8].

Figure 6: Float glass manufacturing in the EU in December 2013 (source: Glass for Europe)



[6] Glazing which is factory-sealed and made up of sheets of glass (double-glazing, triple-glazing) separated by a space filled with dehydrated air and/or gas using a spacer.
[7] "All about Glass - Home." AGC News. N.p., n.d. Web. 12 Aug. 2014. www.yourglass.com.
[8] "FEVER Member Companies Conference Call: Flat Glass Treatment and Recycling." Telephone interview. 26 Feb. 2015.

Today, close to three quarters of the EU flat glass production originates from Germany, France, Italy, Belgium, the UK, and Spain. In Central and Eastern Europe, production is concentrated in Poland and, to a slightly lesser extent, the Czech Republic. [9] The table below gives information on the localisation of sites of Glass for Europe members in the EU.

Table 2: Operating float plants from Glass for Europe members in 2014

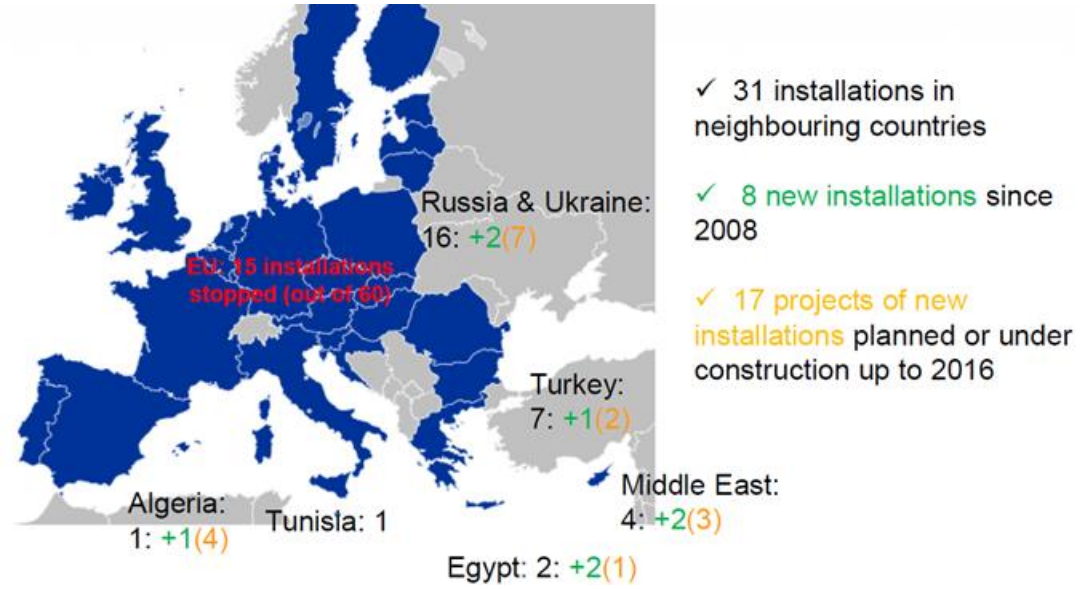
Country	Region	Company	Site(s)
BELGIUM	Flanders	AGC	Mol
	Wallonia	AGC	Moustier *(LLN eventually)*
BULGARIA	*Entire country*	Sisecam	Targovishte *(east Bulgaria)*
CZECK REP	*Entire country*	AGC	Retenice *(north-west)*
GERMANY	North Rhine Westphalia	SGG	Porz, Stolberg, Torgau, Herzogenrath
		NSG	Gladbek,
	Bavaria	NSG	Weiherhammer
	Sachsen-Anhalt	Guardian	Talheim
		AGC	Osterweddingen
SPAIN	*Entire country*	Guardian	Llodia *(Basque country)* & Tuleda *(Navarra)*
		AGC	Sagunto *(Valencia)*
		SGG	Aviles *(Asturias)* & Arbos *(Catalunya)*
FRANCE	North-West	SGG	Chantereine *(Picardie)*
		AGC	Boussois *(region Nord)*
	East	AGC	Seingbouse *(Lorraine)*
	South East	SGG	Salaise *(Rhone-Alpes)*
UK	North West	NSG	St Helens
	Yorkshire & Humber	SGG	Eggborough
		Guardian	Goole
HUNGARY	*Entire country*	Guardian	Oroshajza *(Békés county)*
ITALIA	North	AGC	Cuneo *(Piemonte)*
	Central	SGG	Pisa *(Tuscany)*
	South	NSG	San Salvo *(Abruzzo)*
LUXEMBOURG	*Entire country*	Guardian	Bascharage, Dudelange
POLAND	*Entire country*	NSG	Sandomierz *(south)*
		SGG	Dabrowa Gornicza *(Silesia)*

[9] "Main Glass Sectors." - Glass Alliance Europe. N.p., n.d. Web. 9 July 2014. www.glassallianceeurope.eu/en/main-glass-sectors

Country	Region	Company	Site(s)
		Guardian	Częstochowa *(Silesia)*
ROMANIA	*Entire country*	SGG	Calarasi *(Wallachia)*

As Figure 7 shows below, there are currently 39 float glass installations outside the EU, in neighbouring countries. While float lines closed in the EU, 17 new installation projects are planned or are under construction up to 2016 in neighbouring countries.

Figure 7: Float glass manufacturing outside the EU in December 2013 (source: Glass for Europe)



Sources of post-consumer building glass waste

There is very little glass waste generated during the construction phase of a building, and most of end-of-life building glass originates from the replacement stage (distributors, installers) as well as at the demolition stage. [10] This is the reason why this paper mainly addresses glass waste in demolition and renovation projects, i.e. 'post-consumer' waste.

Throughout this study, two main sources of post-consumer building glass waste have been distinguished: 1) glass waste from residential renovation (continuous flows) and demolition (occasional flows), and 2) glass waste from commercial renovation and demolition (occasional flows), i.e. from tertiary/non-domestic buildings. The broad range of buildings and glass types (especially in offices and

[10] An expert from *L'Institut du Verre* estimates that only 4% of C&D glass waste is arising during the construction phase of a building.

commercial centres) and the fact that glass is usually part of a framed window and not a 'stand-alone' product makes collection schemes complex.

Current trends indicate that post-consumer building glass waste tonnages increase due to replacements of old windows and glass walls by double or triple-glazing for energy-efficiency reasons (and, to a lesser extent, for aesthetic reasons).

Outlets for post-consumer building glass cullet

Flat glass cullet (treated glass) can be used within the production process of various industries:

- The glass wool industry: The proportion of treated glass can reach 80%;
- The packaging industry: The proportion of treated glass can reach near 90%;
- The flat glass industry: The proportion of treated glass is lower than other glass product types due to the need for high quality cullet and the absence of available cullet that is of good enough quality to integrate within the production process. Typical percentages of cullet in the flat glass composition are between 25-50% but this percentage could be increased in case of availability of high quality cullet ;
- The glass bead industry (micro-balls of glass are embedded in the paint, which makes it retro-reflective, like in road paints): The proportion of treated glass can be relatively high;
- Cullet can also be recovered for public works as aggregates for a road base course or as backfill for trenches and earthworks. In this case, quality requirements for this sector are less strict, as quality does not need to be as high as in the aforementioned industries mentioned.

The advantages of adding cullet to glass furnaces are well proven. In a furnace, using 1 tonne of cullet saves 1.2 tonnes of raw materials, including 850kg of sand. In general terms, each 10% increase in cullet usage results in an energy saving of 2-3% in the melting process and each tonne of cullet used saves 0.3 tonnes of CO_2 emitted.[11] Yet, one must be aware that the environmental impact of treating building cullet *highly* depends on transport distances travelled for cullet.

In spite of its recyclability, "post-consumer" glass waste (i.e. waste arising in renovation or demolition projects) is almost never recycled into new glass products. In the case of demolition projects for instance, it is very often crushed together with other building materials, and recovered together with other C&D waste or sent to landfills. Flat glass waste currently has a low market value because there is a lack of properly organised collection and treatment systems to make what would be a valuable glass-making raw material.

The consultation of the European Federation of Glass Recyclers provided interesting insights on the issue of outlets for building glass cullet. They are summarised in the box below and further detailed in the annexes.

[11] "Highlights." Glass for Europe. N.p., n.d. Web. <http://www.glassforeurope.com/en/>.

Insight from FERVER consultation

- The practical issue of glass waste quality can impede all recycling efforts as well as reuse as aggregate, as glass with a high level of contamination would not be accepted by treatment centres.
- Treatment companies have little-to-no traceability of the origin of flat glass waste (i.e. demolition, renovation, tertiary, residential sectors) for often times, flat glass waste is collectively stored at a waste management site, and may be mixed in with waste from other projects. This has several implications, including on the possibility to optimise the costs of transport and to ensure the appropriate collection of glass waste.
- Better communication throughout the chain, between treatment centres, sites/project managers and glass manufacturers could help increase the volumes of glass recycled, by limiting the risks of rejects and optimise recyclability.

Key terms

Table 3: Key Terms

Term	Definition
Waste arisings	Quantity of waste generated over a year. In the present study, "waste arisings" is the quantity of post-consumer building glass waste originating from demolitions and renovations, over a year.
Contaminants	Most common contaminants of post-consumer cullet are: ceramics, cork, rocks, cutting blades, spacer bars from sealed units, wood, aluminium or PVC in the case of windows having frames when they are collected, etc.
Dwellings	Dwellings are buildings used entirely or primarily as residences, including any associated structures, such as garages, and all permanent fixtures customarily installed in residences; movable structures, such as caravans, used as principal residences of households are included. [12]
Flat glass	The flat glass products can be roughly categorised into two types: float glass and rolled glass. Float glass is used for huge number of applications including glazing for building. Rolled glass is used primarily in the manufacture of glass doors, partitions, shower enclosures, appliances, and photovoltaic panels. Rolled glass installations have much smaller furnaces than float glass.
Float glass	Float glass is a sheet of glass made by floating molten glass on a bed of molten tin; This method gives the sheet uniform thickness and very flat surfaces.
Floor area /space	"The floor area of buildings is the sum of the area of each floor of the building measured to the outer surface of the outer walls including the area of lobbies, cellars, elevator shafts and in multi-dwelling buildings all the common spaces. Areas such as balconies and car parks are excluded". [13] "In dwelling statistics, the useful floor area is the floor area/space of dwellings measured inside the outer walls, excluding cellars, non-habitable attics and, in multi-dwelling houses, common areas."[13] *Note: Countries often have different approaches to the measurement of floor area that can include external gross, internal gross, net, heated and treated parts of a building. The same term may not have the same meaning or definition in different countries. Moreover, assuming that two countries adopt the same definition, the different approaches for taking measurements (e.g. measuring the attic space) imply that comparing the resulting floor areas is difficult. In the absence of a common definition and measurement method, the above definition has been used.*

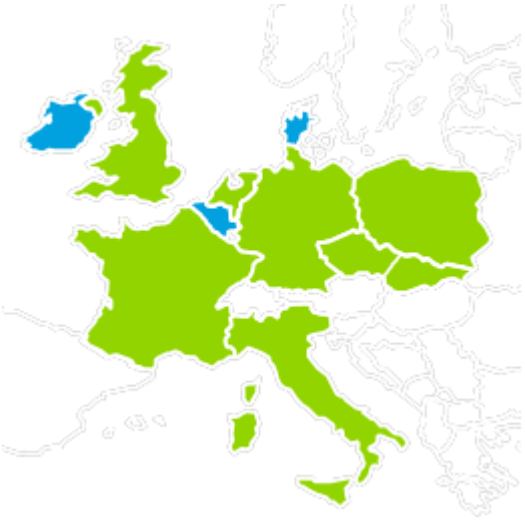
[12] "Eurostat Home." Eurostat Home. N.p., n.d. Web. 2014. <http://epp.eurostat.ec.europa.eu/portal/page/portal/eurostat/home/>.

[13] OECD, Glossary of statistical terms. These definitions originally come from the Bulletin of Housing and Building Statistics for Europe and North America (UNECE, Geneva, 2000, Annex II, *Definitions and General Terms*, p.83).

Term	Definition
Insulated glass/ glazing	Flat glass consisting of usually two or three sheets of glass separated by a spacer on the edges and sealed to create a gas filled space between the two panes - double/ triple-glazing units (DGU / TGU) -, which is part of energy conservation sustainable architecture design for low energy buildings. This type of glass is common in residential and tertiary buildings for its thermal insulation properties and noise reduction. Insulated Glass Units (IGU) are manufactured with glass in range of thickness from 3mm to 10mm
Laminated glass	Flat glass that is toughened by bonding two or more sheets of glass together with layers of polyvinyl butyral (PVB) to create a single sheet of glass. Laminated glass can be most commonly found in automobiles as a safety measure, for the PVB aids in preventing glass from breaking apart upon shock, creating a “spider web” cracking effect
Patterned glass	Flat glass manufactured with a pattern or design directly imprinted into the glass.
External cullet	Waste glass that is collected and/ or reprocessed with the purpose of recycling. External cullet can be of two types, pre-consumer, also called post-industrial glass cullet, and post-consumer glass cullet.
Pre-consumer cullet	Waste glass resulting from the manufacturing of products that contain glass as one of their components, and which leaves the specific facility where it was generated but not reaching the consumer market. An example is glass cullet constituted by off cuts of the production of windows. Pre-consumer cullet if sorted properly fulfils the cullet specifications of the flat glass manufacturers and can be directly sent back to the furnace without additional treatment
Post-consumer cullet	It is waste glass originated after the use of the glass products on the consumer market.
Recycling	Any recovery operation by which waste materials are reprocessed into products, materials or substances whether for the original or other purposes. It includes the reprocessing of organic material but does not include energy recovery and the reprocessing into materials that are to be used as fuels or for backfilling operations. [14]
Tertiary buildings	Mainly offices, Educational buildings, Hospitals, Hotels & Restaurants, Sport facilities, Wholesale and retail trade. [15]

[14] "Directive 2008/98/CE of the European Parliament and Council." EUR-Lex. N.p., 19 Nov. 2008. Web. <http%3A%2F%2Feur-lex.europa.eu%2Flegal-content%2FFR%2FALL%2F%3Furi%3DCELEX%3A32008L0098>.
[15] "BPIE - Buildings Performance Institute Europe." BPIE - Buildings Performance Institute Europe. N.p., n.d. Web. <http://www.bpie.eu/>.

Chapter 1: Case studies (Phase I.1)



It is impossible to quantify building glass waste at the EU scale without making hypotheses at the national level, just as it is not possible to analyse the opportunities and barriers of collecting and recycling flat glass waste in Europe without starting to look at what is functioning or not at the local and regional scale. Yet, it would have been extremely time-consuming to interview country experts for from all 28-EU member states, so six European countries covering diverse economic and geographic realities were studied in-depth. The selected countries are France, Germany, Italy, the Netherlands, Poland, and the United Kingdom. Their geographic conditions might for instance differ by climate (which has an impact on the number of panes in a window and thus on the quantity of glass in buildings) and by size (which has an impact on the transport cost of glass). Additionally, their economic context might differ in terms of GDP per capita (e.g. less new constructions and renovation activities in the residential sector when people have a low purchasing power), population density, proportion of building surface occupied by businesses (offices and retail) compared to dwellings (less glass in dwellings than in offices and retail), etc.

As seen in the introduction, each case study initially gives an overview of the flat glass waste generated by the demolition and renovation of buildings, and identifies the existing collection and recycling schemes – or the lack thereof – as regards the of end-of-life building glass. The type of data present – or at least used for estimations present in the case studies – is the following:

- Consumption of flat glass in the construction sector;
- Waste generated from building renovations and demolitions, for residential and non-residential buildings;
- The quantity of building glass transformed into cullet (when available);
- Socio-economic data,: Size of territories, density of population, number of flat glass producers and treatment facilities, average distances between treatment centres and manufacturers, transport infrastructures, etc.;
- When feasible, a cost-benefit analysis of existing building glass collection and treatment systems in the country were considered, i.e. extra cost of dismantling, regarding existing obligations; collection cost (rent of skips + transport cost), cost of segregating the glass from the window frame (and at which stage), cost of the cullet preparation, etc.

Basic assumptions for case studies

Tonnage of building glass put on the residential and tertiary markets

Eurostat data on insulating glass consumption by European countries in 2013 is available in square meters but not in tonnes. To convert square meters in tonnes of glass, and to quantify insulating glass consumption in the residential and in the tertiary sectors, the following assumptions were made:

- Weight of glass = 2,51 g/cm³;[16]
- The thickness of a square meter of glass is generally thicker in the non-residential sector, as shown in the two tables below.

Residential insulating glazing	1m² of glass at 4mm thickness
SGU (simple glass unit)	10 kg/m²
DGU (double glass unit)	20 kg/m²
TGU (triple glass unit)	30 kg/m²

Non-Residential insulating glazing	1m² of glass at 6mm thickness
SGU	15 kg/m²
DGU	30 kg/m²
TGU	45 kg/m²

Building glass used for renovation purposes

According to Lapeyre, in France, 73% of the insulating glass put on the market is sold for renovation purposes. Experts interviewed throughout the study estimate that this figure approaches 60% in Germany[16], the Netherlands[17], and the United Kingdom[18], 55% in Italy[19], and 65% in Poland[20]. Deloitte has therefore assumed that **in the EU-28**, **60% of the insulating glass put on the market is, on average, sold for renovation purposes.**

Furthermore, in Europe's Buildings under the Microscope (BPIE, 2011), residential buildings in Northern and Western European countries[21] represent on average 72% of the total building floor space[22]. In the same study, residential buildings in Central and East Europe[23] represent on average

[16] Data obtained from BF Flachglas, BV Glas and Saint Gobain Glas Deutschland.
[17] Data obtained from Economisch Instituut voor de Bouw (EIB).
[18] Data obtained from British Glass Manufacturers' Confederation.
[19] Data obtained from Saint Gobain Italy.
[20] Data obtained from Saint Gobain Glass, Poland.
[21] AT, BE, CH, DE, DK, FI, FR, IE, LU, NL, NO, SE, and the UK.
[22] The "floor space" in BPIE's report is the "total area of all the floors of a building, including intermediately floored tiers, mezzanine, basements, etc., as measured from the exterior surfaces of the outside walls of the building" (BPIE). This

76% of the total building floor space. In addition, in South Europe[24] they represent on average 82% of the total building floor space.

The percentage of the total **renovation glass allocated to the residential sector was thus considered to be near 72% in Northern and Western European** (except in France where it is 66%[25]), **76% in Central and East Europe, and 82% in South Europe**.

Percentage of glass in the floor area of a dwelling

According to a recent French scientific study conducted for professional associations in the field of flat glass and window manufacturing[26], glass should represent, legally (i.e. as required in the French *Thermal Regulation*[27]), at least the equivalent of 1/6th (~17%) of the "useful floor area"[28] of a dwelling in France. Furthermore, according to an interview with the UK National Federation of Demolition Contractors, glass represents about 30% of the "useful floor area" of a dwelling in the UK. German, Polish, Dutch, and Italian glass manufacturers were not able to estimate precisely such data regarding their countries, yet they assumed that in Northern and Western Europe, glass should represent, on average, about 20% of the useful floor area of a dwelling, while in the rest of the EU, this figure should rather be 15% because of historical construction habits.

It was therefore assumed that on average, glass (all types of flat glass mixed up, from mirrors to glass roofs) represents the equivalent of 15% to 20% of residential buildings' floor area.

Percentage of glass in the floor area of a tertiary building

Non-residential buildings account for 25% of the total building floor space in Europe and comprise a more complex and heterogeneous sector compared to the residential sector.[29] The retail and wholesale buildings comprise the largest portion of the non-residential building stock while office buildings are the second biggest category. Variations in usage pattern (e.g. warehouse versus schools), energy intensity (e.g. surgery rooms in hospitals versus to storage rooms in retail), and construction techniques (e.g. supermarket versus office buildings) are some of the factors adding to the complexity of the sector. It is therefore extremely complicated to estimate the average percentage that windows and glass walls represent of the square meter floor space in a non-residential building. It has yet been assumed that there is at least twice more glass in a given floor space of a tertiary building than in the same area of a domestic building, i.e. 40%.

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corresponds to the OECD definition given for "floor area". As regards residential buildings, BPIE floor area data corresponds to the "useful floor area" of dwellings.

[23] BG, CZ, EE, HU, LT, LV, PL, RO, SI, and SK.

[24] CY, GR, ES, IT, MT, and PT.

[25] Data obtained from French glass manufacturers.

[26] Etude de l'impact de la surface des parois vitrées sur le besoin en énergie des bâtiments résidentiels, study conducted by 'Carbonnel Ingénierie', 2010.
< http://www.lemoniteur.fr/media/FICHIER/2010/03/18/FICHIER_2010_03_18_2479420.pdf>

[27] < http://www.gasinfocus.com/en/focus/french-thermal-regulation-rt-2012/>

[28] See OECD definition in the glossary.

[29] "BPIE - Buildings Performance Institute Europe." BPIE - Buildings Performance Institute Europe. N.p., n.d. Web. <http://www.bpie.eu/>.

France

1 The French building glass market

Over 11 Million insulating windows were sold in France in 2012[30] – which makes approximatively 7 million m² of insulating glass[31]; 73% of it was sold for renovation purposes[32].

Furthermore, 80% of building glass (insulating glass + interior glass + toughened & laminated safety glass) goes into the residential sector and 20% in other sectors (mostly tertiary).

Table 4: Window frames sold in France

Frame type	% each frame type represents in old windows actually being replaced	% each frame type represents in new windows put on the market
PVC	~27%	62%
Wood	~65%	13%
Metal (mostly aluminium)	~8%	23%
Other (composite)	**n.a.**	**3%**

2 Building glass waste arisings

Glass waste arising from renovation

Out of the 11 million windows sold in France in 2012, about 8 million were sold for renovation purposes (72% i.e. 5.8 million for residential buildings[33]) in France and the rest for new constructions. Furthermore, out of the 8 Million replaced windows, 80% were single-paned[34] and the remaining 20% double paned (replaced by double- and triple-glazed windows only).

Considering assumptions at the beginning of chapter one, it means that:

- Over 77,000 tonnes/year of glass waste is generated by the replacement of old windows (and doors) in residential buildings, and
- Over 59,000 tonnes/year of glass waste is generated by the replacement of old windows (and doors) in tertiary buildings.

[30] "L'Espace Datapresse - L'UFME Présente L'étude Du Marché 2012 De La Fenêtre En France." L'Espace Datapresse - L'UFME Présente L'étude Du Marché 2012 De La Fenêtre En France. N.p., n.d. Web. 2014. <http://www.espacedatapresse.com/fil_datapresse/consultation_cp.jsp?idcp=2771902>.
[31] One window measures about 1,2m².
[32] Data obtained from Lapeyre.
[33] See basic assumptions at the beginning of chapter one.
[34] Saint Gobain Glass estimation.

In France today, 60-70% of windows that are taken down have wooden frames. This ratio is evolving as more and more frames are made out of PVC.

The glass waste generated by the renovation of interior glass and glass walls in dwellings could not be estimated, but most glass in buildings comes from windows, and interior glass is more rarely renovated.

Glass waste arising from demolition

About 0.1% of the installed base of residential buildings is demolished in France each year, i.e. about 30,000 dwellings[35] (2.7 Million m²). If we assume that windows and glass walls represent on average about 20% of the square meter floor space in a French dwelling,[36] and that in demolished dwellings, 80% of windows and glass walls are currently single-glazed and 20% double-glazed, then near 7,000 tonnes of glass waste is generated through the demolition of residential buildings.

According to CEREN's (Centre of Studies and Economic Research on Energy) statistical data, 922 Million m² have been demolished in the tertiary sector in 2012 (0.46% of tertiary buildings). Considering assumptions at the beginning of chapter one, there should be over 30,000 tonnes of glass waste generated through the demolition of tertiary buildings. This estimation is to be considered with precaution.

Table 5: Country estimations of flat glass waste arising from building demolition and renovation (2013)

Sector	Tonnage generated	Sub-sector	Tonnage generated
Residential	83,981 tonnes	Renovation	77,403 tonnes
		Demolition	6,578 tonnes
Tertiary	90,172 tonnes	Renovation	59,811 tonnes
		Demolition	30,361 tonnes
Total		**174,153 tonnes**	

Table 6: PROJECTIONS for 2025: country estimations for flat glass waste arising from building demolition and renovation[37]

Residential	100,777	Renovation	100,777
		Demolition	6,578 tonnes
Tertiary	108,206 tonnes	Renovation	108,206 tonnes
		Demolition	30,361 tonnes
Total		208,983 tonnes	

[35] INSEE, 2006
[36] Data obtained from Lapeyre.
[37] Deloitte Estimations.

3 Collection and recycling of building glass

Institutional and regulatory context

New thermal regulations came into effect in 2001, leading to the installation of double-glazing becoming common practice.[38] France has therefore seriously started to replace simple glazing by double gazing less than 15 years ago, contrary to Germany whose thermal regulation has existed for over 30 years.

Collection and recycling of building glass

Although France does not have a national-scale collection scheme like in the Netherlands, the country counts two unique initiatives of post-consumer building glass recycling systems.

REVALO project: the recovery and recycling of tertiary buildings' glass

Figure 8: Treatment process of tertiary building glass

Window dismantling

Stacking windows in a skip

Cullet after recycling

REVALO (Reduction and valorisation of building waste), powered by the partnership between AGC Glass Europe, GTM Bâtiment (subsidiary of VINCI Construction France), Veka Recycling (plastic treatment company), Veolia Propreté, and ISel (engineering school of *Le Havre University*), collects and treats waste flat glass and PVC joinery from the tertiary sector. Set in place by GTM Bâtiment in 2011, this pilot project is financed in large part by its stakeholders and by the French Environment Agency (ADEME).

In practice, REVALO collects old windows (only with PVC frames) from construction and renovation sites of medium-sized tertiary buildings. The recycling route of windows is the following:

1. Windows and/or glazing are dismantled from buildings before replacement (renovation).
2. Windows and/or glazing are collected separately from other buildings products.

Skips/containers are usually open, and are either 2 m^3 or 15 m^3 (holds 10-15 tonnes of glass/frames). AGC pays for the rent of the skips. It is difficult to make general estimates about the total cost per year of container fees because container collection frequencies are reliant on the nature of the project site.

3. Glass is segregated from other window components (plastic, wood, aluminium, etc.) – for this step, there are three possible scenarios; two of them are used in practice, the third is judged too dangerous. Within these scenarios, there are three aspects to take into account: glass quality (if gravel contaminants are smaller than 8 millimetres, it is nearly impossible to sort them out of the collected broken glass before melting the glass waste; and 40 millimetres is the ideal glass size to be recovered), profitability, and safety (of workers). The possible scenarios are below.

[38] Wilberforce, Rick. Building Regulations for Windows in European Countries(2003): n. pag. 28 May 2003. Web. 2014.

Scenario 1: Window glass is manually separated from the frame on the renovation site (with specific tools)	
Positive aspects ensured	High glass quality, safety
Negative aspects encountered	High cost to administer, not profitable
Cost: a window frame is separated from the glass unit in 5 minutes, which means 12 windows are handled in an hour (cost is 50€/hour). Handling a tonne of windows takes 4 hours and costs 200€ /t of window glass set apart from frames (a 1m² double-paned window weights 20 kg of glass).	EUR 200/tonne of glass and frames
Note: REVALO trains and employs people on subsidized employment contracts to do the job, which slightly helps out the ratio of labour costs vs profitability, but to a small degree.	

Scenario 2: Window glass is manually broken apart from the frame at a treatment site.	
Positive aspects ensured	Safety, profitability
Negative aspects encountered Contamination occurs at project sites before delivery. Entire windows and their frames are transported to REVALO who then crushes (without grinding) the mixed material in order to quickly separate the different materials.	Low glass quality, high landfill rate
Cost	Cost estimates unavailable
Note: Priority is given to sift out PVC from the piles, because of its profitable aspect, followed by glass. Highly contaminated glass is sent to landfill, which results in an extra cost (especially if glass ix mixed with plastic, metals or painted wood). Window sealants are also landfilled.	

Scenario 3: Window glass is manually broken apart from the frame on the renovation site	
Positive aspects ensured	High glass quality, profitability
Negative aspects encountered Workers balance the window on the edge of a skip and break the glass with a hammer; the glass then immediately falls into the skip. Because this process requires workers to manually smash glass into bins, it can put the worker in high risk for injury.	Unsafe
Cost	Cost estimates unavailable
Note: As result of the identified health and safety risks corresponding to this treatment tactic, REVALO does not use this process.	

4. Glass collected is cleaned from impurities to fulfil end-of-waste criteria. Once cleaned, cullet from tertiary building glass is primarily sent to flat glass manufacturers.
5. Depending on its quality, the cullet is recycled in flat glass furnaces (AGC) or in other glass sub-sectors. As for PVC, it is sold to Veka Recycling.

Average distance from renovation site to treatment/sorting site and then to Veka and AGC is not estimable because glass waste comes from all over the country. However, a viable estimate is that the total distance travelled between a renovation site and a producer incorporating the cullet should not be more than 300 km.

Since its beginning, REVALO project has collected and recycled into new flat glass over 20,000 double-paned units from about 40,000 old windows. This means that at least 320 tonnes of post-consumer cullet entered AGC's furnaces, and 672 tonnes of PVC were recycled from the joinery collected.[39]

Saint-Gobain, Lapeyre and Paprec project: the recovery and recycling of residential buildings' glass

The waste management and recycling company Paprec, the flat glass manufacturer Saint-Gobain Glass, and Lapeyre Group (one of France's largest manufacturers/ distributors of joinery, i.e. doors, windows, and cabinetry) joined forces to create the first industrial collection and treatment scheme for old residential windows and other end-of-life joinery. Until now, the project focuses on the residential sector and flat glass from the tertiary sector is not collected. The latter is usually more complicated to sort and treat (because of tinted, laminated, or enamelled glass, which is more complex to treat and recycle, although remaining 100% recyclable, with the exception of metallic laminates[40]).

The partnership works as follows:

- Lapeyre takes joinery deposits in containers located at 10 of its 130 distribution centres (DCs).
- Two facilities of Paprec, one in Saint-Herblain (near Nantes), and one in Pont Sainte-Maxence (Picardy), collect and segregate windows (frames from glass), before sorting components. The sites can treat up to 12,000 tonnes of joinery per year.
- The cullet from windows is sent for recycling to a Saint-Gobain Glass manufacturing facility in South Western France.

Window installers and carpenters bring back old windows at a cost of EUR 3 - 7 per window to Lapeyre collection points, which are situated at Lapeyre store parking lots. On average, these actors bring 5 windows each per trip, which makes a total cost of EUR 15-35 per drop off[41]. The average distance travelled by window installers is about 15 km.

While the fee paid to Lapeyre is more economically sound for window installers/carpenters in the Greater Paris area[42], this would not the case in Western France. For this reason, Lapeyre is in the

[39] "REVALO, "REVALO, Recyclage Complet Des Fenêtres En Fin De Vie Et Déjà 40.000 Fenêtres ! | Ecovinews." REVALO, Recyclage Complet Des Fenêtres En Fin De Vie Et Déjà 40.000 Fenêtres ! | Ecovinews. N.p., Nov. 2013. Web. 2014. <http://www.ecovinews.com/?p=4274>.
[40] Bowers, Mark. "Lloyd's of London: A World First for Recycling." 2011: n. pag. Web. 15 Feb. 2015.

[41] Lapeyre.
[42] This region has some of the highest landfill costs in France.

process of testing the implementation of these deposit fees in 6 to 7 shops within the Greater Paris area only.

In practice, actors bring old windows to Lapeyre once they have a big enough stock to drop them off in bulk at Lapeyre collection points. Up to 12 windows are collected per stillage, rather than skips, because it is less costly and more convenient and because stillages slightly lower the risk of glass breakage (as compared to glass collection in skips).

Window installers and carpenters can also host stillages on their sites, but very few do so.

Paprec collects old joinery from Lapeyre DCs as well as from demolition and renovation sites (operated by Bouygues, Vinci, etc.). Paprec has collected 20,000 windows in 2013 (mostly single paned), out of which 200 tonnes of cullet entered Saint-Gobain Glass's furnaces, and out of which 230 tonnes of materials from frames were recovered.

Lapeyre's DCs that collect old windows are on average within a hundred kilometres from Paprec's sites[43]. Because window deposits stem from small window installers and carpenters, the collected material is not as homogeneous as the deposit resulting from large renovation / demolition sites. To clarify, carpenters recover windows with a variety of different frames, such as aluminium, wood and PVC, while large renovation/demolition sites have windows with homogenous frames types.

Paprec's two sites have invested in machines that are able to mechanically separate window frames from glass at an industrial scale. There are less material losses than if the segregation is done manually, it is much quicker and less expensive in labour cost.

Paprec considers that the sector will grow with the emergence of the French market of PVC and aluminium frames, materials whose prices stimulate recycling; and with the decline of wood frames, which is a resource more difficult to exploit. In comparison, in Germany, where the PVC windows have spread massively on construction sites since the 90's, there is a structured recovery industry for PVC joinery.

Paprec collects more and more windows with PVC frames, but few with aluminium frames because demolition/renovation companies often break apart themselves frames and glass when windows are aluminium-framed in order to recover aluminium and resell it to scrap metal dealers. In general, Paprec demands:

- 80€/tonne for the treatment of skips filled with wood framed windows or mixed materials (windows with different frames or with composite material), and
- 40-50€/tonne for the treatment of skips filled with PVC framed windows.

For the collection and treatment of skips with aluminium-framed windows, Paprec *buys* the aluminium waste at the market price of aluminium.

The advantage of being settled near Nantes is that there is a higher landfill tax than elsewhere in France. Paprec's Saint-Herblain site is therefore able to offer its customers a more competitive price for old windows than the price practiced by the landfill operator.

PVC and aluminium are transformed back into raw materials. Wood is still very present in the installed base of buildings in France; it is used to manufacture particleboard and to produce energy.

[43] Paprec's two facilities are located in Saint-Herblain (near Nantes), and in Pont Sainte-Maxence (Picardy).

Lease of a stillage	**10€/month**
Lease of a skip	70€/month on average (depends of many factors)
Transport cost between collection points and Paprec *(depends on the distance)*	Variable: 15-40€ /t
Net treatment cost of old joinery at Paprec sites *(once cullet and other materials have been sold)*	30-35€ /t
Transport cost for the cullet, between Paprec and SGG furnace	*Confidential*
Price of the cullet	*Competitive price confidential*

At the end of the supply chain, Saint-Gobain Glass buys the decontaminated glass cullet to Paprec, grinds it, and melts it in its furnaces. 80% is melt back into flat glass, and 20% into glass wool.

The **main obstacles** to the development and success of such a project are the following:

- The national landfill tax is too low in France (20€/tonne on average, versus EUR 100/tonne in the UK, and between 20 and 220€/tonne in Germany[44]).
- Lapeyre's customers (window installers, etc.) are not used to carefully removing old windows and to stock them without breaking them. Lapeyre must therefore make their customers aware of this issue.
- The collection system costs Lapeyre 5,000€/year/store, and Lapeyre will not be able to pay such an amount for 130 DCs.
- The transport cost between Paprec's sites and Saint-Gobain Glass is currently too high because the distance to travel is too long (350km and 650 km).

Window installers and carpenters are quite reluctant in paying a collection service or a rent fee for stillages, because it would still be cheaper for them to landfill old windows, and it would be unsecure to transport themselves the stillages with windows to Lapeyre or Paprec.

On the mid-run, when the project reaches a bigger scale, they wish to get a financial contribution of users (professionals) to be able to equilibrate the scheme.

Ultimately, the potential of post-consumer cullet collection for Saint Gobain ranges between 70,000 and 120,000 tonnes per year. At the moment, the industry aims to achieve a return of 10,000 tonnes per year within a few years, provided that renovators play the game.

Conclusions

In 2013 in France, about 520 tonnes of post-consumer building cullet was recycled into new flat glass, and a few hundred tonnes were recycled in other glass sub-sectors. In total, we estimate that less than 1% of old windows were collected to be recycled (8 Million windows reach their end of life in France each year, among which more than 5 Million are in domestic buildings). Building glass is still for the most part, crushed together with other building materials and landfilled or recovered as aggregates. Initiatives mentioned above are still at a starting point and it remains complex to ensure at the same

[44] Commissariat, Général Au, Développement, and Dura. 2013 Gestion Des Déchets : Bilans 2009-2012 De La TGAP Et Des Soutiens De L'ADEME(2013): n. pag. Web. 2014.

time 1) high cullet quality, 2) workers' safety (during dismantling and segregation of windows), and 3) profitability.

If both schemes are not economically profitable in their current state, their dissemination on the national level could be economically feasible if main obstacles (transport distances, collection cost, and landfill tax) are coped with. Indeed, window frames are more and more valuable and represent an opportunity for treatment companies. Today, 61% of window frames put on the market are PVC, 23% are aluminium, and only 13% are wood.[45]

Besides the above-mentioned obstacles, some issues are related to the sector in which glass waste is collected. As seen before, the issue with windows originating from residential buildings is that they are not homogeneous in terms of frames, so the sorting cost is heavy. In the tertiary sector, frames are usually of one same type in a building, but more and more buildings contain tinted, laminated, or enamelled glass, which are more complex to sort and treat.

Possible solutions identified by treatment facilities to encourage collection and recycling of building glass in France are:

- To provide subsidies to construction, renovation or demolition companies/ entrepreneurs, for the rent of containers for example and the development of wide collection schemes;
- To raise landfill taxes.

Yet no concrete actions have been taken regarding these requirements yet.

4 Sources

- Lapeyre;
- Paprec;
- Saint Gobain Glass France;
- REVALO;
- Veka Recyclage;
- AGC France.

[45] AGC data.

Germany

1 The German building glass market

There are 12 flat glass production lines in Germany, with each production line producing 500-1,000 tonnes of glass per day. The flat glass produced is used to create windows and facades for interior application (mirrors, lacquered glass, doors, etc.) along with automotive glass products (windshields, rear windows, sidelights).

In 2013, Germany was the biggest producer of flat glass in the EU. It produced 30.3 million m² of insulating glass for windows (DGU[46]), which is about 26% of the EU DGU production. Furthermore, Germany consumed 27.2 million m² of DGU (consumption = Production - Export + Import).[47] In that same year, 57.5% of the insulated glass units put on the market consisted of triple-glazing, which has become increasingly utilised, while 42.5% consisted of double-glazing.

60% of the insulating glass put on the market was allocated to renovation purposes. Furthermore, 72% of insulating glazing *sold for renovation purposes* are destined for use in the residential sector.[48]

In 2013, the total quantity of consumed flat glass in the German construction sector (insulating windows + interior glass+ toughened & laminated safety glass) was 1.3 Mt.

2 Building glass waste arisings

Glass waste arising from renovation

The German Thermal Ordinance of 1977, which was then replaced by the 2002 Energy Saving Ordinance,[49] is based on increasing thermal insulation of a building and indirectly increased the use of double-glazing units in buildings. As window glass units in Germany are replaced every 25 to 30 years[50] and this ordinance has been in existence for over 30 years, most windows that are replaced on renovation sites are already double-glazed.

Considering the assumptions outlined in the beginning of chapter one, the following estimations can arise:

- Over 218,000 tonnes/year of glass waste originates from the replacement of old windows (and doors) in residential buildings;
- Over 127,000 tonnes/year of glass waste originates from the replacement of old windows (and doors) in tertiary buildings.

[46] DGU = double-glazing unit.
[47] Statistics of BV Glass and "Navigation Und Service." Startseite - Statistisches Bundesamt (Destatis). N.p., n.d. Web. <https://www.destatis.de/>.
[48] See assumptions at the beginning of Chapter one.
[49] "German Energy Savings Regulation (ENEV)." // Gip. N.p., n.d. Web. <http://www.gip-fassade.com/en/System_VHF/Energieeinsparverordnung_ENEV>.
[50] Data obtained from BF Flachglas, BV Glas and Saint Gobain Glas Deutschland.

The glass waste generated by the renovation of interior glass and glass walls in dwellings could not be estimated, but most glass in buildings comes from windows, and interior glass is more rarely renovated.

Glass waste arising from demolition

It is estimated that more than **26,000 tonnes of window glass waste** is generated **from the demolition of residential buildings**[51]. The quantity of interior glass in residential buildings is negligible, compared to the quantity of window glass.

Based on the floor area[52] of tertiary buildings in Germany[53], taking into account that about 0.3%[54] of Germany's tertiary building surface area is demolished annually, and estimating that glass represents about 40% of the floor area of a tertiary building,[55] it can be estimated that at least **74,000 tonnes of glass waste originates from the demolition of tertiary buildings**. According to BV Glas, this rough estimation seems high. Therefore, it should be considered with precaution.

Table 7: Country estimations of flat glass waste arising from building demolition and renovation (2013)

Sector	Tonnage generated	Sub-sector	Tonnage generated
Residential	244,534 tonnes	Renovation	218,116 tonnes
		Demolition	26,418 tonnes
Tertiary	201,121 tonnes	Renovation	127,234 tonnes
		Demolition	73,887 tonnes
Total		445,665 tonnes	

Table 8: PROJECTIONS for 2025: country estimations for flat glass waste arising from building demolition and renovation[56]

Sector	Tonnage generated	Sub-sector	Tonnage generated
Residential	249,839 tonnes	Renovation	223,421 tonnes
		Demolition	26,418 tonnes
Tertiary	206,014 tonnes	Renovation	130,329 tonnes
		Demolition	75,685 tonnes
Total		455,853 tonnes	

[51] Estimations of BF Flachglas, BV Glas and Saint Gobain Glas Deutschland, 2014.
[52] Refer to 'key terms' at the beginning of the study.
[53] Buildings Performance Institute Europe (BPIE), *Country Factsheets 2013*. German data for tertiary buildings come from the Federal Institute for Research on Building, Urban Affairs and Spatial Development (BBSR).
[54] Schimschar, Sven, Jan Grözinger, Henning Korte, Thomas Boermans, Velizara Lilova, and Riadh Bhar. "Panorama of the European Non-residential Construction Sector." (2011): n. pag. Web. <http://www.leonardo-energy.org/sites/leonardo-energy/files/documents-and-links/European%20non-residential%20building%20stock%20-%20Final%20Report_v7.pdf>.
[55] See basic assumptions at the beginning of the study.
[56] Deloitte Estimations.

3 Collection and recycling of building glass

Institutional and regulatory context

In **Germany**, there is neither a national tax[57] nor ban[58] on landfilling of C&D waste material; however, three national ordinances, unified in 2009 under the Landfill Ordinance, transposed the EU Landfill Directive into German national law, which imposed stricter requirements than those of the Directive[59]. Some standards or certification schemes have been developed, taking into account C&D waste treatment issues. For example, the German Sustainable Building Certificate, a voluntary scheme run by the German Sustainable Building Council, instates different criteria to ensure that buildings are sustainable via facilitating the ease of dismantling and recycling building materials. Furthermore, the German regulations (KrWG[60] and GewAbfV[61]), call for the separation of the different waste materials during demolition. However, this statement is negated with its exemption clause, which indicates that waste stream separation can be abandoned if it is technically or economically unfeasible.

Aside from these regulations, landfill fees throughout Germany vary per region, since municipal authorities are responsible for determining these regional fees through by-laws. One source identified that the landfill fees range from €20 to €220 per tonne[59]. It must be noted that German landfills only accept mineral waste that contain less than 5% burnable content.[62] Thanks to rising landfill prices, a growing emphasis is placed on recycling rather than landfilling building glass waste.

Collection and recycling of building glass

Thanks to the Green Dot System, the collection of container glass is a common practice in Germany since the early 1970's. Within this nationwide system, there are several container glass collection sites, along with 23 glass treatment installations. Although this system has worked nicely for container glass collection, a treatment facility interviewed for this study believes that it is not yet replicable to flat glass collection. However, in the last few years, building glass collection and recovery has been extended.

While the quantity of post-consumer building glass waste that has arisen in Germany in 2013 is approximately 446,000 tonnes, there are no national statistics on the amount that was collected and treated.

Nevertheless, Germany has nine main facilities specialised in flat glass sorting and treatment. Six of them belong to Reiling and the Reiling-owned company Lauenburg, while the others are operated by Komi, Schirmbeck, and Tönsmeier. All treatment companies are located nearby Germany's 12 float lines.

Collection and treatment on the national level

A stakeholder interviewed for this study estimated that Tönsmeier may collect and treat around 40,000-50,000 tonnes of building glass per year.[63] This estimation gives us a general idea on the quantity that a German flat glass treatment company having national coverage is able to collect and treat.

[57] A landfill tax is paid on top on landfill fees.
[58] Are covered by the landfill ban any municipal waste that can be recovered, untreated municipal waste, all biodegradable municipal waste to be separately collected and composted, and waste wood (source: Landfill Ban Investigation, Department of the Environment).
[59] European Commission DG ENV, Use of Economic Instruments and Waste Management Performances, April 2012.
[60] Kreislaufwirtschaftsgesetz.
[61] Gewerbeabfallverordnung.
[62] Interview with a German flat glass recycler, 2014.
[63] Estimation to be taken with precaution, because Tönsmeier could not be interviewed.

Reiling Glas Recycling GmbH & Co: a wide collection network supporting the recycling of post-consumer building glass waste in the glass industry

Reiling is **one of Germany's leading treatment centres**, which has nationwide coverage on hollow and flat (building and automotive) glass, plastic and wood treatment. Although the majority of this treatment centre's flat glass collection comes from pre-consumer cullet (about 75%), the company nevertheless manages to collect an average of about **80,000 tonnes of post-consumer building glass** per year.

To coordinate the collection of flat glass waste with its clients (renovation and demolition companies along with flat glass manufacturers), Reiling creates personalised service contract rates. The rates are notably based on the client's distance to the treatment centre, the estimated frequency of collections (how much flat glass waste is expected to arise on the renovation/ demolition site), and the estimated length of the rental. The skips Reiling installs at its client's sites are either open and closed skips, and they come in various sizes i.e. **between 1m³ and 20m³, starting at 20 €/ skip/ month** (price can be much higher). The exact cost of collection depends on the abovementioned factors. Furthermore, Reiling owns **25 trucks that collect flat glass** which **travel an average of 150 km one-way**; however, there are cases where they may travel up to 300 km one way. For its downstream activities, Reiling contracts a transport company that helps them deliver all prepared cullet to various industries, and in some cases, participate in flat glass waste collection. Reverse logistics is practiced whenever possible.

Throughout this organised collection system, it has proved to be impossible for Reiling to determine precisely the sectors in which the collected glass originates from, as glass originating from demolition sites and glass arising from renovation sites, would buildings be tertiary or residential, are mixed together at the treatment facilities. Reiling expressed that when a contract is made with a renovation or demolition company, it does not necessarily mean that all of the flat glass that is collected comes from only one sector, for it is common for these companies to work on both renovation and demolition sites, and tertiary and residential sites alike. Therefore, even if they tracked the glass that is collected per company, it would still not be representative.

Taking a look at Reiling's flat glass treatment itself, this company prides itself with treating 100% of all collected flat glass (clear, laminated, mirrored, ceramic, amongst others) regardless of its quality. Although their business model excludes the collection or management of window frames, there are minimal cases that poor supervision during a glass waste pick up or drop off lead to frame collection. When these rare cases occur, an ad hoc decision on how to dispose of it is taken by the company. PVC and aluminium are almost never mixed in with the flat glass, however when the more commonly collected wood pieces are mixed in, the wood is sold to the Reiling Wood Recycling Company.

At the Reiling glass treatment centre, a wide variety of machines have the capability of sorting out waste and glass via magnet machines, crushers, ceramic sorters, and x-ray technology to detect lead and heat-resistant glass. Much precaution is taken within treatment in order to meet their ongoing objective to prepare as much high quality cullet as possible to sell it back into the flat glass sector (closed-loop recycling). Currently, **40% (highest quality cullet) is sold to the flat glass industry**; the remaining 40% and 20% is sold to the hollow glass and the glass wool industry, respectively. Although the price at which cullet is sold to each sector has been kept confidential, transportation costs can compose anywhere between 1%-20% of the final cullet cost, once again depending on how far the prepared cullet is transported to.

Collection and treatment on the regional and local level

Next to treatment companies having a nationwide coverage, there are also various locally and regionally run collection systems.

To exemplify a small and local collection initiative within the state of Bavaria, the town of Amberg gives individuals the opportunity to bring small amounts of residential flat glass to two collection yards

("Wertstoffhof") in the north and south of the city. Although flat glass collection is not its main focus, (these collection yards collect everything from metal cans to cork, from household hazardous waste to car batteries) old household/residential flat glass waste such as mirrors and windowpanes is accepted for collection[64]. However, no similar initiative has been identified elsewhere in Germany.

Operating at a local scale, a small treatment company compensates the fact that it collects low volumes of glass with the revenue aquired from recycling window frames

In a county of North Rhine-Westphalia lies a local flat glass treatment company, which collects post-consumer building glass. 95% of the collected flat glass waste comes from **renovations** and 5% from demolitions. This treatment centre annually collects **600 tonnes** of post-consumer building glass, thanks to its array of two hundred 40m³ open skips located at **residential building sites**. Renovation/demolition sites that rent out these **skips are charged around €45/tonne for the rent**, and €**50/tonne on average for the collection, separation of the frame from the window, and treatment of windows**. The average **distance between renovation/demolition sites and this local treatment facility** is around **100 km**. Once alerted by project site actors, it usually takes this treatment facility 1-2 days to replace skips. Although this company's 20 trucks are capable of carrying up to two skips at a time, and aim at servicing other locations in the area during the same trip, it is not always possible because it services a small area and does not necessarily have the demand from clients.

Since this treatment centre collects flat glass and window frames, project site actors may mix flat glass and frame waste on site; **the frames, flat glass, and waste are sorted** manually and mechanically (wheel loaders and excavators) **at the treatment site**. During this process, any unwanted rubbish or non-glass materials, such as wood, PVC and aluminium, is removed. Although this particular treatment centre segregates windows from frames, it is common for other treatment centres to require flat glass waste to be separated from its frame before entering treatment centres.

Once the flat glass and frame waste is sorted at the treatment centre, **80% of this company's highest quality cullet is sold to a nearby glass beads production site** for a price of about **€65/tonne**. This glass beads company reprocesses and transforms it **into an additive for paint**; the flat glass mixed into the product gives the paint a reflective quality. **15% of the lesser quality cullet is sold to a nearby hollow glass manufacturer** for a price of about **€16/tonne**. Although the production of hollow glass from cullet typically requires high quality cullet, this hollow glass company is able to accept this treatment centre's lesser quality flat glass because of their effective technology to clean out contamination. **Both companies are around 35 km from the treatment centre**, keeping transformation costs at a minimum and contributing to their cullet's cost-competitiveness. The remaining cullet (5%), which is of a very poor quality, is landfilled. Since German landfills do not accept complete windows, this treatment centre must first grind it down to mineral waste that consists of less than 5% burnable content. The **regional landfill fee of 20-40 €/ tonne** is paid by the treatment centre.

In an attempt to sell its cullet to other outlets, this treatment centre has approached a flat glass manufacturer to negotiate a competitive selling price for his cullet. However, because the transportation costs were too high to keep the business deal profitable, they did not pursue any further business towards selling their cullet to the flat glass sector.

The **collected frames represent most of their revenues. PVC** (25% of the collected frames) is sold at **€220/tonne** to plastic profile manufacturing companies, such as Rewindo; while **wood** (74% of the collected frames) is sold at **€15-20/tonne** to an incinerator company. Aluminium frames represent only 1% of the collected frames.

[64] There is no current data on collection levels of flat glass or the success rate of this initiative.

Rewindo's[65] members (including Veka UT and Tönsmeier Kunststoffe, amongst others) collect 1,000-1,200 post-consumer PVC window frames each year from various treatment centres, window manufacturers, real estate companies, demolition companies, etc. In 2013, the members' combined output consisted of 22,000 tonnes of PVC, 70% originating from post-consumer window frames. The Rewindo association actively supports window collection and treatment initiatives in Germany, focusing on their strong and steady communication geared at stakeholders in order to stimulate positive behaviour amongst relevant actors.

4 Sources

- BF Flachglas;
- BV Glas;
- Saint Gobain Glas Deutschland;
- Rewindo GmbH (a common initiative of Germany's leading plastic profile manufacturers whose goal is to recycle window frames, shutters and doors to increase plastic resources);
- BVSE (trade association for glass recycling in Germany);
- Reiling Glas Recycling GmbH, one of the leading treatment centres in Germany for glass, plastic and wood treatment;
- A German local flat glass treatment company.

[65] Rewindo is an association grouping Germany's leading plastic profile manufacturers. It is a member of the European PVC Window Profile and Related Building Products Association (EPPA)

Italy

1 The Italian building glass market

According to Saint Gobain Italy, in 2013, about 600,000 tonnes of flat glass were put on the construction market, Out of this total[66], which represents an unknown number of square meters, 10 million m² of *insulating glass* were put in the Italian market, 55% of it sold for renovation purposes.

Today, 90% of registered window refurbishment works consist in changing glazing pane from single to double.[67]

In the historical progression of window frames in Italy, installed windows were initially almost entirely made up of wood. Afterwards, metal frames made a rise on the market, particularly allocated to tertiary buildings.

Table 9: Window frames sold in Italy[68]

Frame type	% old windows replaced	% new windows placed on the market (2013)
PVC	~ 10%	37%
Wood	~ 75%	35%
Metal (mostly aluminium)	~ 15%	30%

Specificities on the Italian hollow glass industry

Per known knowledge, Italy is the only Member State that has a public and centralised database of all Italian-based treatment centres and manufacturing sites per name and location, which can be found on the website[69] of the Italian national consortium for glass collection (CoReVe). Currently there are 22 Italian treatment centres; according to CoReVe, all but one of these treatment centres treat, or have the capacity to treat, both hollow and flat glass.

[66] Total flat glass = insulating windows + interior glass+ toughened & laminated safety glass.
[67] Francesco Emanuele Contaldo, The value of traditional windows in the Mediterranean context, 2011.
[68] Data obtained from Saint Gobain Italy.
[69] http://www.coreve.it/showPage.php?template=chi_siamo&id=1

Figure 9: Italian-based Hollow and flat glass locations (source CoReVe[70])

Although it is understood that these treatment centres treat post and pre-consumer hollow glass alike, it is unknown in which proportion. Furthermore, if these centres treat flat glass, it is unknown from which sector it originates. However, from an interview with the association of glass recyclers (FERVER), it is estimated that around two thirds of glass collected by flat glass treatment centres in Italy is post-consumer[71]. Research in Phase I specifies that 4 out of the 22 treatment centres take on post-consumer building glass treatment (Eurovetro, Emiliana Rottami S.p.A., La Vetri SRL, and Tecno Recuperi SPA, although there may be others). In any case, like Poland, treatment capacity is not a bottleneck in the country, meaning that these centres could potentially collect more glass to treat.

In Italy, there are only 3 Glass for Europe member companies which manufacture flat glass (see red stars in Figure above) and 1 non-Glass for Europe flat glass manufacturer (see turquoise dot) which covers most of the North-Eastern side of the nation.

2 Building glass waste arisings

Glass waste arising from renovation

As previously indicated, 55% of insulating glazing is sold for renovation purposes. Taking into account assumptions in the beginning of chapter one, and notably the fact that 82% of renovation glass is allocated to the residential sector, it can be estimated that in 2013, 990,000 m² and 4.5 million m² of building glass were pulled out from renovation, respectively in the tertiary and the residential sector. Since 2010, the Italian legislation, which awards a 65% money back financial reimbursement to actors that partake in improving energy efficiency via window renovation projects, helped finance the replacement of 5.5 million m² of building glass on the market.

[70] It should be noted that the original map created by CoReVe was modified for this study to include the locations of Glass for Europe flat glass manufacturing sites.
[71] "FEVER Member Companies Conference Call: Flat Glass Treatment and Recycling." Telephone interview. 26 Feb. 2015.

Taking into account that about 80% of the replaced windows were single-glazed (especially in the south of the country) and the rest were double-glazed (especially in the north)[72], while considering assumptions at the beginning of chapter one, this means that:

- Over 54 000 tonnes/year of glass waste is generated by the replacement of old windows (and doors) in residential buildings, and
- Over 17 000 tonnes/year of glass waste is generated by the replacement of old windows (and doors) in tertiary buildings.

The glass waste generated by the renovation of interior glass and glass walls in dwellings could not be estimated. However, most glass within buildings comes from its windows; interior glass is rarely renovated.

Glass waste arising from demolition

About 0.1% of the installed base of residential buildings was demolished in Italy in 2004, i.e. about 27 000 dwellings.[73] Updated data is not available, yet it has been assumed that like in Spain, the demolition rate decreased after the economic crisis of 2008 to about 0.05% for the residential sector. The average useful floor area of an Italian dwelling being 96 m²,[74] this means that about 1.3 million m² of **dwellings** are demolished each year.

In southern Europe, glass approximatively represents the equivalent of 15% of the useful floor area of a residential building generating; a dwelling's single glass unit weights 10kg; and in Italy, it is estimated that 80% of windows of demolished buildings are single paned (see assumptions at the beginning of chapter one). Therefore, it can be appraised that around **2 400 tonnes** of glass waste originated from demolitions in the residential sector in Italy in 2013.

Furthermore, we assume that the Italian demolition rate for tertiary buildings is close to that of Spain's (0.1%[75]). Based on this hypothesis and on the assumptions at the beginning of chapter one, there should be around 3 000 **tonnes** of glass waste generated annually through the **demolition of tertiary buildings**. This estimation is to be considered with precaution.

Table 10: Country estimations of flat glass waste arising from building demolition and renovation (2013)

Sector	Tonnage generated	Sub-sector	Tonnage generated
Residential	56 703 tonnes	Renovation	54 336 tonnes
		Demolition	2 367 tonnes
Tertiary	20 667 tonnes	Renovation	17 891 tonnes
		Demolition	2 776 tonnes
Total		77 370 tonnes	

[72] European Commission DG ENV, Use of Economic Instruments and Waste Management Performances, April 2012.
[73] ISTAT, Report 2004.
[74] The Hague Ministry of the Interior and Kingdom Relations. "Housing Statistics in the European Union 2010." (2010): n. pag. Web. 2014. <https://www.bmwfw.gv.at/Wirtschaftspolitik/Wohnungspolitik/Documents/housing_statistics_in_the_european_union_2010.pdf>
[75] Ministerio de Fomento, 2010.

Table 11: PROJECTIONS for 2025 Country estimations for flat glass waste arising from building demolition and renovation[76]

Sector	Tonnage generated	Sub-sector	Tonnage generated
Residential	68 045 tonnes	Renovation	65 204 tonnes
		Demolition	2 841 tonnes
Tertiary	24 801 tonnes	Renovation	21 470 tonnes
		Demolition	3 331 tonnes
Total		**92,845 tonnes**	

3 Collection and recycling of building glass

Institutional and regulatory context

Impact of public policies on building glass waste arisings

As previously mentioned, since 2010 the Italian government grants a tax credit of 65% for the replacement of old windows and shutters by new energy efficient insulating ones, which encourages individuals and businesses to replace their old windows, and thus increases the quantity of available building glass waste.

Impact of public policies on recycling

In 1999, the introduction of a national landfill tax (with ratio set at the regional level) has played a role in municipal solid waste management, driving the progression of landfill diversion and incentivizing alternatives like recycling or incineration. As they represent costly technologies and infrastructure, recycling and incineration have been more easily adopted in richer provinces and regions, like Lombardy. Similarly, the higher population density of this region has stimulated the adoption of land saving technologies and deterred from landfilling. [77] In Lombardy, the landfill price rose up to around 100€/tonne[78] (landfill *tax* only amounts to 10.5€/tonne 2013[77]). Over the last 15 years in Northern Italy, until municipalities could develop the capacity to treat waste and avoid using landfill, most of it was exported to southern regions (not always legally).[78]

Collection and recycling of building glass

Despite the fact that in the bottle glass sector, Italy has only started sorting colour from clear glass over the past couple of years (although this is still not performed nationwide), Italian *building glass* waste collection has experienced a steady rise over the years.[79] Most of the post-consumer building glass collected yet still originates from sites in northern Italy, where renovation and demolition are

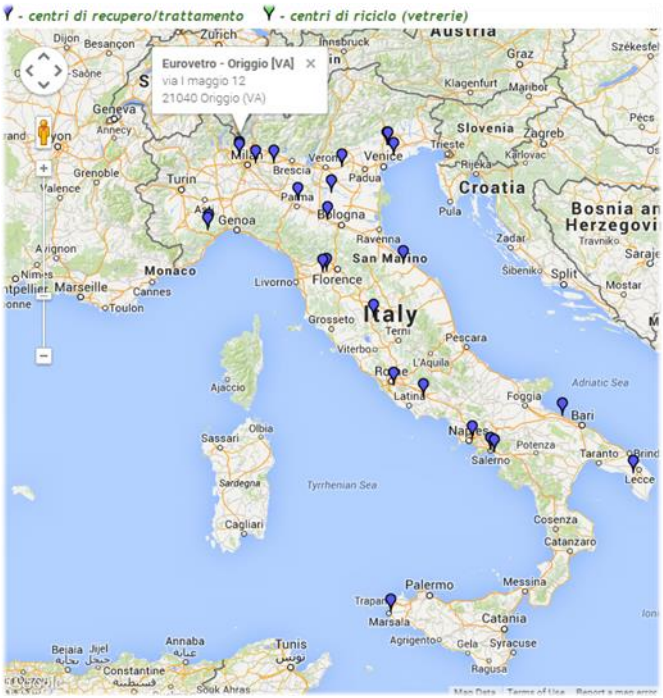
[76] Deloitte Estimations.
[77] European Topic Centre on Sustainable Consumption and Production (ETP/SCP), *Regional Municipal Solid Waste Management in Lombardy*, Italy, February 2014.
[78] OECD Economic surveys, Italy 2011.
[79] "CoReVe - Consorzio Recupero Vetro." CoReVe - Consorzio Recupero Vetro. N.p., n.d. Web. 2014. <http://www.coreve.it/showPage.php?template=homepage>.

more frequent than in the south of the country, and where investments have been made in collection and recycling infrastructure.[80]

It proved quite difficult to collect data on the topic, mostly because of confidentiality issues. According to CoReVe, the consortium of glass treatment companies in Italy (mainly focused on hollow glass treatment), 21 to 22 treatment facilities collect and treat flat glass, although it is unknown whether this flat glass waste originates from the pre or post-consumer sector, or the building or automobile sector. It is however confirmed that out of the 21 to 22 glass collection and treatment facilities[80] located in Italy, at least 4 facilities collect and treat post-consumer *building glass*: Eurovetro, Emiliana Rottami S.p.A., La Vetri SRL, and Tecno Recuperi SPA.

Below is a location breakdown of the glass treatment facilities within Italy; as stated above, apart from the 4 treatment facilities, it is unknown if there are others that collect and treat *building glass*. As the map shows, more glass treatment facilities are located in Northern Italy. Flat glass waste treatment facilities operate regionally; none has national coverage.

Figure 10: Glass treatment centre locations in Italy (source: CoReVe)



Furthermore, some glass manufacturers such as Saint Gobain Italy are studying the opportunity of recovering post-consumer building glass through take-back systems. However, such projects are at a starting point and no information can be currently shared.

Eurovetro's regional collection scheme in Northern Italy

Eurovetro has two treatment sites in the region of Lombardy, which collects and treats all types of glass; though mainly hollow and flat glass. Eurovetro's flat glass collection levels have been rather stable over the last several years. Despite a small 10% decrease in their collection levels around 2008-2009, Eurovetro declares remaining at an average of about 10,000 tonnes of collected post-

[80] Data obtained from the Italian building glass recycler Eurovetro.

consumer building glass per year.[81] This treatment centre roughly estimates that 70-80% of its building glass collection originates from building demolitions and 20-30% from renovations.

Eurovetro supplies its clients with skips, varying between **15m³-30m³** (monthly rental costs are confidential). These prices may vary on the longevity of the contract, (anywhere from one week to several years) and are furthermore tailored to the client's situation, the distance travelled to these sites, the estimated frequency of collections, etc.

About half of flat glass collected is transported to Eurovetro's facility via their 10 company trucks, which on average travel **around 100 km one-way (break-even point)**, although they may travel up to 200 km one way. The other half of the collection is brought to their facility by their clients or even particular local municipalities that have their own (small) flat glass collection sites[82].

At the treatment facility, Eurovetro currently uses automatic, magnetic and non-magnetic sorting to sort out their generally high level of contaminants, which most commonly consists of paper, plastic, rubble, and frame pieces. To optimise their sorting capabilities, they are currently researching how to implement different technologies that could more efficiently sort out small and thin pieces of glass, in order to ensure that 100% of all glass is collected.

Dismantling frames is not part of Eurovetro's focus and clients are deterred from mixing frames with glass waste. Nevertheless, a few tonnes of frames are still collected annually. The metal pieces, deemed valuable, and sold on an ad-hoc basis to scrap metal recyclers.

According to Eurovetro, one of the main flat glass Italian treatment companies, the landfill cost in Lombardy is generally enough to serve as an incentive to recycle flat glass.

Eurovetro sells good quality cullet to the hollow glass industry while poor quality cullet is used as aggregates in roadworks or in the ceramic sector, amongst others.

4 Sources

- Saint Gobain Italy;
- CoReVe;
- Eurovetro SRL.

[81] This is a declarative figure, which could not be verified by Deloitte, so it must be taken with precaution.
[82] Data obtained from the Italian building glass recycler Eurovetro.

The Netherlands

1 The Dutch building glass market

The main flat glass producer in the Netherlands is AGC Flat Glass Nederland.[83] In 2013, the Netherlands construction sector consumed 4.3 million m² of insulating glazing.[84] 60% of it was dedicated to renovation sites.

In the Netherlands, most buildings still have timber-framed windows, as shown in *Table 12*. More and more plastic frames are sold on the Dutch market yet no data is available on the issue.

Table 12: Window frames in the Netherlands[85]

Frame type	% each frame type represents in old windows actually being replaced	% each frame type represents in new windows put on the market
PVC	~15%	*n.a.*
Wood	~80%	*n.a.*
Metal (mostly aluminium)	~5%	*n.a.*

Furthermore, compared to other EU countries, there is a uniform way of integrating window frames into building structures at the stage of construction. Indeed, when glass units are added in a building structure, frames are already part of the structure. This specificity allows easy and low cost disassembly of window glazing, rather than the high cost task of dissembling an entire window (glazing + frame). It is not the case in other EU countries, where windows (glazing + frames) are added after the construction of the building structure, and where, at the stage of renovation or prior to demolition, disassembling a window means having to disintegrate the glazing from its frame, which is a costly operation.

2 Building glass waste arisings

Glass waste arising from renovation

2.6 million m² of glazing was replaced in the Netherlands in 2013. According to EIB (the Economisch Instituut voor de Bouw), 20% of old windows were single-glazed and 80% double-glazed (replaced by double- and triple-glazed windows only). Considering assumptions at the beginning of chapter one, this means that:

- Over 33 000 tonnes/year of glass waste is generated by the replacement of old windows (and doors) in residential buildings, and
- Over 19 000 tonnes/year of glass waste is generated by the replacement of old windows (and doors) in tertiary buildings.

It was not possible to estimate the waste glass generated by the renovation of interior glass and glass walls in dwellings, but most glass in buildings comes from windows, and interior glass is more rarely renovated.

[83] Association of Dutch Glass manufacturers (VNG).
[84] Eurostat, 2013.
[85] Estimations obtained from Vlakglas Recycling Nederland (VRN).

Glass waste arising from demolition

12,903 dwellings were demolished in 2013 in the Netherlands [86] (0.18% of the installed base of residential buildings). It is considered that windows and glass walls represent on average about 20% of the square meter floor space in a Dutch dwelling. Furthermore, it has been assumed that 20% of windows and glass walls in demolished dwellings are single-glazed (the rest double-glazed); and that dwellings in the Netherlands have an average size of 125 m². [87] We can therefore estimate that near **6 000 tonnes of glass waste are generated through the demolition of residential buildings**.

Considering assumptions at the beginning of chapter one, there should be nearly **16 000 tonnes of glass waste generated through the demolition of tertiary buildings**. This estimation is to be considered with precaution.

Table 13: Country estimations of flat glass waste arising from building demolition and renovation (2013)

Sector	Tonnage generated	Sub-sector	Tonnage generated
Residential	39 453 tonnes	Renovation	33 623 tonnes
		Demolition	5 830 tonnes
Tertiary	35 162 tonnes	Renovation	19 613 tonnes
		Demolition	15 549 tonnes
Total		74 615 tonnes	

Table 14: PROJECTIONS for 2025: country estimations for flat glass waste arising from building demolition and renovation[88]

Sector	Tonnage generated	Sub-sector	Tonnage generated
Residential	40 767 tonnes	Renovation	34 743 tonnes
		Demolition	6 024 tonnes
Tertiary	36 334 tonnes	Renovation	20 267 tonnes
		Demolition	16 067 tonnes
Total		77 101 tonnes	

3 Collection and recycling of building glass: a unique system in Europe

How the compliance scheme for flat glass started

[86] "CBS StatLine - Voorraad Woningen En Niet-woningen; Mutaties, Gebruiksfunctie, Regio." CBS StatLine - Voorraad Woningen En Niet-woningen; Mutaties, Gebruiksfunctie, Regio. N.p., n.d. Web. 2014. <http://statline.cbs.nl/StatWeb/publication/?DM=SLNL&PA=81955NED&D1=a&D2=1-2&D3=0&D4=16,33&HDR=G1,G2,G3&STB=T&VW=T>.

[87] The Hague Ministry of the Interior and Kingdom Relations. "Housing Statistics in the European Union 2010." (2010): n. pag. Web. 2014.<https://www.bmwfw.gv.at/Wirtschaftspolitik/Wohnungspolitik/Documents/housing_statistics_in_the_european_union_2010.pdf

[88] Deloitte Estimations.

In 2000, Dutch sheet glass manufacturers and sheet glass wholesalers and importers decided to set up a **voluntary system** to meet their producer responsibility. They first conducted an experiment in the Northern provinces of the Netherlands, and on the basis of this experiment's favourable results, the Dutch Ministry of Housing, Spatial Planning and the Environment (VROM) approved the system at a **national scale** and its financing model in 2001. The Foundation 'Vlakglas Recycling Nederland' (VRN) was founded in **2002** thanks to the collaboration of the Dutch sheet glass and double-glazing industry and trading companies. Since companies within the sheet glass industry in the Netherlands generally find it important to exercise producer responsibility, the aim of VRN was to set up a **waste sheet-glass management chain** (in other words, **a collection network) in the Netherlands**.

VRN is an **independent non-profit foundation** representing the sheet glass (flat glass) industry, comprised in part by: companies that import and produce double, triple, or more than three panes of insulated glass glazing, and/or manufacture flat glass nationally in the Netherlands, along with sheet-glass industrials, which account for a significant proportion of its membership.[89] VRN currently has six employees (two are full time), all of which are in charge of organising and maintaining the collection network. In particular, they provide the public information about sheet glass collection and recycling, and ensure the receipt of any income due by manufacturers, double, triple or more than three paned insulated glass glazing importers. In **2002**, as VRN's voluntary system had proven to be effective in the field of manufacturer responsibility, the Ministry saw no immediate need to enact legislation in the area. As far as the sheet-glass industry is concerned, the advantage is that it is not faced with intrusive government regulations.

Regulation

The Ministry of Infrastructure and the Environment[90] imposes the obligation to pay a levy tax on every m² of double, triple, and more than three panes of insulation flat glass put on the market (produced within the country or imported) is imposed by at the request of VRN. This, incidentally, is the only area where the Ministry plays any role in VRN's operations. This measure is needed in order to prevent companies using the system without actually paying anything into it. The obligation to pay a levy tax is therefore examined and controlled by the Dutch government. Given the confidential nature of the information (concerning production figures), the levy is collected by an independent firm of accountants. VRN has no access to information regarding the amounts paid by individual manufacturers. Furthermore, an international and independent accountancy firm annual examines VRN's functions..

There are **242 companies that pay the levy to the VRN (200 in 2011)**. In addition, some nine foreign producers voluntarily pay the fee to VRN on behalf of, and as a gesture to, their customers in the Netherlands. Every year, VRN's accountant independently selects ten companies at random in order to carry out a check on their contributions. If any firm is found to refuse to pay the levy or fails to agree to an inspection, VRN will take legal action to compel such firms to cooperate.

Description of the Collection system

Since 2001, VRN has set up a network of sheet glass collection containers in over 400 locations in the Netherlands. As of 31 December 2013, 1,384 long-stay and temporary containers were set out on collection points, company sites, and on construction and demolition sites, however the real amount of containers has and will continue to fluctuate according to demand.

[89] VRN now has 3 board members: 2 from the glass concerns (AGC, SGGS) and 1 independent traders.
[90] Since 2013 it is imposed by the Ministry of Infrastructure and Environment.

Locations are chosen if the collection point is projected to collect a minimum of 60-80 tonnes per year, and if the selected geographic location for the collection point makes logistical sense. For example if there is a lack of containers in a certain area that is projected to have a high yield of flat glass waste, VRN would aim to put containers in these underserviced areas. Currently, VRN has collection points every ~50 km; however the aim is to have enough collection points country-wide so that no more than 15 km need to be driven to drop off sheet glass waste. It can be estimated that there is **one collection point for every 112 tonnes of insulating glass put on the building market**.[91]

Among VRN's 2013 network of **1 384 sheet-glass collection containers**, there are **389 free-of-charge** collection points, most of which are available on-site at sheet-glass manufacturers, wholesalers, window-frame factories, municipal waste dumps and container companies. Within these 389 collection points, VRN has 52 off-site storage points where companies can transport their sheet glass waste. Companies who deliver sheet glass waste to these storage points may be charged a € 5 per tonne handling fee.

Various sizes of long-stay open and closed containers can be additionally rented monthly from VRN (see tables below). As of 31 December 2013, there were about **320 rented collection points,** namely at flat glass manufacturers' sites. These rented bins are an attractive alternative to public free-of-charge collection points because of the on-site privacy advantage, as well as the ability to better monitor the sorting of their own flat glass waste.

Furthermore, equally varied sizes of temporary collection containers can be rented out monthly, namely for demolition and renovation sites. There are currently **453 temporary collection points**; an estimated 90% of the total amount of collection points is based on renovation sites, leaving around 10 % on demolition sites. This low number of containers at demolition sites is attributed to the fact that demolition companies typically use their own containers for their generated waste streams and because of the current economic situation, which consequently demands less demolition projects.

Table 15: Long and temporary stay container rates[92]

Long stay rates – Container size	Container Fees
0.5 m^3 container	€26.50 /month
1 m^3 container	€26.50 /month
2 m^3 container	€26.50 /month
Lid for the 2m^3 container	€10 /month
Prices are per month and exclusive VAT. Prices include transport for placing, exchanging and removing container.	

Table 16: Temporary stay container rates

Temporary stay rates – Container size	Container Fees
2m^3 container	€37.50 /month
Lid for the 2m^3 container	€10 /month
18m^3 open container	€110 /month

[91] About 155 000 tonnes of insulating glass where put on the Dutch market in 2012 – this calculation is based on Eurostat data for production, imports and exports of insulating glass in the Netherlands.
[92] These rental rates are planned to be reduced in 2015.

18m^3 closed container	€135 /month
Prices are per month and exclusive VAT. Prices include transport for placing, exchanging and removing container.	

All of the variously sized containers' **rental fees include the cost of transporting, replacing, maintaining, and removing containers from sites**, which is then paid by VRN to the original owners of the containers (transport company, Van Gansewinkel). Containers are of various sizes, and, as seen previously, VRN offers good rental conditions for the containers to be placed in areas where there are demolition/renovation projects.

The most commonly rented skips are the 2m^3 (holding about 2 tonnes of waste) or 18m^3 (holding about 10 tonnes of waste) sizes. This latter-sized skip is the most requested for C&D projects.

The 2m^3 containers are normally placed on sites that use the skip exclusively for their site's waste. These skips are only placed at C&D projects when the site is located in a big city centre for special issues.

1m^3 containers are also rented out, but in a lesser frequency. These containers, which hold around 1 tonne of waste are used for very small projects or for collecting pre-consumer glass, in this case it is usually placed next to a glass cutting table so that the glass off-cuts can conveniently fall into the skip. These skips are not placed at C&D projects.

Below are examples of the different types of containers that VRN provides. The following figures corresponding to each container comprises the total amount of containers actually placed on site, not the total quantities available.

Figure 11: As of 31st of December 2013, VRN has 442 open containers at collection points, long-stay rentals, and temporary rentals with an 18 m³ capacity holding +/- 10 tonnes of waste (2013)

Figure 12: As of 31 December 2013, VRN has 55 closed containers at collection points, long-stay rentals, and temporary rentals with an 18 m³ capacity holding +/- 10 tonnes of waste (2013)

Figure 13: As of 31 December 2013, 887 VRN containers at collection points, long stay rentals, and temporary rentals have a capacity between 0.5 and 2 m³ holding +/- 2 tonnes of waste (2013)

VRN collection points accept three types of sheet glass: **float glass, laminated glass and combination glass** (i.e. a mixture of all kinds of sheet glass[93]). They have strict quality acceptance guidelines that state which materials (ceramics, cork, plastic, etc.) or glass type (like heat resistant glass or leaded glass) are not accepted in the glass container. The sheet glass collected can either be single, double or triple-glazing. Such waste glass may **result from the production and processing of glass, or from building renovation or demolition projects**. Their high quality glass cullet (i.e. without contamination by bricks, stones, porcelain, organic impurities, cork, paper, plastics, etc.), is attributed to VRN's established high standards of quality and glass acceptance guidelines.

The service for glass collection is fast: **containers are replaced within three working days after notification** has been received that they are full. VRN outsources transport to a single national transport company (chosen through a tender procedure) that collects sheet glass from the collection points and exchanges containers. VRN has created special transport routes, tailored to efficiently picking up small containers. This makes it possible to have the smaller containers (0,5m^3, 1m^3 and 2m^3 containers) exchanged 1 time per week on a fixed day, depending on the location.

[93] Float glass, insulated glass, wired glass, laminated glass, silvered glass, toughened glass, horticultural glass, coated glass, etc.

About 25 to 30 containers are collected every day. In 2013, **74 821 tonnes** of waste sheet glass were collected, yet it is difficult to translate this figure in an average tonnage collected per collection point per year, as the collected tonnage includes cullet from temporary containers. These figures are a slight decrease from 2012, which can be attributed to less renovation and demolition projects stemming from the crisis. These quantities are divided up in the following glass types:

Table 17: Glass waste collected by VRN in 2012 and 2013

Glass Type	2012	2013
Clear float (very pure)	8 978	6 452
Green house glass	0	0
Mirror	301	339
Laminated glass (has a PVB film)	9 121	7 674
Combination glass	66 809	60 277
Dirty combination glass	381	79
Total	85 590	74 821

80.6 % of flat glass collected in 2013 (a slight increase from 78 % in 2012) **is combination glass**; **partly from building renovation projects,** and, to a lesser extent, from demolition projects. Some of the glass is also cutting waste of glass **producers or window manufacturers.**

Communication is key

Communication is vital in collecting large volumes of sheet glass, preferably of the highest quality, so VRN attempts to publicise as much information as possible in many different ways:

- A newsletter published three to four times a year;
- An informative website listing all the collection points;
- A Twitter page with an updated newsfeed;
- A flyer that glass suppliers can give to their customers;
- Participation at relevant trade fairs in order to meet people manufacturing, distributing or using sheet glass in their work;
- Training of collection point managers about what type /quality of sheet glass should be accepted; and
- Several mailings to municipalities and local authorities giving them information about VRN.

Good logistics is paramount

Logistics is where more than half of the costs are involved. VRN has thoroughly looked together with the transport company Van Gansewinkel[94], were the collection points should be located and how they could reduce the transport distances between each stage (collection, treatment, and recycling i.e. incorporation into production) for economic and environmental reasons (CO_2 emissions). Therefore **2**

[94] This transport company was selected to work with VRN based on a public tender.

storage points, in Amsterdam and Meppel, were set up to receive the glass from some of the collection containers; and from there the **glass is transported to treatment facilities by vessel** (a vessel can transport 800 tonnes of glass), which is cheaper than by road.

Maltha, a cullet preparation facility located in Belgium, treats waste glass collected in Belgium and the Netherlands, travels up to 300 km one way to pick up flat glass waste; however they usually do reverse logistics to maximise resources. Trucks are either rented from a logistics company, or a logistics company itself deals with the glass transport, depending on distances and costs.

Although Maltha is based in Belgium, this Dutch company is well situated geographically with good access to VRN and to outlet industries, via boat or truck. From some other locations, containers are transported directly from the collection point to the treatment facility by truck. Minerale SA, another treatment company that VRN works with is also based in Belgium, and thanks to its geographic advantage, 100% of waste is transported from VRN to Minerale via vessel. In 2013, about **37 692 tonnes of building glass waste was transported by vessel**. This enabled to **reduce the CO_2 emissions by 25% between 2008 and 2013**. [95]

Although the environmental benefit of transporting flat glass cullet via vessel is clear, the economic advantage is no better than transporting by truck; both forms of transport bear the same economic cost (choosing to transport the glass by vessel means extra costs of storage place, handling and administration).

Description of the recycling system

Sheet glass is 100% recyclable and reusable. Via a public tender, VRN currently contracts with two **treatment facilities based in Belgium**, Minerale in Lodelinsart and Maltha in Lommel. Treatment facilities sort and prepare the waste sheet glass into cullet before selling it; Maltha in particular receives windows and wood frames (PVC frames are bought and treated by another Belgian treatment facility) from the residential sector, and sells its cullet to the following industries (in descending order): bottle glass, flat glass, glass wool (isolation glass), and foam glass industries.

Any sheet glass that is too dirty to be recycled is removed as residual waste and landfilled. Only a small percentage of all sheet glass is too filthy to be recycled. In 2013 only 79 tonnes of the total tonnage VRN collected did not meet the standards. VRN's quality control and acceptance guidelines improves the quality and results in a less tonnage to be rejected. Moreover, VRN encourages treatment facilities to sell their prepared sheet glass to the sheet glass industry as much as possible via their communication efforts.

In 2013, 13% of prepared sheet glass cullet **went into the flat glass industry** (target is 20% in 2014), 32% **into the glass wool industry**, and **55% to the packaging industry (to make clear glass bottles). No sheet glass went to the glass bead industry or any other industry.** These percentages are indirectly influenced by VRN since treatment facilities must first consider VRN's selling rate for flat glass waste (~EUR 10-30/tonne) in order for them to price and allocate their cullet to the most appropriate and profitable outlets (different quality requirements in different industries).

Considering the environmental impact of cullet usage, for every 10% of cullet used in glass manufacturing, energy consumption is reduced by 2.5% and CO_2 emissions by 5%.[96]

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[95] VRN received in 2011 the Lean and Green award from Connekt and **in 2013 the Lean and Green Star award**. This is an **incentives program** which stimulates companies to grow to a higher level of sustainability in their logistics, by taking measures which do not only yield saving in costs, but also reduce the environmental impact.
They have also been nominated for the November 2013 Lean and Green Award Star, next step in this program.

[96] "Vlakglasrecycling Nederland - Home." Vlakglasrecycling Nederland - Home. N.p., n.d. Web. 2014. <http://www.vlakglasrecycling.nl/index.php?page=home-en>.

VRN currently carries research into enhanced treatment techniques, in collaboration with treatment facilities and knowledge institutes. Having a 'Cradle to Cradle' philosophy, their aim is to achieve a highest possible amount of sheet glass to be re-used in the sheet glass industry, because less raw materials and energy would then be needed by this industry.

Specificities and adaptability of the setup in other geographic regions

VRN's country-specific collection scheme is reliant on the following factors:

- Its small geographical boundaries are beneficial when ensuring short distance transportation of flat glass waste, and consequently lower transportation costs.
- As seen at the beginning of this case study, there is a uniform way of integrating window frames into building structures at the stage of construction (glass units are added afterwards into frames already in the building) which allows easy and low cost disassembly of window glazing.
- The Netherlands glass manufacturers are willing to finance the system via an eco-fee on double or triple-glazing put on the market.
- Pursuant to environmental laws, the Dutch Ministry of Infrastructure and Environment has declared VRN's system regarding the waste levy generally binding.

On the one hand, it must be noted that some of the treatment facilities interviewed throughout this study see some unattractive aspects about "VRN's monopolistic position". Since VRN is the only Dutch compliance scheme for building glass, (i.e. the only entity that collects fees from flat glass manufacturers in the Netherlands), they are not challenged enough by national competitors, and thus not incentivised to rationalize their costs and offer a lower price for the glass waste they sell to cullet preparation facilities. As mentioned before, nowadays VRN sells the glass waste from € 10 to € 30 per tonne, depending on quality. In this sense, some treatment facilities would like to see the introduction of another compliance scheme in the Netherlands for building glass.

On the other hand, according to VRN, there are other national and commercial competitors which have recycling networks. Moreover, it is possible under environmental laws to obtain a release from the collection system of VRN, which has taken place (there are also exemptions foreseen in the environmental laws). To rationalize its costs, VRN organizes tenders to contract with treatment company partners.

The waste levy remained stable over the last few years without changing VRN's service level, and VRN's aim is to decrease this waste levy in the near future. Cost rationalisation has therefore the particular attention of VRN, although profitability is not there yet.

Best practices

The Netherlands have strict acceptance conditions for the collected sheet glass waste – one of them is that they do not accept any window frame or other materials whatsoever. Indeed, quality of glass skips is lower if frames are left inside, and as very few of Dutch buildings' window frames are in aluminium (most of old frames are in wood, and those in aluminium are difficult to collect because they are frequently sold informally to scrap dealers), recycling frames is not a profitable operation. Thanks to proper communication and training, the quality of the glass collected through VRN network is on the rise.

Economic aspects: breakdown of cost elements at different stages

- **Dismantling versus demolition**

In the Netherlands, 25% of flat glass is removed from buildings (and from their frames) before demolition. This is still not profitable because of the labour cost.

- **Collection scheme costs: 2012 vs 2013**

VRN expects that the costs will remain stable next year. They are studying the idea of having their own containers.

Table 18: Collection scheme costs, 2012 vs 2013

Collection Scheme Costs 2012		
Transport (~€ 27/tonne)	€ 2 292 819	55,6%
Other (including office costs € 169k, external consultancy and assistance costs: € 330k:; and sales costs: € 143k)	€ 642 820	15,6%
Container rent	€ 424 858	10,3%
Collection system (VRN pays the collection points a small compensation for time spend on quality and safety checks and costs of cleaning)	€ 380 844	9,2%
Wages and salary	€ 178 944	4,3%
Costs of the different storage points for the cullet	€ 117 489	2,9%
Social security charges	€ 53 085	1,3%
Depreciation on tangible fixed assets	€ 30 630	0,7%
Total	€ 4 121 489	
Collection Scheme Costs 2013		
Transport (~€ 29/tonne)	€ 2 220 641	57,8%
Other	€ 436 113	11,3%
Container rent	€ 420 428	10,9%
Collection system	€ 400 209	10,4%
Wages and salary	€ 228 576	6,00%
Costs of the different storage points for the cullet	€ 73 725	2,0%
Social security charges	€ 36 645	1,0%
Depreciation on tangible fixed assets	€ 24 781	0,6%
Total	€ 3 841 118	

Estimations of window removal times, glass separation and labour costs

- **Average removal time (hours) for 1 tonne of windowpanes from buildings**

This scenario has numerous variant factors to take into account. As the weight of the windowpane depends on the size and thickness of the glass along with the composition of its frame, it is hard to

give a general calculation per tonne. Furthermore, window-removal techniques change if the window in question is on the ground floor of a residential building versus if it is in a high-rise tertiary building. For example, a high rise tertiary building would require a crane for window removal, while a one story residential building would not. For these reasons, it is difficult to indicate a standard scenario that would encompass all factors.

The following hypotheses were therefore made by VRN to make assumptions on time and labour needed for window removals:

- ✓**One story residential and terraced family house**
- ✓**Double glass pane 4/15/5 (9 mm glass)**
- ✓**Size of the pane +/- 1300 x 1200 mm.**

VRN approached 3 glaziers[97] for their input on the example. The above example takes into account the fact that buildings in the Netherlands only require windowpane removal, as the frames are integrated into the building's structure. This situation is furthermore to be approached as one with normal conditions and with windows using normal sealants

1) Scenario 1: Removing glass panes from PVC, aluminium or steel window frames
Around +/- 15 minutes per person is needed to remove a window from its frame. This windowpane needs to be removed by two people.
2) Scenario 2: Removing glass panes from wooden frames
Around +/- 30 minutes per person is needed to remove a window from its frame. This removal time is longer because a wooden strip that seals the windowpane from the wooden frame needs to be removed. On average, a windowpane needs to be removed by two people.

These estimated times for window removal may undoubtedly change if the size and weight of the window is lighter or heavier than the one in the hypothesis. For heavier windows, more glaziers are needed in order to comply by worker safety rules and building norms, which stipulates that a worker cannot carry an object that is over a certain weight.

In most cases, it would take longer to remove a window in a high-rise tertiary building than in the two ground floor scenarios above because cranes and other window-removal machinery would need to be factored in.

- **The costs per hour for a glazier**

Based on VRN calculations[98], along with the gross wages per month for the sheet glass industry in the Netherlands, the cost per hour for a glazier is a gross rate of +/- € 25,00 per hour. These wages include a +/-25-30% originating from social security costs, retirement costs, etc., and an additional overhead cost.

[97] As the information regarding removal time only comprises the input of three glaziers, the information presented should be approached with caution.
[98] "Vlakglasrecycling Nederland Removal Costs and Worker Wage." based on the collective labour agreement of the Dutch glass industry." Email interview. 20 Feb. 2015.

Criteria for financial viability of the collection scheme

The scheme is mostly financed by means of a waste management levy (waste disposal fee). This amounts to 0.50€ for every square meter of insulated double or triple-glazing[99] that is put on the Dutch market. Every manufacturer and importer is obliged to pay the charge. No fee has to be paid for single sheet glass, as the current waste levy for single-glazing is established at € 0/tonne.

In VRN's scheme, revenues do not cover all operating costs; the 2013 operating result is negative: - € 452.572, as compared to - € 376 514 in 2012.

A **compensation revenue (14€/tonne)** is also received from the treatment facility for the delivered cullet.

Collection Scheme Revenues 2013		
Waste management levy	€ 2 061 767	61,4%
Sales of cullet to treatment facility (€14/tonne)	€ 1 075 500	32,1%
Container rentals	€ 217 098	6,4%
Other earnings	€ 979	0,1%
Total revenues	€ 3 355 344	100%

VRN can lose money as long as the waste management levies of previous years cover this loss. Yet VRN expects that, due to the economic crisis, the earnings of the waste management levy to decrease by 8 to 10%, because there are less construction projects and thus less flat glass put on the market. Other revenues should remain stable. Other materials from flat glass products (e.g., metal and wood from window frames) are out of VRN's collection scheme, therefore these other materials could never be additional sources of revenue for VRN.

In a nutshell, the criterion that could impede from financial viability are logistics costs and the lack of fees levied from producers. VRN's transparent financial yearly results have showed a progressive trend downwards. According to VRN, *"this has been taken into account in the last tender procedure of 2013. The 2014 tender procedure for treatment resulted in new contracts and consequently in small, yet positive numbers based on 2014's initial figures".*

Presence of innovative solutions (for dismantling, collecting, and recycling)

In anticipation of the new European legislation banning the landfilling of demolition waste, which includes glass, VRN is conducting a study together with several other branch organisations on the opportunity and challenges to dismantle more sheet glass from buildings during renovation and demolition projects. About 15 000 to 20 000 tonnes of glass is lost in demolition glass each year (these quantities are based on information of 2011, no exact recent figures are known at this moment), which represents 3/4th of the available flat glass waste in buildings being demolished[100].

[99] Double-glazing (also called insulated glazing or double-pane) is double glass window panels separated by an air or other gas filled space to reduce heat transfer across a part of the building envelope.

[100] These estimated figures are based off of VRN's 2011 statistics and were calculated as follows: One residential building has +/- 22m² of flat glass. Thanks to data from CBS, it was possible to determine the amount of demolished houses per year. This means that the amount multiplied by 22m flat glass multiplied by 20kg (average weight of 4 mm float glass) results in a total. There are some collection and storage points that receive glass from demolition projects, and VRN is aware of how much sheet glass is collected from these points. The total from these points is reduced from the former calculated total and added a margin of 30% (because some demolished buildings have double-glazing instead of single-glazing). This results in a +/- total of glass cullet that is not collected from demolition.

Possibilities for synergies (recycling of residual materials)

- **Research into collecting and recycling of empty plastic sealant tubes:**

VRN ran a project until 2012 to collect and treat empty plastic sealant tubes that commonly contaminated flat glass containers. By recycling the plastic sealant tubes, 20% of CO_2 emission was reduced and 70% less virgin material was used, the quality of the prepared product being very good. A demonstration pilot for collecting and recycling of sealants tubes ran and was evaluated at the end of 2013. After evaluating the demonstration pilot, VRN concluded not to continue and not to set up a structural system of collection of plastic coatings as during the demonstration it showed that some plastic sealant tubes collected were still mixed with pollutants. Furthermore, as all materials besides glass are excluded from VRN's scheme, it would not be applicable to integrate empty plastic sealant tubes into its recycling system.

4 Sources

- Vlakglas Recycling Nederland (VRN);
- Maltha recycling;
- Association of Dutch Glass manufacturers (VNG);
- Economisch Instituut voor de Bouw (EIB).

Poland

1 The Polish building glass market

There are four main flat glass producers in Poland: Saint Gobain, NSG, Guardian, and Euroglass and each production line produces about 600 tonnes of glass per day. While Saint Gobain is Poland's main flat glass manufacturer, this company is more focused on the automotive sector than on the building sector. Out of the four main glass producers, Euroglass is the smallest producer. Saint-Gobain estimates that 80% of the flat glass produced in Poland is destined to the construction sector[101].

Poland consumed 13.6 million m² of insulating glazing in 2013[102]; 65% of it was allocated to renovation purposes.

Historically speaking, Polish buildings have used double paned windows for many years, due to the country's cold climate, especially in winter. According to the Polish Glass Manufacturers Federation, single-paned windows are still mainly found in some old wooden buildings in the countryside, but in a negligible proportion.

In any case, these double-paned windows, which were installed in buildings before the communist era (before the 90's), have low preforming energy efficiency/insulation characteristics, compared to modern double paned windows that are installed nowadays. These double paned windows consist of two single panes of glass forming one unit, without coatings, and without special inert gas inside (these components are used in modern double paned windows to give the window its isolative property). Moreover, these windows were not made of float glass, but of rolled glass (the first float glass line in Poland opened in the 90's).[101] The rolling process makes a patterned, figured and cast transparent glass product.

In regards to window frames, 80% of collected frames from the residential or tertiary sector and the renovation and tertiary sector in Poland are composed of timber. In the 1990s, window frame installations changed from wood to mostly PVC. Today in new construction projects, which are mostly carried out in urban areas, 75% of window installations consist of PVC frames, 20% consist of timber, and 5% consist of metal.

The 2012 report "*Social Dialogue Centre for Glass Industry: Report on Project Implementation*", commissioned by the Polish Glass Manufacturers Federation, forecasts that doors may open in the Polish market for the future of flat glass manufacturing, because of projected investments in production capacities and thanks to the modernisation of existing glass furnaces[103]. Poland has an advantageous position to further develop and grow their flat glass industry, thanks to their country's availability of raw materials, ample human resources, central geographic location, and developing market – all signs indicating growth within this sector. Regardless, they still produce nearly two times less flat glass then Western and Northern Europe. [104]

Specificities on the Polish hollow glass industry

[101] Polish Glass Manufacturers Federation.
[102] "Eurostat Home." Eurostat Home. N.p., n.d. Web. 2014. <http://epp.eurostat.ec.europa.eu/portal/page/portal/eurostat/home/>. (Eurostat 2013 data).
[103] Poland, Focus. "Glass in Pole Position." Glass in Pole Position (n.d.): 19. Nov. 2012. Web. 22 Oct. 2014. <http://www.stoelzle.com/UserFiles/stoelzle/File/pdf/News/Poland_focus.pdf>.
[104] Poland, Focus. "Glass in Pole Position." Glass in Pole Position (n.d.): 19. Nov. 2012. Web. 22 Oct. 2014. http://www.stoelzle.com/UserFiles/stoelzle/File/pdf/News/Poland_focus.pdf

In Poland, the hollow glass industry, like the flat glass industry is still young. According to the Polish Glass Federation, the national hollow glass production capacity in Poland is around 1,400 thousand tonnes/year. There are a total of seven hollow glass treatment sites, in which two treat both hollow and flat glass (DSS Recykling in the centre, and TEW Recykling Szkla in the South). In addition, four out of these seven treatment sites have together the potential capacity to take on an additional 500 thousand tonnes of glass waste per year meaning that Polish treatment centres are collectively and currently *under* their potential treatment capacity.

This bottleneck was identified as not sourcing from manufacturers' infrastructural inability to take on more glass for treatment. Rather, it stems from an underdeveloped glass waste collection system. An interesting point to underline is that these four hollow glass treatment centres are geographically near flat glass manufacturers, a potential advantage in terms of transportation.

The following four regions (see circles in map) embody the locations of treatment centres that have the capacity to take on more glass waste, which are also within the same vicinity as flat glass manufacturers.

1. Mazowieckie region: One treatment centre
2. Wielkopolskie region: Two treatment centres
3. Silésie region: One treatment centre

Figure 14: Map of Poland Flat Glass Manufacturers and Regions with Treatment Centres (not to scale)

2 Building glass waste arisings

Glass waste arising from renovation

As 65% of insulating glazing is sold for renovation projects, 8.9 million m² of glazing was replaced in Poland in 2013. Considering that around 5% of old windows were single-glazed and 95% double-glazed (replaced by double- and triple-glazed windows only),[105] and taking into account assumptions at the beginning of chapter one, it can be estimated that:

- Over 132 000 tonnes/year of glass waste is generated by the replacement of old windows (and doors) in residential buildings, and
- Over **62,000** tonnes/year of glass waste is generated by the replacement of old windows (and doors) in tertiary buildings.

The glass waste generated by the renovation of interior glass and glass walls in dwellings could not be estimated. However, most glass within buildings comes from its windows; interior glass is rarely renovated.

[105] In Western, Northern and Central (only Germany & Austria) Europe, the penetration of double paned glass overall is ~80% (85% in Germany and the Netherlands).

Glass waste arising from demolition

The number of dwellings demolished is unavailable in Polish statistics but it has been assumed that the Polish residential demolition rate is close to that of the Czech Republic (0.02%[106]) and Slovakia (0.07%[106]). Taking these figures into account, the Polish residential demolition rate should therefore be around 0.05%. Furthermore, it is considered that windows and glass walls represent an average of about 15% of the square meter useful floor area in a Polish dwelling, and that in demolished dwellings, 5% of windows and glass walls are single-glazed and 95% double-glazed. Since 13 million dwellings in Poland have an average size of 70 m², which indicates that *more than* **1 000 tonnes of glass waste** (about 69 000 m²) **are generated annually through the demolition of residential buildings.**[107]

It is difficult to estimate what percentage of the surface area of a tertiary building glass represents on average, but it has been assumed that there is at least twice more glass (windows and glass walls) in a tertiary building than in a domestic building, i.e. 40%. Based on this hypothesis, and knowing that in the EU in general, about 0.2% of non-domestic buildings are demolished annually[108], there should be over **8,000 tonnes** (about 282 000 m²) **of glass waste generated through the demolition of tertiary buildings**. This is a very rough estimation, to be considered with precaution.

Table 19: Country estimations of flat glass waste arising from building demolition and renovation (2013)

Sector	Tonnage generated	Sub-sector	Tonnage generated
Residential	133 463 tonnes	Renovation	132 111 tonnes
		Demolition	1 352 tonnes
Tertiary	70 872 tonnes	Renovation	62 579 tonnes
		Demolition	8 293 tonnes
Total		204 335 tonnes	

Table 20: PROJECTIONS for 2025 Country estimations for flat glass waste arising from building demolition and renovation[109]

Sector	Tonnage generated	Sub-sector	Tonnage generated
Residential	134 489 tonnes	Renovation	133 127 tonnes
		Demolition	1 362 tonnes
Tertiary	71 417 tonnes	Renovation	63 060 tonnes
		Demolition	8 357 tonnes

[106] Equals the number of dwellings demolished divided by the installed base of dwellings (national statistics).
[107] National census, GUS, 2007. (Source of the number of dwellings and average dwelling size)

[108] Schimschar, Sven, Jan Grözinger, Henning Korte, Thomas Boermans, Velizara Lilova, and Riadh Bhar. "Panorama of the European Non-residential Construction Sector." (2011): n. pag. Web. <http://www.leonardo-energy.org/sites/leonardo-energy/files/documents-and-links/European%20non-residential%20building%20stock%20-%20Final%20Report_v7.pdf>.
[109] Deloitte Estimations.

Total	205 906 tonnes

3 Collection and recycling of building glass

Previously, waste collection companies needed to establish contracts with each individual household to collect municipal waste (including hollow glass), and collected waste door-to-door. Since 1st July 2013, this system changed. Local municipalities were given the responsibility to collect any type of waste originating from each commune's inhabitants. Taxes varying from one municipality to the other were additionally implemented to finance waste collection, and each municipality was given the possibility to contract with a waste management company to operate its system. Yet, regardless of the fact that selective collection of end-of-life building materials are included in the 2014 National Plan for Waste Management (*Krajowy Planu Gospodarki Odpadami),* municipalities are not required to, and therefore do not have specific targets on demolition waste for each type of waste stream.

In this context, Poland does not have a developed collection scheme for building glass. Most of it is known to be landfilled (landfill cost is perceived as a high cost yet it is still cheaper than sending glass waste to treatment centres). Regardless, to date, no hard data exists on the topic.

There are four main glass treatment centres in Poland, with only two specialising in flat glass recycling. The first being TEW Recykling Szkla and the second being DSS Recykling, which is headquartered by the German glass treatment company, Reiling. These treatment facilities could not be interviewed for this study, but according to the Polish Glass Manufacturers Federation, DSS Recykling now collects and treats some old windows originating from the renovation of residential buildings, although the exact amount is unknown. DSS Recykling specialises in architectural flat glass treatment – although the majority, if not all, originates from the pre-consumer sector (from Poland's largest flat glass manufacturers: Guardian in Czestochowa, Pilkington in Sandomierz and Saint Gobain Glass in Dabrowa Górnicza).[110]

4 Sources

- Polish Glass Manufacturers Federation
- Saint-Gobain Glass Polska

[110] Poland, Focus. "Glass in Pole Position." Glass in Pole Position (n.d.): 19. Nov. 2012. Web. 22 Oct. 2014. http://www.stoelzle.com/UserFiles/stoelzle/File/pdf/News/Poland_focus.pdf

The United Kingdom

1 The UK building glass market

The glass manufacturing industry in the UK is mostly based in the north of England. The UK manufactures 700,000 tonnes of flat glass yearly; three quarters of which is devoted to glazing products for buildings, i.e. about 525 000 tonnes.[111] The UK consumed 15.3 million m² of insulating glazing in 2013 (60% for renovation purposes[112]). Historically, the volume of glass used in buildings has grown, with a change from single to double or even triple-glazing.

2 Building glass waste arisings

Glass waste arising from renovation

10 years ago, the UK domestic replacement window market renovated 6.6 million windows and 0.99 million secondary glazing units per annum. [113] Furthermore, over 5 million window frames had been removed per annum consistently since 1990. Whilst at that time some signs of market maturation were already present, the replacement of "replacement windows" (i.e. windows of second generation) was increasing. One fourth of window replacements per annum were replacements of replacement windows: 73% of the windows replaced where single-glazed wooden windows, 11% were single-glazed steel windows, 9% were double-glazed aluminium windows, and 7% were double-glazed PVC windows. As the types of frames used by the replacement window sector increasingly migrate from single-glaze panes to double-glaze panes and from soft wood frames to PVC frames, the volume of waste glass and PVC frames is expected to increase significantly in the coming years. [114]

9.2 million m² of glazing were replaced in the UK in 2013. Considering that only 40% of replaced windows are currently single glazed and 60% double-glazed (replaced by double and triple glazed windows only) and taking into account assumptions at the beginning of chapter one, it can be estimated that:

- Over 106 000 tonnes/year of glass waste is generated by the replacement of old windows (and doors) in residential buildings, and
- Over 62 000 tonnes/year of glass waste is generated by the replacement of old windows (and doors) in tertiary buildings.

It was not possible to estimate the cullet generated by the renovation of interior glass and glass walls in dwellings, but it can be determined that most glass in buildings comes from windows, and interior glass is rarely renovated.

Case study: City of London icon Lloyds of London's large scale flat glass renovation project

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[111] WRAP Environment Agency. *Collection of flat glass for use in flat glass manufacture.*
[112] Interview with Saint Gobain Glass, France
[113] "There are over 12,500 specialist double-glazing and home improvement companies who fit windows and doors in the UK, primarily in the domestic sector. Most of these companies (about 11,000) do not manufacture, and will buy their products from a fabricator. Installers are often loyal to a particular window system brand, and can vary in size considerably (from those installing under 25 frames per week to those installing well over 250 per week). Furthermore, many local builders will also install windows and doors, often as part of a refurbishment or extension, or while installing a new kitchen, bathroom or during renovation work. There is a growing trend for local builders to promote double-glazing as part of their service, rather than simply as part of a refurbishment/extension." Find more info on https://www.insightdata.co.uk/double-glazing-window-conservatory-industry.htm.
[114] Hurley, James (BRE). "RESEARCH INTO WASTE GLASS, WINDOW AND DOOR FRAMES FROM THE DEMOLITION AND REPLACEMENT WINDOW INDUSTRIES." (2003): n. pag. Web. 2014. <http://www2.wrap.org.uk/downloads/ResearchIntoWasteGlassWindowAndDoorFrames.32acb1ef.377.pdf>.

Built in 1986, the Lloyds of London building was notorious for its unique shimmering, or glowing-effect that it cast on the city. This shimmering-effect was caused by a special type of glass material used throughout the building, known as “sparkle glass”, which is characterised as having small 8mm divot lenses that produces a sparkle-effect upon contact with light. In 2010, it was determined that a comprehensive window replacement project would be launched to replace the sparkle glass with clear glass. As sparkle-glass is known to impede high levels of light penetration through glass, the objective of this window replacement project was to make the building’s interior more luminous.

The window design of the building consisted of one solar-control coated outer double glazing unit (DGU) and one inner secondary glazing layer (SGL) consisting of sparkle glass. The majority of sparkle glass was removed and replaced with clear glass, however, a portion of the sparkle glass was reintegrated into the building to create thinner bands of sparkle glass across its façade to ensure the building’s glowing appearance. To revalorise the building’s characteristics, a small percentage of the remaining glass was cut and designed into “sparkle-glass” coffee tables that were distributed throughout the building.

On site engineers and project managers were a crucial part of the project’s successful execution, who took the building’s uninform shape into account and monitored the risk for glass contamination. Windowpanes, which were dismantled on a rolling basis were stored on temporary stillages before collection and transport to either a site in Belgium to be prepared for reintegration into the building, or sent to Saint Gobain Glass (SGG) UK to carry out window and frame separation for reintegration into their manufacturing process. All post-consumer flat glass from the building was treated and reintegrated into manufacturing; for those window frames that came out with defects, they were crushed and treated for a second time.

This collaboration with SGG **marked the first time that this flat glass manufacturer integrated post-consumer flat glass into their manufacturing process to create new glass**, although they had facilitated pre-consumer flat glass reintegration since 2001 with various factories and suppliers.

The cost of this renovation had three main pillars: labour: £4 896 + dismantling cost: £ 1 525; disposal: £335 = total of £6756 (EUR 9 098).

As a comparison, the cost for landfilling the glass waste (including transport) would have been £6 756 (EUR 9 110).

Although these cost outcomes are not much different from one another, this breakdown shows that treating and reincorporating cullet for manufacturing is not more expensive than landfilling. However, if SGG’s payment of £15 (EUR 20) per tonne, the treatment and reincorporation of this post-consumer cullet ends up being more financially viable.

This unique project, which has not been replicated to date, was successfully carried out with a waste production level of less than 1%[115].

Glass waste arising from demolition

Near 16 000 dwellings were demolished in the UK in 2012[116] (the average size of a UK dwelling is 76 m²). This means that about 1.2 million m² of **dwellings** are demolished each year, generating **6 000**

[115] Bowers, Mark. "Lloyd's of London: A World First for Recycling." 2011: n. pag. Web. 15 Feb. 2015.

[116] Department for Communities and Local Government. Net Supply of Housing: 2012-13, England (n.d.): n. pag. Web. 2014. <https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/255431/Net_Supply_of_Housing_England__2012-13.pdf>.
http://www.scotland.gov.uk/Topics/Statistics/Browse/Housing-Regeneration/HSfS/Demolitions ; "Scottish Government." Housing Statistics for Scotland. N.p., n.d. Web. 2014. <http://www.scotland.gov.uk/Topics/Statistics/Browse/Housing-Regeneration/HSfS/Demolitions>.Wales : https://statswales.wales.gov.uk/Catalogue/Housing/Demolitions ; Wales : https://statswales.wales.gov.uk/Catalogue/Housing/Demolitions; Dwellings Demolished by Local Authority and Clearance Area.

tonnes of glass waste from the residential sector; taking for granted that in the UK, glass represents approximatively the equivalent of 30%[117] of the floor surface of a residential building.

Furthermore, we assume that the UK demolition rate for tertiary buildings is close to the German demolition rate (0.3%[118]). Based on this hypothesis, there is an estimated **23 000 tonnes** of glass waste generated annually through the **demolition of tertiary buildings**. This estimation is to be considered with precaution. Indeed, it largely depends on the percentage glass represents in the floor surface of a tertiary building. According to the UK National Federation of Demolition Contractors, the surface of offices could contain as much as 90% of glass, with many offices now having full height glazed facades. Yet, renovated or demolished buildings rarely consist of 90% glass. As for the retail sector, it is difficult to make an assumption on the percentage of glass that makes up a building as many retail units are nowadays located within mall settings which have high levels of glass frontage. Without any data on the topic, it was preferred to use the same assumption of the other case studies within this study. This means that glass represents at least the equivalent of 40% of the floor surface of a tertiary building.

Table 21: Country estimations of flat glass waste arising from building demolition and renovation(2013)

Sector	Tonnage generated	Sub-sector	Tonnage generated
Residential	113 792 tonnes	Renovation	106 840 tonnes
		Demolition	6 952 tonnes
Tertiary	85 456 tonnes	Renovation	62 324 tonnes
		Demolition	23 132 tonnes
Total		199,248 tonnes	

Table 22: PROJECTIONS for 2025 Country estimations for flat glass waste arising from building demolition and renovation[119]

Sector	Tonnage	Sub-sector	Tonnage generated
Residential	122 328 tonnes	Renovation	114 854 tonnes
		Demolition	7 474 tonnes
Tertiary	91 865 tonnes	Renovation	66 998 tonnes
		Demolition	24 867 tonnes
Total		214 192 tonnes	

3 Collection and recycling of building glass

Economic and regulatory context

The trend to furnish buildings with increasingly large glazed areas and the increase in replacement of double-glazed units will inevitably lead to increasing volumes of flat glass waste arising from the demolition and replacement window sectors. This increase in waste, coupled with the increasing

Stats Wales, n.d. Web. 2014. <https://statswales.wales.gov.uk/Catalogue/Housing/Demolitions/DwellingsDemolished-by-Authority-Clearance>.
[117] Estimation of the UK National Federation of Demolition Contractors.
[118] DESTATIS, 1999-2009.
[119] Deloitte Estimations.

landfill costs (doubling from £40 (EUR ~50) per tonne on average on 1 April 2009[120] to £80 (EUR ~100) per tonne on average on 1 April 2014[121]) will prove a significant burden to the industry and may incentivise the development of other disposal routes such as flat glass treatment.

Collecting and recycling building glass in the UK

Five companies in the UK collect glass waste from construction sector in view of recycling. Three are treatment companies (Berrymans, GB Cullet and Viridor), one is a flat glass manufacturer (Saint-Gobain), and the last one is a ballotini (glass beads) manufacturer.

While Berrymans and Viridor[122] have nationwide coverage, they collect flat glass waste near their treatment sites. The flat glass that they collect consists of offcuts from window makers ("pre-consumer" glass), and of old windows which have been replaced, such as old glass architectural facades, old mirrors, etc. ("post-consumer" waste).

Collection sites

Berrymans, GB Cullet and Viridor collect glass in large labelled metal skips (containers) at C&D sites. Individual consumers and window installers can also bring flat glass from the residential sector directly to collection/treatment depots. For instance, the Household Waste Recycling Centre (HWRC) in Oldbury (near Birmingham) successfully collects 10 tonnes of flat glass per week from individuals. Berrymans picks up the flat glass at the HWRC twice a week and asks the local council a far lower cost for collection and treatment as compared to the landfill cost. ***The case study below***, written by an Environmental Policy Adviser of British Glass Manufacturers' Confederation after a field visit, ***illustrates this experiment.***

Case Study: Household waste collection centre in Oldbury, UK collects flat glass

[120] 2015, February. "Landfill Taxes & Bans." (n.d.): n. pag. CEWEP, Feb. 2015. Web. 1 Feb. 2015. <http://www.cewep.eu/media/www.cewep.eu/org/med_557/1406_2015-02-03_cewep_-_landfill_inctaxesbans.pdf>.
[121] GOV.UK "Green Taxes, Reliefs and Schemes for Businesses." - GOV.UK. N.p., n.d. Web. 2014. <https://www.gov.uk/green-taxes-and-reliefs/landfill-tax>.
[122] Viridor has 3 sites which process flat glass, however these are run independently of each other and have their own commercial arrangements.

Case Study: Household waste collection centre in Oldbury, UK collects flat glass	
 *Figure 15: Specially designed flat glass recycling container*	
✓Location: Oldbury (near Birmingham), UK ✓Local authority: Sandwell council ✓Operator: Serco ✓Treatment company: Berrymans ✓Operational since: Early 2013	
Why did this scheme start?	We believe that a proactive and innovative person who was interested in glass treatment and recycling started the scheme. There is no legislative requirement to treat and recycle flat glass in the UK.
Types of flat glass collected for treatment	Window units, glass panes, broken clear glass (mirrors are not accepted)
How is the glass collected	Members of the public bring glass to the site and place it in a specially designed container for flat glass.
Amount of glass collected	The container is emptied twice per week. This is approximately 10 tonnes of glass per week.

Case Study: Household waste collection centre in Oldbury, UK collects flat glass	
Frames segregation	Frames must be removed before glass can be put into the container. Next to the flat glass collection container, another container collects doors & window frames. Sometimes, windows with glass are placed in the wrong container; site staff will try to separate the glass unit from the frame when this happens.  *Figure 16: Window frames are collected in a separate container next to the flat glass collection container*
Contamination controlled	There are large, clear signs on the front of skips, indicating which skips are for flat glass and which are for frames. The openings in the flat glass container are specifically designed to help prevent contamination. (i.e. A narrow slit allows for flat glass panes and window units to be inserted while keeping contamination such as Pyrex oven dishes out). Site staff are vigilant. They regularly observe what people bring to the site and check containers for contamination.  *Figure 17: Specially designed tray and chute allows flat glass to be inserted but prevents contamination (such as bricks or Pyrex oven dishes)*
Cost of scheme	Berrymans collects the glass from the local council at a far lower cost than cost of landfill. Cost of landfill is approximately £80 (EUR ~100) per tonne.[123]
Cullet processing	Glass collected at this HWRC is taken to a bulking/transfer station a few miles away. The glass is then loaded onto trucks holding approximately 28.5 tonnes each and driven to the processing centre 200 km away.
Keys to success	✓It is easy for members of the public to access and use this collection site. ✓Skip design is specially designed for flat glass collection and prevents contamination. ✓Other materials are also collected at the site and this helps to prevent contamination. Next to the flat glass skip, another skip to collect doors &

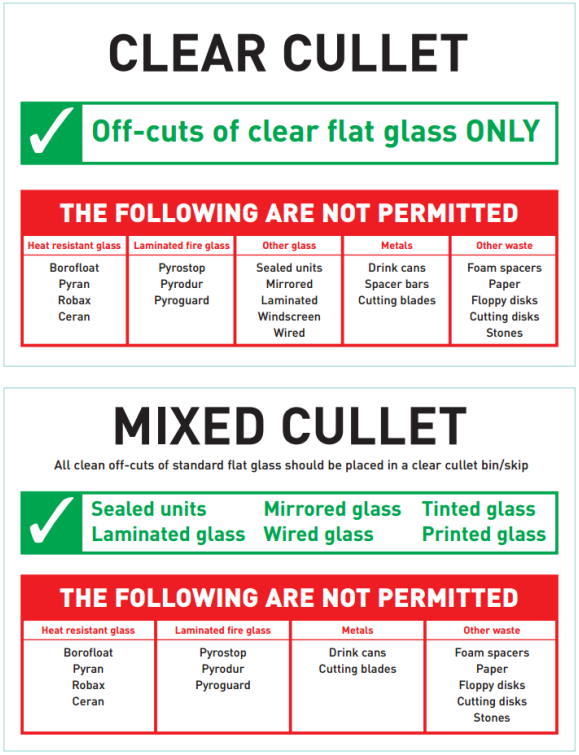
[123] 2015, February. "Landfill Taxes & Bans." (n.d.): n. pag. CEWEP, Feb. 2015. Web. 1 Feb. 2015. <http://www.cewep.eu/media/www.cewep.eu/org/med_557/1406_2015-02-03_cewep_-_landfill_inctaxesbans.pdf>.

Case Study: Household waste collection centre in Oldbury, UK collects flat glass	
	window frames is available, along with an additional skip for bottle collection. At the HWRC, there are also facilities to treat many other types of materials in addition to a skip for general waste. ✓Good site management – A competent site manager regularly monitors what is being put into containers and minimises contamination. The site is also kept clean and tidy which encourages the public to carefully segregate their recyclables.
Benefits of the Serco system	✓There is an overall financial and environmental benefit to all parties, when taking landfill and associated costs into consideration. ✓Treatment and recycling rates would improve and landfill would reduce. ✓More glass cullet would become available, hence reducing energy use and CO_2 emissions from glass manufacturing.
Potential ways to increase glass treatment and recycling	✓This scheme could be rolled out to other parts of the UK. ✓Flat glass from businesses is not officially accepted at the site. It is a common situation in the UK that HWRCs only accept waste from householders and not the commercial sector. Household sites could be opened to certain businesses such low volume, small window installers with an account and charging system.

It is generally understood that the quality of glass collected in skips is highly dependent on the managing capabilities of the site manager to properly supervise glass collection. Since several different types of glass make up buildings, it is the duty for site managers to ensure that workers and staff are properly educated on sorting, and most importantly, that they properly sort glass into their appropriate skips in practice. A poor project site management will result in a poor quality of collected glass, contaminated with bricks, metal cans, unacceptable forms of glass (bottles, heat-resistant containers, ceramics,) and other rubbish. Labels are not effective because construction workers many times see a skip and assume that any type of rubbish can be thrown into it, or they are simply not interested in flat glass treatment.

Figure 18: Examples of skip labels

Source: WRAP Environment Agency – Selective collection of building glass



Considering that glass is heavy to carry and that it induces a safety risk, an additional deterrent for workers to sort glass is the unavailability of properly placed skips on a project site.

When skips are very contaminated, it is no longer possible to recycle the glass because it becomes difficult to clean it to a standard acceptable to glass manufacturers. Contamination of recovered glass is generally the biggest challenge for the UK system[124]. Without increasing the availability of high quality cullet, it will be difficult to increase its use for glass manufacture.

According to treatment companies and to the UK Glazing Association, glass could be successfully collected when:

1. There is an incentive during the planning stage to collect glass separately at the end-of-life or renovation stage of a building, instead of mixing it with aggregates; this could be specified in contracts (early incentives allow careful planning of recycling);
2. The site manager or other responsible person regularly monitors collection and ensures that the containers are not contaminated by construction staff (this requires training site managers);
3. There is an incentive for construction staff to ensure that containers are not contaminated e.g. a small reward for staff for each good quality skip;
4. The C&D site is located near a treatment and/or recycling factory and/or some transport solution (such as back-hauling, or a collection round) is available;
5. Large quantities of glass can be collected in one place (e.g. at large renovation projects);

Logistics

Transport and logistics are very important to consider, as recovered glass is very heavy and consequently expensive to transport long distances. There is not sufficient infrastructure in the UK to enable large quantities of flat glass to be easily treated and recycled. In general, treatment facilities **do not set up/collect skips more than 50 km** away from their treatment centre or at least from their storage facilities, for the transport cost outweighs the benefits of using cullet.[125] Furthermore, they are located as close as possible to glass manufacturers.

Treatment companies cannot afford to provide skips to businesses that generate small quantities of flat glass (e.g. small window installers) because they may only get a few loads per year which is worth much less than the cost of the container. If governments or compliance schemes could provide (via subsidies) collection containers for small-scale users, this could allow treatment companies to collect flat glass from a large number of locations which currently have no glass treatment services. A possible solution to cutting down on the treatment centre's transportation costs when collecting flat glass waste could be to instate storage points complete with proper skips in low-service areas, which could also increase flat glass countrywide coverage.

Costs

A study made by the Glass Technology Services in 2003[126] illustrates the experience of two workers, which used a variety of techniques to remove 40 windows on a demolition site over an 8-hour shift and placed them into a 6.3 m³ skip. The total weight of materials was 658kg, of which 544kg of glass and 114kg of metal and wood. At an hourly rate of € 10 per hour for each staff, the cost for their time was € 161.

Table 23: Results of removing 40 windows over one day by two staff[82]

Number of operatives	Removal time	Element removed	Tools	Number removed	Number of undamaged panes	Weight of material
2	4 hours	Windowpane only 1m x 1m	Window sucker + Screwdriver + Saw + Hammer	20	2	272 kg
2	4 hours	Window frame with glass 1m x 1m	Window sucker + Screwdriver + Saw	20	20	386 kg

Removing entire windows and dismantling them on site with a hammer was thought of as being more onerous than only removing glass panes from a building, because of constant bending to pick up the broken glass on site and always being on alert for injuries from shattered panes

These results were then extrapolated to indicate what time and resources would be needed to remove all of the 400 windowpanes from the Nestle site in question. To remove all of the site's windows, it would have taken the two workers 10 days and would have generated 6.58 tonnes of material including 5.44 tonnes of glass and 1.14 tonnes of metal and wood. Furthermore, this would have cost € 1,608 in staff time and perhaps two skips at € 415 each. It would therefore have cost about **€ 370 per tonne to remove windows from the building**. [126]

[125] "UK Building Glass Recycling: British Glass Manufacturers' Confederation." Telephone interview. July 2014.

[126] WRAP, June 2003. Research into waste glass, window and door frames from the demolition and replacement window industries. (p.22-24).

Table 24: Extrapolated results to remove 400 windows over 10 days using two staff[82]

Total number of windowpanes	Weight of each pane	Element removed	Time taken to remove each pane	Total time	Total Person Hours	Cost per hour	Total removal cost
400	13.6 kg	5440 kg	12 min	80 hours	160 hours	€ 20.10	€ 3 215.92

Aside from this study, some treatment centres are willing to accept the material free of charge at their collection points, however, the average collection costs in the 2003 study ranged from € 37 to € 62 per 6.3 m³ skip, (assuming that the collection areas were within accepted parameters). The collection cost added to the cost of removing windows would therefore vary between € 407 and € 432 per tonne.

Comparing this to landfill charges plus transport, the cost per tonne to landfill would have been, in 2003, about € 370 per tonne, but at current landfill charges (€ 100 per tonne on average), the cost per tonne to landfill would nowadays be around € 446 per tonne. [126] This case study demonstrates that recovery of glass from **demolition projects** is hardly financially viable due to additional time and man power required, yet it depends, for a given demolition site, on the nearby presence of treatment centres willing to accept the waste at a low cost, and on the quality of the glass waste collected (contamination rate).

Of course, metal and plastic frames, which are worth more than the glass, could be additional sources of revenues. Yet, treatment companies interviewed during this study do not typically collect and revalorise frames. On one hand, removing frames in a manner that ensures its quality for selling requires added investment in technology to liberate frame materials from a feedstock of mixed C&D glass. On the other hand, this additional form of revenue is not typically envisioned as being a focus, as there are already other specialised companies that have a better hold on this market[127].

Cullet outlets

There is a demand for cullet; however, there has been a move towards the use of container glass cullet due to its high PRN value (evidence note), particularly in the fibreglass (loft insulation) market, rather than a move towards flat glass cullet. This means that the processing of the poorer quality demolition glass becomes more complicated, as the market for the processed cullet becomes narrower.[128]

4 Sources

- British Glass Manufacturers' Confederation;
- Glass and Glazing Federation UK;
- Glass Technology Services Ltd (GTS);
- NSG Group;
- Construction Products Association;
- National Federation of Demolition Contractors;
- Berrymans (treatment company);
- Viridor (treatment company).

[127] "FERVER Flat Glass Recycling." Telephone interview. 13 Feb. 2015.
[128] WRAP Environment Agency. Flat Glass Manufacture Waste Protocols Project Collection of Flat Glass for Use in Flat Glass Manufacture: A Good Practice Guide (n.d.): n. pag. Web. 2014. http://www.wrap.org.uk/sites/files/wrap/WRAP_Flat_Glass_GoodPractice_FINAL%20(2).pdf>.

Chapter 2:Quantification of available post-consumer building glass waste in Europe (Phase I.2)

As seen previously, triple-glazing or '2+1' windows has become the norm in northern European countries. In some central European countries, the longer-term plans of most governments include progress towards triple-glazing as the regulatory norm, as zero and low energy buildings become common. An example of the market-transforming effect of building regulations is the sharp increase in demand for low-emissivity glass in Germany in the 90's from less than 2 million to over 25 million m^2. Even before it came into force in 1995, knowledge of the legislation drove the penetration of low-e (low emissivity) glass in insulating glass units to around 50%. Low-e glass has now been standard in Germany for many years and the experience is being repeated in other countries such as the UK. This trend is borne out across the globe, dramatically increasing the demand for low-e glass. [129] As a result, post-consumer building glass waste tonnages are likely to increase in the next decade due to replacements of old windows and glass facades by insulating glazing.

This chapter first aims at quantifying the available post-consumer building glass waste generated in 2013 in Europe, from renovation and demolition sites, and in the residential and non-residential sectors. Furthermore, the end of the chapter gives an estimation of market projections for 2025.

Methodology and basic assumptions

To quantify waste originating from renovation, only the glass replaced by *insulating glass* has been taken into account. The two other types glass that can be found in buildings – interior glass and toughened and laminated safety glass – were not taken into account.

Firstly, mirrors mainly represent interior glass and it is difficult to estimate the quantity of mirrors put on the market that replace old mirrors versus those sold to customers just making a "new acquisition".

Secondly, in the construction industry, when toughened and laminated safety glass panes are put on the market, they either might have a direct application in buildings, or might be transformed into insulating glass (2 or 3 panes of glass). Therefore, to avoid double counts, toughened and laminated safety glass were not taken into account in the study. However, one must keep in mind that this assumption introduces a potential bias in final results.

[129] Pilkington and the Flat Glass Industry, 2010

The quantity of insulating glass sold in 2013 in the EU-28 Member States (MS) is the type of data that can be found on Eurostat website. The Eurostat market data, available for 22 of the 28 EU MS, has been extrapolated at the EU-28 scale thanks to population ratios.

Eurostat figures on insulating glass production, exports and imports (consumption = production + imports – exports) are given in m², so as mentioned in basic assumptions at the beginning of Chapter one, they have been converted in tonnages thanks to the following hypotheses.

Residential insulating glazing	1m² of glass at 4mm thickness
SGU (simple glass unit)	10 kg/m²
DGU (double glass unit)	20 kg/m²
TGU (triple glass unit)	30 kg/m²

Non-Residential insulating glazing	1m² of glass at 6mm thickness
SGU	15 kg/m²
DGU	30 kg/m²
TGU	45 kg/m²

Theses hypotheses enable to differentiate glass waste originating from the residential sector and the glass waste originating from the non-residential sector. Indeed, glass units tend to be thicker in the non-residential sector.

As for glass originating from building demolitions, it has proved to be much more complicated to estimate. The method used to carry out such estimation will be explained further.

Besides, based on the findings in phase 1, the 28 EU MS have been categorised in a table where they have been identified 1) by similarity of context/ stakes with the countries analysed in case studies, and 2) by geography. The criteria used to classify them were their climate, their economic wealth (GDP per capita), and construction and demolition habits. Therefore, countries have been classified into five regions: Northern Europe, Western Europe, North Eastern Europe, South Eastern Europe, and Southern Europe. Northern Europe countries have the “maximum” U value requirements[130] (insulation requirements) for roof, wall, floor, window and door because of their cold climate. The quantity of insulating glazing is thus higher such countries, which has consequences on the quantity of glass waste generated.[131]

Table 25 shows the basic assumptions used throughout the study (based on the findings in Chapter one).

[130] They are expressed in W/m²K. U values are worst acceptable standards which as a stand-alone measure would not necessarily mean that a building meets the overall performance-based requirements in the respective country.
[131] "BPIE - Buildings Performance Institute Europe." BPIE - Buildings Performance Institute Europe. N.p., n.d. Web. <http://www.bpie.eu/>.

Table 25: Basic assumptions

BASIC ASSUMPTIONS
60% of insulating glazing is sold for renovation purposes on average *If no estimations from country experts were available on the percentage of replaced windows which were single paned, the following assumptions have been made, based on the data available in the six case studies:* • In Northern Europe, only 20% of windows replaced (old windows) are single paned and the rest double paned (because of the cold climate). • In Western Europe, ~ 50% of windows replaced (old windows) are single paned and the rest is double paned. • In North-Eastern Europe, only 20% of windows replaced (old windows) are single paned and the rest double paned (because of the cold climate). • In South and South-Eastern Europe, 80% of windows replaced (old windows) are single paned, and the rest double paned (because of the hot climate). *If no estimations from country experts were available on the demolition rate of residential building stocks, the following assumptions have been made, based on the data available in the six case studies(justification is given further):* • In Northern & Western Europe, the demolition rate of residential building stocks is ~0.1%. • In Eastern & Southern Europe, the demolition rate of residential building stocks is ~0.05%. *If no estimations from country experts were available on the demolition rate of tertiary building stocks, the following assumptions have been made, based on the data available in the six case studies (justification is given further):* • In Northern Europe, the demolition rate of tertiary building stocks is ~ 0.6%. • In Western Europe, the demolition rate of tertiary building stocks is ~ 0.3%. • In Europe as a whole, the demolition rate of tertiary building stocks is ~ 0.2%. This figure has been used for Eastern and Southern Europe. *If no estimations from country experts were available on the average percentage that windows represent of the floor area of a dwelling (see definition at the beginning of the study), the following assumptions have been made, based on the data available in the six case studies:* • In Northern and Western Europe, this percentage is 20%. • In Eastern and Southern Europe, this percentage is 15%. As seen in assumptions at the beginning of Chapter one, there should be at least twice more glass (all types of flat glass mixed up) in a given surface of a tertiary building than in the same surface of a domestic building, i.e. 40%.

Table 26 shows the general market data used for the calculation of the quantity (in m²) of insulating glazing sold for renovation purposes, in the tertiary and in the residential sectors.

Table 26: Market data on insulating glass in EU-28 member states

Country	*Population*[132]	Insulating glazing put on the market (POM) in 2013[133]	% of insulating glazing sold for renovation[134]	Insulating glazing sold for renovation	Insulating glazing sold for renovation in the residential sector	Insulating glazing sold for renovation in the tertiary sector	*% of windows replaced which are single paned*[134]	*% of windows replaced which are double paned*[134]	*% of new windows which are double paned*[134]	*% of new windows which are triple paned*[134]
NORTHERN EUROPE										
Denmark	*5 602 628*	2 445 633 m²	60%	1 467 380 m²	1 056 513 m²	410 866 m²	*20%*	*80%*	*40%*	*60%*
Finland	*5 426 674*	1 347 805 m²	60%	808 683 m²	582 252 m²	226 431 m²	*20%*	*80%*	*40%*	*60%*
Sweden	*9 555 893*	2 037 817 m²	60%	1 222 690 m²	880 337 m²	342 353 m²	*20%*	*80%*	*30%*	*70%*
WESTERN EUROPE										
Austria	*8 451 860*		60%				*20%*	*80%*	*40%*	*60%*
Belgium	*11 161 642*	4 453 183 m²	60%	2 671 910 m²	1 923 775 m²	748 135 m²	*20%*	*80%*	*40%*	*60%*
France	*65 578 819*	13 334 400 m²	73%[135]	9 734 112 m²	6 424 514 m²	3 309 598 m²	*80%*	*20%*	*90%*	*10%*
Germany	*80 523 746*	27 183 000 m²	60%[136]	16 309 800 m²	11 743 056 m²	4 566 744 m²	*15%*	*85%*	*43%*	*58%*
Ireland	*4 591 087*	385 510 m²	60%	231 306 m²	166 540 m²	64 766 m²	*50%*	*50%*	*90%*	*10%*
Luxemburg	*537 039*		60%				*50%*	*50%*	*90%*	*10%*
Netherlands	*16 779 575*	4 306 665 m²	60%[137]	2 583 999 m²	1 860 479 m²	723 520 m²	*20%*	*80%*	*90%*	*10%*
United Kingdom	*63 896 071*	15 395 665 m²	60%	9 237 399 m²	6 650 927 m²	2 586 472 m²	*40%*	*60%*	*80%*	*20%*
NORTH-EASTERN EUROPE										
Czech Republic	*10 516 125*	293 447 m²	60%	176 068 m²	133 812 m²	42 256 m²	*20%*	*80%*	*90%*	*10%*
Estonia	*1 320 174*	498 613 m²	60%	299 168 m²	227 368 m²	71 800 m²	*20%*	*80%*	*90%*	*10%*
Latvia	*2 023 825*		60%				*20%*	*80%*	*90%*	*10%*

[132] COMPENDIUM - Cultural Policies and Trends in Europe - Statistics - Population, 2013
[133] Insulating glazing put on the market = production of insulating glazing + imports – import.
Production, imports and exports data come from Eurostat (PRODCOM ANNUAL SOLD, NACE Rev. 2., [DS-066341], 2013).
[134] Estimations made during interviews with glass manufacturers and window distributors (e.g. Lapeyre in France) in the member states targeted for the six case studies.
[135] Interview with Lapeyre, 2014.
[136] Estimations of BF Flachglas, BV Glas and Saint Gobain Glas Deutschland, 2014.
[137] Interview with Economisch Instituut voor de Bouw (EIB), Netherlands, 2014.

Lithuania	*2 971 905*	669 119 m²	60%	401 471 m²	305 118 m²	96 353 m²	*20%*	*80%*	*90%*	*10%*
Poland	*38 533 299*	13 659 763 m²	65%[138]	8 878 846 m²	6 747 923 m²	2 130 923 m²	*5%*	*95%*	*90%*	*10%*
Slovakia	*5 410 836*	1 398 505 m²	60%	839 103 m²	637 718 m²	201 385 m²	*20%*	*80%*	*90%*	*10%*
SOUTH-EASTERN EUROPE										
Bulgaria	*7 284 552*	1 195 879 m²	60%	717 527 m²	545 321 m²	172 207 m²	*80%*	*20%*	*90%*	*10%*
Hungary	*9 908 798*	1 067 389 m²	60%	640 433 m²	486 729 m²	153 704 m²	*80%*	*20%*	*90%*	*10%*
Romania	*20 020 074*	2 421 125 m²	60%	1 452 675 m²	1 104 033 m²	348 642 m²	*80%*	*20%*	*90%*	*10%*
Slovenia	*2 058 821*	417 232 m²	60%	250 339 m²	190 258 m²	60 081 m²	*80%*	*20%*	*90%*	*10%*
SOUTHERN EUROPE										
Croatia	*4 262 140*		60%				*80%*	*20%*	*90%*	*10%*
Cyprus	*865 878*						*80%*	*20%*	*90%*	*10%*
Greece	*11 062 508*	38 472 m²	60%	23 083 m²	18 928 m²	04 155 m²	*80%*	*20%*	*90%*	*10%*
Italy	*59 685 227*	10 000 000 m²	55%[139]	5 500 000 m²	4 510 000 m²	990 000 m²	*80%*	*20%*	*90%*	*10%*
Malta	*421 364*		60%				*80%*	*20%*	*90%*	*10%*
Portugal	*10 487 289*	2 022 977 m²	60%	1 213 786 m²	995 305 m²	218 482 m²	*80%*	*20%*	*90%*	*10%*
Spain	*46 727 890*	3 770 969 m²	60%	2 262 581 m²	1 855 317 m²	407 265 m²	*80%*	*20%*	*90%*	*10%*
EU28 TOTAL	*505 665 739*	**108 343 168 m²**		**66 922 361 m²**	**49 046 223 m²**	**17 876 137 m²**				

[138] Interview with Saint Gobain Glass, Poland, 2014.
[139] Interview with Saint Gobain Glass, Italy, 2014.

Glass waste arising from renovation

Note 1: A French expert from the REVALO project estimates that the average lifetime of windows in Western and Northern Europe is about 30 years. The amount of flat glass placed on these market 30 years ago would thus roughly indicate how much potential flat glass cullet is available on the market nowadays, yet such data is not available. Such reasoning would not have been valid for Eastern countries, a region where the replacement rate of windows is not as constant as in Western and Northern Europe.

Based on the assumptions made in the methodology above, on Eurostat 2013 data, and on the findings in chapter one, it can be estimated that **approximately 1.3 Mt of glass waste (from windows) was generated through the renovation of buildings in the EU-28 in 2013**.

This figure depends on a range of parameters. First, the weight of one square meter of glass, which depends of its thickness, may differ between countries and over time, which for instance means that whether a window being replaced is 20 or 40 years old, and whether it comes from an old Polish building or from an old Italian building, it might not have the same weight. In ex-USSR countries for instance, according to the Polish Glass Manufacturers Federation, windowpanes sold before the 90's might be 2 to 3 mm thick (5-7kg/ m² of glass). No check could be made on such data, but in case it appears to be true, the glass waste arising from the renovation (and demolition) sector in Eastern countries might be lower than estimated. A bias in therefore potentially introduced in the present study by the fact that general assumptions were made 1) on the weight of a square meter of glass in the residential sector, and 2) on the weight of a square meter of glass in the residential sector.

Other parameters potentially representing a bias are the calculation made on the quantity of glass (in m²) that is effectively being replaced in renovation works[140], and the assumption made on the percentage of old glazing replaced that is single paned.

[140] The calculation is based on the quantity of *insulating glass* put on the market and allocated to renovation purposes, but does glass being replaced by toughened and laminated glass.

Table 27: glass waste from renovation of residential buildings

Country	*Population*[132]	Insulating glazing sold for renovation in the residential sector (m²)	% of windows replaced which are single paned[134]	% of windows replaced which are double paned[134]	glass waste from renovation of residential buildings
NORTHERN EUROPE					
Denmark	*5 602 628*	1 056 513 m²	20%	80%	**19 093 ton**
Finland	*5 426 674*	582 252 m²	20%	80%	**10 522 ton**
Sweden	*9 555 893*	880 337 m²	20%	80%	**15 909 ton**
WESTERN EUROPE					
Austria	*8 451 860*		20%	80%	**26 326 ton**[141]
Belgium	*11 161 642*	1 923 775 m²	20%	80%	**34 766 ton**
France	*65 578 819*	6 424 514 m²	80%	20%	**77 403 ton**
Germany	*80 523 746*	11 743 056 m²	15%	85%	**218 116 ton**
Ireland	*4 591 087*	166 540 m²	50%	50%	**2 508 ton**
Luxemburg	*537 039*		50%	50%	**293 ton**[141]
Netherlands	*16 779 575*	1 860 479 m²	20%	80%	**33 623 ton**
United Kingdom	*63 896 071*	6 650 927 m²	40%	60%	**106 840 ton**
NORTH-EASTERN EUROPE					
Czech Republic	*10 516 125*	133 812 m²	20%	80%	**2 418 ton**
Estonia	*1 320 174*	227 368 m²	20%	80%	**4 109 ton**
Latvia	*2 023 825*		20%	80%	**3 755 ton**[141]
Lithuania	*2 971 905*	305 118 m²	20%	80%	**5 514 ton**
Poland	*38 533 299*	6 747 923 m²	5%	95%	**132 111 ton**
Slovakia	*5 410 836*	637 718 m²	20%	80%	**11 525 ton**
SOUTH-EASTERN EUROPE					
Bulgaria	*7 284 552*	545 321 m²	80%	20%	**6 570 ton**
Hungary	*9 908 798*	486 729 m²	80%	20%	**5 864 ton**
Romania	*20 020 074*	1 104 033 m²	80%	20%	**13 301 ton**

[141] Estimated figure thanks to population ratios

Slovenia	*2 058 821*	190 258 m²	80%	20%	**2 292 ton**
SOUTHERN EUROPE					
Croatia	*4 262 140*		80%	20%	**3 880 ton**
Cyprus	*865 878*		80%	20%	**18 ton**[141]
Greece	*11 062 508*	18 928 m²	80%	20%	**228 ton**
Italy	*59 685 227*	4 510 000 m²	80%	20%	**54 336 ton**
Malta	*421 364*		80%	20%	**9 ton**[141]
Portugal	*10 487 289*	995 305 m²	80%	20%	**11 991 ton**
Spain	*46 727 890*	1 855 317 m²	80%	20%	**22 353 ton**
EU28TOTALS	**505 665 739**	**49 046 223 m²**			**825 676 ton**

Table 28: glass waste from renovation of tertiary buildings

Country	***Population***[132]	**Insulating glazing sold for renovation in the tertiary sector (m²)**	**% of windows replaced which are single paned**[134]	**% of windows replaced which are double paned**[134]	**glass waste from renovation of tertiary buildings**
NORTHERN EUROPE					
Denmark	*5 602 628*	410 866 m²	20%	80%	**11 138 ton**
Finland	*5 426 674*	226 431 m²	20%	80%	**6 138 ton**
Sweden	*9 555 893*	342 353 m²	20%	80%	**9 281 ton**
WESTERN EUROPE					
Austria	*8 451 860*		20%	80%	**15 357 ton**[141]
Belgium	*11 161 642*	748 135 m²	20%	80%	**20 280 ton**
France	*65 578 819*	3 309 598 m²	80%	20%	**59 811 ton**
Germany	*80 523 746*	4 566 744 m²	15%	85%	**127 234 ton**
Ireland	*4 591 087*	64 766 m²	50%	50%	**1 463 ton**
Luxemburg	*537 039*		50%	50%	**628 ton**[141]
Netherlands	*16 779 575*	723 520 m²	20%	80%	**19 613 ton**
United Kingdom	*63 896 071*	2 586 472 m²	40%	60%	**62 324 ton**
NORTH-EASTERN EUROPE					
Czech Republic	*10 516 125*	42 256 m²	20%	80%	**1 145 ton**
Estonia	*1 320 174*	71 800 m²	20%	80%	**1 946 ton**

Latvia	*2 023 825*		20%	80%	**2 984 ton**[141]
Lithuania	*2 971 905*	96 353 m²	20%	80%	**2 612 ton**
Poland	*38 533 299*	2 130 923 m²	5%	95%	**62 579 ton**
Slovakia	*5 410 836*	201 385 m²	20%	80%	**5 459 ton**
SOUTH-EASTERN EUROPE					
Bulgaria	*7 284 552*	172 207 m²	80%	20%	**3 112 ton**
Hungary	*9 908 798*	153 704 m²	80%	20%	**2 778 ton**
Romania	*20 020 074*	348 642 m²	80%	20%	**6 301 ton**
Slovenia	*2 058 821*	60 081 m²	80%	20%	**1 086 ton**
SOUTHERN EUROPE					
Croatia	*4 262 140*		80%	20%	**1 278 ton**
Cyprus	*865 878*		80%	20%	**260 ton**[141]
Greece	*11 062 508*	04 155 m²	80%	20%	**75 ton**
Italy	*59 685 227*	990 000 m²	80%	20%	**17 891 ton**
Malta	*421 364*		80%	20%	**126 ton**[141]
Portugal	*10 487 289*	218 482 m²	80%	20%	**3 948 ton**
Spain	*46 727 890*	407 265 m²	80%	20%	**7 360 ton**
EU28TOTALS	**505 665 739**	**17 876 137 m²**			**454 206 ton**

Glass waste arising from demolition

Demolition of residential buildings

In terms of floor space per capita, the central and eastern countries are among the countries with the lowest residential space, whether in single-family houses or apartment blocks (both considered as dwellings[142]). Northern and western countries have the highest residential floor areas per capita compared to other regions while countries in the South have a highest dwelling floor space per capita than in the Centre and East. [143]

Based on the assumptions made in the methodology above and on the findings in chapter one, it has been estimated that around **63 000 tonnes of glass waste were generated through the demolition of residential buildings in the EU-28 in 2013** (see *Table 29*).

This figure particularly depends upon three variables: the weight of one m² of glass, the demolition rate of residential building stocks, and the percentage that glass represents in the surface of a dwelling.

[142] In the present study, a dwelling is understood as a unit of accommodation such as an apartment/ flat, or house.
[143] "BPIE - Buildings Performance Institute Europe." BPIE - Buildings Performance Institute Europe. N.p., n.d. Web. <http://www.bpie.eu/>.

Table 29: Calculation of glass waste generated from the demolition of residential buildings

Country	*Population*[132]	Residential building stock (number)[144]	Number of dwellings demolished[144]	Demolition rate of residential building stock[145]	Average useful floor area per dwelling (m²)[144]	Useful floor area of residential buildings demolished	% that glass represents in the useful floor area per dwelling[145]	glass waste from demolition of residential buildings (m²)	glass waste from demolition of residential buildings (tonnes)
NORTHERN EUROPE									
Denmark	*5 602 628*	2 680 000		0,10%	114	305 520 m²	20%	61 104 m²	**1 104 ton**
Finland	*5 426 674*	2 784 000		0,10%	81	225 504 m²	20%	45 101 m²	**815 ton**
Sweden	*9 555 893*	4 503 000	500	0,01%	128	64 000 m²	20%	12 800 m²	**231 ton**
WESTERN EUROPE									
Austria	*8 451 860*	3 598 000		0,10%	75	269 850 m²	20%	53 970 m²	**975 ton**
Belgium	*11 161 642*	5 043 000		0,10%	91[146]	458 913 m²	20%	91 783 m²	**1 659 ton**
France	*65 578 819*	35 000 000	30 000	0,09%	91	2 730 000 m²	20%[147]	546 000 m²	**6 578 ton**
Germany	*80 523 746*	39 268 000	39 000	0,10%	100	3 900 000 m²	20%	780 000 m²	**26 418 ton**
Ireland	*4 591 087*	1 700 000	10 000	0,59%	104	880 000 m²	20%	176 000 m²	**2 651 ton**
Luxemburg	*537 039*	188 000		0,10%	81	15 228 m²	20%	03 046 m²	**46 ton**
Netherlands	*16 779 575*	7 107 000	12 903[148]	0,18%	125	1 612 875 m²	20%	322 575 m²	**5 830 ton**
United Kingdom	*63 896 071*	24 000 000	15 853[149]	0,07%	91[150]	1 442 623 m²	30%	432 787 m²	**6 952 ton**

[144] *Housing statistics in the European Union 2010*, Netherlands Ministry of the Interior and Kingdom Relations, The Hague 2010.
[145] Estimation of Deloitte, based on data collected for case studies.
[146] Average of the dwelling sizes of other countries of the same region. The same estimation method has been used for the following countries: Czech Republic, Estonia, Latvia, Lithuania, Slovakia, Bulgaria, Hungary, Romania, Slovenia, Cyprus, Greece, and Malta.
[147] Etude de l'impact de la surface des parois vitrées sur le besoin en énergie des bâtiments résidentiels, Carbonnel Ingénierie, 2010.
[148] Netherlands Central bureau of Statistics, 2013.
[149] Demolition statistics (2012-2013) of:
- England: 12,060
- Scotland: 3,67
- Wales: 118 (only by local authorities in clearance areas)

NORTH-EASTERN EUROPE									
Czech Republic	*10 516 125*	6 683 000[151]	1 300	0,02%	70	91 000 m²	15%	13 650 m²	**247 ton**
Estonia	*1 320 174*	651 000		0,05%	70	22 785 m²	15%	03 418 m²	**62 ton**
Latvia	*2 023 825*	1 042 000		0,05%	70	36 470 m²	15%	05 471 m²	**99 ton**
Lithuania	*2 971 905*	1 308 000		0,05%	70	45 780 m²	15%	06 867 m²	**124 ton**
Poland	*38 533 299*	13 150 000		0,05%	70[152]	460 250 m²	15%	69 038 m²	**1 352 ton**
Slovakia	*5 410 836*	1 711 000	1 200	0,07%	70	84 000 m²	15%	12 600 m²	**228 ton**
SOUTH-EASTERN EUROPE									
Bulgaria	*7 284 552*	3 692 000[153]		0,05%	70	129 220 m²	15%	19 383 m²	**234 ton**
Hungary	*9 908 798*	4 303 000	4 100	0,10%	70	287 000 m²	15%	43 050 m²	**519 ton**
Romania	*20 020 074*	8 329 000	9 500	0,11%	70	665 000 m²	15%	99 750 m²	**1 202 ton**
Slovenia	*2 058 821*	800 000		0,05%	70	28 000 m²	15%	04 200 m²	**51 ton**
SOUTHERN EUROPE									
Croatia	*4 262 140*	2 257 515[154]	500[154]	0,02%	60[154]	30 000 m²	15%	04 500 m²	**54 ton**
Cyprus	*865 878*	286 500		0,05%	94	13 466 m²	15%	02 020 m²	**24 ton**
Greece	*11 062 508*	3 657 000	4 100	0,11%	94	385 400 m²	15%	57 810 m²	**696 ton**
Italy	*59 685 227*	27 292 000		0,05%	96	1 310 016 m²	15%	196 502 m²	**2 367 ton**
Malta	*421 364*	139 000		0,05%	94	06 533 m²	15%	00 980 m²	**12 ton**
Portugal	*10 487 289*	5 537 000		0,05%	98	271 313 m²	15%	40 697 m²	**490 ton**
Spain	*46 727 890*	25 209 000	15 000	0,06%	122	1 830 000 m²	15%	274 500 m²	**3 307 ton**
EU28TOTALS	**505 665 739**								**64 808 ton**

[150] English Housing Survey, Housing stock report 2008 - National Statistics.
[151] Czech Republic national statistics, 2014.
[152] Polish Market Review, PMR Consulting, 2007.
[153] *Regular National Report on Housing Developments in European Countries*, Department of the Environment, Heritage and Local Government, Ireland, 2004.
[154] Croatian Bureau of Statistics, 2013.

Demolition of tertiary buildings

Data on demolition for *non-residential buildings* is quite scarce. Through comprehensive research, including interviews with the national statistical agencies, we could only find adequate data for Germany, France, Spain and Norway. The *Panorama of the European non-residential construction sector* (ECOFYS, 2011) provides several examples illustrating that reasonable conclusions about demolition in other EU countries cannot be drawn, taking incomplete data into account. For instance, Sweden provides statistics for its residential and non-residential building stock as well as for new annual building permits. In theory, the Swedish demolition rate could be derived from that data. However, this approach is not viable, because the statistics for the total building stock is the result of a yearly survey with a sample of 10,000 non-residential buildings and the data does not come from the same department and therefore is not consistent in itself. This implies the possibility of deviations in the statistics in different years, not necessarily reflecting real changes. Yet the variations are in the order of magnitude of a reasonable demolition rate (from 0.3% to 0.8%).

Since Norway, Germany, France and Spain have viable data, we decided to use this data as representative value for the sub region in which they have here been classified. For Eastern European countries, no data on demolition is available nor can be calculated on basis of stocks and new building permits. The *Panorama of the European non-residential construction sector* (ECOFYS, 2011) assumes the average EU-27 demolition rate for non-residential buildings was 0.2% in 2010. We therefore used this estimation for Eastern Europe. Table 30 gives an overview of demolition rates in countries where data was available.

Table 30: demolition rates in countries

Hypothesis	Demolition rate
Germany (2009)	0.29%
Spain (2009)	0.1%
Norway (2009)	0.6%
France (2012)	0.46%
EU-27: 0.2% (2010)	0.2%

Source: [DESTATIS, 1999-2009; Ministerio de Fomento, 2010; Statistics Norway, 2011; CEREN, 2012][155]

Based on such assumptions and on the findings in chapter one, we could estimate that at least **196 000 tonnes of glass waste** (from windows, facades, glass ceilings and interior glass) **was generated through the demolition of non-residential buildings in the EU-28 in 2013** (see Table 31).

This figure highly depends upon three variables: the weight of one m² of glass, the demolition rate of non-residential building stocks and the percentage that glass represents in the surface of a non-residential building. This last parameter particularly influences the result.

[155] Schimschar, Sven, Jan Grözinger, Henning Korte, Thomas Boermans, Velizara Lilova, and Riadh Bhar. "Panorama of the European Non-residential Construction Sector." (2011): n. pag. Web. <http://www.leonardo-energy.org/sites/leonardo-energy/files/documents-and-links/European%20non-residential%20building%20stock%20-%20Final%20Report_v7.pdf>.

Table 31: Calculation of glass waste generated from the demolition of tertiary buildings

Country	*Population*[132]	Floor area of tertiary buildings[156]	Demolition rate of tertiary building stock[157]	Floor area of tertiary buildings demolished	Minimum % that glass represents in the floor area of a tertiary building[157]	glass waste from demolition of tertiary buildings (m²)	glass waste from demolition of tertiary buildings (tonnes)
NORTHERN EUROPE							
Denmark	*5 602 628*	102 000 000 m²	0,60%	612 000 m²	40%	244 800 m²	**6 636 ton**
Finland	*5 426 674*	80 000 000 m²	0,60%	480 000 m²	40%	192 000 m²	**5 205 ton**
Sweden	*9 555 893*	125 000 000 m²	0,60%	750 000 m²	40%	300 000 m²	**8 132 ton**
WESTERN EUROPE							
Austria	*8 451 860*	227 000 000 m²	0,30%	681 000 m²	40%	272 400 m²	**7 384 ton**
Belgium	*11 161 642*	95 600 000 m²	0,30%	286 800 m²	40%	114 720 m²	**3 110 ton**
France	*65 578 819*	922 000 000 m²	0,46%[158]	4 200 000 m²	40%	1 680 000 m²	**30 361 ton**
Germany	*80 523 746*	2 210 000 000 m²	0,30%[158]	6 630 000 m²	40%	2 652 000 m²	**73 887 ton**
Ireland	*4 591 087*	39 400 000 m²	0,30%	118 200 m²	40%	47 280 m²	**1 068 ton**
Luxemburg	*537 039*	4 400 000 m²	0,30%	13 200 m²	40%	05 280 m²	**0 119 ton**
Netherlands	*16 779 575*	478 000 000 m²	0,30%[159]	1 434 000 m²	40%	573 600 m²	**15 549 ton**
United Kingdom	*63 896 071*	800 000 000 m²	0,30%	2 400 000 m²	40%	960 000 m²	**23 132 ton**
NORTH-EASTERN EUROPE							
Czech Republic	*10 516 125*	79 800 000 m²	0,20%	159 600 m²	40%	63 840 m²	**1 731 ton**
Estonia	*1 320 174*	27 000 000 m²	0,20%	54 000 m²	40%	21 600 m²	**586 ton**
Latvia	*2 023 825*	15 000 000 m²	0,20%	30 000 m²	40%	12 000 m²	**325 ton**
Lithuania	*2 971 905*	25 000 000 m²	0,20%	50 000 m²	40%	20 000 m²	**542 ton**

[156] Buildings Performance Institute Europe (BPIE), country factsheets (all data comes from official sources or country experts, and is as recent as possible).
[157] Estimation of Deloitte, based on data collected for case studies.
[158] ECOFYS, Panorama of the European non-residential construction sector, 2011.
[159] Netherlands Central bureau of Statistcs, 2013.

Poland	*38 533 299*	353 000 000 m²	0,20%	706 000 m²	40%	282 400 m²	**8 293 ton**
Slovakia	*5 410 836*	33 600 000 m²	0,20%	67 200 m²	40%	26 880 m²	**729 ton**
SOUTH-EASTERN EUROPE							
Bulgaria	*7 284 552*		0,20%		40%		
Hungary	*9 908 798*	98 300 000 m²	0,20%	196 600 m²	40%	78 640 m²	**1 421 ton**
Romania	*20 020 074*	67 200 000 m²	0,20%	134 400 m²	40%	53 760 m²	**972 ton**
Slovenia	*2 058 821*	23 100 000 m²	0,20%	46 200 m²	40%	18 480 m²	**334 ton**
SOUTHERN EUROPE							
Croatia	*4 262 140*		0,10%		40%		
Cyprus	*865 878*	7 000 000 m²	0,10%	07 000 m²	40%	02 800 m²	**51 ton**
Greece	*11 062 508*	130 000 000 m²	0,10%	130 000 m²	40%	52 000 m²	**940 ton**
Italy	*59 685 227*	384 000 000 m²	0,10%	384 000 m²	40%	153 600 m²	**2 776 ton**
Malta	*421 364*		0,10%		40%	00 000 m²	
Portugal	*10 487 289*	93 800 000 m²	0,10%	93 800 m²	40%	37 520 m²	**678 ton**
Spain	*46 727 890*	284 000 000 m²	0,10%[158]	284 000 m²	40%	113 600 m²	**2 053 ton**
EU28TOTALS	**505 665 739**						**196 014 ton**

Total glass waste from demolition is therefore estimated close to 261,000 tonnes/year.

Market projections

As seen throughout the six case studies, the tonnage of flat glass waste is likely to rise in the coming years due to various considerations. Among them is the implementation of legislation and policies related to building sustainability (thermal regulations, tax credits for the replacement of old windows, etc.), new targets for building's environmental and energy performances, as well as new trends in architecture and consumers behaviour.

The growing market share of triple-glazing in the glazing market is a recent trend, but it is particularly accelerated by public policies such as the Energy Savings Ordinance[160] in Germany. In 2013, this policy introduced the "climate-neutral building" standard, to be applied to all new buildings by 2020 and which will probably promote the use of triple insulation glazing. According to the German Flat Glass Manufacturers' Association (Bundesverband Flachglas), between 2008 and 2011, the share of triple glazing sales in Germany rose by around 10% to over 50%. In 2014, the association expects a share of around 60%, and they stay convinced that the market share will grow to over 90% within a few years. In Sweden, Finland, Austria and Switzerland, where triple glazing has also a very high market share, one can see similar trend perspectives as those in Germany.[161] These elements only indicate that, at least in Northern and Western Europe, the generation of windows that will be replaced within 20 to 50 years will mostly be triple-glazes, i.e. heavier than windows actually being changed.

In parallel to this evolution, in the residential as well as commercial construction sector, another trend that will influence the quantity of glass waste arising from future demolitions and renovations is the trend towards the use of increasingly large glass units. Indeed, "architects and building owners want to have an open room ambience for their buildings with the maximum amount of daylight incidence and highest degree of external views". [161]

On the other hand, a parameter that might lower the quantity of waste arisings is the development of lighter glass panes, to facilitate the transport and installation of triple-glazing panes, especially if panes are larger and larger. [161]

Many other parameters might influence the tonnage of glass waste arising in the following years, but further research needs to be done on the issue to quantify such volumes.

[160] Energieeinsparverordnung – EnEV.
[161] The burden of the weight, GLASSTEC, 2012. http://www.tradefair.it/tradefair/tradefair.nsf/DBCB8419692E7EA4C1257A1A0054897B/$file/glasstec2012_No_5_thin_glass_GB.pdf>

Conclusions

Finally, it is estimated thanks to Phase I that at around **1.5 Mt of glass waste has arisen from building renovations and demolitions in 2013, 58%** in **the residential sector** and **42% in the tertiary sector** (industrial buildings being out of scope). European flat glass manufacturers' previous estimation, who considered that around 1.2 Mt of C&D glass waste arises each year in the European Union[162], is thus lower than the present study result.

One must take such results with precaution because of the number of assumptions within the study, and must be kept in mind that it remains the first study of its kind. Compared to previous estimates made on the topic, a reliable methodology has been used. It is based, above all, on statistical data and expert views; and the calculation model developed by Deloitte takes the form of an Excel tool that will be easily updated in the future and will include the possibility to change all assumptions per country.

The main results of the quantification of flat glass waste arising in Europe are shown in the tables below.

Glass waste from RENOVATION *(83% of total waste arisings) (tonnes)*		Glass waste from DEMOLITION *(17% of total waste arisings) (tonnes)*		Total building glass waste arisings in the EU-28 *(tonnes)*
1 279 882		**260 822**		**1 540 704**
Residential sector	Tertiary sector	Residential sector	Tertiary sector	
825 676	**454 206**	**64 808**	**196 014**	

	Glass waste from renovation *(tonnes)*	Glass waste from demolition *(tonnes)*	*% from demolition sites*	Total glass waste *(tonnes)*	*% from residential sector*
NORTHERN EUROPE					
Denmark	30 231	7 740	*20%*	37 971	*53%*
Finland	16 661	6 020	*27%*	22 680	*50%*
Sweden	25 190	8 364	*25%*	33 554	*48%*
WESTERN EUROPE					
Austria	41 683	8 360	*17%*	50 042	*55%*
Belgium	55 047	4 769	*8%*	59 815	*61%*
France	137 214	36 939	*21%*	174 153	*48%*
Germany	345 350	100 305	*23%*	445 655	*55%*
Ireland	3 971	4 201	*51%*	8 172	*69%*
Luxemburg	0 921	0 165	*15%*	1 086	*31%*
Netherlands	53 236	21 379	*29%*	74 614	*53%*
United Kingdom	169 164	30 084	*15%*	199 249	*57%*
NORTH-EASTERN EUROPE					
Czech Republic	3 564	1 977	*36%*	5 541	*48%*

[162] Glass for Europe, Recycling of end-of-life building glass - Glass for Europe, June 2013.

	Glass waste from renovation *(tonnes)*	Glass waste from demolition *(tonnes)*	*% from demolition sites*	Total glass waste *(tonnes)*	*% from residential sector*
Estonia	6 055	0 647	*10%*	6 703	*62%*
Latvia	6 739	0 424	*6%*	7 163	*54%*
Lithuania	8 126	0 666	*8%*	8 792	*64%*
Poland	194 690	9 645	*5%*	204 335	*65%*
Slovakia	16 984	0 956	*5%*	17 940	*66%*
SOUTH-EASTERN EUROPE					
Bulgaria	9 682	0 234	*2%*	9 916	*69%*
Hungary	8 642	1 940	*18%*	10 582	*60%*
Romania	19 602	2 173	*10%*	21 775	*67%*
Slovenia	3 378	0 385	*10%*	3 763	*62%*
SOUTHERN EUROPE					
Croatia	5 158	0 054	*1%*	5 212	*75%*
Cyprus	0 277	0 075	*21%*	0 352	*12%*
Greece	0 303	1 636	*84%*	1 939	*48%*
Italy	72 228	5 143	*7%*	77 371	*73%*
Malta	0 135	0 012	*8%*	0 147	*14%*
Portugal	15 940	1 168	*7%*	17 108	*73%*
Spain	29 713	5 360	*15%*	35 073	*73%*

The table below shows the amount of building glass waste arisings in kg/inhabitant (kg/inh) for the residential as well as for the tertiary sector. Apparently, Northern and Western European countries generate more building glass waste arisings per inhabitant than other regions of the EU-28.

On average, about 1.76 kg/ inhabitant/ year of glass waste arises from the residential sector in the EU-28. Denmark, Poland, Belgium, Austria, Estonia and Germany rank among the countries where the biggest quantities of glass waste originate from this sector.

As for the tertiary sector, about 1.29 kg/ inhabitant/ year of glass waste arises on average in the EU-28; i.e. less than in the residential sector.

No specific relation exists between the population density and the quantity of glass waste arising/ inhabitant. The explanatory factors rather lay in the economic context of each country.

Based on the quantitative and qualitative data collected thanks to this benchmark and throughout the study, Chapter 3: analyses three potential scenarios for recovering building glass waste:

- Recovery within the flat glass industry (closed loop recycling) (option 1);
- Recovery within the hollow glass industry (option 2), or
- Recovery with other C&D waste (option 3).

Building glass waste arisings in the residential sector	
Country	**kg/inh/year**
Denmark	3,61
Poland	3,46
Belgium	3,26
Austria	3,23
Estonia	3,16
Germany	3,04
Netherlands	2,35
Slovakia	2,17
Finland	2,09
Latvia	1,90
Lithuania	1,90
United Kingdom	1,78
EU28 average	**1,76**
Sweden	1,69
France	1,28
Ireland	1,23
Portugal	1,19
Slovenia	1,14
Italy	0,95
Bulgaria	0,93
Croatia	0,92
Romania	0,72
Hungary	0,64
Luxemburg	0,63
Spain	0,55
Czech Republic	0,25
Greece	0,08
Cyprus	0,05
Malta	0,05

Building glass waste arisings in the tertiary sector	
Country	**kg/inh/year**
Denmark	3,17
Austria	2,69
Germany	2,50
Belgium	2,10
Netherlands	2,10
Finland	2,09
Estonia	1,92
Poland	1,84
Sweden	1,82
Latvia	1,64
Luxemburg	1,39
France	1,38
United Kingdom	1,34
EU28 average	**1,29**
Slovakia	1,14
Lithuania	1,06
Slovenia	0,69
Ireland	0,55
Portugal	0,44
Bulgaria	0,43
Hungary	0,42
Romania	0,36
Cyprus	0,36
Italy	0,35
Croatia	0,30
Malta	0,30
Czech Republic	0,27
Spain	0,20
Greece	0,09

National densities of building glass waste arisings per sector

A general overview on the potential building glass waste available in 2013[163] is presented below, demonstrating the different waste densities per Member State in the residential and tertiary sectors, whether waste originates from demolition or renovation. The locations of Glass for Europe member companies (float glass lines) are indicated with a red star in light of illustrating whether a low glass waste density correlates with a low presence of float glass lines, and vice versa.

In each four sectors, either the Netherlands or Belgium have the highest potential glass waste per km², followed by Germany. Furthermore, at 1 370 thousand tonnes per year, potential flat glass waste generated by the renovation sector and was over 4.5 times more than the volume originating from the demolition sector (278 thousand tonnes). The difference between the residential sector (955 thousand tonnes) and the tertiary sector (694 thousand tonnes) was not as drastic.

Table 32: Building glass waste volumes arising per sector and type of building

Demolition versus Renovation	Total
Demolition sector	278 thousand tonnes
Renovation sector	1 370 thousand tonnes
Residential versus Tertiary	Total
Residential buildings	954 thousand tonnes
Tertiary buildings	694 thousand tonnes

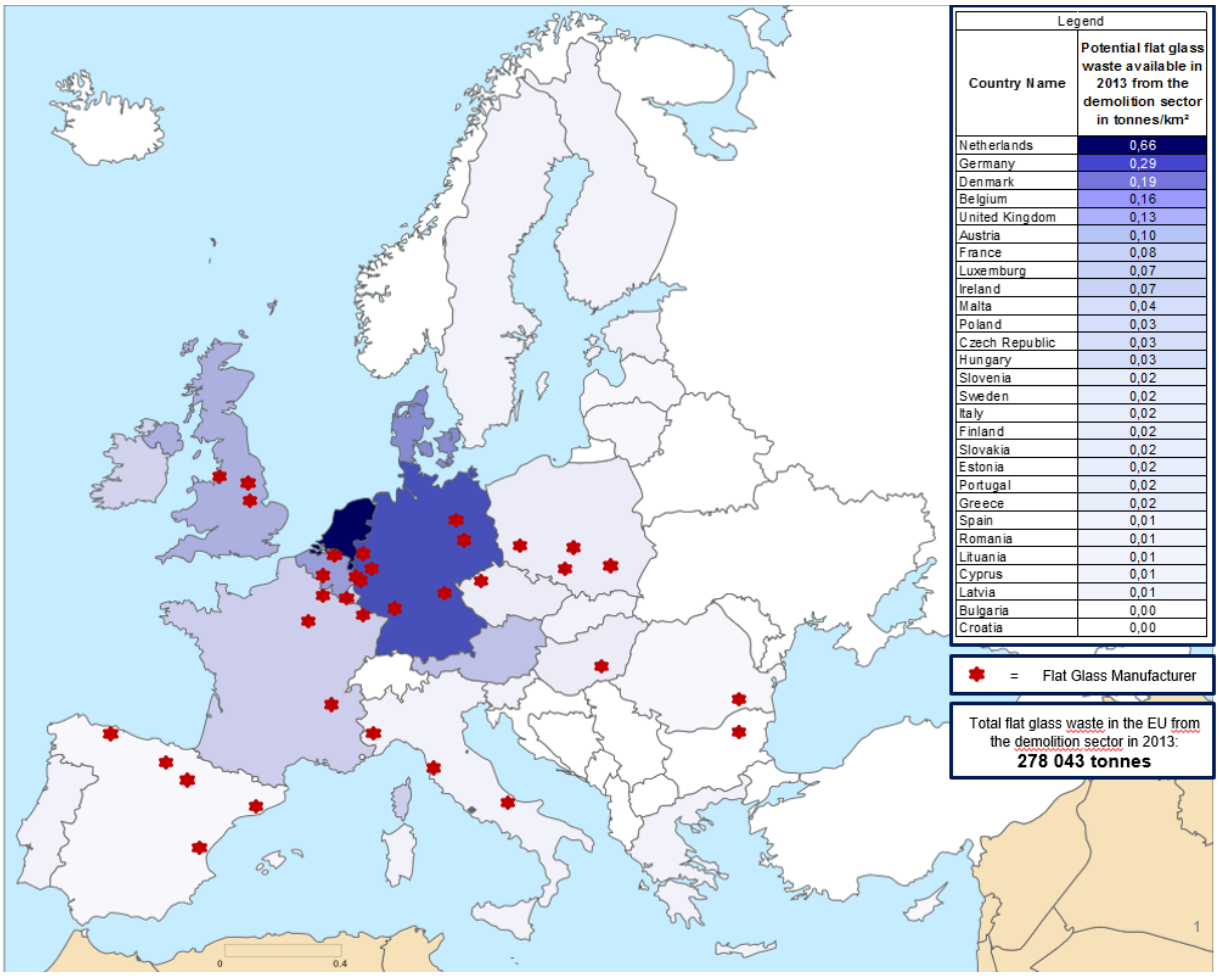
[163] 2013 is the most recent year that Eurostat data exists for all Member States.

1 Density of demolition building glass waste per MS

In 2013, there were 278 thousand tonnes of potential flat glass waste originating from the demolition sector. Out of this total, **the Netherlands experienced the highest density of glass waste arising from demolition, with 0.66 tonnes/km²**.

Float glass lines located in Belgium and Germany are not far from the Netherlands' surrounding boarders, and are provided cullet by Belgian glass treatment centres, which collect large quantities of glass waste from the Netherlands by vessel.

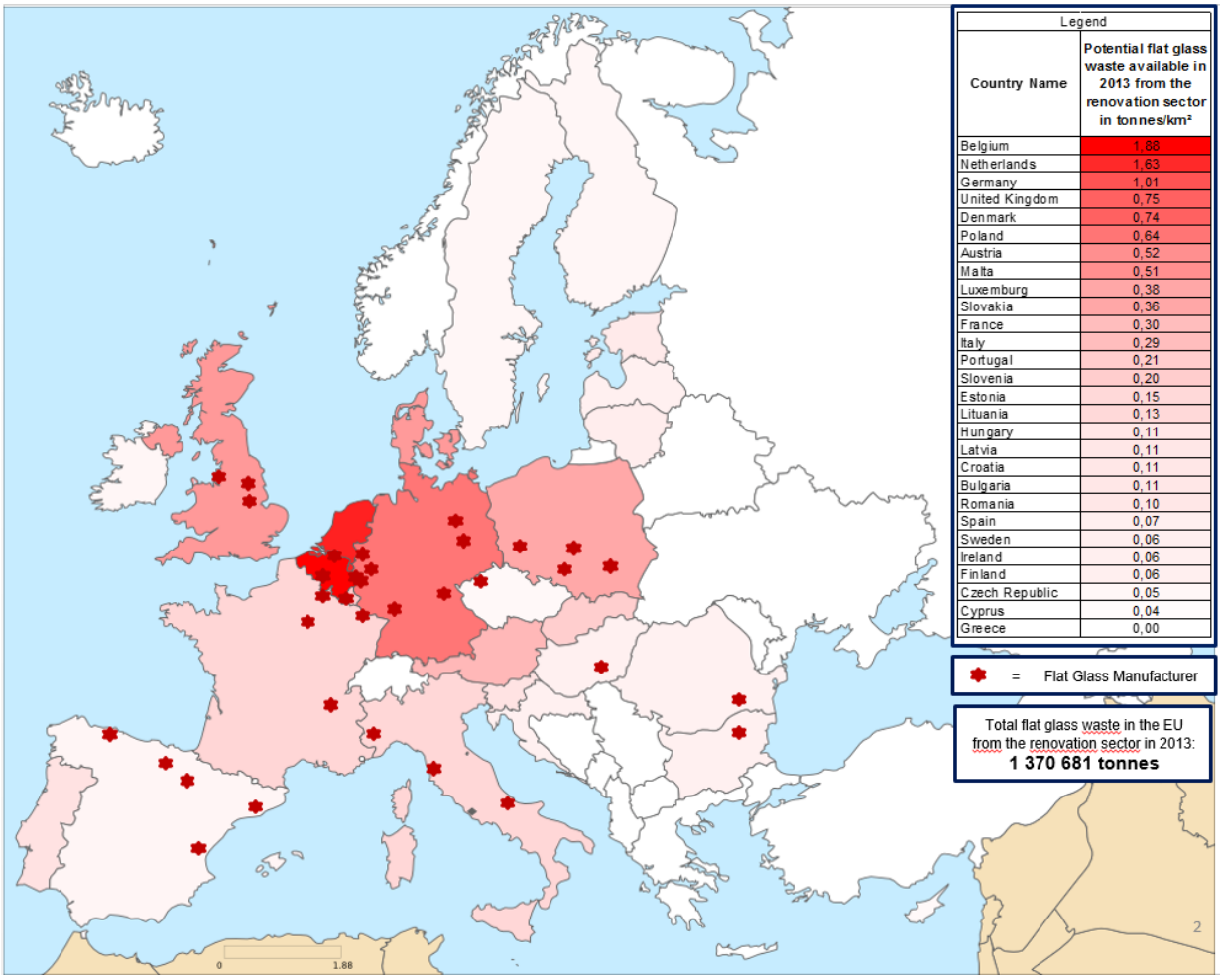
Figure 19: Density of Demolition Building Glass Waste Per MS (2013)



2 Density of renovation building glass waste per MS

In 2013, 1 370 thousand tonnes of potential flat glass waste was generated by the renovation sector. Out of this total, **Belgium experienced the highest density of glass waste arising from renovation with 1.88 tonnes/km².**

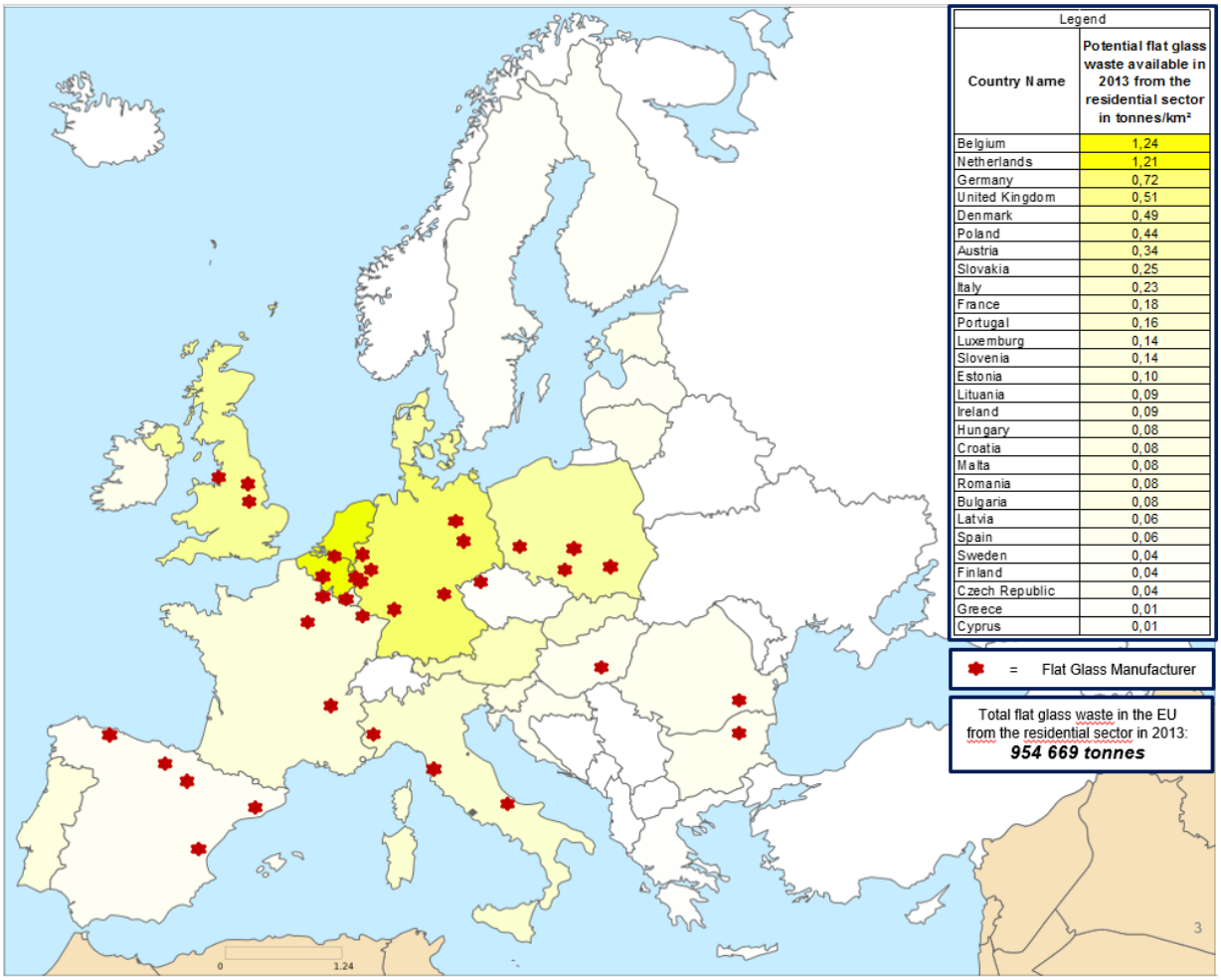
Figure 20: Density of Renovation Building Glass Waste Per MS



3 Density of residential building glass waste per MS

In 2013, 954 thousand tonnes of potential flat glass waste originated from the residential sector. Out of this total, **Belgium experienced the highest density of glass waste arising from the residential sector** with 1.24 tonnes/km².

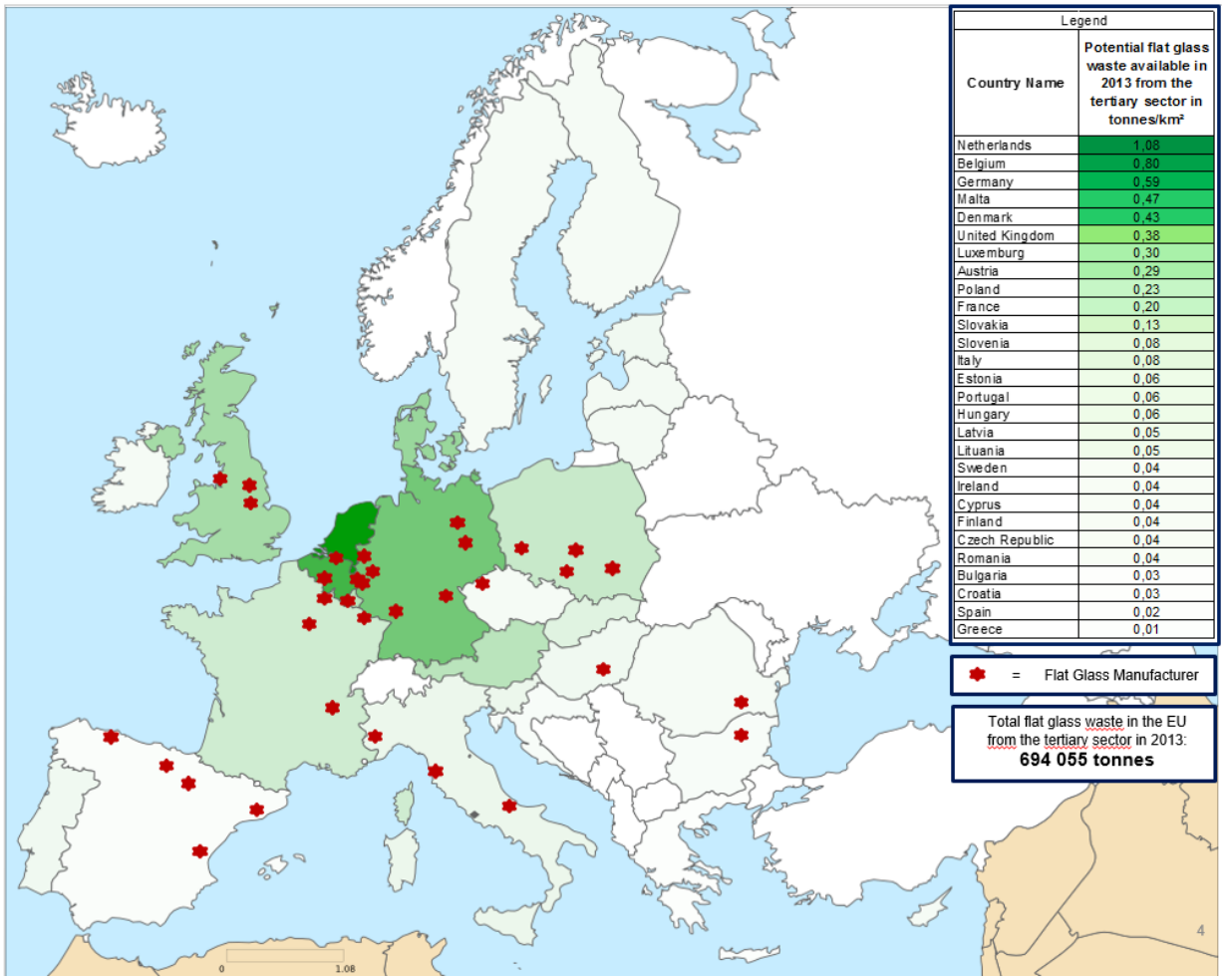
Figure 21: Density of Residential Building Glass Waste Per MS



4 Density of tertiary building glass waste per MS

In 2013, 694 thousand tonnes of potential flat glass waste originated from the demolition sector. Out of this total, the **Netherlands experienced the highest density of glass waste arising from the tertiary sector with 1.08 tonnes/km²**.

Figure 22: Density of Tertiary Building Glass Waste Per MS



Chapter 3: Evaluation of the environmental impacts and cost-benefit analysis of potential recyling routes for C&D glass waste (Phase II)

Objectives and Methodology

As previously seen, Phase I presents and analyses quantitative building glass waste data from the tertiary, residential, renovation, and demolition sectors in the EU-28, and particularly illustrates a qualitative and quantitative benchmark of six Member States. The extensive information illustrated in Phase I acts as the foundation for Phase II. This latter phase evaluates and compares potential scenarios for recovering C&D glass waste within the EU-28 in order to determine the **economic and environmental costs and benefits** of each recycling route:

- Option 1: Recovery within the flat glass industry (closed loop recycling);
- Option 2: Recovery within the hollow glass industry, or
- Option 3: Recovery with other C&D waste.

For each option investigated, costs have been assessed in three types of situation:

- Renovation in residential sites, where only a few windows are replaced by window installers / carpenters (“light renovations”);
- Renovation in tertiary sites, where several tonnes of windows / glass doors & walls are replaced (“major renovations”); and
- Demolition of residential and tertiary sites.

Furthermore, Phase II provides a section on recommendations on recycling routes.

Research and stakeholder consultations were carried out extending beyond the flat glass industry. Federations, associations, and relevant entities within other glass sectors (i.e. hollow glass, glass wool, and special glass) were contacted and consulted.

Stakeholders previously contacted in Phase I were followed up with in order to clarify or precise information presented in Phase I and furthermore to gather their input on Phase II assumptions.

In addition, extensive collaboration with the European association of glass recyclers (FERVER) provoked an interesting series of exchanges.

Environmental impacts of various recycling routes for C&D glass

Cullet (broken or crushed glass for remelting) is of very high importance for glass manufacturing, due to its direct contribution to energy and raw materials saving and reduction of CO_2 emissions from the glass melting process, helping to meet manufacturer commitments on climate change policy.

As a general rule (for flat and hollow glass furnaces), every 10% of extra cullet results in a 2.5 to 3% reduction in furnace energy consumption. [164] Based on a survey conducted in Germany, energy savings are estimated at around 8 MJ for every percent increase (by weight) in cullet use. [165] Furthermore, in general terms, each tonne of cullet used in the melting process allows saving approximately an equivalent amount of raw materials (1.2 tonne) and 300 Kg in CO_2 emissions (246 kg according to a 2014 British Glass report).[166]

In addition to energy savings and reduction of the amount of raw materials extracted, cullet use increases the life of the furnace by up to 30 % due to decreased melting temperatures and a less corrosive batch.[165]

However, quality issues may limit the potential of cullet to reduce environmental impacts. For instance:

- The presence of metallic impurities can cause significant refractory damage and shorten furnace life;
- Contamination with ceramics degrades quality and ultimately results in rejects/inability to use cullet, thus reducing the positive environmental impact of cullet use;
- The difficulty to control glass quality and associated rejects: large amounts of cullet used in a furnace for production means that glass composition may be variant (as compared to virgin cullet). These composition variations indicate that there are more physical characteristics to consider and control throughout production in light of diminishing the possibility of impurities carrying through within the final product;
- Impurities in cullet composition may give rise to undesired air emissions.[164]

Recovering glass waste into the glass manufacturing sector also has its own environmental impact, in particular through the impact of transport. Is it more environmentally friendly when transporting C&D glass waste up to the nearest flat glass furnace (option 1, i.e. when glass waste has been prepared into cullet), to the nearest hollow glass furnace (option 2, i.e. when glass waste has been prepared into cullet), or up to the nearest site recovering C&D waste for public works?

In this chapter, parameters such as window dismantling and cullet preparation have been disregarded in the environmental impact assessment because their impacts are deemed low compared to transport environmental effects and to the benefits related to the substitution of raw materials.[167]

1 Assumptions for calculations

[164] IPTS/EC, 2013
[165] Energy Efficiency Improvement and Cost Saving Opportunities for the Glass Industry, An ENERGY STAR® Guide for Energy and Plant Managers, Ernst Worrell, Christina Galitsky, Eric Masanet, and Wina Graus, Sponsored by the U.S. Environmental Protection Agency, March 2008.
[166] Recyclable waste flat glass in the context of the development of end-of-waste criteria, Glass for Europe, June 2010.
[167] Glass Technology Services Ltd (GTS), UK centre for glass research

- The impact of transport on climate change, for a lorry whose capacity is over 32 metric tonnes, is around **0.084037 kg of CO_2 eq per tonne per km** (European average).[168]
- The *Table 46* (in Appendix 2) sets out the average tonnages transported and average distances travelled (for round trips) between each step of the recycling chain, for scenarios relative to options 1, 2 and 3.
- Each tonne of cullet used in the melting process allows saving approximately 300 Kg in CO_2 emissions (Glass for europe data).

Thanks to these assumptions, the environmental impacts of transport for different recycling scenarios can be approximated.

2 Environmental impacts for different recycling scenarios

As shown in previous chapters, more than 1.5 million tonnes of glass waste are generated each year in the EU. In options 1 and 2, it is assumed that 100% of the glass waste is recycled. In option 3, it is assumed that, in average, 40% of glass waste is recovered, while the rest is redirected to landfills.

These different recycling routes generate different environmental impacts, for example on resource consumption through the quantity of waste going to landfill and raw material consumption or on climate change through energy savings and associated reductions in CO_2 emissions. A further assessment would require an LCA analysis, which is not conducted in the frame of this study.

The assumption is made that each tonne of cullet saves:

- tonne of waste from landfills;
- 1 200 kg of virgin raw materials, of which 850 kg of sand;
- 25% of energy;
- 300 kg of direct CO_2 emissions.

Avoided waste going to landfill

Table 33 provides orders of magnitude of avoided waste going to landfills for the different recycling scenarios. If options 1 and 2 were applied, up to 60% (i.e. about 925 000 supplementary tonnes) of glass waste could be recovered in the EU compared to option 3.

Table 33: Impacts of each recycling scenario on the avoided waste going to landfills

Origin of glass waste	Avoided waste going to landfills, depending on the recycling scenario		
	Option 1	Option 2	Option 3
Glass waste from renovation	~ 1 280 000 tonnes		~ 512 000 tonnes
Glass waste from demolition	~ 261 000 tonnes		~ 104 000 tonnes
Total avoided glass waste	**~ 1 541 000tonnes**		**~ 616 000 tonnes**

[168] Ecoinvent - https://v31ecoquery.ecoinvent.org

Impact on raw material consumption

Table 34 provides estimates of raw material savings for the different recycling scenarios. If options 1 or 2 were applied, up to 1 085 000 tonnes of raw material could be recovered in the EU, i.e. about 1 023 000 tonnes more than in option 3.

Table 34: Impacts of each recycling scenario on raw material savings

Origin of glass waste	Raw material savings, depending on the recycling scenario		
	Option 1	Option 2	Option 3[169]
Glass waste from renovation	~ 1 536 000 tonnes		~ 512 000 tonnes
Glass waste from demolition	~ 313 000 tonnes		~ 104 000 tonnes
Total raw material savings	**~ 1 849 000 tonnes**		**~ 616 000 tonnes**

Impact on climate change (energy savings and CO_2 emissions)

The *Table 35* provides the impacts on climate change of transport of C&D glass waste, per type of road journey, and per origin of waste. Depending on the type of material transported, which influences the tonnage present in a container, the environmental impact of transport might vary for a same distance travelled.

Table 35: Impacts on climate change of transport of C&D glass waste, per type of road journey, and per origin of waste

Distances travelled (round trips)	CO_2 emissions due to transport (in kg CO_2 eq / tonne of glass), depending on the type of material transported			
	If glass panes only *(large renovation / demolition projects)*	If framed windows *(light renovation projects)*	If prepared cullet	Demolition waste containing glass
Between renovation/ demolition site and collection/gathering point (100 km)	8 kg CO_2 eq /t	n.a.	n.a.	n.a.
Between collection/gathering point and treatment centre (200 km)	17 kg CO_2 eq /t	17 kg CO_2 eq /t	n.a.	n.a.
Between treatment centre and flat glass manufacturer (362 km)	n.a.	n.a.	28 kg CO_2 eq /t	n.a.
Between treatment centre and hollow glass manufacturer (166 km)	n.a.	n.a.	14 kg CO_2 eq /t	n.a.
Between renovation/ demolition site and the nearest landfill (43 km)	n.a.	n.a.	n.a.	4 kg CO_2 eq /t

[169] For this option, we estimate that the recovery of 1 tonne of cullet allows saving 1 tonne of raw material, as cullets are used as simple construction materials.

Table 36: Impacts on climate change of transport of C&D glass waste, per origin of waste, for each recycling scenario

Origin of glass waste[99]	CO_2 emissions due to transport, depending on the recycling scenario		
	Option 1	Option 2	Option 3
Glass waste originating from light renovations of residential buildings/ houses	**45** kg CO_2 eq /t	**31** kg CO_2 eq /t	**4** kg CO_2 eq /t
Glass waste originating from large renovation or demolition sites	**53** kg CO_2 eq /t	**39** kg CO_2 eq /t	

As shown in Table 36, in general terms, negative impacts on climate change caused by the transport of C&D glass waste from a site generating waste up to a recycling outlet are significantly higher (~ 8 to 13 times higher) in options 1 and 2 than in option 3. CO2 emissions for option 1 are ~ 45% higher than for option 2.

When the energy saving parameter is taken into account (each tonne of cullet used in the melting process allows saving approximately 300 Kg in CO2 emissions), the total environmental impact of each scenario approaches the results presented in

Table *37*.

Table 37: Balance between CO_2 emissions and savings for each recycling scenario, per origin of waste

Origin of glass waste	Balance between CO_2 emissions and savings, depending on the recycling scenario		
	Option 1	Option 2	Option 3
Glass waste originating from light renovations of residential buildings/ houses	**-255** kg CO_2 eq /t	**-269** kg CO_2 eq /t	**4** kg CO_2 eq /t
Glass waste originating from large renovation or demolition sites	**-247** kg CO_2 eq /t	**-261** kg CO_2 eq /t	

As shown in

Table 37, in general terms, both **options 1 and 2 avoid CO_2 emissions. More emissions (~5% per tonne) are *avoided*** in option 2 than in option 1 due to assumed shorter transport distances and therefore reduced impacts from transport. Additionally, within each option, more CO_2 emissions are *avoided* when glass waste originates from light renovations of residential buildings/ houses.

In conclusion, from an environmental point of view, when considering carbon emissions, avoided waste going to landfill and raw material consumption, option 2 and option 1 are the best alternative. Option 2 shows slightly higher benefits than option 1, mostly due to the assumed shorter transport distances. Both options provide benefits in terms of energy and CO_2 savings (between ~ - 240 and – 265 kg CO_2 eq per tonne of glass waste compared to option 3). There, the energy savings through substituting raw materials with cullet far outweigh the impacts related to longer transportation distances. They would allow avoiding up to 925 000 tonnes of waste going to landfills and the

consumption of 1.23 million tonnes of raw materials (of which ~ 873 000 tonnes of sand) compared to option 3.[170]

[170] Option 3 does not enable to avoid any CO2 emissions except the emissions avoided at the extraction stage, because glass replaces, in public works, raw materials that have been extracted, yet emissions due to extraction cannot be measured as it depends of which material glass replaces.

Cost-influencing factors for the production of cullet

While data on costs proved to be difficult to obtain, factors that influence the net costs of cullet can be listed:

- The cost of dismantling windows from buildings + separating glass panes from frames;
- The cost of transport up to a collection/gathering point;[171]
- The cost of transport from collection points treatment centres;
- The cost of treating the glass waste (cullet preparation)[172];
- The cost of transport from treatment centres up to glass manufacturers or up to sites where cullet is recovered for public works, used as a road base course, or as backfill for trenches and earthworks;
- Landfill costs and accessibility (in terms of location)[173].

Cost-benefit analysis of various recycling routes for C&D glass waste

1 Assumptions used to evaluate total costs

Cost items included in total costs

"Total costs" correspond to the cost of:

a) Producing cullet in view of recovering it in the glass sector → in case of options 1 and 2;

b) Collecting + transporting glass waste for recovery with other C&D waste → in case of option 3 (glass waste is not transformed into cullet).

a) <u>"Total costs" in case of options 1 and 2 include:</u>

- The cost of **dismantling windows from a buildings' structure**:

[171] Collection points exist in France, Belgium, UK and the Netherlands, although the type of collection points varies: a "collection point" can be either an area which already collects waste other than glass ("déchèterie") or an area which was set up by a treatment centre to collect a certain type of waste (e.g., C&D waste, glass waste, etc.).
[172] It is assumed in this study that treatment costs for options 1 and 2 are similar. In reality, the cullet quality requirements for flat glass recycling are generally higher (option 1) than for hollow glass, however it was not possible to differentiate the respective treatment costs associated to these higher quality standards.
[173] See Appendix for informational tables on landfill taxes/costs and number of locations per country.

- In case of old windows originating from renovation, the cost of dismantling windows is not included in the cost of 'producing cullet' because window installers / carpenters dismantle windows in any case, would there be a specific collection and recycling system or not.
- In case of old windows originating from demolition sites, the cost of dismantling windows is included in the cost of 'producing cullet' because it is done appropriately (and induces a higher manpower cost) in case it has been planned to collect separately old windows in view of recycling;

- The cost of **separating window glass panes from their** (wooden / PVC / metallic) **frames**:
  - In case of old windows originating from light renovation of residential buildings / houses, the separation of window glass panes from frames is deemed to be done by treatment centres (such as in the case of the Lapeyre/ Paprec / Saint-Gobain project), and *not* on the renovation sites neither on the collection/ gathering points.
  - In case of old windows originating from renovation of tertiary sites or from demolition sites, the separation of window glass panes from frames is deemed to be done directly on sites where waste is generated, which means that treatment centres receive unframed windows.
  - Costs are likely to be different depending on whether panes are separated from frames on-site or at the treatment centre, as shown by the Revalo case study for France, in Phase I. However, because costs cannot be distinguished in the present study, the assumption is made that costs are equivalent.
- The cost of **transporting dismantled windows** from the site where it is generated, **up to the nearest collection/gathering point**
  - In case of old windows originating from light renovation of residential buildings / houses, the cost of transporting the dismantled windows up to the nearest collection/gathering point (e.g., at the Lapeyre shop in the case of the Lapeyre/ Paprec / Saint-Gobain project) is not included in the cost of 'producing cullet'. Indeed, a window installer / carpenter who dismantles a few windows in residential building / house, bears in any case the burden of transporting old windows to a collection point, regardless if that collection point sends the waste to landfill or not;
- The cost of **stocking dismantled windows** (with or without frames) **on stillages or in skips** at a collection/gathering point;
- The cost of **transporting dismantled windows (with or without frames)** from the collection/gathering point, **up to the nearest treatment centre**;
- The cost of **treating** dismantled windows (with or without frames), i.e. the cost of **preparing the cullet**;
- The cost of **transporting the prepared cullet up to the nearest recycling outlet** (flat glass manufacturer, hollow glass or glass wool manufacturer).

b) <u>"Total costs" in case of option 3 include:</u>

- The cost of **transporting C&D waste from the renovation/demolition site, up to the nearest site recovering C&D waste for public works** or up to the nearest landfill, if some of the waste is oriented towards a landfill;

- The **cost of landfill,** in case part of the waste is landfilled.

Dismantling windows and separating glass panes from frames

The "dismantling" and "separation" costs can vary significantly depending on the floor level; on the type, size and weight of windows; on the tools and techniques used; on the fact that workers have been trained or not; and of course on the labour cost. For instance, different estimations can be made in the Netherlands where only the windowpane without the window frames are removed from the buildings at renovation works. Furthermore, if the panes are bigger or heavier, it could take longer and maybe more glaziers would be required. In case of a higher building, a crane might also be needed for taking out the windowpanes from the frames, which shall increase the removal time, etc.

A study made in 2003 by the UK Glass Technology Services illustrates the experience of two workers, on a demolition site, which used a variety of techniques to remove 40 windows containing 14kg of glass each, over an 8-hour shift. If both workers had been paid the minimum wage, i.e. ~21€/ hour as of today in the UK, it would have cost about 382€ (including overhead costs) to remove 1 tonne of window glass and separate glass from frames.

For the purpose of this study, assumptions were made on "generic" costs, based on extrapolation from available data at country levels.

Dismantling window

It is assumed that it costs on average 296€ per tonne of glass for dismantling windows, based on data from different European countries and the assumption that this work requires about 6 hours from 2 workers, with an average salary of 20€ per hour and about 30% of overhead costs[174]. However, costs vary from a country to another, depending on all the aforementioned factors. In absence of accurate data on the cost of dismantling of windows, it was decided to use this unique estimate as a reference. Therefore, it this estimate should be taken with much precaution.

Separating glass panes from frames

It costs, on average, around 50€ per tonne of glass to separate glass panes from frames on-site (excluding window dismantling).

This estimation is based on what AGC Glass Europe has experienced during French large renovation and demolition projects, and on the following assumption: to separate glass panes from frames in order to obtain about a tonne of glass requires hiring two workers during an hour, where each receive a salary of 25€/ hour while the company hiring this operators pays overhead costs representing ~30% of the wages, leading to a cost of 65€ per tonne.

Two other flat glass manufacturers than AGC have been sound out in order to crosscheck this estimation. They have estimated that in the case of France, 65€ per tonne of glass a seemed realistic figure. In absence of accurate data on the cost of separation of glass panes from frames, it was decided to use the assumptions underlying this value as a reference (number of working hours, number of employees). An EU average salary of 20€/ hour was used to estimate the separating costs in the EU, resulting in 50€ per tonne. Furthermore, based on the minimum wage of each EU country, the cost of manually separating glass panes from frames on-site could be estimated for each of the 28 EU countries. For more detail, please refer to

Table 38 in Appendix 3.

[174] Most windows dismantled are not at the ground floor, which means that the company in charge of dismantling windows must use a scaffolding lift, a mast-climbing platform or an aerial work platform to enable workers to dismantle windows / glass walls from the building's floors. The cost of using such a machine is included in the overhead costs.

However, costs vary from a country to another, especially depending on the techniques used and depending on whether panes are separated from frames on sites or at the treatment centre. Therefore, this estimate should be taken with much precaution.

Transport distances and costs

The average distance travelled by window installers/ carpenters between residential buildings where they replace windows and the sites of window distributors (such as Lapeyre shops) which act as collection points, is around 15 km. Yet the cost for travelling such distance is not included in total costs of the following section (which compares options 1, 2 and 3), because window installers / carpenters bear this cost in any case, would they bring windows to the collection point or to the landfill. They will be willing to bring old windows to collection points if the deposit fee at the collection point is lower than the landfill cost.

In option 3 (recovering of C&D glass with other C&D waste):

- Hypothesis: 50% of the waste generated by demolition or renovation sites can be considered as recovered today in the EU, based on the declared recycling rates from a few European countries. More specifically, it is assumed that glass is recovered at around 40% on demolition sites. The rest of the waste generated is deemed to be landfilled, i.e. 60% of the glass is landfilled in option 3 and 40% recovered for public works, used as a road base course, or as backfill for trenches and earthworks.[175] This is below the target specified in the European directive for C&D waste, but considered more realistic today.
- The average transport distance between a renovation (light *or* large renovation) or demolition site and the nearest area where cullet can be recovered for public works is appraised equal to the average transport distance from the renovation or demolition site up to the nearest landfill.
- For the average distance travelled to "the nearest landfill", please refer to Table 48 in Appendix 3.

For assumptions and calculations made to obtain the following transport costs, please refer to Appendix 2:

- Average transport between site generating waste and collection/gathering point (for major renovations and demolitions): 50 km (EU average);
- Average transport distance from collection/gathering point to treatment centre: 100 km (EU average);
- (Option 1) Average transport distance from treatment centre to flat glass manufacturer: 167 km (EU average);
- (Option 2) Average transport distance from treatment centre to hollow glass manufacturer: 83 km (EU average);
- (Option 3) Average transport distance from large renovation or demolition site to the nearest landfill or to a site where cullet is recovered for public works, used as a road base course, or as backfill for trenches and earthworks:22 km (EU average).

The estimation of the overall transport costs is based on "round trips", with the "worst-case" assumption that reverse logistics are not implemented. Aforementioned distances are therefore multiplied by two in the calculation of costs. These assumed transport distances have a major influence on the findings of the work.

[175] Hypothesis of Deloitte.

Glass treatment (cullet preparation)

Treatment costs vary whether old windows are still framed or not when they arrive in a treatment centre. **If window frames have been separated from glass panes directly on renovation / demolition sites**, i.e. windows are unframed when they arrive at treatment sites, the preparation of the cullet by glass treatment centres is estimated to cost between **30 and 50€ /tonne of glass**.[176] Whereas **if windows arrive *framed* in treatment centres**, the cost of preparing the cullet includes the cost of separating glass panes from frames (manually or automatically), and cullet preparation costs are estimated to vary between **55 and 75€/tonne of glass**.

Cost of glass waste recovered with other C&D waste and cost of landfill

I**t is estimated that it costs close to 0€** (and does not bring any revenue although it enables to avoid paying landfill costs) **to provide demolition waste to a site where cullet is recovered for public works**, used as a road base course, or as backfill for trenches and earthworks. In France for instance, as a recent report by the French Building Federation (FFB – Fédération Française du Bâtiment) focusing on C&D waste management indicates, this cost ranges between 1 and 8€ per tonne (cost estimation excluding costs of transport and container rental). [177]

When C&D glass is not recycled, it costs between 10 and 180€/tonne to landfill it (the average is estimated to be around 80€/tonne for the EU, although it varies widely across the EU[178]), regardless of the cost of transport from the site where waste comes from up to the nearest (and/or cheapest) landfill.

2 Results of calculations regarding collection, treatment and transport of C&D glass waste for each recycling scenario

Table 38: Cost of dismantling windows & separating glass pane from frames, on large renovation or demolition sites[179]

	Cost of separating glass pane from frames (€/ tonne of glass)	Cost of dismantling windows (€/ tonne of glass)
Northern Europe	65.0 €	-
Western Europe	62.7 €	-
North-Eastern Europe	18.2 €	-
South-eastern Europe	12.0 €	-
Southern Europe	32.1 €	-
EU-28 average	50.0 €	296.0 €

[176] Estimations from interviews made along Phase I and II.
[177] http://www.dechets-chantier.ffbatiment.fr/res/dechets_chantier/PDF/Dechets_QR_231014_V5protege.pdf
[178] Landfill costs (tax + gate fee) for inert waste vary widely across the EU:
- In Northern EU: between 70 and 180€/tonne
- In Western EU: between 40 and 150€/tonne
- In North-Eastern EU: between 30 and 65€/tonne
- In South-Eastern EU: between 10 and 50€/tonne
- In Southern EU: between 10 and 104€/tonne

Source: "Landfill Taxes & Bans." (n.d.): n. pag. CEWEP, Feb. 2015. Web. 1 Feb. 2015.
[179] See Appendix 3. Regional averages are weighted averages based on tonnages of C&D glass waste available in each country of this region.

Table 39: Costs of transporting (round trips) and stocking dismantled windows

Cost item	Renovation in residential sites (light renovations)	Renovation in tertiary sites (major renovations)	Demolition of residential and tertiary sites
Transporting dismantled windows from the renovation/ demolition site up to the nearest collection/gathering point	*Not included (see assumptions)*	14€/ t of glass	
Stocking window glass panes on stillages (on renovation/demolition site or on collection/gathering point)	10€/tonne of glass		
Transporting dismantled windows from collection/gathering point up to a treatment centre	39€/ t of glass	26€ /t of glass	

Table 40: Cost of treating dismantled windows / preparing the cullet in view of option 1 or 2

Cost item	Renovation in residential sites (light renovations)	Renovation in tertiary sites (major renovations)	Demolition of residential and tertiary sites
Cost of treating dismantled windows / preparing the cullet	55 to 75€ /t of glass[180]	30 to 50€ /t of glass	

Table 41: Cost of transporting (round trips) the prepared cullet, depending on the option chosen

Cost item	
Transporting the cullet from a treatment centre to the nearest flat glass manufacturer (option 1)	25€ /t of glass
Transporting the cullet from a treatment centre to hollow glass manufacturer (option 2)	13€ /t of glass
Transporting 40% of the cullet from a demolition or large renovation site to a site where cullet is recovered for public works and 60% up to a landfill (option 3)	5€ /t of glass

The table below summarises the total costs incurred for glass waste collection, stocking, transport and treatment, per recycling scenario (option 1 and 2 only) and per sector (residential versus tertiary, renovation versus demolition), before cullet is sold. These costs are EU averages but might vary widely between EU countries and even between two regions of a country.

[180] Includes the cost of separating window glass panes from frames.

Table 42[181]: Total costs incurred in options 1, 2 and 3, per sector

	Glass waste originating from light renovations of residential buildings/ houses	Glass waste originating from large renovations	Glass waste originating from demolition sites
Option 1	Min: 130 € /t of glass Max: 150 t of glass **Average: 140 €/ tonne of glass**	Min: 156 € /t of glass Max: 176 € /t of glass **Average: 166 € /t of glass**	Min: 452 € /t of glass Max: 472 € /t of glass **Average: 462 € /t of glass**
Option 2	Min: 118 € /t of glass Max: 138 € /t of glass **Average: 128 € /t of glass**	Min: 144 € /t of glass Max: 164 € /t of glass **Average: 154 € /t of glass**	Min: 440 € /t of glass Max: 460 € /t of glass **Average: 450 € /t of glass**
Option 3	**Average: 48€ /t of glass**[182]	**Average: 53€ /t of glass**	

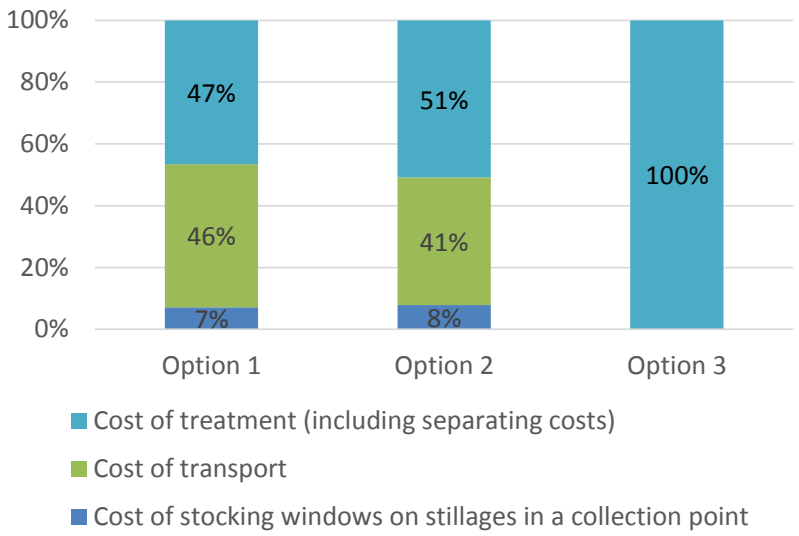
In options 1 and 2 alike, collecting and treating building glass originating from *light renovations* appears slightly more cost-effective (~16% less expensive per tonne) than from major renovations and significantly less expensive (~70% less expensive per tonne) than from demolitions.

A cost analysis shows that **for glass waste originating from light renovations of residential buildings/ houses** (*Figure 23*), the main cost is due to treatment, followed by transport, and to a least extent stocking[183]:

- In option 1: treatment cost (including separation costs[184]) represents 47%, followed by transport cost (46%);
- In option 2: treatment cost represents 51%, followed by transport (41 %);
- In option 3: costs only reflect the costs of landfilling (100%), as transport costs are borne by other operators.

[181] The information presented within this table should be taken with precaution.
[182] In the case of light renovations, the overall costs only include the costs of landfilling (80€ /tonne of glass in average in the EU-28), as transport costs are born by window installers / carpenters.
[183] The cost of dismantling windows is not included in the cost of 'producing cullet' because window installers / carpenters dismantle windows in any case, would there be a specific collection and recycling system or not.
[184] In case of old windows originating from light renovation sites, the separation of window glass panes from frames done at the treatment centre.

Figure 23: Cost analysis for glass waste originating from light renovations of residential buildings/ houses, in the different options

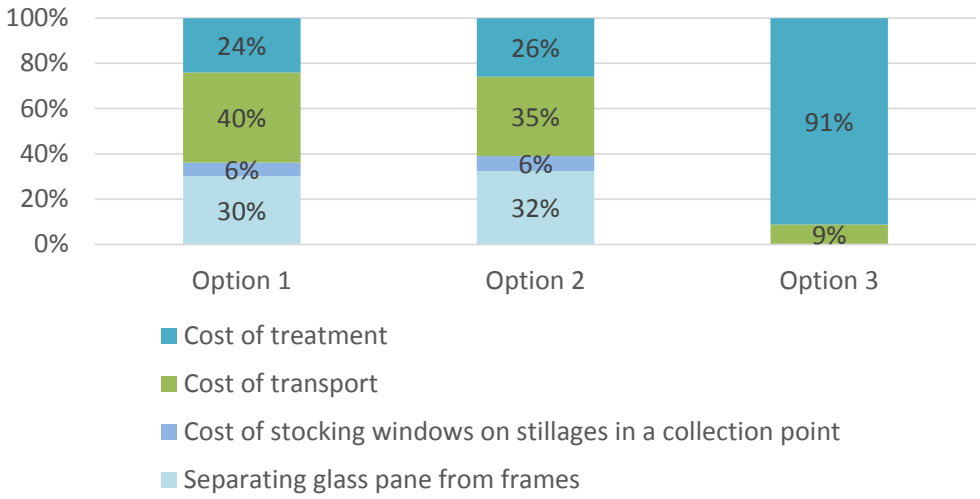


Regarding **glass waste originating from large renovations** (*Figure 24*), the cost analysis demonstrated that the main cost is due to transport, followed by the cost of the separation of glass from frames[185], the cost of treatment and to a least extent the cost of stocking[186]:

- In option 1: cost for transport represents 40% of total costs, followed by the cost of "separation of glass from frames" (30%), and the cost for treatment (24%);
- In option 2: cost for transport represents 35% of total costs, followed by the cost of separation of glass from frames (32%), and the cost of treatment (26%);
- In option 3: landfilling (treatment) is the main contributor to the overall costs (91%) compared to transport costs (9%).

[185] Separating costs are distinguished here from treatment costs, as in case of old windows originating from renovation of tertiary sites, the separation of window glass panes from frames is deemed to be done directly on sites where waste is generated.
[186] The cost of dismantling windows is not included in the cost of 'producing cullet' because window installers / carpenters dismantle windows in any case, would there be a specific collection and recycling system or not.

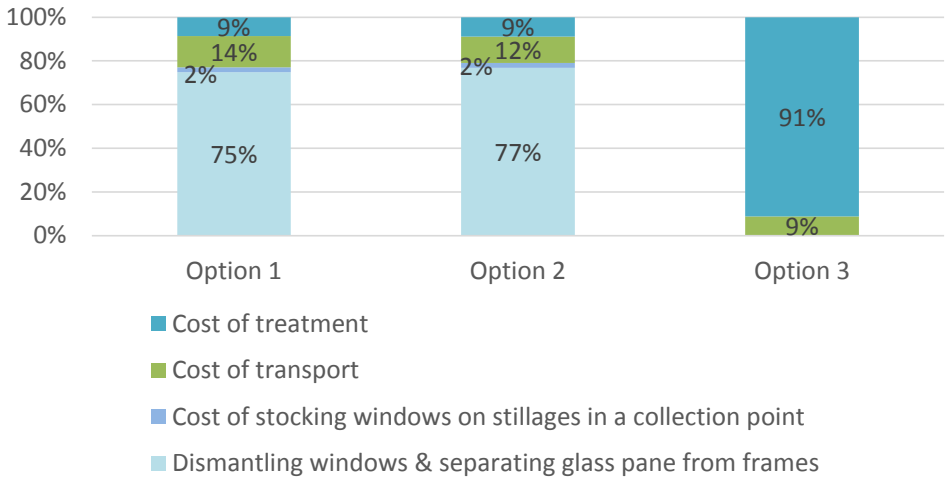
Figure 24: Cost analysis for glass waste originating from large renovations, in options 1, 2 and 3



Regarding **glass waste originating from demolition sites** (*Figure 25*), the cost analysis demonstrated that the main cost by far is due to the dismantling and separation of glass from panes from frames[187], followed by the cost of transport and the cost of treatment:

- In option 1: the cost for dismantling windows and separating glass frames represents 75% of total costs, followed by the cost for transport (14%), the cost for treatment (9%) and to a least extent the cost for stocking (2%);
- In option 2: the cost for dismantling windows and separating glass frames represents 77% of total costs, followed by the cost for transport (12%), the cost for treatment (9%) and to a least extent the cost for stocking (2%);
- Similarly to large renovations, in option 3: landfilling (treatment) is the main contributor to the overall costs (91%) compared to transport costs (9%).

Figure 25: Cost analysis for glass waste originating from demolition sites, in options 1, 2 and 3



[187] Separating costs are distinguished here from treatment costs, as in case of old windows originating from renovation of tertiary sites, the separation of window glass panes from frames is deemed to be done directly on sites where waste is generated.

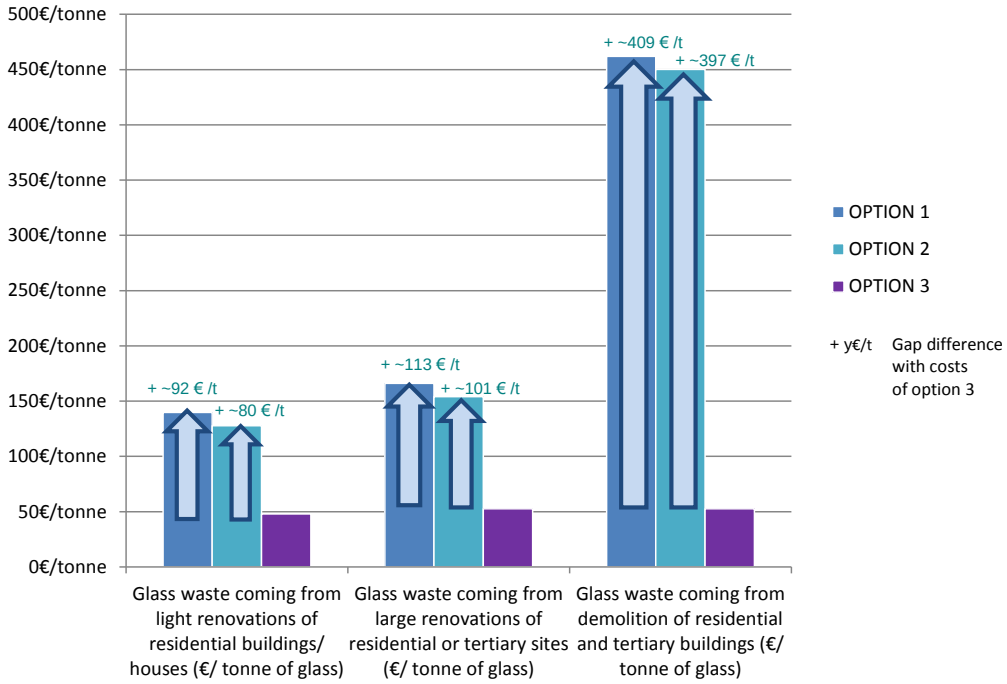
The analysis above shows that options 1 and 2 involve significant costs compared to option 3. This is synthesised in the table below.

Table 43: Cost difference between options 1 and 3, and 2 and 3, per sector[188]

	Glass waste originating from light renovations of residential buildings/ houses	Glass waste originating from large renovations	Glass waste originating from demolition sites
Cost difference between option 1 and 3	**92 € /t of glass**	**Average: 113 € /t of glass**	**Average: 409 € /t of glass**
Cost difference between option 2 and 3	**80 € /t of glass**	**Average: 101 € /t of glass**	**Average: 397 € /t of glass**

Figure 26 provides a graphical overview of these costs. Depending on options and sectors, the difference in cost between options 1 & 2 on the one hand and option 3 on the other hand can range from ~80€ per tonne of glass to ~410€ per tonne of glass.

Figure 26: Overview of total costs for each option and relevant sectors



[188] Assumption that landfilling tax amounts to 80€ /t of glass waste.

This difference in cost could be partially covered, or reduced, in options 1 and 2, through e.g.:

- the price paid for cullets by glass manufacturers;
- the optimisation of dismantling and separation costs (including the collection of valuable frames such as PVC or aluminium, especially to cover the costs of dismantling windows, which has been fully attributed to glass in this study);
- the optimisation of transport costs (e.g. reverse logistics);
- adapting landfilling prices and/or taxes paid by producers to better take into account the environmental benefits of options 1 and 2.

Recovery of cullet

Beyond costs, option 1 and 2 provide revenues that option 3 does not provide, through the possible sale of cullet. Although option 3 enables avoiding paying landfill costs for 100% of C&D glass waste collected, it does not provide waste management companies any additional revenue.[189]

This supplementary revenue in options 1 and 2 may allow partially filling the difference of costs with option 3. However, realistic estimates for the price of cullet show that within the EU, the income from the sale of cullet is, in theory, insufficient to cover collection and treatment costs. The difference is particularly high when glass waste is collected from large renovations or from demolition sites (which represent near 50% of the post-consumer building glass waste arising each year).

According to interviews made along Phase I and Phase II, estimations on the maximum price that EU flat and hollow glass manufacturers may pay for C&D cullet range between 50 and 80 €/ tonne. *Table 44* and *Figure 27* highlight remaining differences in costs under the assumption that cullet can be sold at ~65€/ tonne.

Table 44: Production costs minus potential revenue from the sales of cullet, under the assumption that cullet can be sold for 65€ per tonne

	Glass waste originating from light renovations of residential buildings/ houses	Glass waste originating from large renovations	Glass waste originating from demolition sites
Production costs in option1 minus revenue	75 € /t of glass	101€ /t of glass	397 € /t of glass
Cost difference between option 1 and 3	**27 € /t of glass**	**Average: 48 € /t of glass**	**Average: 344 € /t of glass**
Production costs in option 2 minus revenue	63€ /t of glass	89€ /t of glass	385€ /t of glass
Cost difference between option 2 and 3	**15 € /t of glass**	**Average: 36 € /t of glass**	**Average: 332 € /t of glass**

[189] Estimation based on Deloitte experience in waste management.

Figure 27: Overview of potential reduction of costs for options 1 and 2 through cullet selling (assumption: 65€ /t)

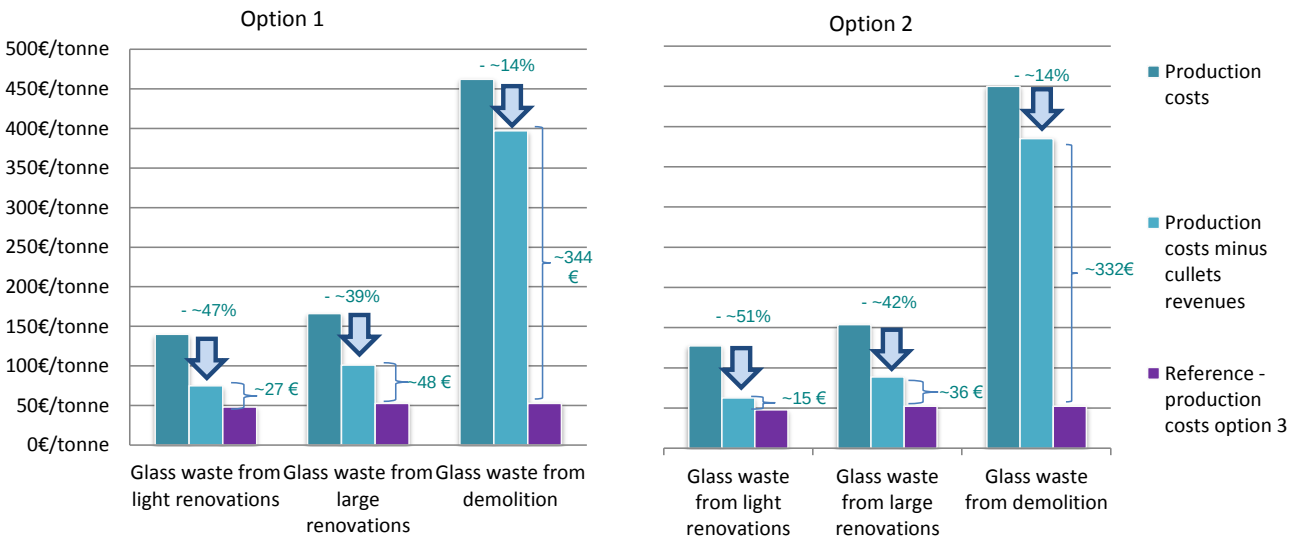
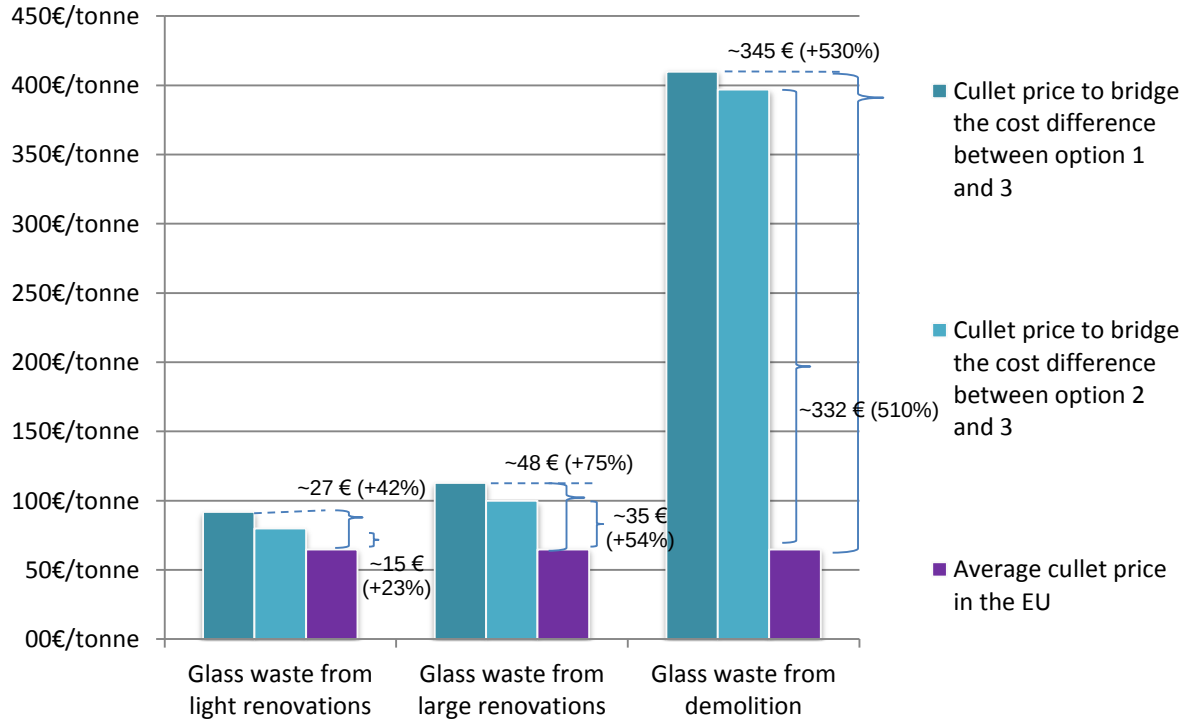


Figure 28: Levels of cullet prices if to bridge cost difference between options 1 and 3 on the one hand and option 2 and 3 on the other hand



Optimisation of collection and transport costs

A scenario in which windows are collected with monetarily viable frames, such as PVC or aluminium, these frames could potentially compensate or help equilibrate the collection and treatment costs. However, in practice, interviewed stakeholders from the Netherlands, UK, and Germany indicated that frame collection is usually out of the scope of their business model and is not foreseen as a potential source of revenue because the window recovery market is already dominated by PVC or aluminium treatment companies, which have an expertise in the recycling of frame materials. Hence, this

developed market for frame recycling leaves little room for glass treatment sites to expand their activity in that direction.

As seen in *Figure 23* and *Figure 24*, logistics (transport) represent near half of the costs involved in light and large renovations. In the case of demolition (*Figure 25*), it contributes to a lesser extent (9-14%) to the costs, the cost of dismantling windows being predominant. Unlike treatment costs, for which there may be little flexibility, transport costs can be significantly optimised, through e.g.:

- Increasing transport by train rather than by road (but not by vessel: indeed, although the environmental benefit of transporting flat glass cullet via vessel is clear, the economic advantage is no better than transporting by truck; both forms of transport bear the same economic cost, because choosing to transport the glass by vessel means extra costs of storage place, handling and administration);
- Implementing reverse logistics[190];
- Owning one's fleet of trucks versus renting trucks from a logistics company, depending on distances and costs;
- Setting up storage points with proper skips in low-service areas, which could also increase flat glass countrywide coverage;
- Reducing distances from the site of waste generation to collection points and/or from treatment centres to manufacturers (for instance by considering glass wool manufacturers which are numerous across Europe).

Taking into account the original objective of option 2 (analyse recovery operations within several glass industries), adding **glass wool manufacturers** to the present hollow glass scenario would only diminish option 2's overall costs by a very small extent (1 or 2 € per tonne). Under the assumption that there are currently 43 plants in the EU[191], this would indeed reduce average transport distances of only ~10 km from the collection treatment site (from 83 km to 74km one-way). The small impact on the overall cost can be explained by the fact that these transport costs represent only ¼ of the overall transport costs. These costs include transportation from the waste-generating site to the collection point followed by the transportation from the collection point to the treatment centre (the latter being twice as high as the other transport costs).

Simulations show that **reducing overall transport distances** cannot solely bridge the difference of costs with the option 3. This is particularly true for all types of glass provenance (light renovation, large renovation, demolition) if possible revenue from glass cullet are not taken into account. In the case where transport costs would be null, production costs for options 1 and 2 would still be twice as much expensive as option 3 in the case of glass waste from light and large renovations, and more than 7 times more expensive in the case of glass waste from demolition. The only case where reducing transport distances could bridge the gap with option 3 concerns glass waste from light and large renovations and would require to divide overall transport distance by ~2 and 4, respectively, under the assumption that glass cullet are sold at 65€ per tonne. This option remains unlikely in the large scale as it would require to significantly increase the number of site collections, treatment centres and manufacturers to increase geographical coverage. As illustrated in the maps of *Figure 19*, *Figure 20*, *Figure 21*, and *Figure 22*, the EU countries having the highest density of glass waste arising (in tonnes per km²), and thus the highest transport cost reduction opportunity, are the Netherlands, Belgium, Germany, Denmark and the UK, followed by Poland. In this respect, the Commission Regulation

[190] In theory, transporters and/or treatment centres that collect building glass from sites try to implement reverse logistics, however as they do not always find other materials to either bring or take from the site, it is not always practiced. The Belgian treatment company, Maltha, is among the recyclers which have established reverse logistics in their building glass collection business model.

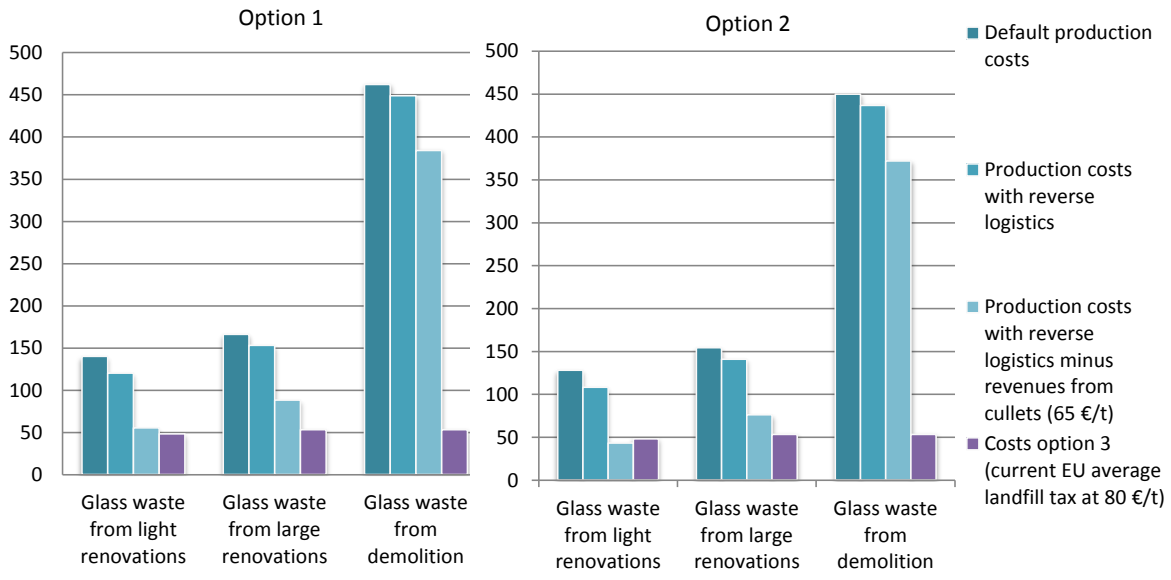
[191] Very preliminary estimates based on an Ecofys study (2009), which shows that they were 87 mineral wool plants in the EU, producing stone wool or glass, in about the same proportion.

(Regulation (EU) No 1179/2012 of 10 December 2012) establishing end-of-waste criteria (EoW) for waste glass, including specific requirements for flat glass, should facilitate and ease logistics, in particular the transportation of glass between waste treatment and glass manufacturers' facilities[192].

Promoting reverse logistics seems to be a more relevant option that would allow reducing overall costs for options 1 and 2 by about 14-15%, 8-9%, and 3% for glass from light renovation, large renovation and demolition site, respectively. These estimates were based on the assumption that overall transport costs between collection sites and treatment centres were divided by two, as trucks do no return empty. It must however be noted that reverse logistics is an option in the hands of transport companies rather than treatment companies. Additionally, this solution does not allow bridging the whole cost difference with option 3.

Production costs of options 1 and 2 remain, however, 2-3 times (glass from light renovation), 3 times (glass from large renovation) and 9-8 times (glass waste from demolition sites) more expensive than option 3. If combined with the sales of cullet (at 65€ per tonne), difference in costs could be null for light renovation and brought to 2 times in the case of large renovation or 7 times in the case of demolition.

Figure 29: Production costs for options 1 and 2 and difference with option 3 if applying reverse logistics and/or additional revenue from cullet



Better take into account environmental externalities through economic instruments

From a purely 'economic modelling standpoint', there could be other ways to bridge the gap (i.e. the difference in costs) and make it interesting to recover cullet in flat glass sector (option 1) and or in the hollow glass sector (option 2):

- Raise landfill taxes
- Distribute dismantling costs better by allocating part of it to window frame recycling (PVC and aluminium)

[192] Once the EoW criteria are met (generally after treatment) the glass cullet is no longer a waste and its transportation does not require any 'waste transportation licence'

- Scale-up flat glass collection and sorting facilities and practices to bring down costs; for example by way of requirements for selective demolitions
- Find another source of revenue, e.g. through an Extended Producer Responsibility (EPR) system such as in the Netherlands, where a fee is imposed on producers.

It is not within the scope of this work to evaluate all possible options, be it in economic or in practical terms. The various options above may not necessarily prove to be cost-efficient or practically implementable once fully researched. This could be the topic of a separate piece of work.
Only the effect of landfill taxes was simulated as the single parameter of landfill costs for inert waste is 'relatively easy' to compute.

Regarding landfill costs, in some areas of Belgium (in Flanders, landfill costs for inert waste rise up to 120€/ tonne), in Sweden (landfill costs for inert waste range from 110-160€/tonne) or in the United Kingdom (average landfill costs for inert waste amount to 100€/tonne) for instance, options 1 and 2 might be profitable options compared to option 3.[193] Indeed, when landfill costs rise, net costs in option 3 rise automatically (assuming 60% of the glass is landfilled in option 3).

Although these taxes are above the EU average, they generally remain insufficient to fully cover the gap in costs between options 1-2 and option 3, except when they are combined with the consideration of the revenue from cullet (assumption of 65€ /t)) for large renovation (*).

Table 45 and *Figure 30*).

Table 45: Simulation of the levels of landfill taxes required to bridge the difference in costs between options 1-2 and option 3, for the different sectors, in combination or not with the sales of cullet (at 65€ per tonne)

	Current level of landfill taxes in the EU	Case of light renovations		Case of large renovations		Case of demolition	
		Total costs	Net costs (combination with cullet sales)	Total costs	Net costs (combination with cullet sales)	Total costs	Net costs (combination with cullet sales)
Option 1	80€ /t	235€ /t	125€ /t	270€ /t	160€ /t	760€ /t	655€ /t
Option 2		215€ /t	105€ /t	250€ /t	140€ /t	740€ /t	635€ /t

[193] 2015, February. "Landfill Taxes & Bans." (n.d.): n. pag. CEWEP, Feb. 2015. Web. 1 Feb. 2015. <http://www.cewep.eu/media/www.cewep.eu/org/med_557/1406_2015-02-03_cewep_-_landfill_inctaxesbans.pdf>.

Figure 30: Level of landfill tax required to bridge the cost difference between options 1-2 and 3

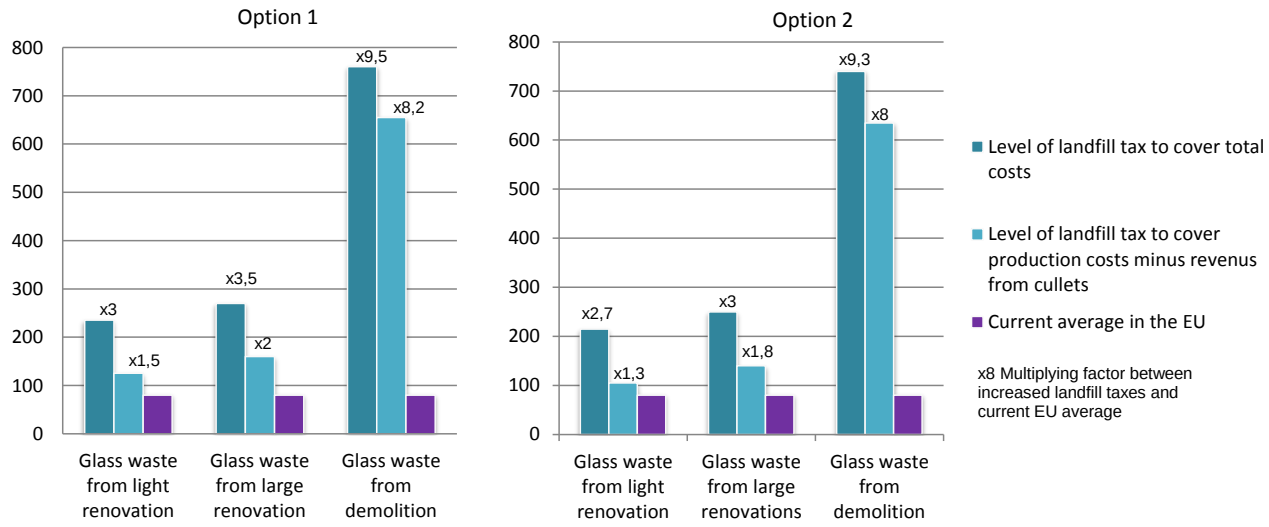
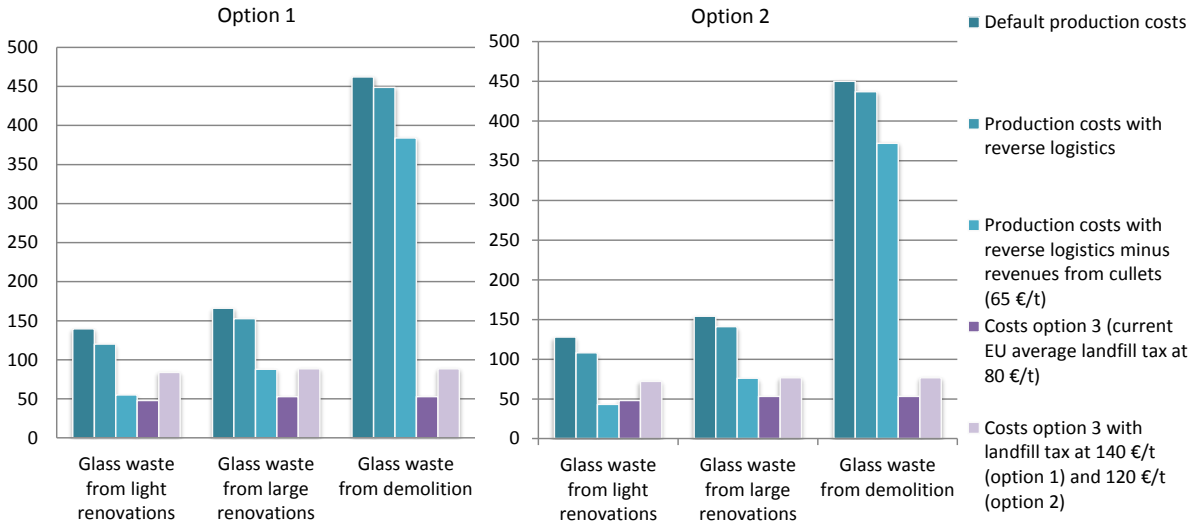


Figure 31 illustrates possible benefits of a combination of reverse logistics, cullets sellings and increased landfill taxes. It illustrates conditions where recycling could be very competitive in the renovation sector. In particular, in the light renovation sector, the combination of reverse logistics, cullets selling at average cullets price and average taxation would decrease the cost of recycling so that it competes with the cost of option 3. In the large renovation sector, increasing the landfill tax from 80 to 120€ /tonne (option 1) or 140€ /tonne would allow achieving comparable costs with option 3.

Figure 31: Illustrative example of economic benefits when combining mitigation actions



In the case of demolition, however, these measures – even strengthened - would not be sufficient to cover cost difference. For glass recycling to be economically feasible, there is a need to find a solution to cover dismantling costs. An option could be first to share the dismantling costs by allocating part of it to the frames, while all the costs are currently assigned to the glass. A further option could be to introduce requirements for selective demolition towards the buildings owners, which should be considered from the conception and construction of the buildings.

Conclusions

The present study shows that the building industry generates each year significant amounts of glass waste in the EU-28 (about 1.5 million tonnes in 2013). In spite of its recyclability, waste arising from renovation or demolition projects is almost never recycled into new glass products. It is rather recovered together with other C&D waste or sent to landfills, as in the case of demolition projects.

The analysis of two glass recycling scenarios, which assume that flat glass is either entirely recycled within the flat glass industry (option 1) or within the overall glass sector (option 2), indicates that recycling would provide significant environmental benefits compared to the business as usual scenario (option 3: 40 % recovery – 60% landfill). Both scenarios 1 and 2 indeed reveal comparative benefits in terms of energy and CO2 savings (between ~ - 240 and – 265 kg CO2 eq per tonne glass waste compared to option 3), as well as reduction in the amount of waste going to landfill (up to 925 000 tonnes) and raw material consumption (~1.1 million tonnes of raw materials, of which ~935 000 tonnes of sand) compared to option 3. Option 2 present slightly higher benefits than option 1 in terms of CO2 emissions due to the short transport distances assumed, although the order of magnitude remains similar (~-5% emissions for option 2).

The economic picture, however, points to the need to carefully consider the issue of costs, should such recycling routes be promoted across the EU. Options 1 and 2 present additional costs compared to business-as-usual scenario, in both the sectors of renovation and demolition (average of 140 to 462 €/ tonne of glass for option 1 depending on renovation or demolition, and 128 to 450 €/ tonne of glass for option 2, compared to 48 to 53 €/ tonne of glass for option 3). These additional costs would already be partially covered by the price at which glass manufacturers would buy cullet, whose scarcity may soon become a source of concern for the industry. Although results are given at an EU scale and based on many assumptions because of a lack of available data and confidentiality issues, this shows that the economic balance of glass recycling for both options is not attained under current conditions.

In the case of *light and large renovations*, the difference in costs is lower than in the case of demolition and it could be partially bridged through:

- The price cullet are sold to glass manufacturers;
- The optimisation of collection and transport costs, in particular through reverse logistics, as it has been shown that reducing distances only has limited influence on overall costs; and/or
- The adaptation of landfilling prices to better consider positive environmental externalities arising from recycling.

Simulations show that stand-alone measures will not be sufficient to reach an economic balance. Combined efforts on these items and possibly other ones may be necessary to increase the competitiveness of recycling (compared to business-as-usual scenario) while proposing realistic actions. It must be kept in mind however that it is not within the scope of this work to evaluate all possible options / measures, be it in economic or in practical terms. After further analysis, it could be that some of the listed options do not prove cost-efficient or practically implementable.

In the case of *glass waste arising from demolition sites*, the difference in costs is particularly marked, because of the very high cost of dismantling (there, separating glass panes from frames and dismantling windows account for themselves to ¾ of total costs). There, any of the mitigation actions

highlighted before would remain clearly insufficient to ensure the economic feasibility of recycling, both for options 1 and 2.

Promoting recycling in the sector of demolition would call for a change of paradigm concerning the allocation of costs and/or financial responsibilities given to the different operators involved in glass waste management. An option would be to attribute the cost of dismantling windows not only to the glass recycling sector but also to other industries involved in selective demolition of buildings as well as in recycling other materials used for windows (e.g. PVC and aluminium frames). Another option would be to rethink responsibilities and extend waste management financial requirements to the owners of the demolition site.

To conclude, the study shows that there are many environmental benefits to increasing the recycling of building glass. Because of the burden of transporting recycled glass, the recycling of flat glass will always be more profitable when recycling takes place in the glass industry closest to the glass collection point. This means that building glass waste recycling should not be confined to a closed-loop system (flat glass to flat glass) but rather be open to other glass industries, depending on local / regional specificities and industrial presence. A set of concrete and realistic actions (e.g. cullet sales, optimisation of transport through reverse logistics, increase of landfill taxes) could be taken in the renovation sector to ensure a better competitiveness of recycling and its implementation compared to the current recovery/landfilling practices. The case of demolition is more complex and requires to address dismantling costs. This would involve significant changes in operational and financial requirements from different operators (e.g. redistribution of costs within sectors providing materials for windows other than glass, extension of selective demolition requirements) should glass recycling be effectively deployed in the EU-28.

Chapter 4:Bibliography

- "All About Glass - Home." AGC News. N.p., n.d. Web. 12 Aug. 2014. <www.yourglass.com>
- Bowers, Mark. "Lloyd's of London: A World First for Recycling." 2011: n. pag. Web. 15 Feb. 2015.
- "CBS StatLine - Voorraad Woningen En Niet-woningen; Mutaties, Gebruiksfunctie, Regio." *CBS StatLine - Voorraad Woningen En Niet-woningen; Mutaties, Gebruiksfunctie, Regio*. N.p., n.d. Web. 2014. <http://statline.cbs.nl/StatWeb/publication/?DM=SLNL&PA=81955NED&D1=a&D2=1-2&D3=0&D4=16,33&HDR=G1,G2,G3&STB=T&VW=T>.
- Commissariat, Général Au, Développement, and Dura. *2013 Gestion Des Déchets : Bilans 2009-2012 De La TGAP Et Des Soutiens De L'ADEME* (2013): n. pag. Web. 2014.
- "CoReVe - Consorzio Recupero Vetro." *CoReVe - Consorzio Recupero Vetro*. N.p., n.d. Web. 2014. <http://www.coreve.it/showPage.php?template=homepage>.
- DESTATIS, 1999-2009.
- Department for Communities and Local Government. *Net Supply of Housing: 2012-13, England* (n.d.): n. pag. Web. 2014. <https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/255431/Net_Supply_of_Housing_England__2012-13.pdf>.
- *Dwellings Demolished by Local Authority and Clearance Area*. Stats Wales, n.d. Web. 2014. <https://statswales.wales.gov.uk/Catalogue/Housing/Demolitions/DwellingsDemolished-by-Authority-Clearance>.
- Ecofys (2009). Methodology for the free allocation of emission allowances in the EU ETS post 2012. Sector report for the mineral wool industry. For the European Commission. DG CLIMA. http://ec.europa.eu/clima/policies/ets/cap/allocation/docs/bm_study-mineral_wool_en.pdf
- European Commission. "DIRECTIVE 2008/98/CE DU PARLEMENT EUROPÉEN ET DU CONSEIL." *EUR-Lex*. N.p., 19 Nov. 2008. Web. <http%3A%2F%2Feur-lex.europa.eu%2Flegal-content%2FFR%2FALL%2F%3Furi%3DCELEX%3A32008L0098>.
- European Commission DG ENV, *Use of Economic Instruments and Waste Management Performances*, http://ec.europa.eu/environment/waste/pdf/final_report_10042012.pdf April 2012.
- "Europe's Buildings under the Microscope ." *BPIE*. N.p., n.d. Web. 2014. <http://www.bpie.eu/eu_buildings_under_microscope.html#.VEinsiKUeCk>.
- "Eurostat Home." *Eurostat Home*. N.p., n.d. Web. 2014. <http://epp.eurostat.ec.europa.eu/portal/page/portal/eurostat/home/>.

- "FEVE: The Relationship between Hollow and Building Glass Industries." Telephone interview. 26 Feb. 2015.
- "FERVER Flat Glass Recycling." Telephone interview. 13 Feb. 2015.
- "FEVER Member Companies Conference Call: Flat Glass Treatment and Recycling." Telephone interview. 26 Feb. 2015.
- "France Building Glass Recycling: Lapeyre." Telephone interview. July 2014.
- "France Building Glass Recycling: Paprec." Telephone interview. July 2014.
- "France Building Glass Recycling: REVALO." Telephone interview. July 2014.
- "France Building Glass Recycling: Saint Gobain Glass France." Telephone interview. July 2014.
- "France Building Glass Recycling: Veka Recyclage." Telephone interview. July 2014.
- "France Building Glass Recycling: AGC France." Telephone interview. July 2014.
- Francesco Emanuele Contaldo*, The value of traditional windows in the Mediterranean context*, 2011.
- "Fused Cast Range." Special Glass. N.p., n.d. Web. 26 Mar. 2015.
- "German Energy Savings Regulation (ENEV)." *// Gip*. N.p., n.d. Web. <http://www.gip-fassade.com/en/System_VHF/Energieeinsparverordnung_ENEV>.
- “Germany Building Glass Recycling: BF Flachglas; BV Glas, Saint Gobain Glas Deutschland.” Interview. July 2014.
- "Germany Building Glass Recycling: Rewindo." Telephone interview. July 2014.
- "Germany Building Glass Recycling: BVSE." Telephone interview. July 2014.
- "Germany Building Glass Recycling: Reiling." Telephone interview. October 2014.
- "Germany Building Glass Recycling: Local Flat Glass Treatment Company." Telephone interview. September 2014.
- "Green Taxes, Reliefs and Schemes for Businesses." - *GOV.UK*. N.p., n.d. Web. 2014. <https://www.gov.uk/green-taxes-and-reliefs/landfill-tax>.
- "Glass." Industrial Efficiency Technology & Measures. N.p., n.d. Web. 26 Mar. 2015.
- The Hague Ministry of the Interior and Kingdom Relations. "Housing Statistics in the European Union 2010." (2010): n. pag. Web. 2014. <https://www.bmwfw.gv.at/Wirtschaftspolitik/Wohnungspolitik/Documents/housing_statistics_in_the_european_union_2010.pdf>.
- "Highlights." *Glass for Europe*. N.p., n.d. Web. <http://www.glassforeurope.com/en/>.
- "Housing Market in Poland Still Far from Equilibrium." *Polish Market Review* 10 (122) (2007): n. pag. Web. 2014. <http://static3.bzwbk.pl/asset/p/m/r/pmr-0710en_29135.pdf>.
- Hurley (BRE), James. "RESEARCH INTO WASTE GLASS, WINDOW AND DOOR FRAMES FROM THE DEMOLITION AND REPLACEMENT WINDOW INDUSTRIES." (2003): n. pag. Web. 2014. <http://www2.wrap.org.uk/downloads/ResearchIntoWasteGlassWindowAndDoorFrames.32acb1ef.377.pdf>.
- "Italy Building Glass Recycling: Saint Gobain Italy." Telephone interview. June 2014.

- "Italy Building Glass Recycling: Saint Gobain Italy." Telephone interview. June 2014.
- "Italy Building Glass Recycling: CoReVe." Telephone interview. June 2014.
- "Italy Building Glass Recycling: Eurovetro SRL." Telephone interview. September 2014.
- "L'Espace Datapresse - L'UFME Présente L'étude Du Marché 2012 De La Fenêtre En France." *L'Espace Datapresse - L'UFME Présente L'étude Du Marché 2012 De La Fenêtre En France*. N.p., n.d. Web. 2014. <http://www.espacedatapresse.com/fil_datapresse/consultation_cp.jsp?idcp=2771902>.
- 2015, February. "Landfill Taxes & Bans." (n.d.): n. pag. CEWEP, Feb. 2015. Web. 1 Feb. 2015. <http://www.cewep.eu/media/www.cewep.eu/org/med_557/1406_2015-02-03_cewep_-_landfill_inctaxesbans.pdf>.
- "Main Glass Sectors." - Glass Alliance Europe. N.p., n.d. Web. 9 July 2014. <www.glassallianceeurope.eu/en/main-glass-sectors>
- Ministerio de Fomento, 2010.
- National census, GUS, 2007. (Source of the number of dwellings and average dwelling size)
- "Navigation Und Service." Startseite - *Statistisches Bundesamt (Destatis)*. N.p., n.d. Web. <https://www.destatis.de/>.
- "Netherlands Building Glass Recycling: Vlackglas Recycling Nederland." Interview. June 2014.
- "Netherlands Building Glass Recycling: Maltha Recycling." Telephone interview. July 2014.
- "Netherlands Building Glass Recycling: Association of Dutch Glass manufacturers (VNG)." Telephone interview. August 2014.
- "Netherlands Building Glass Recycling: Economisch Instituut voor de Bouw." Interview. August 2014.
- "Netherlands Building Glass Recycling: Economisch Instituut voor de Bouw." Interview. August 2014.
- "Poland Building Glass Recycling: Polish Glass Manufacturers Federation." Telephone interview. June 2014.
- OECD, Glossary of statistical terms. These definitions originally come from the Bulletin of Housing and Building Statistics for Europe and North America (UNECE, Geneva, 2000, Annex II, Definitions and General Terms, p.83).
- "Poland Building Glass Recycling: Saint-Gobain Glass Polska." Telephone interview. August 2014.
- Poland, Focus. "Glass in Pole Position." *Glass in Pole Position* (n.d.): 19. Nov. 2012. Web. 22 Oct. 2014. <http://www.stoelzle.com/UserFiles/stoelzle/File/pdf/News/Poland_focus.pdf>.
- "REVALO, Recyclage Complet Des Fenêtres En Fin De Vie Et Déjà 40.000 Fenêtres ! | Ecovinews." *REVALO, Recyclage Complet Des Fenêtres En Fin De Vie Et Déjà 40.000 Fenêtres ! | Ecovinews*. N.p., Nov. 2013. Web. 2014. <http://www.ecovinews.com/?p=4274>.
- Schimschar, Sven, Jan Grözinger, Henning Korte, Thomas Boermans, Velizara Lilova, and Riadh Bhar. "Panorama of the European Non-residential Construction Sector." (2011): n. pag. Web. <http://www.leonardo-energy.org/sites/leonardo-energy/files/documents-and-links/European%20non-residential%20building%20stock%20-%20Final%20Report_v7.pdf>.

- "Scottish Government." *Housing Statistics for Scotland*. N.p., n.d. Web. 2014. <http://www.scotland.gov.uk/Topics/Statistics/Browse/Housing-Regeneration/HSfS/Demolitions>.
- "UK Building Glass Recycling: British Glass Manufacturers' Confederation." Telephone interview. July 2014.
- "UK Building Glass Recycling: Glass and Glazing Federation UK." Telephone interview. June 2014.
- "UK Building Glass Recycling: Glass Technology Services Ltd." Interview. August 2014.
- "UK Building Glass Recycling: Berrymans." Telephone interview. August 2014.
- "UK Building Glass Recycling: Construction Products Association." Interview. August 2014.
- Verlinden, Lies & Loncke, Peter. OVAM. 2012. Technical and economic assessment of recycling routes for automotive glass.
- "Vlakglasrecycling Nederland - Home." *Vlakglasrecycling Nederland - Home*. N.p., n.d. Web. 2014. <http://www.vlakglasrecycling.nl/index.php?page=home-en>.
- "Vlakglasrecycling Nederland Removal Costs and Worker Wage." based on the collective labour agreement of the Dutch glass industry. Email interview. 20 Feb 2015.
- Wilberforce, Rick. *Building Regulations for Windows in European Countries* (2003): n. pag. 28 May 2003. Web. 2014.
- WRAP Environment Agency. *Flat Glass Manufacture Waste Protocols Project Collection of Flat Glass for Use in Flat Glass Manufacture: A Good Practice Guide* (n.d.): n. pag. Web. 2014. <http://www.wrap.org.uk/sites/files/wrap/WRAP_Flat_Glass_GoodPractice_FINAL%20(2).pdf>
- WRAP, June 2003. Research into waste glass, window and door frames from the demolition and replacement window industries. (p.22-24).
- "WRAP Gate Fees Report 2013." *WRAP*. N.p., 2013. Web. 23 Oct. 2014. <http://www.wrap.org.uk/content/wrap-gate-fees-report-2013>.
- A study of the balance between furnace operating parameters and recycled glass in glass melting furnaces, Glass Technology Services Ltd, September 2014

Chapter 5:Appendix

1 Appendix 1: Landfill taxes and costs & number of landfills per Member State

Below is a breakdown of the landfill taxes in EUR/tonne per Member State (sometimes landfill costs are also mentioned). These costs are national averages, but in many countries such as Germany and Spain, landfill taxes vary per region. Landfill accessibility can also influence whether actors choose to landfill glass waste, or take it to a treatment centre. Treatment costs per country were not available to make an analysis on this assumption.

The below table comprises data from the Confederation of European Waste-to-Energy Plants, unless confirmed national data was available.

Figure 32: Landfill tax EUR/tonne per Member State[194]

Region	Country	Landfill Tax EUR/tonne
NORTHERN EUROPE	Denmark VAT 25%	63 €/t Average net price: 44€ (10-95€) Total price: 75-180€
	Finland VAT 23%	60 €/t (hazardous waste excluded) Average total price 99.60 €/t, from 70 to 150 €/t.
	Sweden	45 €/t Average net fee: 50-75 €/t Total price: 110-160 €/t
WESTERN EUROPE	Austria VAT 20%	87€/t Average net price: €60-130€
	Belgium, Flanders VAT 21%	31.70 - 84.89 €/t (depending on public/private and combustible/non-combustible waste) Average net price: 60-120€/t
	Belgium, Brussels VAT 21%	No landfill
	Belgium, Wallonia VAT 21%	25 – 65 €/t (depending on the kind of waste) Average net price: 40-80 €/t
	France VAT:	150€/t (“non-authorised” landfills)

[194] 2015, February. "Landfill Taxes & Bans." (n.d.): n. pag. CEWEP, Feb. 2015. Web. 1 Feb. 2015. <http://www.cewep.eu/media/www.cewep.eu/org/med_557/1406_2015-02-03_cewep_-_landfill_inctaxesbans.pdf>.

	5.5% municipal waste / 19.6% industrial waste *Taxes increase automatically every 1st January*	40€/t ("authorised" landfills) 32€/t ("authorised + ISO 14001") 20€/t (minimum energy recovery 75%)
	Germany VAT 19%	60-220[195]
	Ireland VAT 13.5%	75€/t Average net price: 30-40 €/t
	Luxemburg	Below 30 €/t
	Netherlands VAT 21%	17 €/t (2014) Average net price: 40 – 50 €/t
	United Kingdom	100 €/t [196]
NORTH-EASTERN EUROPE	Czech Republic VAT 19%	20€/t Current gate fees 32-48 €/t
	Estonia	30 €/t Average gate fee (2013): 65 €/t
	Latvia	9.96 €/t MSW Average net price: 30€/t Total price: 40€/t
	Lithuania VAT 21%	0 €/t
	Poland VAT 23%	26.6€/t Typical charges: 28.13-92.94€/t (but mostly 48.92 €/t)

[195] Based on German stakeholders
[196] GOV.UK "Green Taxes, Reliefs and Schemes for Businesses." - GOV.UK. N.p., n.d. Web. 2014. <https://www.gov.uk/green-taxes-and-reliefs/landfill-tax>.

	Slovakia	Not indicated
SOUTH-EASTERN EUROPE	Bulgaria	18 €/t (landfills compliant with Landfill Directive)
	Hungary VAT 25%	Average net fee: 25 €/t Total price: 35 €/t
	Romania	0 €/t
	Slovenia	2.2€/t (inert waste) 11€/t (non-hazardous waste)
SOUTHERN EUROPE	Croatia	Not indicated
	Cyprus	Not indicated
	Greece	40 €/t
	Italy VAT 10%	1–10€/t inert waste 5–10€/t other waste 10–25€/t MSW, depending on Region Average net price: 79 – 94€/t Total price: 88-104€/t
	Malta	Not indicated
	Portugal VAT 5%	5€/t Total price: 3.67 €/t
	Spain VAT 7%	Catalonia: 12 €/t (municipalities with separate collection systems) 21 €/t (municipalities without separate collection systems) Average net fee Madrid: 25.36€/t Catalonia: 40€/t

The following table presents the number of (authorised) landfill locations per Member State.

Figure 33: Number of landfill locations per Member State which accept glass waste[197]

Country	Authorised landfills for inert waste
Belgium	4
Bulgaria	3
Czech Republic	78
Denmark	6
Germany	805
Estonia	2
Ireland	Data unavailable
Greece	0
Spain	183
France	657
Croatia	1
Italy	185
Cyprus	2
Latvia	0
Lithuania	3
Luxembourg	11
Hungary	6
Malta	6
Netherlands	Data unavailable
Austria	36
Poland	9
Portugal	4
Romania	0
Slovenia	10
Slovakia	15
Finland	43
Sweden	67
United Kingdom	226

2 Appendix 2: Assumptions on volumes of glass waste transported and transport distances

All assumptions regarding transport costs were made for the following transport mode: a lorry with a PTAC of 44 tonnes (the weight of the lorry + the weight of the waste in carries cannot amount to more than 44 tonnes).

Table 46: Average tonnages transported and average distance travelled (for round trips) between each step of the recycling chain[198]

Distances travelled (round trips)	Tonnage transported per trip, depending on material transported (in tonnes)			
	If glass panes only	If framed windows	If prepared cullet	Demolition waste containing glass

[197] Eurostat.
[198] Assumptions based on results in phase I.

	(large renovation / demolition projects)	*(light renovation projects)*		
Between renovation/ demolition site and collection/gathering point (100 km)	**15**	*n.a.*	*n.a.*	*n.a.*
Between collection/gathering point and treatment centre (200 km)	**15**	**10**	*n.a.*	*n.a.*
Between treatment centre and flat glass manufacturer (362 km)	*n.a.*	*n.a.*	**25**	*n.a.*
Between treatment centre and hollow glass manufacturer (166 km)	*n.a.*	*n.a.*	**25**	*n.a.*
Between renovation/ demolition site and the nearest landfill (43 km)	*n.a.*	*n.a.*	*n.a.*	**25**

ASSUMPTIONS: [199]

- Time needed for loading + unloading each lorry: 1 hour
- Average speed of a lorry (PTAC 44t): 70 km/h

Table 47: Average distance from a glass treatment site to the nearest flat glass manufacturer and to the nearest flat glass manufacturer (EU average)

Europe surface area[200] (A)	**4 494 600 km²**
Number of flat glass manufacturing sites[201] (B)	40
Number of hollow glass manufacturing sites[202] (C)	162
Area covered by each flat glass producer (D = A/B)	112 365 km²
Area covered by each hollow glass producer (E = A/C)	27 744 km²
Average distance travelled to a flat glass manufacturer (one-way) [203] (=√D/2)	167 km
Average distance travelled to a hollow glass manufacturer (one-way)[204] (=√E/2)	83 km

[199] Source : Deloitte estimates from an ADEME study
[200] http://europa.eu/about-eu/facts-figures/living/index_en.htm
[201] Glass For Europe, 2015
[202] FEVE, 2015
[203] Half of the side of the area covered by each flat glass producer
[204] Half of the side of the area covered by each hollow glass producer

Table 48: *Average distance from a glass treatment to the nearest landfill (EU average)*

Europe surface area (A)	4 494 600 km²
Number of landfills (F)	2 362
Area "covered" by each landfill (G= A/F)	1 903 km²
Average distance travelled to the nearest landfill (one-way)[205] (=√G/2)	22 km

Table 49: Cost of transport by road, per hour and per kilometre [199]

Cost per hour (EU average estimation) Error! Bookmark not defined.				**Cost per km (EU average estimation)**		
Cost of conductor (€/hr) (estimate of an average cost for Europe)	Fixed costs per vehicle (€/hr)	Overheads and margin (€/hr)	Total (€/hr)	Kilometric cost (€/km)	Overheads and margin (€/km)	Total (€/km)
Q	R	S	T=(Q+R)*(1+S)	U	V	W=U*(1+V)
20 €	10 €	25%	38 €	1 €	25%	1,25 €

1.Appendix 3: Cost of dismantling & separating a tonne of glass

Table 50: Costs of separating a tonne of glass

	Salary per hour of a glazier / a worker onsite (€)[206]	**Cost of separating a tonne of glass (€ /t of glass)**	**Weighted averages based on tonnages of C&D glass waste available (€ /t of glass)**
***EUROPE** (average EU-28)*			***50,0 €***
NORTHERN EUROPE			**65,0 €**
Denmark	25,0 €	65 €	
Finland	25,0 €	65 €	
Sweden	25,0 €	65 €	
WESTERN EUROPE			**62,7 €**
Austria	17,3 €	45 €	
Belgium	26,0 €	68 €	
France	25,0 €	65 €	
Germany	25,5 €	66 €	
Ireland	25,3 €	66 €	
Luxemburg	33,3 €	86 €	

[205] Half of the side of the area covered by each hollow glass producer

[206] For all EU-28 countries, data on minimum wages comes from Eurostat 2014, except for Germany, Poland, Luxemburg, Cyprus and Malta, for which data comes from FedEE *Review of minimum wage rates across Europe* (available at http://www.fedee.com/pay-job-evaluation/minimum-wage-rates/). As for Italy, a hypothesis was made by Deloitte, based on the average minimum wage of countries of the same region.

Netherlands	25,7 €	67 €	
United Kingdom	21,0 €	55 €	
NORTH-EASTERN EUROPE			**18,2 €**
Czech Republic	5,7 €	15 €	
Estonia	6,1 €	16 €	
Latvia	5,5 €	14 €	
Lithuania	5,0 €	13 €	
Poland	7,3 €	19 €	
Slovakia	6,1 €	16 €	
SOUTH-EASTERN EUROPE			**12,0 €**
Bulgaria	3,0 €	8 €	
Hungary	6,0 €	15 €	
Romania	3,3 €	9 €	
Slovenia	13,6 €	35 €	
SOUTHERN EUROPE			**32,1 €**
Croatia	7,0 €	18 €	
Cyprus	16,0 €	42 €	
Greece	11,8 €	31 €	
Italy	13,0 €	34 €	
Malta	12,5 €	32 €	
Portugal	9,8 €	25 €	
Spain	13,0 €	34 €	

Table 51: Time required for transport, for round trips, per type of trajectory

	Distances for round trips	Time of transport (calculation)	Time needed for loading + unloading the tractor trailer	Total time required (calculation)
Average transport between site generating waste and collection/gathering point *(for major renovations and demolitions)*	100 km[207]	1,43 h	1 h	2,43 h
Average transport between collection/gathering point and treatment centre	200 km[207]	2,86 h	1 h	3,86 h
Average transport distance from treatment centre to flat glass manufacturer	333 km	4,76 h	1 h	5,76 h
Average transport distance from treatment centre to hollow glass manufacturer	166 km	2,37 h	1 h	3,37 h
Average transport distance between site where waste is generated and the nearest landfill --> *considered more or less equal to the average transport distance from demolition or renovation site to a site where cullet is recovered for public works, used as a road base course, or as backfill for trenches and earthworks (round trip)*	43 km	0,62 h	1 h	1,62 h

[207] Assumption based on phase I results.

Table 52: Total cost of transport per tonne of glass, for round trips, per type of trajectory

(Lorry of PTAC 44t)	*(distances for round trips)*	Total cost per hour	Total cost per km	Total cost of transport	Total cost of transport per tonne of glass			
					Glass panes only (large renovation projects)	Framed windows (residential)	Prepared cullet	Demolition waste containing glass
Average transport between site generating waste and collection/gathering point *(for major renovations and demolitions)*	100 km	91 €	125 €	216 €	14 €			
Average transport between collection/gathering point and treatment centre	200 km	145 €	250 €	395 €	26 €	39 €		
Average transport distance from treatment centre to flat glass manufacturer	333 km	216 €	417 €	633 €			25 €	
Average transport distance from treatment centre to hollow glass manufacturer	166 km	126 €	207 €	333 €			13 €	
Average transport distance between site where waste is generated and the nearest landfill *--> considered more or less equal to the average transport distance from demolition or renovation site to a site where cullet is recovered for public works, used as a road base course, or as backfill for trenches and earthworks (round trip)*	43 km	61 €	54 €	115 €				5 €

2.Appendix 4: Specificities on various glass sectors

The following section outlines the insights of stakeholder consultation within various glass sectors. The aim of the stakeholder consultation was notably to understand which industries incorporate post-consumer cullet and to understand the factors that influence their will and ability to use it or not.

Hollow glass industry

Main information gathered for this section sources from the association of European manufacturers of glass packaging containers and machine-made glass tableware (FEVE), the Italian national consortium for glass collection (CoReVe), and the Polish Glass Manufacturers Federation.

As outlined in the map below, there are 162[208] hollow glass manufacturing sites throughout Europe that are member companies of FEVE, which comprise about 95% of the total hollow glass manufacturing sites in Europe.

Figure 34: FEVE Member Hollow Glass Manufacturing Sites Per MS (2011)

EUROPE	Number of Hollow Glass Manufacturing Sites
NORTHERN EUROPE	
Denmark	1
Finland	0
Sweden	1
WESTERN EUROPE	
Austria	3
Belgium	2
France	24
Germany	32
Ireland	0
Luxemburg	0
Netherlands	5
United Kingdom	12
NORTH-EASTERN EUROPE	
Czech Republic	4
Estonia	1
Latvia	0
Lithuania	1
Poland	18
Slovakia	2
SOUTH-EASTERN EUROPE	
Bulgaria	3
Hungary	1
Romania	2
Slovenia	0
SOUTHERN EUROPE	
Croatia	0
Cyprus	0
Greece	1
Italy	27
Malta	0
Portugal	6
Spain	16

Hollow glass manufacturing is split into three categories: bottles and jars, flacons (perfume and pharmaceutical bottles), and table wear (glasses and glass wear).

[208] "FEVE: The Relationship between Hollow and Building Glass Industries." Telephone interview. 26 Feb. 2015.

Bottles and jars are by far the majority of European production, with 18 million tonnes, or 90% of total manufactured hollow glass originating from this category[209]. Bottles and jars can easily integrate cullet within production. In fact, within the bottles and jars category, there are three sub-categories that have different "cullet capacities" for production. Green coloured bottles and jars can integrate up to 90% cullet, while brown coloured bottles and jars use a lesser and unquantifiable percentage of cullet and flint (clear glass) can only integrate a very small percentage of cullet.

Flacons and table wear, which each comprise 1 million tonnes, or 5% of European production[210], integrate hardly to no cullet within their production process, as they require cullet of a very high quality.

For specificities on the Polish and the Italian hollow glass sectors, please refer to the Polish case study and the Italian case study in Chapter 1.

Estimations[211] on the maximum price that Italian hollow glass manufacturers may pay for C&D cullet are the following:

- For mixed cullet (composition: 50% clear, 50% coloured), manufacturers may pay up to **EUR 50-55/tonne** of flat glass cullet.
- For clear cullet, manufactures may pay up to **EUR 70-78/tonne**.

According to CoReVe, for the production of clear hollow glass, manufacturers may be willing to pay slightly more for flat glass cullet, as the production of clear hollow glass necessitates high quality cullet.

Special glass industry

Special glass is split into two main categories: soda-lime glass and borosilicate glass[212]. Speciality glass is destined to a wide range of sectors and has a high variety of different chemical compositions. To coincide with the variety of destination markets, manufacturing processes and furnace use are extremely variant[213]. An example of products comprised within the special glass industry can be glass medical devices such as beakers or glass used for injection devices.

According to the European Special Glass Association (ESGA), special glass does not have the capacity to use cullet because of the high quality it requires. Special glass producers are therefore not currently pursuing cullet incorporation within their manufacturing processes.

Glass fibre industry

Although it was determined in Phase I of this study that glass fibre is a common outlet for cullet, the contacted associations[214] were unable to provide qualitative or quantitative information about the relationship between the building and flat glass industry.

3.Appendix 5: FERVER members' insight on flat glass treatment

[209] "FEVE: The Relationship between Hollow and Building Glass Industries." Telephone interview. 26 Feb. 2015.
[210] "FEVE: The Relationship between Hollow and Building Glass Industries." Telephone interview. 26 Feb. 2015.

[211] This CoReVe estimation should be considered with caution, as it was not possible to cross-check this estimation with Italian flat glass manufacturers due to their unavailability for an interview.
[212] "Glass." Industrial Efficiency Technology & Measures. N.p., n.d. Web. 26 Mar. 2015.
[213] "Fused Cast Range." Special Glass. N.p., n.d. Web. 26 Mar. 2015.
[214] The European Insulation Manufacturing Association, (EURIMA) declined an interview due to confidentiality reasons.

The conclusions of this section are drawn from a series of exchanges with FERVER members, in addition to an organised conference call.

Flat glass collection

An initial assumption during this study was that glass treatment companies might prefer to collect flat glass waste from a particular sector (tertiary, residential, renovation or demolition). Based upon the conclusions, an assessment and identification was projected to take place on the pros and cons of collecting and treating glass from each sector, outlining main constraints and facilitators.

However, via FERVER feedback, it was determined that this assumption is not applicable to reality, for treatment centres rarely know the origin (residential versus tertiary buildings, on demolition versus renovation sites) of the C&D glass waste they are provided with by many waste management companies. In practical terms, glass treatment companies will take any and all glass waste that is of good quality. Listed as a **higher priority than transportation costs**, their main criterion for selecting glass waste is insured **low contamination rates.**

The relationship between treatment companies and waste management companies

Large scale glass collection is rarely facilitated directly between a project site and a treatment company. Many times treatment companies are not aware of large scale renovation projects, and are usually contacted for their treatment services in a downstream manner by waste management companies, who act as a middleman between renovation project managers and treatment companies. This latter scenario has proven to be problematic for treatment companies, as glass quality is not always ensured during collection and is many times highly contaminated when arriving on treatment sites. The reasoning behind this is that waste management companies are not specialised in glass waste collection, and therefore may unintentionally lack caution or expertise when setting forth glass management techniques, which are usually mastered by specialised glass waste treatment companies.

An example of problematic initiatives that waste management companies implement could be rotating skips between materials (i.e. concrete, glass, wood, rubbish) that in turn leave contaminants within skips. If skips are already contaminated when flat glass collection starts, the quality is immediately uninsured. Furthermore, throughout the duration of the collection, site managers may not have as high vigilance levels regarding the nature of the collected glass material, as compared to specialised treatment companies.

However, the “do-it-all” nature of these waste management companies is one off the natural advantageous reasons why companies are attracted to contracting them for a project, as only one interlocker is needed to coordinate all aspects of a project’s waste management.

Once waste management companies finish collection, treatment companies are contacted to see if they would be interested in purchasing the glass waste for treatment. Although some treatment companies interviewed during this study indicated that glass collected from waste management companies can sometimes be purchased for treatment, this is a minority case, as the glass is highly contaminated. A common misconception is that highly contaminated glass waste can be unconditionally used as aggregate, when in most cases it is actually sent to landfill[215].

Via this system, **treatment companies have little-to-no traceability of the origin of flat glass waste** (i.e. demolition, renovation, tertiary, residential sectors) for often times, flat glass waste is collectively stored at a waste management site, and may be mixed in with waste from other projects. Therefore, by the time that the glass waste is transported to the treatment centre, traceability is not

[215] "FEVER Member Companies Conference Call: Flat Glass Treatment and Recycling." Telephone interview. 26 Feb. 2015.

ensured. There are minimal cases in which treatment centres are summoned to pick up glass waste directly on a project site.

Regarding large-scale renovation projects in particular, **treatment companies could potentially better ensure the recyclability of glass waste if open communication were instilled between flat glass manufacturers,** as these latter actors are usually contacted by the project site before renovation begins.

Specificities on frame collection and glass composition

Theoretically, collecting and selling frames would be an interesting form of additional revenue, however treatment centres generally perform this collect on exceptional circumstances. There are already developed markets for PVC and aluminium frames collection, consequently not leaving much room for glass recyclers to have a spot.

Regarding the different types of glass collected, such as traditional tinted, pattered, laminated, and coloured flat glass, treatment companies generally do not face any concerns about its recyclability, much less encounter infrastructural constraints that would hinder carrying out glass treatment.

However, in the recent years, they have experienced a growing **concern over the recyclability of the ingredients and chemicals used in newer glass**. There is not enough information on the market regarding the composition of these glass products on these new technological advancements, which has made recyclability more complex. **Treatment companies would be favourable to having closer collaboration with flat glass manufacturers on new glass technology to assess the impacts of treatment.**

Market requirements for cullet quality

After collection and treatment, the most common impurities present in building glass cullet are small portions of[216]:

- Plastics
- Ceramic – Stones – Porcelain (CSP)
- Metals
- Coloured glass

While small levels of these impurities do not impede cullet reintegration onto the market, cullet cannot supersede threshold allowances corresponding to various outlet markets. In other words, treatment centres must be cautious that the quality of their produced cullet is high enough to be considered for purchase by different outlet markets, as different outlets require higher or lower impurity allowances for production.

Considering CSP in particular, the following maximum quantities of CSP are accepted for the following outlet markets:

- Float glass: > 5 g/tonne CSP
- Container glass: <20 g/tonne CSP(<15 g/tonne in 2013)
- Foam (cellular) glass: < 100 g/tonne CSP
- Fibre glass: 0 g/tonne CSP

[216] Verlinden, Lies & Loncke, Peter. OVAM. 2012. Technical and economic assessment of recycling routes for automotive glass.

As these thresholds fluctuate in parallel to technological advancements, treatment companies have to be keen and conscious on adapting to market evolutions. In general, these advancements in technologies should be advantageous to these actors, as it may open up new opportunities for quicker impurity removal or more precise identification of impurities in prepared cullet batches.