ENABLING BUSINESS MODELS INNOVATION FOR SUSTAINABILITY IN THE UK GLASS SECTOR

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Executive Summary

This report discusses policy interventions (public and private) needed to enable business model innovation for circular economy in the flat glass industry in the UK. The focus of the project is on flat glass products (windows and glazing) that are typically used by the construction, demolition, and renovation sectors. This scope is justified by the high circularity potential of these materials but the low recycling rates. Keeping flat glass within a circular economy model presents a great opportunity for decarbonization, and it is economically beneficial. However, public policy attention has focused on recycling and reusing container glass, while most end-of-life post-consumer windows and glazing is not recycled and reusing it is less appropriate.

This project asked what policy interventions are needed to enable sustainable business model innovation in this industry. We reviewed good practices in the European Union; interviewed industry stakeholders representing recycling, construction, and manufacturing, among others; and held a workshop where representatives from the construction, glazing, manufacturing, and recycling sectors discussed the future of flat glass recycling.

We worked closely with **Paul Pearcy and Dave Dalton** from **British Glass** during all the stages of the project. British Glass is the representative body for the UK glass manufacturing industry, working on behalf of container glass, flat glass, and fiberglass manufacturers.

Our findings show that policy and industry initiatives should aim at creating a market for cullet supported by an integrated value chain, adequate recycling infrastructure (including collection, transport, and re-processing of cullet), appropriate economic incentives, and flat glass waste-specific regulations that would encourage recycling. As government action around flat-glass recycling in the UK is still in early stages, industry-driven initiatives should focus on collective action aimed at achieving greater coordination and awareness in the value chain, as well as promoting that cullet is treated as a resource instead of a waste material.

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Background

Glass is the perfect circular material due to its unlimited recyclability with no loss of quality. However, end-of-life flat glass products that are used in the construction, demolition, and renovation sectors (e.g., windows, glass doors, transparent walls, roof lights and mirrors), are more likely to end up in low value aggregates, be remelted for container glass, or be sent to landfill than be recycled for flat glass. Glass waste generated during the construction phase is typically very little, while most glass waste originates from the renovation and demolition stages (post-consumer waste).

Collecting post-consumer flat glass and transforming it into cullet (crushed waste glass) suitable for recycling into the same application (close loop) are still challenging. It is estimated that flat glass products in the UK contains no more than 1% of post-consumer flat glass[1]. While public policy attention has been around recycling and reusing household container glass, most end-of-life flat glazing, refurbishment and demolition glass are not recycled, and reusing them is less appropriate. Even glass which is difficult to recycle such as black glass, and laminated glass can be diverted from landfill and recycled into non-window glass applications (e.g., reflective paint), and aggregates (e.g., concrete and asphalt).

The glass sector has a great potential to implement circular economy to achieve decarbonisation[2]. Keeping flat glass within a circular economy model presents a great opportunity for reducing CO_2 emissions and it is economically beneficial[3]. Recycling reduces energy and raw materials consumption. Remelting a tonne of glass saves up to 300kg of direct CO_2 emissions (combustion and process emissions) thanks to reduced energy and use of raw material[4].

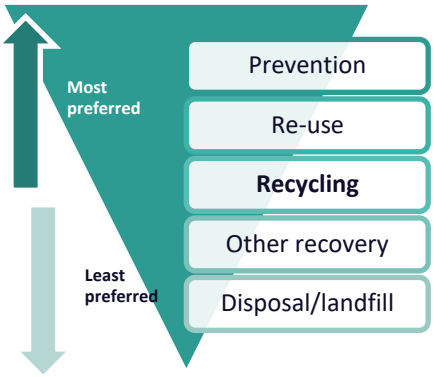

Figure 1: UK waste hierarchy.

Creating a circular economy model requires fundamental changes throughout the value chain and the policy environment. There is recognition that the range and depth of powers that only the government can call upon will be required if these changes are to be achieved[5]. Policy interventions should facilitate innovation by removing regulatory barriers and creating incentives. Similarly, industry initiatives should look at improving value chain coordination.

This report explores policy interventions (public and private) needed to enable circular economy in the flat glass industry in the UK.

[1] Hartwell, R., Coult, G., & Overend, M. (2023). Mapping the flat glass value-chain: a material flow analysis and energy balance of UK production. *Glass Structures and Engineering*, 8, 167–192.
[2] Zier, M., Stenzel, P., Kotzur, L., & Stolten, D. (2021). A review of decarbonization options for the glass industry. In *Energy Conversion and Management: X,* 10, 100083.
[3] BEIS, & British Glass. (2017). *Glass Sector: Joint Industry-Government Industrial Decarbonisation and Energy Efficiency Roadmap Action Plan*. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/652080/glass-decarbonisation-action-plan.pdf
[4] British Glass (no date). Recycling flat glass. Available at https://www.britglass.org.uk/sites/default/files/British%20Glass%20-%20how%20to%20recycle%20flat%20glass.pdf
[5] British Glass. (2021). *Glass sector Net zero strategy 2050*. Available at: https://www.britglass.org.uk/sites/default/files/British%20Glass%20-%20Net%20Zero%20Strategy.pdf

Method

We reviewed good practices in the grey literature; interviewed industry stakeholders representing recycling, construction, and manufacturing, among others; and held a workshop where representatives from the construction, glazing, manufacturing, and recycling sectors discussed the future of flat glass recycling in the UK. Each interlinked activity aimed at:

- Reviewing best practices regarding policy interventions enabling flat glass recycling considering EU and UK literature.
- Identifying enablers/barriers for flat glass recycling in the UK.
- Identifying public and private policy interventions to enable flat glass recycling in the UK.

This research had ethical approval by the Nottingham University Business School's Ethics Committee who operates according to University of Nottingham's Code of Research Conduct and the Economic and Social Research Council (ESRC) Framework for Research Ethics.

We worked closely with British Glass during all the stages of the project.

British Glass

Review relevant literature and reports from the EU and UK

13 interviews with UK industry stakeholders representing recycling, construction, and manufacturing, among others

One stakeholder workshop with UK participants from the construction, glazing, manufacturing, and recycling sectors.

The project gathered the invaluable insights of participants from British Glass, Glass Futures, URM Group, Saint-Gobain, Eckersley O'Callaghan, The Recycling Association, Sibelco, Glass and Glazing Federation, RECONMATIC, Morgan Sindall, Guardian Glass, CNC Recycling, and Glass Technology Services.

Images by authors

Challenges for Flat Glass Circularity

Challenges for flat glass recycling are associated with barriers for dismantling, collection, storage, logistics, and infrastructure for reprocessing of post-consumer glass waste, as well as a limited incentives for recycling. While pre-consumer glass waste (e.g., glass off-cuts) remains under the control of the manufacturer, post-consumer glass is likely to get contaminated in the demolition and renovation process. Recycling post-consumer flat glass is challenging due to an insufficient regulatory framework, lack of economic incentives, high costs, geographically concentrated reprocessing infrastructure, and inadequate information, among other reasons.

Regulatory framework

The process of turning flat glass waste into cullet is classified as a waste recovery operation and is therefore subject to waste management legislation. Waste management regulations in the UK have given limited attention to glass waste from renovation and demolition activities. The focus has been on municipal waste which includes glass household waste (e.g., container glass). There is no legal requirement for households to collect flat glass resulting from, for instance, their retrofitting projects (e.g., The Household Waste Recycling Act).

Recent updated regulations strengthen existing producer responsibility laws around packaging, batteries, and waste electronics and electrical equipment (see The Environment Act 2021). Similar reforms are taking place across Europe at the same time as in the UK, with France and Germany leading the way. However, these reforms are not specific enough to stop the loss of cullet.

These regulatory changes are coming alongside the introduction of sustainability (ESG) reporting across Europe progressively encouraging companies to assess and report on their circularity performance and carbon emissions. However, these regulations target mainly large companies which have developed their own ESG agenda and net-zero statements. Most companies involved in flat glass recovery will not be covered by these regulations.

Economic incentives

The current regulatory framework does not provide incentives for the recycling of flat glass. There is no incentive or obligation to separate flat glass during demolition and renovation work. Most construction and demolition waste, including flat glass, will be considered as inert or inactive waste and pay the lower landfill tax rate in the UK (£3.25 per tonne in September 2023)[6] making it easier sending flat glass waste to the landfill or to aggregates rather than back to flat glass.

In addition, the market price of glass cullet is in average cheaper compared to the expensive process of deglazing, segregation, storage, and transportation. If the costs are transferred to the market price of cullet, manufacturers will have little incentive to buy glass cullet unless the cost is lower than buying raw materials. Keeping a low market price for cullet pushes recyclers to move glass cullet away from manufacturers if another buyer offers a higher price for their combined waste (e.g., aggregates, energy, etc.).

[6] HM Revenue & Customs. (2023, September). Excise Notice LFT1: a general guide to Landfill Tax. Available at: https://www.gov.uk/government/publications/excise-notice-lft1-a-general-guide-to-landfill-tax/excise-notice-lft1-a-general-guide-to-landfill-tax

Data and information

There is currently a lack of data regarding flat glass on the market, and the destinations of post-consumer, end of life flat glass products such as window glazing panes. Neither the infrastructure nor the legal requirements are currently sufficient to record the flows of recyclable materials in such a way that a large proportion can be fed back into the production of higher-quality products. What is more, there are no easy ways to find information about supply and demand for recycled windows, facades, or cullet.

Infrastructure

There is not a well-developed infrastructure for flat glass recycling, as there is for container glass. This is associated to the lack of collection points and processing facilities as well as their geographical concentration.

Glass cullet needs to be transported from demolition/renovation sites to processing facilities (recyclers and/or glass manufacturers). In the UK, glass manufacturers all sit along the M62 motorway. The farther glass is being collected, the more difficult and expensive will be to take it to the manufacturer. Infrastructure should support the removal, storage, and distribution of material back to the manufacturer in a way that maintains and preserves the materials integrity.

Similarly, homeowners wishing to recycle their windows glass will find no collections points to do so. Local waste collection centres do not offer flat glass facilities.

Costs and technical issues

Glass must be separated from other materials to be recycled. Hight costs are involved in dismantling glass and in transporting it to collection points, to treatment facilities, and to manufacturers[7]. Flat glass cullet arrives at processing facilities in a variety of forms depending on the application but is rarely just float or cast glass. All of this complicates the preparation process and reduces the number of ways in which the cullet can be reprocessed[8].

Cullet also needs to be stored separately to avoid contamination from other materials (such as metals and ceramics) and glass colours. The risk of contamination means that sorting of flat glass must be carefully performed and thus remain labour-intensive. The amount of work and personnel costs for separating the building elements, the space requirements for storage, and the transport expenses are just some of the factors that need consideration.

Training and awareness

There is a lack of awareness on renovation and demolition sites, and other associated activities, about the recyclability of glass and its quality requirements. Those involved in dismantling, collecting, and segregating glass may not be fully aware of the impact of how they handle cullet, how they store it, and transport it.

Recycling flat glass is not straight forward for end-users either. Besides the lack of collection points, there is no information regarding how glass can be recycled at the end of its life. Knowledge is lacking on a societal level, due to an unawareness of what happens to the glass, but also on a more local level,

[7] Forslund, H., & Björklund, M. (2022). Toward Circular Supply Chains for Flat Glass: Challenges of Transforming to More Energy-Efficient Solutions. *Energies*, 15(19), 7282.

[8] Hartwell, R., Coult, G., & Overend, M. (2023). Mapping the flat glass value-chain: a material flow analysis and energy balance of UK production. *Glass Structures and Engineering*, 8, 167–192.

due to the lack of information and expertise networks[9].

Eco-design

Glass products are designed with no end-of-life in mind. Glass can have thermal insulation, be printed with ceramic inks, be part of laminated units, among others. All these variations make the process of recycling more difficult.

Similarly, as windows are not made for recycling, it is also challenging to safely disassemble them. Removing glazing components are an obstacle for recycling making disassembly very difficult and frequently caused by the permanently glued connections. This makes the process labour intensive and cullet more affected by contamination.

In addition, the current designs and specifications for new building do not maximise the potential of glass to be recycled[10].

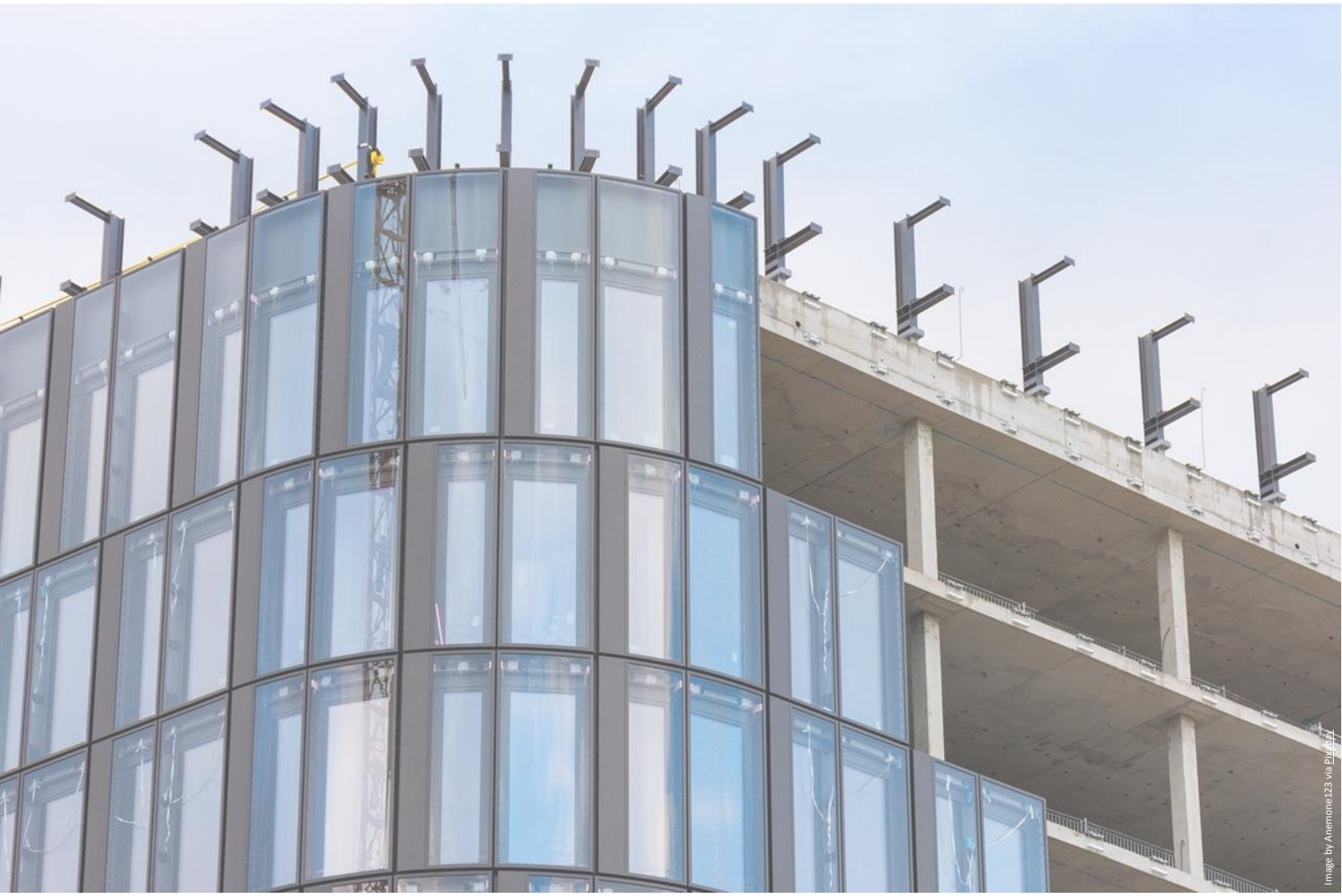

Image by Anemone123 via Pixabay

[9] Forslund, H., & Björklund, M. (2022). Toward Circular Supply Chains for Flat Glass: Challenges of Transforming to More Energy-Efficient Solutions. *Energies*, 15(19), 7282.

[10] Arup (2018). Re-thinking the life cycle of architectural glass. Available: at. https://www.arup.com/perspectives/publications/research/section/re-thinking-the-life-cycle-of-architectural-glass

Policy Approaches for Glass Circularity

Policy approaches to promote circular economy are based on a combination of government-led legislation as well as industry self-regulation (hard and soft policy instruments). Legislation, as a regulatory tool operating in isolation, can have many caveats (e.g., lack of enforcement capabilities, bureaucracy, international misalignment, among others). Governments are therefore relying increasingly on private actors and stakeholders' cooperation for achieving public goals[11]. The outcome is a softer form of regulation. Soft regulation is not an alternative to government action, but a supplementary tool (e.g., guidance, eco-labels, sustainable procurement, etc.) [12].

Flat glass recycling in the EU and the UK has been promoted mainly by softer forms of regulation as well as private initiatives as presented in the following sections.

Economic policy for glass circularity

At the government level the discussion has focused on the economic incentives needed to boost markets for recycled materials, including glass. Economic instruments aim at making preferred waste management options, such as recycling, more cost-competitive with their alternatives[13]. These policies have typically focused on the separate collection of paper and cardboard, plastics, container glass, and metals. The EU Waste Framework Directive have recently included bio-waste (food and garden waste), and it will include a requirement for textiles and hazardous household waste by 2025[14]. There are however no plans to add flat glass to the list and setting individual recycling targets.

Common economic instruments used to increase recycling are:[15]

- ***Taxes*** seek to increase the cost of sending waste to landfills, making recycling and reuse more competitive. Landfill taxes are the most common economic instrument used across the European Union, while others such as incineration taxes are not as common. As it was mentioned in a previous section, in the UK the landfill tax also exists but it insufficient to incentivise the recycling of flat glass.
- ***Landfill bans*** are frequently used in combination with landfill taxes. In COM (2014)398, the European Commission proposed a ban on the landfilling of recyclable and biodegradable materials by 2025, while it requested Member States to virtually eliminate landfill by 2030[16]. All five of the EU Member States with the highest recycling rates: Germany, Austria, Slovenia, the Netherlands, and Luxembourg, use a well-designed landfill tax or landfill ban, or a combination of these. However, the effectiveness of these taxes depends not only on their level but also on how they are designed, implemented, and enforced.

  In the UK, public and private waste collectors are not allowed to landfill wastepaper, metal,

[11] Torres, L. (2024). Compliance. in Lee Matthews, Lara Bianchi, and Claire Ingram (eds). *Concise Encyclopedia of Corporate Social Responsibility*. Edward Elgar Publishing

[12] Torres, L., Ripa, D., Jain, A., Herrero, J., & Leka S. (2023). The potential of responsible business to promote sustainable work - An analysis of CSR/ESG instruments. *Safety Science*, Vol. 164

[13] OECD (2019), Waste management and the circular economy in selected OECD countries: Evidence
from environmental performance reviews. Available at https://doi.org/10.1787/9789264309395-en

[14] European Commission (no date). Waste Framework Directive. Available at: https://environment.ec.europa.eu/topics/waste-and-recycling/waste-framework-directive_en

[15] European Environment Agency. (2023). Economic instruments and separate collection systems — key strategies to increase recycling. Available at: https://www.eea.europa.eu/publications/economic-instruments-and-separate-collection

[16] Towards a circular economy: a zero-waste programme for Europe. COM (2014)398

plastic, or glass that has been separately collected to prepare it for recycling[17]. However, the requirement is unlikely to apply to flat glass waste because of exceptions around disproportionate economic costs, technical feasibility, and co-mingled waste collection.

- ***Pay-as-you-throw*** (PAYT) schemes are also widely implemented in the EU (e.g., Belgium, Holland, Sweden, Germany, Italy, France, and Austria). Waste producers pay for waste collection services in proportion to the volume of waste they produce, and they pay less or nothing for recyclables separated at source. However, any PAYT scheme needs to be supported by a developed collection infrastructure, information for participants, and a transparent pricing policy[18]. In the UK there are some recent examples of Councils (e.g., Northumberland, and Norfolk) implementing PAYT schemes for municipal waste, but little information is available on the effectiveness of such implementations.
- ***Separate collection systems*** require that waste is separated and put into different collection containers. The EU Waste Framework Directive establishes an obligation to sort and separately collect different materials. Similarly in the UK the obligation is for public and private waste collectors working with commercial, industrial, and household waste unless waste is mixed[19] as in the case of demolition rubble.
- ***Extended producer responsibility (EPR)*** is a policy approach that makes producers responsible for their products at the post-consumer stage[20]. In the EU, EPR is implemented through a group of directives covering packaging, batteries, end of life vehicles, and electrical and electronic equipment. France has recently included within the Circular Economy Act of 2020 an obligation to set up an EPR scheme for the construction and demolition sector.

  In the UK the system of producer responsibility for packaging has been in place since 1997 and updated in 2023. However, EPR policies have not yet included construction, demolition, and renovation products.

Multi-stakeholder collaboration

Some of the most successful initiatives and more specific for flat glass recycling have been implemented through the collaboration between industry, government, and/or civil society organisations. However, reports on the effectiveness of these initiatives specifically for flat glass recovery are lacking as data has focused on glass waste from households and packaging, or information is not made public.

These initiatives can be classified into:

- ***Fully managed by the private sector*****:** There are several examples of private companies managing their own flat glass recycling schemes. For instance, Reiling Group[21] provides a national network to collect and support the recycling of post-consumer buildings glass waste in Germany. The highest quality collected cullet is sold to the flat glass industry for recycling, the remaining is sold to the hollow glass and the glass wool industries.

[17] Environment Agency (2023). Guidance: Dispose of waste to landfill. Available at https://www.gov.uk/guidance/dispose-of-waste-to-landfill#banned-waste
[18] Ukkonen, A., & Sahimaa, O. (2021). Weight-based pay-as-you-throw pricing model: Encouraging sorting in households through waste fees. *Waste Management*, 135, 372-380.
[19] Environment Agency (2020). Guidance: Separate collection of waste paper, plastic, metal or glass. Available at: https://www.gov.uk/guidance/separate-collection-of-waste-paper-plastic-metal-and-glass
[20] Brown, A., F. Laubinger, and P. Börkey (2023), "New Aspects of EPR: Extending producer responsibility to additional product groups and challenges throughout the product lifecycle", OECD Environment Working Papers, No. 225, OECD Publishing, Paris, https://doi.org/10.1787/cfdc1bdc-en.
[21] Reiling (no date). Flat-glass recycling. Available at: https://www.reiling.de/en/recycling-products#progress--anchor--151

Similarly, Eurovetro[22] in Italy supplies its clients with skips and scheduled collection services. Eurovetro sells good quality cullet to the flat glass industry while poor quality cullet is used as aggregates in roadworks or in the ceramic sector, amongst others. In both cases, the service rates are based on the client's distance to the treatment centre, the frequency of collections, and the length of the skips rental. Similarly, Sibelco and Mineris Environnement created the joint-venture Recyverre for flat glass recycling in France[23]. Recyverre brings together Sibelco's flat glass recycling capabilities with Mineris's capabilities in flat glass collection and transportation.

In the UK, Saint-Gobain Glass[24] has introduced a Glass Forever Partners certification as a part of its cullet return programme. Saint Gobain's customers setup and manage the collection and return of glass waste depending on their needs (e.g., collection bags, standing trailer, or on-site cullet crushing machine).

- ***Multistakeholder collaboration***: flat glass circularity initiatives bringing together governments, industry participants, and civil society organisations are less common in the EU and the UK. Vlakglas Recycling Nederland[25] is one of such examples. Vlakglas is a non-profit organisation coordinating all the activities associated with recycling and collecting waste glass in the Netherlands. Vlakglas was founded in 2002 as a result of a voluntary recycling scheme launched in 2000 by glass manufacturers aiming at meeting their producer responsibilities. The system is financed through a mandatory recycling fee (€0.30 per square metre of insulating glass[26]) enacted by The Ministry of Housing, Spatial Planning and Environment. In 2018, Vlakglas Recycling Nederland collected 73,637 tonnes of waste sheet glass which saved the equivalent of 8,541,892 kilos of CO2[27].

Fully voluntary initiatives are also available at the EU level to facilitate the reprocessing of waste from renovation and demolition activities. This is the case of the EU Construction and Demolition Waste Management Protocol[28]. This initiative was launched by the European Commission, but the project is built on the active participation and contribution from industry and national government officials. We did not find research reporting the impact of such initiative on flat glass recycling.

At the enterprise level, such voluntary initiatives are typically categorised under corporate social responsibility (CSR) or Environmental, Social and Governance (ESG). Particularly for listed companies, the ESG agenda integrated with corporate governance standards can give rise to reputational damage and reduce financing opportunities when non-compliance is found.

[22] Eurovetro Recycling (no date). Available at: https://www.eurovetro.com/en/eurovetro-recycling
[23] http://recyverre.eu/
[24] Saint-Gobain Glass (no date). Glass forever - help to drive change. Available at: https://www.saint-gobain-glass.co.uk/en-gb/our-sustainability-journey
[25] Vlakglas Recycling Nederland (no date). Available at: https://www.vlakglasrecycling.nl/index.php?page=home-en
[26] Netherlands Enterprise Agency (2023). Flat glass recycling fee. Available at: https://business.gov.nl/regulation/sheet-glass-waste-disposal-fee/
[27] Glass International (2020). Collecting and recycling flat glass. Available at https://www.vlakglasrecycling.nl/uploads/documenten/Glass%20International%20February%202020%20VRN.pdf
[28] European Commission (2018). EU Construction and Demolition Waste Protocol and Guidelines. Available at: https://single-market-economy.ec.europa.eu/news/eu-construction-and-demolition-waste-protocol-2018-09-18_en

Enabling Flat Glass Recycling in the UK

Our research identified several initiatives that require action by the government, local authorities, and industry participants.

Government-led policies

Local and central administration policies have a key role to play in the promotion of circular economy principles in waste management practices. Our interview and workshop discussions have demonstrated that regulations are the cornerstone for adequate glass waste management. However, current regulations and policies are not encouraging further glass recovery. There is a need for **central government** to support a 'market' for high quality cullet. Creating a market for recycled materials is essential to increasing the rate of flat glass recycling. Legislation needs to be revised to eliminate landfill deposit of recyclable glass, improve collection of building glass waste, and increase the recycling rate by a combination of the following measures:

- ✓ making it costly to not recover by banning on landfill disposal of single clear glass panes and insulating glass units, while making it expensive to use raw materials (local and imported) by creating new or revisiting existent taxes on raw materials. Revenue from these taxes could be used to finance flat glass infrastructure and innovative technologies that accelerate the removal of glazing and/or windows from buildings, as well as the separation of different window components.
- ✓ increasing the price of cullet using available policy instruments such as the Climate Change Levy (CCL), the carbon tax, the landfill tax (considering the recycling potential of materials) and designing tax exemptions or capital allowances for flat glass products that use cullet. The key balance here is to avoid that recycled products become much higher than those using raw materials.
- ✓ guaranteeing that frames and windows are designed for dismantling and recycling
- ✓ establishing individual recycling targets for flat glass in line with the target on construction and demolition waste. These targets should lead to increased dismantling, sorting, and collection of glazing and windows.

Figure 2: Flat glass circularity process in renovation and demolition activities.

Local authorities can support greater flat glass recovery by:

- ✓ embedding flat glass recycling requirements into planning permits including renovation and demolition projects.
- ✓ include requirements around recycled flat glass into public procurement
- ✓ facilitate the collection and transport of cullet. Local authorities are instrumental in facilitating collection points. Large quantities of glass can be collected in one place (e.g., demolition or renovation sites), and transport solutions should be available considering the limited availability of recycling facilities in the UK.

- ✓ provide environmental surveillance of waste disposal sites to avoid the landfill of recyclable materials from demolition and renovation projects.

Industry action

Glass manufactures can:

- ✓ design glass returns schemes and make them available to their customers. Manufacturers would collect the cullet and bring it directly back to their facilities rather than going through a glass recycler or any other third party (e.g., Saint Gobain). This could be managed by individual companies or be deployed nationally by taking the form of a collaborative industry initiative like Vlakglas in the Netherlands.
- ✓ promote awareness around the increasing pressure on raw materials. This could be one of the most important drivers of circular economy transition from an environmental perspective[29]. This could be achieved through the enactment/commitment to an industry sustainable sourcing standard, and the promotion of training sessions directed to construction/demolition professionals, construction material suppliers, waste management companies, glazing contractors, and end-users.

Alongside regulatory control and compliance, the greatest driver of circularity is consumer pressure. This calls **construction companies and end-users** (e.g. homeowners) to specify in their contracts requirements around glass recycling when hiring **demolitions and renovation contractors** (early incentives allow careful planning of recycling). This could be incentivised through regulatory requirements for construction companies and homeowners as well as voluntary schemes (e.g., certifications) for contractors.

Value chain integration

Participatory and inclusive planning mechanisms should be promoted, involving all relevant stakeholders[30]. Adequate communication platforms should be created to disseminate demolition and renovation waste management programs, and the corresponding results achieved, promoting, involvement, awareness, and guidance[31]. **Multi-stakeholder collaboration** is needed for:

- ✓ creating an online and accessible flat glass marketplace. The absence of marketplaces implies existing uncertainty and a lack of easy access to information on supply and demand for recycled windows, facades, and cullet. For example, creating an online portal with centralised information about where flat glass is recycled, as well as the composition of end products (e.g., supported with QR codes and/or blockchain).
- ✓ Measuring the flat glass recycling performance. This involves facilitating the collection of better data as there is little data on how much flat glass the industry currently recycles.
- ✓ Building capabilities among those involved in the process of flat glass recycling. Cullet for flat glass manufacturing requires high quality making contamination an issue which could be prevented with better training to those involved in the process. For example, the site manager or other responsible person regularly

[29] Upadhyay, A., Kumar, A., & Akter, S. (2022). An analysis of UK retailers' initiatives towards circular economy transition and policy-driven directions. *Clean Technologies and Environmental Policy*, 24(4), 1209–1217.
[30] Gálvez-Martos, J. L., Styles, D., Schoenberger, H., & Zeschmar-Lahl, B. (2018). Construction and demolition waste best management practice in Europe. *Resources, Conservation, and Recycling*, 136, 166-178.
[31] Ghaffar, S. H., Burman, M., & Braimah, N. (2020). Pathways to circular construction: An integrated management of construction and demolition waste for resource recovery. *Journal of cleaner production*, 244, 118710.

monitors collection and ensures that the containers are not contaminated by construction staff. This requires training site managers, and anyone involved in the collection process including contractors, and demolition/renovation companies. Industry associations and professional associations operating at the national and regional level could have an important role in the promotion and delivery of these trainings, supported by local universities.

- ✓ working with designers, architects, and builders to design flat glass products that take into consideration their recyclability at the end of life.

Image by jwvein via Pixabay

The Way Forward

We underline the significance of the smart design of policy to accelerate the circularity transition by providing appropriate incentives. Public policies with a focus on market demand creation play a key role as they exercise meaningful impacts on the likelihood of adopting circular economy innovations[32]. They can influence firms' adoption of activities aimed at recycling, reducing waste, and decreasing material usage[33]. However, government policy serves only as the starting point for the successful recovery of flat glass waste. As we have seen, if the intention is to move glass waste further up the waste hierarchy and into recycling, it is likely that a combination of policy instruments will be required to drive this. Smart policy design in this context implies the use of a combination of government-driven policies and private self-regulation.

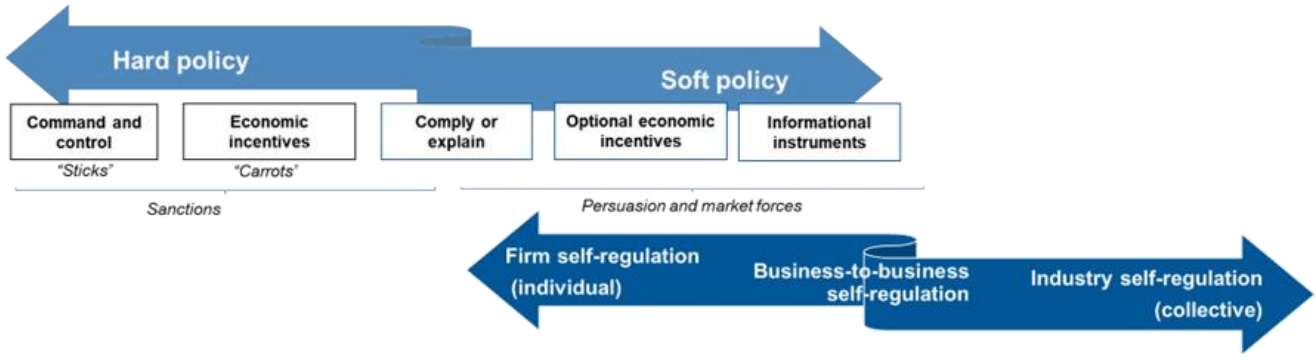

Figure 3: Policy framework for flat glass circularity.

Government action: Combining hard and soft policy

At the government level, an appropriate command and control measure would be a legal requirement to sort flat glass waste from demolition and renovation sites (including homeowners' renovations) as well as a landfill ban on recyclable materials. In combination, they would increase the cullet available for reprocessing. However, these policies would not be enough to create a market for cullet.

The creation of new markets or the broadening of niche markets needs economic incentives such as increased landfill taxes, and material specific EPR regulations. The design of these policies needs to also consider taxes that increase the cost of raw materials and reward those who achieve higher rates of cullet reprocessing and those who use cullet products (e.g., subsidies or tax reliefs for people buying homes, cullet products, or contractors with a certified flat glass recycling plan).

[32] Ren, Q., & Albrecht, J. (2023). Toward circular economy: The impact of policy instruments on circular economy innovation for European small medium enterprises. *Ecological Economics*, 207.

[33] Cainelli, G., D'Amato, A., & Mazzanti, M. (2020). Resource efficient eco-innovations for a circular economy: Evidence from EU firms. *Research Policy*, *49*(1), 103827.

These policies can be supported by sector-specific and value chain inclusive public reporting requirements. These typically come in the form of 'comply or explain' regulations targeting large and listed companies. By including the value chain, companies would need to extend the data requirements to their own suppliers and customers.

Similarly, public procurement requirement around flat glass recycling would extend the data and use of cullet products to smaller and non-listed companies wishing to do business with the government, its agencies, and local authorities. At the local authority level, it would include embedding flat glass recycling requirements into planning permits for renovation and demolition projects, as well as setting collection points.

Consumers can also be targeted by government action by being encouraged to change purchase decisions. Labelling and certification systems to strengthen the protection against greenwashing and reinforce product guarantees are examples of this circular approach.

Industry leading the way

While our interviewees agreed on that government policy was fundamental to increase the rate of flat glass recycling, they also recognised that industry could lead the way. In a context where government action is insufficient, industry can show to the government where and how regulations are needed. One example of this type of initiatives is Vlakglas in the Netherlands which started as a collaboration of manufacturing companies to be supported by the government through taxes aiming at financing and extending the programme.

In the UK, some individual companies have implemented their own flat glass return and certification schemes, requested contractors to have a waste management plan (including flat glass), and invested in technologies to sort and recycle. They represent steps in the right direction.

However, they are unlikely to address flat glass recycling to the extent that it is currently needed. Within and between industries collaboration is fundamental to drive transformative change. Industry initiatives can be initiated by one industry (e.g., manufacturing), but it should include collaboration with all relevant industries (e.g., construction, demolition and renovation, recycling, glazing). The reason behind this is the technical, logistical, and infrastructural challenges of dismantling, collecting, and sorting flat glass from demolition and renovation sites.

These initiatives should aim at creating a marketplace for flat glass where companies and homeowners know where flat glass collection points are available, where to buy products that use cullet, as well as the composition of end products.

Conclusions: From waste to resource

This report discusses policy interventions (public and private) needed to enable business model innovation for circular economy in the flat glass industry in the UK. We find that turning flat glass waste into a resource depends on the balance of incentives, enforcement, collaboration, and awareness.

Creating a market for recycled materials is essential to increasing the rate of flat glass recycling. This should be supported by an integrated value chain, adequate recycling infrastructure (including collection, transport, and re-processing of cullet), appropriate economic incentives, and flat glass waste-specific regulations that would encourage recycling.

Although government action around flat-glass recycling in the UK is still in early stages, there is an urgent need for regulatory solutions in this respect. Some of those need to combine landfill taxes, landfill bans, and material-specific extended producer responsibility regulations. Similarly, industry-driven initiatives should focus on collective action aimed at achieving greater coordination and awareness in the value chain, as well as promoting that cullet is treated as a resource instead of a waste material.

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