British Glass

Glass sector Net zero strategy 2050

Contents

Foreword

Whilst we have demonstrated good progress so far from our 2015 decarbonisation roadmap, (published in partnership with the Department for Business, Energy & Industrial Strategy (BEIS) which aimed for an 80% reduction in CO_2 emissions by 2050) the UK government has committed to an even more ambitious target of net zero greenhouse gas emissions by 2050.

This new target brings a significant challenge to UK glass manufacturing over the next 30 years as we look to reach net zero, but it is a challenge we as an industry are collectively working to achieve, as outlined in this net zero strategy, which has been supported and devised in conjunction with British Glass members.

As an industry, we have a continued commitment to working towards a net zero, globally competitive glass manufacturing industry for the UK. Over the past 40 years the industry has seen a 50% increase in the energy efficiency of UK glass furnaces, increased recycled content of glass packaging, high performance glazing and invested in waste heat recovery to bring down CO_2 and improve resource efficiency – we appreciate there is still much to do despite the great strides taken already and this strategy document outlines the various routes available to achieve the government's target. The key barrier to decarbonisation is the cost of alternative fuels, which are currently cost prohibitive.

UK manufacturers are already evaluating and researching ways to reduce both combustion and process emissions but future development of these depend on availability, viability, and feasibility, all of which should be considered carefully.

Looking outside of the scope of glass manufacture, glass is a wonderful material, with a vast part to play in achieving the decarbonisation of other sectors with CO_2 savings through glazing products, the use of glass fibre in the automotive and energy sectors and of course, the huge part glass plays in the circular economy by reducing the needs of raw materials.

We, however, cannot attain or support the achievement of net zero alone and we will work closely with government to help shape future policy, while also continuing to lobby to protect the UK's foundation industries to ensure we can remain competitive against the EU marketplace and rest of the world and invite industry stakeholders to have their voice heard with government leaders.

We cannot dictate to the sector which options the industry will or should take, but this document sets out the key routes for our industry now. However, these options will be heavily reliant on a number of factors and future government policy to reduce the barriers to success.

Thank you to our members, foundation industry partners and policy advisers who have provided valuable feedback and support in devising the glass industry's net zero strategy.

Dave Dalton, British Glass CEO

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Executive summary

British Glass and the glass industry published a decarbonisation roadmap in 2015 in conjunction with the Department for Business, Energy & Industrial Strategy (BEIS)[1]. The roadmap was based on an 80% reduction in CO_2 emissions by 2050. Since then, the UK government has committed to the United Nations Climate Change Paris Agreement at COP 21 in December 2015. The Paris Agreement is a legally binding international treaty on climate change, with a goal to limit global warming to below 2^0C, preferably to 1.5^0C, compared to pre-industrial levels.

The UK government has committed to bring all greenhouse gas emissions to net zero by 2050. The glass industry is a key foundation industry and has set out a strategy to achieve net zero CO_2 by 2050.

The UK large scale[2] glass manufacturing industry is significant and includes 10 companies with 17 sites throughout England, Scotland, and Northern Ireland, manufacturing container, flat and continuous filament fibre glass. The glass industry employs around 6,000 direct staff and indirectly around 150,000.

The glass industry has already made significant strives to reducing CO_2 and improving resource efficiency, with:

- an increase of 50% in the energy efficiency of UK glass furnaces over the past 40 years;
- investment in waste heat recovery for UK plants from two multinational glass companies in the past three years.

This net zero strategy is an update of the 2015 decarbonisation roadmap and reviews the opportunities and challenges to achieve net zero manufacturing processes by 2050 and providing energy saving products through high performance glazing, light-weighted products and being a 100% recyclable material that meets circular economy principles.

For the glass sector to achieve net zero by 2050, it is essential that all stakeholders are informed and engaged, so the aims and objectives of this document are to:

- Inform stakeholders of the glass industry options for achieving net zero.
- Address the potential barriers to decarbonisation for the UK glass industry.
- Inform the UK and devolved administrations on how the glass industry will contribute to achieving net zero and the circular economy.
- Inform policy makers of recommendations to help the UK achieve net zero and improve the circular economy.

The key statistics for 2019 are:

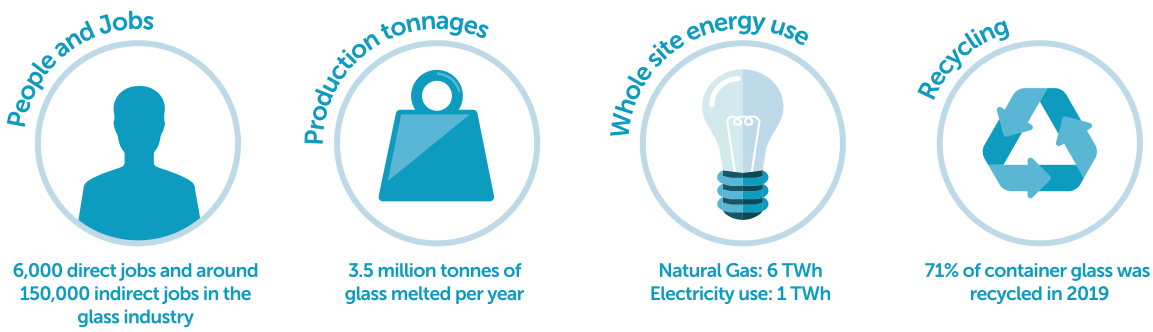


Figure 1: 2019 key stats

[1] A clear future - UK glass manufacturing sector decarbonisation roadmap to 2050_summary.pdf (britglass.org.uk)
[2] large scale glass manufactures are defined as producing over 20 tonnes per day

Current energy efficiency technologies

Energy efficiency improvement – An opportunity to make incremental improvements to furnace and process equipment when it is updated.

Waste heat recovery – Utilisation of waste heat to pre-heat the raw materials using a batch and/or cullet preheater, generate electricity or compressed air using an Organic Rankine Cycle or steam turbine and/or preheat combustion fuel and oxidants.

Reducing combustion emissions (short term to 2028)

Increased use of cullet – Replacing raw materials with cullet (recycled glass) to produce new glass products reduces the energy required by the furnace. This means that the furnace uses less fuel therefore reducing combustion emissions.

Oxyfuel combustion – Oxyfuel combustion is an established technology which has been successfully implemented in each of the glass sectors. The technology uses oxygen instead of combustion air which gives a furnace energy saving of 10 to 15% and reduces emissions of NOx.

Liquid biofuels – Replace fossil fuel with bio derived liquid fuels. Given most natural glass furnace designs could be easily converted to run standard biofuels, they offer a short-term relatively quick solution to decarbonise a large proportion of site CO_2 emissions using existing furnace technologies. Longer term biofuels could be used in combination with carbon capture storage resulting in negative CO_2 emissions.

Reducing combustion emissions (longer term 2030 onwards)

All-electric melting – All-electric furnaces are an established technology in the glass sector and are more efficient than gas fired furnaces. However, there is little experience of using all-electric furnace for large scale glass melting and further development work is required. In addition, there will need to be investment in the electricity supply infrastructure, and electricity must be cost competitive with natural gas.

Hybrid furnace – A hybrid furnace is a furnace that can run on multiple fuels, the latest development is using up to 80% electricity with 20% gas energy, with the future opportunity to consider hydrogen combustion. The hybrid furnace concept has the potential to tackle one of the key issues for decarbonising the glass sector which is the long furnace life of between 10 and 20 years. The hybrid furnace approach allows manufacturers to future proof their furnace so that as electricity becomes more cost-competitive with natural gas, they can switch to using a higher proportion of electricity.

Hydrogen combustion – The glass sector has recently started investigating the feasibility of using hydrogen to fuel a glass furnace. Until recently the sector did not consider hydrogen to be a viable option due to its flame characteristics, however, there has been renewed interest driven by plans in the EU and UK for large scale production and eventual replacement of natural gas with hydrogen. There are currently five projects in the UK and Europe looking at the feasibility of using 100% hydrogen as well as different proportions of hydrogen blended with natural gas for glass melting. In the UK there has been significant investments into infrastructure and research into hydrogen technologies and it is expected that the first industrial clusters with access to hydrogen supplies could be online as soon as 2026.

Reducing process emissions

Increased cullet use – Increased cullet use reduces the amount of carbonate raw materials required therefore reducing CO_2 emissions. Every tonne of cullet that is remelted to make new glass products saves 1.2 tonnes of raw materials and reduces emissions of process CO_2 by approximately 200kg.

Calcined raw materials – Calcined materials such as calcium oxide, which is produced from heating limestone to remove the CO_2, could be used to replace carbonates in the batch and reduce site CO_2 emissions.

Alternative raw materials – There is on-going research investigating alternative raw materials such as mineral slags, waste incineration ashes and other secondary raw materials. Some of these could be used to replace carbonate raw materials, whilst others may reduce the melting temperature of the glass therefore reducing the energy requirements.

Carbon capture, utilisation, and storage – Carbon capture, utilisation, and storage (CCUS) is the process in which the CO_2 is separated from the flue gas and either used as a feedstock in another process or stored securely underground. Whilst the combustion emissions can be eliminated by fuel switching, the process emissions are more challenging and may require CCUS to meet net zero emissions. There may also be an opportunity to combine the technology with use of biofuel to give negative CO_2 emissions.

Circular economy – Glass recycling

Expanding the circular economy for glass is a critical part of the glass industry's strategy to achieve net zero, accounting for around a third of planned CO_2 reduction.

Once produced, glass is a permanent and sustainable material. It is 100% recyclable and can be melted and re-melted without ever reducing its quality. Recycling has many important benefits, as it reduces the demand for virgin raw materials such as sand, limestone, dolomite and soda ash, and using cullet in the production process of new glass is more cost effective for glass manufacturers compared to using raw materials. Most importantly cullet produces no process emissions – every 10% addition of cullet will reduce the energy consumption by 3% and CO_2 by 5%. In addition, air pollution is reduced by 20% and water pollution is cut by 50%.

Container glass – The recycling of container packaging glass is well established, reducing CO_2 emissions by 580kg[3]. Proposed changes to Extended Producer Responsibility and Consistency of Collections regulations will drive more packaging glass recycling. The container sector has a target of 90% collected for recycling rate by 2030.

Flat glass – Most end-of-life glazing in buildings is not currently recycled and presents a great opportunity for reducing CO_2 process emissions. This will require engagement of all stakeholders involved in building renovations and demolition, to ensure there is an infrastructure that is economic and provides good quality recovered cullet for remelt rather than being lost to aggregate or landfill.

[3] https://feve.org/about-glass/facts-product-details/

How glass products can help to decarbonise other sectors

Flat glass potential carbon savings – Domestic CO_2 emissions account for 15%[4] of the total UK CO_2 emissions. Glazing products have a significant part to play in reducing CO_2 emissions from residential and commercial properties. If all buildings in the UK updated their glazing to high efficiency glazing (1.4 U value) by 2030, it is estimated that the UK could save 14,376 $KtCO_2$ per year[5] which equates to a 32% reduction in energy consumption from buildings.

In addition, flat glass has an important role to play in transport by reducing the weight of vehicles to reduce transport emissions. Over the last 20 years, glass coverage in cars has increased by 17%. Flat glass is also a key component in solar technology, although the majority of this is not manufactured in the UK due to higher manufacturing costs and international competitiveness.

Continuous filament glass fibre role in decarbonising UK – Continuous filament glass fibre products are mainly used in the reinforcement of thermosetting and thermoplastic resins. These composite materials play a crucial role in the automotive industry in reducing vehicle weight, increasing fuel efficiency, and reducing transport CO_2 emissions. Glass fibre also plays a key role in the construction of wind turbine blades. Advancements in glass fibre products have allowed manufacturers to construct longer, lighter, and more efficient rotor blades for larger wind turbines.

Barriers and challenges

The document reviews the barriers that need to be overcome for different technology and process options:

- **Financial viability** – Energy costs account for around a third of overall manufacturing costs. The high cost of alternative fuels which are typically over 3 times that of natural gas, currently prohibit manufacturers from fuel switching.
- **Infrastructure** – Most sites would need to upgrade their connection for hydrogen and electricity.
- **Compatibility with future technologies** – Up to 2050 new technology will be introduced and it is essential compatibility is considered and incorporated if possible.
- **Technical feasibility** – Many glass manufacturing sites have limited space for additional saving technologies, and it is essential that new processes, fuels and materials are trialled before they can be utilised on a full-scale manufacturing site.
- **Large scale demonstration** – New technology, materials and fuels must be trialled at full production scale.
- **Security of supply** – There is uncertainty over the long-term availability of biofuels. Availability may be affected by increased use of biofuels in other industries such as aviation and transport.
- **Availability of fuel** – Hydrogen is initially planned to be available in a small number of industrial clusters. Initially only a few glass sites which are located close to these clusters will be able to use hydrogen.
- **Availability of alternative raw materials** – Any new material would need to be available in sufficient quantities with no interruption in supply. There may be competition from other foundation industries for supply. The composition of such materials can be variable and new technical solutions are required to address such challenges.
- **Availability of cullet** – There is shortage of good quality cullet for glass manufacture to maximise the CO_2 saving.
- **H&S** – New fuels and materials will impact on H&S risk and migration controls on production sites and will need to be considered.
- **Education** – There remains a lack of public awareness around the value of closed loop recycling compared to low value recycling such as glass being 'recycled' as aggregate. There is also a perception in the construction and demolition industries of glass being difficult to recycle.

[3] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/863325/2018-final-emissions-statistics-summary.pdf
[4] https://glassforeurope.com/wp-content/uploads/2019/05/Glazing_potential_brochure_2019.pdf

Roadmap to net zero

If the whole glass industry has access to competitively priced fuels, technology and supportive regulations (see section 5), it will be possible to achieve net zero by 2050.

The figures below provides an indication of what is possible.

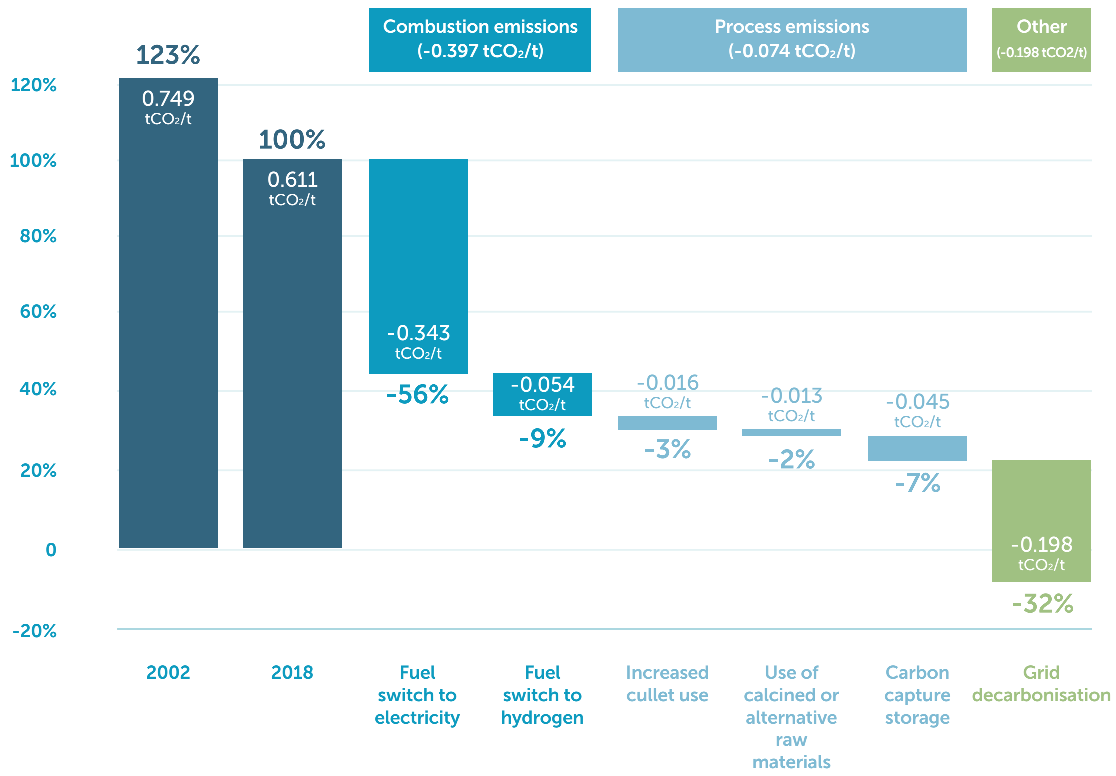


Figure 2: Potential route to net zero by 2050

Policy recommendations

The UK glass industry is willing to contribute to the goal of net zero and as a material, glass is very well suited to a circular economy. The industry needs to be supported with clear policy direction by the UK government, to protect and help the industry continue manufacturing beyond 2050.

For policy recommendations please see Section 6.

Introduction

British Glass and the glass industry published a decarbonisation roadmap in 2015 in conjunction with the Department for Business, Energy & Industrial Strategy (BEIS). The roadmap was based on an 80% reduction in Greenhouse gas emissions, which now needs to be reassessed based on the 100% commitment made by the UK government in 2019.

There are barriers and challenges for the glass sector to achieve net zero with most of the sector emissions currently associated with the combustion of natural gas. To achieve net zero, the sector will need to switch to low carbon fuels – electricity, biofuels or hydrogen.

To ensure glass manufacturing remains in the UK, the sector must work with government to ensure decarbonising is not achieved by de-industrialising. The glass industry is at risk of carbon leakage which means if energy and policy costs are uncompetitive in the UK, glass will be imported from the EU or the rest of the world, which will most likely increase global CO_2 emissions.

The glass industry has a key role to play in helping the UK reach net zero by 2050 by providing a circular economy solution to the packaging industry (container glass), providing high efficiency glazing to improve energy efficiency in buildings (flat glass) and continuous filament glass fibre to be incorporated into wind turbines for renewable energy and lightweight vehicles.

This strategy is not to dictate which options the industry should take, but to show what options are feasible at this moment in time. The option(s) adopted by the industry will be heavily reliant on finance and availability, if these areas are not addressed the industry will struggle to achieve the goal of net zero by 2050.

This report will recommend policy changes that are essential to help the UK glass industry thrive and achieve net zero by 2050 (see section 6).

Scope of the strategy

The scope of this strategy covers the manufacture of container, flat and continuous filament fibre glass in the UK.

Glass wool insulation manufacture is not covered although most of the technology options may also be applicable to these manufacturers.

Aims and objectives of the strategy are to:

- inform stakeholders of the glass industry options for achieving net zero;
- address the potential barriers to decarbonisation for the UK glass industry;
- inform the UK and devolved administrations on how the glass industry will contribute to achieving net zero and the circular economy;
- inform policy makers of recommendations to help the UK achieve net zero and improve the circular economy.

Section 1: Sector overview

The UK large scale[6] glass manufacturing industry includes 10 companies with 17 sites throughout England, Scotland, and Northern Ireland. The glass industry employs around 6,000 direct staff and indirectly around 150,000.

Container – Food, drink, and pharmaceutical products. There are currently six companies across 12 manufacturing sites in the UK.

Flat – Flat glass is used in commercial and residential buildings for glazing. Sophisticated coatings enable high efficiency glazing installation to reduce building CO_2.

Fibre – Continuous filament fibres of glass are incorporated into reinforced plastic materials used in numerous applications in manufacturing, and predominantly for wind turbine blades and light weighting of vehicles.

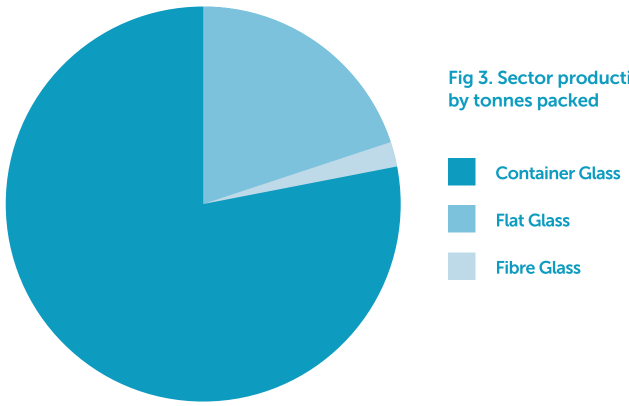


Fig 3. Sector production by tonnes packed

Company	Type
Ardagh	Container
Allied	Container
Beatson Clark	Container
Encirc	Container
O-I	Container
Stoelzle	Container
Guardian	Flat
NSG	Flat
Saint Gobain	Flat
Nippon Electric Glass	Fibre

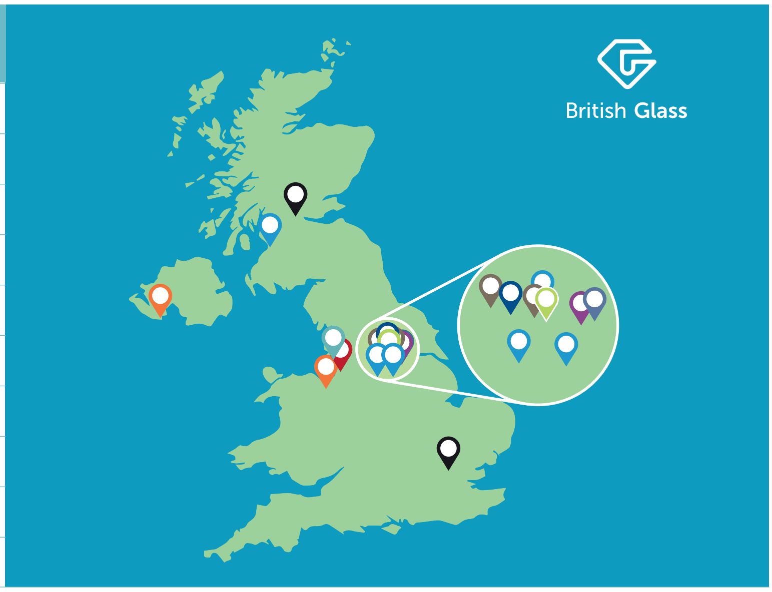


Fig 4. UK glass manufacturing locations

1.1 Key statistics for UK glass 2019

6,000 direct jobs and around 150,000 indirect jobs in the glass industry

3.5 million tonnes of glass melted per year

Natural Gas: 6 TWh
Electricity use: 1 TWh

71% of container glass was recycled in 2019

[6] Large scale glass manufacturers are defined as producing over 20 tonnes per day.

Production tonnages	**3.5 million tonnes of glass melted per year (2019)**	• Glass melted across container, flat and continuous filament fibre.
Whole site energy use	**Natural Gas: 6 TWh** **Electricity use: 1 TWh**	• The energy efficiency of glass furnaces has been improved by more than 54% since 1979 with technical innovation and progressive improvements. • It is estimated that the energy costs for the glass industry are around £240 million per year
Emissions	**CO_2: 1.5 million tonnes of ETS (site emissions reported under the ETS)**	• Fossil fuel combustion equates to around 75-85% of the CO_2 emissions. • Raw materials equate to around 15-25% of CO_2 emissions dependent on recycled content, therefore with 100% cullet there would be no CO_2 from raw materials
Recycling	**71% of container glass was recycled in 2019[7]**	• In Wales over 87%[8] of glass packaging collected by local authorities. English local authorities in comparison collect 78% with the UK average being 76.5% of household container glass collected for recycling. • Every tonne of cullet used in the manufacture of new glass packaging produces a CO_2 saving of 580kg. • Of the 71% recycled, over 72% is remelted into new containers glass

Table 1: Key statistics for UK Glass

1.2 CO_2 emissions in UK glass industry from 2002-2019

Figure 5 shows the UK glass industry has reduced both absolute and some relative emissions over the previous 13 years. This is mainly due to the installation of more energy efficient furnace technology and increased cullet use. For future potential decarbonisation options please see section 4.

Emission Trading Scheme (ETS) CO_2 emissions include combustion (75-85%) and raw material (15-25%) CO_2.

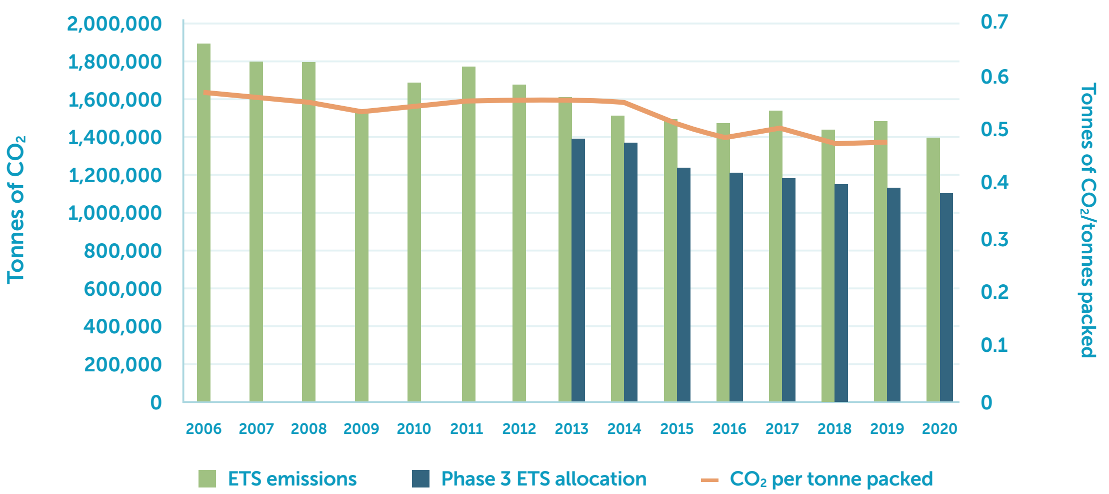


Figure 5: Absolute and relative ETS emissions from 2006-2020

[7] https://www.valpak.co.uk/more/material-flow-reports/packflow-covid-report
[8] https://wrapcymru.org.uk/sites/default/files/2020-09/WRAP-municipal-waste-composition-2015-16_0.pdf

1.3 How can glass help to achieve net zero?

Recycling – Each time one tonne of glass is recycled, approximately 580kg[9] CO_2 is saved through the supply chain, air pollution is reduced by 20% and water pollution is cut by 50%.

- The container glass sector has set itself a 90% target for container glass collected for recycling by 2030 to further the GHG reductions from the sector.
- The flat glass sector is working to increase the recycled content of flat glass, as increasing the recycled content reduces the carbon footprint of glass.

Double glazing – Double glazing and triple glazing has the potential to significantly increase energy efficiency in buildings, reducing energy use and CO_2.

Wind Turbines – Continuous filament glass fibre is used in the construction of wind turbine blades which provide renewable energy.

Light weighting vehicles – Continuous filament glass fibre is used as an alternative material to reduce the weight of vehicles to improve efficiency.

Solar – Glass products are used for solar products which provide renewable energy.

Glass wool insulation – Used for commercial and domestic buildings for improved thermal efficiency to reduce energy use and CO_2.

1.4 Glass manufacturing process

The below illustrations (figure 6 and 7) show the container and flat glass manufacturing processes. The first three stages of this process – raw materials, batch house and furnace – are common to each of the glass sectors and utilise similar batch preparation and furnace technologies. Once the glass leaves the furnace the forming and downstream processes are unique to each sector.

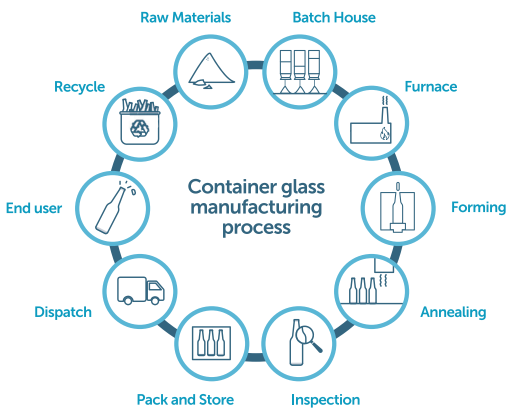


Figure 6: Container glass manufacturing process

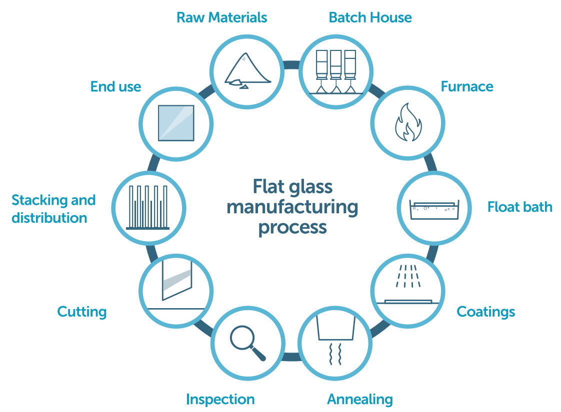


Figure 7: Flat glass manufacturing process

In the **batch house**, the high purity raw materials (typically 60% silica sand, 21% sodium carbonate and 19% limestone for container glass production) are weighed and mixed along with other materials. In the case of flat and container glass, cullet is also added. Depending on the glass type small amounts of other materials may also be added to either colour the glass or improve its chemical and physical properties.

In the **furnace** stage, the batch is continuously fed into the furnace at a constant rate. A glass furnace is a refractory box-like structure which operates at temperatures up to 1,700°C. The furnace is heated by gas burners which fire above the surface of the melt and heat the glass by radiation. A furnace may also have submerged electrodes (within the glass) that heat the glass via resistive heating. Once melted, the glass is allowed to homogenise and refine (allow gas bubbles

[9] https://feve.org/about-glass/facts-product-details/

to rise and escape). Leaving the furnace, the glass enters the **forming** stage of the process.

Container glass production is achieved by streaming the molten glass down several channels known as forehearths which lead to the glass **forming** machines (blow and blow, or press and blow forming), operating at 1,050-1,200°C. The glass drops through a hole at the end of these forehearths and is then redirected into a series of iron moulds. Compressed air blows the glass to the required shape.

For **flat glass production** the glass from the furnace flows gently over a refractory lip onto a bath of molten tin (electrically heated by radiation heating elements). The glass floats on top of the surface of molten tin and is drawn across the tin to form a solid ribbon of glass.

Once formed, flat and container glass can be coated to add additional properties. In the forming process, very rapid temperature changes are encountered, inducing internal stresses within the glass. To remove these stresses, the glass goes through the process of **annealing**, which involves re-heating (400-600°C) the glass followed by a controlled cooling cycle. Annealing is generally performed continuously with the glass on a conveyor belt being fed through a long tunnel kiln known as a lehr which is either gas fired or electrically heated and can take up to 40 minutes depending on the thickness of the glass. In the last phase of production, glass passes through a highly automated **inspection** before it can leave the factory. **Pack and store**, and **dispatch** are also highly automated.

Continuous filament fibre glass is produced by drawing the glass through an electrically heated bushing (1,200°C) containing many hundreds of tiny holes to form continuous flexible fibres that are drawn onto drums and used for textile type applications. The fibres are rapidly cooled as they are formed, and a water-based binder is applied. The drums are then dried in either gas fired or electric ovens in batches.

1.5 Environmental compliance

UK glass manufacturers comply with several climate change policies to ensure that they reduce their carbon emissions in line with government targets.

- Emission Trading Scheme (ETS) – All large manufacturing sites must annually report and surrender allowances to cover their CO_2 emissions from combustion and process emissions.
- Climate Change Agreements (CCA) – energy efficiency targets for processes not covered by the mineralogical and metallurgical exemptions.
- ESOS – Energy Savings Opportunity Scheme – mandatory energy efficiency audits required every four years.
- Streamlined Energy and Carbon Reporting (SECR) – large UK companies must disclose energy and CO_2 emissions in Companies House Directors' Reports.

1.6 Carbon leakage and international competitiveness

The glass industry is classed as an industry at risk of carbon leakage:

> **"Carbon leakage refers to the situation that may occur if, for reasons of costs related to climate policies, businesses were to transfer production to other countries with laxer emission constraints. This could lead to an increase in their total emissions."**[10]

The UK government must continue to support and protect industries from the risk of carbon leakage to ensure foundation industries remain in the UK. These industries are critical in achieving the net zero goal.

Many of the glass manufacturers in the UK are global companies and therefore are competing for investment within the global group, this means UK climate policy needs to be clear and long term to give companies security over investment decisions.

[10] Carbon leakage | Climate Action (europa.eu)

Section 2: Decarbonisation technologies

2.1 The use of decarbonisation technologies

2.1.1 Energy efficiency Improvement

Typically, over 80% of the fuel consumed on a UK glass site is natural gas, the majority of which is used in the furnace. In terms of energy efficiency improvements, the regenerative air/fuel furnaces used by most of the glass sector are approaching the limit of what is technically possible. As the furnace ages it becomes less efficient by approximately 1% per year. The furnace is re-built every 10-20 years, which improves energy efficiency and is an opportunity to make incremental improvements on the previous design efficiency.

There are also opportunities in other stages of the process and other parts of the production site to reduce electricity consumption through efficiency improvements. The main areas for improvement include compressed air systems, installing fitting variable speed drives and fitting LED lighting.

Barriers

- **Financial viability** – Some projects do not meet company criteria for payback (typically less than 2 years) or may lose out to competition from other projects within the company.
- **Resource** – Sites may not have the resource to investigate potential opportunities and develop a cost benefit analysis and business case.

2.1.2 Waste heat recovery

The majority of the glass furnaces in the UK (31 out of 34) fire on air and natural gas and have regenerators that recover waste heat which is used to pre-heat the combustion air. Despite this, around a third of the energy input to a gas fired furnace exits as waste heat in the flue gases. This waste heat can be utilised to pre-heat the raw materials using a batch and/or cullet preheater, as a result improving the efficiency of the melting process or generate electricity or compressed air using an Organic Rankine Cycle or steam turbine.

Novel ways of utilising waste heat from an oxyfuel furnace have been demonstrated at industrial scale. These include the Praxair Optimelt system which utilises the waste heat to convert the natural gas fuel supply into a hot syngas and the Air Liquide Heatox system which uses the waste heat to pre-heat the furnace oxygen and natural gas supply.

Not all the of the heat can be recovered from the furnace waste gases as they need to be kept above the acid dew point (180 °C) to avoid corrosion of the waste gas flue system and any pollution abatement equipment. In some cases, the flue gas abatement system may limit the amount of waste heat that can be recovered if they require a higher flue gas temperature to operate.

Barriers

- **Financial viability** – Generally the payback for waste heat recovery projects is greater than 5 years, which exceeds most companies' criteria for payback without government support.
- **Compatibility with future furnace technologies** – A switch to using more electricity for glass melting in the future will reduce the available waste heat.
- **Compatibility with future abatement technologies** – Glass furnace emissions limits are reviewed at regular intervals. A reduction in emissions limits may require installation of additional abatement measures which could reduce the amount of heat that can be recovered.
- **Technical feasibility** – Sites do not always have sufficient space to install the additional equipment required.

2.2 Reducing combustion emissions (short term to 2028)

2.2.1 Increased use of cullet

Replacing raw materials with cullet to produce new glass products reduces the energy required by the furnace. This means that the furnace uses less natural gas therefore reducing combustion emissions. Every 10% addition of cullet saves approximately 2.5% furnace energy[11]. Using cullet also reduces process emissions (see section 2.4.1).

Barriers

- **Availability** - Glass manufacturers are already using all the available cullet which meets their quality requirements. There is a shortage of flint and amber container cullet for container glass manufacture and flat glass cullet for float glass manufacture. Policies are required that increase the amount of good quality cullet available for glass manufacture (see circular economy policy recommendations).

2.2.2 Oxyfuel combustion

Oxyfuel combustion is an established technology which has been successfully implemented in each of the glass sectors. The technology uses oxygen instead of combustion air which gives a furnace energy saving of 10-15% and reduces emissions of NOx.

Barriers

- **Financial viability** – Despite using less natural gas the OPEX costs are higher than for air/fuel furnaces due to the high cost of the electricity which is used to generate oxygen on-site.
- **Technical feasibility** – Some sites may not have the space for an oxygen generation plant.

2.2.3 Liquid biofuels

Liquid biofuels cover a wide range of different fuel grades, from biodiesel (high quality, high consistency, higher cost) to lower-grade organic by-products from other manufacturing processes for which limited other applications exist. Prior to using natural gas, glass furnaces in the UK ran on either heavy fuel oil or diesel (which have similar properties to some biofuels), so the sector is confident that liquid biofuels with similar properties to these can be used.

Given most natural glass furnace designs could be easily converted to run standard biofuels, they offer a short-term relatively quick solution to decarbonise a large proportion of site CO_2 emissions using existing furnace technologies. Longer term biofuels could be used in combination with carbon capture storage resulting in negative CO_2 emissions.

It is important that any biofuel used by the sector meets strict sustainability criteria.

Barriers

- **Technical feasibility** – Although the technical feasibility of using biofuels has recently been demonstrated at large scale in the UK, not all sites will have sufficient space for the fuel storage tanks it requires.
- **Variability of supply** – For lower grade fuels the quality and consistency can vary batch-to-batch. Some biofuels may also contain contaminants that might be detrimental to standard furnace refractories.
- **Limited shelf-life** – Some biofuels can have limited shelf-life and may require additional measures to avoid issues such as gelling or microbial growth in tanks and pipes.
- **Security of supply** – There is uncertainty over the long-term availability of biofuels. Availability may be affected by increased use of biofuels in other industries such as

[11] https://feve.org/wp-content/uploads/2016/04/FEVE-brochure-Recycling-Why-glass-always-has-a-happy-CO2-ending-.pdf

aviation and transport, changes in government policy on biofuel use and competition with other countries for supply.

- **Financial viability** – The OPEX cost of using biofuels is currently higher than natural gas. The cost of zero-carbon rated sustainable biofuels may increase further due to competition for this limited resource as more industries and countries realise the carbon benefit. Sites may also need to invest in fuel storage tanks and pipelines, heaters and pumps to deliver the fuel to the furnace.

Case study – Encirc Derrylin

As part of the BEIS fuel switching project led by Glass Futures, Encirc have successfully trialled using liquid biofuel on one of their furnaces at the Derrylin site. As part of the trial, they have reported to have been able to use 100% cullet to produce glass bottles.

2.3 Reducing combustion emissions (longer term 2030 onwards)

2.3.1 All-electric melting

All-electric furnaces are an established technology in the glass sector and are more efficient than gas fired furnaces. The National Grid predict that the electricity grid could be net zero by the early 2030s which makes electric melting a viable option for decarbonising glass production. Currently the high cost of electricity in the UK means that electric melting is not a viable option. The difference in melting efficiency for electricity versus natural gas increases with decreasing furnace size. Generally worldwide, all-electric melting is currently only used for smaller furnaces producing higher value products such as glass tableware.

All electric melting is thought to be limited to furnaces below 300 tonnes/day, but to date no one has attempted to build a larger all-electric furnace. However, a possible solution to this is a modular approach where a larger furnace is replaced by several smaller furnaces.

Barriers

- **Financial viability** – High OPEX costs due to the price of electricity in the UK is the main barrier. Based on a typical container glass furnace, the energy cost for electric melting is around three times that of natural gas. Upgrading the sites electricity connection could also cost up to £12m per site.
- **Security of supply** – An interruption in power supply for longer than 2 hours, would cause serious issues and potential loss of the furnace. The site supply would require double circuit security to minimise the risk.
- **Infrastructure** – Most sites would need to upgrade their connection. It is estimated that this could take between 4 and 7 years to implement.
- **Technical feasibility** – For flat glass it is thought to be technically challenging to use high levels of electrical boost (>40%).

2.3.2 Hybrid furnace

A hybrid furnace is a furnace that can run on multiple fuels. Traditional gas fired furnaces already use a small proportion of electricity; however, the new designs of hybrid furnace can supply between 20-80% of the melting energy from electricity.

The hybrid furnace concept has the potential to tackle one of the key issues for decarbonising the glass sector which is the long furnace life of between 10 and 20 years. The hybrid furnace approach allows manufacturers to future proof their furnace so that as electricity becomes more cost-competitive with natural gas, they can switch to using a higher proportion for glass melting.

Future designs may also be compatible with hydrogen so that the switch to hydrogen can be made when it becomes available at a particular site.

Another advantage of a hybrid furnace is that the control system can be set up to respond to changes in energy prices. This would allow manufacturers to be paid to turn down electricity during peak times and take advantage of cheaper electricity when there is an excess from renewables.

FEVE Furnace for the future

FEVE are applying for funding through the EUETS Innovation Fund for a project to the hybrid furnace concept at industrial scale. Their proposal includes plans for a 300 tonnes/day hybrid furnace which can run on up to 80% renewable electricity. The furnace is planned to be built by 2022 and if successful, this will give manufacturers confidence in the technology and help speed up adoption by the glass sector.

Barriers

- **Financial viability** – High OPEX costs due to the price of electricity in the UK, and initial cost of upgrading the site electricity connection is the main barrier.
- **Infrastructure** – the majority of sites will require an additional capacity, It is estimated that this could take between 4-7 years to implement at a cost up to £12 million per site.
- **Large scale demonstration** – The new designs have not yet been demonstrated.
- **Technical feasibility** – For float glass, high levels of electrical boost are not currently considered technically feasible. More work is required in this area to understand how more electricity can be used.

2.3.3 Hydrogen

The glass sector has recently started investigating the feasibility of using hydrogen to fuel a glass furnace. Until recently the sector did not consider hydrogen to be a viable option due to its flame characteristics, however, there has been renewed interest driven by plans in the EU and UK for large scale production and eventual replacement of natural gas with hydrogen. There are currently five projects in the UK and Europe looking at the feasibility of using 100% hydrogen as well as different proportions of hydrogen blended with natural gas for glass melting (see Appendix 1).

In the UK there has been significant investments into infrastructure and research into hydrogen technologies and it is expected that the first industrial clusters with access to hydrogen supplies could be online as soon as 2026.

Barriers

- **Financial viability** – As commercially available hydrogen is still a long way off it is difficult to predict the OPEX cost. The government is currently looking at business models and is expected to publish a hydrogen strategy in 2021.
- **Infrastructure** – It is likely that significant modifications to furnace designs, burners and pipework and fuel control system will be required for a site to transition to hydrogen. New health and safety measures will also need to be adopted.
- **Availability** – Hydrogen is initially planned to be available in a small number of industrial clusters. Initially only a few glass sites which are located close to these clusters will be able to use hydrogen. The Climate Change Committee (CCC) predict that hydrogen will start to be available outside of the clusters by 2035.
- **Technical feasibility** – The technical feasibility of using hydrogen is still being investigated, however initial results are promising.

2.4 Reducing process emissions

Process CO_2 emissions are produced from the decomposition of the carbonate raw materials (limestone, dolomite, and soda ash) used to manufacture glass. The only options available for reducing process emissions are to either replace the carbonate raw materials with CO_2 free materials or capture the CO_2 released using carbon capture storage.

2.4.1 Increased cullet use

The melting of cullet produces no process emissions unlike raw materials. Increased cullet use reduces the amount of carbonate raw materials required therefore reducing CO_2 emissions. Every tonne of cullet that is remelted to make new glass products saves 1.2 tonnes of raw materials and reduces emissions of process CO_2 by approximately 200kg. (see combustion section 2.3 for barriers).

2.4.2 Calcined raw materials

Calcined materials such as calcium oxide, which is produced from heating limestone to remove the CO_2, could be used to replace carbonates in the batch and reduce site CO_2 emissions.

Barriers

- **Technical feasibility** – Further work is required in this area to understand the impact of using calcined materials. There are concerns over melting behaviour, furnace corrosion and batch carry over.
- **H&S** – Calcined materials are classified as hazardous due to their corrosive nature. Batch handling systems would need to be re-designed to mitigate any health and safety risk.
- **Financial viability** – Calcined raw materials are more expensive than their carbonate equivalents due to the heat energy required to remove the CO_2. The cost of net zero production of calcined raw materials will be even higher as it will require carbon capture storage.

2.4.3 Alternative raw materials

There is on-going research investigating alternative raw materials such as mineral slags, waste incineration ashes and other secondary raw materials. Some of these could be used to replace carbonate raw materials, whilst others may reduce the melting temperature of the glass therefore reducing the energy requirements.

Barriers

- **Availability** – Any new material would need to be available in sufficient quantity and quality with no interruption in supply. There may be competition from other foundation industries for supply. The composition of such materials can be variable and new technical solutions are required to address such challenges.
- **Demonstration** – Any new material will require industrial demonstration to give manufacturers confidence that it will not impact on glass quality or affect the process in any other way.

2.4.4 Carbon capture, utilisation, and storage

Carbon capture, utilisation, and storage (CCUS) is the process in which the CO_2 is separated from the flue gas and either used as a feedstock in another process or stored securely underground. Whilst the combustion emissions can be eliminated by fuel switching, the process emissions are more challenging and may require CCUS to meet net zero emissions. There may also be an opportunity to combine the technology with biofuel to give negative CO_2 emissions.

Barriers

- **Technical feasibility** – Viability of capturing CO_2 from the furnace waste gas still needs to be demonstrated. The current amine scrubber technologies are not compatible with glass furnace flue gases. Some sites may not have sufficient space for CCUS equipment.
- **Infrastructure** – Most glass sites are not close to the planned industrial clusters so will not have access to pipelines for transporting the captured CO_2.
- **Financial viability** – CCUS is likely to be a very expensive option for reducing process emissions.

2.5 Policy recommendations

Section	Policy recommendations
Energy costs **HIGH priority**	• Establish a funding mechanism to support operational, as well as capital costs associated with switching to low carbon fuels such as hydrogen, biofuels, and electricity (CCC recommendation). • Reform electricity pricing to reflect the much lower costs of supplying low-carbon electricity in the mid-2020s and beyond (CCC recommendation). • The design of policies to reduce UK manufacturing emissions must ensure that it does not damage UK manufacturers' competitiveness and drive manufacturing overseas. (CCC recommendation) • In the near term, taxpayer funding or innovative financial schemes should be used to support deep decarbonisation in manufacturing sectors at risk of carbon leakage (CCC recommendation). • Clear long-term policy to support industrial decarbonisation and protect UK manufacturers from the risk of carbon leakage (CCC recommendation). • Clear policy which allows first movers using higher priced low-carbon fuels to remain competitive. • Ensure all EIIs (including glass) are exempt from policy costs on natural gas to protect against carbon leakage.
Energy infrastructure **HIGH priority**	• Upgrade and future-proof electricity capacity and networks to enable electrification of glass manufacturing. • Support for upgrading site electricity connections for electrification of glass manufacturing. • Ensure that the Biomass Strategy reviews and addresses concerns over availability and sustainability of biofuels. • Ensure that hydrogen infrastructure allows non-clusters connections by 2035.
Decarbonisation technologies **MEDIUM priority**	• Continue support for deep decarbonisation innovation projects. • Establish funding for large scale industrial demonstration projects which covers additional OPEX costs as well as CAPEX.

Section 3: Circular economy – Glass recycling

Expanding the circular economy for glass is a critical part of the glass industry's strategy to achieve net zero, accounting for around a third of planned CO_2 reduction.

Once produced, glass is a permanent and sustainable material. It is 100% recyclable and can be melted and re-melted without ever reducing its quality. In the UK the glass industry are pioneers of the circular economy and recycling by introducing the first bottle banks in the 1970s to provide glass container manufactures with cullet. With over 40 years of glass being recycled in the UK, bottles placed into a bottle bank in the 1970s are likely to form a fraction of bottles on shelves today.

Recycling has many important benefits – it reduces demand for virgin raw materials such as sand, limestone, dolomite and soda ash, and using cullet in the production process of new glass is more cost effective for glass manufacturers compared to using raw materials. Most importantly, cullet reduces carbon emissions, as melting cullet produces no process emissions, unlike raw materials and reduces the energy required for melting and the associated CO_2.

3.1 Container glass

Re-melting glass in the manufacturing process of new containers brings major CO_2 savings. Recycling 1 tonne of cullet:

- avoids the extraction of 1.2 tonnes of virgin raw materials;
- reduces the CO_2 emissions by 580kg (includes scope,1, 2 and 3 emissions)[12];
- reduces the energy consumption of the furnace (every 10% increase in the recycled content will reduce the energy consumption by 3% and CO_2 by 5%);
- there are no CO_2 process emissions;
- air pollution is reduced by 20% and water pollution is cut by 50%.

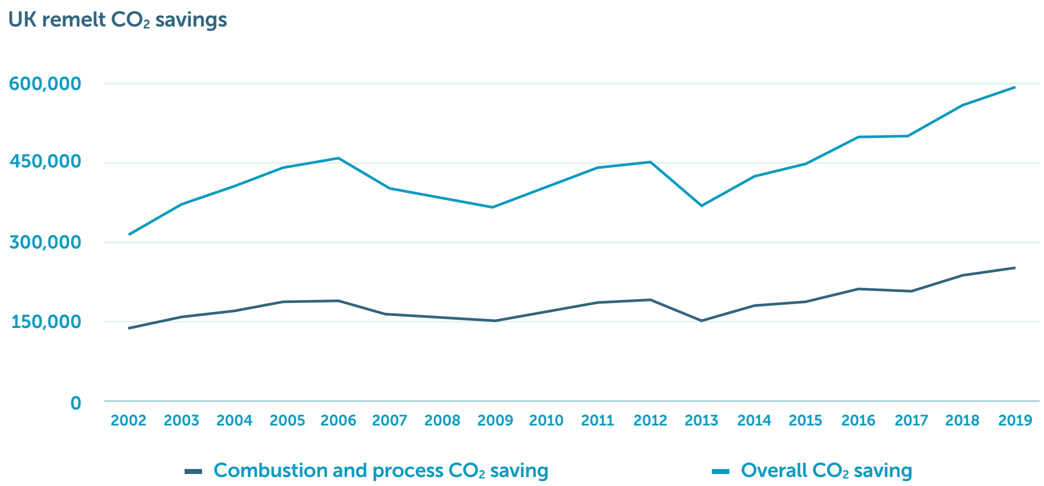


Figure 8: UK remelt CO_2 savings

Recycling infrastructure has driven increasing quantities of glass to remelt into new bottles and jars. The overall annual CO_2 saving from using cullet in place of raw materials has almost doubled over the past two decades, from 324,796 tonnes in 2002, to 593,978 tonnes in 2019.

The UK glass container value chain has developed a successful closed loop recycling system over 40 years enabling a bottle placed in a kerbside recycling bin to be remelted and returned to the shop floor as a new bottle in as little as 30 days.

12 https://feve.org/about-glass/facts-product-details/

Every tonne of glass re-melted into new bottles and jars

saves 580 kg of CO_2 - equivalent to charging 74,000 smartphones

this is because using recycled glass to replace raw materials in the production process emits less CO_2 to the environment.

Currently, green glass bottles have a recycled content of up to 90% and clear and amber bottles at around 40 to 50%.[13] To increase the recycled content further, the glass container sector requires high quantities of good quality colour sorted cullet which means improving recycling rates further.

In 2019, the UK's glass packaging recycling rate was 71%, which is the highest rate of any packaging material such as plastic, aluminium, and steel.[14] The sector is committed to continuing to develop the circularity of glass packaging by increasing recycling rates and the recycled content in glass packaging. As part of this commitment, the UK's glass container manufacturers are supporting an industry led project (Close the Glass Loop) to achieve a **90% collected for recycling rate by 2030**, working to bring the entire glass value chain together to drive glass recycling in the UK and the associated CO_2 savings.

Case study: The Welsh blueprint

Wales as a nation is the third best performing country in the world for its recycling rate. Most local authorities in Wales follow the Collections Blueprint, achieving an 87.3% glass collection rate at the kerbside. The Welsh approach provides consistency of collections through a kerbside sort and provides local authorities recycling targets to achieve, with the Welsh Government spending over £1bn in recycling infrastructure and nationwide communication campaigns over the last two decades.

Challenges to overcome to build a circular economy for container glass

- **Deposit return schemes (DRS)** – DRS is a significant threat to the UK and could have a detrimental impact on the quantity of quality glass available for remelt back into containers.
- **Unambitious glass recycling targets** – Under the current producer responsibility system, obligated producers must recycle 81% of glass packaging in 2021 with 72% required to be recycled for remelt (as opposed to recycled for aggregate). However this could and does not incentivise closed loop recycling.
- **Cullet imbalance** – Exports of flint (clear) glass results in a limited supply of flint cullet for flint production. There is also an oversupply of green cullet in the UK. This imbalance leads to green cullet being exported abroad whilst the under supply of flint means it is either imported into the UK or manufacturers must use a higher percentage of raw materials, in all cases emitting CO_2 emissions.

[13] https://feve.org/wp-content/uploads/2019/07/Recycled-Content-FEVE-Position-June-2019.pdf
[14] https://wrap.org.uk/sites/default/files/2020-12/Packflow%20COVID-19%20Glass%20Phase%20I%20Report%20FINAL%20v2.pdf

3.2 Flat glass

Window (flat) glass is an essential everyday material used in buildings, vehicles, as well as other applications such as solar panels. In the UK, three manufacturers produce around 750,000 tonnes of glass each year, with the majority used for glazing products for buildings[15]. Like glass bottles, flat glass can be collected, processed, and remelted into new glass with the right incentives and infrastructure in place. However, of the 750,000 tonnes of end-of-life waste flat glass generated each year in the UK, around 500,000 is being landfilled[16]. The rest is currently recycled for use as aggregates in construction.

Over the last 30 years, the flat glass industry has reduced its CO_2 emissions by 43%, but while this is positive, the UK flat glass sector is committed to build on this by developing the circularity of the industry, driving down the amount of flat glass going to aggregate or landfill, and improving the quantities and quality of glass recycled to contribute towards a net zero economy.[17]

Producing new flat glass from cullet saves around 300kg of CO_2 emissions (covers only direct emissions) with every tonne of glass re-melted. That means if all the flat glass currently going to landfill was diverted to being recycled, the CO_2 savings would be around 150,000 tonnes.

Challenges to overcome to build a circular economy for flat glass

- **Quality** – The majority of end-of-life glazing in buildings could be dismantled and recycled, however, contamination is the main barrier to recycling flat glass.
- **Economics** – The low material value of glass and the high cost of labour and transport to recycle flat glass means the economics often do not stack up.
- **Education** – There remains a lack of public awareness around the value of closed loop recycling compared to low value recycling such as glass being 'recycled' as aggregate. There is also a perception in the construction and demolition industries of glass being difficult to recycle.

3.3 Policy recommendations

Section	Policy recommendations
Circular economy HIGH priority	**Container glass** • Improve consistency across UK glass recycling. • A new reformed extended producer responsibility for packaging. • A new remelt target for obligated producers of glass. • Obligations on businesses across the UK to recycle a core set of dry recyclables including glass. • Continued innovation in the recycling system to reduce losses to a minimum and increase yields of glass available for remelt. • Exclude glass from the upcoming UK wide deposit return schemes. **Flat glass** • Recycling of flat glass written into public sector contracts. • Boost to collection infrastructure for flat glass to improve quality and increase flat glass recycling. • Regulate for flat glass recycling – there is a duty of care in the UK for waste handlers to prioritise high value recycling – this must be upheld. • A landfill tax that incentivises flat glass recycling. • Reformed building regulations on design for end of life to increase recycling of flat glass. • Raising awareness of the circular options within the construction industry.

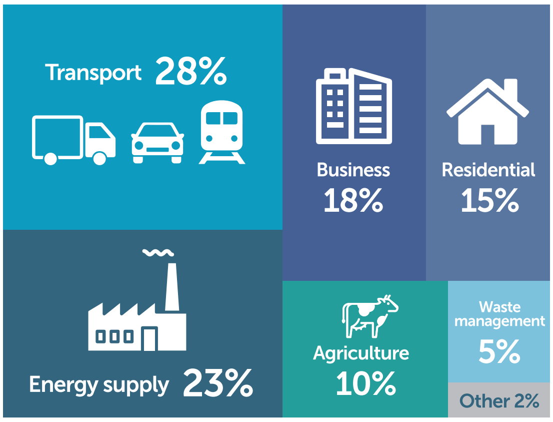
[15] https://preprod.wrap.org.uk/sites/default/files/2020-09/WRAP_Flat_Glass_GoodPractice_FINAL%20%282%29.pdf
[16] https://glassforeurope.com/recycling-of-end-of-life-building-glass/
[17] https://glassforeurope.com/wp-content/uploads/2020/01/flat-glass-climate-neutral-europe.pdf

Section 4: How glass products can help to decarbonise other sectors

4.1 Flat Glass potential CO_2 savings

The domestic CO_2 emissions account for 15% of the total emissions according to government statistics.[15] Glazing products have a significant part to play in reducing the CO_2 emissions from residential and commercial properties. These have been overlooked by existing government decarbonisation funding and regulations due to the green homes grant being cancelled at the end of March 2021.

Transport was the largest emitting sector of UK greenhouse gas emissions in 2018



Energy supply delivered the largest reduction in emissions from 2017 to 2018

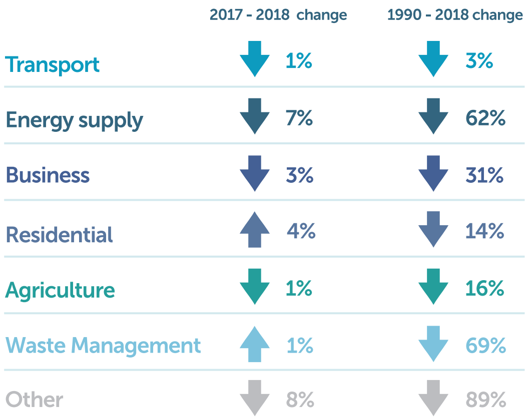


Figure 9: Greenhouse gas emissions

Residential properties have not seen a drastic reduction in energy efficiency from 1990-2018 (14% reduction). Further work is required to improve energy efficiency, high efficiency glazing could help to greatly reduce residential and commercial emissions. It is estimated that windows in the UK have an average insulation performance of U value 3.9, which is equivalent to 1960s windows due to low renovation rates.

4.1.1 What are U Values?

U-values show, in units of W/m^2K, the ability of a building component/material, such as a window unit, to transmit heat from a warm space to a cold space in a building, and vice versa. The lower the U-value, the better insulated the window.

4.1.2 Why is flat glass important?

- Flat glass has an important role to play in transport. By reducing the weight of vehicles it helps to reduce emissions. Over the last 20 years glass coverage in cars has increased by 17%.
- Flat glass is a key component in solar technology, although the majority of this is not manufactured in the UK due to higher manufacturing costs and international competitiveness.

[18] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/863325/2018-final-emissions-statistics-summary.pdf

- Windows have a long lifespan staying in buildings for 40-50 years on average.
- The CO_2 emitted during production and manufacture double glazing is offset within 6-20 months[19] and saves 10 times the energy required to produce it.

4.1.3 CO_2 saving potential for retrofitting glazing products

Installing or upgrading to a higher energy efficient specification glazing system will reduce energy consumption and make a significant contribution to the UK's energy efficiency and net zero target.

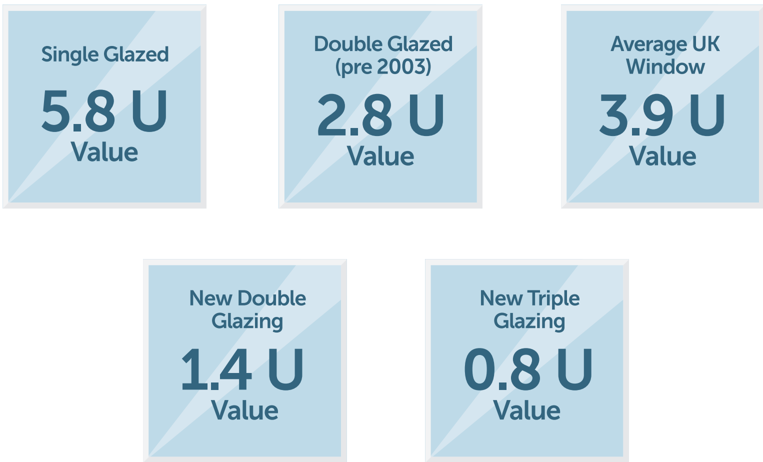


Figure 10: U values

If all buildings in the UK updated their glazing to high efficiency glazing (1.4 U value) by 2030, it is estimated that the UK could save 14,376 $KtCO_2$ per year[20] which equates to a 32% reduction in energy consumption from buildings.

Current standards for new builds – Building Regulations (Part L)

Advancements in glazing technology mean the current specifications of 1.6 U value products in building standards are very conservative and lag behind innovation by decades. To help ensure the UK meets the net zero objective:

- New building stock should be mandated to install high efficiency glazing with U value rating of less than 1.4;
- The building renovation rate (estimated at 2% per year) needs to be increased to ensure old inefficient glazing products are replaced.

4.1.4 Education and energy efficiency calculation

Most architects and building designers have a lack of knowledge of available energy efficient glazing products. It is therefore essential the glazing unit supply chain inform architects and building designers of the available products and how these can be incorporated into new builds and refurbishments.

British Glass will provide knowledge on the available glass products through support and resources, including training and seminars. All UK flat glass manufacturers have resources on the properties of glass products and British Glass will engage with architects and building designers to ensure these resources are utilised when choosing the most appropriate glass for the glazing unit.

19 2050 Flat glass in a Climate-Neutral Europe - Glass for Europe

20 https://glassforeurope.com/wp-content/uploads/2019/05/Glazing_potential_brochure_2019.pdf

4.2 Container glass role in the circular economy

Glass is the perfect packaging material for food, beverages, pharmaceuticals and cosmetics as it is transparent yet impermeable, non-toxic and with a virtually inert durable permanent barrier that does not interact with the contents, providing a long shelf life and not leaching any toxic or harmful compounds. Glass packaging is infinitely recyclable, reusable and refillable and meets the requirements of food contact regulations. As food waste is a major contributor to GHG, glass packaging reduces impact with a long shelf life and the ease of removal of the contents resulting in very little food waste.

Glass packaging is also 100% recyclable and is a truly circular economy packaging material, in that it can be melted and made into new containers again and again with no loss of quality or performance.

Production efficiency continues to improve with modern forming machines capable of manufacturing 36,000 bottles or jars an hour. And thanks to increasingly precise control of the manufacturing process, today's glass containers are approximately 40% lighter than they were 30 years ago. This saves virgin materials, fuel and reduces CO_2 emissions throughout the supply chain.

The recycled content of glass packaging continues to increase as more recycled glass packaging becomes available through improvement in glass recycling infrastructure and further consumer engagement in recycling. As decarbonisation options become available and are adopted glass packaging will become net zero.

4.3 Continuous filament glass fibre role in decarbonising the UK

Continuous filament glass fibre products are mainly used in the reinforcement of thermosetting and thermoplastic resins. These composite materials play a crucial role in the automotive industry in reducing vehicle weight, increasing fuel efficiency, and reducing CO_2 emissions.

Glass fibre also plays a key role in the construction of wind turbine blades. Advancements in glass fibre products have allowed manufacturers to construct longer, lighter, and more efficient rotor blades for larger wind turbines.

It is important to ensure that all UK windfarms use UK manufactured continuous filament glass fibre to help protect the industry and jobs in the UK. In the UK, there is currently only one manufacturer of glass fibre and this is at risk of carbon leakage due to cheap imports from heavily subsided non-EU countries, such as Asia.

4.4 Policy recommendations

Section	Policy recommendations
Glass products can help to decarbonise other sectors **MEDIUM priority**	• Update building regulations for new builds and refurbishments for domestic and non-domestic buildings to be mandated to install the best available glazing products (B standard EPR as a minimum or 1.4 U value). • The public building sector to lead the way by specifying high efficiency glazing products via the public sector decarbonisation fund. • Ensure that British Glass and the Glass and Glazing Federation are included in stakeholder plans for the Social Housing decarbonisation fund, public sector decarbonisation scheme and the future homes standard. • Ensure that UK manufactured glass fibre is used in the manufacture of UK windfarms.

Section 5: Potential route to net zero by 2050

As part of the net zero strategy, British Glass has developed a model which looks at how the glass sector can work towards net zero by 2050.

The model assumes all necessary research and large-scale industrial demonstrations of new technologies take place; the grid decarbonises and becomes carbon negative by early the 2030s; and government implements the policies outlined in the strategy. This will enable the industry to transition to net zero at a cost that remains competitive.

The results from the model for 2050 are summarised in figure 11 and show that the sector has the potential to go beyond net zero by 2050.

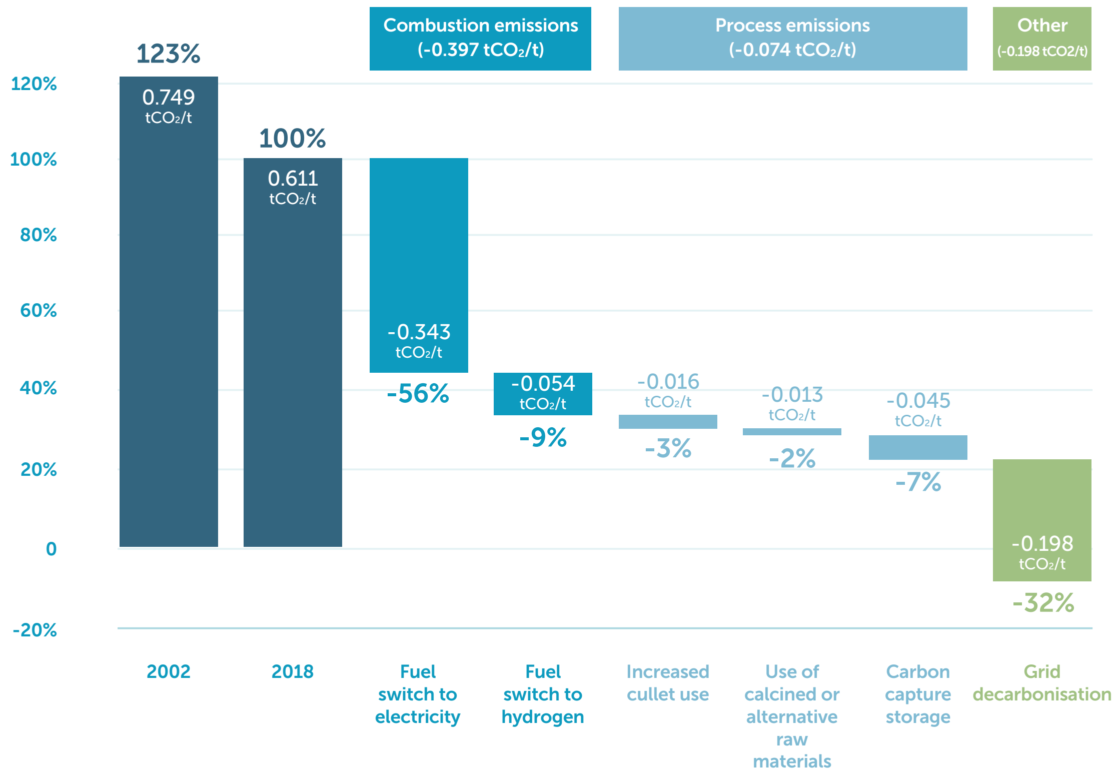


Figure 11: Potential route to net zero by 2050

5.1 Combustion emissions (-0.397 tCO_2/t)

Fuel Switch to electricity (-0.343 tCO_2/t)

Improvements to the electricity grid, government support for upgrading site connections and policies on electricity pricing for large industrial users enable the sector to gradually transition from natural gas to electricity.

Successful large scale industrial demonstration of oxyfuel hybrid furnaces capable of running on up to 80% electricity enables this technology to be adopted in the container glass sector. Hybrid furnaces with a lower electricity input are utilised by the flat glass sector. Some smaller furnaces (<250 t/d) are converted to all-electric.

Fuel switch to hydrogen (-0.054 tCO_2/t)

Innovation projects followed by large scale industrial demonstration show that hydrogen is a viable option to replace natural gas. Hydrogen is initially available inside the clusters by 2030 and the hydrogen network is extended to reach all glass sites by 2050. Sites using hybrid furnaces gradually transition to hydrogen from natural gas as it becomes available.

5.2 Process emissions (-0.074 tCO_2/t)

Increased cullet use (-0.016 tCO_2/t)

Improvement in the container glass recycling rate and policies which incentivise the recycling of glass to remelt applications increase the availability of cullet to the container glass sector.

It is assumed there will still be a colour imbalance between what is placed on the market and produced in the UK so there will be a shortage of good quality cullet to produce some glasses especially clear (flint).

Policies which incentivise recycling of flat glass from buildings increase the availability of cullet which is suitable for flat and container glass production.

Use of calcined and alternative raw materials (-0.013 tCO_2/t)

Successful research into calcined and alternative raw materials followed by large scale industrial demonstration allows sites to replace some carbonate raw materials in the batch, where economically feasible.

Carbon capture storage (-0.045 tCO_2/t)

By 2050 research into CCS in the glass sector finds a viable solution to capture CO_2 from glass furnace emissions. Government investment in infrastructure allows for transport of CO_2 from dispersed sites outside the industrial clusters. CCS is only seen as a solution for the larger furnaces (>500t/day) running on lower cullet ratios.

5.3 Grid decarbonisation (-0.198 tCO_2/t)

The grid continues to decarbonise in line with the National Grid, Future Energy Scenarios forecast and becomes CO_2 negative by the early 2030s due to electricity generation from bi-omass combined with CCS (BECCS). The high proportion of electricity used by the sector and the negative grid factor results in the sector going beyond net zero in 2050.

5.4 Potential fuel use to 2050

Figure 12 gives a breakdown from the model of potential fuel use by the sector to 2050. It shows a gradual switch from natural gas to electricity followed by the application of hydrogen as it becomes available. This illustrates the sector will be heavily dependant on electricity to meet net zero. Given the long investment cycle of a glass furnace (up to 20 years) urgent action is required to ensure electricity costs are reduced, network and connections to glass sites are upgraded to allow the sector is to transition to net zero by 2050.

Glass sector energy use by fuel type

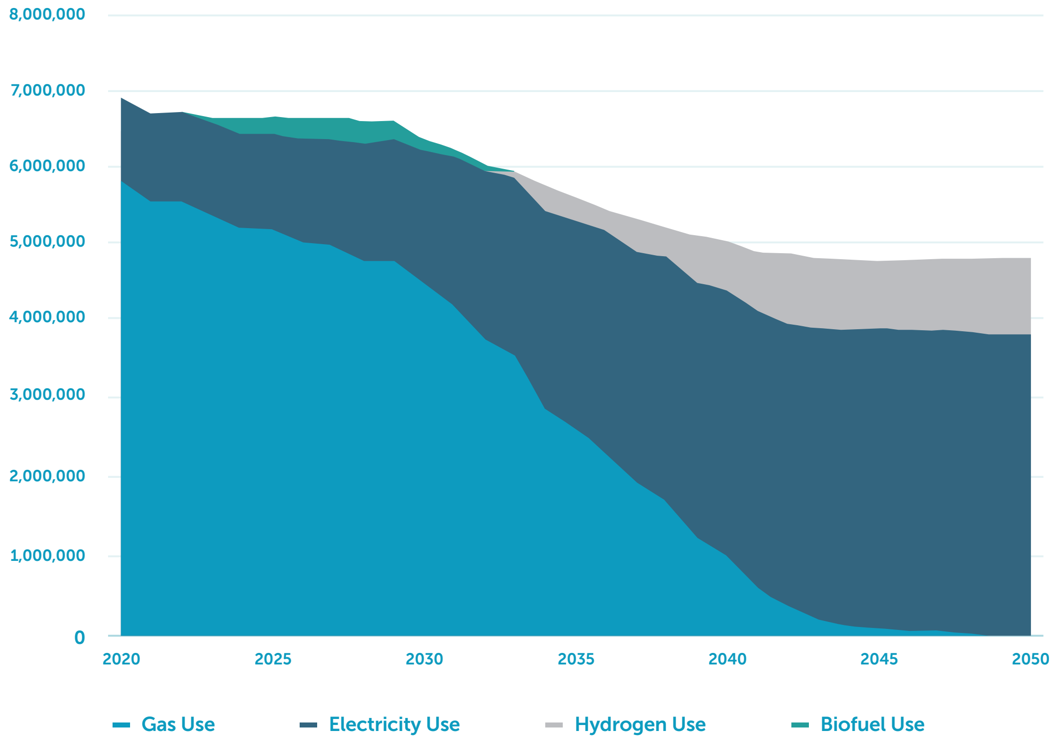


Figure 12: Glass sector energy use by fuel type

Section 6: Summary of government actions required

This section highlights the policy recommendations that need to be addressed for the UK glass industry to reach the goal of net zero by 2050. Some of these recommendations have also been suggested by the Climate Change Committee (CCC) in the 6th carbon budget published December 2020[21].

The UK glass industry is willing to contribute to the goal of net zero and as a material is very well suited to a circular economy. The industry needs to be supported with clear policy direction by the UK government, to protect and help the industry continue manufacturing up to and beyond 2050.

Section	Policy recommendations
Energy costs **HIGH priority**	• Establish a funding mechanism to support operational, as well as capital costs associated with switching to low carbon fuels such as hydrogen, biofuels and electricity (CCC recommendation). • Reform electricity pricing to reflect the much lower costs of supplying low-carbon electricity in the mid-2020s and beyond (CCC recommendation). • The design of policies to reduce UK manufacturing emissions must ensure that it does not damage UK manufacturers' competitiveness and drive manufacturing overseas. (CCC recommendation) • In the near term, taxpayer funding or innovation financial schemes should be used to support deep decarbonisation in manufacturing sectors at risk of carbon leakage (CCC recommendation). • Clear long-term policy to support industrial decarbonisation and protect UK manufacturers from the risk of carbon leakage (CCC recommendation). • Clear policy which allows first movers using higher priced low carbon fuels to remain competitive. • Ensure all EIIs (including glass) are exempt from policy costs on natural gas to protect against carbon leakage.
Energy infrastructure **HIGH priority**	• Upgrade and future-proof electricity capacity and networks to enable electrification of glass manufacturing. • Support for upgrading site electricity connections for electrification of glass manufacturing. • Ensure that the Biomass Strategy reviews and addresses concerns over availability and sustainability of biofuels. • Ensure that hydrogen infrastructure allows non-clusters connections by 2035.
Decarbonisation technologies **MEDIUM priority**	• Continue support for deep decarbonisation innovation projects. • Establish funding for large scale industrial demonstration projects which covers additional OPEX costs as well as CAPEX.

[21] Sixth Carbon Budget - Climate Change Committee (theccc.org.uk)

Section	Policy recommendations
Circular economy HIGH priority	**Container glass** • Improve consistency across UK glass recycling. • A new reformed extended producer responsibility for packaging. • A new remelt target for obligated producers of glass. • Obligations on businesses across the UK to recycle a core set of dry recyclables including glass. • Continued innovation in the recycling system to reduce losses to a minimum and increase yields of glass available for remelt. • Exclude glass from the upcoming UK wide deposit return schemes. **Flat glass** • Recycling of flat glass written into public sector contracts. • Boost to collection infrastructure for flat glass to improve quality and increase flat glass recycling. • Regulate for flat glass recycling – there is a duty of care in the UK for waste handlers to prioritise high value recycling – this must be upheld. • A landfill tax that incentivises flat glass recycling. • Reformed building regulations on design for end of life to increase recycling of flat glass • Raising awareness of the circular options within the construction industry.
Glass products can help to decarbonise other sectors MEDIUM priority	• Update building regulations for new builds and refurbishments for domestic and non-domestic buildings to be mandated to install the best available glazing products (B standard EPR as a minimum or 1.4 U value). • The public building sector to lead the way by specifying high efficiency glazing products via the public sector decarbonisation fund. • Ensure that British Glass and the Glass and Glazing Federation are included in stakeholder plans for the Social Housing decarbonisation fund, public sector decarbonisation scheme and the future homes standard. • Ensure that UK manufactured glass fibre is used in the manufacture of UK windfarms.

Section 7 - Appendix 1 - Glass sector decarbonisation projects

UK

Project	Description	Further details
Industrial fuel switching – Glass Futures	The project will evaluate the associated technical, economic, and environmental aspects of electric, hydrogen, biofuel and hybrid-fuel melting technologies with the objective of designing a flexible demonstration scale glass furnace, capable of demonstrating and assessing these fuel-switching opportunities for the entire glass sector. This project involves multiple industry partners and will include a biodiesel trial on a full-scale commercial line and a large lab scale hydrogen demonstration.	www.glass-futures.org/our-innovation
Hynet North West – Progressive Energy and Cadent	Hynet North West is a large-scale project to deliver a low carbon industrial cluster in the North West of England. The project is based on large scale production of hydrogen from natural gas combined with CCS. As part of the project, they have secured funding to demonstrate the feasibility of switching from natural gas to hydrogen in several key industrial processes including manufacture of float glass. There are several glass sites in the area which could eventually be connected to the hydrogen supply.	hynet.co.uk
Enviro Ash – Glass Technology Services	Project looking at replacing carbonate raw materials with waste ash.	www.c-capture.co.uk/c-capture-to-demonstrate-carbon-capture-capabilities-for-glass-manufacturing-with-pilkington-united-kingdom-limited

Appendix 1 cont.

Project	Description	Further details
Use of CCS in the glass sector – C Capture and NSG	Trials to quantify the compatibility of Carbon Capture and Storage technology with the requirements of the glass manufacturing industry.	www.c-capture.co.uk/c-capture-to-demonstrate-carbon-capture-capabilities-for-glass-manufacturing-with-pilkington-united-kingdom-limited
Recycled Glass Briquettes – Ardagh Glass	Development of a method to produce briquettes from the fine glass particles rejected during the recycling process, allowing 100% of recovered glass to be recycled.	www.ardaghgroup.com/news-centre/triple-win-for-ardagh-briquette-project

Europe

Project	Description	Further details
Heat transfer from hydrogen-rich flames in glass tanks – GlassTrend (Netherlands)	Analysis of heat transfer efficiency from flames of hydrogen and syngas (H2/CO combinations) and of sooty hydrogen flames to the glass melt in an industrial glass tank by glass furnace simulations.	www.glasstrend.nl
Batch heating and melting in cold-top furnaces– GlassTrend (Netherlands)	Develop experimental techniques to evaluate cold-top melting and feasibility cold-top batch thickness sensor.	www.glasstrend.nl
Consequences of H2-rich combustion on foaming– GlassTrend (Netherlands)	Laboratory study (2 scales) of the impact of hydrogen combustion on foaming of glass melts for various glass types.	www.glasstrend.nl

Appendix 1 cont.

Europe

Project	Description	Further Details
Innovative decarbonated raw materials – GlassTrend (Netherlands)	Assessment of various alternative (low CO_2) raw materials with respect to CO_2 emissions, energy demand, melting performance, etc.	www.glasstrend.nl
Hyglass – BV Glas and Gas Wärme Insitut Essen (GWI) (Germany)	The project will investigate the addition of increasing percentages of hydrogen to natural gas and the use of pure hydrogen as a fuel. Tests will be carried out on a high-temperature furnace at GWI. In addition, the researchers are investigating the potential of using hydrogen for glass manufacture industry via CFD modelling simulations and production site analyses.	www.in4climate.nrw/en/best-practice/projects/2020/hyglass
VERCANE – ENGIE, Fives, Saverglass and Verescence (France)	The programme will study three carbon-neutral energy options for decarbonising the glass sector: hydrogen, bioresources and process electrification, as well as how to adapt existing furnaces to these energy sources.	www.engie.com/en/decarbonization-glass-industry
SUGAR – EU LIFE Project lead by Stara Glass (Italy)	The project will investigate using waste heat for steam methane reforming of natural gas to produce a hot syngas, which will be used to fuel the furnace. The system will be based on the existing Centauro furnace developed by Stara Glass.	www.lifesugarproject.com