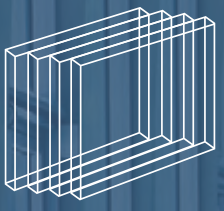
2050 FLAT GLASS IN CLIMATE-NEUTRAL EUROPE

TRIGGERING A VIRTUOUS CYCLE OF DECARBONISATION

GLASS FOR EUROPE



Flat glass

Glass is a high-tech material vital to the energy performance, safety, security and comfort of buildings and cars. In all its numerous applications, glass enables further innovation and improves people's lives and their environment.

GLASS FOR EUROPE

Glass for Europe is the trade association for Europe's flat glass sector.

www.GLASSFOREUROPE.com

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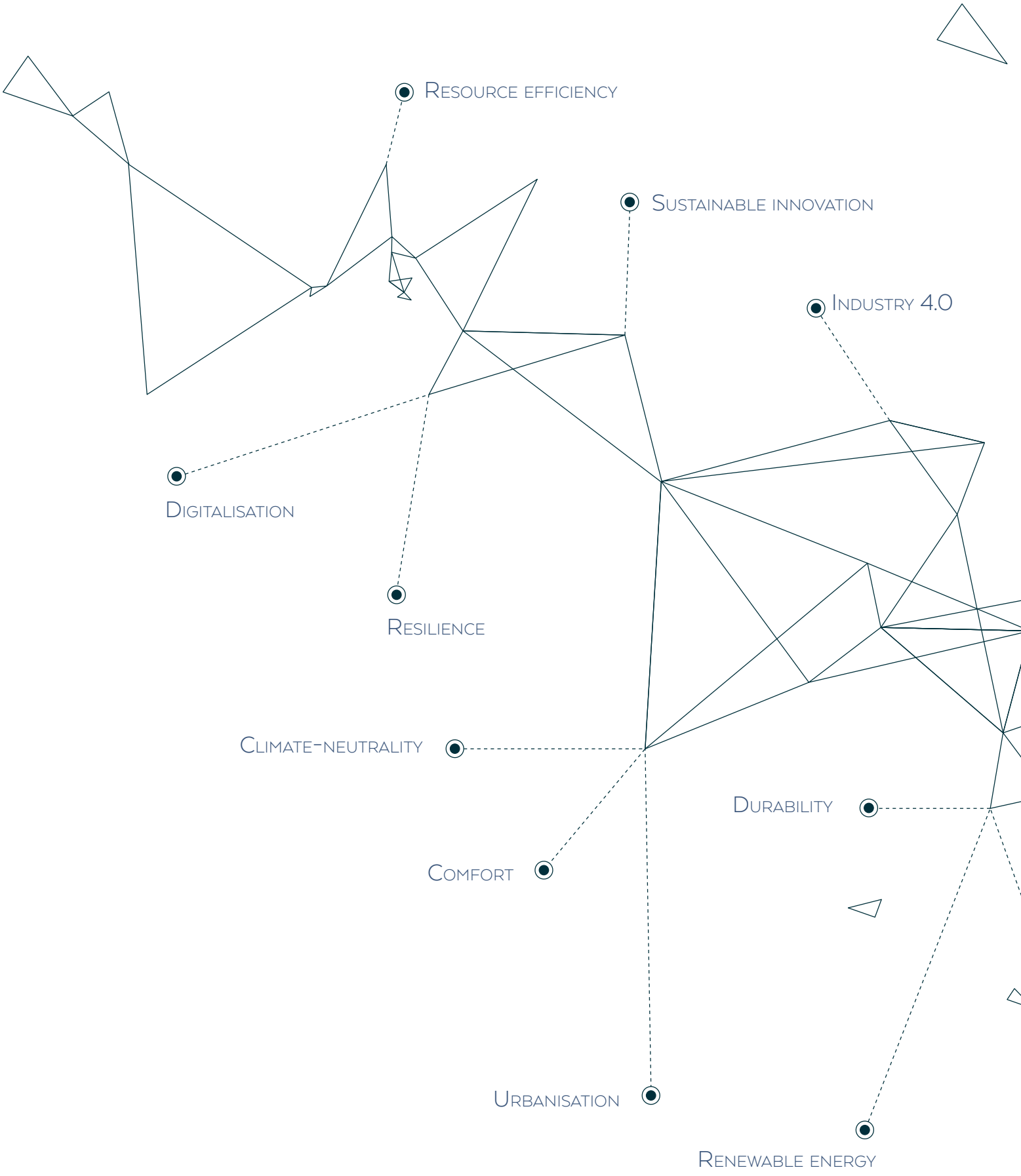

Resource efficiency
Sustainable innovation
Industry 4.0
Digitalisation
Resilience
Climate-neutrality
Durability
Comfort
Urbanisation
Renewable energy

E-MOBILITY

SHARED ECONOMY

CIRCULARITY

FOREWORD

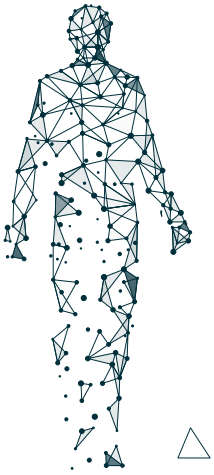
The transition to a carbon neutral EU requires deep energy demand reductions in key sectors of the economy such as buildings and transport, and that the remaining energy consumed is carbon neutral. Such transformations can only be achieved if the conditions are created for all actors and industrial sectors to maximise their multi-faceted contributions to this low-carbon revolution.

The European flat glass sector takes it as its role to produce at a competitive price the materials essential for renovating Europe's buildings, for supporting the clean mobility transition and for increasing the share of renewable solar energy in Europe. While already providing net carbon-avoidance products, the flat glass sector is looking into ways to massively scale up its contributions to the carbon neutral transition, including by developing novel ways to lower its industrial emissions.

The challenges and barriers to overcome are not to be under-estimated and realising the industry's mission of the lowest possible carbon flat glass sector in a climate-neutral Europe will not be an easy task but one the sector has long embraced.

Our industry believes that if Europe successfully triggers a virtuous cycle of decarbonisation, the flat glass sector will be able to maximise its contributions to this unprecedented societal and climate challenge and will strategically contribute to a vibrant climate-neutral Europe.

Bertrand Cazes,
Secretary General of Glass for Europe

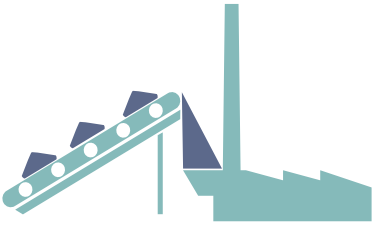


THE EU FLAT GLASS SECTOR

The flat glass sector has strong European roots: from raw materials to production, transformation, installation and end-of-life management, it provides economic activity and jobs across Europe.

Today in Europe, 48 industrial installations subject to the EU ETS located in 12 countries produce 10 million tonnes of glass annually to meet primarily the EU market demand. For instance, over 85% of windows installed in the EU are made with European glass[1].

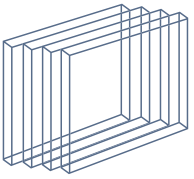
A network of thousands of SMEs produces and installs Insulating Glazing Units (IGUs), automotive glazing and other products, such as solar glass, to enable the transition to a carbon neutral economy.



48 FLAT GLASS MELTING **PLANTS**
16.000 JOBS IN GLASS MANUFACTURING
10 MILLION TONNES OF FLAT GLASS
PRODUCED ANNUALLY

90% OF RAW MATERIALS
COME FROM EUROPE

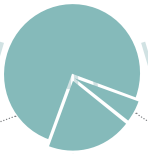
ENDLESSLY RECYCLABLE
MATERIAL

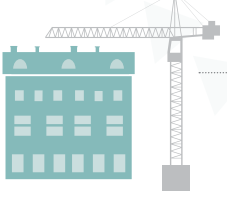


OVER 15 BILLION EUROS
OF ANNUAL TURNOVER

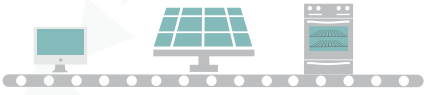
OVER 1.000 COMPANIES
PROCESSING AND TRANSFORMING FLAT GLASS

110.000 JOBS
IN PROCESSING AND TRANSFORMING

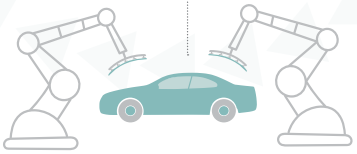




80%
BUILDINGS



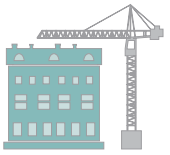
5%
SOLAR AND OTHER APPLICATIONS



15%
AUTOMOTIVE

An irreplaceable material in buildings

Glazed facades and windows provide daylight inside buildings, offer views to the outside to provide comfort and well-being to occupants, and create healthy indoor environments. **No other material provides such transparency, energy-efficiency, safety and durability at an affordable cost** in the construction industry.



ABOVE 675 KM² OF FLAT GLASS IS INSTALLED IN EUROPE'S BUILDINGS[2] EVERY YEAR FOR NEW CONSTRUCTIONS AND WINDOWS' REPLACEMENT.

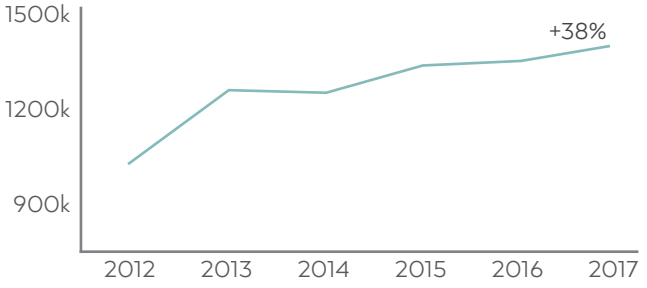
THIS IS THE EQUIVALENT TO NEARLY 100.000 FOOTBALL PITCHES!

A dynamic supplier to the automotive industry

1.3 million tonnes of flat glass is manufactured and transformed into windshields, side windows, sunroofs, backlights and mirrors every year in Europe to supply the automotive sector worldwide.

Over the last five years, this glass segment has experienced a 38% rise in sales[3] to support Europe's car manufacturers demand. **The clean and autonomous mobility will require ever more sophisticated glass** products in the coming decades.

Flat glass sales in the automotive sector

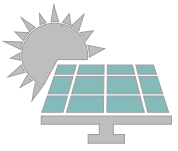


1.3 MILLION TONNES OF EU FLAT GLASS SUPPLY THE AUTOMOTIVE SECTOR WORLDWIDE.

Enabling advances in so many sectors

Flat glass is used in many other applications such as **solar-energy, electronics and digital devices, appliances, furniture,** etc. where it supports different functions and provides new functionalities.

You may be surprised to learn that glass is by weight the first component of photovoltaic modules. Did you realise that it is a glass innovation, the touch screen technology, which made smartphones user-friendly and paved the way for a new era in the digital economy?



GLASS REPRESENTS FROM 65% TO OVER 95% OF THE WEIGHT OF PV MODULES.[4]

UNLEASHING THE **CARBON SAVING POTENTIAL** OF GLASS

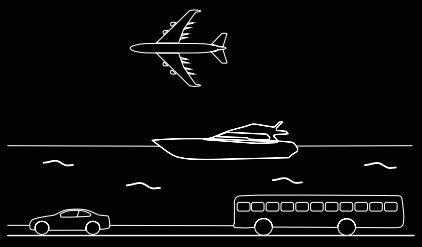
Flat glass products are indispensable to key sectors of the European Union economy (building, automotive and energy). **A climate neutral EU by 2050 will demand more glass** for highly energy efficient windows, light safety glass for clean vehicles and solar energy glass.

Glass in buildings

Installing energy performance glazing when windows are replaced or new buildings constructed is sine qua non in a strategy for a decarbonised building stock.

On average, 48% of the building façade is glass[5] while this can go up to 100% in skyscrapers. Over the last decades, thanks to continuous improvements in thermal insulation performance, combined with new methods of modulating solar heat and light transmission, glazing has strengthened its position as an essential construction material for low energy buildings.

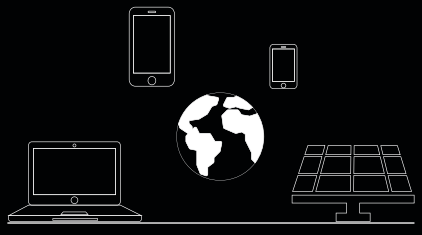
Glass in transport



Glass is an integral part of the vehicle body. Over the last 20 years, the glass area in passenger car has increased by approximately 17%[6] while thinner panes meeting safety requirements decreased the vehicle's weight thus contributing to a reduction of emissions.

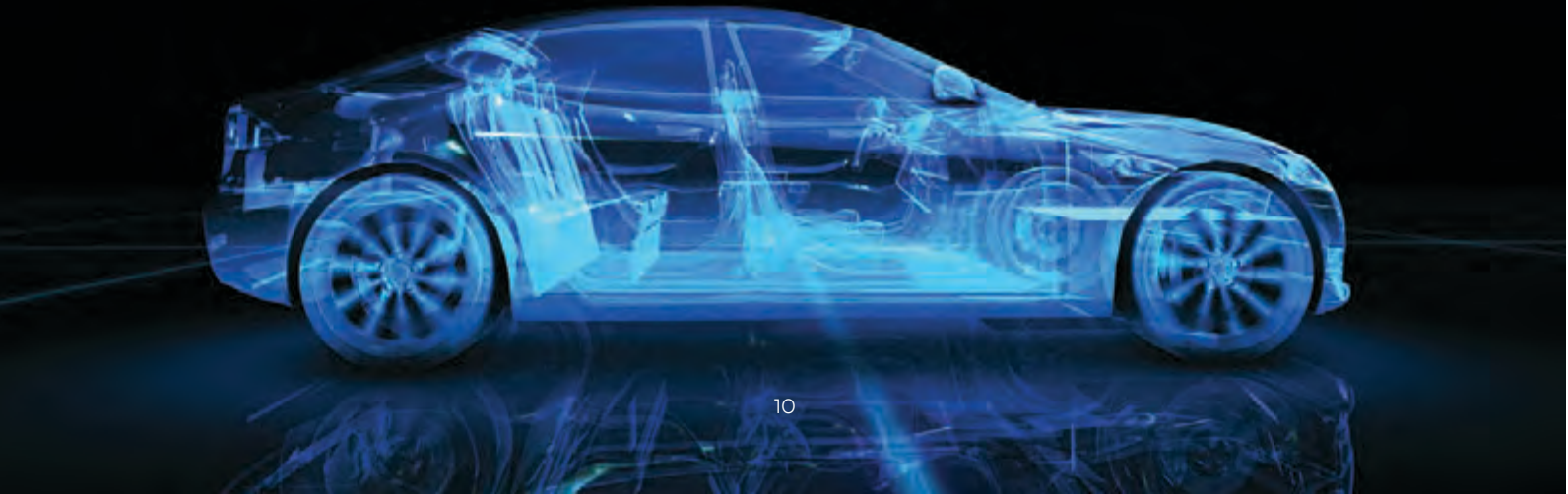
Beyond the contribution to the reduction of vehicles' weight, innovations in the glass industry made possible further savings. For instance, solar control glass minimises the need for air conditioning in vehicles which allows reducing emissions from conventional vehicles and increasing electric vehicles' range. Soon glass roof integrating photovoltaic cells will be an additional flat glass contribution to clean mobility.

Glass everywhere



The contribution of flat glass to the decarbonisation is not limited to energy savings, it is an indispensable material for the production of solar energy as a key component of photovoltaic panels or as a substrate for the integration of transparent photovoltaic cells in buildings (BIPV). The latter is a fast increasing market expected to progress in Europe from €400m (2015) to €1.6bn (2022)[7].

It is also an invisible, yet frontline enabler of the digital transition when equipping smart devices such as smartphones, tablets, laptops, smart mirrors, and other digital displays.



High performance glazing in Europe's buildings

With 36% of total EU emissions[8], buildings are the most CO_2 emitting sector in the European Union. Reducing buildings' energy consumption and related emissions is a necessity to achieve a carbon neutral economy by 2050. The increased performances of windows available on the EU market can contribute to meeting this objective.

Studies show that the EU building stock is aged with dated inefficient glazing, and that a tremendous potential for improvement exists with windows available on the market today. **Up to 37% of the total energy consumption in the EU building stock can be saved in 2050 thanks to high-performance glazing** products[9]. In fact, both energy and GHG savings could be even more substantial if adaptive glazing and glazing integrated photovoltaics were to become mainstream.

-37% CO_2 emissions from buildings[9]

This corresponds to annual CO_2 emission avoidance of up to 68.5 million tonnes in 2050.

Glazing keeps expanding possibilities: technologies for energy positive buildings

Switchable glazing

Due to **its ability to adapt to solar heat and light depending on the weather conditions and comfort needs,** switchable glass allows significant reduction of both heating energy demand in winter and cooling energy demand in summer, corresponding to an increase in performance of over 20%[10]. When integrated into the automated control systems of buildings, these smart glazing solutions provide for a dynamic building envelope adapting to its environment.

Building Integrated PhotoVoltaics (BIPV)

Apart from photovoltaic panels that can be put on roofs, it is now possible **to cover all the opaque parts of buildings with glazing integrating a photovoltaic electricity generation function.** This is called BIPV for "Building Integrated PhotoVoltaics". Thanks to safety glass, different colors, shapes and finishing, BIPV respond to all design needs and support the development of more sustainable buildings.

Transparent PV glazing

Electricity generation does not stop at the opaque fabric. Thanks to advances in double and triple glazing units combined with **transparent photovoltaic cells integration,** building facades and windows will provide unaltered transparency and renewable electricity at the same time. With more sophistication and market take up, the potential for renewable electricity generation will be tremendous thanks to this glazing technology!

Durable, lighter and connected glazing

The European flat glass sector continues to invest to enhance the unique properties of glass and glazing. Future products which are currently under development will contribute to Europe's sustainable future in many novel ways.

*The industry is working on **extending the durability of high-performance insulated glazing units.** While their environmental performances are based on a 30-year service life, the stability of performance over a longer period would contribute to making our buildings more sustainable by reducing the use of raw-materials and energy throughout the building's lifetime.*

*Alongside this evolution, reinforcing glass' strength especially for achieving **thinner and lighter glazing products** is another priority area for product development. Thinner, lighter and stronger glazing already play a vital role in decarbonising transport and is equally relevant for decarbonising buildings. In addition to reduced raw materials input, it will ease products' installation and reduce glass transportation's carbon load.*

***Glazing enabling 5G transmission** and including transparent antennas will pave the way for a connected urban environment and automated mobility. These new technologies will be an invisible contributor to the deployment of new digital applications to make objects more intelligent and add digital layers in the transport sector for a reduction of road fatalities, emissions and road congestion.*

BOOSTING **BUILDING RENOVATION** TO DELIVER **ENERGY SAVINGS** AND **ECONOMIC GROWTH**

Doubling the windows' renovation rate over 10 years with the installation of high performance glazing will reduce by 14% the projected energy consumption and related emissions of the building stock in 2030[11]. It is urgent to ensure that high efficiency products are installed as of now to ensure long lasting savings. Windows stay on buildings for 40 to 50 years on average[12].

An increase in the buildings' renovation rate will have a direct impact on the number of windows to be produced to meet the market demand. It represents an economic opportunity as well as a challenge for the EU industry to meet local demand with low-carbon EU-made products.

AVERAGE INSULATION PERFORMANCE OF WINDOWS IN EU BUILDINGS?

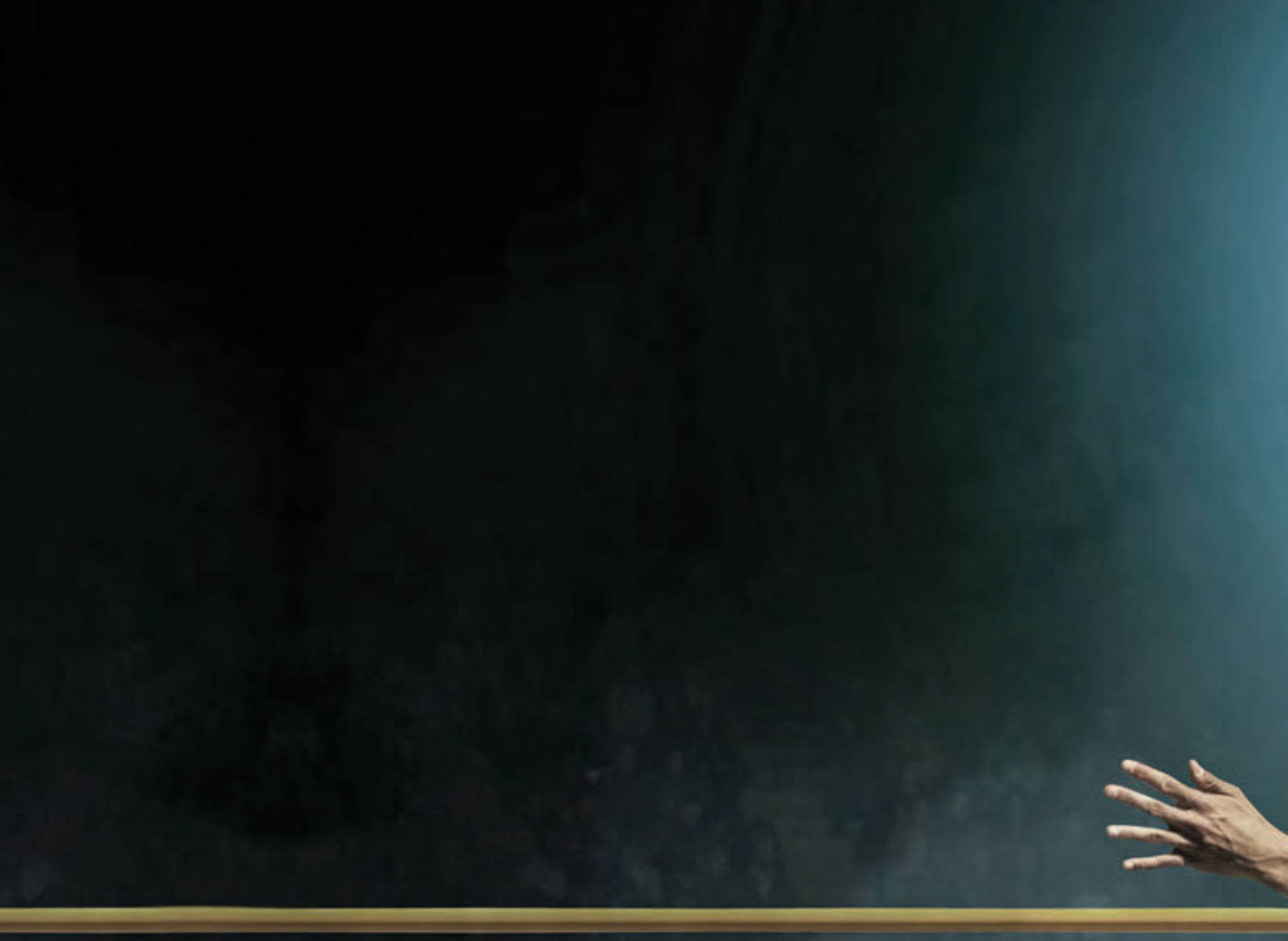
U_W 3.4[13]

EQUIVALENT TO LATE **1960**'S WINDOWS.

THE CO_2 EMITTED TO PRODUCE AN ENERGY EFFICIENT DOUBLE GLAZING IS OFFSET WITHIN 6 TO 20 MONTHS BY ITS ENERGY SAVINGS[14].

In new constructions, high energy performance windows are most often chosen by professionals when designing buildings to meet the nearly zero energy building (nZEB) requirements. By contrast, the uptake of high performance products is low in the renovation segment in the absence of requirements compatible with a decarbonised building stock objective. Given the fact that 97% of today's buildings will still be standing in 2050[13], and most will have their windows replaced, it is essential to correct this situation as of today.

The average insulation performance of windows in the EU building stock is estimated to be Uw 3.4 [W/(m2K)][13]. This value is equivalent to a mix of single glazing and uncoated double-glazing unit (two mainstream products respectively in the 1960's and 1970's). **Products available today exhibit incomparably better performance,** which makes possible zero energy or energy positive buildings.



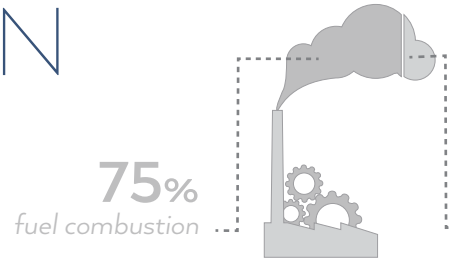
Pushing further the boundaries of low-carbon manufacturing

The EU flat glass sector has reduced by 43% its CO_2 emissions per output between 1990 and today[15]. Yet **flat glass manufacturing must rise above today's technology frontiers** on the journey to 2050.

HIGH-EFFICIENCY FLAT GLASS PRODUCTION

Flat glass manufacturing is one of the highest temperature industrial processes, yet it represents only 0.65% of EU's industrial CO_2 emissions[16]. Both sand and recycled glass need to be heated up to 1600°C to form a ribbon of molten glass. Such a high temperature is necessary to minimize defects, which could alter light transmission and transparency, that are essential properties, as well as customer and safety requirements for building, automotive and solar energy glass.

75% of CO_2 emissions from flat glass manufacturing derive from the use of natural gas to heat the melting furnace. The remaining 25% of emissions come from the release of CO_2 from raw materials carbonates. These 'process emissions' can hardly be reduced without reducing virgin raw materials input.



A HIGH TEMPERATURE INDUSTRIAL PROCESS **0.65% OF TOTAL EU INDUSTRIAL EMISSIONS** AND **0.13% OF TOTAL EU EMISSIONS**[16]

The use of 'cullet', i.e. recycled glass, as raw material is also critical for the industry. Because it requires less energy to melt, it contributes to reducing energy consumption and 'heat-related CO_2 emissions'. It also helps reduce 'process emissions' as cullet saves 1.2 times the same amount of raw materials[17]. Today, 26% of the raw materials' input that goes into European flat glass furnaces is cullet[22].

26%
OF RECYCLED GLASS IN RAW MATERIALS[22]

1600°C
FURNACE TEMPERATURE FOR FLAT GLASS MELTING

Europe leading the way in low-carbon production

The European industry has an impressive track record in reducing emissions and energy consumption. It is all the more remarkable when considering the performance of other installations worldwide.

Compared to China, world leader in flat glass manufacturing with over 50% of the world's installations, EU installations emit far less CO_2 with a reduced energy consumption. In equivalent size and when using the same amount of cullet, a Chinese float plant emits on average 90% more CO_2[18] and consumes 32% more energy[19] for the same production.

+90%
CO_2 PER TONNE OF FLAT GLASS[18]

+32%
ENERGY PER TONNE OF FLAT GLASS[19]

650 *TONNES A DAY OF GLASS PRODUCED PER FLOAT LINE ON AVERAGE*

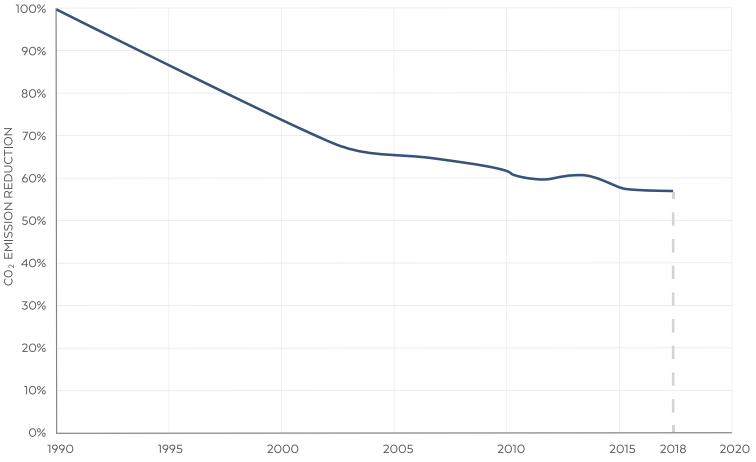
16 *TO* **20** *YEARS LIFESPAN OF A FURNACE*

Excellent track record in decreasing emissions

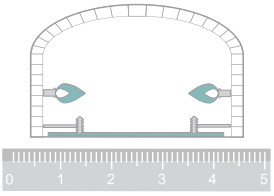
Despite a reduction in performance of individual installations over time due to normal wear of the furnace (est. +1% CO_2 increase annually), the EU flat glass industry succeeded in reducing by over 40% its CO_2 emissions per tonne of glass between 1990 and today[15].

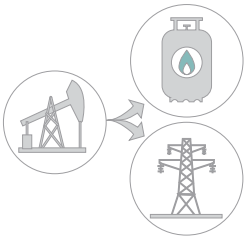
-43%
CO_2 IN 25 YEARS PER TONNE OF FLAT GLASS[15]

Average CO_2 emissions per tonne of float glass produced in the EU



TO MAKE THIS POSSIBLE, THE SECTOR WORKED ON CONTINUOUS IMPROVEMENTS IN ALL ITS EU ETS INSTALLATIONS. THREE COMPLEMENTARY ROUTES WERE PURSUED:





1 FURNACE DESIGN, CONSTRUCTION AND OPERATIONS

The float glass process invented in the 1950's has been constantly improved over the decades thanks to advanced furnace engineering, use of innovative materials and digitalisation of the sector. Experts estimate that between 1990 and today, innovations in this field coupled with an increase in capacity have made possible up to 25% CO_2 savings[20].

2 RAW MATERIALS AND USE OF RECYCLED GLASS

The share of recycled glass (i.e. cullet) used as raw material has increased over the last decade thanks to collection schemes set in place by the industry with transformers and recyclers. Moving from 20 to 26% of cullet has made possible a further reduction of 6% of CO_2 emissions[20].

3 EVOLUTIONS IN THE ENERGY MIX

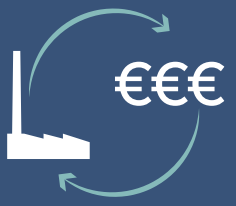
In the early 90's, some of the EU installations were running totally or partially on fuel oil. Despite an increase in the energy consumption resulting from a switch to natural gas, **the industry phased out fuel oil-fired plants.** This decision, coupled with electric boosting and raw material preheating, have made possible CO_2 savings up to 30% in installations previously running on fuel oil only[20].

A MAJOR CHALLENGE FOR THE FUTURE

Thanks to continuous improvements, the flat glass sector has been able to reduce its emissions per tonne of melted glass by 43% since 1990. **Experts consider that improvements to the float process are likely to improve efficiency marginally,** while being technology-intensive.

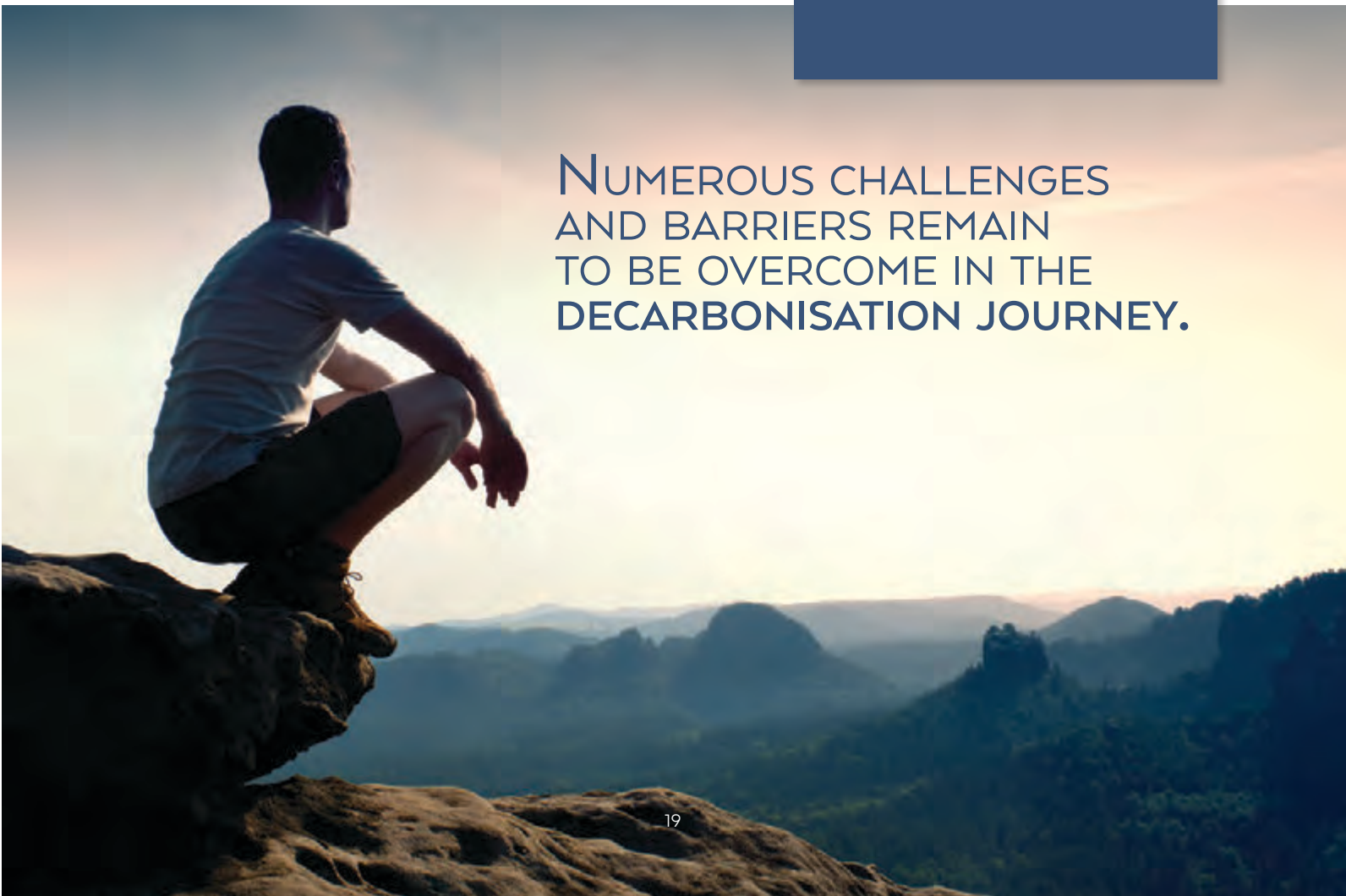
The continuous implementation of Best Available Technologies (BATs) and future incremental improvements would only contribute to 7 points additional emission reduction per tonne of flat glass produced.

To go beyond this 7 points savings, **major evolutions will be needed in infrastructures, science and society.**



Flat glass production is a capital-intensive and high-volume process. Float glass plants are the largest of all glass industries precisely to minimize energy needs and costs. It is also a continuous process operating 24/7 for uninterrupted periods of 16 to 20 years. During this period, only limited upgrades to plants can be realised so as to keep furnaces hot and to minimize energy waste.

THE 2050 HORIZON FOR DECARBONISATION IS **1 TO 2 INVESTMENT CYCLES AWAY** IN FLAT GLASS MAKING.



NUMEROUS CHALLENGES AND BARRIERS REMAIN TO BE OVERCOME IN THE **DECARBONISATION JOURNEY.**

BEYOND STATE-OF-

MAJOR **TRANSFORMATIONS**

Major transformations in manufacturing process, infrastructure, feedstock, science, technology and society will be needed to cut CO_2 emissions in much larger scale.

-75%
CO_2 EMISSIONS*

ENERGY SWITCH

Provided technological breaktrough for high temperature and capacity furnaces, and availability of carbon neutral energy to power alone the furnaces.

B

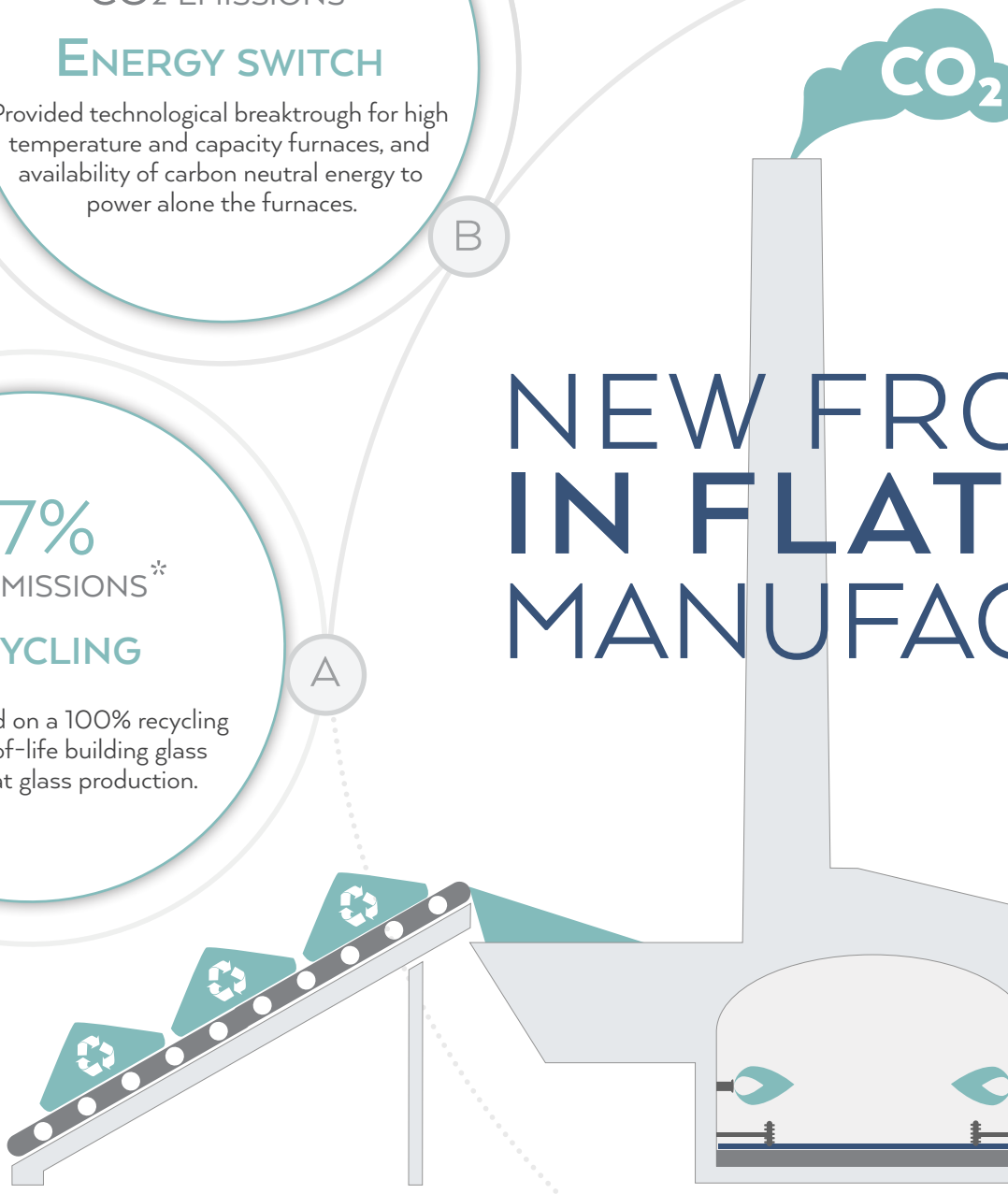
-7%
CO_2 EMISSIONS*

RECYCLING

Estimate based on a 100% recycling rate of end-of-life building glass reused in flat glass production.

A

NEW FRO
IN FLAT
MANUFAC



ART TECHNOLOGIES

THREE **ROUTES**

Three disruptive routes are identified with their respective maximum theoretical potential for CO_2 reduction, independently of today's technological and economic barriers.

PUSHING **BOUNDARIES**

Boundaries will need to be pushed for these new frontiers in flat glass manufacturing to be reached.

-85%

CO_2 EMISSIONS*

CCU/CCS

Conditioned by the availability of an extensive CCS/CCU transport and storage network, and technologies.

C

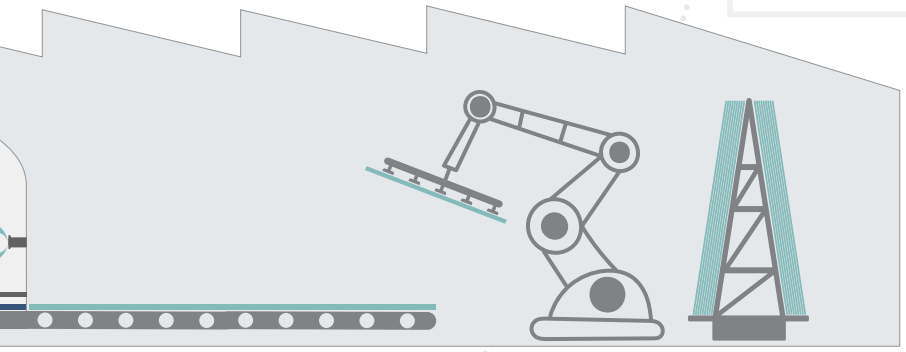
ONTIERS
GLASS
CTURING

-7%

CO_2 EMISSIONS

INCREMENTAL IMPROVEMENTS

Estimate based on evolution in flat glass melting technology and uptake of BATs in the sector over the last decades.



** Maximum potential reduction compared to 2018. Potentials cannot be added as some options are mutually exclusive.*

ROUTE A

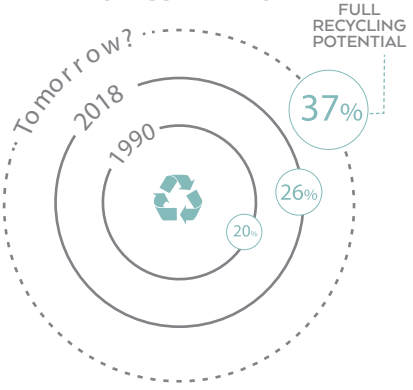
CLOSING THE RECYCLING LOOP

The flat glass' quality requirements for recycled glass is unique in the glass industry. The safety and performance requirements for the final product (e.g. optical safety test for automotive glass) permits only the use of recycled glass of the highest quality; i.e. clean flat glass. **The use of recycled flat glass, or "cullet", in the batch presents two major benefits for the industry:**

1. It reduces the energy needed for melting the raw materials (i.e. 2 to 3% reduction of energy consumption per 10% cullet in the batch)[21];
2. It reduces the CO_2 emissions, and in particular the process emissions which cannot be reduced by an energy switch to carbon neutral energy.

Closing the recycling loop is therefore considered as environmental, economic and societal sound business by the industry.

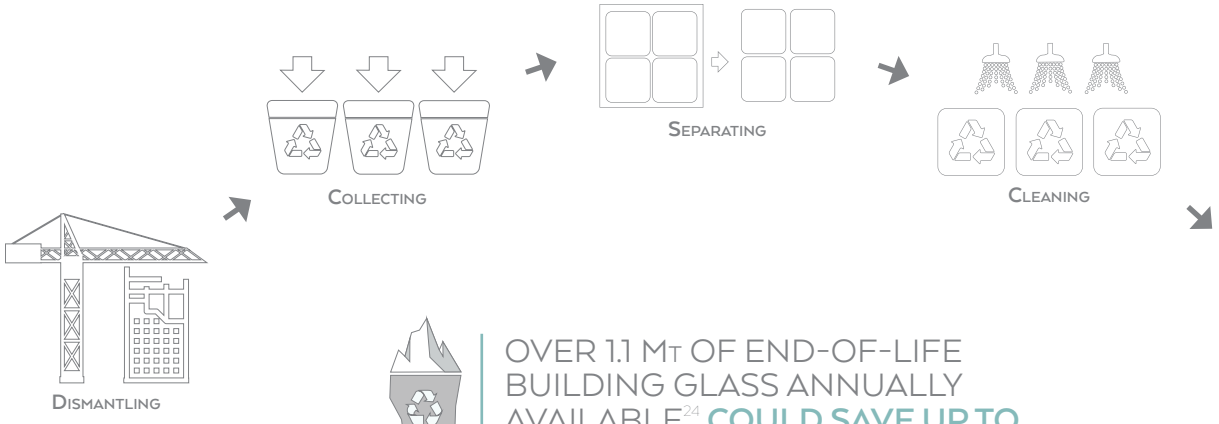
RECYCLED GLASS IN FLAT GLASS MAKING



Over the last decades, the industry's zero-waste policy and actions made possible **an increase in the share of cullet in the batch from 20% to 26%[22].** While the industry recycling loop has been closed, additional potentials exist down the value-chain: where the glass is cut to size and when windows are replaced. The estimated maximum potential - based on maximum quantities of end-of-life building glass not yet recycled - **would increase cullet use by 40%[23]. This translates in a batch made of 37% cullet for an additional reduction of 7% CO_2 emission.**

It is worth noting that this estimate is an absolute maximum, which ignores a number of barriers (technical, economical and in waste infrastructures) and emissions from transport, which could in some cases outweigh the emissions savings in manufacturing.

INCREASING RECYCLED GLASS USE COULD DELIVER A MAXIMUM 7% CUT IN CO_2 EMISSIONS BUT **WASTE GLASS COLLECTION** REMAINS A MAJOR OBSTACLE.



OVER 1.1 MT OF END-OF-LIFE BUILDING GLASS ANNUALLY AVAILABLE[24] **COULD SAVE UP TO 1.32 MT OF RAW MATERIALS.**

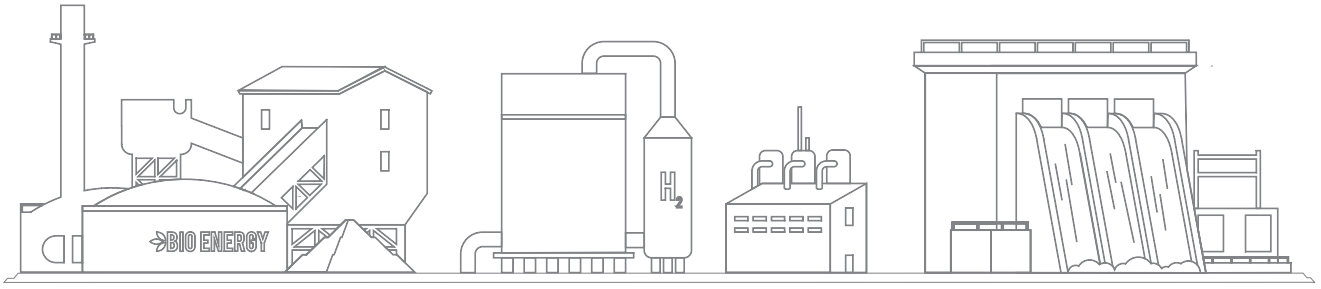
ROUTE B

SWITCHING TO CARBON NEUTRAL ENERGY

Today, 75% of flat glass furnaces emissions are resulting from the use of fossil fuel to melt raw materials. A switch to a carbon neutral source of energy alone presents an important reduction potential. Before it materializes, **the technology adapted to this new feedstock will need to be found and tested**, while **alternative energy sources need to be available in sufficient quality and quantity at an economic viable cost.**

Today, **3 new fuels** are considered, but none of them meet the above conditions:

DEALING WITH **TECHNOLOGICAL CONSTRAINTS** AND **AVAILABILITY OF FEEDSTOCK** IS REQUIRED FOR AN ENERGY SWITCH



1 BIO-GAS

A switch to bio-gas is technically possible, particularly with biomethane of similar quality to natural gas. However, leaving aside the cost, quality requirement and distribution challenges, this potential is directly limited by the quantities available. An average float plant of 650 tonne a day has energy needs slightly above 1.4 million GJ. It results from the above that, even if the current annual production of biomethane, i.e. 19352 GWh equivalent to 70 million GJ[25], was to be entirely directed toward the flat glass sector's plants, this would be insufficient to meet the energy needs of today's 52 EU-based float lines.

2 HYDROGEN

Hydrogen could also be considered. However, injecting more than 20% of hydrogen in the gas grid would require research to adapt the furnace technology. Hydrogen has a high combustion velocity and a non-luminous flame which makes it difficult to monitor. While heat transfer contributes to the efficiency of flat glass making, hydrogen flames provide relatively low radiation heat tranfer. In addition, handling and storing hydrogen on site present difficulties due to its explosive properties[26].

3 ELECTRICITY

Provided carbon-neutral electricity is available, major breakthrough in technologies would be needed to make possible full electric melting in flat glass furnaces. Electric melting is not yet compatible with high temperature glass furnaces with a production above 200 tonnes a day (i.e. 3 times below an average float glass plant). An additional technical challenge to electric melting is that it is not suitable for high cullet ratios as it is difficult to keep down the superstructure temperatures. Therefore, savings from a switch to carbon neutral electricity could partly be reduced by an increase in process emissions.

ALL OF EUROPE'S PRODUCTION OF BIOMETHANE **INSUFFICIENT TO POWER EU'S FLAT GLASS PLANTS.**

ROUTE C

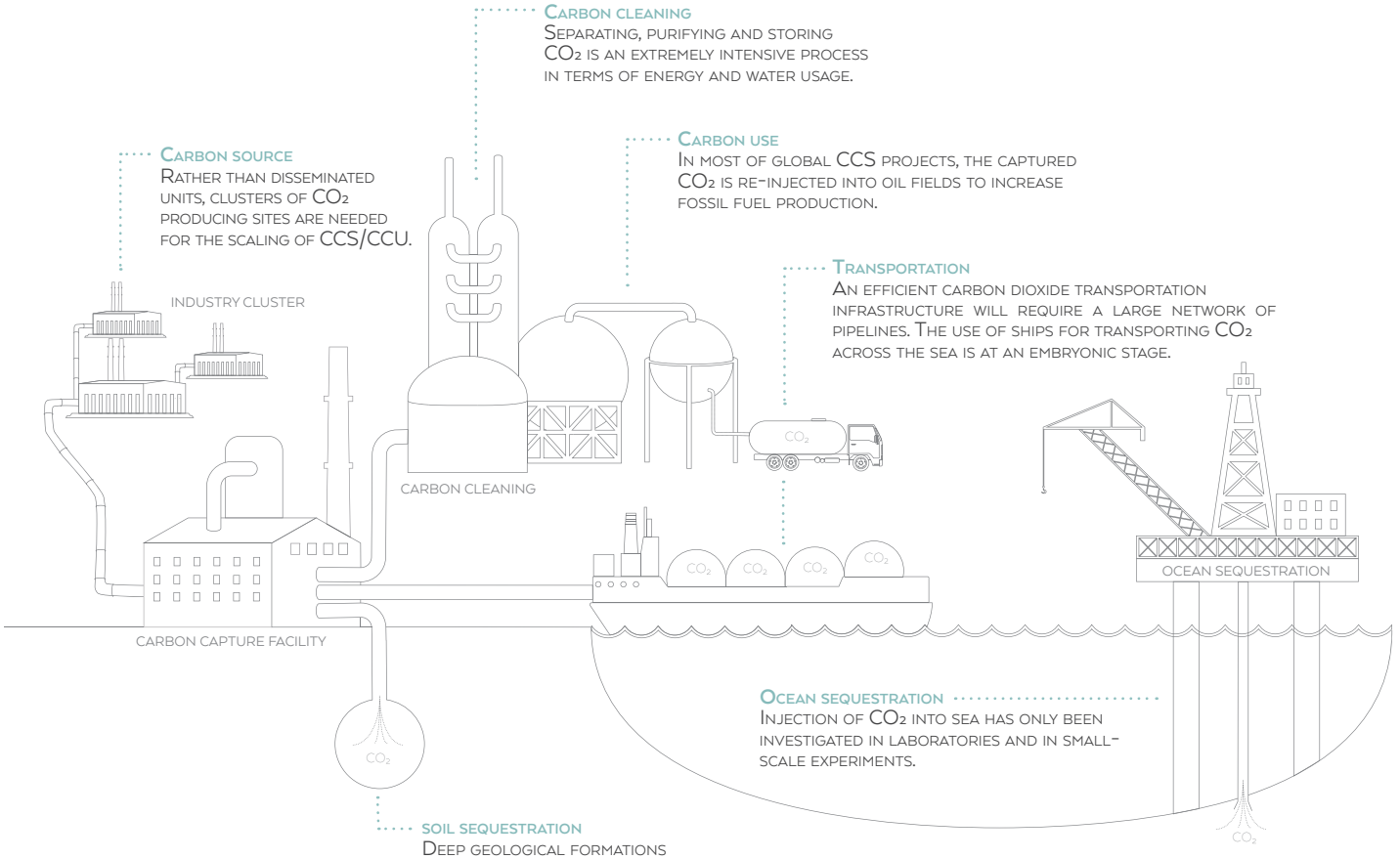
Carbon capture
UTILISATION AND STORAGE

Carbon capture is interesting to consider for addressing the process emissions (25% of today's emissions) in glass manufacturing which cannot be avoided by an energy switch. Nevertheless, **a number of barriers remain to be overcome to consider carbon capture as an option.** Carbon capture would require creating extensive transport and storage infrastructures to be a large-scale solution by 2050.

Taking into account that the industry is characterised by disseminated units mostly located in brownfields, the CCS/CCU options are also limited by technical constraints (space limitation, presence of acidic compounds, low CO_2 concentration), the limited market demand for carbon and societal acceptance.

LARGE SCALE DEVELOPMENT OF **CCS** AND **CCU** REMAIN **UNCERTAIN** IN FLAT GLASS SECTOR.

BENEATH TECHNICAL DIFFICULTIES, **THE COST OF TECHNOLOGIES AND SOCIETAL ACCEPTANCE** REMAIN KEY BARRIERS.



An industry already on the move

Below are **a few examples only of the many projects undertaken by float glass manufacturers** around Europe in order to reduce further CO_2 emissions across the value chain. Be it in terms of deployment of novel technologies, improved logistics or in enhanced recycling, all companies are active on all fronts. When it comes to more exploratory research fields, the high commercial and technical sensitivity of projects prevent us from displaying them, but the work is on-going to push further the boundaries of low-carbon manufacturing.

AGC · Guardian Glass · NSG Group · Saint-Gobain

HotoxyGlass furnace technology

A demonstration project supported by the EU LIFE Programme

With the support the EU Life programme, a research and industrial-size demonstration project was set up on the use of pre-heated oxygen, instead of air, mixed with natural gas for powering float glass furnaces. Both oxygen and gas are pre-heated thanks to the recovered energy from waste gases. Furnace melting energy can be reduced by 19.7% and CO_2 emissions by 5.5% while accounting CO_2 emitted by oxygen production. It also offers other environmental benefits such as decreased NOx, SOx and dust emissions, as observed at the equipped facility in Northern France.

Glass Futures

A new Centre of Excellence for Glass in R&D & Innovation

Float glass manufacturers are partners in the industry cluster for glass R&D and innovation, called *Glass Futures*, alongside several companies of other glass sectors and academic partners. Thanks to a flexible and multi-fuelled demonstration-scale glass making facility based in the United Kingdom, *Glass Futures* will help ensure that advances in fundamental research successfully convert to innovation after testing at industrial level. Sustainability and low-carbon production are essential fields of research and testing in this cluster for float glass manufacturers.

Electricity Generation and Logistics

All float glass manufacturers are investing in green electricity generation, making use of both facilities for the installation of photovoltaic panels and of the manufacturing process itself thanks to Organic Rankine Cycle technologies (ORC). With ORC technology, waste heat is recovered and used to make compressed air and generate electricity that can be directly reused in glass manufacturing.

Cooperation in the value-chain is also being explored to improve flat glass transport and reversed logistics in order to optimise and to reduce flat glass truck operations, road traffic and its CO_2 impact.

Closing the Recycling Loop

Organising the collection and dismantling of old windows in France

In France, an initiative involving a construction materials retailer, a waste management firm and a flat glass manufacturer was launched. It aims to collect old windows that have been replaced and to sort and separate the different frame materials before glass is returned to float glass plants. With this initiative taking up on speed and volume, it supports the realisation of the 'Green Growth Deal' signed between the glass and window industries and the French Ministry for Environment aiming at tapping into the recycling potential of the 250.000 tonnes of old windows disposed every year in France.

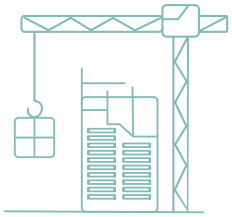
ACTIVATING DECARBONISATION LEVERS

The flat glass sector is indispensable to the massive decarbonisation of the building, transport and energy sectors, which represent the lion's share of Europe's CO_2 emissions. To contribute to the fullest to a climate-neutral Europe, the industry is also working hard to overcome the numerous technical and economic obstacles on the way to a further reduction of the 0.13% of Europe's total emissions generated by its own manufacturing facilities[16].

In today's climate urgency context, the flat glass sector wants to offer its vision of **a rapidly actionable virtuous decarbonisation cycle,** fit for the climate, the transition journey and one of Europe's decarbonisation-enabling industries.

THE VIRTUOUS DECARBONISATION CYCLE

To kick start the virtuous decarbonisation cycle, **concentrating emission reduction efforts on those sectors where solutions already exist** for a massive decarbonisation, like buildings, transport and energy, is an imperative. As new business opportunities are generated, **decarbonisation-enabling industries will need space to grow** to respond to product demand so long as the manufacturing process is not yet largely decarbonised. This is what will generate most rapid CO_2 emission reductions, economic activity and will further unlock investments in the research, pilot-testing and ultimately roll-out of novel clean manufacturing technologies.



Mainstream carbon avoiding products

While the **net carbon avoiding flat glass products are readily available**, market forces alone do not necessarily ensure their uptake in a scale compatible with the climate objectives. The starting point of a virtuous decarbonisation cycle needs to make carbon-avoiding products mainstream, particulary in those sectors with high decarbonisation potential.

To meet the carbon neutrality objective of the EU, 97% of the building stock needs to be renovated by 2050, which entails at the very least **to double the building and window renovation rates**[13]. Immediate scaling up is needed to meet these targets.

Mainstreaming carbon-avoiding products and solutions will also create business opportunities. For instance, it is estimated that a doubling of glazing renovation rate in Europe **would trigger an increase in market demand for flat glass products of at least 66%**[27].

To seek long-term climate impacts, markets are powerful tools, but they need to be shaped to deliver climate neutrality.

DECARBONISING BUILDINGS COULD TRIGGER AN INCREASE IN FLAT GLASS DEMAND OF AT LEAST 66%[27].

4483 Million tonnes CO_2 equivalents[16]

Total EU Greenhouse Gas Emissions in 2017

Flat glass manufacturing represents 0.13% of total EU emissions[16].

helps decarbonising the largest emitting sectors:

Buildings

Transport

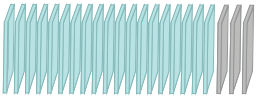
Energy

Nurture the EU industry's competitiveness

The transition to a carbon neutral economy can be an engine of industrial growth for those sectors, like flat glass, which produce the key materials enabling a climate-neutral Europe. Growth, jobs, investments and innovations could flow in the entire value-chain provided the competitiveness of Europe's based industry is nurtured.

Although it faces higher regulatory and energy costs than competitors, **Europe's flat glass manufacturing industry supplies over 85% of the EU demand for building glass**[1]. This strong position needs to be preserved during the journey towards low-carbon manufacturing, which will entail major investments and higher production costs.

Designing adequate competitiveness mitigation tools will be critical to the success of the transition towards a climate-neutral Europe. It is about **making sure this transition profits Europe's industries** and does not lead to importing more glazing products with higher carbon footprint. Most importantly **in the case of hardly substitutable products, like flat glass, it is essential to ensure products' affordability** to consumers to help avoid even more CO_2.



85% OF THE EU DEMAND FOR BUILDING GLASS SUPPLIED TODAY BY EU INDUSTRY.[1]

Global competition in the flat glass sector

***432** float lines **worldwide**[28]*
***243** in **China** alone*

***Russia** has twice **lower production cost** than the EU*[29]

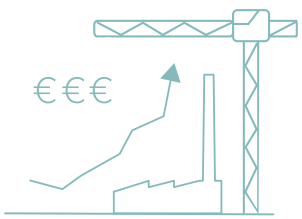
***+90% of imports** in the EU between 2012 and 2017*[30]

***+35% float capacity increase** in surrounding countries*[28]

Over the last five years, a substantial increase in imports of flat glass from outside the European Union can be observed. This is the consequence of a large increase in production capacity at the EU borders, targeting the EU market. The pressure from external competition is likely to continue increasing in the coming years, while over-capacity of production in China needs careful monitoring.

Europe remains a major exporter of high added value / specialised flat glass products. The pressure from external competition is likely to remain high on both domestic and export markets, hence the importance of safeguarding the industry's competitiveness all along its decarbonisation journey.

The risk is otherwise high that Europe keeps importing more products and carbon.

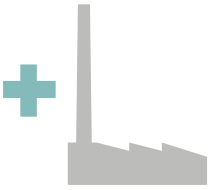


ATTRACT INDUSTRIAL INVESTMENTS

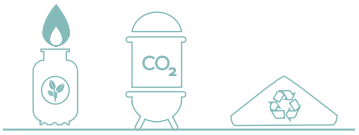
The estimated increase in demand for low-carbon flat glass products, combined with a competitive manufacturing environment could unleash major investments in the flat glass industry.

To meet the 66% increase in building glass demand with EU production, **the production capacity in the EU would need to increase from today's 52 float lines to over 85[31].** The industrial and climate policy must allow for these industrial investements to materialize to avoid massive imports of high carbon content products. **These investments could amount to several billion Euros** in industrial investments at the cost of today's state-of-the-art manufacturing technologies.

Investments by industry would need to flow at even higher levels considering that novel low-carbon manufacturing techniques will entail higher costs and risks. At the same time, old assets will have to be depreciated.



INCREASING TODAY'S 52 FLOAT LINES TO OVER 85[31] WILL ENTAIL BILLIONS OF EUROS OF INVESTMENT.



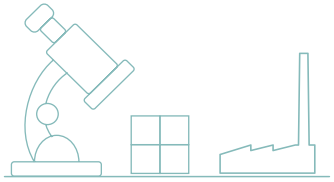
Develop **sustainable** infrastructures

For industrial investments to cross the existing frontiers in low CO_2 flat glass manufacturing, it will be essential that **major investments in infrastructures have already been realised across Europe.** Timing will be key since all the technological routes imaginable today require that infrastructures are first available before investments can be envisaged.

These infrastructures needs include:

1. **Waste management facilities** to collect and recycle end-of-life building glass.
2. **The availability of biogas** of sufficient quality and quantity for the sector to embrace this alternative source.
3. T**he guaranteed supply of carbon-free electricity,** independently of peak consumption time, thanks to a versatile network and storage facilities.
4. Carbon capture transport networks and storage facilities.

SHORT DISTANCES BETWEEN RECYCLING FACILITIES AND RENOVATED BUILDINGS IMPROVE OVERALL CO_2 BALANCE AND REDUCE COSTS.[32]



REWARD INNOVATIONS IN CLEAN TECHNOLOGIES AND PRODUCTS

A virtuous cycle of decarbonisation will provide industrial actors the means and confidence to invest even more in research and development of net zero carbon solutions.

The European flat glass industry has been investing massively in both product and process innovations for years. Its main players are all committed to continue improving even further the already net carbon saving balance of their products. **R&D efforts need to be stimulated and better supported in Europe.** This is particularly true, for example, for research in low-carbon technologies for flat glass melting. Considering the high temperature, the existence of process emissions and the size of melting furnaces, the sector faces one of the toughest decarbonisation challenges.

Technological breakthrough needs to be realised rapidly for successful pilots to be launched before a roll-out across Europe's plants can be envisaged.

Stimulating and rewarding innovation is the bread and butter of the virtuous decarbonisation cycle.

HUNDREDS OF MILLION EUROS INVESTED ANNUALLY IN R&D BY THE FLAT GLASS SECTOR.

TOWARDS NET ZERO EMBODIED CARBON BUILDINGS

Net zero embodied carbon buildings will be the accomplishment of the decarbonisation journey once the manufacturing of all building materials and construction itself are decarbonised.

According to the World Green Building Council's definition[33], a net zero embodied carbon building must have very minimal operational carbon, i.e. the carbon emitted to run the building during its lifetime. All the more, the upfront carbon cost meant to construct the building and manufacture its components, including glazing, as well as carbon emitted at the end of life, must be contained to achieve net zero throughout the life cycle..

Carbon saving cannot wait any longer and, ***already today, the upgrade and replacement of glazing is a net carbon saving measure.***

POLICY RECOMMENDATIONS

The European Union is about to take a far-sighted decision with a climate neutral objective by 2050 enshrined in law. It stands clear that this decision will **require an unprecedented collective effort from citizens to businesses and call for a rethink and adaption of the EU legislative framework**.

As representative of the European flat glass sector vis-à-vis the European institutions, Glass for Europe wishes to contribute to the reflection on how to shape the EU legislative framework to put Europe on the 30 years journey to carbon neutrality. **These recommendations are meant to trigger the virtuous cycle of decarbonisation** and to make the EU transition an economic, social and environmental success.

A EUROPEAN GREEN DEAL

Industrial Strategy

Develop an industrial strategy supporting the transition to a carbon neutral EU.

Take into account in the future industrial strategy and in all relevant climate-related policies the value chains that are strategic to enable the decarbonisation of the EU.

For the decarbonisation-enabling materials that are non-substitutable, such as flat glass, give room for growth in Europe to respond to production needs, so long as their manufacturing process is not yet largely decarbonised.

To address the remaining structural obstacles to the massive decarbonisation of the industrial processes limited in their mitigation potential by existing technologies and today's scientific knowledge.

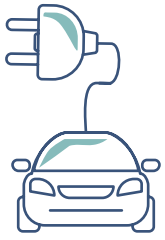
Design adequate competitiveness mitigation tools to ensure EU made products' affordability to consumer.

Energy Positive Building Stock

Prioritise the reduction of energy demand in the EU building stock with an unprecedented renovation campaign whose legally binding objective shall be to renovate 97% of the building stock by 2050.

Use the carbon neutrality objective as reference for a revision of the Energy Performance of Buildings Directive in 2021 to upgrade the minimum performance requirements of building components in all Member States.

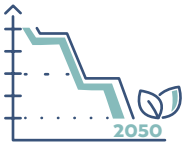
Continue promoting the installation of renewables in buildings with the objective of making new buildings and buildings deeply renovated energy positive.



Sustainable Transport

Update the automotive test cycle (WLTP) to reflect the real energy consumption and emissions of vehicles, and therefore incentivise the uptake of available technologies from automotive suppliers, e.g. heat reflective glass to minimize the use of air-conditioning.

Define pathways for the reduction of vehicles' weights to drastically reduce consumption and CO_2 emissions from conventional vehicles and support the development of light-weight components for electric cars.



Achieving Climate Neutrality

Make use of EU diplomacy in international organisations and trade negotiations to bring EU partners to adopt equivalent measures to tackle climate change.

As long as non-EU industrial competitors produce goods with higher CO_2 footprint without being subject to equivalent carbon pricing, ensure the competitiveness and attractiveness of low-carbon EU made products.

Ensure a proper functioning of the EU ETS scheme, including by granting EU industrial actors subject to risks of carbon leakage adequate levels of free allocations, and assess the possible formats, benefits and risks of carbon border adjustment mechanisms over the medium / longer term.

Include the carbon avoidance of product "in use" within the Life Cycle Assessment (LCA) of materials and products to reflect their effective contribution to decarbonisation.

Transition to a Circular Economy

Remove administrative barriers to the recycling of materials in the value-chain, e.g. effective recognition of flat glass off-cuts as by-products and facilitate the transport of recyclable flat glass within the EU.

Promote the circularity of construction and demolition waste by introducing individual targets for specific recyclable material, like building glass, and do not limit the EU objective, as is the case today, to a percentage of the total building weight.

Introduce in legislation obligations for pre-demolition audits for large buildings, grant free access to container parks to dispose recyclable construction materials, and support the development of collection and sorting schemes for post-consumer building glass products.

Clean, Reliable and Affordable Energy

Moderate energy demand and incentivise on-site renewables in the building sector thanks to an unprecedented renovation campaign.

Develop a strategy for the production, storage and distribution of biogas, hydrogen and carbon-neutral electricity to ensure a reliable and cost-efficient supply to industry.

Provide for compensation of indirect costs under the EU ETS to the flat glass manufacturing industry.

Financing the Transition

Prioritise support to the renovation of the EU building stock in EU financial mechanisms.

Co-finance Research and Development in manufacturing breakthrough technologies: Electrification of large-size furnaces with melting temperature above 1000°C; Fundamental research in materials and process emissions, which cannot be reduced by energy-efficiency measures or a switch to a carbon neutral energy source.

Invest in the sustainable infrastructures required for the transition and in particular for the production of carbon-neutral energy and storage, waste management and recycling facilities, and the creation of CCS/CCU transport and storage network.

TO DELIVER A CLIMATE-NEUTRAL EU

Sources and references

1. EUROSTAT data, 2018, *import / export data* and Glass for Europe 2018, *Annual statistics exercise on float glass sales.*
2. B+L Markdaten, 2018, *Market Analysis float glass – European Union.*
3. Glass for Europe, 2018, *Annual statistics of sales of float glass for automotive applications.*
4. Strachala, D., Hylský, J., Vanek, J., Fafilek, G., Jandová, K., 2017, *Methods for recycling photovoltaic modules and their impact on environment and raw material extraction*, Acta Montanistica Slovaca, volume 22 (3), p.257-269.
5. Estimate based on TNO Built Environment and Geosciences, 2019, *Potential impact of high-performance glazing on energy and CO_2 savings in Europe*, April.
6. Mainstream models such as the GM Astra, Ford Fiesta and VW Golf have increased their glass by around 20% through their various generations.
7. N-tech Research, 2015, *BIPV glass markets: 2015-2022.*
8. European Union, 2018, *Directive of the European Parliament and of the Council amending Directive 2010/31/EU on the energy performance of buildings*, L 156/75, 30 May.
9. TNO Built Environment and Geosciences, 2019, *Potential impact of high-performance glazing on energy and CO_2 savings in Europe*, April.
10. Switch2Save (Project ID 869929), *CORDIS EU research results webpage*, viewed 17 October 2019, <https://cordis.europa.eu/project/rcn/224847/factsheet/en>
11. Janssens, C., 2019, *The contribution of energy efficient glazing to Paris objective in different EU building renovation scenarios*, in ECEEE (eds.), *Summer study proceedings*, p. 1295-1301
12. European Commission, 2015, *LOT32 / Ecodesign of Window Products* by VHK, Ift Rosenheim and Vito, June.
13. European Commission, 2018, *A Clean Planet for all: A European strategic long-term vision for a prosperous, modern, competitive and climate neutral economy* and *In-depth analysis in support of the Commission communication COM(2018)773: A Clean Planet for all*, 28 November.
14. Among other parameters affecting the CO_2 offset calculations is the figure of embodied CO_2. Glass for Europe tested its calculations on a range of data based on Environmental Performance Declarations existing in some countries. The CO_2 savings linked to energy-efficiency gains can also vary depending on climate, reference building, building usage, glazing orientation, previous glazing equipment in the building (i.e. single glazing or early uncoated double glazing), lifespan of the window, space heating and cooling energy mix, CO_2 conversion factors, calculation methods, etc. Glass for Europe has made its calculation based on the model developed for the European Commission in *LOT32 / Ecodesign of Window Products* (see ref.) applying to a single family house combining heating and cooling performance in north, central and south Europe climatic zones. Space heating and cooling energy mix are based on data provided in the *EU reference Scenario 2016: Energy, transport and GHG emissions trends to 2050.*
15. Ratio calculated based on European Commission, *EUTL database for CO_2 performance of installations* and EUROSTAT, 2017, *Greenhouse gas emissions by source sector (all sectors and indirect CO_2).*
16. Flat glass sector total emissions in the EU in 2017 equals 5.8Mt CO_2, *EUTL database.* To calculate the percentage share of flat glass emissions: Total emissions including aviation and indirect, excluding LULUCF are 4483.1Mt in 2017, *GHG statistics 2019 viewed 13 December 2019* <https://ec.europa.eu/eurostat/statistics-explained/images/5/58/2019-GHG_statistics_tables_and_figures-update.xlsx>; EU industrial emissions are estimated at 20% of the total emissions in 2017 equal to 897Mt, European Commission, 2019, *The European Green Deal, 11 December.*
17. European Commission, 2012, *Glass BREF.*
18. China Architectural & Industrial Glass Association, 2014, *Annual Conference.*
19. Wang, X., 2007, *China float glass energy efficiency survey*, ITIBMIC and Liu, Z., 2013, *Asianglass*, April/May cited in International Energy Agency (IEA), 2007, *Tracking industrial energy efficiency and CO_2 emissions: In support of the G8 Plan of Action.*
20. Glass for Europe, Experts simulations based on an average typical float plant, historical reduction figures, technologies' known effects and latest industry data.
21. European Commission, 2012, *Glass BREF.*
22. European Commission, 2012, *Glass BREF*; Glass for Europe, 2019, *Statistics on cullet use and recycled content.*
23. Estimate based on Deloitte, 2016, *Economic study on recycling of building glass in Europe.*
24. Deloitte, 2016, *Economic study on recycling of building glass in Europe.*
25. European Biogas association, 2019, EBA Statistical report 2018, April 2019.
26. International Energy Agency (IEA), 2019, *The Future of Hydrogen: Seizing today's opportunities*, June.
27. Calculations based on several sources including Glass for Europe 2018, *Annual statistics exercise on float glass sales*, and B+L Markdaten, 2018, *Market Analysis float glass – European Union.* This calculation is conservative as it does not compute an extra increase in demand resulting from a higher penetration of triple glazing.
28. BJS Différences, 2018, *Flat Glass Industry Trends.*
29. CEPS et Al for European Commission, 2017, *Cumulative Cost Impact Assessment of the flat glass sector.*
30. EUROSTAT data, 2018, *import / export data.*
31. Calculations on the number of installations (average size capacity of 650 tonne per day) needed to meet 100% of the increased demand in the EU. This calculation does not compute the extra increase capacity needed in case of higher penetration of triple glazing.
32. Deloitte, 2016, *Economic study on recycling of building glass in Europe.*
33. World Green Building Council, 2019, *Bringing embodied carbon upfront, Coordinated action for the building and construction sector to tackle embodied carbon.*

About Glass for Europe

Glass for Europe brings together multinational firms and thousands of SMEs across Europe, to represent the whole building glass value-chain. It is composed of flat glass manufacturers, AGC Glass Europe, Guardian, NSG-Group and Saint-Gobain Glass, and works in association with national partners gathering thousands of building glass processors and transformers all over Europe.

MEMBERS

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CORPORATE PARTNER

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