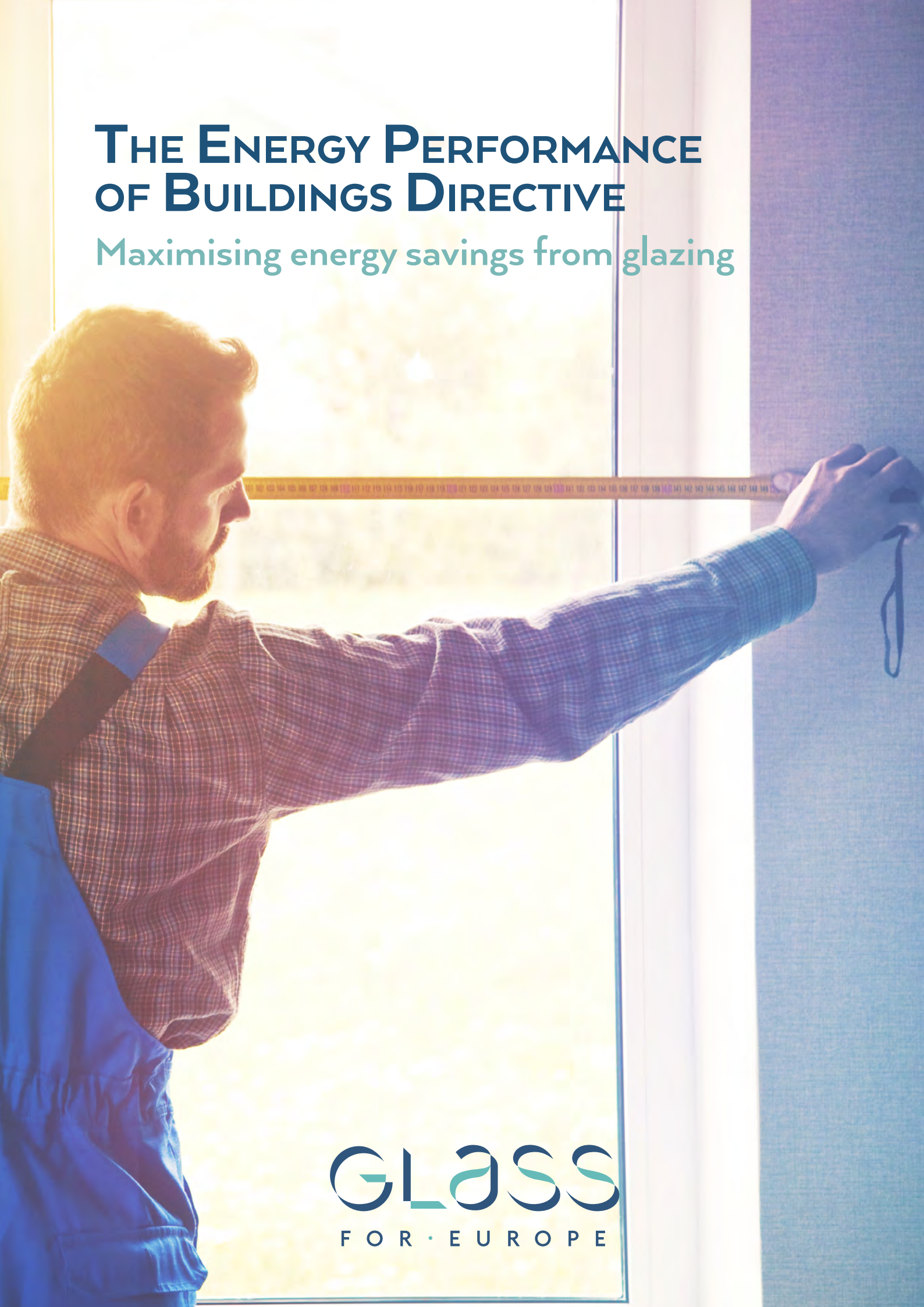
The Energy Performance of Buildings Directive

Maximising energy savings from glazing



GLASS FOR EUROPE

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Foreword

The flat glass industry is a **leader in the development of energy efficiency technologies for buildings**. Different types of glass developed over the years can significantly reduce the need for heating and cooling in buildings, thereby reducing energy consumption and associated CO_2 emissions. The growing recognitions of both the importance of saving energy and the role of glass in achieving those savings can provide the flat glass sector with important market opportunities in the building sector.

Over the past years, Glass for Europe has engaged vigorously with European policy-makers during the revision of the EU's most important legislative tool for energy efficiency in buildings, i.e. the **Energy Performance of Buildings Directive** (EPBD). We believe that through our advocacy work, we have contributed to preserving a high level of ambition and adequate requirements to sustain and grow the market for energy-efficient glazing throughout the EU.

The directive's ambition has become that of a decarbonized building stock by 2050, which should facilitate the cost-effective transformation of existing buildings into nearly-zero energy levels. For the first time, the directive links the energy savings contribution of the building sector to the wider European Union's energy efficiency target. It will require on Member States to focus actions and to track progress realized in the building sector.

It is now national implementation that will determine how effective this framework becomes on the ground and, thus, how much it contributes to massive energy and CO_2 savings.

This publication outlines the main changes brought to the directive by the revision. It aims to provide clues as to how provisions can support upgrade in glazing replacement and performance. **It is meant to empower all stakeholders working on national or regional bulding codes to make sure the energy savings opportunities from glazing are seized.**

Europe cannot afford to miss the new EPBD implementation: for energy savings, for the climate, for delivering healthy and sustainable buildings to citizens, for the business and for the jobs opportunities it can generate.

All these promises are also those of advanced glazing!

Bertrand Cazes
Secretary General of Glass for Europe

GLAZING IN BUILDINGS: ENERGY EFFICIENCY AND BEYOND!

ENERGY EFFICIENCY

With its unique abilities to limit heat loss, to control solar gains and to admit daylight, modern glazing liberates design from energy constraints!

Over the last decades, research and development in glazing has considerably increased the energy performance of facades and windows. A myriad of different types of insulated glass units are now available to ensure that, for each building and in every climate, a specific product exists to optimize energy savings.

In addition to the number of glass panes, i.e. be it double or triple glazing, it is mostly the coated glass technology which enhances efficiency. Coated glass consists in an invisible coating of metal oxides incorporated in one of the internal glass panes. The coating purpose is to let in light but to cut the amount of heat that can escape. Depending on building needs, it can contribute either to maximize heat gains (aka 'Low-E' coatings) or to minimize them (aka 'Solar-control coatings'). Both technologies can be combined to maximize insulation in cooler periods and to control sun's heat in summer.

Additional elements such as the type of inert gas incorporated between the glass panes or the nature of the spacer, also contribute to the energy performance.

A standard Low-E double-glazing unit for example is now 3 times more insulating than double glazing without coated glass and 5 to 6 times more efficient than a single glazing. Triple glazing with the same technology increases further insulation and energy gains.

Because they capture solar heat gains, which contribute to heating the inside of buildings, **today's glazing technologies offer better energy performance than insulated walls and can become net contributors of energy in buildings.**

Low-e glass

Solar control glass

The main functions of windows and facades are to let daylight into buildings and to ensure a visual connection with the exterior. As elements of the building envelope, glazing contributes to the insulation of the building and delivers energy savings.

Yet, glass and glazing have so much more to offer.

COMFORT

In buildings, where we spend 80% of our time, glazing provides daylight whose benefits in terms of sensation of well-being, increased focus, learning, productivity and the maintenance as well as the recovery of good health conditions are well documented.

Glass contributes to comfort in many other ways: its acoustics and insulation properties, the absence of adverse effect on indoor air quality, its easy maintenance, its stylish effect, etc. No wonder, glass is a material valued in modern construction!

SUSTAINABILITY

Made from natural and available resources, glass is an inert material, which can be endlessly recycled into new glass products. Throughout its life-cycle, glass carries minimal environmental impacts as its manufacturing requires low quantity of water and generates very little waste or other pollutants.

Although glass requires energy to be produced, it helps save vast amount of energy when used in windows and buildings. Coming from earth, produced responsibly, fully recyclable, it protects our climate and our planet as a net CO_2 saving material.

SAFETY

Glass is designed to last for decades, to endure all weather conditions and usages while always maintaining its resistance and safety properties.

In buildings, safety glass is used to prevent people and objects from falling down, to slow down the spread of fire in buildings or to resist to fire guns' bullets. Safety glass solutions exist to meet all possible functions and guarantee safety, be it in crowded public places, like rail or metro stations, or in single family homes.

DESIGN

From the cathedrals of the Medieval Ages to contemporary architecture, in furniture, internal partitions and even flooring and staircases, glass contributes distinctively to sleek design.

From perfectly flat surfaces to the warmth of smooth curves, with inimitable colour effects or the highest transparency, glass brings a unique aesthetics while allowing you to see further.

INNOVATION

Vacuum glazing to further reduce heat losses, smart, dynamic and electrochromic glazing to adjust light transmission and heat gains depending on meteorological conditions, fully transparent photovoltaic cells directly integrated into the glass to generate clean electricity, etc. : innovation in glazing technologies is geared towards clean energy.

Beneath increased performance in energy efficiency, resistance or acoustics, we experience the digital world thanks to touch-screen glass technologies. High-tech glass enables smart windows and mirrors and it can incorporate audiovisual displays or OLED lighting. Glass functionalities keep expanding beyond our imagination to make our homes and buildings smarter.

The Energy Performance of Buildings Directive

Introduction

EU rules, national impact

The original Energy Performance of Buildings Directive (EPBD) was adopted in 2002 and reviewed in 2010 and 2018. **It requires national governments to adopt mandatory minimum energy performance standards** and **energy performance certification for buildings**. The directive aimed to create a tool for communicating a building's energy performance and to **drive the sector towards more efficient buildings.**

The legislation allowed national governments **a considerable degree of flexibility** in how the rules were implemented in national law. This led to different levels of standards in each country and to a variety of different national systems of energy performance certificates.

With the growing focus on energy efficiency as way to meet the EU's climate commitment made in the **2015 Paris agreement on climate change**, the directive needed to be reviewed in 2018 to align it with this commitment and to tap further into **the CO_2 saving potential of building renovation**.

Following the European Commission's proposal for a reviewed directive, Glass for Europe worked with EU decision-makers on two streams of actions and provisions meant to deliver more savings:

1. **To preserve the ambition** and **positive elements** already included in the 2010 directive
   - Main objective of a **decarbonized building stock by 2050.**
   - All new buildings to be **'nearly zero energy' by 2020.**
   - Minimum energy performance requirements **for all building elements which are retrofitted or replaced**, and the possibility for this performance to be based on the calculation of its **energy balance.**
   - Minimum energy performance requirements for buildings undergoing "major" renovation.
   - Member States encouraged to put in place **fiscal incentives.**
   - Information on improvement options to be provided on **Energy Performance Certificates (EPC).**

2. **To create a window of opportunity for glass professionals** to engage with authorities **to improve national minimum energy performance requirements for windows**

- Obligation for Member States to establish a **long-term renovation strategy,** which includes estimates of expected energy savings and wider benefits, such as those related to health, safety and air quality.
- Obligation for Member States to carry out **a public consultation,** in an inclusive way, on the long-term renovation strategy prior to its submission to the European Commission.

This revised directive offers a solid basis to revisit energy performance requirements on windows across the Member States. In particular:

1. **When outdated, sub-optimal or based on the sole U-value or separated U-value and g-value**, minimum requirements should be reviewed and be based on the energy balance approach as recommended by the European Commission in the revised EPBD implementation guidelines[1].
2. **Minimum requirements for windows shall apply to new buildings, major renovation down to single window replacement, without limitative conditions.**

Member States now have until end 2019 to put these requirements into national law. As the directive leaves a lot of flexibility to the Member States, **implementation at national level will be key** in determining how effective the rules become in encouraging energy efficiency in buildings and thus in benefiting energy-efficient glazing.

Given the vital role of glazing in determining the energy performance of a building, an ambitious implementation of the EU rules can greatly contribute to driving **the market towards more high-performance glazing products and to realizing massive long-lasting energy and CO_2 savings.**

Reference : **DIRECTIVE (EU) 2018/844 of 30 May 2018[2].**

Member States have to transpose the new elements of the Directive into national law **by 10 March 2020**.

Publication in the Official Journal of the European Union dated 19 June 2018: https://eur-lex.europa.eu/eli/dir/2018/844/oj

Guidance document on the revised Annex I EPBD - Common general framework for the calculation of energy performance of buildings.

1. In its revised implementatio guidelines, the European Commission requires Member States to take into account the positive influence of l*ocal solar conditions* and *natural lighting* when setting the methodologies for calculating the energy performance of buildings and building elements. It also highlights that the energy balance approach is being ***used in some Member States to consider the solar conditions*** in their methodologies. At time of publishing, the European Commission guidelines on the revised EPBD were not officially released.
2. Amending Directive 2010/31/EU on the energy performance of buildings and Directive 2012/27/EU on energy efficiency

Renovation

Objective

To ensure that national renovation plans include targets for reducing the final energy consumption from buildings and for the renovation of the national building stock (ideally aim at a 3%/year renovation rate). To avoid downgrading the energy efficiency target's ambition by discounting on- and off-site renewables from the energy consumption of buildings.

Background information

National renovation strategy

The new EPBD emphasizes the need for facilitating the cost-effective transformation of existing buildings into nearly-zero energy buildings (nZEB). The new EPBD includes in its Article 2 (2) a clear reference to the European Union energy efficiency target defined in the Energy Efficiency Directive (EED) to measure the progress made in the building sector. Member States are expected to report on the contribution of the transformation of their building stock to achieving the target, on the basis of indicative milestones to be included in their national renovation strategies. Under the new EPBD, Member States will have to organise public consultations to define their renovation strategies, which represents an opportunity for the national glazing associations to step forward. The call for ambitious targets for building renovation is essential to provide appropriate long-term signals to investors and market actors but is also a leeway to call for more specific measures on windows (see Appendix 1).

Risk of trade-offs between building renovation and renewables

Although the new EPBD emphasizes the need for renovation, one of its main objectives has become to contribute to the decarbonization of the building stock. This can be achieved by combining measures to reduce buildings' energy demand and the integration of renewables. Both renewable energy supplied on-site or off-site by external energy carriers can be taken into consideration. It creates a risk of trade-offs between the renovation of the building envelope and the use of renewables. Therefore, it is important that national associations advocate for applying the energy efficiency first principle in national renovation plans to maximize synergies between energy savings and renewables in decaronising the building sector.

IMPLEMENTATION RECOMMENDATIONS

Renovation of the building stock is key to achieve the Energy Efficiency Directive savings' objective and to deliver the promises of the COP21 agreement.

To meet the Paris agreement objectives, the European Union and in particular its Member States need to moderate their energy demand. The European building stock presents the highest potential in terms of energy demand reduction with 75% of our housing stock, which is energy inefficient. As highlighted by the European Commission in its " Clean Planet for All" communication, the EU must renovate 97% of the building stock by 2050 in order to achieve its long-term decarbonisation objectives: this means more than doubling the current renovation rate.

National renovation plans are a unique opportunity for each Member State to equip itself with a powerful instrument to reduce its greenhouse gas emissions, while fostering growth and contributing to the alleviation of energy poverty.

National renovation plans must include targets for reducing the final energy consumption from buildings and for an increase in speed of the renovation rate.

Policies must be designed to provide appropriate long-term signals to investors and market actors. Targets are necessary to this end since they can be easily communicated in a way that all actors across the construction industry as well as citizens can plan investments and business strategies with confidence. "Stop and go" policies must be avoided.

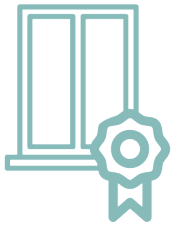
National renovation plans should include targets for reducing the final energy consumption and for the renovation of the national building stock (3%/year).

National renovation plans should **avoid trade-offs** between renewables and energy efficiency.

80% of the energy consumed in a building is used for heating and cooling. Therefore, when addressing the energy efficiency of the building sector, the reduction of energy waste is the key priority.

A well or highly performing building envelope generates the highest thermal comfort and avoids its waste. It is the cost-effective solution to address the energy demand of the building and it presents distinctive benefits for the occupants in terms of comfort, health and well-being, for instance.

The installation of renewable energy production is incentivised in other legislations and should not become an alternative to an improvement of the building envelope, whilst both are needed. Discounting renewable energy produced on or off-site dilutes the energy efficiency objective and should be avoided in the calculation models.



Minimum performance requirements for windows (residential)

Objective

To design minimum performance requirements which drive the market towards energy efficient products:

- When outdated, sub-optimal or based on the sole U-value or separated U-value and g-value, minimum requirements should be reviewed and be based on the energy balance approach.
- Minimum requirements for windows shall apply to new buildings, major renovation down to single window replacement, without limitative conditions.

To avoid window minimum requirements at national level, which incorporate the alleged performance of shading devices into a single set of U and g values.

Background information

Photography of window requirements

In a great number of EU countries, minimum performance requirements are not effective tools to drive the market towards energy efficient windows. In most countries, windows performance requirements refer to sub-optimal choices and apply under many conditions, which limit their applicability. The minimum performance requirements applying in the different Member States can be found in the Appendix 2.

Three main shortcomings can be identified:

1. The minimum requirements are not based on the energy balance: only Denmark and the United-Kingdom are taking into account the energy balance of the window to assess its performance.
2. The minimum performance requirements are outdated and are sub-optimal.
3. The minimum performance requirements do not apply to single window replacement.

Room for action

In the countries facing one or all of these shortcomings, the revised EPBD should serve as a signal that window minimum performance requirements need to be revised. As illustrated in Annex 1, there remains a huge untapped energy savings potential in window retrofitting, which can be realised if minimum performance requirements are designed to become an energy efficiency driver for the glazing and window market.

Today, the average energy performance of windows in the EU building stock is very low (3.4 U value). This situation suggests that windows are the weak point of today's EU building stock, precisely because of the lack of attention to window retrofitting: both aged windows and outdated minimum performance requirements. Considering the performance of glazing products available on the market, windows is one of the building envelope material with the highest potential for saving energy. This requires that minimum performance requirements are revisited to ensure that the best performing windows are installed at time of renovation.

IMPLEMENTATION RECOMMENDATIONS

Minimum requirements for windows shall apply to new buildings, major renovation **down to single window replacement** in the residential sector, without limitative conditions.

The implementation and scope of minimum requirements set in national regulations can differ due to conditions added by the national authorities, generating de facto loopholes in the regulation (i.e. need for a town permit prior to the renovation or minimum area to be renovated for the requirement to apply). It results that, in those countries where conditions apply, windows not meeting the minimum requirements can still be installed in many buildings.

These conditions applying to the minimum requirements limit the market push for energy-efficient windows in the residential sector and should be lifted to seize the full energy savings potential.

As recommended by the European Commission in its revised implementation guidelines, the **energy balance** of a window must be used to assess its energy performance and to **set the minimum performance requirements.**

The energy balance of a window must be used to assess its energy performance. It is this balance that determines the most appropriate glazing solution for a given window. It should be calculated with an equation that factors in the heat gains and heat losses and is weighted by the climatic conditions. Accordingly, the energy balance must become the method used to set the minimum performance requirements for windows.

The **minimum energy performance requirements** must be based on the window performance and **should not integrate shading devices.**

The inclusion of minimum requirements for windows, based on the properties of non-window products (i.e. shading devices), negatively affects the uptake of energy efficient windows. It disregards the window's real performance on the assumption that shading devices are consistently closed in the daytime during summer and open in daytime during winter.

In practice, it contradicts real-usage scenario and it will not deliver expected savings as it sends the wrong signal to the market by rehabilitating less performing or outdated windows.

Maximum and cost-efficient energy savings in buildings will be better realised by addressing both products with separate energy performance requirements. This will ensure that truly energy-efficient windows will be used at time of retrofitting, to provide long lasting and predictable savings. Separate requirements on shading may be considered if deemed appropriate by legislators and industry to garner extra hypothetical savings.

Windows throughout Europe

This map of Europe presents two types of window values per country: first, the average insulation performance (Uw value) of windows in the national building stock and, second, the minimum energy performance requirement applicable to windows in residential buildings. These staggering figures illustrate the poor efficiency of both windows in the building stock and of legislative requirements.

3.4 Uw: average insulation performance of windows in the EU building stock

This value is that of a mix of glazing products from the 60s and 70s! This show how large the room for improvement is with targeted efforts on windows.

Suboptimal efficiency requirements

Window minimum performance requirements are so poor that they do not support savings in buildings. In addition, in most EU countries these requirements apply only under many restrictive conditions (see Appendix 2 for more details). Not only don't they boost most saving products but, most damagingly, they structure and lock window markets downwards, acting as distinctives to energy savings and industry innovation.

Minimum energy performance requirements set by EU Member States
Sources: Ecofys 2007, Glass for Europe

Average insulation performance of windows in the national building stock
Sources: European Commission (December 2018)

Reference

Typical window's U-value

Insulated triple glazing = 0.9
Insulated double glazing = 1.4
Double (uncoated/early) glazing = 2.8
Single glazing = 5.8


Finland
Minimum Performance Requirements
U-value: 1.0
g value: n/a
Average Building Stock
U-value: 1.90
Sweden
Minimum Performance Requirements
U-value: 1.2
g value: n/a
Average Building Stock
U-value: 2.50
Estonia
Minimum Performance Requirements
U-value: n/a
g value: n/a
Average Building Stock
U-value: 1.40
Denmark
Minimum Performance Requirements
U-value: energy balance
g value: energy balance
Average Building Stock
U-value: 2.40
Latvia
Minimum Performance Requirements
U-value: 1.3K / 1.5 K
g value: n/a
Average Building Stock
U-value: 2.50
Lithuania
Minimum Performance Requirements
U-value:1.6 K
g value: n/a
Average Building Stock
U-value: 1.90
Average Building Stock
U-value: 3.20
Poland
Minimum Performance Requirements
U-value: 1.1
g value: n/a
Average Building Stock
U-value: 2.90
Germany
Minimum Performance Requirements
U-value: 1.3
g value: n/a
Average Building Stock
U-value: 2.70
Czech Republic
Minimum Performance Requirements
U-value: 1.1
g value: n/a
Average Building Stock
U-value: 2.70
Average Building Stock
U-value: 2.70
Austria
Minimum Performance Requirements
U-value: 1.2
g value: n/a
Average Building Stock
U-value: n/a
Slovakia
Minimum Performance Requirements
U-value: 1.0
g value: 0.60
Average Building Stock
U-value: 3.00
Slovenia
Minimum Performance Requirements
U-value: 1.3
g value: 0.50
Average Building Stock
U-value: 2.00
Romania
Minimum Performance Requirements
U-value: 1.5
g value: n/a
Average Building Stock
U-value: 2.30
Croatia
Minimum Performance Requirements
U-value: 1.6 / 1.8
g value: n/a
Average Building Stock
U-value: 3.90
Bulgaria
Minimum Performance Requirements
U-value: 1.4
g value: n/a
Average Building Stock
U-value: 2.50
Italy
Minimum Performance Requirements
U-value: 1.7 ... 3.2
g value: 0.35
Average Building Stock
U-value: 4.60
Greece
Minimum Performance Requirements
U-value: 2.6 ... 3.2
g value: n/a
Average Building Stock
U-value: 3.60
Malta
Minimum Performance Requirements
U-value: 4.0
g value: 0.89
Average Building Stock
U-value: 5.80
Cyprus
Minimum Performance Requirements
U-value: 2.9
g value: n/a
Average Building Stock
U-value: 5.00

Energy Balance

Objective

To base windows' minimum energy performance requirements on the calculation of the windows' energy balance.

Background information

The energy balance concept

As a transparent component, glazing in windows provide solar heat gains to buildings. In winter these heat gains are beneficial because they warm up the interior free of charge, thus reducing heating needs and associated energy consumption. In summer, heat gains can be significant and, in some cases, may lead to overheating if suboptimal glazing solutions are used. It stems from this that the energy performance of windows and facades cannot be assessed solely on the basis of their insulation characteristics (u value). It needs to take into account both the solar energy gains (g value) provided by a window and its insulation properties (u value). This is where the concept of energy balance of windows comes in. It allows to compute both heat losses and solar heat gains based on the climatic conditions of the building's location (see Appendix 3).

Energy balance in legal requirements

Only Denmark applies minimum requirements for windows based on the energy balance approach combining both the solar heat gains and heat losses of the window into a single value. However, the United-Kingdom allows legal requirements to be met either by way of meeting minimum requirements based on the Uw-value (i.e. 1.6 W/m^{2}K) or by meeting a band of the Window Energy Rating label (i.e. Band C or better) which is calculated based on the energy balance approach. In the vast majority of countries, minimum requirements remain based on the U-value (being Uw-value or Ug-value) and g-value separately. Where that is the case, the calculation methods should be revisited and the minimum requirements be based on the 'energy balance' approach, as recommended by the European Commission in its revised implementation guidelines.

Passive heating and solar protection

During its 2018 review, Annex 1 of the EPBD was amended to make it compulsory for Member States to consider the positive impact of " passive heating, passive solar system and solar protection, local exposure conditions and natural lighting", while updating their calculation methodologies. Applying the energy balance approach is in fact the only known way to be fully compliant with the revised annex.

For the purpose of the energy balance calculation, as for minimum performance requirements, external devices, such as shading, should be considered separately from the window to guarantee stable and long-lasting savings.

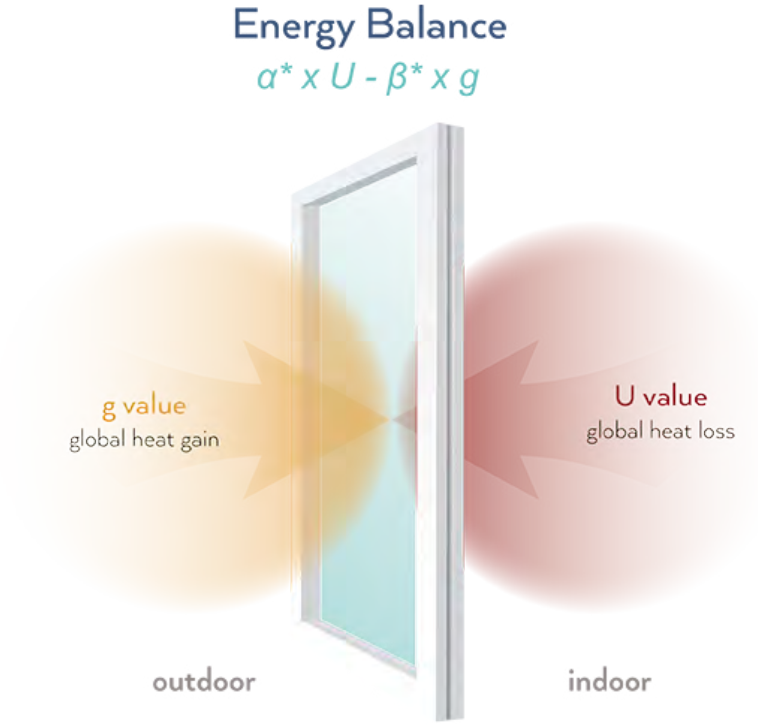
IMPLEMENTATION RECOMMENDATIONS

As recommended by the European Commission in its revised implementation guidelines, the **energy balance** of a window must be used to assess its energy performance and to **set the minimum performance requirements.**

The energy balance of a window must be used to assess its energy performance, as recommended by the European Commission in its revised implementation guidelines. *It is this balance that determines the most appropriate glazing solution for a given window. It should be calculated with an equation that factors in the heat gains and heat losses and is weighted by the climatic conditions. Accordingly, the energy balance must become the method used to set the minimum performance requirements for windows.*

The energy balance must be based on the performance of the window (frame + glazing) and should not integrate external shading devices.

The inclusion of minimum requirements for windows, based on the properties of non-window products (i.e. shading devices), negatively affects the uptake of energy efficient windows. It disregards the window's real performance on the assumption that shading devices are consistently closed in the daytime during summer and open in daytime during winter.
In practice, it contradicts real-usage scenario and it will not deliver expected savings as it sends the wrong signal to the market by rehabilitating less performing or outdated windows.



* alpha and beta values are defined based on the building's geographical location, window size and orientation

Daylight and well-being

Objective

To secure the distinctive benefits of glazing are duly taken into consideration when national long-term renovation strategies are established.
To remove outdated maximum glazed surfaces requirements from national, local and urban planning regulations.
To include a minimum of 20% of glazed surface compared to the floor area in new constructions and major renovations.

Background information

Distinctive benefits of glazing

Thanks to continuous innovations, glazing solutions have achieved very high levels of energy performance. Modern glazing solutions are becoming more energy efficient than the opaque fabric, as they provide free solar heat gains (g value) while guaranteeing high thermal insulation (U value). As a result, enlarging high performing glazed surfaces can contribute to reducing energy consumption from both heating and cooling. In addition, if properly oriented, windows improve the daylight autonomy, thus lowering the need for artificial lighting.

What is more, glass products present the smallest environmental footprint across all LCA indicators compared to other parts of the building envelope and offer distinctive benefits resulting from their main functionality (i.e. to let light and air in, to allow views to the outside). These numerous benefits, like improved comfort and sensations of well-being for occupants and a healthier indoor environment, have been widely researched and acknowledged (see Appendix 4).

Glazed surfaces requirements in local and urban planning regulations

Article 2(1) of the EPBD foresees that Member States shall establish a long-term strategy to support the renovation of the national stock into highly energy efficient and decarbonised building stock by 2050. These plans must encompass an evidence-based estimate of expected energy savings and wider benefits, such as those related to health, safety and air quality. The distinctive benefits of glazing on well-being and healthier indoor environment are evident. The long-term renovation strategies offer a window of opportunity to engage with national authorities, to call for a removal of existing maximum glazed surfaces requirements (no longer grounded on energy savings purposes) and, by contrast, to call for introducing minimum glazed surfaces requirements for comfort, health and sustainability reasons (see Appendix 5).

IMPLEMENTATION RECOMMENDATIONS

To secure the **distinctive benefits of glazing** are duly taken into consideration when establishing the **national long-term renovation strategies.**

Modern glazing solutions are not only becoming highly energy efficient, they also offer distinctive benefits resulting from their main functionality (i.e. to let light and air in, to allow views to the outside). These numerous benefits, like improved comfort and sensations of well-being for occupants and a healthier indoor environment, have been widely researched and acknowledged.

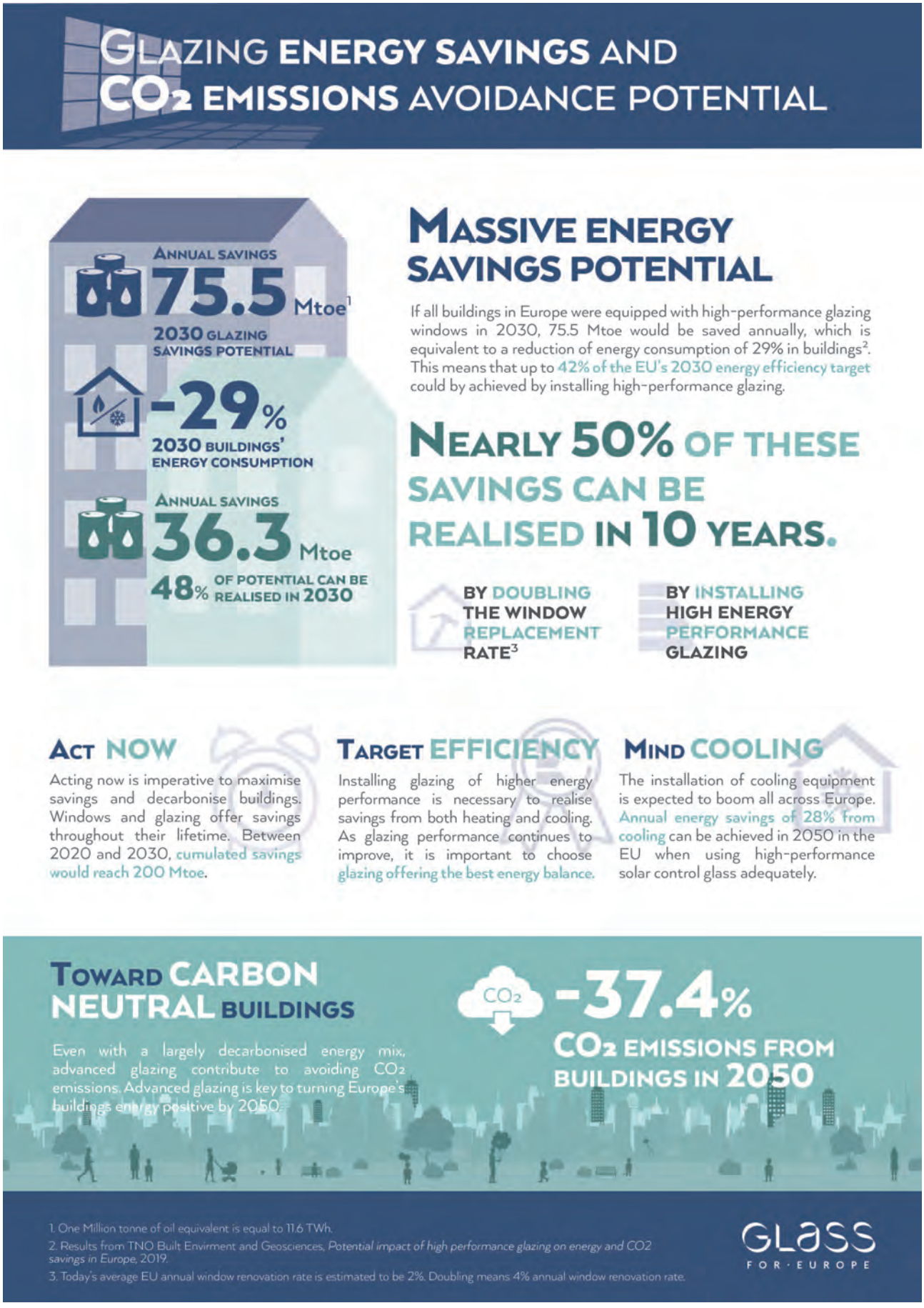
These benefits, together with an accurate assessment of the window's energy performance, based on the energy balance, should be duly taken into consideration when establishing long-term renovation strategies, and in particular, the evidence-based estimate of expected energy savings and wider benefits, such as those related to health, safety and air quality [EPBD Art.2 (1) g].

Local and urban planning regulations should include **a minimum of 20% of glazed surface** compared to the floor area in new constructions and major renovations.

Building regulations and construction codes should adapt alongside improvements to construction materials and should build on scientific evidence to provide better places for building occupants.
Data show that between 20 and 30% of glazed surfaces compared to the floor ratio is the optimum to guarantee a good level of daylight autonomy and energy performance in residential buildings. These should serve as a basis for setting minimum glazed surfaces requirements in local and urban planning regulations for new constructions and major renovations.

Glazing energy savings and CO_2 emissions avoidance potential

Source: Glass for Europe, 2019



Appendix 2

Overview of legal and minimum energy performance requirements for replacement of windows in residential buildings by Member State.

Source: Ecofys 2017, European Commission, Glass for Europe

EU Member States	Legal requirements			Average building stock
	U_w – value (W/m^2K)	g – value	Last update	
Austria	1.2	–	2015	n/a
Conditions: *When performing a renovation in Austria either the above mentioned Uw-value (88%*1.4 = 1.2 W/m^2K) needs to be fulfilled or a renovation concept needs to be developed ensuring the compliance with the energy balance requirements for the whole building. Building elements have not been investigated in the cost optimality report. The requirements also apply for single window replacements.*				
Belgium – Brussels	1.8 (U_g: 1.1)		2014	3.80
Conditions: *This requirement applies / is enforced solely in case of renovation with a town planning permit. There is no need of a permit if only single windows are replaced. Therefore, the requirements do not apply for single window replacements.*				
Belgium – Flanders	1.5* (U_g: 1.1)		2016	3.80
Conditions: *In addition to the average Uw-value requirement of 1.5 W/m^2K a Ug-value of 1.1 W/m^2K needs to be fulfilled. From 2015, all major building renovations (residential, offices and schools) involving 75% or more of the building shell or replacement of the whole HVAC system will have to meet a whole building energy performance requirement. This requirement applies / is enforced solely in case of renovation with a town planning permit. There is no need of a permit if only single windows are replaced. Therefore, the requirements do not apply for single window replacements.*				
Belgium – Wallonia	1.5 (U_g: 1.1)		2017	3.80
Conditions:*U-value requirement might be updated in 2020. This requirement applies / is enforced solely in case of renovation with a town planning permit. There is no need of a permit if only single windows are replaced. Therefore, the requirements do not apply for single window replacements.*				
Bulgaria	1.4*	–	2015	2.50
Conditions: *Valid for windows with PVC frame (further requirements: 1.6 / 1.8 – wood (walls / roofs), 1.7 – Aluminium, 1.75 / 1.9 – glazing facades / with higher requirements). The legal requirement is supposed to become Uw = 0.6 in 2020. An intermediate step of Uw 1.1 is discussed for 2018. It is unclear whether the requirements apply also for replacement of single windows.*				
Croatia	1.6 / 1.8*	–	2015	3.90
Conditions: *Building specific requirements (first figure: buildings up to 2 floors; second figure: buildings with more than 2 floors). The existence of air tightness requirements was mentioned but not specified. In case where only certain building elements of the envelope of a heated part of the building covering a surface area over 25% are renovated, the U-value of the entire building element (for all types of buildings) shall fulfil the prescribed requirements. In case of external walls and transparent elements of the envelope of a heated part of the building covering an area over 25% of that building component or element, the provision from the previous sentence relates to each individual geographic orientation of that building part (Exception: Requirements related to the max. Allowed U-values are not applied to a glass window with a large surface up to 4 m^2 or if there is an additional barrier between such window and the heated indoor area of the building). Therefore, the requirements do not apply for single window replacements.*				
Cyprus	2.9*	–	2017	5.00
Conditions: *As from 1st of January 2017 all buildings that undergo major renovation should reach at least energy class B as far this is technically and financially feasible. The requirements apply for single windows that are replaced in existing and new buildings.*				
Czech Republic	1.1	–	2018	2.70
Conditions: *It is unclear whether the requirements apply also for replacement of single windows.*				
Denmark	-*	–	2015	2.40
Conditions: *Danish energy requirements to windows in the Buildings Regulations are to the energy balance of the window not to the U-value and g-value separately. This is set to create possibility for manufacturers to focus on the total energy performance optimisation of windows instead of focusing on sub-optimisation of the U-value and g-value separately. The requirements concerning the energy gain are Eref > -17 kWh/m^2a (windows) and Eref > 0 kWh/m^2a (roof windows). This approach is compliant with EU regulation and welcomed by the industry but it makes it impossible to provide definite numbers in this report. Therefore, the requirements apply even if only a single window is replaced.*				
Estonia	-*	–	2013	1.40
Conditions: *Estonian legislation do not set any requirements for the window's thermal properties. No component based requirements exist. Energy efficiency of buildings is assessed through primary energy and requirements are set to the primary energy consumption. The minimum energy performance requirements are expressed as a primary energy performance indicator calculated for the building according to its standardised use, and applied to the building as a whole. Therefore, no requirements exist for single window replacements.*				
Finland	1.0*	–	2012	1.90
Conditions: *The U-value of new windows and external doors must be 1.0 $W/(m^2K)$ or better. This requirement applies / is enforced solely in case of renovation with a town planning permit. A permit is needed if you exchange so many windows that the measure has a significant effect on the energy efficiency of the building. The threshold for an effect to be considered "significant" was not reported. Yet, in practice almost 100% of the renovation market were reported to fulfil the given U-values, as manufacturers reportedly don't produce windows above these U-values just for "non-permit" cases. Yet, officially the requirements do not apply for single window replacements.*				

France	1.9*	–	2018	3.10
Conditions: *The value (1.9 W/m²K) is valid for all renovations (also for single window replacements). For windows ≤ 0.5m², a Ug value of minimum 1.5 W/m²K needs to be fulfilled. For roof window, the legislation foresees that solar control glass must be used (no minimum value is set in the legislation). A shading device alone or in combination with a solar control glass can also be used for roof window with a minimum performance of 0.35 Sw.*				
Germany	1.3*	–	2014	2.70
Conditions: *Alternatively, to the above mentioned Uw-value also meeting a whole building energy requirement (140% of new building's primary energy and overall shell transmission coefficient) is possible to meet the requirement. No requirements if less than 10% of the building component area is concerned (building component area for windows consists of: windows, roof windows, window doors and window roofs). Therefore, no requirements exist for single window replacements.*				
Greece	2.6...3.2*	–	2010	3.60
Climate zone specific requirements exist (A: 3.2, B: 3.0, C: 2.8, D: 2.6). There are no specific requirements for renovated buildings. For deep renovations (>25% of building envelope) however these values apply and the total energy class of the building should comply with Class B (100-75% of primary energy consumption of reference building). Therefore, the requirements do not apply for single window replacements.				
Hungary	1.6*	–	2006	2.30
Conditions: *In case of a shallow renovation (< 25% of the building shell is replaced) the shown Uw-value of 1.6 W/m²K is valid. Therefore, the requirements apply even if only a single window is replaced. In case of a major renovation the following requirement concerning the specific heat loss coefficient qm ≤ 0,079+0,27*(A/V) is valid since 2017. The existence of air tightness requirements was mentioned but not specified.*				
Ireland	1.6*	–	2011	3.80
Conditions: *For extensions and material change of use, windows, doors and roof lights should have a maximum U-value of 1.6 W/m²K when their combined area is 25% of floor area. The requirements apply even if only a single window is replaced.*				
Italy	1.7...3.2*	0.35*	2015	4.60
Conditions: *Climate zone specific requirements exist (2015-2020: A & B: 3.2, C: 2.4, D: 2.1, E: 1.9, F: 1.7; by 2021: A & B: 3.0, C: 2.0, D: 1.8, E: 1.4, F: 1.0). The climate zones are defined as follows: Zone A = up to 600 HDD; Zone B = from 601 to 900 HDD; Zone C = from 901 to 1400 HDD; Zone D = from 1401 to 2100 HDD; Zone E = from 2101 to 3000 HDD; Zone F = more than 3000 HDD). The g-value of 0.35 includes movable shading devices. Additionally, the g-value (=0.35) is only for orientation from East to West, passing through South: there is no limit for North-facing sides. This requirement applies / is enforced solely in case of renovation with a town planning permit. A building permit is needed by exchanging all windows of a property unit.*				
Latvia	1.3·k / 1.8·k*	–	2015	2.50
Conditions: *Unorm = normative value / Umax = maximal allowed value. The term "k" is the temperature correction factor (k = 20/(Φi – Φe), where Φi – indoor air temperature and Φe – outdoor air temperature). It is unclear whether the requirements apply also for replacement of single windows.*				
Lithuania	1.6·k*	–	2014	1.90
Conditions: *The term "k" is the temperature correction factor (k = 20/(Φi – Φe), where Φi – indoor air temperature and Φe – outdoor air temperature). The requirements apply even if only a single window is replaced. If the total area of windows and other transparent building elements exceeds 25 % of total external wall area, the U-value of transparent elements even shall not exceed 1.3 W/(m²K). The existence of air tightness requirements was mentioned but not specified. By 2018 the requirement will change to 1.4·k.*				
Luxembourg	1.5*	–	2016	2.70
Conditions: *The requirements apply even if only a single window is replaced.*				
Malta	4.0*	0.89	2015	5.80
Conditions: *Buildings undergoing major renovation will be required to have a maximum yearly overall energy demand per square metre not exceeding that for the dwelling typology with the highest maximum overall energy demand requirement. Building extensions of 14 m² or less as well as major renovation project, to existing dwellings may be assumed to fulfil all the overall energy requirements (as before) provided that this construction is similar to the un-extended building. Where a building element forming part of the building envelope is being replaced or a building is being extended to a degree which may not be described as a major renovation, the building shall not be required to have a minimum overall energy performance level. Each new element forming part of the building envelope shall however not be exempted from compliance with maximum thermal conductivity requirements for that element. Therefore, the requirements apply even if only a single window is replaced. The U-value requirement only applies when windows and glazed door surface is ≥ 20% of exposed wall.*				
Netherlands	2.2	–	2015	3.20
Conditions: *It is unclear whether the requirements apply also for replacement of single windows.*				
Poland	1.1*	–	2017	2.90
Conditions: *Please note that the value applies to new buildings or replacement when you need a town planning permit. Without such a permit, for window retrofitting, no minimum performance requirement is enforced. Therefore, the requirements do not apply for single window replacements. By 2021 the requirement will change to 0.9 W/m²K. The existence of air tightness requirements was mentioned but not specified.*				
Portugal	2.2...2.8*	0.10...0.56*	2016	4.00
Conditions: *This requirement applies / is enforced solely in case of renovation with a town planning permit. There is no need of a permit if only single windows are replaced. Therefore, the requirements do not apply for single window replacements. Climatic zones in Portugal are distinguished by three levels (1, 2 and 3) for winter (I) and also three levels for summer (V) according to the temperature, radiation and altitude. I3 refers to the areas with higher energy needs for heating (heating degrees days for a 18ºC base above 1800) and V3 refers to the areas with higher energy needs for cooling (average temperatures during summer above 22°C). As an example, climatic zone I1V3 refers to a location with mild winters and hot summers. Nevertheless, the heating needs are always significantly more relevant than the cooling needs. Therefore, in many situations the climatic zones are nominated by their winter designation. Concerning the g-value the maximum value for the window system (glass + frame + shading device) is shown. Furthermore, the value depends on the thermal mass of the building.*				

Romania	1.5*	–	2016	2.30
Conditions: *By 2018 the current Uw-value requirement for new buildings (Uw = 1.3 W/m²K) will be enforced for existing buildings. The requirements apply even if only a single window is replaced.*				
Slovak Republic	1.0	0.60	2016	3.00
Conditions: *From 2021 onwards stricter requirements are expected. The existence of air tightness requirements was mentioned but not specified. It is unclear whether the requirements apply also for replacement of single windows.*				
Slovenia	1.3*	0.50	2010	2.00
Conditions: *In case of metal frames, the requirement is set at 1,6 W/m²K. In spring 2017 an update of the Building Code is planned, that will introduce cost-optimal levels for windows. It is unclear whether the requirements apply also for replacement of single windows.*				
Spain	2.5...5.7*	–	2013	4.50
Conditions: *In Spain the maximum U-value for windows for renovation (when these are replaced, if they are not replaced there is not such a requirement) is the same that for new buildings. In the case that more than 25% of the envelope is renovated, the heating demand should be lower than the reference building (the same building but with an envelope that comply with the previous normative from 2006). The requirements apply even if only a single window is replaced. A combination of building specific requirements (distinction between isolated blocks, terraced houses, block within adjacent buildings, semi-detached house) and climate specific (climate zones are defined as a combination of the severity of winter: α (warmest region: Uw = 5.7 W/m²K), A, B, C, D, E (coldest region, Uw = 2.5 W/m²K) and the severity of the summer (1, 2, 3, 4; mild to extreme)) requirements exist. The existence of air tightness requirements was mentioned but not specified.*				
Sweden	1.2*	–	2012	2.50
Conditions: *The building shall primarily fulfil the energy requirements for new buildings. If not, U-value requirements for the various building parts shall be fulfilled. It is unclear whether the requirements apply also for replacement of single windows.*				
UK – England	1.6*	–	2016	3.90
Conditions: *In England either a U-value of 1.6 W/m²K or a Window Energy Rating (WER) of Band C or better is required. The calculation of the WER is set out in the Glass and Glazing Federation (GGF) Guide to the Calculation of Energy Ratings for Windows, Roof Windows and Doors. The requirements apply even if only a single window is replaced.*				
UK – Wales	1.6*	–	2014	3.90
Conditions: *See description of UK-England. Wales follows follows the relevant standards of England's Building Regulations in their Building Regulation. The requirements apply even if only a single window is replaced.*				
UK – Northern Ireland	1.6*	–	2013	3.90
Conditions: *See description of UK-England. Northern Ireland follows the relevant standards of England's Building Regulations in their Building Regulation. The requirements apply even if only a single window is replaced.*				
UK – Scotland	1.6*	–	2016	3.90
Conditions: *See description of UK-England. Scotland follows the relevant standards of England's Building Regulations in their Building Regulation. For extensions to existing dwellings, where the dwelling has poor levels of wall and roof insulation, the requirements are a Uw of 1.4 W/m²K or a Window Energy Rating A. The requirements apply even if only a single window is replaced.*				

Extra EU countries			
Norway	0.8 to 1.2	–	–
Russia	1.25 to 3.33	N/A	2018
Note: *The minimum requirements are set in the national legislation on the thermal performance of buildings (2013). The requirements applying vary depending on the location. Unlike the minimum requirements set in the European Union, the minimum requirements are defined in R-value. The R-value have been converted to Uw values in the table to have comparable data.*			
Switzerland	1.2	–	–
Turkey	2.4	–	–

Appendix 3

Ensuring a proper assessment of the energy performance of windows when implementing the revised EPBD

Source: Glass for Europe

The implementation of the revised Energy Performance of Building Directive[1] offers a unique opportunity to Member States to optimise the energy performance of national building stocks and thus to contribute to achieving the EU's long-term decarbonisation objectives. Simply by way of a reviewed and more appropriate methodology to assess the energy performance of windows, major savings can be achieved across the EU.

Why is it urgent to better evaluate windows' performance?

The main functions of windows and facades are to let daylight into buildings and to ensure a visual connection with the exterior. As elements of the building envelope, high-performance windows contribute to the insulation of the building and deliver energy savings. Moreover, the transparency of glazing offers a unique feature to windows, that is to manage solar energy that heats interior and minimizes energy demand.

Today, the assessment of the energy performance of windows in national cost-optimal calculation methods is too often merely based on insulation properties[2], i.e. the thermal transmittance (U-value). The U-value alone gives an inaccurate picture of windows' performance as it disregards the substantial energy impact of solar heat gains. As a consequence, **most of the cost-optimal calculations underpinning minimum performance requirements in Member States, result in markets structured around sub-optimal window solutions and a less performing building stock.**

In order to ensure a proper assessment of the energy performance of windows, **heat gains (g-value) have to be considered and balanced with heat losses (u-value)**, as it is already the case for new construction[3]. This is the only way to minimize heating demand but also to limit cooling needs.

How to assess the energy performance of windows?

The **energy balance of a window** is the most accurate method to assess its energy performance. It is an equation that factors in the heat gains and heat losses and is weighted by the climatic conditions. Only an assessment based on the energy balance allows to find the most adequate windows[4].

- Member States shall use the energy balance to set minimum energy performance requirements for windows and glazed areas. .
- **Glass for Europe calls on the European Commission to include in its EPBD guidelines a recommendation to Member States to use the energy balance.**

What is needed in the EPBD implementation guidelines?

Member States should consider using the 'energy balance' methodology for determining cost-optimal solutions for windows and glazed areas. The energy balance equation is the balance between the heat gains and heat losses that determines the most appropriate glazing solution for a given building.

The energy balance of a window:

- *Is the balance between the heat gain (g value) and heat losses (Uw-value);*
- *Needs to consider local climatic conditions;*
- *Should consider different standard window size;*
- *Can consider the orientation (North, East, South or West) which impacts solar exposure.*

It must be noted that applying the energy balance is the only way to be fully compliant with the revised EPBD (Annex 1), which requests Member States to consider the positive impact of 'passive heating, passive solar systems and solar protection, local solar exposure conditions and natural lighting', while updating their calculation methodologies.

1 Directive (EU) 2018/844, amending Directive 2010/31/EU
2 *Minimum performance requirements for window replacement in the residential sector*, ECOFYS, 2017.
3 In new buildings, architect and building engineers already take into account the heat gains delivered by transparent components of the envelope.
4 The energy balance was recognised as the only effective way to assess the energy performance of windows in the *Eco-design preparatory study on windows* (ENER LOT 32), ift Rosenheim, 2015.

How is the energy balance affecting energy demand in real life?

The two examples below analyse the minimum requirements set for windows replacement applicable in Strasbourg and Athens[5]. These examples illustrate that using the thermal transmittance (Uw-value) only, leads to a systematic under-estimating of buildings' energy needs, compared to what happens in real life.

1. Cooling needs are completely disregarded, which means that it guides markets towards glazing which can generate over-heating, which, in turn, leads to more installation and energy-demand for air-conditioning, while solar-control glazing would avoid this effect.

2. Heating needs are not properly accounted for, since energy transmittance to the building is disregarded. It therefore fails to account for the benefits of glazing with high energy transmittance, aka Low-E glass, in minimizing heating needs.

Temperate climate: Strasbourg

Legal requirements (2018)

Uw-value: 1.9

g-value: Not considered in the legislation

0.7 is used for the calculations

Induced energy demand based on the energy balance:

Heating performance only: 44 KWh/m²
Heating and cooling combined: 71 KWh/m²

Alternative based on energy balance:

An efficient double glazing (Uw of 1.3 and g value of 0.6)[6] would cut heating needs by 2, while marginally reducing cooling needs.

Hot climate: Athens

Legal requirements (2010)

Uw-value: 3.0

g-value: Not considered in the legislation

0.8 is used for the calculations

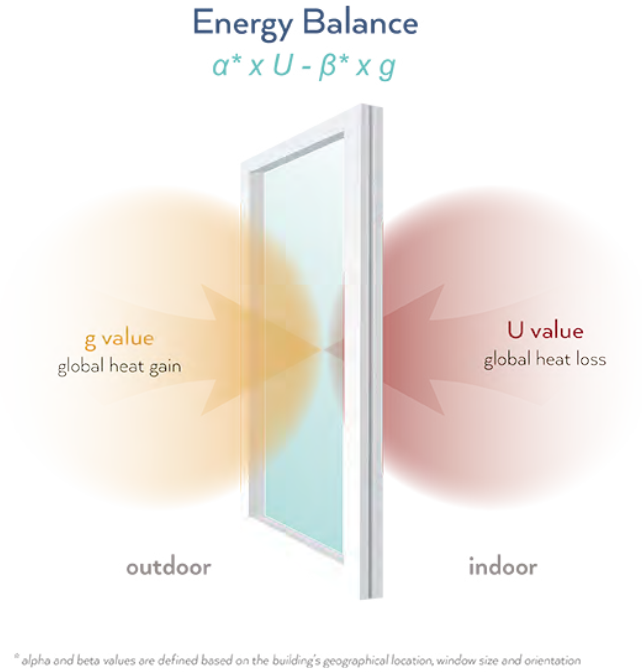
Induced energy demand based on the energy balance:

Heating performance only: -16 KWh/m²
Heating and cooling combined: 189 KWh/m²

Alternative based on energy balance:

A window with the same low insulation performance (Uw 3.0) but with solar protection glazing (g-value 0.35), would reduce cooling needs by over 50%.

Thanks to the use of the energy balance methodology, potential savings linked to new windows are better evaluated and windows offering the best mix of insulation and solar energy transmittance can be identified.



* alpha and beta values are defined based on the building's geographical location, window size and orientation

5 The energy balance model used for the calculations is presented in the Lot32 Ecodesign of windows product (2015) commissioned by the European Commission. All calculations and energy demand numbers are based on this model.
6 It must be noted that such a window can be considered energy-efficient for Strasbourg but is not either the highest performance available nor sold in this region of Fance. Triple glazing with solar control properties, provides even more savings.

Appendix 4

The distinctive benefits of glazing:
The social and economic contributions of glazed areas to sustainability in the built environment

Source: *The distinctive benefits of glazing: the social and economic contributions of glazed areas to sustainability in the build environment*, David Strong Consulting, 2012

We spend over 80% of our lives within buildings and numerous research studies have demonstrated that glazing has profound implications in terms of human health, happiness and productivity, including:

- quality of life, happiness and a sense of wellbeing
- health (and healing)
- ability to learn in educational establishments
- productivity whilst at work
- profitability and shopper-footfall in retail buildings

The non-energy related benefits associated with glazing are primarily linked to the following:

- The provision of daylight within buildings and/or access to sunlight
  - Enabling tasks to be undertaken, whilst also enhancing the spatial environment
- Establishing a link between the internal and external environment, by providing building occupants with a visual connection to the natural world outside the building
- The use of glazing as a structural façade element, aesthetic component and/or cultural art-form

Compelling, objective, independent research evidence regarding human health, happiness and wellbeing associated with glazing is presented in this report. Of particular importance are the findings from the healthcare and education sectors, together with emerging evidence regarding the importance of daylight in retail buildings and in providing a link to the natural world in homes.

- In healthcare, research findings demonstrate that access to daylight provides; a reduction in the average length of hospital stay, quicker post-operative recovery, reduced requirements for pain relief, quicker recovery from depressive illness and disinfectant qualities.
- In educational buildings access to daylight has been shown to result in a dramatic (and demonstrable) improvement in student academic achievement, behaviour, calmness and focus.
- In the workplace numerous studies have identified a preference to work near windows and under conditions which fully utilise natural rather than artificial light.
- In retail establishments, research shows that a substantial improvement in sales can be achieved in daylit shops.
- In buildings of all types, including in the residential sector, many of the studied benefits associated with daylight and connections to the outside world can be equally realised, thus contributing to sensations of well-being.

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Appendix 5

Daylight and glazing requirements in new constructions

Minimum glazing surface for genuinely sustainable buildings

Source: Glass for Europe, 2014

Glazed surfaces in buildings play a pivotal role to ensure the design and construction of genuinely sustainable buildings. The use of glass in constructions delivers economic, environmental and social objectives, all of which are central when defining sustainable buildings. In order to support a shift towards the design of genuinely sustainable buildings, **Glass for Europe calls on national and local decision makers to adapt thermal regulations and local urban planning regulations, to include minimum glazed surfaces in new constructions and major renovations**.

Thanks to continuous innovations, glazing solutions have achieved very high levels of energy performance while their environmental impacts throughout the life-cycle have been minimized. At the same time, **glazed surfaces in buildings maintain their distinctive feature (i.e. transparency), which allows them to provide to occupants of buildings both access to natural daylight and a visual connection with the external environment**. The positive effects of daylight and views to the outside world on human beings are widely researched and acknowledged: they improve comfort and sensations of well-being for occupants while providing a healthier indoor environment.

In order to sustain the development of genuinely sustainable buildings, Glass for Europe believes that building regulations and construction codes should adapt alongside improvements to construction materials and should build on scientific evidence to provide better places for building occupants. For this reason, Glass for Europe calls for

- **the inclusion of minimal glazed surface requirements within thermal regulations**
- **the deletion of outdated maximum glazed surfaces requirements[1] from local urban planning regulations**

Today, some European countries have already introduced a daylight factor and minimal glazing requirements within their national construction regulations. Glass for Europe welcomes the pioneering initiatives of countries such as France which requires a minimum 16% of glazed area for new residential constructions[2]. Nevertheless, there is still room for improvements since data show that between 20 and 30% of glazed surface would be the optimum for residential buildings depending on local climate.

1. Larger windows to design healthier and more comfortable buildings

Nowadays, people spend 80% of their lifetime within buildings whereas humans' quality of life strongly depends on daylight. Because humans are outdoor animals, **daylight plays a fundamental role in the body-clock synchronisation and the maintenance of a stable circadian rhythm**. All this considered, it is clear that access to daylight is vitally important and that concerns over occupants' health and well-being should predominate when setting requirements in the design of buildings. As demonstrated by a recent study from the *American Academy of Sleep Medicine* for example, workers without access to natural daylight *reported poorer scores than their counterparts on quality of life measures related to physical problems and vitality, as well as poorer outcomes on measures of overall sleep quality, sleep efficiency, sleep disturbances and daytime dysfunction.*[3]

There is a vast scientific literature on the benefits of natural daylight into buildings and views to the outside world. Studies in hospitals, schools and offices found the following:

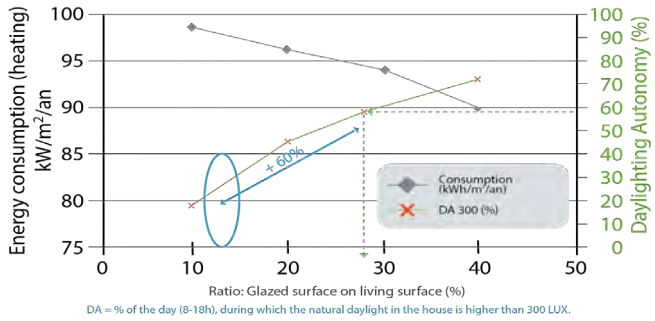
- in healthcare buildings: patients with access to natural daylight leave the hospital sooner, are less exposed to risk of post-operative depression and need less pain relief[4].
- in schools: students in buildings exposed to natural daylight achieve better scores, are calmer and more focused[5].
- in offices: the absence of windows has been connected to higher stress levels and increased absenteeism due to sick leave[6].

1 These requirements are based on the outdated assumption that glass is a weak point in buildings generating excessive heat losses in colder climates and overheating in warmer climates. This is no longer the case with readily available energy-efficient glazing solutions. Today, glass products provide the best energy balance of all building materials thus these outdated limitations need to be suppressed.
2 Ratio: glazed surface compared to living surface.
3 American Academy of Sleep Medicine, "Study links workplace daylight exposure to sleep, activity and quality of life." ScienceDaily. http://tinyurl.com/ngqhj3z
4 David Strong Consulting, *The distinctive benefits of glazing: the social and economic contributions of glazed areas to sustainability in the build environment*, 2012. http://tinyurl.com/kez68ny
5 Ibidem.
6 Ihab M.K. Elzeyadi, Ph.D., LEED Daylighting-Bias and Biophilia: Quantifying the Impact of Daylighting on Occupants Health, School of Architecture & Allied Arts - Uni-

The same benefits (i.e. well-being, quality of life, health benefits, etc.) are expected in residential buildings since homes are the places to provide rest and sleep.

2. Larger windows to improve energy efficiency in buildings

Energy and thermal simulations in different climate zones have demonstrated that enlarging the area of the external envelope occupied by high-performing windows **contributes to reducing the overall energy consumption of buildings**. As a matter of fact, in many existing low energy buildings across Europe, glass already plays an indispensable role in achieving high energy performance standards.



Modern glazing solutions are becoming more energy efficient than the opaque fabric, as they provide free solar heat gains (g value) while guaranteeing high thermal insulation (U value). As a result, enlarging high performing glazed surfaces can contribute to reducing energy consumption from both heating and cooling. In addition, if properly oriented, windows improve the daylight autonomy, thus lowering the need for artificial lighting[7]. The above simulation suggests that, depending on the local climate, between 20 and 30% of glazed surfaces compared to the floor ratio is the optimum to guarantee a good level of daylight autonomy and energy performance[8]. It is therefore no surprise that the highest energy efficient and most sustainable buildings recently built across Europe have larger glazed surfaces than average[9].

3. Larger windows to reduce buildings' environmental footprint

Glass is a sustainable material and contributes to minimizing the environmental footprint of buildings. The flat glass manufacturing process requires low quantities of water and generates very little waste. Inevitably, it has a cost in terms of energy use and CO_2 as the melting process requires the furnace to be heated to temperatures as high as 1650°C. Nevertheless, CO_2 generated during the manufacturing phase is more than compensated by the CO_2 saved by replacing inefficient glazing with high-performing windows. In addition, windows hold the smallest environmental footprint across all LCA indicators compared to other parts of the building envelope[10].

Technical recommendations on glazing in residential buildings

Glazing ratios in buildings are intended to optimize energy performance, to guarantee access to daylight and to improve natural ventilation in order to ensure the comfort and well-being of occupants, while reducing the overall environmental footprint. Below are listed key four principles that should guide architects and specifiers:

- A minimum of 20% of glazed surface compared to the floor area for residential buildings
- Multilateral glazing with different orientations to ensure access to natural daylight throughout the day
- Roof skylight windows to add more natural light and improve ventilation
- Interior glazing to allow natural light to flow throughout the building

versity of Oregon, Eugene, USA http://tinyurl.com/ocfk7cw
7 Studies of newly constructed Nearly-Zero Energy Buildings show that artificial lighting becomes one of the biggest source of energy consumption in buildings when the building's daylight autonomy has been neglected. BPIE, Principles for nearly Zero-Energy Buildings, 2011. http://tinyurl.com/ob95s58
8 Saint-Gobain's internal study. Simulation of thermal performance and glazed areas in residential buildings.
9 Glass for Europe, The smart use of glass in sustainable buildings, 2013. http://tinyurl.com/pd7ozx3
10 CIRCE, UNESCO, uniTwin, Tecnalia, Technical analysis in support of development of EU Ecolabel and GPP criteria for Office Buildings

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