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A Methodology for Accurate Embodied-Carbon Assessment of Insulating Glass Units using EPD Data

Mihail Istratii [a]

a GLF Facades, Ireland, mihailistratii@glf.ie

Abstract

Architectural glass accounts for approximately 26 % to 60 % of the total façade embodied carbon, depending on the façade typology and glazing configuration. Within the European Union the EN 15804 constitutes the core standard for the assessment of environmental impacts of construction products. The standard structures the data in a framework of four life cycle stages (A to D) and further separate these into seventeen modules. The Environmental Product Declarations (EPD's) are voluntary product labelling systems structured according to the modular framework defined in EN 15804. Using Global Warming Potential (GWP) values extracted directly from product specific glass EPD's the embodied carbon of any glass unit configuration can be calculated. Building upon the CWCT approach for embodied-carbon assessment of insulating glass units (IGU's), this paper introduces new expressions and a structured calculation workflow to support consistent use of EPD data in IGU embodied carbon calculations. The method also introduces revised embodied carbon factors for the IGU assembly process which are derived from a comparative assessment of available IGU EPD data. As a result, the proposed method generates EN 15804 compliant results and is implemented in an interactive spreadsheet, referred to as the Glass Embodied Carbon Calculator (Glass ECC) which provides a systematic framework for embodied-carbon assessment across different IGU configurations.

Keywords

Façade embodied carbon calculation, Glass carbon factors, Glass Environmental Product Declaration, Glass Embodied Carbon Calculator, Glass ECC.

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1. Introduction

Reducing greenhouse gas (GHG) emissions from the building sector is central to achieving the European Union's climate objectives set as 55% reduction in GHG emissions by 2030 and climate neutrality by 2050 (EU Climate Law 2021). Within the European Union, buildings account for approximately 36% of energy-related greenhouse gas emissions, which are mainly associated with operational energy used for heating, cooling, ventilation, lighting (European Commission 2024). In contrast, no such proportion is defined at EU level for emissions associated with construction materials and construction processes yet some studies indicate that embodied carbon represents an additional share of approximately 10–15% of total greenhouse gas emissions, and is expected to become increasingly significant as operational emissions decline (BPIE 2022).

Whole building Life Cycle Assessments (LCA) indicate that the façade systems typically contribute approximately by 15 - 30% of a building's total embodied carbon depending on typology and design (Ladipo 2022). Within façade systems, the proportion of embodied carbon attributable to glazing can range from approximately 26 % to 60% of total façade embodied carbon (Arup | Saint-Gobain Glass 2023) and hierarchically the glass is frequently identified as the second major contributor to façade related embodied carbon after the aluminium.

Against this background the glazing configuration becomes a critical design variable in balancing operational and embodied carbon impacts. The transition from single glazing to insulating glass units (IGUs) has reduced heat losses and associated operational carbon emissions where on the other hand it has also led to increased embodied carbon due to the addition of extra glass plies and ancillary components within the IGU assembly. As highlighted by Sanders and Nizich, the environmental benefit of more complex glazing systems is not solely determined by the in use energy performance, but is strongly influenced by assumptions regarding service life, replacement frequency, and end of life treatment.

2. Background

In September 2022, CWCT published the methodology for calculation of the embodied carbon in facades. The document provides an aligned method for the estimation of Global Warming Potential (GWP) indicator in façade assembly. Its primary aim is to equip designers with practical guidance for quantifying the embodied carbon emissions of façade systems and to support consistent application of LCA modules relevant to façades (CWCT 2022).

For the calculation of the embodied carbon associated with glass, the document presents a detailed analytical method in appendix C. This appendix emphasises that architectural glazing requires its own structured assessment because it follows a complex, multi stage manufacturing route that must be carefully accounted for in order to produce an accurate estimation (CWCT, 2022; Capelli et al., 2024).

Building on this methodology, CWCT introduced the Façade Carbon Emissions (FaCE) Tool in September 2025. The FaCE tool is an Excel-based calculator aligned with the CWCT methodology and is intended to enable early-stage comparison of façade options using standardised data inputs by calculating façade-level GWP.

Following the same principles, the Appendix C method can be further developed into a dedicated, automated standalone tool capable of hosting a comprehensive database of embodied-carbon factors for insulating glass unit (IGU) components derived exclusively from manufacturers' Environmental

Product Declarations (EPDs). Such a tool would automate the procedures defined in Appendix C and enable user-friendly assessments of a wide range of glazing build-ups using third-party-verified EPD data.

Many glass manufacturers already issue EPDs for individual glass products and for selected IGU configurations. In parallel the cloud-based IGU configurators normally used for energy performance calculations lately provide indicative embodied-carbon values for the selected glazing build-up. In the case of IGUs, these tools account only for the glass plies, excluding ancillary components such as spacers, sealants, coatings, interlayers. Also, the cloud based tools do not allow the selection of more specialised variants within he IGU the like painted glass or laminated glass with stiff interlayers. The proposed standalone tool aims to address these limitations by adding the options to build any ad-hoc IGU configuration that account for all constituent components using verified EPD data. This tool can also be incorporated in any other large scale façade carbon calculators like FaCE where it will allow the designers to incorporate transparent, verifiable glazing data within holistic façade carbon assessments.

3. Aim

The aim of this paper is to undertake an IGU carbon calculation in accordance with CWCT Appendix C method using GWP values solely from glass suppliers EPD's. It also aims to operationalise the method by translating the EPD data into a neutral cross manufacturer carbon estimation tool. This tool will enable designers to analyse and compare the EPD based embodied carbon of IGU's with different configurations.

4. Objective

To establish a clear analytical structure, the paper is organised around the following objectives:

- To outline the background of embodied carbon assessment for glazing systems, including an overview of the CWCT methodology
- To describe the CWCT Appendix C method, including the associated calculation expressions and sequencing
- To develop an IGU embodied carbon assessment methodology based on EPD data, including definition of the calculation workflow and expressions
- To review the embodied carbon factors associated with IGU production and assembly
- To implement the proposed methodology in an interactive spreadsheet that will enable embodied carbon assessment of different IGU with configurations

5. Previous research

Current studies demonstrate that glazing systems represent a significant contribution to the embodied carbon of building façades. Davis and Scherer (2023) emphasise that the embodied carbon of IGUs is influenced by glass build-up, coatings, and component selection. Also available façade LCA studies confirm that glass frequently constitutes one of the dominant contributors to upfront embodied carbon. Notwithstanding this the glass as a material is still commonly modelled using aggregated datasets and simplified representations (Li et al. 2026) and although the available EPD's provide product-specific environmental data for glass, their direct use at IGU level remains inconsistent. Gargano (2025) identifies that glazing-related assumptions, system boundaries, and functional units are often insufficiently defined in façade LCAs. In similar manner Culp (2024) highlights that EPDs for architectural flat glass are "frequently misunderstood or misapplied", noting that variations in scope, declared units, and lifecycle modules can result in misleading comparisons if not carefully harmonised.

6. Insulating Glass Unit (IGU) components

An insulating Glass Units (IGU) is a multilayered sealed glazing assembly used as transparent element in building facades. It consists of two or more glass panes separated by a hermetically sealed cavity which is normally filled with air or inert gas. To create the intermediate gap for the gas fill the glass panes are held apart by a perimetral spacer and are bonded along the unit perimeter to the spacer bar with a dual-seal system. The primary sealant bonds the spacer bar to the glass with the function of blocking the passage of gas and vapour. The secondary seal bonds the glass panes together and ensure the transfer of mechanical loads.

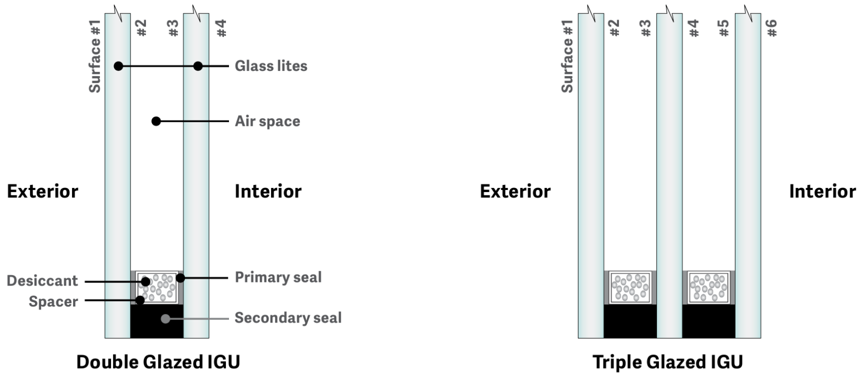

Fig. 1: Double and triple IGU configurations examples (Guardian Glass 2020).

7. Life Cycle Assessment framework

The Life Cycle Assessment (LCA) provides the framework for the assessment of environmental impacts of construction products. The core standard for this method is EN 15804 which organises all product emissions into distinct 4 life cycles stages and 17 modules. Because this study relies on EPD data the modules from EN 15804 are critical to follow as each European based manufacturer disclosure aligns with this standard. The CWCT method follows the EN 15804 workflow by applying façade specific interpretation and prescribing a minimum module scope of A1-A5, B4, and C1 to C4. This framework is essential for cross manufacturer data use and comparability of the results.

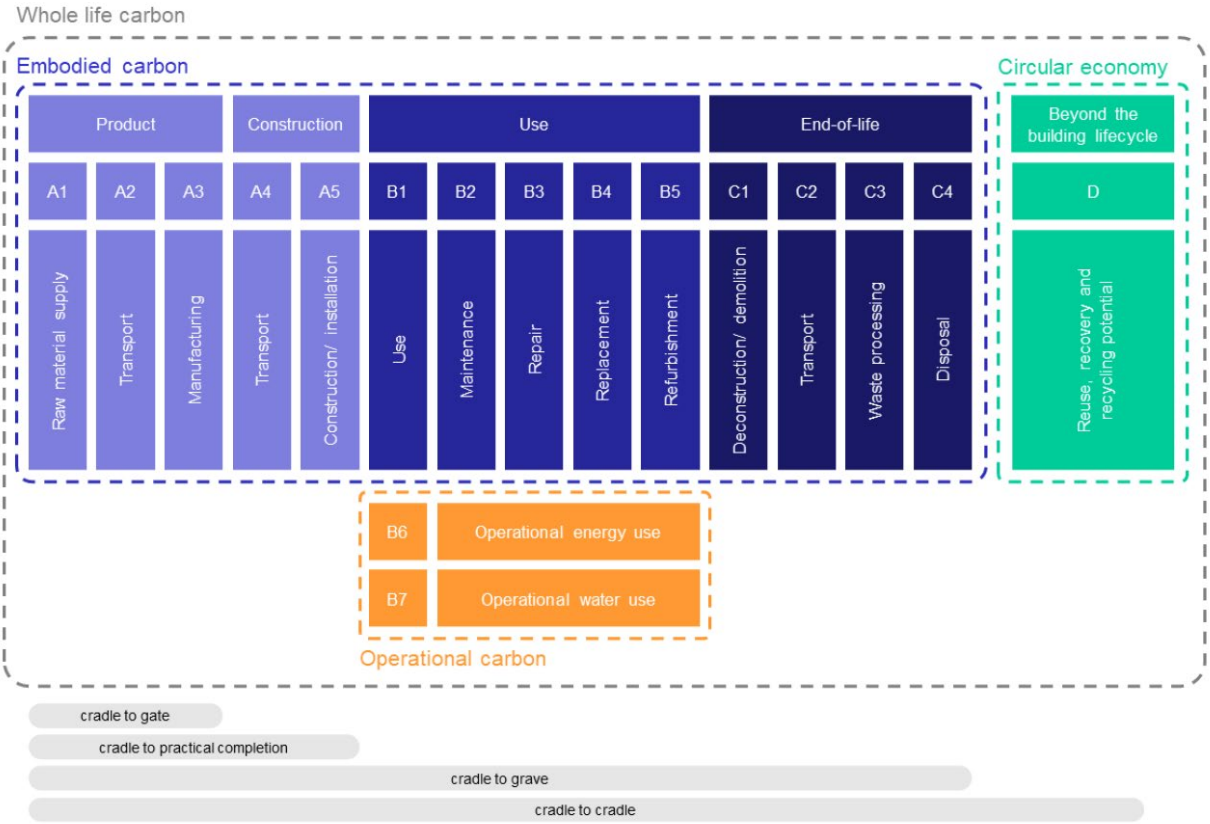

Fig. 2: Life cycle framework as per EN 15804 (CWCT, 2022).

8. EPD review

An Environmental Product Declaration reports on the product environmental impact using verified life cycle assessment data in accordance with EN 15804. It is a voluntary product label system where the results are presented in the standardised modular format allowing for common comparison across the construction products. The data in an EPD is independently reviewed and expressed using the environmental indicators and system boundaries defined in EN 15804. (CWCT 2021, IGBC 2012)

For construction products, the EPD must confirm with EN 15804 or ISO 21930 and must have at least cradle to gate scope

The CWCT Appendix C method states that the most reliable approach to quantify the embodied carbon of insulating glass units is to extract the carbon factors directly from the product specific EPD. By doing this means that the emissions used are third party verified and EN 15804 compliant offering a transparent and traceable data outcome

To ensure transparency and defensible boundaries this study refers to carbon values derived from EPD's based on European manufacturers only. This includes the materials produced and processed within Europe ensuring consistency in transport and material sourcing. At the same time all the EPD used are compliant with EN 15804 and each is reviewed to confirm the manufacturing facility and transport assumptions.

Europe has no official benchmark for glass carbon content instead for GWP reporting on construction products within the European Union the EN 15804 require the manufacturers to provide Type III EPD's.

To ensure the emissions extracted are accurate the following workflow is proposed when screening an EPD:

- Identify the EPD product description and declared functional unit
- Verify compliance with EN 15804
- Check geographical relevance
- Confirm third party verification and validity period
- Extract GWP-total indicator for the required modules and use the values as Embodied Carbon Factor (ECF) in the calculation

9. CWCT general method

The CWCT methodology defines a façade specific LCA framework that aligns with EN 15978 and requires the designers to quantify the façade emissions across the LCA modules defined in EN 15804. The assessment is based on a façade representative area and is focused on the estimation the Global Warming Potential (GWP) environmental impact indicator only.

The methodology outlines three assessment approaches for the embodied carbon in the facades which are the precedent studies approach, the simplified approach and the full approach. The first method refers to a simplistic assessment using precedent similar projects, the second considers only key materials and components of the façade where the third approach evaluates the full range of the façade materials involved.

The embodied carbon of a particular element is estimated by taking its mass and multiplying it by the embodied carbon factor (ECF) assigned to the relevant module. The embodied carbon factor (ECF) ideally should be sourced from the material EPD (i.e. GWP total) or in the absence of this from a reliable open-source database. Numerically the embodied carbon of a construction element can be expressed as follows:

$$Embodied\ Carbon\ (EC) = \sum_i (Mass\,(Q_i) \times Embodied\ Carbon\ Factor\,(ECF_i)) \qquad (1)$$

For the project preliminary stages the method also introduces the notion of the scale-up factors which is a representative of the uncertainties regarding project specifics in early design. The method also anticipates that when the supply chain is known these factors should be no longer required as the exact product carbon factors can be obtained from the manufacturer EPD’s.

10. CWCT IGU method - Appendix C

The CWCT Appendix C provides a supplementary IGU specific method for the calculation of the embodied carbon of architectural glass. It refines the general approach by further breaking the IGU into different components by listing all the processes involved in the manufacturing of specific glazing configuration (CWCT, 2022). For product stage (A1-A3), the methodology encourages the use of carbon factors from existing EPD’s where these are available. In the absence of this data the appendix lists a series of Embodied Carbon Factors (ECF) derived from available EPDs. The appendix also provides formula based procedures that can be used to approximately estimate the carbon content for a particular component or processes involved. Table 1 summarizes the recommended factors.

Table 1: ECF from CWCT Appendix C for different IGU components and manufacturing processes (CWCT, 2022).

Item	Material/process	Embodied Carbon Factors (ECF)
1	Float glass, mid-iron	$ECF_{FL,t,mi}$ = 2.96 kgCO2e/m^2/mm
2	Float glass, low-iron	$ECF_{FL,t,li}$ = 3.16 kgCO2e/m^2/mm
3	Magnetron coating process	ECF_C = 0.91 kgCO2e/m^2
4	Heat treatment process (variable factor)	$ECF_{P,v}$ = 0.47 kgCO2e/m^2/mm
5	Heat treatment process (fixed factor)	$ECF_{P,f}$ = 2.79 kgCO2e/m^2/mm
6	PVB interlayer material, 0.38 mm	ECF_{INT} = 2.74 kgCO2e/m^2
7	Lamination process	ECF_{LAM} = 0.50 kgCO2e/m^2
8	Assembly, DGU	$ECF_{Assembly}$ = 12 kgCO2e/m^2
9	Assembly, TGU	$ECF_{Assembly}$ = 24 kgCO2e/m^2

To exemplify the use of tabulated ECF, the embodied carbon of a monolithic glass pane is obtained by multiplying the relevant ECF to the thickness of the ply which in result gives the ECF pe square meter.

$$ECF_{FL} = t\ x\ ECF_{FL,t} \tag{2}$$

where:

ECF_{FL} – embodied carbon factor of float glass (kgCO2e/m2)

t – thickness of the glass substrate as designed (mm)

To account for the tempering the embodied carbon as a result of this process is estimated as follows

$$ECF_P = ECF_{P,f} + (t\ x\ ECF_{P,v}) \tag{3}$$

where:

ECF_P – embodied carbon factor of the tempering process (kgCO2e/m^2)

The total embodied carbon of a monolithic glass ply accounting for any potential post processing can be estimated by summing the results of equation (2) and (3)

$$ECF_{A1-3,M} = ECF_{Fl} + ECF_C + \sum_{i=0}^{n} ECF_{P,i} \tag{4}$$

where:

$ECF_{A1-3,M}$ – embodied carbon factor of monolithic glass pane (kgCO2e/m^2)

ECF_C – embodied carbon factor related to the application of a performance coating (kgCO2e/m^2)

n – number of processes applied to the glass pane

In the case of laminated glass the ECF for interlayer and lamination process should be accounted for and added to the equation (4)

$$ECF_{A1-3,L} = \sum_{i=0}^{m}(ECF_{A13,M,i}) + ECF_{LAM} + (z\ x\ ECF_{INT}) \tag{5}$$

where:

$ECF_{A1-3,L}$ – embodied carbon factor of laminated glass pane (kgCO2e/m^2)

m – number of monolithic glass sheets that are being laminated, as calculated in (2) (3) and (4)

z - number of interlayers used (assume 0.38 mm as base unit)

Finally, for the total embodied carbon of the IGU assembly the ECF for all the panes is added to the carbon factor of the IGU assembly process

$$ECF_{IGU} = \sum_{i=0}^{k}(ECF_{A13,i}) + ECF_{Assembly} \tag{6}$$

where:

ECF_{IGU} – embodied carbon factor (A1-A3) of the assembled IGU (kgCO2e/m^2)

To note that the method does not provide ECF for the IGU spacer bar and edge sealants. These are accounted as an uplift factor within the $ECF_{Assembly}$. Also the method does not provide any ECF for the processes like glass cutting, edge working, gas filling, Heat Soak Testing, printing, bending of the glass due to lack in data availability at the time of publication.

11. Carbon factors from EPD

To estimate the IGU embodied carbon using EPD data the first step is to collect data. Following on the data must be normalised. The GWP for glass elements is normally given per one meter square per declared thickness. The GWP of the spacer bars is always disclosed pe linear meter of the product and the emissions of the edge sealants is given per one kilogram of the sealant product. To accurately use these units the calculation should be carried out per IGU functional unit in order to account for the full perimeter length of the IGU and also for the volume of the sealant. Following is a non-exhaustive comparison of the GWP factors for the IGU components extracted from valid EPD's published by the reputable European manufacturers.

Table 2: GWP comparison for 8.8 Laminated basic uncoated float glass considering plies with average and low embodied carbon glass – LCA stage A1-A3, $kgCO2eq/m^2$.

Glass manufacturer	Glass range	GWP (A1-A3) Average glass	GWP (A1-A3) Low carbon glass	EPD reference	Valid to
AGC	Stratobel/St	26.5	15.1	20240940457-FC_95237_1121042 20240940458-FC_95151_264	31.12.2029 31.12.2029
Euroglass	Eurolamex	22.9	-	EPD-GLS-20230183-IBB3-EN	04.02.2029
Guardian Glass	Laminated/NEXA 6	24.4	17.7	4791438322.104.1 4791438322.105.1	29.08.2029 29.08.2029
Pilkington/NSG	Optilam/Mirai Optilam	32.3	19.8	S-P-08826 EPD-IES-0024746	30.04.2028 16.01.2031
Saint-Gobain	Stadip/Stadip ORAE	28.6	16.8	S-P-00882 EPD-IES-0024289	14.12.2026 11.06.2030

Table 3: GWP comparison for a 16 mm wide spacer bar – LCA stage A1-A3, kgCO2eq/linear meter.

Spacer bar manufacturer	Type	GWP (A1-A3)	EPD reference	Valid to
ALU PRO	Aluminium spacer H65	0.573	S-P-08910	23.03.2028
ALU PRO	Chromatech Ultra F	0.168	S-P-08910	23.03.2028
ALU PRO	Multitech G	0.211	S-P-08910	23.03.2028
Swisspacer	Advance	0.140	EPD-IES-0011836:001	15.12.2029
Swisspacer	Ultimate	0.142	EPD-IES-0011837:001	15.12.2029
Technoform	Warm edge spacer	0.22	S-P-10425	11.12.2028

Table 4: GWP comparison for primary and secondary sealant – LCA stage A1-A3, kgCO2/kg.

Sealant manufacturer	Type	GWP (A1-A3)	EPD reference	Valid to
Dow Corning	Silicone: DOWSIL DC 3363, DC 993	5.31	EPD-DBC-DOW-20240218-IBF1-EN	30.08.2027
Sika	Silicone: IG-25, IG-25 HM Plus	5.31	EPD-DBC-20220179-IBF1-EN	30.08.2027
Fenzi	Polysulphide: Thiover	1.42	EPD-IES-13059:001	25.07.2029
FEICA,IVC,DBC	Polysulphide	6.03	EPD-FEI-20250067-IBP1-EN	03.06.2030
Fenzi	PIB: Butylver	3.56	EPD-IES-13054:001	25.07.2029
FEICA,IVC,DBC	Products based on butyl chemistry PIB	4.49	EPD-FEI-20250068-IBP1-EN	03.06.2030

12. Embodied carbon per IGU components

To estimate the glass embodied carbon per functional unit the GWP figure from each EPD and for each component should be multiplied by the relevant quantity of material contained within the considered declared unit. The expression (7) is an alternative to the equations (1) to (5) and can be used to obtain the EC for any insulating glass unit composition.

$$EC_{OP/MID/IP} = GWP_{GL,Ai-An}\ x\ Q \tag{7}$$

where:

$EC_{OP/MID/IP}$ – embodied carbon of outer, middle or inner pane per square meter of the declared thickness (kgCO2e/m^2)

$GWP_{GL,Ai-An}$ – Global Warming Potential of the material for the corresponding modules (kgCO2e/m^2)

A_i and A_n – means the first and last module the GWP value corresponds to

Q – quantity (kg or m^2)

For the calculation of the embodied carbon associated with the spacer bar the GWP is multiplied with the overall length used within the unit.

$$EC_{SB} = GWP_{SB,Ai-An}\ x\ P_{IGU} \tag{8}$$

where:

EC_{SB} – total embodied carbon per functional unit associated with the spacer bar (kgCO2e)

$GWP_{SB,Ai-An}$ – GWP of the of the spacer bar for the corresponding modules (kgCO2e/m)

P_{IGU} – perimeter of the IGU functional unit considered in the calculation (m)

To account for the emissions associated with the use of edge sealants the GWP figure should be multiplied by the overall volume of sealants contained within the functional unit.

$$EC_{PS,SS} = GWP_{PS,SS,Ai-An}\ x\ t\ x\ b\ x\ \rho\ x\ P_{IGU} \tag{9}$$

where:

$EC_{PS/SS}$ – total embodied carbon per functional unit associated with the primary sealant (kgCO2e)

$GWP_{PS,SS,Ai-An}$ – GWP of the of the sealants for the corresponding modules (kgCO2e/kg)

P_{IGU} – perimeter of the IGU functional unit considered in the calculation (mm)

t – sealant thickness (mm)

b – sealant bite (mm)

ρ – sealant density (kg/mm^3)

13. Embodied Carbon Factors associated with IGU production

For the IGU processing factors the CWCT Appendix C specifies two default values of 12 and 24 kgCO2e/m2 to be used as carbon factors for the double and triple IGU assembly process. The method does not refer to any background information or scale up factors used in the derivation of these two magnitudes. Using IGU available EPD's these factors can be verified by referring to the emission associated with the IGU processing which can be found in any published IGU EPD under the module A3 manufacturing. The difficulty with this approach is that the modules A1 to A3 are always declared together. IGU EPD's suppliers never break out the A1, A2, A3 individually and never show process-level contributions separately, they only give A1–A3 combined. However the A3 can be obtained if A1 and A2 are known where to obtain these the following steps are proposed:

- Step 1 is to extract the IGU A1-A3 GWP value from the IGU EPD $(A1\ A2\ A3)_{IGU,EPD}$ which will reflect the total cradle to gate impact for the finished product, $EC_{IGU,EPD}$
- Step 2 is to identify all the components used in the IGU make, glass, spacer bar, sealants ($A1_i + A3_i$) and extract their own A1-A3 GWP emissions from their own EPD's.
- Step 3 is to subtract the GWP for the components from the GWP of the IGU

$$EC_P = EC_{A3,IGU} = (A1\ A2\ A3)_{IGU,EPD} - \sum(A1_i + A3_i)_{all\ components} \tag{10}$$

Table 5 summarizes the results of a comparative study across some double and triple IGU configurations using GWP A1-A3 emissions from their EPD in order to determine the emissions associated with the A3 module which can be further used as processing factor (ECF_P).

Table 5: Calculation of Embodied Carbon Factor associated with IGU productions (EC_P) following comparative study across IGU EPD.

IGU Name	Mass/ m^2	EC_{IGUEPD}	GWP_{OP} A1-A3	GWP_{MI} A1-A3	GWP_{IP} A1-A3	GWP_{SB} A1-A3	GWP_{PS} A1-A3	GWP_{SS} A1-A3	ECF_P A3,IGU
Thermobel 4-16-4	20	34.8	12.7		10.6	0.67	0.09	1.06	9.7
LC Thermobel 4-16-4	20	21	6.1		5.5	0.67	0.09	1.06	7.6
Insulight 4-16-4	20	33.5	11.04		11.08	0.67	0.09	1.06	9.6
Insulight 6-16-6	30	25.8	8.89		8.1	0.67	0.13	1.59	6.4
CLIMAPLUS 4-16-4	20	32.6	11.9		10.90	0.67	0.09	1.06	8.0
CLIMAPLUS 6t-16-6	30	48.7	21.7		16.30	0.67	0.13	1.59	8.3
	Average ECF_P A3,IGU for double glazed unit								8.2
Thermobel 4-16-4-16-4	30	53.1	12.7	10.6	10.6	1.34	0.27	4.25	13.3
LC Thermobel 4-16-4-16-4	30	32.1	6	5.1	5.1	1.34	0.27	4.25	10.0
Insulight 4-12-4-12-4	30	49.8	11.04	11.04	11.08	1.34	0.27	4.25	10.8
Insulight, 6-12-6-12-8.8	50	103.5	25.6	25.6	31	1.34	0.45	7.08	12.4
CLIMATOP 4-16-4-16-4	30	52.7	11.9	10.9	10.9	1.34	0.27	4.25	13.1
CLIMATOP 6t-16-6-16-6t	45	77.9	21.0	16.3	21.0	1.34	0.40	6.37	11.5
	Average ECF_P A3,IGU for triple glazed unit								11.9

The final column of Table 5 reports the A3 module embodied carbon emissions for IGU with average values of 8.2 $kgCO_2/m^2$ for double glazed units and 11.9 $kgCO_2/m^2$ for triple glazed units. For both configurations approximately 67 % of the total embodied carbon is attributable to the glass mass, with the remaining associated with ancillary components and manufacturing process.

When compared with the embodied carbon factors for the IGU assembly process defined in CWCT Appendix C and namely 12 $kgCO_2/m^2$ for double glazed units and 24 $kgCO_2/m^2$ for triple glazed units, the values derived in Table 5 using EPD data are substantially lower. To note that the results are based on EN 15804 compliant EPD's and directly reflect the reported manufacturing emissions.

To maintain a conservative approach and account for variability and uncertainty in the available EPD data and the method used, the derived average values of 8.2 $kgCO_2/m^2$ and 11.9 $kgCO_2/m^2$ have been rounded to 10 $kgCO_2/m^2$ and 15 $kgCO_2/m^2$, respectively. This corresponds to scaling factors of 1.21 for double glazed units and 1.26 for triple glazed units.

On this basis, revised embodied carbon factors for the IGU assembly process of 10 $kgCO_2/m^2$ for double glazed units and 15 $kgCO_2/m^2$ for triple glazed units are proposed for use within the present methodology in place of the higher default values provided in CWCT Appendix C.

Table 6: Summary of the embodied carbon factors for the IGU assembly process. As per CWCT Appendix C and proposed.

	Embodied carbon factor for the IGU assembly process, ($kgCO2/m^2$) CWCT Appendix C, (CWCT, 2022)	Proposed embodied carbon factor for the IGU assembly process ECF_P ($kgCO2/m^2$)
Double glazed insulating unit	12	10
Triple glazed insulating unit	24	15

14. Embodied Carbon of an Insulating Glass Unit using EPD data

Using the data estimated with the help of expression (7) to (10) the total embodied carbon of an Insulating Glass Unit (EC_{IGU}) is calculated by summing the contributions of the individual IGU component according to equation (11)

$$EC_{IGU} = EC_{OP/MID/IP} + EC_{SB} + EC_{PS} + EC_{SS} + EC_P \quad (11)$$

Based on expressions (7) to (11), the GWP data extracted from multiple European EPDs have been implemented in an interactive spreadsheet referred to as the Glass Embodied Carbon Calculator (Glass ECC). The tool enables the calculation of embodied carbon for a wide range of glazing configurations by using the EPD based emission factors. This implementation facilitates rapid comparison of alternative IGU build-ups and supports practitioners in assessing the embodied-carbon implications of different glass specifications. In addition to standard glazing configurations, the calculator allows for the inclusion of painted glass, laminated glass with ionoplast interlayers, fire-rated glass, edge-sealants and spacer-bar types. The Glass ECC spreadsheet is provided as a practical implementation of the proposed methodology and is made available by the authors.

15. Conclusions

The paper addressed the assessment of embodied carbon in IGU's within the context of façade systems for which glazing has been identified to represent a substantial proportion ranging in between 26 % to 60 % of the total façade embodied carbon.

Based on the CWCT framework for embodied carbon assessment of IGU, new expressions and a structured calculation workflow have been introduced to enable consistent use of EPD data when performing IGU embodied carbon calculations. The methodology separates the IGU into components and accounts separately for glass panes, spacer bars, sealants. It further incorporates revised embodied carbon factors for the IGU assembly process which were derived from a comparative assessment of available IGU EPD data.

Following the proposed methodology, the embodied carbon results obtained are compliant with EN 15804, and the calculation framework has been implemented in an interactive spreadsheet referred to as the Glass Embodied Carbon Calculator (Glass ECC) which will enable systematic assessment of embodied carbon across different IGU configurations.

References

AGC Glass Europe. (2024). *Magnetron coated glass – 20240940457-FC_95237_1121042*. EPD International (The International EPD® System)

ALU-PRO Srl. (2023). CHROMATECH ULTRA F, ALUMINUM SPACER H65, MULTITECH G, THERMIX TX PRO. Environmental Product Declaration, Registration No. S-P-08910. The International EPD® System.

Arup & Saint-Gobain Glass (2021). *Carbon footprint of façades: significance of glass – Findings from the life cycle assessment of 16 façade typologies & 18,000 design simulations.* Arup & Saint-Gobain Glass. (Accessed 22 January 2026)

BPIE (2022): Towards embodied carbon benchmarks for buildings in Europe. Buildings Performance Institute Europe, Brussels.

Capelli, M., Botti, A., Garoni, A. & Conserva, F. (2024). *Measuring and reducing embodied carbon in the building envelope*. BUILD UP – The European Portal for Energy Efficiency in Buildings. Available at: https://buildup.ec.europa.eu/en/resources-and-tools/articles/measuring-and-reducing-embodied-carbon-building-envelope (Accessed 1 March 2026).

Culp, T.: Embodied carbon and environmental product declarations for architectural flat glass. National Glass Association / New York State Office of General Services Technical Seminar (2024)

European Parliament and Council of the European Union: Regulation (EU) 2021/1119 of the European Parliament and of the Council of 30 June 2021 establishing the framework for achieving climate neutrality and amending Regulations (EC) No 401/2009 and (EU) 2018/1999 (European Climate Law).

European Commission: Directive (EU) 2024/1275 of the European Parliament and of the Council of 24 April 2024 on the energy performance of buildings (2024).

I.S. EN 15978:2011 Sustainability of construction works — Assessment of environmental performance of buildings — Calculation method. National Standards Authority of Ireland, Dublin (2011).

I.S. EN 15804:2012+A2:2019/AC:2021 Sustainability of construction works — Environmental product declarations — Core rules for the product category of construction products. National Standards Authority of Ireland, Dublin (2021).

Centre for Window and Cladding Technology (CWCT) (2022). *How to calculate the embodied carbon of facades: A methodology. Issue 1, September 2022.* Bath, UK: Centre for Window and Cladding Technology. (Accessed 1 March 2026)

CWCT: *How to read an EPD.* Centre for Window and Cladding Technology, Bath (2021)

Davis, C., Scherer, C.: Sustainable glass architecture through IGU and window technology. In: Proceedings of Glass Performance Days (GPD 2023), Tampere (2023)

DOW Europe GmbH (2024). *Environmental Product Declaration: DOWSIL™ silicone-based products, group 1 (including DOWSIL™ 791, 796, 798, 813C, Firestop 700, 813FR, 895, 993, 994, 3362, 3363).* Institut Bauen und Umwelt e.V. (IBU). Declaration No. EPD-DBC-DOW-20240218-IBF1-EN. Issue date: 08 July 2024; Valid to: 30 August 2027. Available at: https://epd-online.com

Fenzi Group: Environmental Product Declaration – BUTYLVER polyisobutylene sealants for insulating glass units. EPD-IES-13054:001, The International EPD® System, EPD International AB, Stockholm (2024). Valid until 25 July 2029.

Fenzi Group (2024). *Environmental Product Declaration: High-quality polysulphide sealants for IGU (THIOVER range)*. The International EPD® System. Registration No. EPD-IES-13059:001. Publication date: 25 Jul 2024; Valid to: 25 Jul 2029. Available at: https://www.fenzigroup.com/public/documents/epd-ies-13059.001_-_thiover.pdf (Accessed: 11 February 2026)

FEICA; IVK; DBC (2025). *Environmental Product Declaration: Products based on polysulfides.* Institut Bauen und Umwelt (IBU). Declaration No. EPD-FEI-20250067-IBP1-EN. Issue date: 04 Jun 2025; Valid to: 03 Jun 2030. Available at: https://epd-online.com/Epd/PdfDownload?id=24236 (Accessed: 28 February 2026).

FEICA; IVK; DBC (2025). *Environmental Product Declaration: Products based on butyl chemistry.* Institut Bauen und Umwelt (IBU). Declaration No. EPD-FEI-20250068-IBP1-EN. Issue date: 04 Jun 2025; Valid to: 03 Jun 2030. Available at: https://epd-online.com/Epd/PdfDownload?id=24235&stat=true (Accessed: 02 February 2026).

IGBC: Measuring the sustainability of our construction products and materials. Irish Green Building Council, Dublin (2012).

Glas Trösch Holding AG. (2024). *Laminated safety glass EUROLAMEX – EPD GLS 20230183 IBB3 EN*. Institut Bauen und Umwelt (IBU).

Gargano, F.: Decarbonizing curtain wall façades: a life-cycle approach to embodied and operational carbon. Master's thesis, Politecnico di Torino (2025)

Guardian Glass (2020). *Expert Series: Insulating Glass – The History, Evolution and Mechanics of the IGU*. Guardian Glass, LLC. Available at: *brochure_expert_series_EN_doc3_igu_2020.pdf* (Accessed 1 March 2026).

Ladipo, T.: Facing up to embodied carbon in façades. CIBSE Journal, June 2022.

Li, X., Motalebi, M., Irger, M., Andrade, J., McCarthy, T., Heffernan, E., Rashidi, A.: Integrated BIM–LCA–optimization for decarbonizing curtain wall façades under carbon pricing uncertainty. Building Research & Information (2026).

Saint-Gobain Glass France. (2024). *Coated glass product EPD – 4791438322.104.1*. EPD International (The International EPD® System).

Saint-Gobain Glass. (2023). *Magnetron coated glass on ORAÉ / PLANILUX – S-P-08826*. EPD International (The International EPD® System).

Saint-Gobain Glass Industry. (2021). *PLANICLEAR® float glass 2–19 mm – S-P-00882*. EPD International (The International EPD® System).

Saint-Gobain Glass Industry (2021). *Environmental Product Declaration: STADIP® (PROTECT/SILENCE).* The International EPD® System, EPD No. S-P-00930. Available at: https://www.environdec.com/library/epd930 (Accessed 28 February 2026).

Technoform Edge Bond Solutions Singapore Pte Ltd. (2023). *Warm Edge Spacer SP12, SP13, SP14.* Environmental Product Declaration, Registration No. S-P-10425. The International EPD® System.

Vetrotech Saint-Gobain (International) AG. (2024). *Swisspacer Advance warm-edge spacer bars (6–56 mm).* Environmental Product Declaration, Registration No. EPD-IES-0011836:001. The International EPD® System.%20en.pdf)

Vetrotech Saint-Gobain (International) AG. (2024). *Swisspacer Ultimate warm-edge spacer bars (6–56 mm).* Environmental Product Declaration, Registration No. EPD-IES-0011837:001. The International EPD® System.%20en.pdf)

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