**ENVIRONMENTAL** PRODUCT DECLARATION

# ELECTROCHROMIC INSULATING GLASS UNIT (IGU)

SAINT-GOBAIN SAGEGLASS
DOUBLE PANE AND DOUBLE PANE VARIO IGU

*(Photo © Jeffrey Totaro, 2015, SageGlass installed at Saint-Gobain's Platinum LEED® certified headquarters, Malvern, PA)*

SageGlass Electrochromic Insulating Glass Unit provides a dynamic control of the admission of the sun's light and heat into buildings while maintaining the view to the outside.

SageGlass
SAINT-GOBAIN

At Saint-Gobain we are committed to providing sustainable building products and to limiting our impacts on the environment while doing so. (See our CSR at https://www.saint-gobain.com/en/corporate-responsibility.)

We are also committed to market transparency through third party verified EPDs. In 2016, Saint-Gobain became the group with the most EPDs registered in the International EPD System. This third party verified EPD for SageGlass continues that commitment.

SageGlass® electronically tintable glass (or electrochromic (EC) glass) has been shown to significantly reduce energy use and peak demand in buildings and it is a key component of the US DOE's road map for net zero energy façade systems.

And because SageGlass® insulating glass eliminated the needs for additional mechanical shading systems, it can help reduce the overall environmental impact of buildings.

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# ENVIRONMENTAL PRODUCT DECLARATION

**SageGlass Electrochromic Insulating Glass Unit**
Double Pane and Double Pane VARIO

**According to ISO 14025, ISO 2193:2007 and EN 15804**

This declaration is an environmental product declaration (EPD) in accordance with ISO 14025. EPDs rely on Life Cycle Assessment (LCA) to provide information on a number of environmental impacts of products over their life cycle. Exclusions: EPDs do not indicate that any environmental or social performance benchmarks are met, and there may be impacts that they do not encompass. LCAs do not typically address the site-specific environmental impacts of raw material extraction, nor are they meant to assess human health toxicity. EPDs can complement but cannot replace tools and certifications that are designed to address these impacts and/or set performance thresholds – e.g. Type 1 certifications, health assessments and declarations, environmental impact assessments, etc. Accuracy of Results: EPDs regularly rely on estimations of impacts, and the level of accuracy in estimation of effect differs for any particular product line and reported impact. Comparability: EPDs are not comparative assertions and are either not comparable or have limited comparability when they cover different life cycle stages, are based on different product category rules or are missing relevant environmental impacts. EPDs from different programs may not be comparable.

| | |
|---|---|
| PROGRAM OPERATOR | UL Environment |
| DECLARATION HOLDER | SAGE Electrochromics, Inc-Saint Gobain |
| DECLARATION NUMBER | 4789086899.101.1 |
| DECLARED PRODUCT | SageGlass Electrochromic Insulating Glass Unit<br>Double Pane and Double Pane VARIO |
| REFERENCE PCR | UL Part B Process Glass, Version 1.0, 2016 |
| REFERENCE PCR STANDARD | ☒ EN 15804 (2012)<br>☒ ISO 21930 (2007)<br>☐ ISO 21930 (2017) |
| DATE OF ISSUE | January 1, 2020 |
| PERIOD OF VALIDITY | 5 Years |
| CONTENTS OF THE DECLARATION | Product definition and information about building physics<br>Information about basic material and the material's origin<br>Description of the product's manufacture<br>Indication of product processing<br>Information about the in-use conditions<br>Life cycle assessment results<br>Testing results and verifications |

| | |
|---|---|
| The PCR review was conducted by: | PCR Review Panel<br>Thomas Gloria-Chair<br>epd@ulenvironment.com |
| This declaration was independently verified in accordance with ISO 14025 by Underwriters Laboratories<br>☐ INTERNAL ☒ EXTERNAL | Grant R. Martin<br>Grant R. Martin, UL Environment |
| This life cycle assessment was independently verified in accordance with ISO 14044 and the reference PCR by: | Thomas S. Gloria<br>Thomas P. Gloria, Industrial Ecology Consultants |

This EPD conforms with ISO 21930:2007 & EN 15804

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**SageGlass Electrochromic Insulating Glass Unit**
Double Pane and Double Pane VARIO

According to ISO 14025

## Comparability

As instructed by the PCR, comparison of the environmental performance of processed glass using EPD information shall be based on the product's use and impacts at the building level, and therefore EPDs may not be used for comparability purposes when not considering the building energy use phase. Full conformance with the PCR for North American Process Glass allows EPD comparability only when all stages of the processed glass life cycle have been considered, which is not permitted under this PCR. However, variations and deviations are possible.

# Product Documentation

## Product Description

The SageGlass electrochromic insulating glass unit (IGU) is a type of dynamic glazing for use in buildings which tints automatically or on demand to control sunlight admission, controlling heat and glare, while maintaining a view to the outdoors and reducing energy consumption. The dynamic functionality is provided by the SageGlass electrochromic coating which is located on the cavity facing surface of the exterior lite of the insulating glass unit (see Figure 1). The SageGlass coating comprises multiple layers of ceramic materials of less than a micron thick that together, and upon application of a low voltage direct current, provides the ability to reversibly tint the glass to dynamically control the admission of the sun's heat and light. SageGlass electrochromic insulating glass units are available in a range of product configurations according to customer specifications. This EPD is specific to the Double Pane and Double Pane VARIO products. The VARIO product is offered in response to significant demand from the EU market. SageGlass VARIO IGUs include an additional U-profile that is positioned in the glass edge seal which are used to connect to retaining anchors in the façade during installation, providing a safe and secure installation. VARIO products typically use a thicker combination of additional lites than the non-VARIO version of the products. A typical IGU configuration is shown in Figure 1. Each configuration comprises (i) a support lite of float glass, the thickness of which depends on the application that is laminated to the 2.2mm device lite, (ii) a 2.2mm thick float glass lite on which the electrochromic coating is deposited (called the device lite), (iii) a third lite of float glass which is the inboard lite of the insulating glass unit (called a cover lite), the thickness and type of which depends on the application, and (iv) associated insulating glass materials which comprise metallic spacer, dessicant, sealants, laminating interlayer materials, and wiring.

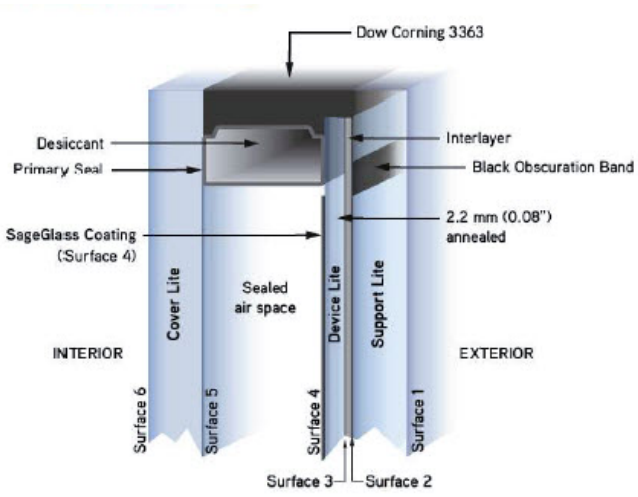


**Figure 1: Cross Section of a Typical Double Pane SageGlass Electrochromic IGU**

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## Application

SageGlass Electrochromic IGUs can be used in any window, skylight, or curtain wall system in commerical, institutional or residential buildings.

## Technical Data

| *Typical SageGlass Insulating Glass Unit Performance for North America (based on 4mm clear w/SR2.0, 0.89mm SentryGlas, 2.2mm SageGlass, 12mm air space w/90% Argon fill, 6mm clear)* | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **SageGlass Clear w/SR2.0** | **Visible light transmission, %** | **Exterior reflection, %** | **Interior reflection, %** | **Solar transmission, %** | **Solar Heat Gain Coefficient** | **U-factor, btu/°F.hr.ft²** | **UV transmission, %** | **Fading protection, % $T_{dw-ISO}$** |
| **Clear State** | 60 | 16 | 14 | 33 | 0.41 | 0.28 | 0 | 35 |
| **Intermediate State (tint) 1** | 18 | 10 | 9 | 7 | 0.15 | 0.28 | 0 | 5 |
| **Intermediate State (tint) 2** | 6 | 10 | 9 | 2 | 0.10 | 0.28 | 0 | 2 |
| **Fully Tinted** | 1 | 11 | 9 | 0.4 | 0.09 | 0.28 | 0 | 1 |

**Table 1: Performance Data for Typical SageGlass Electrochromic IGU**

## Placing on the Market

SageGlass Electrochromic IGUs are certified by the Insulating Glass Certification Council and the Insulating Glass Manufacturers' Alliance IG Certification Program which certifies compliance to ASTM E2190. SageGlass electrochromic coatings also meet the requirements of ASTM E2953 Standard Specification for Evaluating Accelerated Aging Performance of Electrochromic Devices in Sealed Insulating Glass Units.

SageGlass Electrochromic IGUs also meet the CE performance standards for heat treated, laminated, coated glass and insulating glass (EN1096, EN1279, EN1863, EN12150, EN12600).

## Delivery Status

SageGlass Electrochromic IGUs are available in sized up to 1.83m x 3.0m (6ft x 10ft) with a range of overall unit thicknesses up to 50mm (2in).

The packaging consists of a wood A-frame base with foam padding on the support areas, stretch wrap, and plastic banding.

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Double Pane and Double Pane VARIO

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## Standard and Secondary Components

The insulating glass unit is comprised of 2.2mm float glass and additional layers of glass of varying thicknesses according to the application. The scope of this study covered the entire production of SageGlass Electrochromic IGUs for 2018, for the Double Pane and Double Pane VARIO products. The weighted average thickness of the additional glass layers of the Double Pane product was 14.27mm, plus the 2.2mm device lite layer, for an overall glass thickness of 16.47mm. The weighted average thickness of the additional glass of the Double Pane VARIO product was 24.45mm, plus the 2.2mm device lite layer, for an overall glass thickness of 26.65mm.

SageGlass Electrochromic IGUs are available in various product configurations depending on project specifications. Each configuration includes a 2.2mm layer of float glass and two layers of varying thicknesses of support lite glass and cover lite glass. The electrochromic coating process of the glass for any IGU configuration is on the 2.2mm float glass and is considered the standard component, as the impacts of the 2.2mm device lite and accompanying support materials will be similar throughout the various IGU configurations. The support lite and cover lite glass are the components of the product with varying thicknesses and are considered the secondary components.

The standard components of the product consists of 2.2mm float glass, an ionomer interlayer, sealant materials, air, argon or kyrpton gas, spacer materials (including desiccant), wiring components, and metals, that comprise 16.3% of the average final Double Pane product and 10.3% of the average final Double Pane VARIO product. The spacer thickness and amount of silicone varies depending on the customer specified confirguration. A weighted average of the spacer and silicone were used to include them in the standard component.

The secondary components of the product consists of the additional layers of glass that vary according to the customer specified configuration. The secondary components includes the support lite glass, cover lite glass (laminated or non-laminated), and the PVB found in the cover lite if laminated. In the average final product configuration the secondary component comprises 83.7% of the Double Pane product and 89.7% of the Double Pane VARIO product.

A breakdown of the components for the average Double Pane and Double Pane VARIO products is shown in Table 2.

| Component | | Raw Material | Double Pane Weighted Average Glass Thickness 16.47mm | Double Pane VARIO Weighted Average Glass Thickness 26.65mm |
|---|---|---|---|---|
| Standard Component | Device Lite | 2.2mm float glass | 12.6% | 7.9% |
| | Coating | Proprietary Metals | 0.1% | 0.1% |
| | Support Materials | Ionomer interlayer, sealant materials, fill gas, spacer materials (including desiccant), wiring components, VARIO insert (if applicable) | 3.6% | 2.3% |
| | **Standard Component % of Final Product:** | | **16.3%** | **10.3%** |
| Secondary Component | Additional Lites | Support Lites, cover lites | 83.7% | 89.7% |
| | **Total kg per $m^2$:** | | **43.755** | **70.157** |

**Table 2: Product Component Percentages**

SageGlass Electrochromic Insulating Glass Unit
Double Pane and Double Pane VARIO

According to ISO 14025

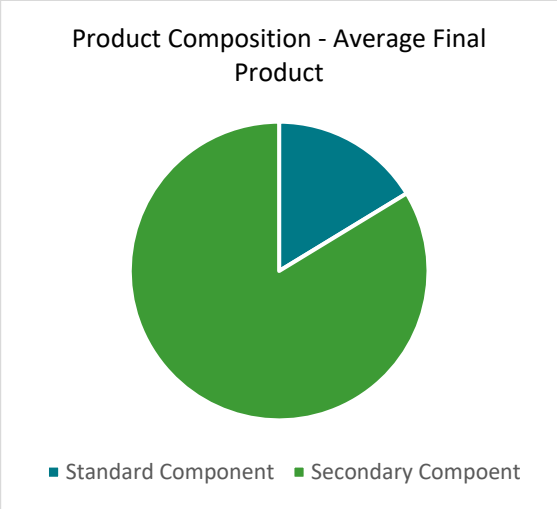


Figure 2: Product Composition by Weight Percentage for Average Final Product

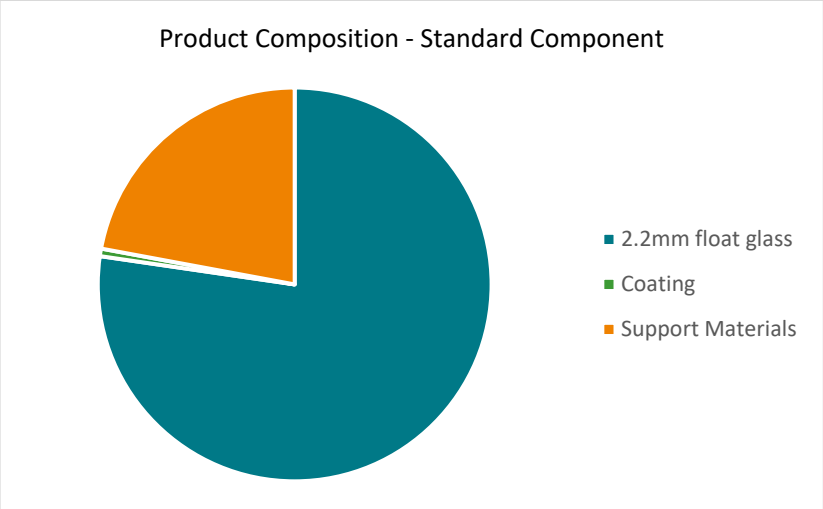


Figure 3: Product Composition by Weight Percentage for the Standard Component

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## Manufacture

SageGlass Electrochromic IGUs are manufactured in Faribault, MN. The production process begins with the trimming and washing of the 2.2mm glass lite. The coatings are then applied by vacuum sputtering, and undergo various heat treatments, frit application, and laser processing. The processed glass lite is then cut to the specified dimensions, becoming the device lite. The device lite is then laminated to the support lite, combined with the cover lite and spacer, and sealed to form the insulating glass unit. Wiring components are added to the unit during the IGU fabrication process. The unit is then tested before packaging and shipping.

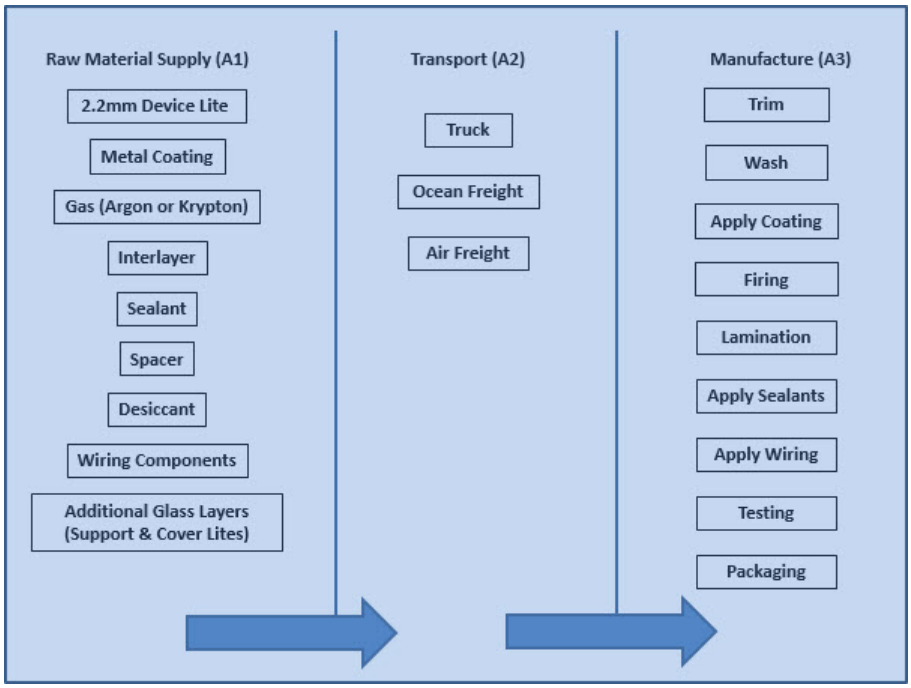


Figure 4: SageGlass Electrochromic IGU Product Flow Diagram

## Packaging

The SageGlass Electrochromic IGUs are packaged prior to shipping from Faribault, MN. The finished IGUs are placed on an A-frame made of wood with foam padding on the support areas. The A-frame with product is then wrapped with stretch wrap and a plastic banding.

## Environment and Health During Manufacture

SageGlass and Saint-Gobain have well-established Environmental, Health, and Safety (EHS) and product stewardship programs, which help to enforce proper evaluation and monitoring of chemicals and raw materials chosen to manufacture products. These programs ensure that all environmental and OSHA requirements are met or exceeded to ensure the health and safety of all employees and contractors.

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## Product Processing/Installation

SageGlass Electrochromic IGUs are installed by glazing contractors into windows, skylights, and curtain walls in a similar manner to convential insulating glass units. The only additional requirement is to connect the pigtail wire exiting the IGU to the frame cable that is routed through the framing system which connects each IGU to the control system. There are no requirements for industrial or environmental protections since there are no dust or other airborne emissions produced as a result of the installation process. Personal protective equipment should be used such as gloves and fall protection appropriate to the installation conditions.

## Condition of Use

SageGlass Electrochromic IGUs allow for control of visible light transmission and solar heat gain over a wide range, to provide a balance of daylight and solar heat entering a building, while still maintaining a view to the outdoors.

## Environment and Health During Use

SageGlass Electrochromic IGUs have no known emisions during use that could affect the environment or human health, confirmed by emission testing performed according to CDPH Section 01350 and VOC testing performed according to German, French, and Belgium regulations.

No additional maintenance is required during the use of SageGlass. Cleaning can be done with a typical glass cleaning solution as needed, in the same way as for convential IGUs. Do not use scrapers or other metal tools to clean glass. SAGE recommends occasional dust removal on sensors as needed.

## Extraordinary Effects

SageGlass Electrochromic IGUs have no extraordinary effects concerning fire, water, or mechanical destruction.

## Re-Use/Recycling/Disposal

SAGE actively monitors and engages in on-going studies regarding processed glass recycling and disposal. At this time, there are currently no known re-use, recycling, or energy recovery programs for conventional or electrochromic IGUs. Although just like convential insulating glass units, recycling of the glass is possible by removing this component from the edge sealant materials.

## Further Information

https://www.sageglass.com/en

## LCA Calculation Rules

### Declared Unit

| Declared Unit | | | |
|---|---|---|---|
| **Name** | **Unit** | **Double Pane** | **Double Pane VARIO** |
| Declared Unit | $m^2$ | 1 | 1 |
| Mass per piece | $kg/m^2$ | 43.76 | 70.16 |
| Standard Component (Device Lite) Thickness | mm | 2.2 | 2.2 |
| Secondary Component (Additional Lites) Average Thickness | mm | 14.27 | 24.45 |
| Total IGU Average Glass Thickness | mm | 16.47 | 26.65 |
| Interlayer percent mass | % | 2.8 | 1.7 |

Table 3: Declared Unit Information

### System Boundary

The life cycle analysis performed for this EPD includes the “cradel-to-gate” life cycle stages. The system boundary includes raw material supply, manufacture, and transport; the Electrochromic IGU manufacture in Fairbault, MN, and the packaging. Transport from the manufacture to customer installation, installation, use, and end-of-life are excluded from this study as required by the PCR.

| Description of the System Boundary (X=included in LCA: MND=module not declared) | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Product Stage | | | Construction Process Stage | | Use Stage | | | | | | | End of Life Stage | | | | Benefits & Loads Beyond System Boundaries |
| Raw Material Supply | Transport | Manufacturing | Transport from the gate to the site | Assembly | Use | Maintenance | Repair | Replacement | Refurbishment | Operational Energy Use | Operational Water Use | De-construction demolition | Transport | Waste Processing | Disposal | Reuse-Recover-Recycling Potential |
| A1 | A2 | A3 | A4 | A5 | B1 | B2 | B3 | B4 | B5 | B6 | B7 | C1 | C2 | C3 | C4 | D |
| X | X | X | MND | MND | MND | MND | MND | MND | MND | MND | MND | MND | MND | MND | MND | MND |

Table 4: System Boundary

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## Estimates and Assumptions

A proxy material was used in place of some of the metals used in the electrochromic coating because the specific metals are not listed in the Gabi Thinkstep US Ecoinvent database. Estimates and assumptions were also used in the manufacture waste transport distance, as well as the water evaporation rate.

## Cut-Off Criteria

The cut-off criteria established for the study include materials, energy, and emissions data. For the purposes of this study, the crtieria are as follows:

- Mass – Chemicals with a combined weight less than 1% of the mass of the modeled product may be excluded, providing its environmental relevance is not a concern.
- Human activity factors were not included in the scope of this study.
- Capital equipment factors were not includd in the scope of this study.

## Background Data

GaBi version 8.2 software system was used for modeling the life cycle of the SageGlass Electrochromic IGU. Each background dataset was taken from the GaBi Thinkstep US Ecoinvent and USLCI databases.

## Data Quality

Wherever secondary data is used, the study adopts critically reviewed data for consistency, precision, and reproducibility to limit uncertainty. The data sources used are complete and representative of North America and Europe (depending on the material source) in terms of the geographic and technological coverage and are less than 10 years old. Any deviations from these initial data quality requirements for secondary data are documented in the report. Overall, the primary data from the manufacturing location is of very high quality, being directly tracked and measured by facility personel. Secondary data sets are of fair-to-good quality.

## Period Under Review

Data for this LCA was collected for the 2018 calendar year.

## Allocation

The Faribault, MN plant is the only Saint-Gobain location that produces SageGlass Electrochromic IGUs and the SageGlass Electrochromic products are the only products made at the facility at this time. All flows and impacts are allocated to the SageGlass Electrochromic IGU product and can be scaled to specific configurations.

## Scaling Factor

SageGlass Electrochromic IGUs are available in various product configurations depending on project specifications. Each configuration includes a 2.2mm layer of float glass and two layers of varying thicknesses of support lite glass and cover lite glass. Depending on the application for the product, the cover lite glass may also be laminated. The electrochromic coating process of the glass for any IGU configuration is on the 2.2mm device lite; therefore, the impacts of the 2.2mm device lite and accompanying support materials will be similar throughout the various IGU configurations. The support lite and cover lite glass are the components of the product with varying thicknesses. This study examined impacts of a weighted average of the support and cover lite glass for both the Double Pane and Double Pane VARIO production volumes separately from the standard components in order to create a scaling factor that can be used to determine the impacts for any configuration.

The weighted average glass thickness for the Double Pane product is 2.2mm of device lite + 14.27mm of additional lites for a total weighted average glass thickness of 16.47mm for the Double Pane product. The weighted average glass thickness for the Double Pane VARIO product is 2.2mm of device lite + 24.45mm of additional lites for a total weighted average glass thickness of 26.65mm for the Double Pane VARIO product.

Impacts for specific configurations of an Electrochromic IGU product can be calculated by adding the impacts for the standard components to the total sum of the support lite and cover lite glass thicknesses that has been multiplied by the per millimeter impact for the additional lites. The calculation of the scaling factor is shown below in Figure 5. The impacts for the selected impact cateogries specified by the PCR per millimeter of the additional lites was determined by dividing the impact result by the total mm of additional lites in the weighted average product and is shown in Table 5.

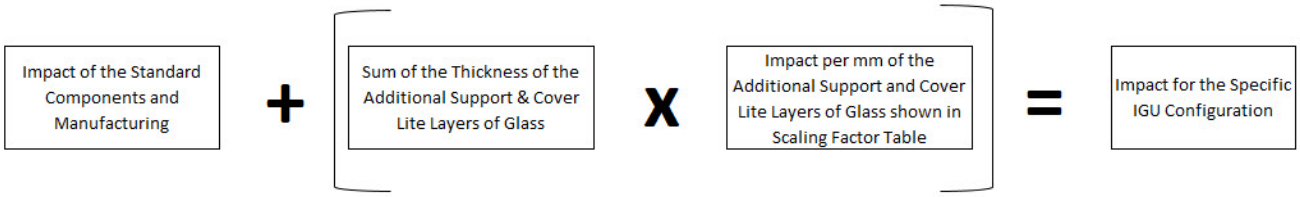


**Figure 5: Scaling Factor Calculation**

| Impact Category | Unit | Double Pane (Additional Glass) | | Double Pane VARIO (Additional Glass) | |
|---|---|---|---|---|---|
| | | Impact Total per $m^2$ for Weighted Average of Combined Support & Cover Lites (14.27mm) | Impact per mm of Combined Support & Cover Lites | Impact Total per $m^2$ for Weighted Average of Combined Support & Cover Lites (24.45mm) | Impact per mm of Combined Support & Cover Lites |
| **North America (TRACI 2.1)** | | | | | |
| GWP (T) | kg $CO_2$ eq | 1.17E+02 | 8.23E+00 | 2.24E+02 | 9.15E+00 |
| ODP (T) | kg CFC 11 eq | 9.13E-09 | 6.40E-10 | 2.29E-08 | 9.36E-10 |
| AP (T) | kg $SO_2$ eq | 7.94E-01 | 5.57E-02 | 1.39E+00 | 5.68E-02 |
| EP (T) | kg N eq | 4.79E-02 | 3.35E-03 | 9.48E-02 | 3.88E-03 |
| POCP (T) | kg $O_3$ eq | 1.12E+01 | 7.85E-01 | 2.09E+01 | 8.54E-01 |
| $ADP_{element}$ (T) | Kg Fe eq | 1.80E+00 | 1.26E-01 | 2.41E+00 | 9.84E-02 |
| $ADP_{fossil}$ (T) | MJ | 1.93E+02 | 1.35E+01 | 3.73E+02 | 1.52E+01 |
| **Europe/Rest of World (CML)** | | | | | |
| GWP (C) | kg $CO_2$ eq | 1.18E+02 | 8.27E+00 | 2.25E+02 | 9.20E+00 |
| ODP (C) | kg CFC 11 eq | 8.62E-09 | 6.04E-10 | 2.16E-08 | 8.84E-10 |
| AP (C) | kg $SO_2$ eq | 7.32E-01 | 5.13E-02 | 1.27E+00 | 5.20E-02 |
| EP (C) | kg (PO4)3 eq | 8.71E-02 | 6.11E-03 | 1.58E-01 | 6.48E-03 |
| POCP (C) | kg ethane eq | -1.93E-02 | -1.36E-03 | 2.12E-02 | 8.67E-04 |
| $ADP_{elements}$ (C) | kg Sb eq | 3.34E-04 | 2.34E-05 | 6.52E-04 | 2.67E-05 |
| $ADP_{fossil}$ (C) | MJ | 1.58E+03 | 1.11E+02 | 3.11E+03 | 1.27E+02 |

Table 5: Per mm Impact of Additional Lites

## LCA Results

### Environmental Impact Potentials: North America

The tables and charts below present the environmental impact potentials for the system boundary modules A1-A3, raw material supply, raw material transport, and manufacturing as specified for North America. The impact assessment method specified for North America is the TRACI 2.1 method with an additional indicator for abiotic depletion potentials of elements from the ReCiPe impact assessment method. The impacts shown are representative of the embodied environmental impacts for 1 square meter of SageGlass Electrochromic IGU for the standard components (2.2mm device lite, coating, and support materials) and the weighted average configuration for the Double Pane and Double Pane VARIO products, using the scaling factor calculation outlined above. In addition, the results for an example product will be shown in order to explain how to calculate the impacts for any configuration.

| Double Pane Product (2.2mm Device Lite + 14.27mm weighted average additional lites = 16.47mm total thickness) | | | | | | |
|---|---|---|---|---|---|---|
| Parameter | Unit | **Raw Materials (A1)** | **Raw Materials Transport (A2)** | **Manufacture (A3)** | **Plus Additional Lite Impacts** (weighted average 14.27mm) | **Total** |
| Global warming potential (GWP) | kg CO2 eq | 1.09E+02 | 1.71E+00 | 3.03E+02 | 1.17E+02 | 5.31E+02 |
| Stratospheric ozone layer depletion potential (ODP) | kg CFC 11 eq | 1.10E-11 | 3.19E-16 | 2.80E-11 | 9.13E-09 | 9.17E-09 |
| Acidification potential (AP) | kg SO2 eq | 2.58E+00 | 8.06E-03 | 4.98E-01 | 7.94E-01 | 3.88E+00 |
| Eutrophication potential (EP) | kg N eq | 1.76E-02 | 6.79E-04 | 4.64E-02 | 4.79E-02 | 1.13E-01 |
| Photochemical ozone creation potential (POCP) | kg O3 eq | 5.26E+00 | 1.91E-01 | 7.25E+00 | 1.12E+01 | 2.39E+01 |
| Abiotic resource depletion potential – elements (ADP-e) | kg Fe eq | 7.41E+01 | 5.08E-03 | 1.42E+00 | 1.80E+00 | 7.73E+01 |
| Abiotic resource depletion potential – fossil fuels (ADP-f) | MJ | 1.57E+02 | 3.20E+00 | 2.91E+02 | 1.93E+02 | 6.45E+02 |

**Table 6: TRACI Environmental Impact Potentials for Double Pane (North America)**

| Double Pane VARIO Product (2.2mm Device Lite + 24.45mm weighted average additional lites = 26.65mm total thickness) | | | | | | |
|---|---|---|---|---|---|---|
| Parameter | Unit | **Raw Materials (A1)** | **Raw Materials Transport (A2)** | **Manufacture (A3)** | **Plus Additional Lite Impacts** (weighted average 24.45mm) | **Total** |
| Global warming potential (GWP) | kg CO2 eq | 1.19E+02 | 1.80E+00 | 3.03E+02 | 2.24E+02 | 6.48E+02 |
| Stratospheric ozone layer depletion potential (ODP) | kg CFC 11 eq | 8.21E-12 | 3.32E-16 | 2.80E-11 | 2.29E-08 | 2.29E-08 |
| Acidification potential (AP) | kg SO2 eq | 2.97E+00 | 8.93E-03 | 4.98E-01 | 1.39E+00 | 4.86E+00 |
| Eutrophication potential (EP) | kg N eq | 1.83E-02 | 7.17E-04 | 4.64E-02 | 9.48E-02 | 1.60E-01 |
| Photochemical ozone creation potential (POCP) | kg O3 eq | 5.49E+00 | 2.12E-01 | 7.25E+00 | 2.09E+01 | 3.38E+01 |
| Abiotic resource depletion potential – elements (ADP-e) | kg Fe eq | 8.33E+01 | 5.35E-03 | 1.42E+00 | 2.41E+00 | 8.71E+01 |
| Abiotic resource depletion potential – fossil fuels (ADP-f) | MJ | 1.63E+02 | 3.37E+00 | 2.91E+02 | 3.73E+02 | 8.30E+02 |

**Table 7: TRACI Environmental Impact Potentials for Double Pane VARIO (North America)**

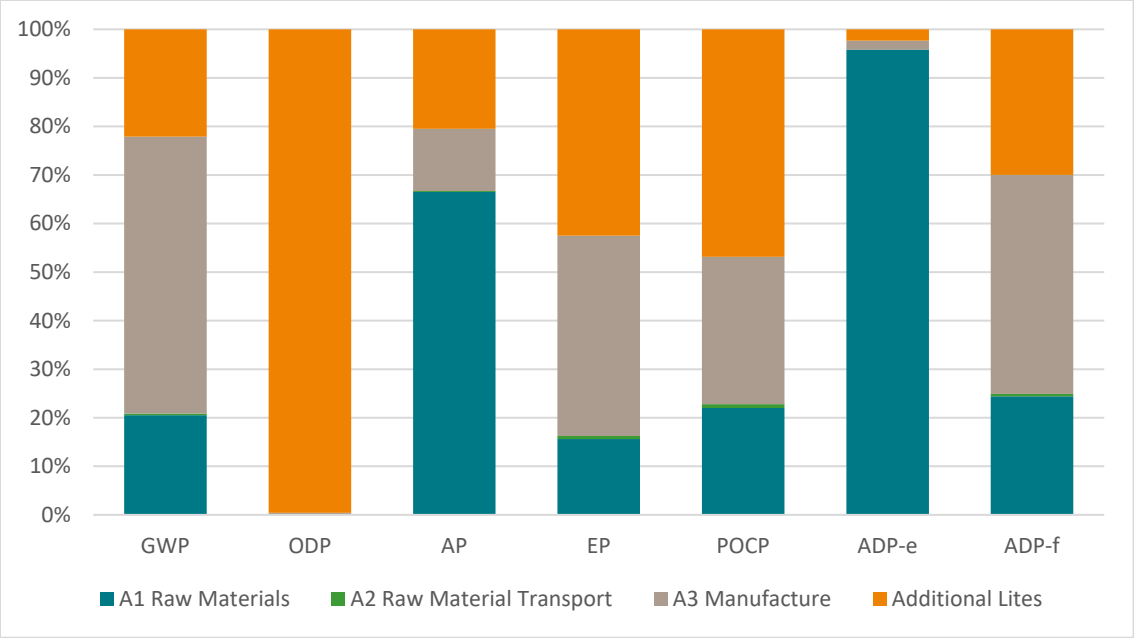


**Figure 6: TRACI 2.1 Environmental Impact Potentials - SageGlass Double Pane Electrochromic IGU**

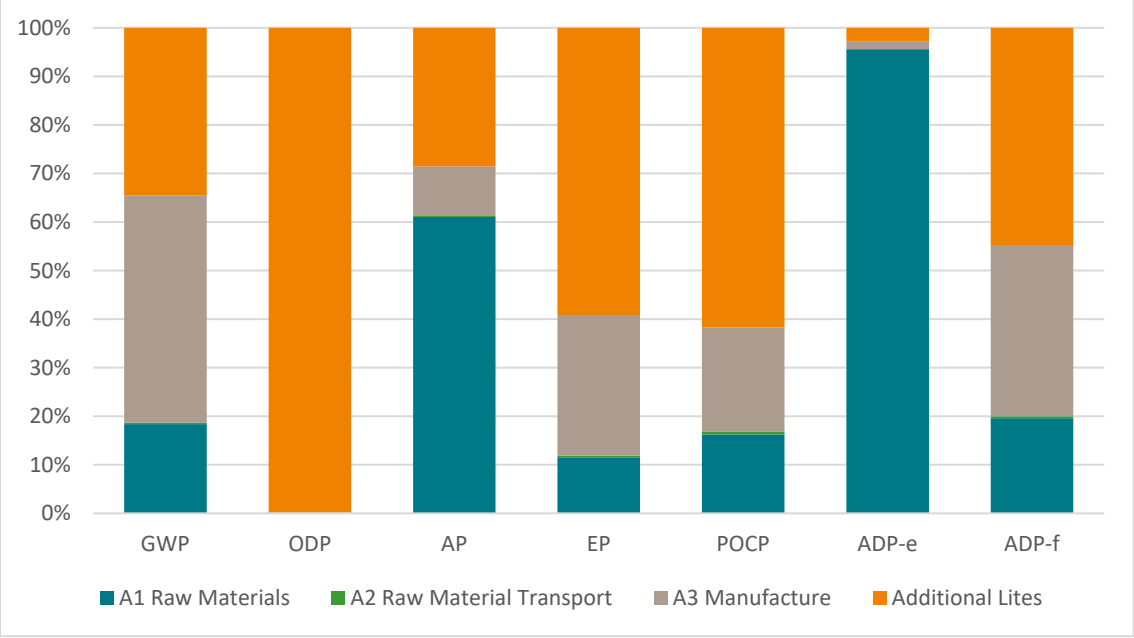


**Figure 7: TRACI 2.1 Environmental Impact Potentials - SageGlass Double Pane VAIRO Electrochromic IGU**

The example product used to show the calculation for the various thicknesses is a Typical SageGlass Double Pane IGU: 4mm clear, 0.89mm SentryGlas, 2.2mm SageGlass, 12mm air space w/90% Argon fill, 6mm clear.

- **Step 1**: Determine the standard and secondary components
  - Standard components in this configuration: 0.89 SentryGlas, 2.2mm SageGlass, 12mm air space w/90% Argon fill
  - Secondary components in this configuration: 4mm clear, 6mm clear
- **Step 2**: Add the results of the standard component results shown in Table 6 columns A1, A2, and A3
  - 1.09E+02 + 1.71E+00 + 3.03E+02 = **4.14E+02**
- **Step 3**: Determine the combined thickness of the secondary components
  - 4mm clear + 6mm clear = ***10mm***
- **Step 4**: Determine the impacts of the combined thickness of the secondary components (Refer to Table 5, Column Impact per mm of combined support & cover lites
  - ***10mm*** * Impact per mm of combined support & cover lites
  - GWP(T) Example: 10mm * 8.23E+00 = **8.23E+01**
- **Step 5**: Determine the impact for the IGU
  - Add the results from Step 2 to the results from Step 4
  - GWP(T) Example: **4.14E+02** + **8.23E+01** = **4.96E+02**

| Example: Double Pane Product (4mm clear, 0.89mm SentryGlas, 2.2mm SageGlass, 12mm air space w/90% Argon fill, 6mm clear) | | | | | | |
|---|---|---|---|---|---|---|
| Parameter | Unit | **Raw Materials (A1)** | **Raw Materials Transport (A2)** | **Manufacture (A3)** | **Plus Additional Lite Impacts** (10mm) | **Total** |
| Global warming potential (GWP) | kg CO2 eq | 1.09E+02 | 1.71E+00 | 3.03E+02 | 8.23E+01 | 4.96E+02 |
| Stratospheric ozone layer depletion potential (ODP) | kg CFC 11 eq | 1.10E-11 | 3.19E-16 | 2.80E-11 | 6.40E-09 | 6.44E-09 |
| Acidification potential (AP) | kg SO2 eq | 2.58E+00 | 8.06E-03 | 4.98E-01 | 5.57E-01 | 3.64E+00 |
| Eutrophication potential (EP) | kg N eq | 1.76E-02 | 6.79E-04 | 4.64E-02 | 3.35E-02 | 9.83E-02 |
| Photochemical ozone creation potential (POCP) | kg O3 eq | 5.26E+00 | 1.91E-01 | 7.25E+00 | 7.85E+00 | 2.05E+01 |
| Abiotic resource depletion potential – elements (ADP-e) | kg Fe eq | 7.41E+01 | 5.08E-03 | 1.42E+00 | 1.26E+00 | 7.67E+01 |
| Abiotic resource depletion potential – fossil fuels (ADP-f) | MJ | 1.57E+02 | 3.20E+00 | 2.91E+02 | 1.35E+02 | 5.87E+02 |

**Table 8: TRACI Environmental Impact Potentials for Example Product 4mm clear, 0.89mm SentryGlas, 2.2mm SageGlass, 12mm air space w/90% Argon fill, 6mm clear**

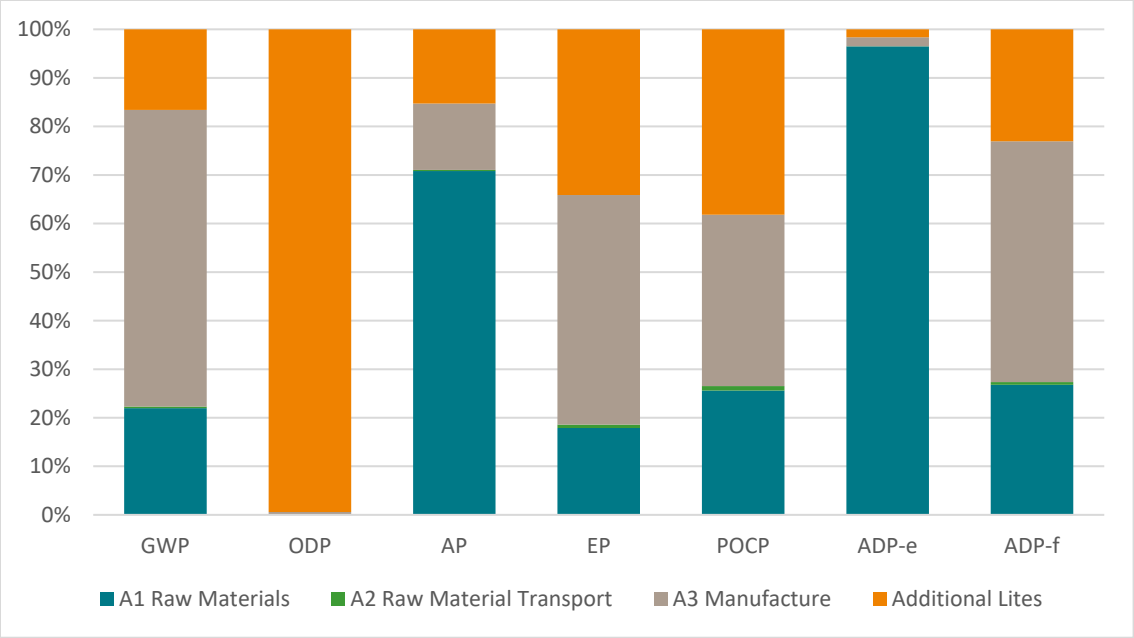


**Figure 8: TRACI Environmental Impact Potentials for Example Product - 4mm clear, 0.89mm SentryGlas, 2.2mm SageGlass, 12mm air space w/90% Argon fill, 6mm clear**

## Environmental Impact Potentials: Europe/Rest of World

The tables and charts below present the environmental impact potentials for the system boundary modules A1-A3, raw material supply, raw material transport, and manufacturing as specified for Europe and the rest of the world. The impact assessment method specified for Europe by EN 15804 is the CML method. The impacts shown are representative of the embodied environmental impacts for 1 square meter of SageGlass Electrochromic IGU for the standard components (2.2mm device lite, coating, and support materials) and the weighted average configuration for the Double Pane and Double Pane VARIO products, using the scaling factor calculation outlined above. In addition, the results for an example product will be shown in order to explain how to calculate the impacts for any configuration.

| Double Pane Product (2.2mm Device Lite + 14.27mm weighted average additional lites = 16.47mm total thickness) | | | | | | |
|---|---|---|---|---|---|---|
| Parameter | Unit | **Raw Materials (A1)** | **Raw Materials Transport (A2)** | **Manufacture (A3)** | **Plus Additional Lite Impacts** (weighted average 14.27mm) | **Total** |
| Global warming potential (GWP) | kg CO2 eq | 1.10E+02 | 1.71E+00 | 3.05E+02 | 1.18E+02 | 5.34E+02 |
| Stratospheric ozone layer depletion potential (ODP) | kg CFC 11 eq | 1.10E-11 | 3.19E-16 | 2.70E-11 | 8.62E-09 | 8.66E-09 |
| Acidification potential (AP) | kg SO2 eq | 3.00E+00 | 6.14E-03 | 4.87E-01 | 7.32E-01 | 4.22E+00 |
| Eutrophication potential (EP) | kg N eq | 3.98E-02 | 1.59E-03 | 5.76E-02 | 8.71E-02 | 1.86E-01 |
| Photochemical ozone creation potential (POCP) | kg O3 eq | 9.25E-02 | -1.48E-03 | 3.43E-02 | -1.93E-02 | 1.06E-01 |
| Abiotic resource depletion potential – elements (ADP-e) | kg Fe eq | 5.54E-02 | 5.34E-07 | 1.24E-04 | 3.34E-04 | 5.59E-02 |
| Abiotic resource depletion potential – fossil fuels (ADP-f) | MJ | 1.51E+03 | 2.40E+01 | 3.98E+03 | 1.58E+03 | 7.09E+03 |

**Table 9: CML Environmental Impact Potentials for Double Pane (Europe/Rest of World)**

| Double Pane VARIO Product (2.2mm Device Lite + 24.45mm weighted average additional lites = 26.65mm total thickness) | | | | | | |
|---|---|---|---|---|---|---|
| Parameter | Unit | **Raw Materials (A1)** | **Raw Materials Transport (A2)** | **Manufacture (A3)** | **Plus Additional Lite Impacts** (weighted average 24.45mm) | **Total** |
| Global warming potential (GWP) | kg CO2 eq | 1.20E+02 | 1.81E+00 | 3.05E+02 | 2.25E+02 | 6.51E+02 |
| Stratospheric ozone layer depletion potential (ODP) | kg CFC 11 eq | 8.21E-12 | 3.32E-16 | 2.70E-11 | 2.16E-08 | 2.16E-08 |
| Acidification potential (AP) | kg SO2 eq | 3.46E+00 | 6.90E-03 | 4.87E-01 | 1.27E+00 | 5.23E+00 |
| Eutrophication potential (EP) | kg N eq | 4.13E-02 | 1.71E-03 | 5.76E-02 | 1.58E-01 | 2.59E-01 |
| Photochemical ozone creation potential (POCP) | kg O3 eq | 1.13E-01 | -1.43E-03 | 3.43E-02 | 2.12E-02 | 1.67E-01 |
| Abiotic resource depletion potential – elements (ADP-e) | kg Fe eq | 6.48E-02 | 5.63E-07 | 1.24E-04 | 6.52E-04 | 6.56E-02 |
| Abiotic resource depletion potential – fossil fuels (ADP-f) | MJ | 1.60E+03 | 2.53E+01 | 3.98E+03 | 3.11E+03 | 8.71E+03 |

**Table 10: CML Environmental Impact Potentials for Double Pane VARIO (Europe/Rest of World)**

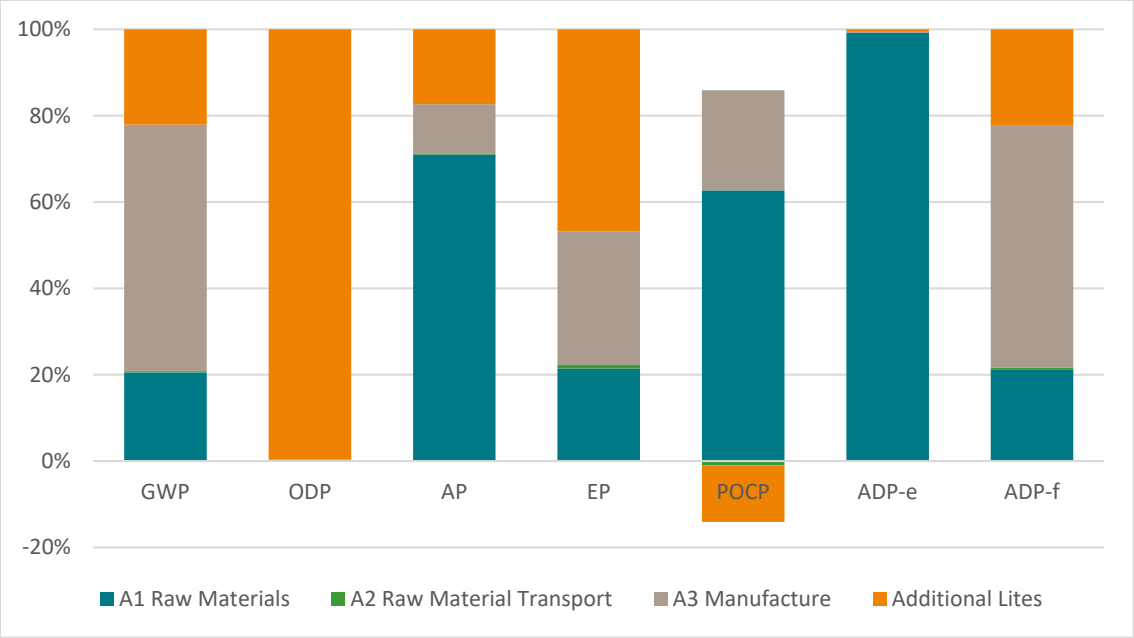


Figure 9: CML Environmental Impact Potentials - SageGlass Double Pane Electrochromic IGU

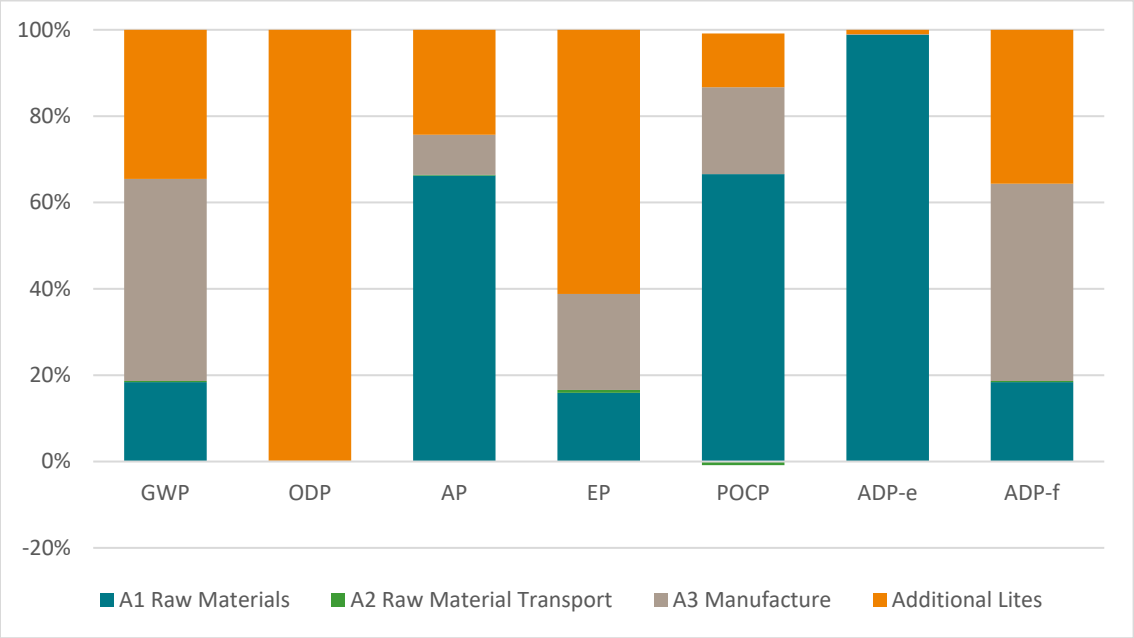


Figure 10: CML Environmental Impact Potentials - SageGlass Double Pane VARIO Electrochromic IGU

The example product used to show the calculation for the various thicknesses is a Typical SageGlass Double Pane IGU: 4mm clear, 0.89mm SentryGlas, 2.2mm SageGlass, 12mm air space w/90% Argon fill, 6mm clear.

- **Step 1**: Determine the standard and secondary components
  - Standard components in this configuration: 0.89 SentryGlas, 2.2mm SageGlass, 12mm air space w/90% Argon fill
  - Secondary components in this configuration: 4mm clear, 6mm clear
- **Step 2**: Add the results of the standard component results shown in Table 9 columns A1, A2, and A3
  - 1.10E+02 + 1.71E+00 + 3.05E+02 = **4.16E+02**
- **Step 3**: Determine the combined thickness of the secondary components
  - 4mm clear + 6mm clear = ***10mm***
- **Step 4**: Determine the impacts of the combined thickness of the secondary components (Refer to Table 5, Column Impact per mm of combined support & cover lites
  - ***10mm*** * Impact per mm of combined support & cover lites
  - GWP(C) Example: 10mm * 8.27E+00 = **8.27E+01**
- **Step 5**: Determine the impact for the IGU
  - Add the results from Step 2 to the results from Step 4
  - GWP(T) Example: **4.16E+02** + **8.27E+01** = **4.99E+02**

| Example: Double Pane Product (4mm clear, 0.89mm SentryGlas, 2.2mm SageGlass, 12mm air space w/90% Argon fill, 6mm clear) | | | | | | |
|---|---|---|---|---|---|---|
| Parameter | Unit | **Raw Materials (A1)** | **Raw Materials Transport (A2)** | **Manufacture (A3)** | **Plus Additional Lite Impacts** (weighted average 10mm) | **Total** |
| Global warming potential (GWP) | kg CO2 eq | 1.10E+02 | 1.71E+00 | 3.05E+02 | 8.27E+01 | 4.99E+02 |
| Stratospheric ozone layer depletion potential (ODP) | kg CFC 11 eq | 1.10E-11 | 3.19E-16 | 2.70E-11 | 6.04E-09 | 6.08E-09 |
| Acidification potential (AP) | kg SO2 eq | 3.00E+00 | 6.14E-03 | 4.87E-01 | 5.13E-01 | 4.00E+00 |
| Eutrophication potential (EP) | kg N eq | 3.98E-02 | 1.59E-03 | 5.76E-02 | 6.11E-02 | 1.60E-01 |
| Photochemical ozone creation potential (POCP) | kg O3 eq | 9.25E-02 | -1.48E-03 | 3.43E-02 | -1.36E-02 | 1.12E-01 |
| Abiotic resource depletion potential – elements (ADP-e) | kg Fe eq | 5.54E-02 | 5.34E-07 | 1.24E-04 | 2.34E-04 | 5.58E-02 |
| Abiotic resource depletion potential – fossil fuels (ADP-f) | MJ | 1.51E+03 | 2.40E+01 | 3.98E+03 | 1.11E+03 | 6.62E+03 |

**Table 11: CML Environmental Impact Potentials for Example Product - 4mm clear, 0.89mm SentryGlas, 2.2mm SageGlass, 12mm air space w/90% Argon fill, 6mm clear**

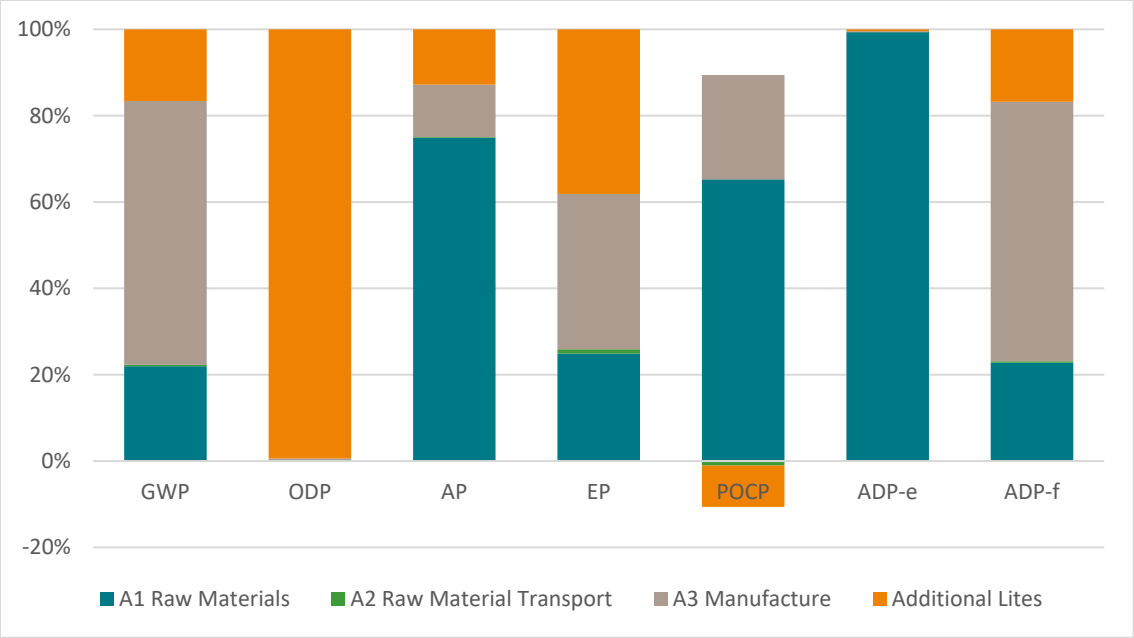


**Figure 11: CML Environmental Impact Potentials for Example Product 4mm clear, 0.89mm SentryGlas, 2.2mm SageGlass, 12mm air space w/90% Argon fill, 6mm clear**

## Resource Use

| Double Pane Product (2.2mm Device Lite + 14.27mm weighted average additional lites = 16.47mm total thickness) | | | | | | |
|---|---|---|---|---|---|---|
| | | **Raw Materials (A1)** | **Raw Materials Transport (A2)** | **Manufacture (A3)** | **Additional Lites** | **Total** |
| **$RPR_E$**: Renewable primary energy used as energy carrier (fuel) | MJ | 1.63E+02 | 8.24E-01 | 9.49E+02 | 2.95E+02 | 1.41E+03 |
| **$RPR_M$:** Renewable primary resources with energy content used as material | MJ | -2.80E-10 | -7.54E-12 | 1.03E+02 | 2.28E-05 | 1.03E+02 |
| **$NRPR_E$**: Non-renewable primary resources used as an energy carrier (fuel) | MJ | 1.62E+03 | 2.41E+01 | 4.54E+03 | 1.68E+03 | 7.87E+03 |
| **$NRPR_M$:** Non-renewable primary resources with energy content used as material | MJ | 1.65E-02 | 2.33E-04 | 3.46E-02 | 6.33E-03 | 5.76E-02 |
| **SM:** Secondary materials | MJ | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| **RSF:** Renewable secondary fuels | MJ | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| **NRSF:** Non-renewable secondary fuels | MJ | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| **RE**: Recovered energy | MJ | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| **FW:** Use of net fresh water resources | $m^3$ | 6.96E-01 | 3.48E-03 | 2.03E+00 | 3.81E-01 | 3.11E+00 |

Table 12: Resource Use - SageGlass Double Pane Electrochromic IGU

| Double Pane VARIO Product (2.2mm Device Lite + 24.45mm weighted average additional lites = 26.65mm total thickness) | | | | | | |
|---|---|---|---|---|---|---|
| | | **Raw Materials (A1)** | **Raw Materials Transport (A2)** | **Manufacture (A3)** | **Additional Lites** | **Total** |
| **$RPR_E$**: Renewable primary energy used as energy carrier (fuel) | MJ | 1.86E+02 | 8.30E-01 | 9.49E+02 | 6.79E+02 | 1.82E+03 |
| **$RPR_M$:** Renewable primary resources with energy content used as material | MJ | -2.28E-10 | -7.71E-12 | 1.03E+02 | 5.71E-05 | 1.03E+02 |
| **$NRPR_E$**: Non-renewable primary resources used as an energy carrier (fuel) | MJ | 1.73E+03 | 2.54E+01 | 4.54E+03 | 3.31E+03 | 9.60E+03 |
| **$NRPR_M$:** Non-renewable primary resources with energy content used as material | MJ | 1.82E-02 | 2.33E-04 | 3.46E-02 | 5.34E-03 | 5.83E-02 |
| **SM:** Secondary materials | MJ | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| **RSF:** Renewable secondary fuels | MJ | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| **NRSF:** Non-renewable secondary fuels | MJ | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| **RE**: Recovered energy | MJ | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| **FW:** Use of net fresh water resources | $m^3$ | 7.87E-01 | 3.49E-03 | 2.03E+00 | 8.37E-01 | 3.66E+00 |

**Table 13: Resource Use - SageGlass Double Pane VARIO Electrochromic IGU**

## Output Flows and Waste Categories

| Double Pane Product (2.2mm Device Lite + 14.27mm weighted average additional lites = 16.47mm total thickness) | | | | | | |
|---|---|---|---|---|---|---|
| | | Raw Materials (A1) | Raw Materials Transport (A2) | Manufacture (A3) | Additional Lites | Total |
| Hazardous waste disposed | kg | 2.39E-07 | 1.88E-09 | 3.08E-07 | 2.48E-01 | 2.48E-01 |
| Non-hazardous waste disposed | kg | 3.00E+01 | 1.97E-03 | 3.34E+01 | 5.77E+00 | 6.92E+01 |
| High level radioactive waste, conditioned, to final repository | kg | 4.67E-02 | 6.46E-05 | 2.18E-01 | 3.96E-02 | 3.05E-01 |
| Intermediate and low level radioactive waste, conditioned, to final repository | kg | 1.02E-03 | 1.47E-06 | 5.04E-03 | 8.25E-04 | 6.89E-03 |
| Components for reuse | kg | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Materials for recycling | kg | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Materials for energy recovery | kg | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Recovered energy exported | kg | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |

Table 14: Output Flows and Waste Categories - SageGlass Double Pane Electrochromic IGU

| Double Pane VARIO Product (2.2mm Device Lite + 24.45mm weighted average additional lites = 26.65mm total thickness) | | | | | | |
|---|---|---|---|---|---|---|
| | | Raw Materials (A1) | Raw Materials Transport (A2) | Manufacture (A3) | Additional Lites | Total |
| Hazardous waste disposed | kg | 2.46E-07 | 1.95E-09 | 3.08E-07 | 6.21E-01 | 6.21E-01 |
| Non-hazardous waste disposed | kg | 3.48E+01 | 2.02E-03 | 3.34E+01 | 8.86E+00 | 7.71E+01 |
| High level radioactive waste, conditioned, to final repository | kg | 5.13E-02 | 6.72E-05 | 2.18E-01 | 8.16E-02 | 3.51E-01 |
| Intermediate and low level radioactive waste, conditioned, to final repository | kg | 1.13E-03 | 1.53E-06 | 5.04E-03 | 1.72E-03 | 7.88E-03 |
| Components for reuse | kg | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Materials for recycling | kg | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Materials for energy recovery | kg | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Recovered energy exported | kg | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |

Table 15: Output Flows and Waste Categories - SageGlass Double Pane VARIO Electrochromic IGU

## Additional Environmental Information

### Renewable Energy Certificates (RECs)

In 2020, SageGlass invested in Renewable Energy Certificates (RECs) from the Trimon Wind 1 LLC via the Great River Energy Company. The RECs were retired by M-RETS Renewable Electricity for SageGlass in April 2021 to assist in lowering their carbon footprint. Updated results reflecting the RECs in the electricity input are shown below.

### Environmental Impact Potentials including RECs: North America

| Double Pane Product (2.2mm Device Lite + 14.27mm weighted average additional lites = 16.47mm total thickness) | | | | | | |
|---|---|---|---|---|---|---|
| Parameter | Unit | **Raw Materials (A1)** | **Raw Materials Transport (A2)** | **Manufacture (A3)** | **Plus Additional Lite Impacts** (weighted average 14.27mm) | **Total** |
| Global warming potential (GWP) | kg CO2 eq | 1.09E+02 | 1.71E+00 | 1.35E+02 | 1.17E+02 | 3.63E+02 |
| Stratospheric ozone layer depletion potential (ODP) | kg CFC 11 eq | 1.10E-11 | 3.19E-16 | 2.79E-11 | 9.13E-09 | 9.17E-09 |
| Acidification potential (AP) | kg SO2 eq | 2.58E+00 | 8.06E-03 | 2.15E-01 | 7.94E-01 | 3.60E+00 |
| Eutrophication potential (EP) | kg N eq | 1.76E-02 | 6.79E-04 | 2.45E-02 | 4.79E-02 | 9.06E-02 |
| Photochemical ozone creation potential (POCP) | kg O3 eq | 5.26E+00 | 1.91E-01 | 3.44E+00 | 1.12E+01 | 2.01E+01 |
| Abiotic resource depletion potential – elements (ADP-e) | kg Fe eq | 7.41E+01 | 5.08E-03 | 1.11E+00 | 1.80E+00 | 7.70E+01 |
| Abiotic resource depletion potential – fossil fuels (ADP-f) | MJ | 1.57E+02 | 3.20E+00 | 2.15E+02 | 1.93E+02 | 5.68E+02 |

Table 16: TRACI Environmental Impact Potentials (w/ RECs) for Double Pane (North America)

| Double Pane VARIO Product (2.2mm Device Lite + 24.45mm weighted average additional lites = 26.65mm total thickness) | | | | | | |
|---|---|---|---|---|---|---|
| Parameter | Unit | **Raw Materials (A1)** | **Raw Materials Transport (A2)** | **Manufacture (A3)** | **Plus Additional Lite Impacts** (weighted average 24.45mm) | **Total** |
| Global warming potential (GWP) | kg CO2 eq | 1.19E+02 | 1.80E+00 | 1.35E+02 | 2.24E+02 | 4.78E+02 |
| Stratospheric ozone layer depletion potential (ODP) | kg CFC 11 eq | 8.21E-12 | 3.32E-16 | 2.79E-11 | 2.29E-08 | 2.29E-08 |
| Acidification potential (AP) | kg SO2 eq | 2.97E+00 | 8.93E-03 | 2.15E-01 | 1.39E+00 | 4.58E+00 |
| Eutrophication potential (EP) | kg N eq | 1.83E-02 | 7.17E-04 | 2.45E-02 | 9.48E-02 | 1.38E-01 |
| Photochemical ozone creation potential (POCP) | kg O3 eq | 5.49E+00 | 2.12E-01 | 3.44E+00 | 2.09E+01 | 3.00E+01 |
| Abiotic resource depletion potential – elements (ADP-e) | kg Fe eq | 8.33E+01 | 5.35E-03 | 1.11E+00 | 2.41E+00 | 8.68E+01 |
| Abiotic resource depletion potential – fossil fuels (ADP-f) | MJ | 1.63E+02 | 3.37E+00 | 2.15E+02 | 3.73E+02 | 7.53E+02 |

Table 17: TRACI Environmental Impact Potentials (w/ RECs) for Double Pane VARIO (North America)

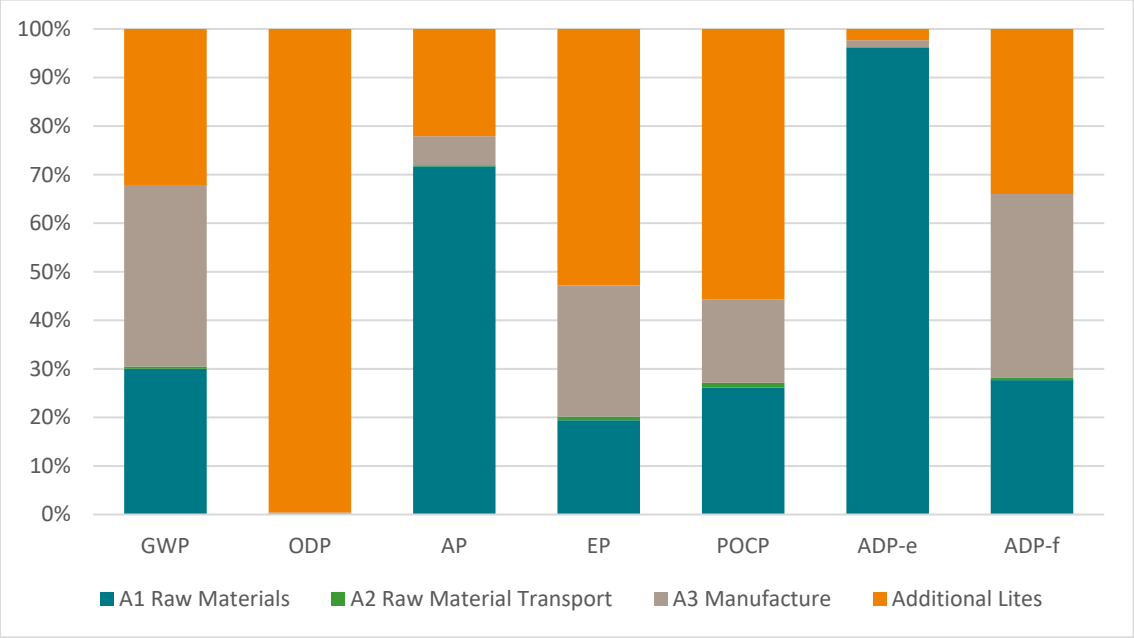


Figure 12: TRACI 2.1 Environmental Impact Potentials (w/ RECs) - SageGlass Double Pane Electrochromic IGU

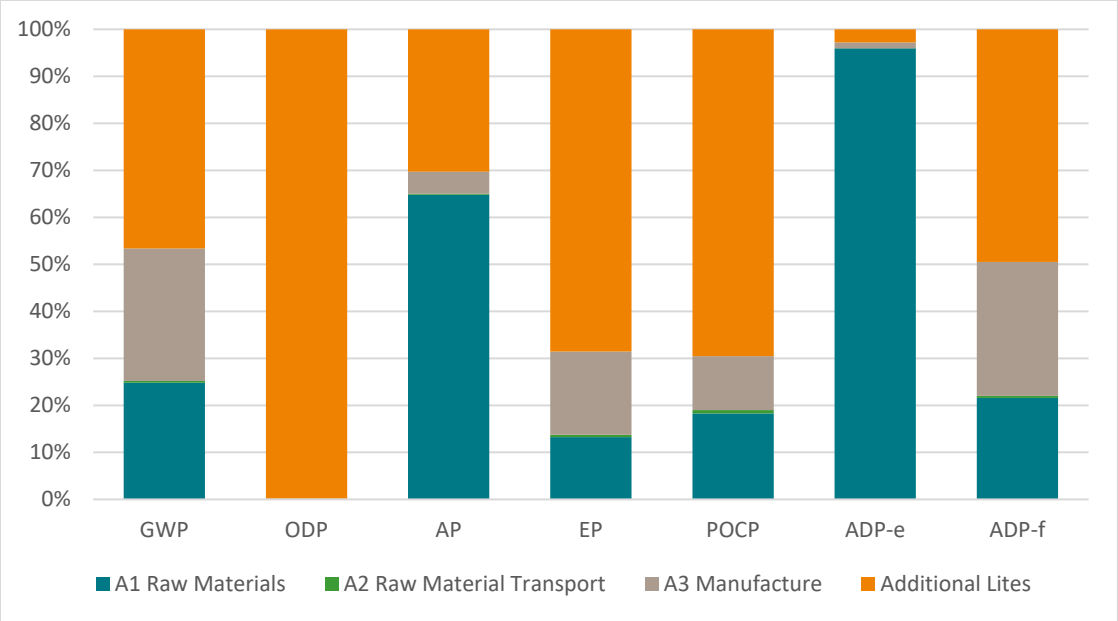


**Figure 13: TRACI 2.1 Environmental Impact Potentials (w/ RECs) - SageGlass Double Pane VAIRO Electrochromic IGU**

The example product used to show the calculation for the various thicknesses is a Typical SageGlass Double Pane IGU: 4mm clear, 0.89mm SentryGlas, 2.2mm SageGlass, 12mm air space w/90% Argon fill, 6mm clear.

- **Step 1**: Determine the standard and secondary components
  - Standard components in this configuration: 0.89 SentryGlas, 2.2mm SageGlass, 12mm air space w/90% Argon fill
  - Secondary components in this configuration: 4mm clear, 6mm clear
- **Step 2**: Add the results of the standard component results shown in Table 16 columns A1, A2, and A3
  - 1.09E+02 + 1.71E+00 + 1.35E+02 = **2.46E+02**
- **Step 3**: Determine the combined thickness of the secondary components
  - 4mm clear + 6mm clear = ***10mm***
- **Step 4**: Determine the impacts of the combined thickness of the secondary components (Refer to Table 5, Column Impact per mm of combined support & cover lites
  - ***10mm*** * Impact per mm of combined support & cover lites
  - GWP(T) Example: 10mm * 8.23E+00 = **8.23E+01**
- **Step 5**: Determine the impact for the IGU
  - Add the results from Step 2 to the results from Step 4

- GWP(T) Example: 2.46E+02 + 8.23E+01 = 3.28E+02

| Example: Double Pane Product (4mm clear, 0.89mm SentryGlas, 2.2mm SageGlass, 12mm air space w/90% Argon fill, 6mm clear) | | | | | | |
|---|---|---|---|---|---|---|
| Parameter | Unit | **Raw Materials (A1)** | **Raw Materials Transport (A2)** | **Manufacture (A3)** | **Plus Additional Lite Impacts** (10mm) | **Total** |
| Global warming potential (GWP) | kg CO2 eq | 1.09E+02 | 1.71E+00 | 1.35E+02 | 8.23E+01 | 3.28E+02 |
| Stratospheric ozone layer depletion potential (ODP) | kg CFC 11 eq | 1.10E-11 | 3.19E-16 | 2.79E-11 | 6.40E-09 | 6.44E-09 |
| Acidification potential (AP) | kg SO2 eq | 2.58E+00 | 8.06E-03 | 2.15E-01 | 5.57E-01 | 3.36E+00 |
| Eutrophication potential (EP) | kg N eq | 1.76E-02 | 6.79E-04 | 2.45E-02 | 3.35E-02 | 7.63E-02 |
| Photochemical ozone creation potential (POCP) | kg O3 eq | 5.26E+00 | 1.91E-01 | 3.44E+00 | 7.85E+00 | 1.67E+01 |
| Abiotic resource depletion potential – elements (ADP-e) | kg Fe eq | 7.41E+01 | 5.08E-03 | 1.11E+00 | 1.26E+00 | 7.64E+01 |
| Abiotic resource depletion potential – fossil fuels (ADP-f) | MJ | 1.57E+02 | 3.20E+00 | 2.15E+02 | 1.35E+02 | 5.11E+02 |

**Table 18: TRACI Environmental Impact Potentials (w/ RECs) for Example Product 4mm clear, 0.89mm SentryGlas, 2.2mm SageGlass, 12mm air space w/90% Argon fill, 6mm clear**

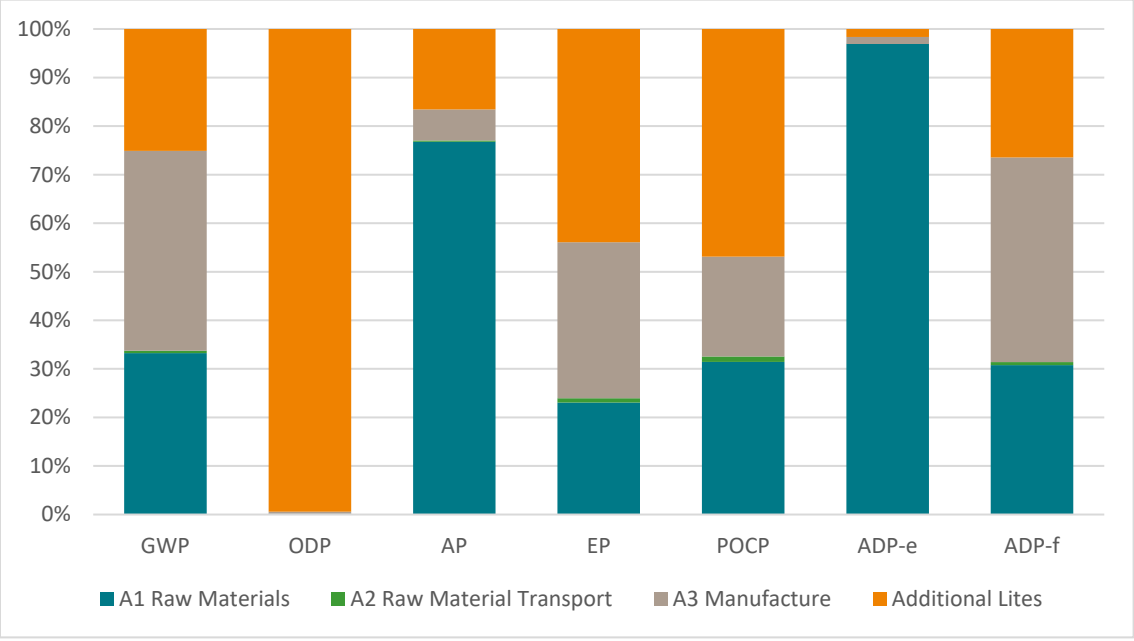


**Figure 14: TRACI Environmental Impact Potentials for Example Product (w/RECs) - 4mm clear, 0.89mm SentryGlas, 2.2mm SageGlass, 12mm air space w/90% Argon fill, 6mm clear**

## Environmental Impact Potentials including RECs: Europe/Rest of World

| Double Pane Product (2.2mm Device Lite + 14.27mm weighted average additional lites = 16.47mm total thickness) | | | | | | |
|---|---|---|---|---|---|---|
| Parameter | Unit | **Raw Materials (A1)** | **Raw Materials Transport (A2)** | **Manufacture (A3)** | **Plus Additional Lite Impacts** (weighted average 14.27mm) | **Total** |
| Global warming potential (GWP) | kg CO2 eq | 1.10E+02 | 1.71E+00 | 1.36E+02 | 1.18E+02 | 3.65E+02 |
| Stratospheric ozone layer depletion potential (ODP) | kg CFC 11 eq | 1.10E-11 | 3.19E-16 | 2.69E-11 | 8.62E-09 | 8.66E-09 |
| Acidification potential (AP) | kg SO2 eq | 3.00E+00 | 6.14E-03 | 2.04E-01 | 7.32E-01 | 3.94E+00 |
| Eutrophication potential (EP) | kg N eq | 3.98E-02 | 1.59E-03 | 2.98E-02 | 8.71E-02 | 1.58E-01 |
| Photochemical ozone creation potential (POCP) | kg O3 eq | 9.25E-02 | -1.48E-03 | 1.58E-02 | -1.93E-02 | 8.75E-02 |
| Abiotic resource depletion potential – elements (ADP-e) | kg Fe eq | 5.54E-02 | 5.34E-07 | 1.14E-04 | 3.34E-04 | 5.59E-02 |
| Abiotic resource depletion potential – fossil fuels (ADP-f) | MJ | 1.51E+03 | 2.40E+01 | 2.12E+03 | 1.58E+03 | 5.23E+03 |

Table 19: CML Environmental Impact Potentials (w/ RECs) for Double Pane (Europe/Rest of World)

| Double Pane VARIO Product (2.2mm Device Lite + 24.45mm weighted average additional lites = 26.65mm total thickness) | | | | | | |
|---|---|---|---|---|---|---|
| Parameter | Unit | **Raw Materials (A1)** | **Raw Materials Transport (A2)** | **Manufacture (A3)** | **Plus Additional Lite Impacts** (weighted average 24.45mm) | **Total** |
| Global warming potential (GWP) | kg CO2 eq | 1.20E+02 | 1.81E+00 | 1.36E+02 | 2.25E+02 | 4.83E+02 |
| Stratospheric ozone layer depletion potential (ODP) | kg CFC 11 eq | 8.21E-12 | 3.32E-16 | 2.69E-11 | 2.16E-08 | 2.16E-08 |
| Acidification potential (AP) | kg SO2 eq | 3.46E+00 | 6.90E-03 | 2.04E-01 | 1.27E+00 | 4.95E+00 |
| Eutrophication potential (EP) | kg N eq | 4.13E-02 | 1.71E-03 | 2.98E-02 | 1.58E-01 | 2.31E-01 |
| Photochemical ozone creation potential (POCP) | kg O3 eq | 1.13E-01 | -1.43E-03 | 1.58E-02 | 2.12E-02 | 1.49E-01 |
| Abiotic resource depletion potential – elements (ADP-e) | kg Fe eq | 6.48E-02 | 5.63E-07 | 1.14E-04 | 6.52E-04 | 6.56E-02 |
| Abiotic resource depletion potential – fossil fuels (ADP-f) | MJ | 1.60E+03 | 2.53E+01 | 2.12E+03 | 3.11E+03 | 6.85E+03 |

Table 20: CML Environmental Impact Potentials (w/ RECs) for Double Pane VARIO (Europe/Rest of World)

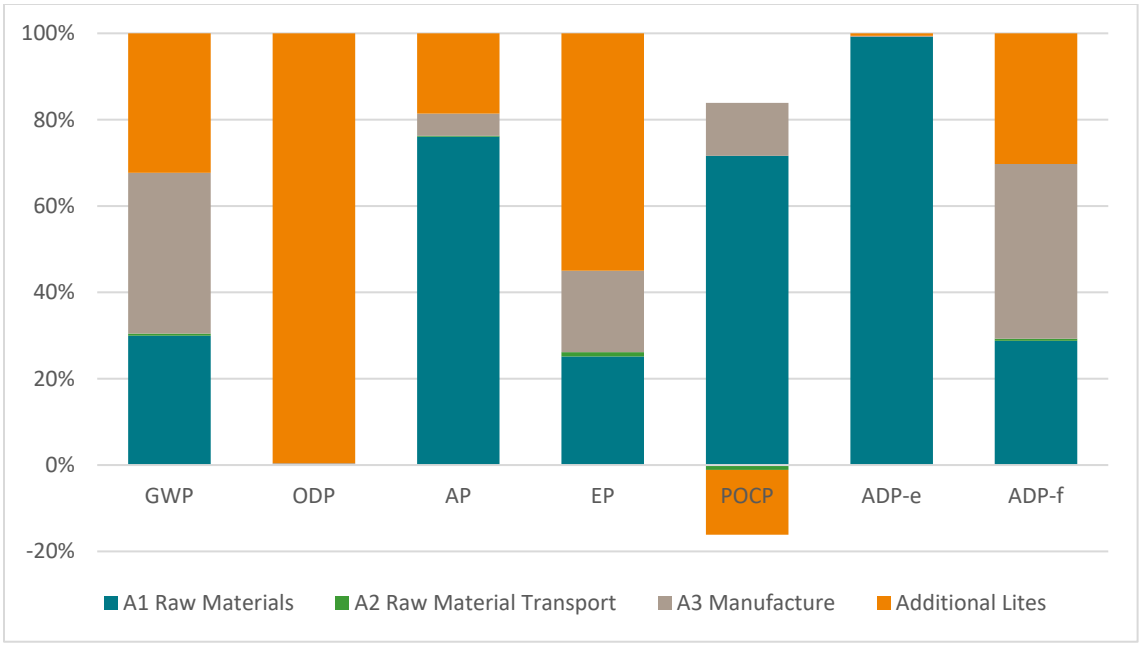


Figure 15: CML Environmental Impact Potentials (w/ RECs) - SageGlass Double Pane Electrochromic IGU

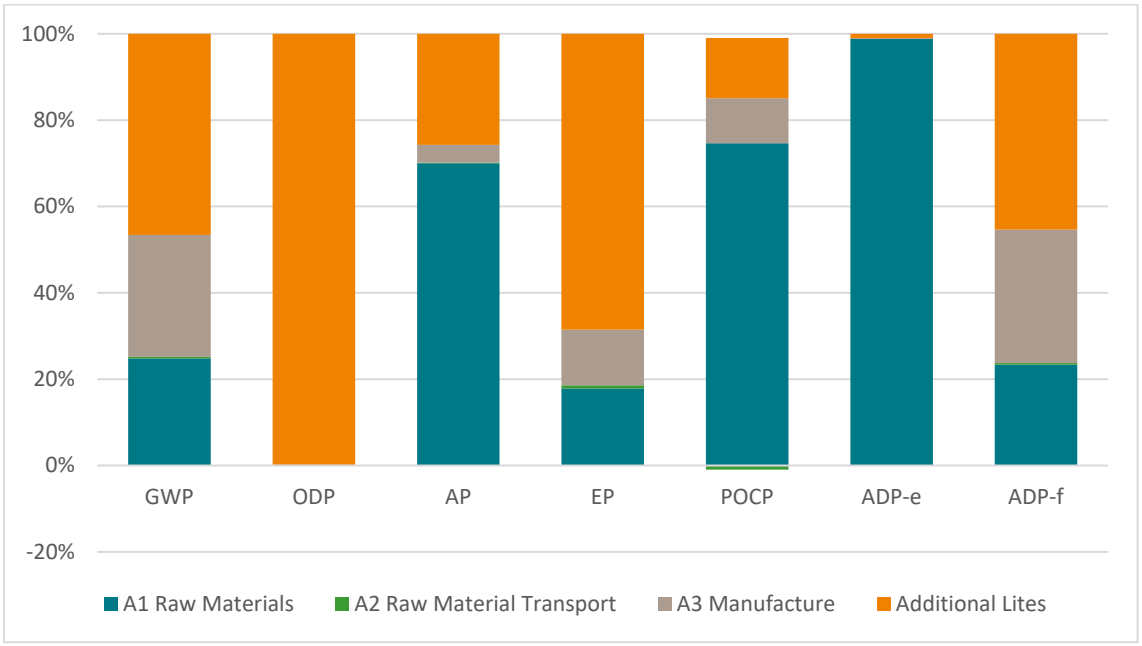


Figure 16: CML Environmental Impact Potentials (w/ RECs) - SageGlass Double Pane VARIO Electrochromic IGU

The example product used to show the calculation for the various thicknesses is a Typical SageGlass Double Pane IGU: 4mm clear, 0.89mm SentryGlas, 2.2mm SageGlass, 12mm air space w/90% Argon fill, 6mm clear.

- **Step 1**: Determine the standard and secondary components
  - Standard components in this configuration: 0.89 SentryGlas, 2.2mm SageGlass, 12mm air space w/90% Argon fill
  - Secondary components in this configuration: 4mm clear, 6mm clear
- **Step 2**: Add the results of the standard component results shown in Table 19 columns A1, A2, and A3
  - 1.10E+02 + 1.71E+00 + 1.36E+02 = **2.47E+02**
- **Step 3**: Determine the combined thickness of the secondary components
  - 4mm clear + 6mm clear = ***10mm***
- **Step 4**: Determine the impacts of the combined thickness of the secondary components (Refer to Table 5, Column Impact per mm of combined support & cover lites
  - ***10mm*** * Impact per mm of combined support & cover lites
  - GWP(C) Example: 10mm * 8.27E+00 = **8.27E+01**
- **Step 5**: Determine the impact for the IGU
  - Add the results from Step 2 to the results from Step 4
  - GWP(T) Example: **2.47E+02** + **8.27E+01** = **3.30E+02**

| Example: Double Pane Product (4mm clear, 0.89mm SentryGlas, 2.2mm SageGlass, 12mm air space w/90% Argon fill, 6mm clear) | | | | | | |
|---|---|---|---|---|---|---|
| Parameter | Unit | **Raw Materials (A1)** | **Raw Materials Transport (A2)** | **Manufacture (A3)** | **Plus Additional Lite Impacts** (weighted average 10mm) | **Total** |
| Global warming potential (GWP) | kg CO2 eq | 1.10E+02 | 1.71E+00 | 1.36E+02 | 8.27E+01 | 3.30E+02 |
| Stratospheric ozone layer depletion potential (ODP) | kg CFC 11 eq | 1.10E-11 | 3.19E-16 | 2.69E-11 | 6.04E-09 | 6.08E-09 |
| Acidification potential (AP) | kg SO2 eq | 3.00E+00 | 6.14E-03 | 2.04E-01 | 5.13E-01 | 3.72E+00 |
| Eutrophication potential (EP) | kg N eq | 3.98E-02 | 1.59E-03 | 2.98E-02 | 6.11E-02 | 1.32E-01 |
| Photochemical ozone creation potential (POCP) | kg O3 eq | 9.25E-02 | -1.48E-03 | 1.58E-02 | -1.36E-02 | 9.33E-02 |
| Abiotic resource depletion potential – elements (ADP-e) | kg Fe eq | 5.54E-02 | 5.34E-07 | 1.14E-04 | 2.34E-04 | 5.58E-02 |
| Abiotic resource depletion potential – fossil fuels (ADP-f) | MJ | 1.51E+03 | 2.40E+01 | 2.12E+03 | 1.11E+03 | 4.76E+03 |

**Table 21: CML Environmental Impact Potentials (w/ RECs) for Example Product - 4mm clear, 0.89mm SentryGlas, 2.2mm SageGlass, 12mm air space w/90% Argon fill, 6mm clear**

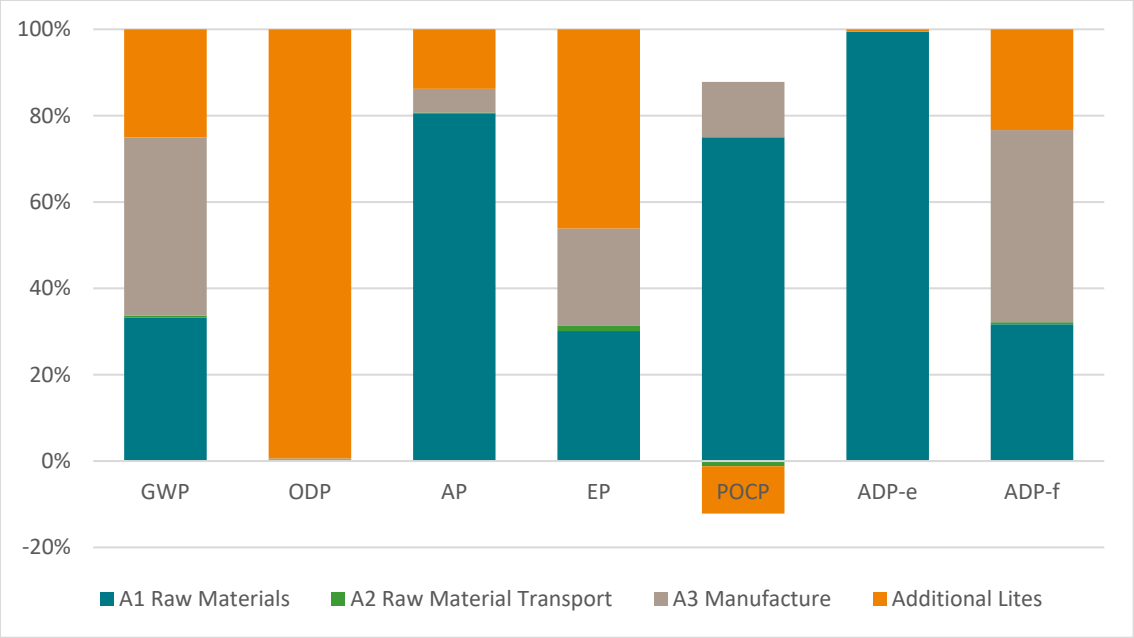


**Figure 17: CML Environmental Impact Potentials (w/ RECs) for Example Product 4mm clear, 0.89mm SentryGlas, 2.2mm SageGlass, 12mm air space w/90% Argon fill, 6mm clear**

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**SageGlass Electrochromic Insulating Glass Unit**
Double Pane and Double Pane VARIO

According to ISO 14025

## LCA Optimization

In 2016, SageGlass performed an LCA and published an EPD using the 2014 data from the Faribault, MN manufacturing site. The initial LCA model was completed using the Simapro v8.1 Software with datasets from Ecoinvent v3, US Ecoinvent, and USLCI. In order to perform an analysis for this study, the 2016 model was converted to a GaBi model using the Thinkstep Gabi US Ecoinvent and USLCI datasets. In 2014 the Double Pane Electrochromic IGU product comprised the majority of the product configurations, thus was the only product evaulated in the 2016 LCA. Therefore, only the Double Pane product used in the current study was included in the optimization analysis.

A number of process improvement were completed in the 2015-2018 timeframe including a reduction of waste material and defects throughout the process. Other improvements included a reduction in electricity consumption per square meter of product by more than 75% and a reduction in natural gas consumption per square meter by more than 60%. Much of this reduction is contributed to the increase in production volume.

In order to base the analysis on products from 2014 and 2018 with the same thickness, the additional lite weighted average used in the 2016 study of 11.7mm for a total thickness of 13.9mm was used for both sets of results.

| 2014 Double Pane Weighted Average 13.9mm (2.2mm Device Lite + 11.7mm Additional Lites) | | | | | | |
|---|---|---|---|---|---|---|
| Parameter | Unit | **Raw Materials (A1)** | **Raw Materials Transport (A2)** | **Manufacture (A3)** | **Plus Additional Lite Impacts** (weighted average 14.27mm) | **Total** |
| Global warming potential (GWP) | kg CO2 eq | 4.01E+02 | 1.22E+01 | 1.42E+03 | 8.86E+01 | 1.92E+03 |
| Stratospheric ozone layer depletion potential (ODP) | kg CFC 11 eq | 3.28E-12 | 2.37E-15 | 9.48E-09 | 3.12E-09 | 1.26E-08 |
| Acidification potential (AP) | kg SO2 eq | 1.13E+01 | 6.97E-02 | 2.20E+00 | 6.83E-01 | 1.43E+01 |
| Eutrophication potential (EP) | kg N eq | 5.35E-02 | 5.73E-03 | 1.69E-01 | 3.34E-02 | 2.62E-01 |
| Photochemical ozone creation potential (POCP) | kg O3 eq | 1.61E+01 | 1.59E+00 | 3.16E+01 | 8.70E+00 | 5.80E+01 |
| Abiotic resource depletion potential – elements (ADP-e) | kg Fe eq | 3.12E+02 | 3.63E-02 | 5.81E+00 | 2.06E+00 | 3.20E+02 |
| Abiotic resource depletion potential – fossil fuels (ADP-f) | MJ | 4.36E+02 | 2.28E+01 | 1.09E+03 | 1.43E+02 | 1.69E+03 |
| **2018 Double Pane 13.9mm Product (2.2mm Device Lites + 11.7mm Additional Lites)** | | | | | | |
| Parameter | Unit | **Raw Materials (A1)** | **Raw Materials Transport (A2)** | **Manufacture (A3)** | **Plus Additional Lite Impacts** (weighted average 24.45mm) | **Total** |
| Global warming potential (GWP) | kg CO2 eq | 1.09E+02 | 1.71E+00 | 3.03E+02 | 9.63E+01 | 5.10E+02 |
| Stratospheric ozone layer depletion potential (ODP) | kg CFC 11 eq | 1.10E-11 | 3.19E-16 | 2.80E-11 | 7.49E-09 | 7.52E-09 |
| Acidification potential (AP) | kg SO2 eq | 2.58E+00 | 8.06E-03 | 4.98E-01 | 6.51E-01 | 3.74E+00 |
| Eutrophication potential (EP) | kg N eq | 1.76E-02 | 6.79E-04 | 4.64E-02 | 3.92E-02 | 1.04E-01 |
| Photochemical ozone creation potential (POCP) | kg O3 eq | 5.26E+00 | 1.91E-01 | 7.25E+00 | 9.18E+00 | 2.19E+01 |
| Abiotic resource depletion potential – elements (ADP-e) | kg Fe eq | 7.41E+01 | 5.08E-03 | 1.42E+00 | 1.48E+00 | 7.70E+01 |
| Abiotic resource depletion potential – fossil fuels (ADP-f) | MJ | 1.57E+02 | 3.20E+00 | 2.91E+02 | 1.58E+02 | 6.10E+02 |

Table 22: TRACI 2.1 Environmental Impact Potentials - SageGlass Double Pane Electrochromic IGU 2014 vs 2018

| 2014 vs 2018 Comparison Double Pane Weighted Average 13.9mm (2.2mm Device Lite + 11.7mm Additional Lites) | | | | | |
|---|---|---|---|---|---|
| Parameter | Unit | **2014 Total A1-A3 plus Additional Lites** | **2018 Total A1-A3 plus Additional Lites** | **Difference** | **% Change** |
| Global warming potential (GWP) | kg CO2 eq | 1.92E+03 | 5.10E+02 | -1.41E+03 | -73.44% |
| Stratospheric ozone layer depletion potential (ODP) | kg CFC 11 eq | 1.26E-08 | 7.52E-09 | -5.08E-09 | -40.32% |
| Acidification potential (AP) | kg SO2 eq | 1.43E+01 | 3.74E+00 | -1.06E+01 | -73.85% |
| Eutrophication potential (EP) | kg N eq | 2.62E-01 | 1.04E-01 | -1.58E-01 | -60.31% |
| Photochemical ozone creation potential (POCP) | kg O3 eq | 5.80E+01 | 2.19E+01 | -3.61E+01 | -62.24% |
| Abiotic resource depletion potential – elements (ADP-e) | kg Fe eq | 3.20E+02 | 7.70E+01 | -2.43E+02 | -75.94% |
| Abiotic resource depletion potential – fossil fuels (ADP-f) | MJ | 1.69E+03 | 6.10E+02 | -1.08E+03 | -63.91% |

**Table 23: 2014 vs 2018 Comparison of TRACI 2.1 Environmental Impact Potentials for SageGlass Double Pane Electrochromic IGU**

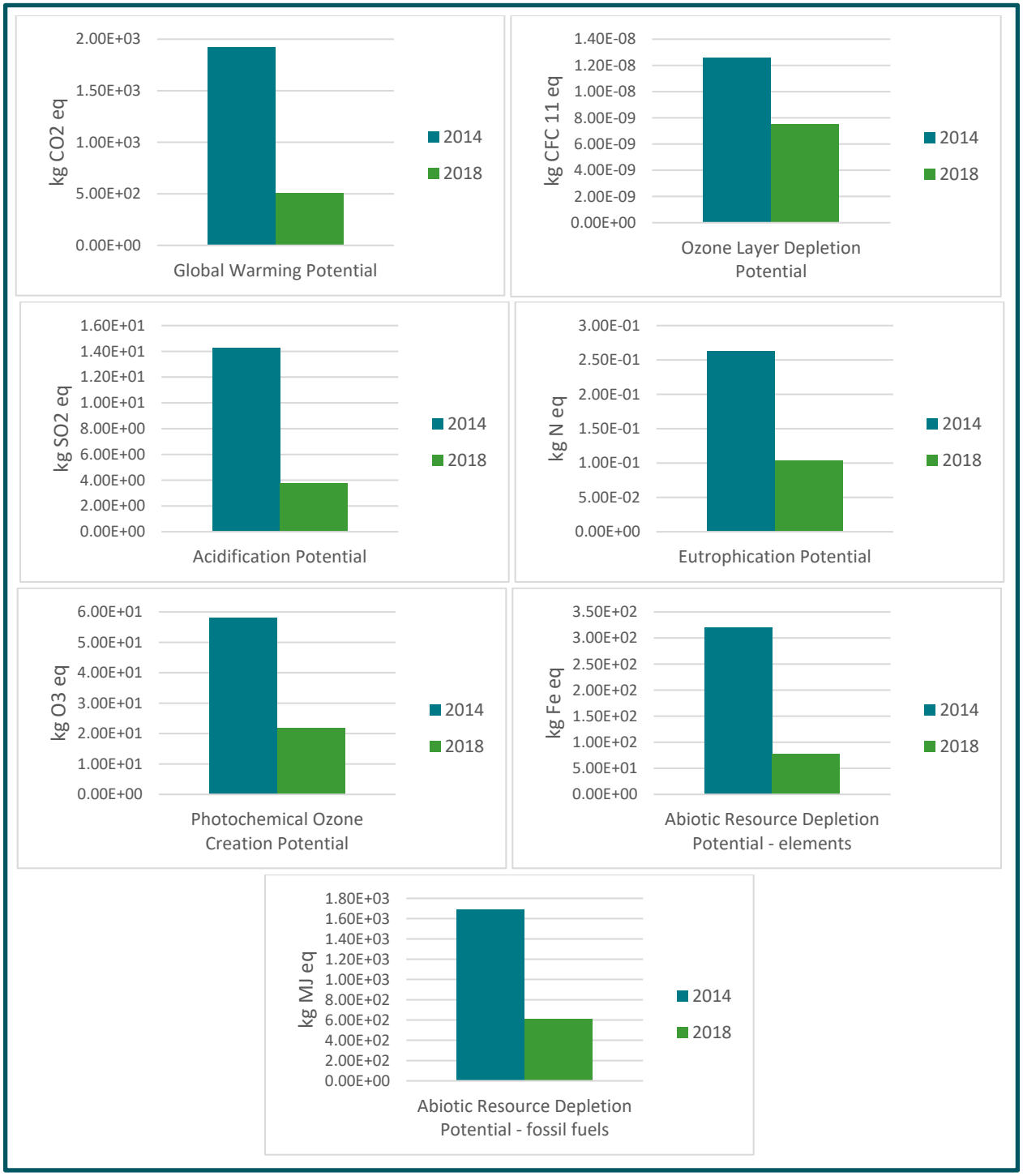


**Figure 18: TRACI Environmental Impact Potential Results - Double Pane SageGlass Electrochromic IGU 2014 vs 2018**

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## LCA Interpretation

Based on the results from the life cycle assessment, the life cycle impacts are strongly driven by the additional lites used to complete the IGU, contributing as much as 50% of the cradle-to-gate impacts of the SageGlass Electrochromic IGU. These high impacts for the additional lites, are attributed to the total input of additional lites that are required for each square meter of finished product. The VARIO products typically use a thicker combination of the additional lites than the non-VARIO version, which leads to the VARIO products having greater environmental impact potentials. SageGlass has made significant improvements in the process since 2014, showing a marked improvement of the impacts; continuing improvements to improve efficiencies throughout the process will continue to help lower the overall impacts of the Electrochromic IGU.

### LCA Development

This EPD and the corresponding LCA were prepared by Saint-Gobain Corporation North America in Malvern, Pennslyvania.

## References


- IBU / UL Environment (2014). PCR for Building-Related Products and Services - Part A: Calculation Rules for the LCA and Requirements Project Report. V1.3, 06.19.2014)
- Product Category Rule Guidance for Building-Related Products and Services: Part B – Processed Glass EPD Requirements. Version 1.0 2016. UL Environment
- ISO 14040: 2006 Series – Environmental Management-Life Cycle Assessment
- EN 15804 – Sustainability of construction works – Environmental Product Declarations – Core rules for the product category of construction products
- ISO 21930 – Sustainability in building construction – Environmental declaration of building products
- SageGlass Electrochromic IGU EPD Report 2016. Saint-Gobain North America EHS&S Department
- SageGlass Website. https://www.sageglass.com/en