New Design Resources for Embodied Carbon Targets

2024 Comparative Study
Conducted by RDH Building Science + Toronto Metropolitan University (TMU) and sponsored by The Atmospheric Fund (TAF)

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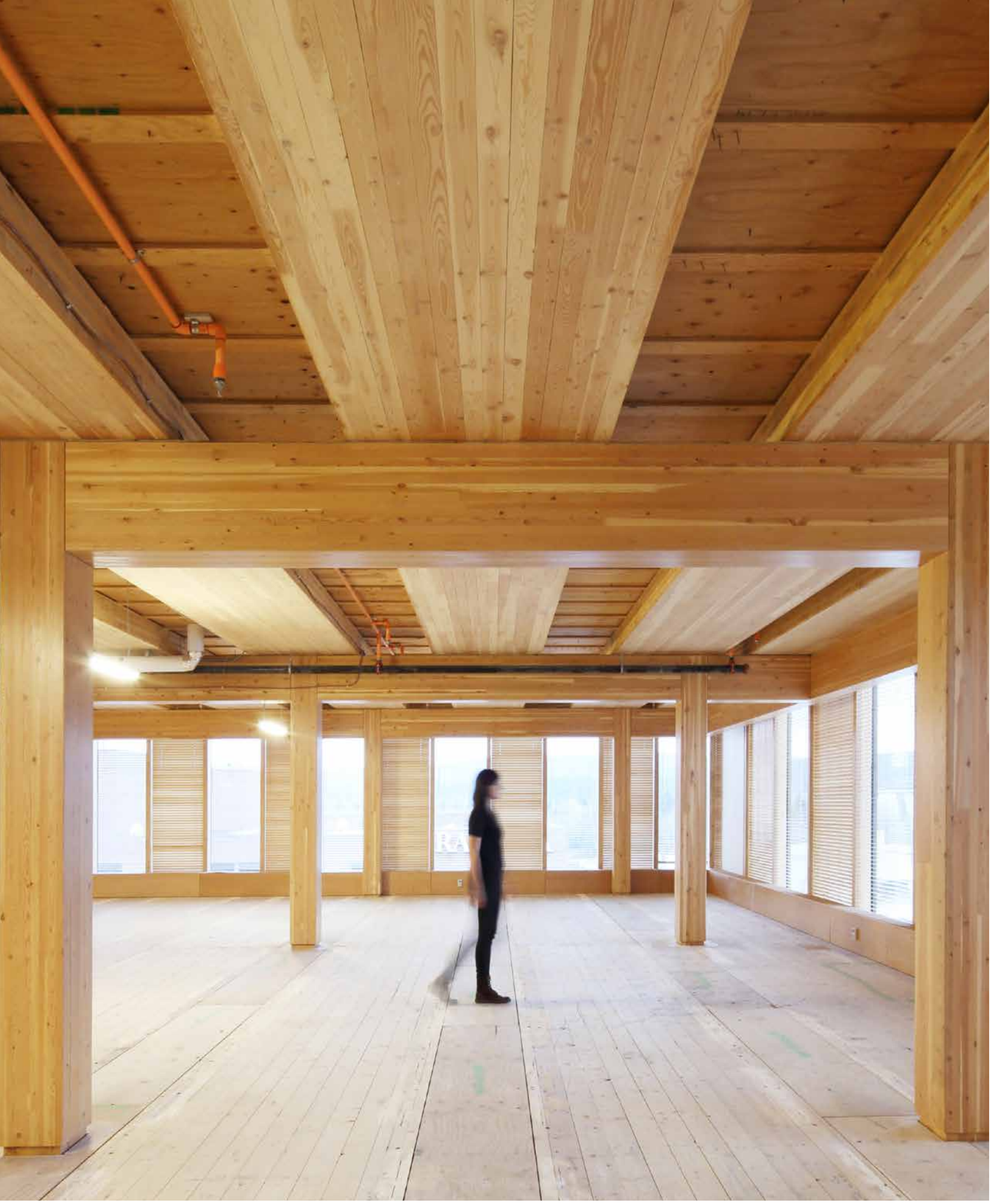


Abstract
Building enclosure design has until now mainly focused on thermal performance and its impact on operational carbon emissions.

This area is now well understood, and industry-trusted tools exist to evaluate thermal bridging and whole building thermal performance. Embodied carbon emissions associated with building enclosure systems are not well understood but contribute significantly to the emissions over a building's lifespan.

This project aims to build understanding of the embodied carbon emissions from building enclosures by providing analysis of 26 commonly used enclosure systems which provide tools for design teams to start to consider and address this issue.

Introduction
The buildings and construction industry represent around 37% of global operational energy and process-related CO2 emissions[1].

Responding to the climate crisis, the building industry has largely focused on reducing the emissions associated with the cumulative energy demand required by the building during its operation (operational carbon). However, as rapid reductions to our operational energy use and thus carbon emissions are achieved by designing high performance buildings, and our electrical grids decarbonize, the impact of the carbon embodied in all the materials and components required to construct a building (i.e. embodied carbon) on buildings total lifecycle carbon emissions is fast becoming the driving factor. In Canada, between 2023 and 2050, embodied carbon could represent the majority of new building's carbon emissions[2].

Figure 1 through 3 from CAGBC's Embodied Carbon Primer published in March 2022 demonstrate the significance of embodied carbon on lifecycle carbon from now to 2050 for high performance building examples in Vancouver, Toronto, and Calgary respectively. In the case of Calgary, projections today based on the current electrical grid do show operational emissions surpassing embodied emission by 2030, however this balance will change as Calgary's electrical grid becomes cleaner.

Figure 1: Vancouver High Performance Building
(Cumulative Tonnes CO_2e)

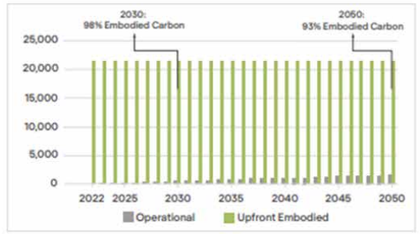


Figure 2: Toronto High Performance Building
(Cumulative Tonnes CO_2e)

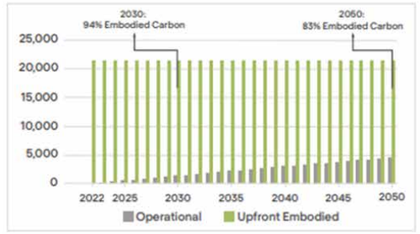
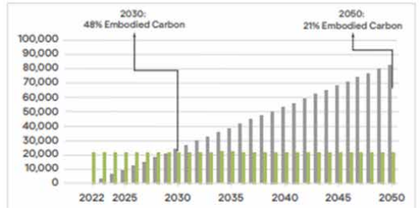


Figure 3: Calgary High Performance Building
(Cumulative Tonnes CO_2e)



Furthermore, up to 2030 upfront carbon emissions still have a significant overall impact and addressing these will be critical in all regions to meet Canada's 2030 targets under the Paris Agreement.[3]

This global context is driving the development and implementation of stricter building codes and regulations throughout North America, with the goal of reducing the negative environmental impacts pertaining to both operational and embodied carbon emissions resulting from the built environment. At a national level, the Government of Canada has committed to a legislated goal of achieving net-zero emissions by 2050 under the Canadian Net-Zero Emissions Accountability Act.

[1]2022 GLOBAL STATUS REPORT FOR BUILDINGS AND CONSTRUCTION – UNEP. The Government of Canada's 'Canadian Net-Zero Emissions Accountability Act' was legalized on June 29, 2021, as per https://www.canada.ca/en/services/environment/weather/climatechange/climate-plan/net-zero-emissions-2050.html

[2]Canadian Green Building Council – Zero Carbon Building Design Standard Version 3 as per https://www.cagbc.org/wp-content/uploads/2022/06/CAGBC_Zero_Carbon_Building-Design_Standard_v3.pdf

[3]Canadian Green Building Council (CaGBC) Embodied Carbon Primer: A Primer for Buildings in Canada, available https://www.cagbc.org/wp-content/uploads/2022/03/Embodied-carbon-white-paper-March-2022.pdf

Organizations such as the Canada Green Building Council's (CAGBC) Zero Carbon Building (ZCB) Design Standard is an example of a certification that was developed to help incentivize, advertise, and guide green building design through the lens of total carbon emissions.

The ZCB Design Standard Version 3 Update outlines potential pathways projects can follow to attain certification. These pathways all implement the use of life cycle assessments (LCAs) as measures to determine the total embodied carbon intensity (in kgCO2e/m2 of gross floor area) of a building. On a more localized scale, the city of Toronto has outlined a new requirement as part of the Toronto's Green Building Standard (TGS) Version 4 updates, to carry out embodied carbon emission assessments upfront for certain project types . While there is no specific requirement yet to conduct life cycle assessments, they provide one straightforward way of calculating and presenting that data. Other municipalities are looking at similar requirements to reduce embodied carbon emissions.

Most embodied carbon analysis to date has focused on structural materials such as concrete due to the large quantities required for mid- and high-rise construction and the high embodied emissions impact of cement. Building enclosure design with regards to high-performance buildings has until now focused on optimizing thermal performance during op`eration. Embodied carbon emissions associated with building enclosure systems are not well understood (and vary widely) but contribute significantly to the emissions over a building's lifespan. Also, additional materials needed to improve the thermal performance for high-performance, low energy buildings considered "green" may add to the overall embodied carbon emissions. Thus, a carbon balance point must be reached.

Responding to the urgent need for a better understanding of embodied carbon by the Architecture, Engineering, and Construction (AEC) industry, the following embodied carbon database and guide for building enclosure design seeks to provide a resource for designers, manufacturers, and policy makers on how to meet this challenge and to make more informed decisions early in the design, specification, and review process when the greatest opportunity for impact and change is available.

In this guide, we have quantified the embodied carbon intensity of commonly used enclosure systems in the Greater Toronto and Hamilton Area (GTHA) used in office, multi-unit residential and institutional buildings (Ontario Building Code (OBC) Part 3 buildings). Using a standardized life cycle assessment methodology for calculating CO2 equivalent emissions, embodied carbon metrics were established for 26 different enclosure assemblies. As our focus is narrowed to the specific implications for the Canadian market, the analysis is specific to the embodied carbon contributions of the locally available materials and typical enclosure systems. The resulting database will inform design at the earliest stages, prior to the establishment of detailed design information, through the lens of embodied carbon, enabling designers to choose optimum enclosures that balance embodied and operational carbon emissions across the building's life-cycle and consider material substitutions to reduce emissions.

How to Use This Guide

The authors envision a number of use cases for this enclosure database. They are:

- Provide designers of offices, multi-unit residential and institutional buildings with early-stage design information regarding the embodied carbon impact of enclosure assembly type and the material within.
- Allow designers and consultants to estimate the embodied carbon impact of their buildings early in design to support in the achievement of current and future absolute embodied carbon emission targets.
- Assist in the development of embodied carbon targets for codes and standards development and/or references (baseline).
- Allow manufacturers to develop an understanding of context for their product, including meeting ever evolving demands for low carbon design choices.
- Encourage manufacturers to develop their product specific Environmental Product Declarations (EPDs) that will allow designers to have greater choices of materials with available data to inform decisions in designing their enclosure assemblies.

[4]As per the Toronto Green Building Standard Version 4 (https://www.toronto.ca/legdocs/mmis/2021/ph/bgrd/backgroundfile-168196.pdf#:~:text=Embodied%20Carbon%20%E2%80%93A%20new%20requirement%20has%20been%20added,sequestration%20within%20landscape%20designs%20has%20also%20been%20added.), embodied carbon should be measured through a materials emissions assessment.

Early Stage Design Decisions

A problem with early stage decisions is that not all information is available for a comprehensive analysis. At the beginning of the design process, in concept and schematic design, the enclosure assembly details and often the enclosure assembly types are not yet developed. This makes evaluation of the quantities of material and choosing data from appropriate EPDs challenging. Developing detailed drawings for multiple enclosure assemblies being considered increases design effort when many other design elements are still in flux. LCA practitioners could develop this information over time using prior projects, however the urgency of the climate emergency requires the ability to make these decisions today.

The assemblies included in this work provide both detailed material descriptions and material quantities for 26 assemblies typically used in commercial construction. While normalized values for embodied carbon emissions are provided in kilograms of equivalent carbon dioxide per square meter of enclosure area (kgCO2e/m2), these values should only be used as the starting point for any user of this database.

The EPDs used in most cases represent product category averages only, and are not project or manufacturer specific. Furthermore, new and updated EPDs are constantly becoming available. However, when armed with the embodied carbon breakdown by assembly component, users can readily understand which components have the most significant contribution to whole assembly carbon content, and how to seek improvement by selecting project specific materials, substituting these preliminary EPD values with their own sources.

Codes and Standards

Whole building embodied carbon emissions targets are more frequently being developed in both voluntary standard and code regulations. For example the Canada Green Building Council's Zero Carbon Building Design standard has an embodied carbon maximum target of 500 kgCO2e /m2 of gross floor area and the Toronto Green Standard (Tier 2) has set a target of 350 kgCO2e/m2. Targets like these have been developed from LCA benchmarking of many buildings and have been selected based on that past experience.

Presumably these targets will be lowered in the future as industry reduces embodied carbon in their products and materials used in buildings, and designers become more knowledgeable and experienced with their design choices. Based on the current practice of past benchmarking, updating these standards will have to wait for more final embodied carbon emissions values for newly constructed buildings to update their targets. Understanding the balance point between operational and embodied carbon emissions will also support in further reducing these targets, or in transforming targets into a whole life cycle carbon emission metric, combining the two.

The information in this database will accelerate this process. As new products with reduced embodied carbon become mainstream, the impact on whole building embodied carbon can be evaluated before waiting for the next generation of low embodied carbon buildings to be constructed.

Providing Context for Manufacturers Products

For any manufacturer to understand the impact of the embodied carbon of their products, they need to understand the context in a whole building life cycle analysis. While every improvement in a manufacturer's carbon emission goes toward improving their own carbon footprint and should be pursued, when marketing their product, manufacturers require proper context to avoid overselling and damaging their credibility with potential product specifiers and builders.

This database highlights the impact of specific materials in enclosure assemblies, and as manufacturers reduce the environmental impacts of their products, this database can be used to estimate the impact on the overall enclosure emissions. The database also demonstrates industry average embodied carbon emissions from a specific product type in Canada, which manufacturers can use as a benchmark for improving their own emissions. In addition, manufacturers can use this database to understand how their products contribute to various assemblies and how to focus their marketing efforts.

Encourage Expansion of EPD Availability
The existence of this database highlights which components are the largest contributor to the environmental impact of enclosure assemblies. This allows designers to focus on components in their assembly that have the highest environmental impact and seek alternatives. The request for these alternatives will incentivise manufacturers to develop EPDs for their own products particularly where they have lower emissions compared with generic values.

Manufacturers that are improving their environmental footprint will be incentivized to demonstrate that their product has a lower environmental footprint than the industry average values used in creating this database.

METHODOLOGY USED TO DEVELOP LCAS FOR ASSEMBLIES

Assembly Selection and R-value Calculations
The building enclosure systems included in this study focus on some of the most commonly used assemblies in OBC Part 3 commercial, residential, and institutional buildings (as defined by the Ontario Building Code) in the Greater Toronto and Hamilton Area (GTHA). Based on the authors' collective industry experience, and consultation with industry representatives, a total of 26 building enclosure assemblies were selected for analysis, prioritizing variety in the materials used to establish a strong data set for comparison and to maximize the usefulness of the data for analysis and industry guidance. The majority of the assemblies selected are suitable for new construction projects, however some assemblies suitable to existing building retrofits are also included.

Low energy and low carbon use buildings require a high-performance thermal enclosure to significantly reduce environmental loads; typically, this leads to added number and quantity of materials within the specified assemblies. However, this added material cost must be balanced with a low-embodied carbon enclosure design. This relies on the use of low carbon materials as well as durable materials that minimize maintenance and replacement needs throughout the building's life cycle.

To achieve these performance values, a focus on the "effective" thermal performance is required. Effective thermal resistance values for assemblies are calculated by summing the thermal resistance of all layers in the assembly, and also accounts for the additional heat loss (i.e. thermal bridging) as a result of repetitive higher conductivity materials bridging through lower conductivity materials (i.e. insulation). The targets established in this study therefore focused on effective R-values.

In order to establish reasonable performance targets that both meet current needs of designers as well as meeting future performance requirements of local energy codes such as the Toronto Green Standard Version 4, the "City of Toronto Zero Emissions Building Framework (2017) Appendix C: Parametric modeling results" was used as a reference point to set recommended baseline target effective R-values for the roof, wall, exposed floor, and vision glazing. A thermal performance target of R-30 (RSI-5.3) was set for the roof, R-25 (RSI-4.4) for the walls, and R-25 (RSI-4.4) for the floors.

The assemblies are designed to meet the effective R-value targets followed above, and the effective R-value of each of the selected assemblies was calculated following building science best practice principles as well as NECB-2017 and ASHRAE Fundamentals.

An example of an effective R-value calculation is provided below for wall W01, which includes the assembly description, material thickness, material conductivity, effective R-value, and nominal R-value. Assumptions and data sources are included for each material.

Global Warming Potential Calculations
The embodied carbon emissions analysis was carried out by calculating the volume or mass of material in each layer of the assembly and then using emissions data from appropriate Environmental Product Declarations (EPDs).

The calculations were made for a functional unit of 9 m2 of enclosure assembly. This was to account for all assembly components that might be missed in a smaller area, such as studs, insulations pins, and anchorage systems. However, the data is reported both for 9m2 and also normalized for 1m2 carbon intensity (kg CO2e/m2) to simplify early design stage calculations from enclosure area take-offs. The LCA calculations assumed a building life span of 60 years. If components had a shorter lifespan, the emissions associated with replacement were included.

Figure 4. *Example W01 Assembly effective R-value calculation table.*

Description	t_{SI}	t_{IP}	k	C (USI)	$RSI_{effective}$	$R_{effective}$	$R_{nominal}$
Units	mm	in	W/mK	W/m^2K	m^2K/W	$ft^2{\cdot}°F{\cdot}h/BTU$	$ft^2{\cdot}°F{\cdot}h/BTU$
Interior Film					0.12	0.68	
Interior gypsum board	12.7	0.50	0.16	27.0	0.04	0.21	
Steel stud-framed wall	63.5	2.50	0.49	7.75	0.13	0.73	
Single-wythe CMU wall	203	8.00	1.18	5.81	0.17	0.98	
Self-adhered sheet-applied air, vapour, and water-resistive barrier (AVB/WRB) membrane	1.00	0.03	-	-	-	-	
Semi-rigid mineral fiber exterior insulation with intermittent stainless steel masonry veneer anchors	152	6.00	0.04	0.24	4.09	23.2	25.8
Air cavity	25.0	0.98	0.03	-	-	-	
Anchored masonry veneer	90.0	3.54	0.79	8.78	-	-	
Exterior air film					0.03	0.17	
TOTALS	**548**	**21.6**			**4.6**	**26.0**	**25.8**

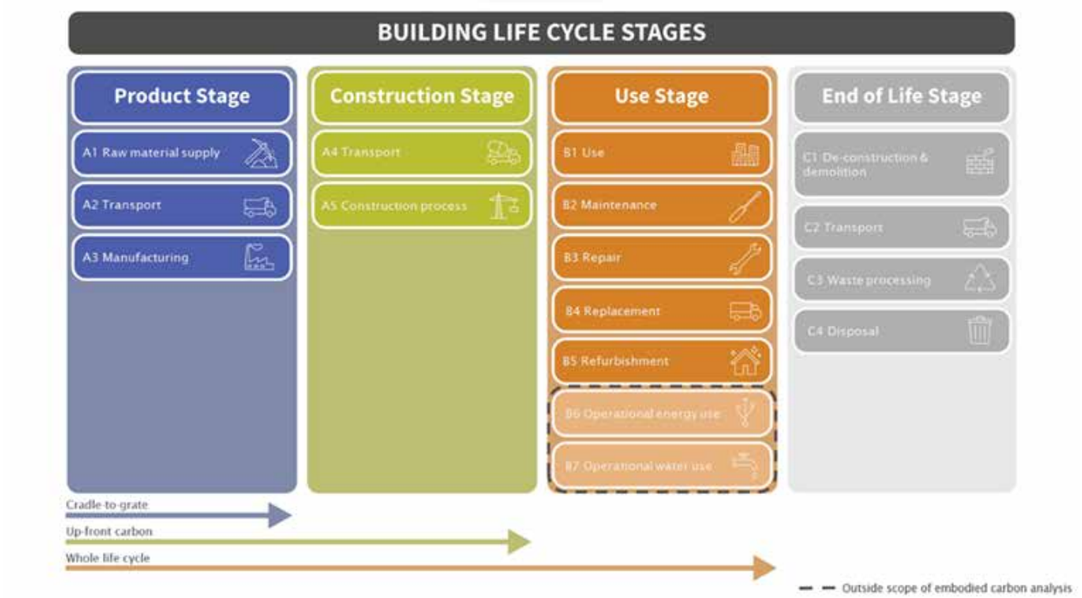
The material quantities for each building enclosure component were calculated using Microsoft Excel spreadsheets using dimensions established from the assembly specifications. The material EPDs were selected from the One Click LCA database, or where necessary other databases such as EC3 were used. In most cases generic or industry average data was selected, but in rare cases it was necessary to search specific manufacturer data when no other data was available or appropriate. The focus of the LCA assessment was embodied carbon emissions (GWP) and this is broken down by material layer.

However, other environmental indicators as defined by the TRACI v2.1 characterization for North America are reported for the assembly as a whole for the various life stages. Default values in OneClick LCA for transport impacts were used.

The outputs for each enclosure include calculations for embodied carbon (kgCO2e/m2) for each layer of the system. Life cycle stages A1 to A3 are highlighted indicating the layers with most impact. Life stages A4 and A5 are also included although these are a small proportion of the total. It should be noted that A5 emissions are attracting considerable attention at present but mostly these are attributed to general site activities and not to individual components or materials. To give some indication of total environmental impact including stages A, B and C, these are also reported based on various TRACI environmental impact categories but with less confidence of their accuracy.

Biogenic carbon, which refers to the carbon that is taken out of the atmosphere and stored in biological materials such as trees or plants through the process of photosynthesis, is also reported where appropriate. Materials that originate from biological sources may sequester carbon while in use as part of the enclosure system. In this respect biogenic carbon stored in timber and other plant based materials can be viewed as a negative emission. Timber used in construction is considered to lock in the biogenic carbon for the lifetime of the building. When a component using such materials reaches the end of its life it is assumed to be incinerated with the stored carbon released back into the atmosphere.

Figure 5. *Building life cycle stages contributing to upfront (embodied) and operational carbon emissions..*



The output summary data for stages A1 to A3 of each enclosure system is presented graphically for each assembly as well as summarized in an as shown below for wall. Total emissions from A1 to A5 are also represented graphically to show the impact of the A4 and A5 category estimated from OneClick as described above. In the summary table, the materials that contribute most significantly to the embodied emissions of the assembly have been highlighted. An example of the graphic representation and summary table are shown for wall type W01 - Exterior Insulated Concrete Masonry Unit (CMU) with Brick Veneer in Figures 6 and 7 respectively.

Limitations of the Study

Embodied carbon analysis of buildings and components is still in its infancy and availability of data is changing quickly. For many materials and components in North America, EPDs are often either generic industry level assessments or are not yet available. In future, it is hoped that more manufacturer or even production plant specific EPDs will allow more detailed analysis and selection of materials. These assessments should not be treated as complete answers to enclosure selection, but rather to inform a consideration of the different materials that make up an enclosure. They also highlight which layers may have significant impact and merit further attention.

Figure 6. *Graphic representation of embodied carbon emissions of each W01 assembly material for a 60 year life cycle for stages A1 to A3 (top) and total assembly emissions for stages A1 to A5 (bottom).*

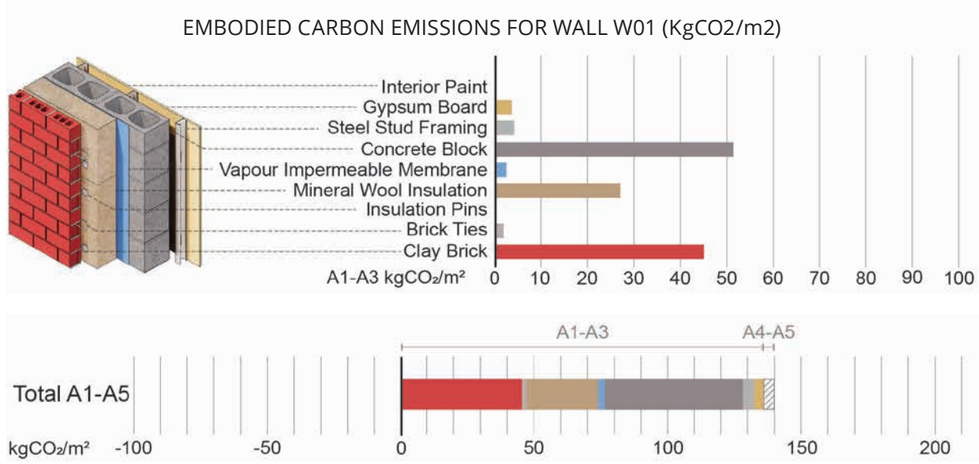


Figure 7. *Example W01 embodied carbon emissions summary for stages A1 to A3, calculated for a 9m2 assembly area, including takeoffs for thickness and volume of material.*

Category	Material	Description (from EPD)	Thickness	Material Volume	Carbon Emissions (A1-A3)	% of total
Units			mm	m^3	kgCO2e	%
Finish	Interior Paint	Eggshell acrylic paint, 1294.29 kg/m3		0.0014	0.6	0.0%
Finish	Interior gypsum board	Gypsum plaster board, regular, generic, 6.5-25 mm, 10.7 kg/m2, (for 12.5 mm), 858 kg/m3	12.7	0.114	26.0	2.1%
Interior finish support	Steel Stud Framing	Steel stud framing for drywall/gypsum plasterboard per sq. meter of wall area (incl. air gaps per m3); 63.5 mm x 30.5 mm, gauge 25	63.5	*	39.0	3.2%
Back-up structure	Reinforced Concrete Block Masonry	Concrete masonry unit (CMU), normal weight, 2250 kg/m3 (Canadian Concrete Masonry Producers Association)	203	1.8	468.0	38.1%
Exterior membrane	Vapour Impermeable Membrane	Latex-based membrane, vapor impermeable, fluid-applied, 40 mils (1mm), 1.15 kg/L, Perm-A-Barrier® NPL 10	1	0.009	22.5	1.8%
Exterior insulation	Exterior Insulation Mineral Wool (Semi-rigid)	Heavy density mineral wool board, Industry average US (NAIMA), 1 m2K/W, 34 mm (1.3"), 4.2 kg/m2, 123.52 kg/m3	152	1.35	241.9	19.7%
Exterior insulation	Insulation Pins	5 insulation pins per panel - 169 pins in total - Hot-dipped galvanised steel; 80% recycled content - 0.28 kg/m2	-	0.0003	3.7	0.3%
Cladding anchorage	Stainless Steel Brick Ties	Assumed 4-foot spacing for angle support - 17 anchors in total - Composed from hot-dipped galvanized cold-formed steel, USA industry average, 7769 - 7849 kg/m3 (SFIA)	-	0.001	17.9	1.5%
Cladding	Clay brick	Clay brick (Acme Brick Company, Belden Brick Company, etc.) 2120 kg/m3	90	0.81	407.4	33.2%
				TOTAL	**1227.1**	100.0%

**Software auto-calculates the impact based on the area provided.*

Data used in EPD assessments and databases such as One Click LCA are often based on national or even continental averages which do not highlight the differences between particular products. The global warming potential of materials within the product stage is often regionally specific and is driven by factors such as the source energy of regional electrical grids, manufacturing processes, regional transportation options, availability of raw materials, and more. The national averages available do not include these critical systemic differences between provinces and industries within provinces, and the resulting global warming potential of the assemblies and materials within these assemblies are subject to change when placed within a specific regional context.

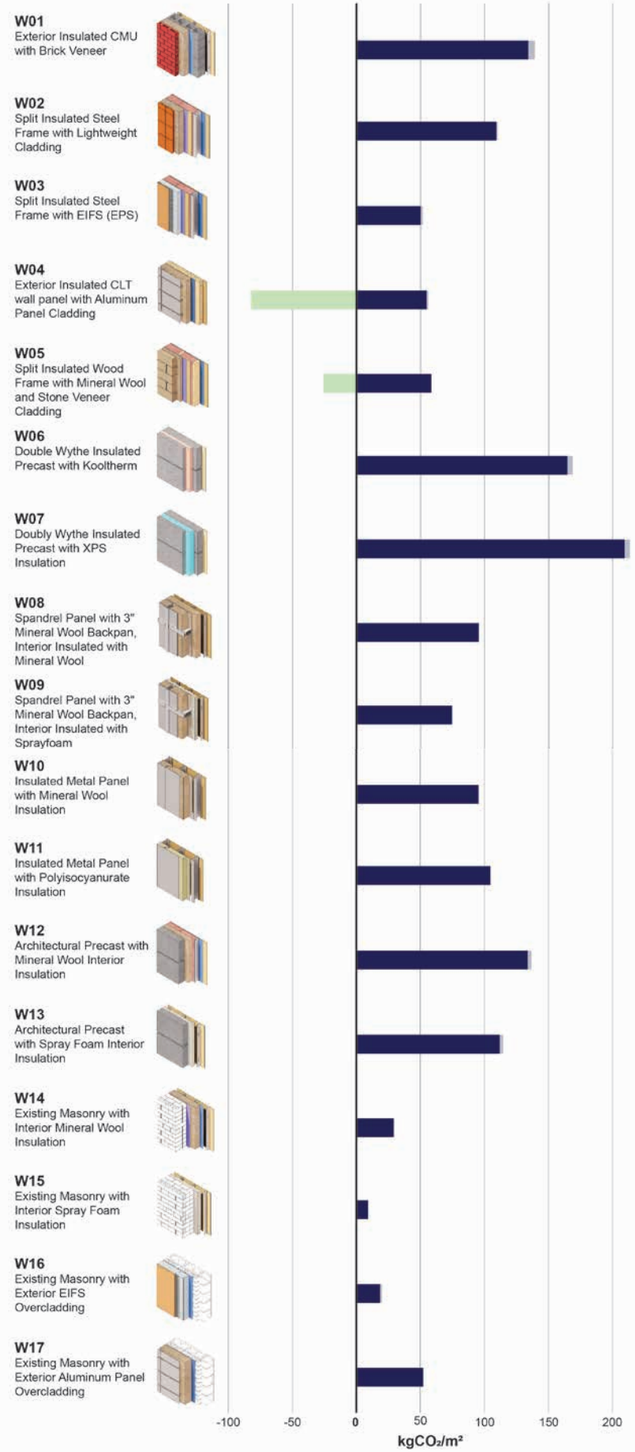
This situation is expected to gradually change and improve as more manufacturers develop specific product and production plant data. This will facilitate the careful selection of locally manufactured materials and components.

Results

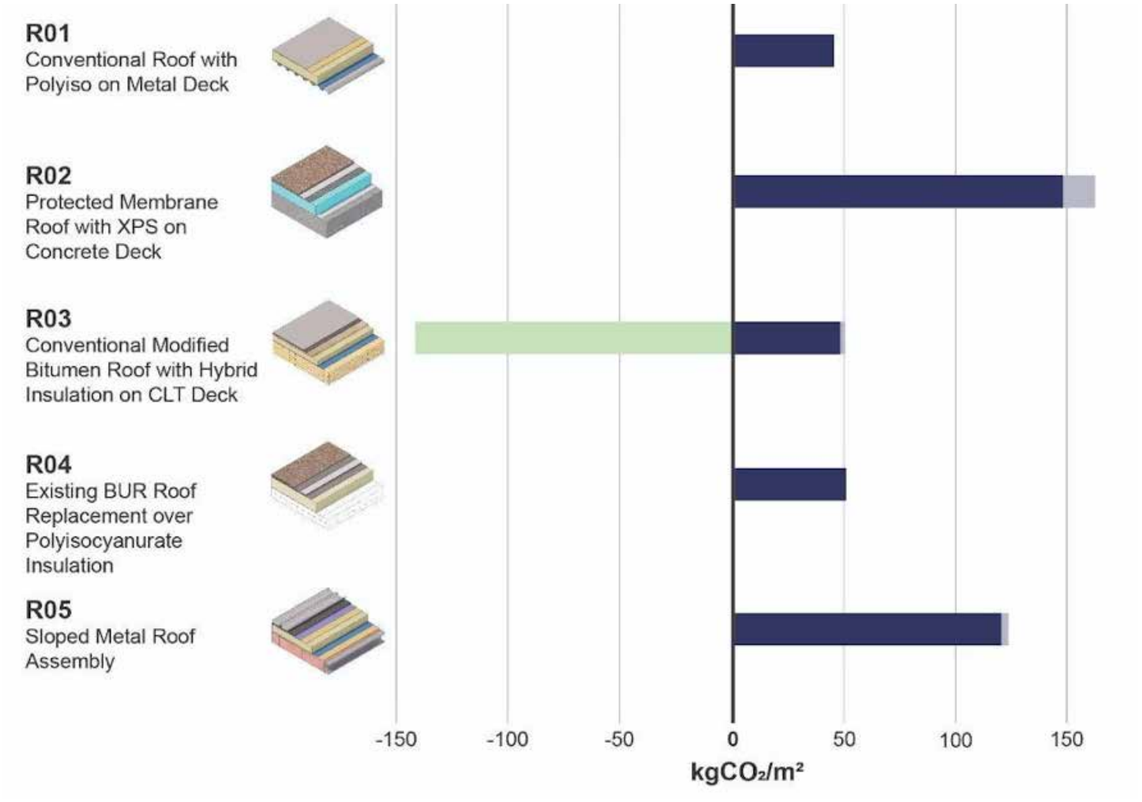
The results of the analysis are summarized below in the form of comparative charts for each building enclosure assembly type evaluated - walls, floors, and roofs. The charts show the total A1 to A3 emissions, the additional estimate emissions associate with A4 to A5, as well as the estimated reduction in assembly emissions resulting from biogenic carbon.

The intent of representing the data in this way is for readers to quickly understand assemblies with the highest embodied emissions, as well as to compare these assemblies with proposed project-specific assemblies and to simplify decision making for projects striving for a low embodied emissions target.

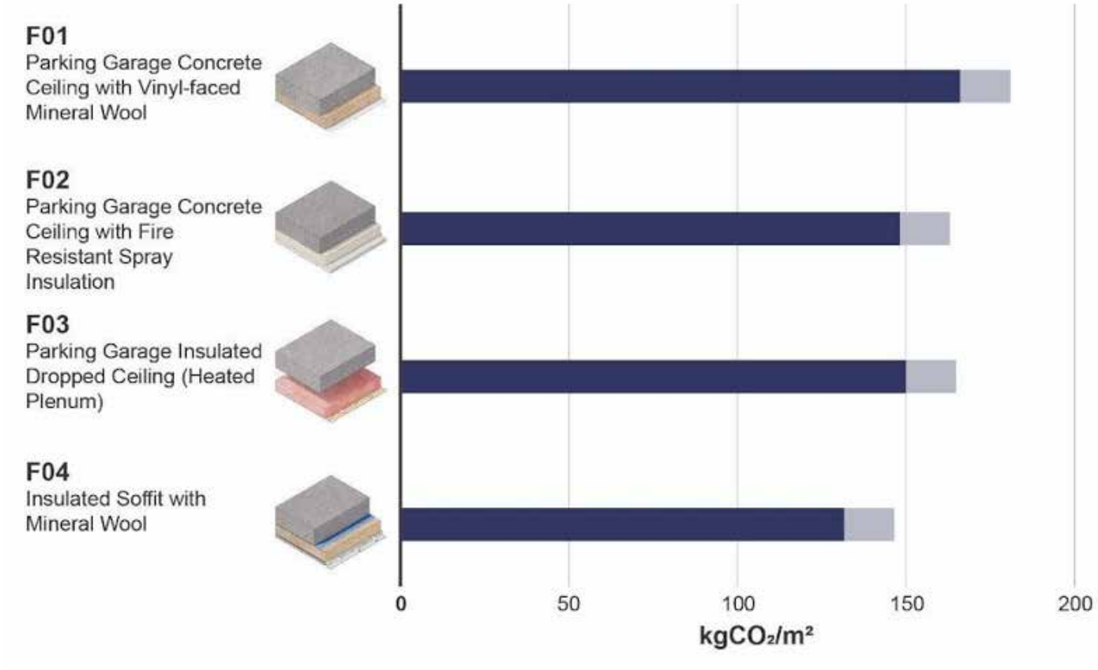
WALL ASSEMBLIES



ROOF ASSEMBLIES



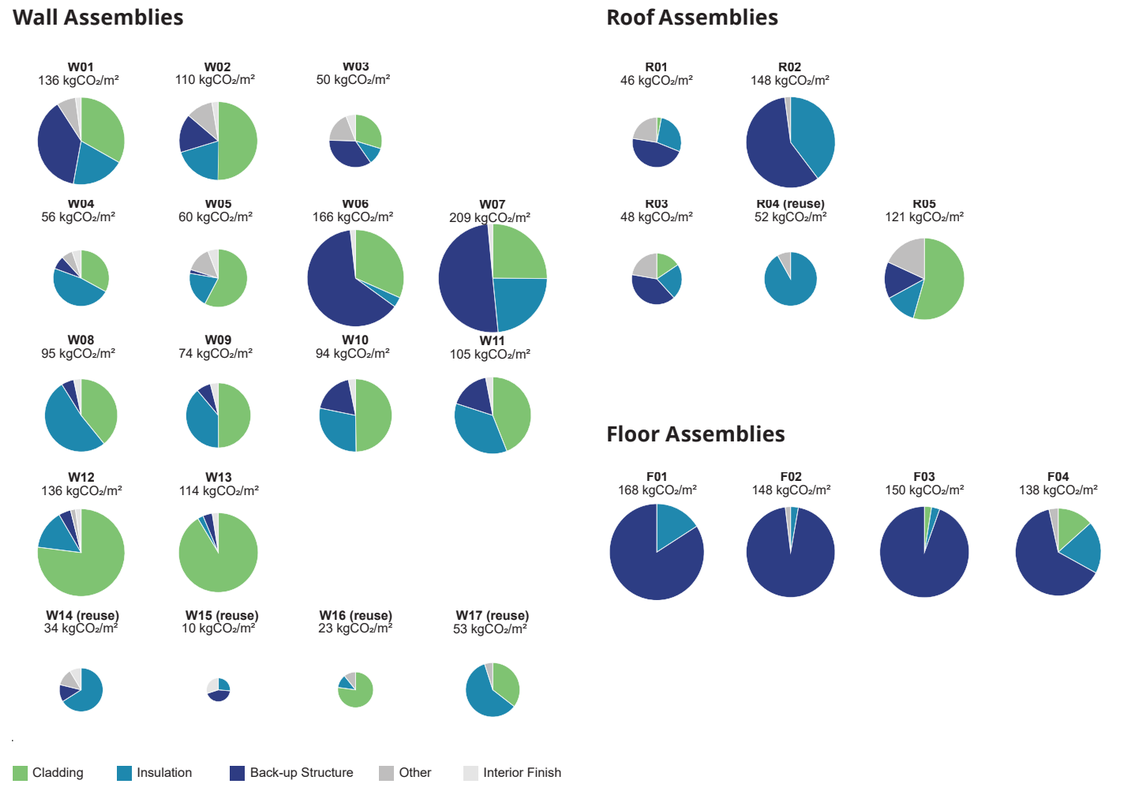
FLOOR ASSEMBLIES



Discussion

The pie charts in Figure 8 below represent the total embodied carbon emissions for each enclosure system. The size of the circles are proportional to the overall impact; large pies show a larger overall carbon emission. The pie slices represent major enclosure component categories. The results show that the embodied carbon emissions of enclosures are generally dominated by the cladding material, followed by the insulation layers, and backup structure. Other components have limited impact. Using the below results, designers are able to choose optimal enclosure designs by prioritizing the selection of low carbon alternatives for the high impact layers highlighted below.

Figure 8. *Summary pie chats for wall, roof, and floor assemblies. The size of the pie represents the total relative embodied carbon emissions for each assembly compared to others (larger pie has greater emissions) as well as the relative impact of each major enclosure component.*



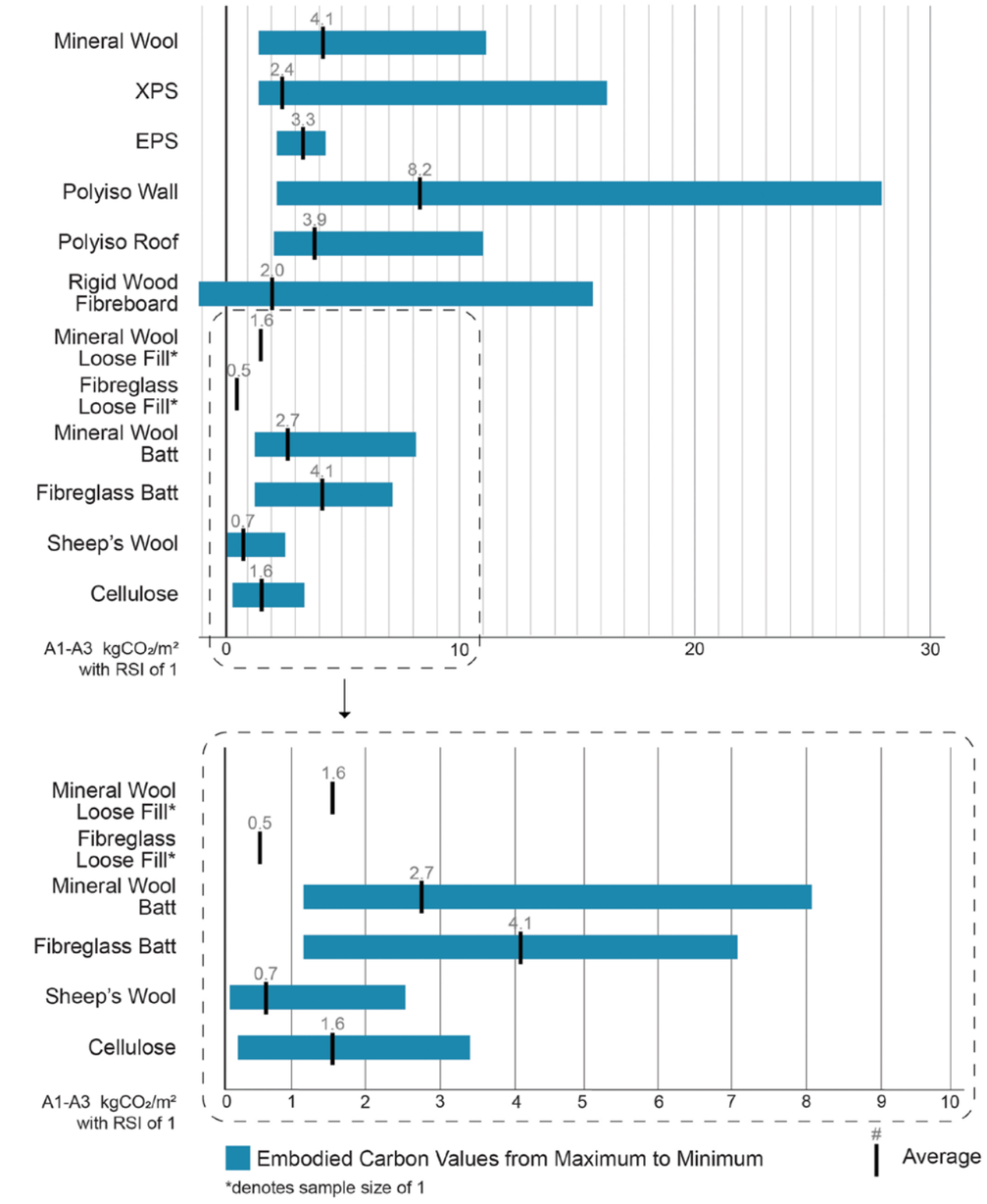
By looking more carefully at insulation using comparison graphs shown in Figure 9, it is clear that careful selection of lower embodied carbon products is a simple way to reduce the overall embodied carbon emissions of an assembly. There is considerable variation between insulation types, and between manufacturers of the same insulation type.

The graphs below highlight the range of values available for each material type. In general, rigid board insulation materials used for external layers outside the structure, both foam based and mineral wool based, have a higher embodied impact compared to batt and loose fill insulation materials used between studs, which are usually less dense. Also, for batt type insulation there are some low impact alternatives such as cellulose and wool insulation.

Thus, the current tendency to use external insulation due to benefits in thermal performance resulting from reduced thermal bridging has to be balanced by the additional embodied carbon emissions associated with these materials. This point highlights the importance of understanding the balance point between operational and embodied emissions.

Figure 9. *Comparison of the embodied emissions of insulation products for stages A1 to A3, normalized by an RSI of 1. The lower graph is an expanded graph of loose fill and batt products that tend to have lower embodied carbon emissions that rigid and semi-rigid board products.*

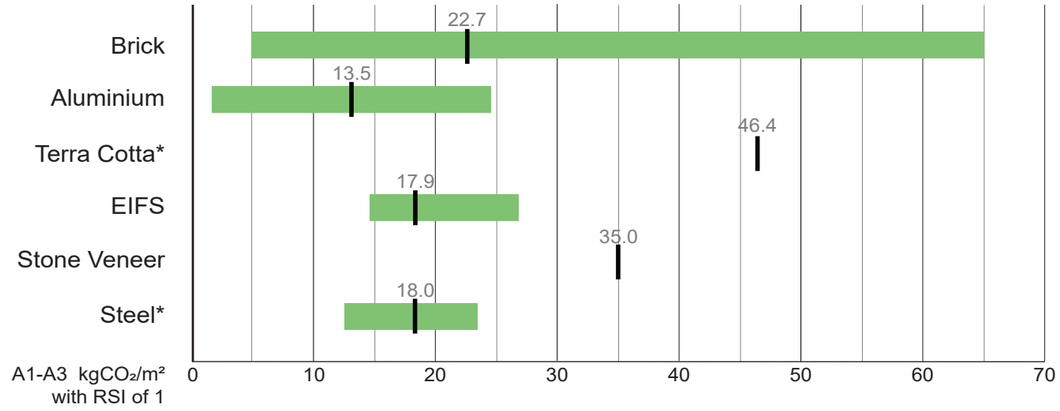
Insulation Comparison



Cladding systems also vary significantly in their impact as shown in Figure 10 below. Depending on the manufacturer, there are large differences in emissions. To address this, designers should request project specific EPDs that meet the project performance requirements while also achieving low emissions. Please note that for some cladding types, limited EPD data is available, and the reported data may be based on a single EPD.

Embodied Carbon Comparison of Cladding Materials

Figure 10. *Comparison of the embodied emissions of cladding products for stages A1 to A3. Data is based on: Brick- 7 products, Aluminum cladding -5 products, Terra Cotta -one product EPD available, EIFS - 10 products (Acrylic-based finish), Stone Veneer - Only one product EPD available, Steel cladding - 4 products.*



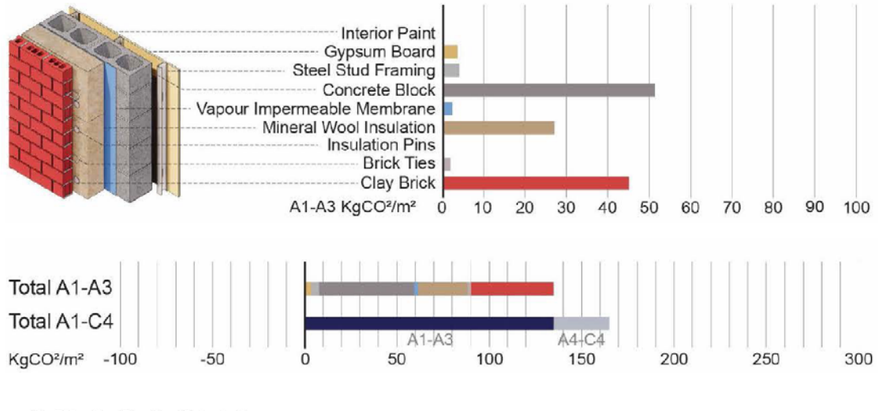
APPENDIX A - DATABASE OF ASSEMBLIES

In this appendix we have summarized the data output for each of the 26 enclosure assemblies.

APPENDIX A **WALL ASSEMBLY 01**

W01: Results Summary

Metrics	Results
Description	**Exterior Insulated CMU with Brick Veneer**
Effective R-value	RSI-4.6 m^2K/W | R-26 $ft^2{\cdot}°F{\cdot}h/BTU$
Embodied Carbon per m^2 of Enclosure (A1-A3)	136.3 $kgCO_2/m^2$
Biogenic Carbon per m^2 of Enclosure	0 $kgCO_2/m^2$



W01: Assembly Effective R-value Calculation

Description	t_{SI}	t_{IP}	k	C (USI)	$RSI_{effective}$	$R_{effective}$	$R_{nominal}$
Units	mm	in	W/mK	W/m^2K	m^2K/W	$ft^2{\cdot}°F{\cdot}h/BTU$	$ft^2{\cdot}°F{\cdot}h/BTU$
Interior Film					0.12	0.68	
Interior gypsum board	12.7	0.50	0.16	27.0	0.04	0.21	
Steel stud-framed wall	63.5	2.50	0.49	7.75	0.13	0.73	
Single-wythe CMU wall	203	8.00	1.18	5.81	0.17	0.98	
Self-adhered sheet-applied air, vapour, and water-resistive barrier (AVB/WRB) membrane	1.00	0.03	-	-	-	-	
Semi-rigid mineral fiber exterior insulation with intermittent stainless steel masonry veneer anchors	152	6.00	0.04	0.24	4.09	23.2	25.8
Air cavity	25.0	0.98	0.03	-	-	-	
Anchored masonry veneer	90.0	3.54	0.79	8.78	-	-	
Exterior air film					0.03	0.17	
TOTALS	**548**	**21.6**			**4.6**	**26.0**	**25.8**

W01: Embodied Carbon Emissions (A1 to A3 Life Stages) for 9m² Assembly Area

Category	Material	Description (from EPD)	Thickness	Material Volume	Carbon Emissions (A1-A3)	% of total
Units			mm	m^3	kgCO2e	%
Finish	Interior Paint	Eggshell acrylic paint, 1294.29 kg/m3		0.0014	0.6	0.0%
Finish	Interior gypsum board	Gypsum plaster board, regular, generic, 6.5-25 mm, 10.7 kg/m2, (for 12.5 mm), 858 kg/m3	12.7	0.114	26.0	2.1%
Interior finish support	Steel Stud Framing	Steel stud framing for drywall/gypsum plasterboard per sq. meter of wall area (incl. air gaps per m3); 63.5 mm x 30.5 mm, gauge 25	63.5	*	39.0	3.2%
Back-up structure	Reinforced Concrete Block Masonry	Concrete masonry unit (CMU), normal weight, 2250 kg/m3 (Canadian Concrete Masonry Producers Association)	203	1.8	468.0	38.1%
Exterior membrane	Vapour Impermeable Membrane	Latex-based membrane, vapor impermeable, fluid-applied, 40 mils (1mm), 1.15 kg/L, Perm-A-Barrier® NPL 10	1	0.009	22.5	1.8%
Exterior insulation	Exterior Insulation Mineral Wool (Semi-rigid)	Heavy density mineral wool board, Industry average US (NAIMA), 1 m2K/W, 34 mm (1.3"), 4.2 kg/m2, 123.52 kg/m3	152	1.35	241.9	19.7%
Exterior insulation	Insulation Pins	5 insulation pins per panel - 169 pins in total - Hot-dipped galvanised steel; 80% recycled content - 0.28 kg/m2	-	0.0003	3.7	0.3%
Cladding anchorage	Stainless Steel Brick Ties	Assumed 4-foot spacing for angle support - 17 anchors in total - Composed from hot-dipped galvanized cold-formed steel, USA industry average, 7769 - 7849 kg/m3 (SFIA)	-	0.001	17.9	1.5%
Cladding	Clay brick	Clay brick (Acme Brick Company, Belden Brick Company, etc.) 2120 kg/m3	90	0.81	407.4	33.2%
				TOTAL	**1227.1**	100.0%

**Software auto-calculates the impact based on the area provided.*

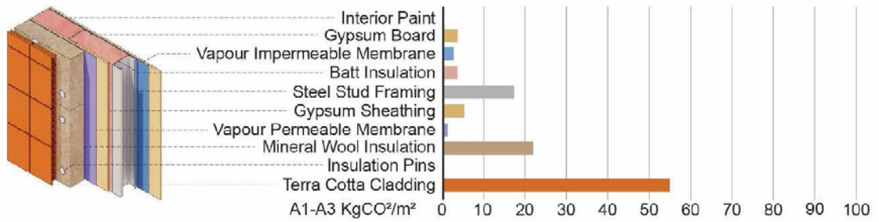
W01: Environmental Emissions (A1 to C4 Life Stages) for 9m² Assembly Area

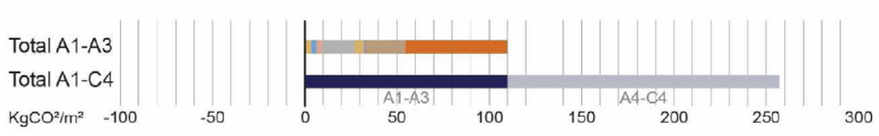
Lifecycle Stage		**A1 to C4**	A1-A3	A4-A5	B1-B5	C1-C4	A1-A3 Contribution to total
Category	Units	**Total**	Construction Materials	Transport to Site & Construction	Material Replacement & Refurbishment	Deconstruction	%
Global Warming	kg CO2e	**1,480.13**	1,221.51	40.35	140.24	78.03	82.5
Acidification	kg SO	**5.69**	5.04	0.23	0.28	0.14	88.6
Eutrophication	kg Ne	**1.15**	1.04	0.03	0.03	0.043	90.5
Ozone Depletion	kg CFC11e	**0.000079**	0.000059	0.000011	0.0000014	0.0000078	74.5
Formation of Tropospheric Ozone	kg O3e	**73.50**	59.15	6.51	5.12	2.72	80.5%
Fossil Fuel Primary Energy	MJ	**18,376**	15,327	1,147	1,338	565	83.4%
Biogenic Carbon Storage	kg CO2e	**0**	0	0	0	0	

APPENDIX A **WALL ASSEMBLY 02**

W02: Results Summary

Metrics	Results
Description	**Split Insulated Steel Frame with Lightweight Cladding**
Effective R-value	RSI-4.4 m^2K/W | R-25.2 $ft^2{\cdot}°F{\cdot}h/BTU$
Embodied Carbon per m^2 of Enclosure (A1-A3)	110.3 $kgCO_2/m^2$
Biogenic Carbon per m^2 of Enclosure	-0.4 $kgCO_2/m^2$





W02: Assembly Effective R-value Calculation

Description	t_{SI}	t_{IP}	k	C (USI)	$RSI_{effective}$	$R_{effective}$	$R_{nominal}$
Units	mm	in	W/mK	W/m^2K	m^2K/W	$ft^2{\cdot}°F{\cdot}h/BTU$	$ft^2{\cdot}°F{\cdot}h/BTU$
Interior air film					0.12	0.68	
Interior gypsum board	12.7	0.50	-	-	0.05	0.30	
Vapour barrier	-	-	-	-	-	-	
Steel stud-framed wall with batt insulation	152	6.00	-	-	1.30	7.38	
Exterior sheathing	12.7	0.50	0.13	10.1	0.10	0.56	
Self-adhered sheet-applied air barrier and WRB membrane (vapour permeable)	1.00	0.04	-	-	-	-	
Semi-rigid mineral fiber exterior insulation with intermittent proprietary fibreglass clips	127	5.00	-	-	2.84	16.1	21.5
Air cavity	25.0	0.98	-	-	-	-	
Terracotta panel cladding	40.0	1.57	-	-	-	-	
Exterior air film	-	-	-	-	0.03	0.17	
TOTALS	**371**	**14.6**			**4.40**	**25.2**	**21.5**

W02: Embodied Carbon Emissions (A1 to A3 Life Stages) for 9m² Assembly Area

Category	Material	Description (from EPD)	Thickness	Material Volume	Carbon Emissions (A1-A3)	% of total
Units			mm	m^3	kgCO2e	%
Finish	Interior Paint	Eggshell acrylic paint, 1294.29 kg/m3		0.0014	0.6	0.06%
Finish	Gypsum Board	Gypsum plaster board, regular, generic, 6.5-25 mm, 10.725 kg/m2 (for 12.5 mm), 858 kg/m3	12.7 (0.5")	0.114	26.04	2.62%
Vapour control	Vapour Impermeable Membrane	Vapor barrier	0.8 (0.032")	0.0072	17.93	1.81%
Interior insulation	Batt Insulation	Mineral fiber batt insulation, 6.89in	152.4 (6")	1.029	31.15	3.14%
Structure	Steel Stud Framing	Steel stud framing for drywall/gypsum plasterboard per sq. meter of wall area (incl. air gaps per m3), C-profile: 152.4 mm x 76.2 mm, gauge 20 (40 cm) spacing	152.4 (6")	*	158.39	15.95%
Sheathing	Exterior Gypsum Sheathing	Glass-mat gypsum board, fire and moisture-resistant; 799 kg/m3	12.7 (0.5")	0.1143	42.26	4.26%
Exterior membrane	Vapour Permeable Membrane	Latex-based membrane, vapor permeable, fluid-applied, fire resistant, 40 mils (1.016 mm), 1.399 kg/L, Perm-A-Barrier® VPL	1 (0.04")	0.009	11.16	1.12%
Exterior insulation	Exterior Insulation Mineral Wool (Semi-rigid)	Heavy density mineral wool board, 1 m2K/W, 1.34 in (34 mm), 0.86 lb/ft2 (4.2 kg/m2), 7.71 lb/ft3 (123.52 kg/m3), Industry average US (NAIMA)	127 (5")	1.143	201.82	20.32%
Exterior insulation	Insulation Pins	5 insulation pins per panel - 169 pins in total Hot-dipped galvanised steel sheets; 80% recycled content - 0.28 kg/m2	-	0.000302	3.73	0.38%
Cladding	Terra Cotta Cladding	Ceramic floor and wall tiles, 7.9375 mm, avg. weight 17.57 kg/m2 (Fireclay Tile)	40 (1.6")	0.36	499.9	50.34%
				TOTAL	**993.0**	100.0%

**Software auto-calculates the impact based on the area provided.*

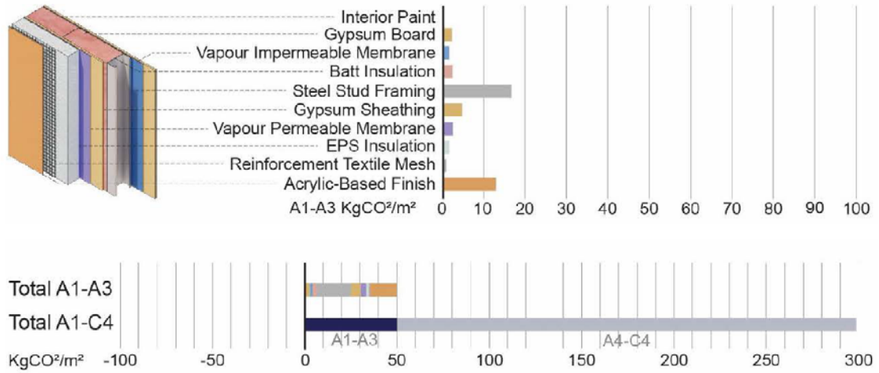
W02: Environmental Emissions (A1 to C4 Life Stages) for 9m² Assembly Area

Lifecycle Stage		**A1 to C4**	A1-A3	A4-A5	B1-B5	C1-C4	A1-A3 Contribution to total
Category	Units	**Total**	Construction Materials	Transport to Site & Construction	Material Replacement & Refurbishment	Deconstruction	%
Global Warming	kg CO2e	**2,407.78**	989.23	10.89	1332.6	75.06	41.08%
Acidification	kg SO	**5.30**	2.47	0.062	2.68	0.091	46.58%
Eutrophication	kg Ne	**0.81**	0.31	0.0087	0.4615	0.033	38.12%
Ozone Depletion	kg CFC11e	**0.000044**	0.0000098	0.0000029	0.000028	0.0000035	22.17%
Formation of Tropospheric Ozone	kg O3e	**172.06**	64.39	1.76	104	1.91	37.42%
Fossil Fuel Primary Energy	MJ	**11,129.73**	4,886.56	309.53	5654.8	278.84	43.91%
Biogenic Carbon Storage	kg CO2e	**-3.74**	3.74	0	0	0	-100.00%

APPENDIX A **WALL ASSEMBLY 03**

W03: Results Summary

Metrics	Results
Description	**Split Insulated Steel Frame with EIFS (EPS)**
Effective R-value	RSI-4.51 m^2K/W | R-25.6 $ft^2{\cdot}°F{\cdot}h/BTU$
Embodied Carbon per m^2 of Enclosure (A1-A3)	50.12 $kgCO_2/m^2$
Biogenic Carbon per m^2 of Enclosure	0 $kgCO_2/m^2$



W03: Assembly Effective R-value Calculation

Description	t_{SI}	t_{IP}	k	C (USI)	$RSI_{effective}$	$R_{effective}$	$R_{nominal}$
Units	mm	in	W/mK	W/m^2K	m^2K/W	$ft^2{\cdot}°F{\cdot}h/BTU$	$ft^2{\cdot}°F{\cdot}h/BTU$
Interior air film					0.12	0.68	
Interior gypsum board	12.7	0.50	-	-	0.05	0.30	
Vapour barrier	1.00	0.04	-	-	-	-	
Steel stud-framed wall with batt insulation	152	6.00	-	-	1.30	7.38	
Exterior sheathing	12.7	0.50	0.13	10.1	0.10	0.56	
Fluid-applied air barrier and WRB membrane (vapour permeable)	3.00	0.12	-	-	-	-	
Expanded polystyrene (EPS) rigid board insulation	102	4.00	0.04	0.34	2.90	16.5	16.5
EIFS base and finish coat	4.00	0.16	-	-	0.01	0.06	
Exterior air film	-	-	-	-	0.03	0.17	
TOTALS	**287**	**11.3**			**4.50**	**25.6**	**16.5**

W03: Embodied Carbon Emissions (A1 to A3 Life Stages) for 9m² Assembly Area

Category	Material	Description (from EPD)	Thickness	Material Volume	Carbon Emissions (A1-A3)	% of total
Units			mm	m^3	kgCO2e	%
Finish	Interior Paint	Eggshell acrylic paint, 1294.29 kg/m3		0.0014	0.6	0.13%
Finish	Gypsum Board	Gypsum plaster board, regular, generic, 6.5-25 mm, 10.725 kg/m2 (for 12.5 mm), 858 kg/m3	12.7 (0.5")	0.114	26.04	5.77%
Vapour control	Vapour Impermeable Membrane	Vapor barrier	0.8 (0.032")	0.0072	17.93	3.97%
Interior insulation	Batt Insulation	Mineral fiber batt insulation	152.4 (6")	1.029	31.15	6.91%
Structure	Steel Stud Framing	Steel stud framing for drywall/gypsum plasterboard, C-profile: 152.4 mm x 76.2 mm, gauge 20 (40 cm) spacing	152.4 (6")	*	158.39	35.11%
Sheathing	Exterior Gypsum Sheathing	Glass-mat gypsum board, fire and moisture-resistant; 799 kg/m3	12.7 (0.5")	0.1143	42.26	9.37%
Exterior membrane	Vapour Permeable Membrane	Latex-based membrane, vapor permeable, fluid-applied, fire resistant, 40 mils (1.016 mm), 1.399 kg/L, Perm-A-Barrier® VPL	3 (0.12")	0.027	32.94	7.30%
Exterior insulation	EPS insulation (rigid)	EPS insulation	101.6 (4")	0.9144	16.66	3.69%
Exterior Finish (EIFS)	Acrylic-based finish	Acrylic-based textured wall finishes, for exterior or interior application, 15.29 kg/m2, Stolit® R1.5 (Sto)		*	125.1	27.73%
	Fluoropolymer powder coating	Fluoropolymer powder coating, with solar-reflective pigments, exterior use, White, Powdura 5000 Bone White (LWS2-80002) (Sherwin-Williams)	(0.978 kg)	1.6		0.35%
	Reinforcement textile mesh	Reinforcement textile mesh for façade cladding, 0.151 kg/m2, (Adfors-Saint Gobain)	*	7.17		1.59%
			TOTAL	**451.07**		100.0%

**Software auto-calculates the impact based on the area provided.*

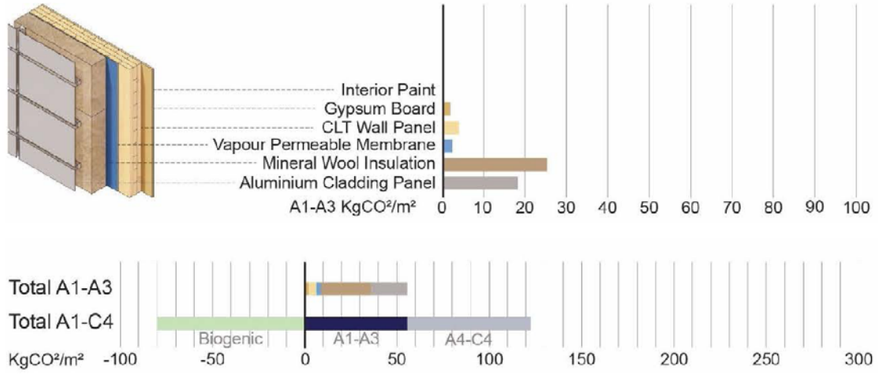
W03: Environmental Emissions (A1 to C4 Life Stages) for 9m² Assembly Area

Lifecycle Stage		**A1 to C4**	A1-A3	A4-A5	B1-B5	C1-C4	A1-A3 Contribution to total
Category	Units	**Total**	Construction Materials	Transport to Site & Construction	Material Replacement & Refurbishment	Deconstruction	%
Global Warming	kg CO2e	**2,677.24**	439.97	14.40	2,034.52	188.35	16.43%
Acidification	kg SO	**11.16**	2.06	0.08	8.84	0.18	18.47%
Eutrophication	kg Ne	**1.99**	0.48	0.01	1.44	0.05	24.14%
Ozone Depletion	kg CFC11e	**0.01**	0.0010	0.0000037	0.010	0.000002	8.91%
Formation of Tropospheric Ozone	kg O3e	**123.22**	24.54	2.08	94.76	1.84	19.92%
Fossil Fuel Primary Energy	MJ	**41,591.61**	6,816.27	404.69	34,207.99	162.66	16.39%
Biogenic Carbon Storage	kg CO2e	**0**	0	0	0	0	

APPENDIX A **WALL ASSEMBLY 04**

W04: Results Summary

Metrics	Results
Description	**Exterior Insulated CLT Wall Panel with Aluminum Panel Cladding**
Effective R-value	RSI-4.4 m^2K/W | R-24.9 $ft^2{\cdot}°F{\cdot}h/BTU$
Embodied Carbon per m^2 of Enclosure (A1-A3)	56.43 $kgCO_2/m^2$
Biogenic Carbon per m^2 of Enclosure	-80.3 $kgCO_2/m^2$



W04: Assembly Effective R-value Calculation

Description	t_{SI}	t_{IP}	k	C (USI)	$RSI_{effective}$	$R_{effective}$	$R_{nominal}$
Units	mm	in	W/mK	W/m^2K	m^2K/W	$ft^2{\cdot}°F{\cdot}h/BTU$	$ft^2{\cdot}°F{\cdot}h/BTU$
Interior air film					0.12	0.68	
Interior gypsum board	12.7	0.50	0.24	18.9	0.05	0.30	
Mass timber wall panel	102	4.00	0.13	1.28	0.78	4.44	
Self-adhered sheet-applied air barrier and WRB membrane (vapour permeable)	0.60	0.02	-	-	-	-	
Semi-rigid mineral fiber exterior insulation with intermittent proprietary fibreglass clips	152	6.00	0.03	0.22	3.41	19.4	25.8
Vertical or horizontal metal girts, air cavity	25.0	0.98	0.03	-	-	-	
Aluminum panel cladding	4.00	0.16	-	-	-	-	
Exterior air film	-	-	-	-	0.03	0.17	
TOTALS	**296**	**11.7**			**4.40**	**24.9**	**25.8**

W04: Embodied Carbon Emissions (A1 to A3 Life Stages) for 9m² Assembly Area

Category	Material	Description (from EPD)	Thickness	Material Volume	Carbon Emissions (A1-A3)	% of total
Units			mm	m^3	kgCO2e	%
Finish	Interior Paint	Eggshell acrylic paint, 1294.29 kg/m3		0.0014	0.6	0.12%
Finish	Gypsum Board	Gypsum plaster board, regular, generic, 6.5-25 mm, 10.725 kg/m2 (for 12.5 mm), 858 kg/m3	12.7 (0.5")	0.114	26.04	5.13%
Interior finish support	CLT Wall Panel	CLT loadbearing internal wall, 3-ply, 105 mm depth, for USA and Canada	101.6 (4")	*	38.96	7.67%
Exterior membrane	Vapour Permeable Membrane	Latex-based membrane, vapor permeable, fluid-applied, fire resistant, 40 mils (1.016 mm), 1.399 kg/L, Perm-A-Barrier® VPL	3 (0.12")	0.027	32.94	6.49%
Exterior insulation	Exterior Insulation Mineral Wool (Semi-rigid)	Heavy density mineral wool board, 1 m2K/W, 34 mm, 4.2 kg/m2, 123.52 kg/m3, Industry average US (NAIMA)	152.4 (6")	1.35	241.9	47.63%
Cladding	Aluminium Cladding Panel	Roll formed aluminum cladding, 4.91 kg/m2 (Metal Construction Association)	1 (0.04")	0.009	167.4	32.96%
				TOTAL	**507.84**	100.0%

**Software auto-calculates the impact based on the area provided.*

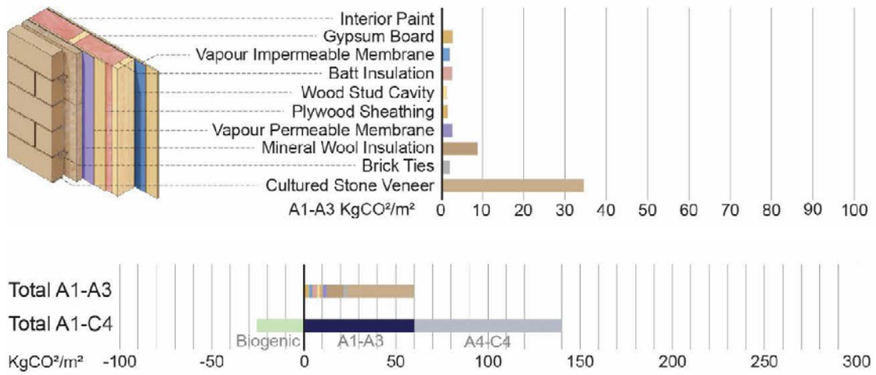
W04: Environmental Emissions (A1 to C4 Life Stages) for 9m² Assembly Area

Lifecycle Stage		**A1 to C4**	A1-A3	A4-A5	B1-B5	C1-C4	A1-A3 Contribution to total
Category	Units	**Total**	Construction Materials	Transport to Site & Construction	Material Replacement & Refurbishment	Deconstruction	%
Global Warming	kg CO2e	**1,105.00**	540.93	12.37	382.33	169.37	48.95%
Acidification	kg SO	**3.04**	2.27	0.07	0.50	0.20	74.74%
Eutrophication	kg Ne	**1.33**	0.43	0.01	0.51	0.38	32.41%
Ozone Depletion	kg CFC11e	**0.000020**	0.000006	0.000003	0.000008	0.000002	32.26%
Formation of Tropospheric Ozone	kg O3e	**35.56**	18.42	1.99	9.50	5.65	51.80%
Fossil Fuel Primary Energy	MJ	**2,875.32**	1,792.68	351.53	562.58	168.53	62.35%
Biogenic Carbon Storage	kg CO2e	**-722.51**	722.51	0	0	0	-100.00%

APPENDIX A **WALL ASSEMBLY 05**

W05: Results Summary

Metrics	Results
Description	**Split Insulated Wood Frame with Mineral Wool and Stone Veneer Cladding**
Effective R-value	RSI-4.26 m^2K/W | R-24.2 $ft^2{\cdot}°F{\cdot}h/BTU$
Embodied Carbon per m^2 of Enclosure (A1-A3)	60.42 $kgCO_2/m^2$
Biogenic Carbon per m^2 of Enclosure	-25.8 $kgCO_2/m^2$



W05: Assembly Effective R-value Calculation

Description	t_{SI}	t_{IP}	k	C (USI)	$RSI_{effective}$	$R_{effective}$	$R_{nominal}$
Units	mm	in	W/mK	W/m^2K	m^2K/W	$ft^2{\cdot}°F{\cdot}h/BTU$	$ft^2{\cdot}°F{\cdot}h/BTU$
Interior air film					0.12	0.68	
Interior gypsum board	12.7	0.50	-	-	0.05	0.30	
Smart vapour retarder	-	-	-	-	-	-	
Wood stud-framed wall with batt insulation	140	5.50	-	-	2.55	14.5	
Exterior sheathing	12.7	0.50	0.09	7.09	0.14	0.80	
Self-adhered sheet- or fluid-applied air barrier and WRB membrane (vapour permeable)	-	-	-	-	-	-	
Semi-rigid mineral fiber exterior insulation with intermittent stainless steel masonry veneer anchors	50.8	2.00	-	-	1.36	7.74	8.60
Air cavity	25.0	0.98	-	-	-	-	
Anchored stone veneer	102	4.00	-	-	-	-	
Exterior air film					0.03	0.17	
TOTALS	**343**	**13.5**			**4.30**	**24.2**	**8.60**

W05: Embodied Carbon Emissions (A1 to A3 Life Stages) for 9m² Assembly Area

Category	Material	Description (from EPD)	Thickness	Material Volume	Carbon Emissions (A1-A3)	% of total
Units			mm	m^3	kgCO2e	%
Finish	Interior Paint	Eggshell acrylic paint, 1294.29 kg/m3		0.0014	0.6	0.11%
Finish	Gypsum Board	Gypsum plaster board, regular, generic, 6.5-25 mm, 10.725 kg/m2 (for 12.5 mm), 858 kg/m3	12.7 (0.5")	0.114	26.04	4.79%
Vapour control	Vapour Impermeable Barrier	Vapor barrier	0.8 (0.032")	0.0072	17.93	3.30%
Interior insulation	Batt Insulation	Mineral fiber batt insulation	139.7 (6")	0.94	28.46	5.23%
Exterior support	Wood Stud Cavity	Wooden stud framing for drywall/gypsum plasterboard per sq. ft of wall area (incl. air gaps per m3), 50.8 mm x 152.4 mm, 400 mm spacing, headers incl. for 2.4 m wall height (American Wood Council, Canadian Wood Council)	139.7 (5.5")	*	11.42	2.10%
Sheathing	Plywood Sheathing	Plywood, generic, 4-50 mm, 620 kg/m3	12.7 (0.5")	0.114	13.95	2.57%
Exterior membrane	Vapour Permeable Membrane	Latex-based membrane, vapor permeable, fluid-applied, fire resistant, 40 mils (1.016 mm), 1.399 kg/L, Perm-A-Barrier® VPL	3 (0.12")	0.027	32.94	6.06%
Exterior insulation	Exterior Insulation Mineral Wool (Semi-rigid)	Heavy density mineral wool board, 1 m2K/W, 34 mm, 4.2 kg/m2, 123.52 kg/m3, Industry average US (NAIMA)	50.8 (2")	0.457	80.69	14.84%
Cladding anchorage	Stainless Steel Brick Ties	Assumed 4-foot spacing for angle support - 17 anchors in total structural and non-structural framing components composed from hot-dipped galvanized cold-formed steel, USA industry average, 7769 - 7849 kg/m3 (SFIA)		0.001	17.92	3.30%
Cladding	Cultured Stone Veneer	Calcium silicate stone cladding, 346.3 lbs/sqft, 130 lbs/ft3 (Arriscraft)	101.6 mm (4")	0.91	313.81	57.71%
				TOTAL	**543.76**	100.0%

**Software auto-calculates the impact based on the area provided.*

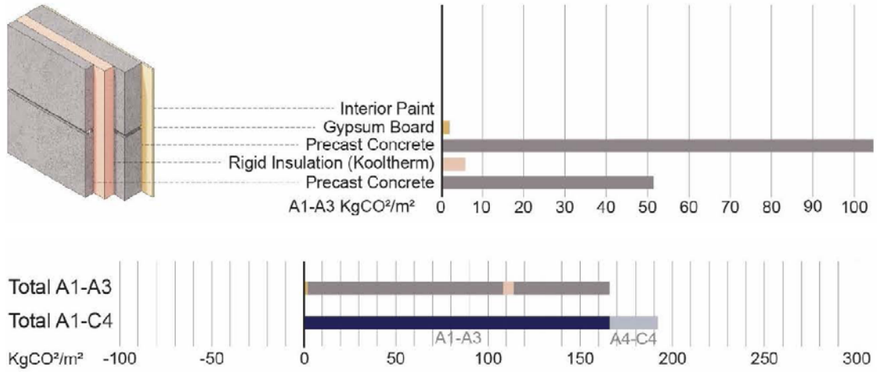
W05: Environmental Emissions (A1 to C4 Life Stages) for 9m² Assembly Area

Lifecycle Stage		**A1 to C4**	A1-A3	A4-A5	B1-B5	C1-C4	A1-A3 Contribution to total
Category	Units	**Total**	Construction Materials	Transport to Site & Construction	Material Replacement & Refurbishment	Deconstruction	%
Global Warming	kg CO2e	**1,265.05**	543.75	12.07	458.26	250.97	42.98%
Acidification	kg SO	**3.93**	2.88	0.07	0.64	0.35	73.23%
Eutrophication	kg Ne	**1.16**	0.40	0.01	0.52	0.23	34.53%
Ozone Depletion	kg CFC11e	**0.000045**	0.00003	0.000003	0.0000089	0.000008	55.60%
Formation of Tropospheric Ozone	kg O3e	**55.41**	33.68	1.93	12.89	6.91	60.78%
Fossil Fuel Primary Energy	MJ	**9,238.42**	5,308.96	342.88	2,878.62	707.96	57.47%
Biogenic Carbon Storage	kg CO2e	**-232**	232	0	0	0	-100.00%

APPENDIX A **WALL ASSEMBLY 06**

W06: Results Summary

Metrics	Results
Description	**Double Wythe Insulated Precast with Kooltherm**
Effective R-value	RSI-4.4 m^2K/W | R-25 $ft^2 \cdot °F \cdot h/BTU$
Embodied Carbon per m^2 of Enclosure (A1-A3)	166.16 $kgCO_2/m^2$
Biogenic Carbon per m^2 of Enclosure	0 $kgCO_2/m^2$



W06: Assembly Effective R-value Calculation

Description	t_{SI}	t_{IP}	k	C (USI)	$RSI_{effective}$	$R_{effective}$	$R_{nominal}$
Units	mm	in	W/mK	W/m^2K	m^2K/W	$ft^2 \cdot °F \cdot h/BTU$	$ft^2 \cdot °F \cdot h/BTU$
Interior air film					0.12	0.68	
Interior gypsum board	12.7	0.50	0.16	27.0	0.04	0.21	
Precast concrete panel (interior)	152	6.00	2.10	13.8	0.07	0.41	
Proprietary advanced thermal rigid insulation board	80.00	3.15	-	-	4.10	23.3	23.3
Precast concrete panel (exterior)	76.2	3.00	2.10	27.6	0.04	0.21	
Exterior air film	-	-	-	-	0.03	0.17	
TOTALS	**321**	**12.6**			**4.40**	**25.0**	**23.3**

W06: Embodied Carbon Emissions (A1 to A3 Life Stages) for 9m² Assembly Area

Category	Material	Description (from EPD)	Thickness	Material Volume	Carbon Emissions (A1-A3)	% of total
Units			mm	m^3	kgCO2e	%
Finish	Interior Paint	Eggshell acrylic paint, 1294.29 kg/m3	-	0.0014	0.6	0.04%
Finish	Gypsum Board	Gypsum plaster board, regular, generic, 6.5-25 mm, 10.725 kg/m2 (for 12.5 mm), 858 kg/m3	12.7 (0.5")	0.114	26.04	1.74%
Structure	Precast concrete	Precast concrete, architectural wall panel	152.4 (6")	1.3716	945.43	63.22%
Exterior Insulation	Rigid insulation	Kooltherm	80 (3.15")	0.72	50.67	3.39%
Exterior Finish	Precast concrete	Precast concrete, architectural wall panel	76.2 (3")	0.6858	472.71	31.61%
				TOTAL	**1495.45**	100.0%

**Software auto-calculates the impact based on the area provided.*

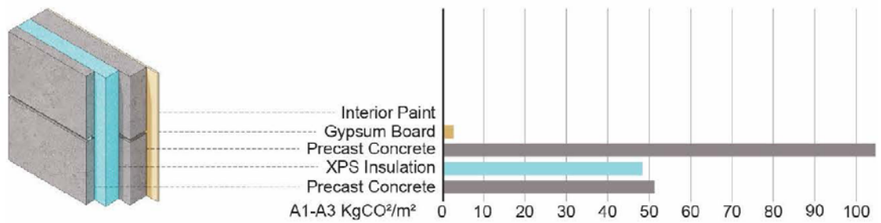
W06: Environmental Emissions (A1 to C4 Life Stages) for 9m² Assembly Area

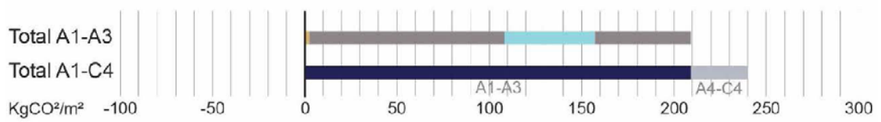
Lifecycle Stage		**A1 to C4**	A1-A3	A4-A5	B1-B5	C1-C4	A1-A3 Contribution to total
Category	Units	**Total**	Construction Materials	Transport to Site & Construction	Material Replacement & Refurbishment	Deconstruction	%
Global Warming	kg CO2e	**1,722.52**	1,444.36	35.09	8.78	234.29	83.85%
Acidification	kg SO	**29.17**	28.27	0.20	0.05	0.65	96.93%
Eutrophication	kg Ne	**1.69**	1.44	0.03	0.0028	0.22	85.17%
Ozone Depletion	kg CFC11e	**0.008**	0.01	0.000009	0.0000006	0.000018	99.65%
Formation of Tropospheric Ozone	kg O3e	**350.40**	332.41	5.67	0.98	11.34	94.87%
Fossil Fuel Primary Energy	MJ	**14,251.81**	11,581.40	997.65	68.36	1,604.40	81.26%
Biogenic Carbon Storage	kg CO2e	**0**	0	0	0	0	

APPENDIX A **WALL ASSEMBLY 07**

W07: Results Summary

Metrics	Results
Description	**Double Wythe Insulated Precast with XPS Insulation**
Effective R-value	RSI-4.5 m^2K/W | R-25.4 $ft^2{\cdot}°F{\cdot}h/BTU$
Embodied Carbon per m^2 of Enclosure (A1-A3)	209.30 $kgCO_2/m^2$
Biogenic Carbon per m^2 of Enclosure	0 $kgCO_2/m^2$





W07: Assembly Effective R-value Calculation

Description	t_{SI}	t_{IP}	k	C (USI)	$RSI_{effective}$	$R_{effective}$	$R_{nominal}$
Units	mm	in	W/mK	W/m^2K	m^2K/W	$ft^2{\cdot}°F{\cdot}h/BTU$	$ft^2{\cdot}°F{\cdot}h/BTU$
Interior air film					0.12	0.68	
Interior gypsum board	12.7	0.50	0.16	27.0	0.04	0.21	
Precast concrete panel (interior)	152	6.00	2.10	13.8	0.07	0.41	
Extruded polystyrene (XPS) rigid board insulation	127	5.00	0.03	0.24	4.18	23.8	25.0
Precast concrete panel (exterior)	76.2	3.00	2.10	27.6	0.04	0.21	
Exterior air film	-	-	-	-	0.03	0.17	
TOTALS	**368**	**14.5**			**4.50**	**25.4**	**25.0**

W07: Embodied Carbon Emissions (A1 to A3 Life Stages) for 9m² Assembly Area

Category	Material	Description (from EPD)	Thickness	Material Volume	Carbon Emissions (A1-A3)	% of total
Units			mm	m^3	kgCO2e	%
Finish	Interior Paint	Eggshell acrylic paint, 1294.29 kg/m3		0.0014	0.6	0.03%
Finish	Gypsum Board	Gypsum plaster board, regular, generic, 6.5-25 mm, 10.725 kg/m2 (for 12.5 mm), 858 kg/m3	12.7 (0.5")	0.114	26.04	1.38%
Structure	Precast concrete	Precast concrete, architectural wall panel	152.4 (6")	1.3716	945.43	50.19%
Exterior Insulation	XPS (Rigid Insulation)	XPS insulation (extruded polystyrene)	127 (5")	1.143	438.9	23.30%
Exterior Finish	Precast concrete	Precast concrete, architectural wall panel	76.2 (3")	0.6858	472.71	25.10%
				TOTAL	**1883.68**	100.0%

**Software auto-calculates the impact based on the area provided.*

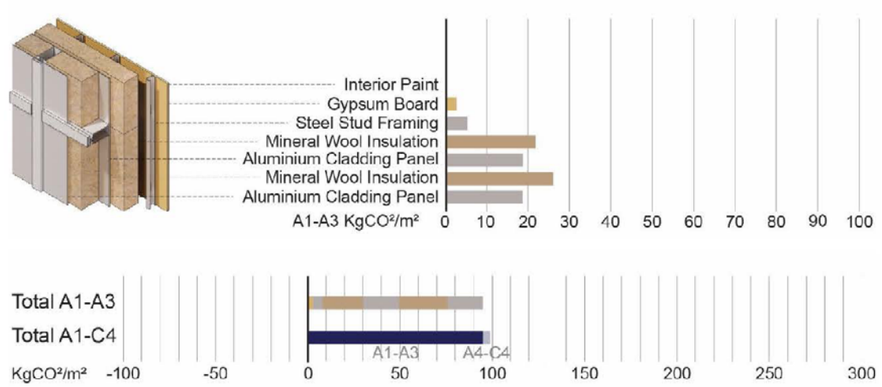
W07: Environmental Emissions (A1 to C4 Life Stages) for 9m² Assembly Area

Lifecycle Stage		**A1 to C4**	A1-A3	A4-A5	B1-B5	C1-C4	A1-A3 Contribution to total
Category	Units	**Total**	Construction Materials	Transport to Site & Construction	Material Replacement & Refurbishment	Deconstruction	%
Global Warming	kg CO2e	**2,163.63**	1,883.68	35.45	8.78	235.72	87.06%
Acidification	kg SO	**29.24**	28.33	0.20	0.05	0.66	96.90%
Eutrophication	kg Ne	**1.69**	1.44	0.03	0.00	0.22	85.17%
Ozone Depletion	kg CFC11e	**0.01**	0.01	0.000009	0.0000006	0.000018	99.67%
Formation of Tropospheric Ozone	kg O3e	**351.93**	333.82	5.72	0.98	11.41	94.85%
Fossil Fuel Primary Energy	MJ	**14,305.58**	11,614.97	1,008.06	68.36	1,614.19	81.19%
Biogenic Carbon Storage	kg CO2e	**0**	0	0	0	0	

APPENDIX A **WALL ASSEMBLY 08**

W08: Results Summary

Metrics	Results
Description	**Spandrel Panel with 3" Mineral Wool Backpan, Interior Insulated with Mineral Wool**
Effective R-value	RSI-4.7 m^2K/W | R-26.7 $ft^2 \cdot °F \cdot h/BTU$
Embodied Carbon per m^2 of Enclosure (A1-A3)	94.82 $kgCO_2/m^2$
Biogenic Carbon per m^2 of Enclosure	0 $kgCO_2/m^2$



W08: Assembly Effective R-value Calculation

Description	t_{SI}	t_{IP}	k	C (USI)	$RSI_{effective}$	$R_{effective}$	$R_{nominal}$
Units	mm	in	W/mK	W/m^2K	m^2K/W	$ft^2 \cdot °F \cdot h/BTU$	$ft^2 \cdot °F \cdot h/BTU$
Interior air film					0.12	0.68	
Interior gypsum board	12.7	0.50	0.16	27.0	0.04	0.21	
Smart vapour retarder	-	-	-	-	-	-	
Steel stud-framed wall	63.5	2.50	0.49	7.75	0.13	0.73	
Rigid or semi-rigid mineral fibre board insulation (continuous)	127	5.00	0.00	0.03	3.60	20.4	21.5
Spandrel Panel with rigid or semi-rigid mineral fiber exterior insulation	152	6.00	-	-	0.79	4.50	
Exterior air film					0.03	0.17	
TOTALS	**356**	**14.0**			**4.70**	**26.7**	**21.5**

W08: Embodied Carbon Emissions (A1 to A3 Life Stages) for 9m² Assembly Area

Category	Material	Description (from EPD)	Thickness	Material Volume	Carbon Emissions (A1-A3)	% of total
Units			mm	m^3	kgCO2e	%
Finish	Interior Paint	Eggshell acrylic paint, 1294.29 kg/m3	-	0.0014	0.6	0.07%
Finish	Gypsum Board	Gypsum plaster board, regular, generic, 6.5-25 mm, 10.725 kg/m2 (for 12.5 mm), 858 kg/m3	12.7 (0.5")	0.114	26.04	3.05%
Interior Finish Support	Steel Stud Framing	Steel stud framing for drywall/gypsum plasterboard per sq. meter of wall area (incl. air gaps per m3); 63.5 mm x 30.48 mm, gauge 25	63.5 (2.5")	*	47.91	5.61%
Exterior Insulation	Exterior Insulation Mineral Wool (Semi-rigid)	Heavy density mineral wool board, 1 m2K/W, 34 mm, 4.2 kg/m2, 123.52 kg/m3, Industry average US (NAIMA)	127 (5")	1.143	201.82	23.65%
Exterior Insulated Aluminum Spandrel Panel	Aluminium Cladding Panel	Roll formed aluminum cladding, 4.91 kg/m2 (Metal Construction Association)	1 (0.04")	0.009	167.4	19.62%
	Exterior Insulation Mineral Wool (Semi-rigid)	Heavy density mineral wool board, 1 m2K/W, 34 mm, 4.2 kg/m2, 123.52 kg/m3, Industry average US (NAIMA)	152.4 (6")	1.37	242.18	28.38%
	Aluminium Cladding Panel	Roll formed aluminum cladding, 4.91 kg/m2 (Metal Construction Association)	1 (0.04")	0.009	167.4	19.62%
				TOTAL	**853.35**	100.0%

**Software auto-calculates the impact based on the area provided.*

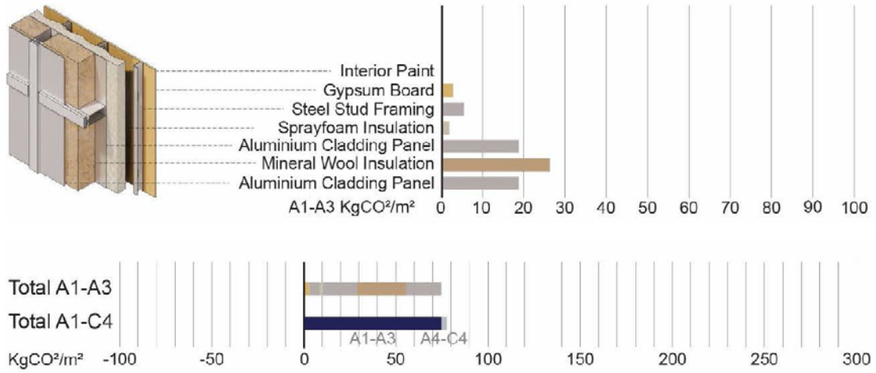
W08: Environmental Emissions (A1 to C4 Life Stages) for 9m² Assembly Area

Lifecycle Stage		**A1 to C4**	A1-A3	A4-A5	B1-B5	C1-C4	A1-A3 Contribution to total
Category	Units	**Total**	Construction Materials	Transport to Site & Construction	Material Replacement & Refurbishment	Deconstruction	%
Global Warming	kg CO2e	**887.57**	853.34	5.42	8.78	20.03	96.14%
Acidification	kg SO	**2.68**	2.54	0.03	0.05	0.06	94.92%
Eutrophication	kg Ne	**0.17**	0.14	0.0043	0.0028	0.02	84.81%
Ozone Depletion	kg CFC11e	**0.000008**	0.000005	0.0000014	0.00000056	0.0000014	58.30%
Formation of Tropospheric Ozone	kg O3e	**33.85**	30.95	0.87	0.98	1.05	91.43%
Fossil Fuel Primary Energy	MJ	**1,607.14**	1,227.14	154.07	68.36	157.57	76.36%
Biogenic Carbon Storage	kg CO2e	**0**	0	0	0	0	

APPENDIX A **WALL ASSEMBLY 09**

W09: Results Summary

Metrics	Results
Description	**Spandrel Panel with 3" Mineral Wool Backpan, Interior Insulated with Sprayfoam**
Effective R-value	RSI-4.3 m^2K/W | R-24.4 $ft^2{\cdot}°F{\cdot}h/BTU$
Embodied Carbon per m^2 of Enclosure (A1-A3)	74.48 $kgCO_2/m^2$
Biogenic Carbon per m^2 of Enclosure	0 $kgCO_2/m^2$



W09: Assembly Effective R-value Calculation

Description	t_{SI}	t_{IP}	k	C (USI)	$RSI_{effective}$	$R_{effective}$	$R_{nominal}$
Units	mm	in	W/mK	W/m^2K	m^2K/W	$ft^2{\cdot}°F{\cdot}h/BTU$	$ft^2{\cdot}°F{\cdot}h/BTU$
Interior air film					0.12	0.68	
Interior gypsum board	12.7	0.50	-	-	0.05	0.30	
Steel stud-framed wall	63.5	2.50	0.49	7.75	0.13	0.73	
Closed-cell spray foam insulation (continuous)	76.2	3.00	0.00	0.03	3.17	18.0	18.0
Spandrel Panel with rigid or semi-rigid mineral fiber exterior insulation	152	6.00	-	-	0.79	4.50	
Exterior air film					0.03	0.17	
TOTALS	**305**	**12.0**			**4.30**	**24.4**	**18.0**

W09: Embodied Carbon Emissions (A1 to A3 Life Stages) for 9m² Assembly Area

Category	Material	Description (from EPD)	Thickness	Material Volume	Carbon Emissions (A1-A3)	% of total
Units			mm	m^3	kgCO2e	%
Finish	Interior Paint	Eggshell acrylic paint, 1294.29 kg/m3	-	0.0014	0.6	0.09%
Finish	Gypsum Board	Gypsum plaster board, regular, generic, 6.5-25 mm, 10.725 kg/m2 (for 12.5 mm), 858 kg/m3	12.7 (0.5")	0.114	26.04	3.88%
Interior Finish Support	Steel Stud Framing	Steel stud framing for drywall/gypsum plasterboard per sq. meter of wall area (incl. air gaps per m3); 63.5 mm x 30.48 mm, gauge 25	63.5 (2.5")	*	47.91	7.15%
Exterior Insulation	Sprayfoam insulation	Spray polyurethane foam insulation for closed cell, with HFO blowing agent, 0.022 W/mK, 32 kg/m3 average density, SealTite CC+, Walltite HFO, Walltite CMxx lines, Heatlok®HFO High Lift, Heatlok® HFO Pro, Ultra-Thane 200, UPC 2.0 HFO, GacoOnePass Low GWP, ProSeal HFO™, FOAM-LOK® FL 2000-4G, JM Corbond IV, InsulStar®, InsulBloc®, Nexseal™ 2.0, Nexseal™ 2.0 LE) (Spray Polyurethane Foam Association (SPFA), (Accella, BASF, Demilec, General Coatings, Gaco-Western, Icynene-Lapolla, Johns-Manville, NCFI Polyurethanes, SES))	76.2 (3")	0.68	18.75	2.80%
Exterior Finish	Aluminium Cladding Panel	Roll formed aluminum cladding, 4.91 kg/m2 (Metal Construction Association)	1 (0.04")	0.009	167.4	24.97%
	Exterior Insulation Mineral Wool (Semi-rigid)	Heavy density mineral wool board, 1 m2K/W, 34 mm, 4.2 kg/m2, 123.52 kg/m3, Industry average US (NAIMA)	152.4 (6")	1.37	242.18	36.13%
				TOTAL	**670.28**	100.0%

**Software auto-calculates the impact based on the area provided.*

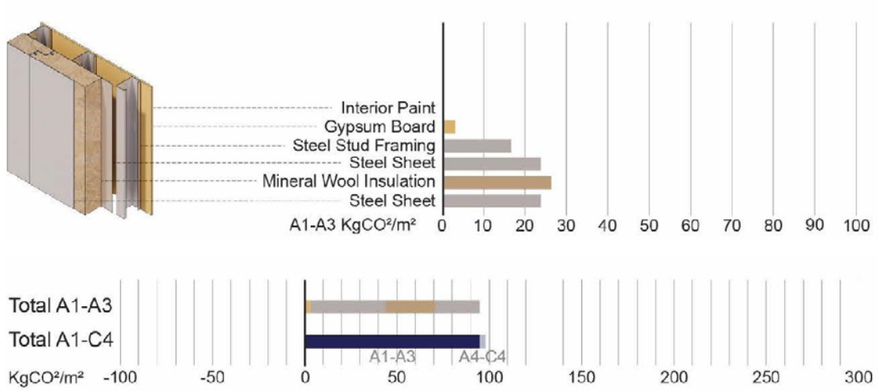
W09: Environmental Emissions (A1 to C4 Life Stages) for 9m² Assembly Area

Lifecycle Stage		**A1 to C4**	A1-A3	A4-A5	B1-B5	C1-C4	A1-A3 Contribution to total
Category	Units	**Total**	Construction Materials	Transport to Site & Construction	Material Replacement & Refurbishment	Deconstruction	%
Global Warming	kg CO2e	**698.24**	670.27	4.71	8.78	14.48	95.99%
Acidification	kg SO	**2.48**	2.36	0.03	0.05	0.04	95.28%
Eutrophication	kg Ne	**0.16**	0.14	0.004	0.0028	0.01	87.74%
Ozone Depletion	kg CFC11e	**0.000008**	0.0000049	0.0000012	0.0000006	0.000001	63.95%
Formation of Tropospheric Ozone	kg O3e	**30.47**	27.95	0.76	0.98	0.78	91.73%
Fossil Fuel Primary Energy	MJ	**1,548.95**	1,227.22	133.78	68.36	119.59	79.23%
Biogenic Carbon Storage	kg CO2e	**0**	0	0	0	0	

APPENDIX A **WALL ASSEMBLY 10**

W10: Results Summary

Metrics	Results
Description	**Insulated Metal Panel with Mineral Wool Insulation**
Effective R-value	RSI-4.4 m^2K/W | R-24.9 $ft^2{\cdot}°F{\cdot}h/BTU$
Embodied Carbon per m^2 of Enclosure (A1-A3)	94.49 $kgCO_2/m^2$
Biogenic Carbon per m^2 of Enclosure	0 $kgCO_2/m^2$



W10: Assembly Effective R-value Calculation

Description	t_{SI}	t_{IP}	k	C (USI)	$RSI_{effective}$	$R_{effective}$	$R_{nominal}$
Units	mm	in	W/mK	W/m^2K	m^2K/W	$ft^2{\cdot}°F{\cdot}h/BTU$	$ft^2{\cdot}°F{\cdot}h/BTU$
Interior air film					0.12	0.68	
Steel sheet (interior)	-	-	-	-	-	-	
Rigid mineral fiber insulation	152	6.00	-	-	4.23	24.0	
Steel sheet (exterior)	-	-	-	-	-	-	-
Exterior air film	-	-	-	-	0.03	0.17	
TOTALS	**152**	**6.00**			**4.40**	**24.9**	**0**

W10: Embodied Carbon Emissions (A1 to A3 Life Stages) for 9m² Assembly Area

Category	Material	Description (from EPD)	Thickness	Material Volume	Carbon Emissions (A1-A3)	% of total
Units			mm	m^3	kgCO2e	%
Finish	Interior Paint	Eggshell acrylic paint, 1294.29 kg/m3	-	0.0014	0.6	0.07%
Finish	Gypsum Board	Gypsum plaster board, regular, generic, 6.5-25 mm, 10.725 kg/m2 (for 12.5 mm), 858 kg/m3	12.7 (0.5")	0.114	26.04	3.06%
Interior finish support	Steel Stud Framing	Steel stud framing for drywall/gypsum plasterboard per sq. meter of wall area (incl. air gaps per m3), C-profile: 152.4 mm x 76.2 mm, gauge 20 (40 cm) spacing	152.4 (6")	*	158.39	18.62%
Interior Finish	Steel sheet	Steel façade panel (Metal Construction Association)	1 (0.039")	0.009	211.62	24.88%
Exterior Insulation	Exterior Insulation Mineral Wool (Semi-rigid)	Heavy density mineral wool board, 1 m2K/W, 34 mm, 4.2 kg/m2, 123.52 kg/m3, Industry average US (NAIMA)	152.4 (6")	1.37	242.18	28.48%
Exterior Finish	Steel sheet	Steel façade panel (Metal Construction Association)	1 (0.04")	0.009	211.62	24.88%
				TOTAL	**850.45**	100.0%

**Software auto-calculates the impact based on the area provided.*

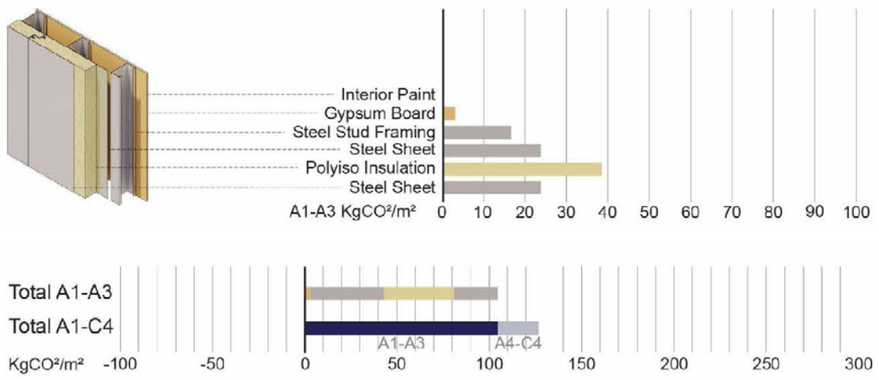
W10: Environmental Emissions (A1 to C4 Life Stages) for 9m² Assembly Area

Lifecycle Stage		**A1 to C4**	A1-A3	A4-A5	B1-B5	C1-C4	A1-A3 Contribution to total
Category	Units	**Total**	Construction Materials	Transport to Site & Construction	Material Replacement & Refurbishment	Deconstruction	%
Global Warming	kg CO2e	**880.78**	850.44	7.08	8.78	14.48	96.56%
Acidification	kg SO	**3.02**	2.89	0.04	0.05	0.05	95.60%
Eutrophication	kg Ne	**0.18**	0.16	0.01	0.0028	0.01	88.71%
Ozone Depletion	kg CFC11e	**0.00002**	0.000012	0.000002	0.000001	0.0000009	77.91%
Formation of Tropospheric Ozone	kg O3e	**59.42**	56.44	1.14	0.98	0.86	94.98%
Fossil Fuel Primary Energy	MJ	**8,324.56**	7,913.47	201.28	68.36	141.45	95.06%
Biogenic Carbon Storage	kg CO2e	**0**	0	0	0	0	

APPENDIX A **WALL ASSEMBLY 11**

W11: Results Summary

Metrics	Results
Description	**Insulated Metal Panel with Polyisocyanurate Insulation**
Effective R-value	RSI-5.2 m^2K/W | R-29.7 $ft^2{\cdot}°F{\cdot}h/BTU$
Embodied Carbon per m^2 of Enclosure (A1-A3)	105.2 $kgCO_2/m^2$
Biogenic Carbon per m^2 of Enclosure	0 $kgCO_2/m^2$



W11: Assembly Effective R-value Calculation

Description	t_{SI}	t_{IP}	k	C (USI)	$RSI_{effective}$	$R_{effective}$	$R_{nominal}$
Units	mm	in	W/mK	W/m^2K	m^2K/W	$ft^2{\cdot}°F{\cdot}h/BTU$	$ft^2{\cdot}°F{\cdot}h/BTU$
Interior air film					0.12	0.68	
Steel sheet (interior)	-	-	-	-	-	-	
Rigid polyisocyanurate insulation	102	4.00	-	-	5.07	28.8	
Steel sheet (exterior)	-	-	-	-	-	-	-
Exterior air film	-	-	-	-	0.03	0.17	
TOTALS	**102**	**4.00**			**5.20**	**29.7**	**0**

W11: Embodied Carbon Emissions (A1 to A3 Life Stages) for 9m² Assembly Area

Category	Material	Description (from EPD)	Thickness	Material Volume	Carbon Emissions (A1-A3)	% of total
Units			mm	m^3	kgCO2e	%
Finish	Interior Paint	Eggshell acrylic paint, 1294.29 kg/m3 **(Generic)**	0.16 (0.0063")	0.0014	0.56	0.1%
Finish	Gypsum board	Gypsum plaster board, regular, generic, 6.5-25 mm (0.25-0.98 in), 10.725 kg/m2 (2.20 lbs/ft2) (for 12.5 mm/0.49 in), 858 kg/m3 (53.6 lbs/ft3) **(Generic)**	12.7 (0.5")	0.1143	26	2.7%
Interior finish support	Interior steel studs	Steel stud framing for drywall/gypsum plasterboard per sq. meter of wall area (incl. air gaps per m3), C-profile: 152.4 x 76.2, gauge 20, 3 m height x 406.4 mm (400 mm) spacing **(Generic)**	-	*	160	17%
Exterior Insulated Prefabricated Pannelized System	Steel sheets	Steel sheets, generic, 30% recycled content, S235, S275 and S355 (Generic)	1 (0.04")	0.009	210	22%
	Polyiso	Generic Polyisocyanurate (PIR) insulation boards (Generic)	101.6 (4")	0.9144	340	36%
	Steel sheets	Steel sheets, generic, 30% recycled content, S235, S275 and S355 (Generic)	1 (0.04")	0.009	210	22%
				TOTAL	**946.56**	100.0%

**Software auto-calculates the impact based on the area provided.*

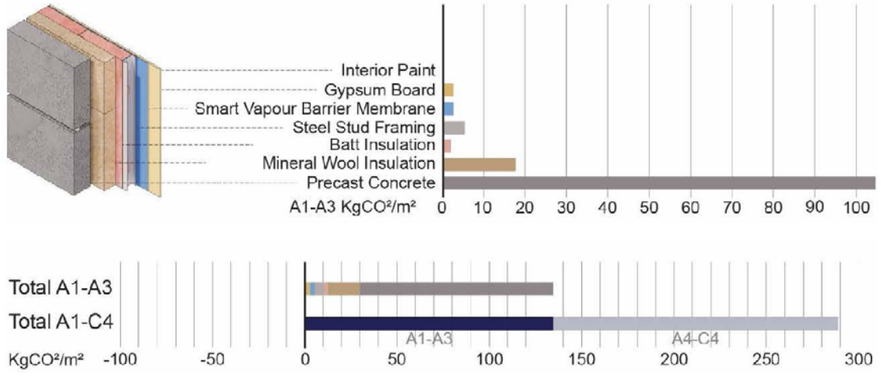
W11: Environmental Emissions (A1 to C4 Life Stages) for 9m² Assembly Area

Lifecycle Stage		**A1 to C4**	A1-A3	A4-A5	B1-B5	C1-C4	A1-A3 Contribution to total
Category	Units	**Total**	Construction Materials	Transport to Site & Construction	Material Replacement & Refurbishment	Deconstruction	%
Global Warming	kg CO2e	**1147.5473**	948.17	6.94	3.84	188.5973	82.63%
Acidification	kg SO	**4.59E-05**	3.54E-05	0.000001821	0.00000026	8.48E-06	77.00%
Eutrophication	kg Ne	**5.235084**	4.1932	0.0394	2.30E-02	0.979484	80.10%
Ozone Depletion	kg CFC11e	**1.157371**	1.069044	0.00555	0.00098	0.081797	92.37%
Formation of Tropospheric Ozone	kg O3e	**72.305173**	68.999	1.116	0.49	1.700173	95.43%
Fossil Fuel Primary Energy	MJ	**14373.131**	14075.52	197.19	31.43	68.991	97.93%
Biogenic Carbon Storage	kg CO2e	**0**	0				

APPENDIX A **WALL ASSEMBLY 12**

W12: Results Summary

Metrics	Results
Description	**Architectural Precast with Mineral Wool Interior Insulation**
Effective R-value	RSI-4.2 m^2K/W | R-24.1 $ft^2 \cdot °F \cdot h/BTU$
Embodied Carbon per m^2 of Enclosure (A1-A3)	135.8 $kgCO_2/m^2$
Biogenic Carbon per m^2 of Enclosure	0 $kgCO_2/m^2$



W12: Assembly Effective R-value Calculation

Description	t_{SI}	t_{IP}	k	C (USI)	$RSI_{effective}$	$R_{effective}$	$R_{nominal}$
Units	mm	in	W/mK	W/m^2K	m^2K/W	$ft^2 \cdot °F \cdot h/BTU$	$ft^2 \cdot °F \cdot h/BTU$
Interior air film					0.12	0.68	
Interior gypsum board	12.7	0.50	0.16	27.0	0.04	0.21	
Smart vapour retarder	-	-	-	-	-	-	
Steel stud-framed wall with mineral fiber batt insulation	88.9	3.50	0.01	0.16	1.10	6.25	
Rigid or semi-rigid mineral fibre board insulation (continuous)	102	4.00	0.01	0.06	2.88	16.3	17.2
Precast concrete panel	152	6.00	2.10	13.8	0.07	0.41	
Exterior air film					0.03	0.17	
TOTALS	**356**	**14.0**			**4.20**	**24.1**	**17.2**

W12: Embodied Carbon Emissions (A1 to A3 Life Stages) for 9m² Assembly Area

Category	Material	Description (from EPD)	Thickness	Material Volume	Carbon Emissions (A1-A3)	% of total
Units			mm	m^3	kgCO2e	%
Finish	Interior Paint	Eggshell acrylic paint, 1294.29 kg/m3 (Generic)	0.16 (0.0063")	0.0014	0.56	0.1%
Finish	gypsum board	Gypsum plaster board, regular, generic, 6.5-25 mm (0.25-0.98 in), 10.725 kg/m2 (2.20 lbs/ft2) (for 12.5 mm/0.49 in), 858 kg/m3 (53.6 lbs/ft3) (Generic)	12.7 (0.5")	0.1143	26.00	2.1%
Exterior Membrane	Smart vapour barrier membrane	Vapor Barrier, (Generic)	-	*	23	1.9%
Back-up structure	Steel stud	Steel stud framing for drywall/gypsum plasterboard per sq. meter of wall area (incl. air gaps per m3), C-profile: 92 x 40 mm, gauge 25, 3 m height x 406.4 mm (400 mm) spacing (Generic)	-	*	55	4.5%
Insulation	mineral wool insulation	Mineral fiber batt insulation (Generic)	88.9 (3.5")	0.6001	18	1.5%
Exterior Insulation	Mineral wool insulation board (continuous)	Heavy density mineral wool board, 1 m2K/W, 34 mm (1.34 in), 4.2 kg/m2 (0.86 lb/ft2), 123.52 kg/m3 (7.71 lb/ft3), Industry average US (NAIMA)	101.6 (4")	0.9144	160	13.1%
Exterior Finish	Precast concrete	Precast concrete, architectural wall panel (Generic)	152.4 (6")	1.3716	940	77.0%
				TOTAL	**1222.56**	100.2%

**Software auto-calculates the impact based on the area provided.*

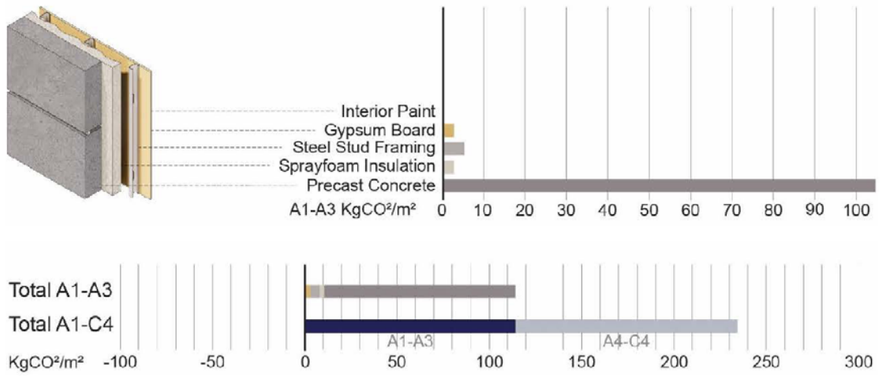
W12: Environmental Emissions (A1 to C4 Life Stages) for 9m² Assembly Area

Lifecycle Stage		**A1 to C4**	A1-A3	A4-A5	B1-B5	C1-C4	A1-A3 Contribution to total
Category	Units	**Total**	Construction Materials	Transport to Site & Construction	Material Replacement & Refurbishment	Deconstruction	%
Global Warming	kg CO2e	**2599.9**	1226.5	25.8	47.6	1299.9	47.18%
Acidification	kg SO	**0.0**	0.0	0.0	0.0	0.0	49.93%
Eutrophication	kg Ne	**39.5**	19.5	0.1	0.1	19.7	49.42%
Ozone Depletion	kg CFC11e	**2**	1	0	0	1	48.90%
Formation of Tropospheric Ozone	kg O3e	**473.9**	230.7	4.2	2.2	237.0	48.67%
Fossil Fuel Primary Energy	MJ	**23601.0**	9594.1	733.9	1472.5	11800.5	40.65%
Biogenic Carbon Storage	kg CO2e	**0**	0	0	0	0	

APPENDIX A **WALL ASSEMBLY 13**

W13: Results Summary

Metrics	Results
Description	**Architectural Precast with Spray Foam Interior Insulation**
Effective R-value	RSI-4.7 m^2K/W | R-26.6 $ft^2{\cdot}°F{\cdot}h/BTU$
Embodied Carbon per m^2 of Enclosure (A1-A3)	114.3 $kgCO_2/m^2$
Biogenic Carbon per m^2 of Enclosure	0 $kgCO_2/m^2$



W13: Assembly Effective R-value Calculation

Description	t_{SI}	t_{IP}	k	C (USI)	$RSI_{effective}$	$R_{effective}$	$R_{nominal}$
Units	mm	in	W/mK	W/m^2K	m^2K/W	$ft^2{\cdot}°F{\cdot}h/BTU$	$ft^2{\cdot}°F{\cdot}h/BTU$
Interior air film					0.12	0.68	
Interior gypsum board	12.7	0.50	-	-	0.05	0.30	
Steel stud-framed wall	63.5	2.50	0.49	7.75	0.13	0.73	
Closed-cell spray foam insulation	102	4.00	0.02	0.24	4.26	24.2	24.2
Precast concrete panel	152	6.00	1.60	10.5	0.10	0.54	
Exterior air film					0.03	0.17	
TOTALS	**330**	**13.0**			**4.70**	**26.6**	**24.2**

W13: Embodied Carbon Emissions (A1 to A3 Life Stages) for 9m² Assembly Area

Category	Material	Description (from EPD)	Thickness	Material Volume	Carbon Emissions (A1-A3)	% of total
Units			mm	m^3	kgCO2e	%
Finish	Interior Paint	Eggshell acrylic paint, 1294.29 kg/m3 (Generic)	0.16 (0.0063")	0.0014	0.56	0.1%
Finish	gypsum board	Gypsum plaster board, regular, (Generic)	12.7 (0.5")	0.1143	26.00	2.5%
Back-up structure	Steel stud framing, no insulation	Steel stud framing for drywall/gypsum plasterboard per sq. meter of wall area (incl. air gaps per m3), C-profile: 63.5 x 30.48 mm, gauge 25, 3 m height x 406.4 mm (400 mm) spacing (Generic)	-	*	39	3.80%
Exterior Insulation	Sprayfoam insulation (continuous)	Spray polyurethane foam insulation for closed cell, with HFO blowing agent, 0.022 W/mK, 32 kg/m3 average density, SealTite CC+, Walltite HFO, Walltite CMxx lines, Heatlok®HFO High Lift, Heatlok® HFO Pro, Ultra-Thane 00, UPC 2.0 HFO, GacoOnePass Low GWP, ProSeal HFO™, FOAM-LOK® FL 2000-4G, JM Corbond IV, InsulStar®, InsulBloc®, Nexseal™ 2.0, Nexseal™ 2.0 LE) (Spray Polyurethane Foam Association (SPFA), (Accella, BASF, emilec, General Coatings, Gaco-Western, Icynene-Lapolla, Johns-Manville, NCFI Polyurethanes, SES))	101.6 (4")	0.9144	23	2.30%
Back-up structure	Precast concrete	Precast concrete, architectural wall panel (Generic)	152.4 (6")	1.3716	940	91.40%
				TOTAL	**1028.56**	100.0%

**Software auto-calculates the impact based on the area provided.*

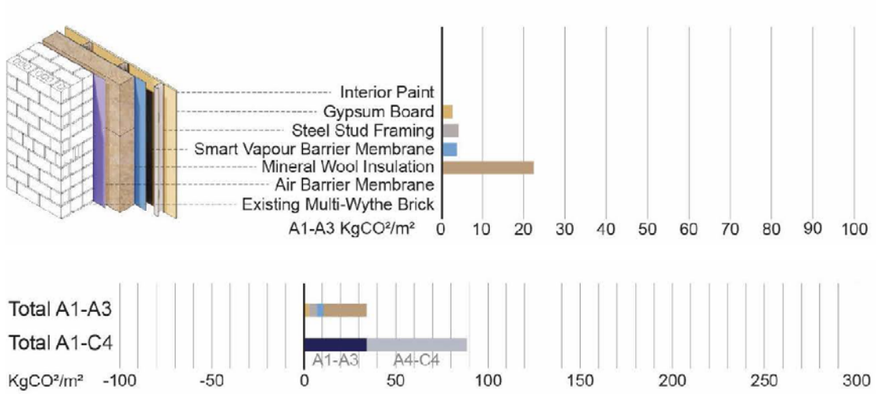
W13: Environmental Emissions (A1 to C4 Life Stages) for 9m² Assembly Area

Lifecycle Stage		**A1 to C4**	A1-A3	A4-A5	B1-B5	C1-C4	A1-A3 Contribution to total
Category	Units	**Total**	Construction Materials	Transport to Site & Construction	Material Replacement & Refurbishment	Deconstruction	%
Global Warming	kg CO2e	**2123.42**	1033.3	24.58	3.83	1061.71	48.66%
Acidification	kg SO	**0.01061744**	0.005302	6.46E-06	2.60E-07	0.00530872	49.94%
Eutrophication	kg Ne	**38.6018**	19.1402	0.1397	0.021	19.3009	49.58%
Ozone Depletion	kg CFC11e	**2.030588**	0.994944	0.01935	0.001	1.015294	49.00%
Formation of Tropospheric Ozone	kg O3e	**462.044**	226.569	3.963	0.49	231.022	49.04%
Fossil Fuel Primary Energy	MJ	**18279.62**	8409.05	698.62	32.14	9139.81	46.00%
Biogenic Carbon Storage	kg CO2e	**0**	0	0	0	0	

APPENDIX A **WALL ASSEMBLY 14**

W14: Results Summary

Metrics	Results
Description	**Existing Masonry with Interior Mineral Wool Insulation**
Effective R-value	RSI-4.2 m^2K/W | R-24.0 $ft^2 \cdot °F \cdot h/BTU$
Embodied Carbon per m^2 of Enclosure (A1-A3)	33.7 $kgCO_2/m^2$
Biogenic Carbon per m^2 of Enclosure	0 $kgCO_2/m^2$



W14: Assembly Effective R-value Calculation

Description	t_{SI}	t_{IP}	k	C (USI)	$RSI_{effective}$	$R_{effective}$	$R_{nominal}$
Units	mm	in	W/mK	W/m^2K	m^2K/W	$ft^2 \cdot °F \cdot h/BTU$	$ft^2 \cdot °F \cdot h/BTU$
Interior air film					0.12	0.68	
Interior gypsum board	12.7	0.50	-	-	0.05	0.30	
Steel stud-framed wall	63.5	2.50	0.49	7.75	0.13	0.73	
Smart vapour retarder	-	-	-	-	-	-	-
Rigid or semi-rigid mineral fibre board insulation (continuous)	127	5.00	-	-	3.75	21.3	21.5
Fluid-applied air barrier and WRB membrane (vapour permeable)	-	-	-	-	-	-	
Existing multi-wythe brick masonry	203	8.00	1.31	6.45	0.16	0.88	
Exterior air film					0.03	0.17	
TOTALS	**406**	**16.0**			**4.20**	**24.0**	**21.5**

W14: Embodied Carbon Emissions (A1 to A3 Life Stages) for 9m² Assembly Area

Category	Material	Description (from EPD)	Thickness	Material Volume	Carbon Emissions (A1-A3)	% of total
Units			mm	m^3	kgCO2e	%
Finish	Interior Paint	Eggshell acrylic paint, 1294.29 kg/m3 (Generic)	0.16 (0.0063")	0.0014	0.56	0.20%
Finish	gypsum board	Gypsum plaster board, regular, (Generic)	12.7 (0.5")	0.1143	26.00	8.60%
Back-up structure	Steel stud framing, no insulation	Steel stud framing for drywall/gypsum plasterboard per sq. meter of wall area (incl. air gaps per m3), C-profile: 63.5 x 30.48 mm, gauge 25, 3 m height x 406.4 mm (400 mm) spacing (Generic)	-	*	39	12.80%
Exterior Membrane	Smart vapour barrier membrane	Vapor Barrier (Generic)	-	*	33	10.90%
Exterior Insulation	Mineral wool insulation board	Heavy density mineral wool board, 1 m2K/W, 34 mm (1.34 in), 4.2 kg/m2 (0.86 lb/ft2), 123.52 kg/m3 (7.71 lb/ft3), Industry average US (NAIMA)	127 (5")	1.143	200	66.0%
Air barrier	Liquid applied air barrier membrane	Air and water barrier system, fluid applied, 0.9 kg/m2 (0.184 lbs/ft2), Tyvek (DuPont) (Product specific)	-	*	5.1	1.70%
Existing Structure	Existing Multi-wythe brick	Existing- Not Included in Calculations				
				TOTAL	**303.7**	100.0%

**Software auto-calculates the impact based on the area provided.*

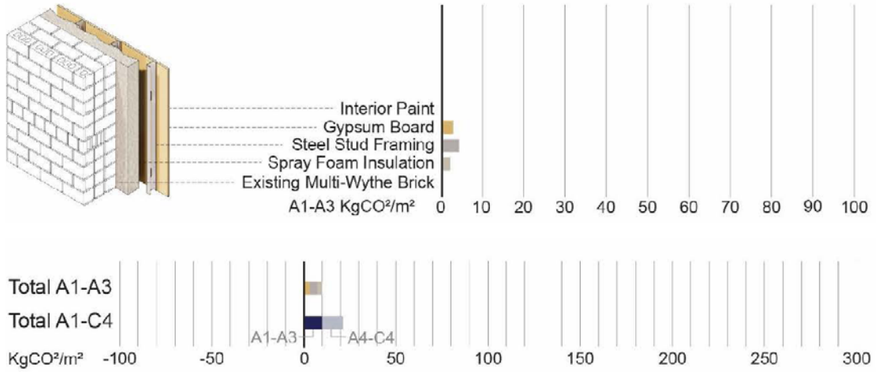
W14: Environmental Emissions (A1 to C4 Life Stages) for 9m² Assembly Area

Lifecycle Stage		**A1 to C4**	A1-A3	A4-A5	B1-B5	C1-C4	A1-A3 Contribution to total
Category	Units	**Total**	Construction Materials	Transport to Site & Construction	Material Replacement & Refurbishment	Deconstruction	%
Global Warming	kg CO2e	**805.356**	304.58	3.288	94.81	402.678	37.82%
Acidification	kg SO	**7.61E-06**	1.31E-06	8.67E-07	1.63E-06	3.81E-06	17.21%
Eutrophication	kg Ne	**1.68252**	0.6532	0.01806	0.17	0.84126	38.82%
Ozone Depletion	kg CFC11e	**0.219704**	0.095394	0.002558	0.0119	0.109852	43.42%
Formation of Tropospheric Ozone	kg O3e	**30.102**	10.299	0.502	4.25	15.051	34.21%
Fossil Fuel Primary Energy	MJ	**8004.48**	1725.22	92.85	2184.17	4002.24	21.55%
Biogenic Carbon Storage	kg CO2e	**0**	0				

APPENDIX A **WALL ASSEMBLY 15**

W15: Results Summary

Metrics	Results
Description	**Existing Masonry with Interior Spray Foam Insulation**
Effective R-value	RSI-4.7 m^2K/W | R-26.8 $ft^2 \cdot °F \cdot h/BTU$
Embodied Carbon per m^2 of Enclosure (A1-A3)	9.8 $kgCO_2/m^2$
Biogenic Carbon per m^2 of Enclosure	0 $kgCO_2/m^2$



W15: Assembly Effective R-value Calculation

Description	t_{SI}	t_{IP}	k	C (USI)	$RSI_{effective}$	$R_{effective}$	$R_{nominal}$
Units	mm	in	W/mK	W/m^2K	m^2K/W	$ft^2 \cdot °F \cdot h/BTU$	$ft^2 \cdot °F \cdot h/BTU$
Interior air film					0.12	0.68	
Interior gypsum board	12.7	0.50	0.16	27.0	0.04	0.21	
Steel stud-framed wall	63.5	2.50	0.49	7.75	0.13	0.73	
Closed-cell spray foam insulation	102	4.00	-	-	4.26	24.2	24.2
Existing multi-wythe brick masonry	203	8.00	1.31	6.45	0.16	0.88	
Exterior air film					0.03	0.17	
TOTALS	**281**	**15.0**			**4.70**	**26.8**	**24.2**

W15: Embodied Carbon Emissions (A1 to A3 Life Stages) for 9m² Assembly Area

Category	Material	Description (from EPD)	Thickness	Material Volume	Carbon Emissions (A1-A3)	% of total
Units			mm	m^3	kgCO2e	%
Finish	Interior Paint	Eggshell acrylic paint, 1294.29 kg/m3 (Generic)	0.16 (0.0063")	0.0014	0.56	0.6%
Finish	gypsum board	Gypsum plaster board, regular, (Generic)	12.7 (0.5")	0.1143	26.00	29.30%
Back-up structure	Steel stud framing, no insulation	Steel stud framing for drywall/gypsum plasterboard per sq. meter of wall area (incl. air gaps per m3), C-profile: 63.5 x 30.48 mm, gauge 25, 3 m height x 406.4 mm (400 mm) spacing (Generic)	-	*	39	43.70%
Exterior Insulation	SPRAY FOAM	Spray polyurethane foam insulation for closed cell, with HFO blowing agent	101.6 (4")	0.9144	23	26.40%
Existing structure	Existing Multi-wythe brick	Existing - Not Included		-	-	-
				TOTAL	**88.56**	100.0%

**Software auto-calculates the impact based on the area provided.*

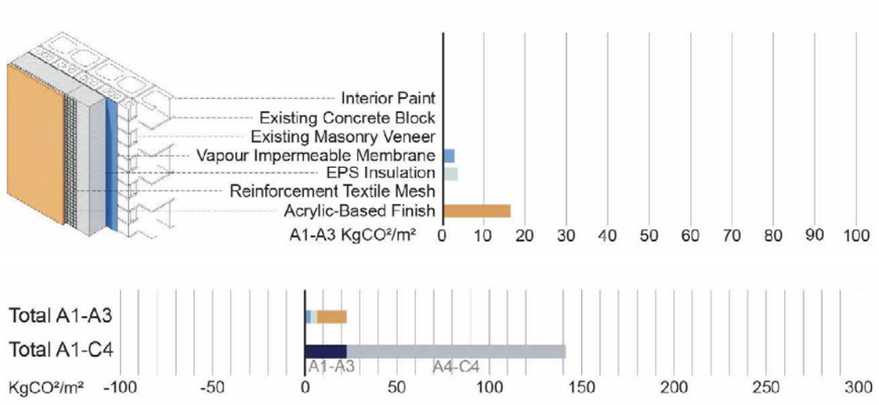
W15: Environmental Emissions (A1 to C4 Life Stages) for 9m² Assembly Area

Lifecycle Stage		**A1 to C4**	A1-A3	A4-A5	B1-B5	C1-C4	A1-A3 Contribution to total
Category	Units	**Total**	Construction Materials	Transport to Site & Construction	Material Replacement & Refurbishment	Deconstruction	%
Global Warming	kg CO2e	**189.12**	89.01	1.72	3.83	94.56	47.07%
Acidification	kg SO	**4.59E-06**	1.58E-06	4.55E-07	2.60E-07	2.30E-06	34.42%
Eutrophication	kg Ne	**0.9018**	0.4202	9.70E-03	0.021	0.4509	46.60%
Ozone Depletion	kg CFC11e	**0.194588**	0.094944	0.00135	0.001	0.097294	48.79%
Formation of Tropospheric Ozone	kg O3e	**13.624**	6.049	0.273	0.49	6.812	44.40%
Fossil Fuel Primary Energy	MJ	**1541.3**	689.85	48.66	32.14	770.65	44.76%
Biogenic Carbon Storage	kg CO2e	**0**	0				

APPENDIX A **WALL ASSEMBLY 16**

W16: Results Summary

Metrics	Results
Description	**Existing Masonry with Exterior EIFS Overcladding**
Effective R-value	RSI-4.4 m^2K/W | R-24.8 $ft^2 \cdot °F \cdot h/BTU$
Embodied Carbon per m^2 of Enclosure (A1-A3)	22.9 $kgCO_2/m^2$
Biogenic Carbon per m^2 of Enclosure	0 $kgCO_2/m^2$



W16: Assembly Effective R-value Calculation

Description	t_{SI}	t_{IP}	k	C (USI)	$RSI_{effective}$	$R_{effective}$	$R_{nominal}$
Units	mm	in	W/mK	W/m^2K	m^2K/W	$ft^2 \cdot °F \cdot h/BTU$	$ft^2 \cdot °F \cdot h/BTU$
Interior air film					0.12	0.68	
Existing multi-wythe CMU wall	203	8.00	1.18	5.81	0.17	0.98	
Existing multi-wythe brick masonry	88.9	3.50	1.31	14.7	0.07	0.39	
Fluid-applied air barrier and WRB membrane (vapour impermeable)	3.00	0.12	-	-	-	-	
Expanded polystyrene (EPS) rigid board insulation	152	6.00	0.04	0.25	3.96	0.88	22.5
EIFS base and finish coat	4.00	0.16	-	-	0.01	0.06	
Exterior air film					0.03	0.17	
TOTALS	**451**	**17.8**			**4.40**	**24.8**	**22.5**

W16: Embodied Carbon Emissions (A1 to A3 Life Stages) for 9m² Assembly Area

Category	Material	Description (from EPD)	Thickness	Material Volume	Carbon Emissions (A1-A3)	% of total
Units			mm	m^3	kgCO2e	%
Finish	Interior Paint	Eggshell acrylic paint, 1294.29 kg/m3 (Generic)	0.16 (0.0063")	0.0014	0.56	0%
Existing structure	Existing CMU	Not Included in calculation		-	-	-
Exterior Finish	Existing masonry veneer	Not Included in calculation		-	-	-
Exterior Membrane	Vapor impermeable water resistive barrier membrane	Latex-based membrane, vapor impermeable, fluid-applied, 1.016 mm (40 mils), 1.150 kg/L (9.6 lbs/gal), Perm-A-Barrier® NPL 10	3 (0.12")	0.027	22	10.69%
Exterior Insulation	EPS Insulation	EPS insulation Generic	152.4 (6")	1.3716	25	12.1%
Cladding coating	EIFS base and finish coat system	Acrylic-based finish	-	*	150	72.89%
		Fluoropolymer powder coating	-	(1 kg)	1.6	0.78%
		Reinforcement textile mesh	-	*	7.2	3.50%
				TOTAL	**205.8**	100.0%

**Software auto-calculates the impact based on the area provided.*

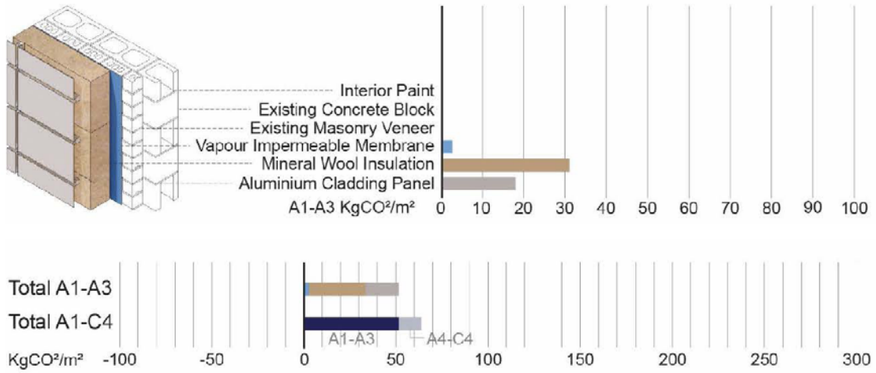
W16: Environmental Emissions (A1 to C4 Life Stages) for 9m² Assembly Area

Lifecycle Stage		**A1 to C4**	A1-A3	A4-A5	B1-B5	C1-C4	A1-A3 Contribution to total
Category	Units	**Total**	Construction Materials	Transport to Site & Construction	Material Replacement & Refurbishment	Deconstruction	%
Global Warming	kg CO2e	**1281.4895**	205.8	11.084	961.7	102.9055	16.06%
Acidification	kg SO	**0.00623053**	0.001	2.81E-06	0.005224	3.72E-06	16.05%
Eutrophication	kg Ne	**5.412342**	0.8692	0.055424	4.366	0.121718	16.06%
Ozone Depletion	kg CFC11e	**0.516917**	0.066844	0.008223	0.39598	0.04587	12.93%
Formation of Tropospheric Ozone	kg O3e	**59.195161**	9.474	1.5218	47.12	1.079361	16.00%
Fossil Fuel Primary Energy	MJ	**23516.7635**	3908.37	309.87	19279.54	18.9835	16.62%
Biogenic Carbon Storage	kg CO2e	**0**					

APPENDIX A **WALL ASSEMBLY 17**

W17: Results Summary

Metrics	Results
Description	**Existing Masonry with Exterior Aluminum Panel Overcladding**
Effective R-value	RSI-4.4 m^2K/W | R-24.8 $ft^2 \cdot °F \cdot h/BTU$
Embodied Carbon per m^2 of Enclosure (A1-A3)	52.5 $kgCO_2/m^2$
Biogenic Carbon per m^2 of Enclosure	0 $kgCO_2/m^2$



W17: Assembly Effective R-value Calculation

Description	t_{SI}	t_{IP}	k	C (USI)	$RSI_{effective}$	$R_{effective}$	$R_{nominal}$
Units	mm	in	W/mK	W/m^2K	m^2K/W	$ft^2 \cdot °F \cdot h/BTU$	$ft^2 \cdot °F \cdot h/BTU$
Interior air film					0.12	0.68	
Existing multi-wythe CMU wall	203	8.00	1.18	5.81	0.17	0.98	
Existing multi-wythe brick masonry	88.9	3.50	1.31	14.7	0.07	0.39	
Self-adhered sheet-applied air barrier and water-resistive barrier (WRB) membrane (vapour impermeable)	3.00	0.12	-	-	-	-	
Semi-rigid mineral fiber exterior insulation with intermittent proprietary fibreglass clips	178	7.00	0.04	0.25	3.98	22.58	30.1
Air cavity	25.0	0.98	-	-	-	-	
Aluminum panel cladding	3.00	0.12	-	-	-	-	
Exterior air film					0.03	0.17	
TOTALS	**501**	**19.7**			**4.40**	**24.8**	**30.1**

W17: Embodied Carbon Emissions (A1 to A3 Life Stages) for 9m² Assembly Area

Category	Material	Description (from EPD)	Thickness	Material Volume	Carbon Emissions (A1-A3)	% of total
Units			mm	m^3	kgCO2e	%
Finish	Interior Paint	Eggshell acrylic paint, 1294.29 kg/m3 (Generic)	0.16 (0.0063")	0.0014	0.56	0.1%
Existing structure	Existing CMU	Not Included in calculations	-	-	-	-
Exterior Finish	Existing masonry veneer	Not Included in calculation	-	-	-	-
Exterior Membrane	Vapor impermeable water resistive barrier membrane	Latex-based membrane, vapor impermeable, fluid-applied,	3 (0.12")	0.027	22	4.70%
Exterior Insulation	Exterior Insulation mineral wool	Heavy density mineral wool board, 1 m2K/W, 34 mm (1.34 in), 4.2 kg/m2 (0.86 lb/ft2), 123.52 kg/m3 (7.71 lb/ft3), Industry average US (NAIMA)	177.8 (7")	1.6002	280	59.60%
Cladding	Aluminum Cladding Panel	Roll formed aluminum cladding, 4.91 kg/m2 (Metal Construction Association) (Generic)	*	*	170	35.5%
				TOTAL	**472.56**	100.0%

**Software auto-calculates the impact based on the area provided.*

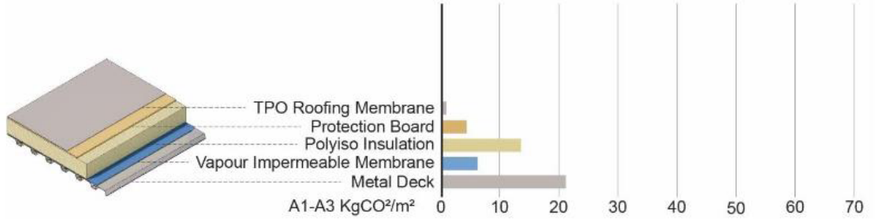
W17: Environmental Emissions (A1 to C4 Life Stages) for 9m² Assembly Area

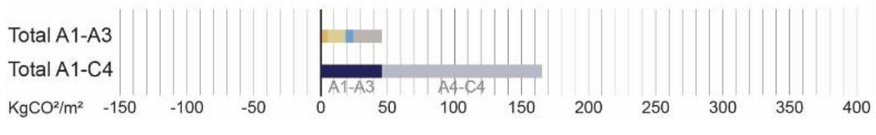
Lifecycle Stage		**A1 to C4**	A1-A3	A4-A5	B1-B5	C1-C4	A1-A3 Contribution to total
Category	Units	**Total**	Construction Materials	Transport to Site & Construction	Material Replacement & Refurbishment	Deconstruction	%
Global Warming	kg CO2e	**579.6443**	471.61	2.60E+00	64.49	40.9443	81.36%
Acidification	kg SO	**6.34E-06**	1.92E-06	0.00000068	0.00000186	1.88E-06	30.29%
Eutrophication	kg Ne	**1.640114**	1.2632	0.0148	0.163	0.199114	77.02%
Ozone Depletion	kg CFC11e	**0.072773**	0.028244	0.00208	0.02398	0.018469	38.81%
Formation of Tropospheric Ozone	kg O3e	**20.158409**	16.549	0.412	2.69	0.507409	82.09%
Fossil Fuel Primary Energy	MJ	**1583.581**	820.53	74.07	674.58	14.401	51.81%
Biogenic Carbon Storage	kg CO2e	**0**	0				

APPENDIX A **ROOF ASSEMBLY 01**

R01: Results Summary

Metrics	Results
Description	**Conventional Roof with Polyiso on Metal Deck**
Effective R-value	RSI-5.2 m²K/W | R-29.6 ft²·°F·h/BTU
Embodied Carbon per m² of Enclosure (A1-A3)	46.3 kgCO₂/m²
Biogenic Carbon per m² of Enclosure	0 kgCO₂/m²





R01: Assembly Effective R-value Calculation

Description	t_{SI}	t_{IP}	k	C (USI)	$RSI_{effective}$	$R_{effective}$	$R_{nominal}$
Units	mm	in	W/mK	W/m²K	m²K/W	ft²·°F·h/BTU	ft²·°F·h/BTU
Interior air film					0.11	0.61	
Corrugated metal roof deck	1.20	0.05	50.00	41530	0.00	0.00	
Self-adhered sheet-applied air barrier and vapour-impermeable membrane	0.80	0.03	-	-	-	-	
Rigid polyisocyanurate insulation, fully adhered (polyurethane adhesive)	127.00	5.00	0.003	0.26	4.93	28.00	28.00
Asphalt protection board, fully adhered (polyurethane adhesive)	4.80	0.19	-	-	0.14	0.79	
Waterproof roof membrane system	2.20	0.09	-	-	-	-	
Exterior air film					0.03	0.17	
TOTALS	**136.0**	**5.40**			**5.20**	**29.60**	**28.00**

R01: Embodied Carbon Emissions (A1 to A3 Life Stages) for 9m² Assembly Area

Category	Material	Description (from EPD)	Thickness	Material Volume	Carbon Emissions (A1-A3)	% of total
Units			mm	m³	kgCO2e	%
Structure	Metal Deck	Steel roof and floor deck, 22-16 gauge (Steel Deck Institute) deck	1.204 (0.05")	0.010836	190	46.50%
Exterior Membrane	Vapour impermeable membrane	SBS polymer-modified bitumen membrane roofing, self-adhered, 6.69 kg/m2 (Certain Teed, Henry, IKO, Malarkey Roofing Products, Siplast, Soprema)	-	*	61	14.7%
Exterior Insulation	Polyiso	Polyisocyanurate (PIR) roof insulation boards, glass fiber reinforced cellulosic faced (GRF), boards	127 (5")	1.3716	120	28%
Insulation Protection	Protection Board	Roof cover board, fiberglass facing, 6.1 kg/m2, EVERBOARD™ - ¼ fiberglass faced (Continuous Materials, plant Philadelphia)	-	*	36	9%
Exterior Membrane	TPO Roofing Membrane	TPO Single ply waterproofing roof membrane (mechanically fastened) (Generic)	2.2 (0.1")	0.0198	10	3%
				TOTAL	**417**	100.10%

**Software auto-calculates the impact based on the area provided.*

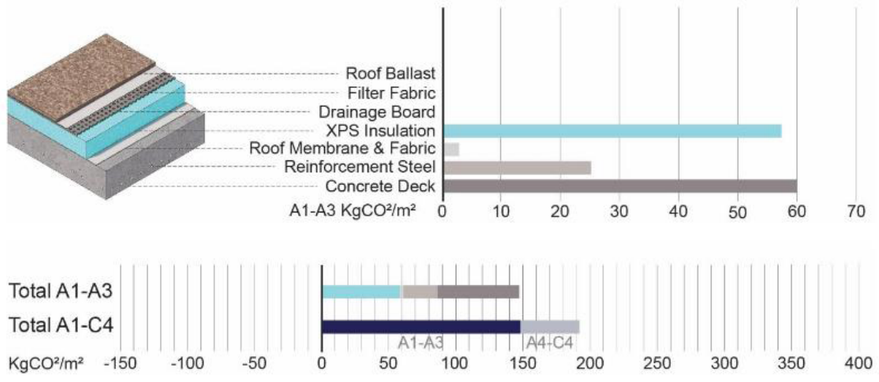
R01: Environmental Emissions (A1 to C4 Life Stages) for 9m² Assembly Area

Lifecycle Stage		**A1 to C4**	A1-A3	A4-A5	B1-B5	C1-C4	A1-A3 Contribution to total
Category	Units	**Total**	Construction Materials	Transport to Site & Construction	Material Replacement & Refurbishment	Deconstruction	%
Global Warming	kg CO2e	**1500.44**	417.57	3.9	328.75	750.22	27.83%
Acidification	kg SO	**5.79E-05**	1.63E-05	1.03E-06	1.16E-05	2.89E-05	28.17%
Eutrophication	kg Ne	**5.6006**	1.908	0.0223	0.87	2.8003	34.07%
Ozone Depletion	kg CFC11e	**1.1659**	0.36179	0.00316	0.218	0.58295	31.03%
Formation of Tropospheric Ozone	kg O3e	**77.622**	25.63	0.631	12.55	38.811	33.02%
Fossil Fuel Primary Energy	MJ	**8260.22**	3262.53	111.16	756.42	4130.11	39.50%
Biogenic Carbon Storage	kg CO2e	**0**	0				

APPENDIX A **ROOF ASSEMBLY 02**

R02: Results Summary

Metrics	Results
Description	**Protected Membrane Rood with XPS on Concrete Deck**
Effective R-value	RSI-5.6 m^2K/W | R-31.7 $ft^2 \cdot °F \cdot h/BTU$
Embodied Carbon per m^2 of Enclosure (A1-A3)	148.4 $kgCO_2/m^2$
Biogenic Carbon per m^2 of Enclosure	0 $kgCO_2/m^2$



R02: Assembly Effective R-value Calculation

Description	t_{SI}	t_{IP}	k	C (USI)	$RSI_{effective}$	$R_{effective}$	$R_{nominal}$
Units	mm	in	W/mK	W/m^2K	m^2K/W	$ft^2 \cdot °F \cdot h/BTU$	$ft^2 \cdot °F \cdot h/BTU$
Interior air film					0.11	0.61	
Concrete roof structure	254.00	10.00	1.60	6.30	0.16	0.90	
Hot-applied rubberized asphalt waterproofing membrane	2.30	0.09	-	-	-	-	
Reinforcing fabric	0.26	0.01	-	-	-	-	
Hot-applied rubberized asphalt waterproofing membrane	3.20	0.13	-	-	-	-	
Drainage mat	10.00	0.39	-	-	-	-	
Extruded polystyrene (XPS) rigid board insulation, fully adhered (polyurethane adhesive)	152.40	6.00	0.03	0.19	5.28	29.98	29.98
Filter fabric	-	-	-	-	-	-	
Aggregate ballast	-	-	-	-	-	-	
Exterior air film					0.03	0.17	
TOTALS	**422.20**	**16.60**			**5.60**	**31.70**	**30.00**

R02: Embodied Carbon Emissions (A1 to A3 Life Stages) for 9m² Assembly Area

Category	Material	Description (from EPD)	Thickness	Material Volume	Carbon Emissions (A1-A3)	% of total
Units			mm	m^3	kgCO2e	%
Structural Deck	Concrete Deck	Ready-mix concrete, Ontario industry average, 35 MPa concrete with air entrainment GU 50 SL	254 (10")	2.263	540	40.3%
	Reinforcement bar	Reinforcement steel (rebar), generic, 60% recycled content, A615	-	0.02286	240	18.0%
Exterior Membrane	Hot Rubber roof membrane and Reinforcing Fabric	Hot-applied rubberized asphalt membrane, waterproofing, 5.56 mm (219 mils), 6.39 kg/m2 (1.3 lb/ft2), Monolithic Membrane 6125 (MM6125) (Hydrotech Membrane Corp)	5.5 (0.22")	0.0495	28	2.1%
Exterior Insulation	XPS	XPS insulation (extruded polystyrene)	152.4 (6")	1.3716	520	39%
Drainage	Drainage Board	Drainage mat and moisture barrier, 2.15 kg/m2, DrainScreen (Sto)	-	*	2.5	0.2%
Drainage	Filter Fabric	Geotextile, generic, 312 g/m2 (1.02 oz/ft2), Composition: PP net, non-woven PE felt, generic	-	*	2.3	0.2%
Exterior Finish	Roof Ballast	Rock to be used for erosion control, Granite, product specific	-	*	2.7	0.2%
				TOTAL	**1336**	

**Software auto-calculates the impact based on the area provided.*

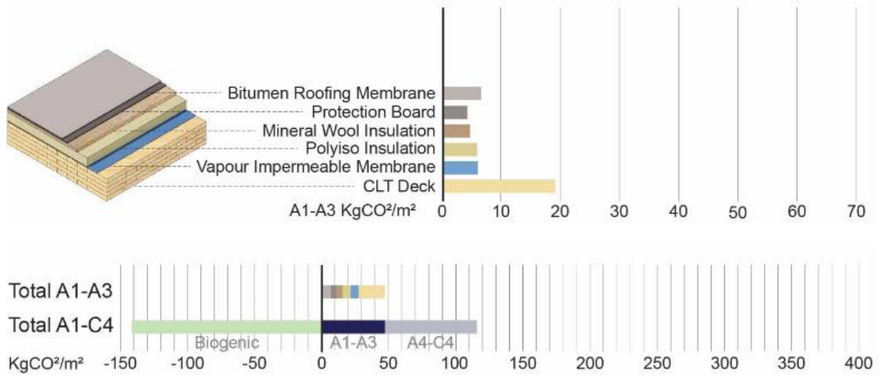
R02: Environmental Emissions (A1 to C4 Life Stages) for 9m² Assembly Area

Lifecycle Stage		**A1 to C4**	A1-A3	A4-A5	B1-B5	C1-C4	A1-A3 Contribution to total
Category	Units	**Total**	Construction Materials	Transport to Site & Construction	Material Replacement & Refurbishment	Deconstruction	%
Global Warming	kg CO2e	**1729.623**	1338.95	135.884	109.49	145.299	77.41%
Acidification	kg SO	**0.00093718**	0.000838	3.07E-05	5.97E-06	8.78E-06	89.42%
Eutrophication	kg Ne	**6.97305**	4.5046	0.21699	0.506	1.74546	64.60%
Ozone Depletion	kg CFC11e	**2.055435**	1.82279	0.094207	0.065	0.073438	88.68%
Formation of Tropospheric Ozone	kg O3e	**78.097398**	72.903	2.6225	1.3	1.271898	93.35%
Fossil Fuel Primary Energy	MJ	**13496.882**	6608.37	2025.96	4783.06	79.492	48.96%
Biogenic Carbon Storage	kg CO2e	**0**	0				

APPENDIX A **ROOF ASSEMBLY 03**

R03: Results Summary

Metrics	Results
Description	**Conventional Modified Bitumen Roof with Hybrid Insulation on CLT Deck**
Effective R-value	RSI-4.4 m^2K/W | R-24.8 $ft^2{\cdot}°F{\cdot}h/BTU$
Embodied Carbon per m^2 of Enclosure (A1-A3)	48.1 $kgCO_2/m^2$
Biogenic Carbon per m^2 of Enclosure	1269.96 $kgCO_2/m^2$



R03: Assembly Effective R-value Calculation

Description	t_{SI}	t_{IP}	k	C (USI)	$RSI_{effective}$	$R_{effective}$	$R_{nominal}$
Units	mm	in	W/mK	W/m^2K	m^2K/W	$ft^2{\cdot}°F{\cdot}h/BTU$	$ft^2{\cdot}°F{\cdot}h/BTU$
Interior air film					0.11	0.61	
Mass timber roof panel	191.00	7.52	0.13	0.68	1.47	8.34	
Self-adhered sheet-applied air barrier and vapour-impermeable membrane	0.80	0.03	-	-	-	-	
Rigid polyisocyanurate insulation, fully adhered (polyurethane adhesive)	76.20	3.00	0.02	0.31	3.18	18.03	16.80
Rigid mineral fibre board insulation, fully adhered (polyurethane adhesive)	25.40	1.00	0.03	1.34	0.75	4.24	4.30
Asphalt protection board, fully adhered (polyurethane adhesive)	4.80	0.19	-	-	0.14	0.79	
SBS modified asphalt membrane (base ply)	2.20	0.09	-	-	-	-	29.98
SBS modified asphalt membrane (cap sheet)	4.00	0.16	-	-	-	-	
Exterior air film					0.03	0.17	
TOTALS	**304.40**	**12.00**			**5.70**	**32.20**	**21.10**

R03: Embodied Carbon Emissions (A1 to A3 Life Stages) for 9m² Assembly Area

Category	Material	Description (from EPD)	Thickness	Material Volume	Carbon Emissions (A1-A3)	% of total
Units			mm	m^3	kgCO2e	%
Structure	CLT Deck	CLT produced in British Columbia, 464.7 kg/m3 (Forestry Innovation Investment) (Generic)	191 (7.5")	1.719	170	39.6%
Exterior Membrane	Vapour impermeable membrane	SBS polymer-modified bitumen membrane roofing, self-adhered, 6.69 kg/m2 (Certain Teed, Henry, IKO, Malarkey Roofing Products, Siplast, Soprema)	-	*	61	14.0%
Exterior Insulation	75% Polyiso adhered in foam	Polyisocyanurate (PIR) roof insulation boards, glass fiber reinforced cellulosic faced (GRF), boards	76.2 (3")	0.6858	58	13.2%
Exterior Insulation	25% mineral wool adhered in foam	Heavy density mineral wool board, 1 m2K/W, 34 mm (1.34 in), 4.2 kg/m2 (0.86 lb/ft2), 123.52 kg/m3 (7.71 lb/ft3), Industry average US (NAIMA)	25.4 (1")	0.2286	40	9.2%
Insulation Protection	Protection Board adhered in foam	Roof cover board, fiberglass facing, 6.1 kg/m2, EVERBOARD™ - ¼ fiberglass faced (Continuous Materials, plant Philadelphia)	-	*	36	8%
Exterior Membrane	Base sheet - SBS torch applied Cap Sheet - SBS torch applied	Bitumen roofing membrane, torch-applied, 9.02 kg/m2 (Asphalt Roofing Manufacturers Association)	-	*	68	15.7%
				TOTAL	**433**	

**Software auto-calculates the impact based on the area provided.*

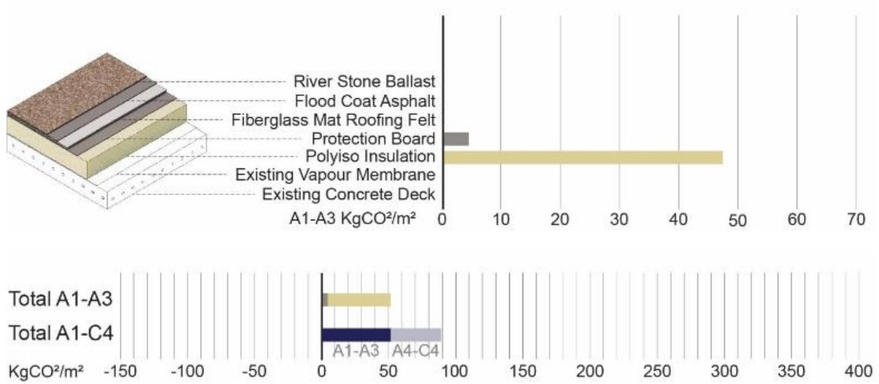
R03: Environmental Emissions (A1 to C4 Life Stages) for 9m² Assembly Area

Lifecycle Stage		**A1 to C4**	A1-A3	A4-A5	B1-B5	C1-C4	A1-A3 Contribution to total
Category	Units	**Total**	Construction Materials	Transport to Site & Construction	Material Replacement & Refurbishment	Deconstruction	%
Global Warming	kg CO2e	**1048.494**	436.93	18.4	417.35	175.814	41.67%
Acidification	kg SO	**3.66E-05**	1.33E-05	4.86E-06	1.10E-05	7.48E-06	36.30%
Eutrophication	kg Ne	**5.00659**	2.938	0.1043	1.45	0.51429	58.68%
Ozone Depletion	kg CFC11e	**1.020318**	0.46635	0.01428	0.237	0.302688	45.71%
Formation of Tropospheric Ozone	kg O3e	**80.104007**	53.05	2.978	18.74	5.336007	66.23%
Fossil Fuel Primary Energy	MJ	**13016.28**	5891.15	523.04	6556	46.09	45.26%
Biogenic Carbon Storage	kg CO2e	**1269.96**	1269.96				

APPENDIX A **ROOF ASSEMBLY 04**

R04: Results Summary

Metrics	Results
Description	**Existing BUR Roof Replacement over Polyisocyanurate Insulation**
Effective R-value	RSI-5.5 m^2K/W | R-31.2 $ft^2{\cdot}°F{\cdot}h/BTU$
Embodied Carbon per m^2 of Enclosure (A1-A3)	52.31 $kgCO_2/m^2$
Biogenic Carbon per m^2 of Enclosure	0 $kgCO_2/m^2$



R04: Assembly Effective R-value Calculation

Description	t_{SI}	t_{IP}	k	C (USI)	$RSI_{effective}$	$R_{effective}$	$R_{nominal}$
Units	mm	in	W/mK	W/m^2K	m^2K/W	$ft^2{\cdot}°F{\cdot}h/BTU$	$ft^2{\cdot}°F{\cdot}h/BTU$
Interior air film					0.11	0.61	
Existing concrete roof structure	254.00	10.00	1.60	6.30	0.16	0.90	
Existing self-adhered sheet-applied air barrier and vapour-impermeable membrane	0.80	0.03	-	-	-	-	
Rigid polyisocyanurate insulation, fully adhered (mopped asphalt)	127.00	5.00	0.03	0.21	4.93	28.00	28.00
Asphalt protection board, fully adhered (mopped asphalt)	4.80	0.19	-	-	0.14	0.79	
4-ply fibreglass mat roofing felt, set in mopped asphalt	20.00	0.79	-	-	0.12	0.67	
Asphalt flood coat, with embedded river stone ballast	6.00	0.24	0.43	71.67	0.01	0.08	
Exterior air film					0.03	0.17	
TOTALS	**412.60**	**16.20**			**5.50**	**31.20**	**28.00**

R04: Embodied Carbon Emissions (A1 to A3 Life Stages) for 9m² Assembly Area

Category	Material	Description (from EPD)	Thickness	Material Volume	Carbon Emissions (A1-A3)	% of total
Units			mm	m^3	kgCO2e	%
Existing structure	Existing Concrete deck	Not Included in calculations	-	-	-	-
Existing membrane	Existing vapour impermeable membrane		-	-	-	-
Insulation	Polyisocyanurate insulation set in coat of asphalt (mopped)	Generic Polyisocyanurate (PIR) insulation boards (Generic)	127 (5")	1.143	430	91.1%
Insulation Protection	Protection Board set in coat of asphalt	Roof cover board, fiberglass facing, 6.1 kg/m2, EVERBOARD™ - ¼ fiberglass faced (Continuous Materials, plant Philadelphia)	4.8 (0.19")	0.0432	36	7.8%
Insulation Facing	4 ply fiberglass mat roofing felt in mopped asphalt	Fiberglass mat used as insulation facing, 0.062 kg/m2 (Owens Corning)	20 (0.8")	0.18	1.8	0.4%
	Flood coat asphalt (x1) 2mm adhesive layer of mopped asphalt in between each layer of felt (x4) 0.5mm	Asphalt, hot-mix, Nominal Maximum Aggregate Size: 12.7 mm (0.5 inches), 10095203 Grd 3 Pre-coat (RK Hall LLC, Plant 07 Paris plant)	3.2 (0.13")	66 kg	2.7	0.6%
Exterior Finish	embedded river stone ballast	Rock to be used for erosion control, Granite Canyon (WY), D4992-14e1, BALLAST (Martin Marietta)	6 (0.24")	0.054	0.33	0.1%
				TOTAL	**471**	

**Software auto-calculates the impact based on the area provided.*

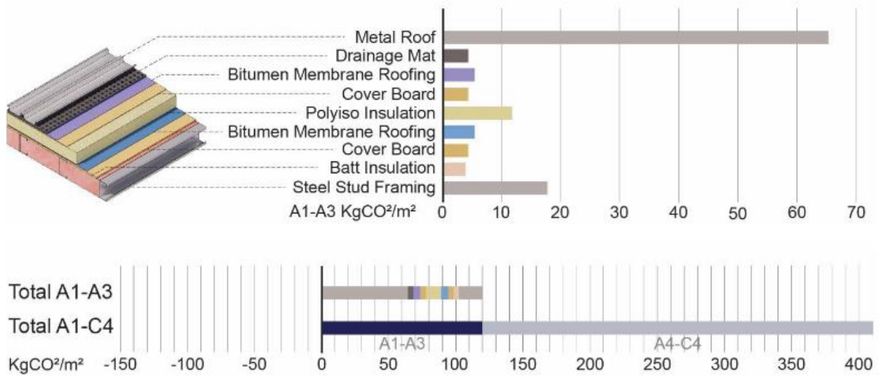
R04: Environmental Emissions (A1 to C4 Life Stages) for 9m² Assembly Area

Lifecycle Stage		**A1 to C4**	A1-A3	A4-A5	B1-B5	C1-C4	A1-A3 Contribution to total
Category	Units	**Total**	Construction Materials	Transport to Site & Construction	Material Replacement & Refurbishment	Deconstruction	%
Global Warming	kg CO2e	**809.4136**	466.54	2.3668	169.07	171.4368	57.64%
Acidification	kg SO	**5.89E-05**	3.52E-05	6.26E-07	1.12E-05	1.18E-05	59.81%
Eutrophication	kg Ne	**2.736358**	2.1637	0.013329	0.273	0.286329	79.07%
Ozone Depletion	kg CFC11e	**1.63835**	1.25666	0.001845	0.189	0.190845	76.70%
Formation of Tropospheric Ozone	kg O3e	**34.0532**	24.985	0.3841	4.15	4.5341	73.37%
Fossil Fuel Primary Energy	MJ	**8410.02**	7849.56	67.12	213.11	280.23	93.34%
Biogenic Carbon Storage	kg CO2e	**0**					

APPENDIX A **ROOF ASSEMBLY 05**

R05: Results Summary

Metrics	Results
Description	**Sloped Metal Roof Assembly**
Effective R-value	RSI-5.5 m^2K/W | R-31.4 $ft^2{\cdot}°F{\cdot}h/BTU$
Embodied Carbon per m^2 of Enclosure (A1-A3)	120.8 $kgCO_2/m^2$
Biogenic Carbon per m^2 of Enclosure	0 $kgCO_2/m^2$



R05: Assembly Effective R-value Calculation

Description	t_{SI}	t_{IP}	k	C (USI)	$RSI_{effective}$	$R_{effective}$	$R_{nominal}$
Units	mm	in	W/mK	W/m^2K	m^2K/W	$ft^2{\cdot}°F{\cdot}h/BTU$	$ft^2{\cdot}°F{\cdot}h/BTU$
Interior air film					0.11	0.61	
Steel stud roof framing with batt insulation	152.40	6.00	-	-	1.30	7.38	
Roof sheathing	12.70	0.50	0.13	10.08	0.10	0.56	
Underlayment	0.80	0.03	-	-	-	-	
Faced rigid polyisocyanurate insulation, fully adhered (polyurethane adhesive)	101.60	4.00	0.03	0.26	3.95	22.40	22.40
Asphalt protection board	6.35	0.25	0.13	20.16	0.05	0.28	
Underlayment	0.80	0.03	-	-	-	-	
Drainage mat	4.00	0.16	-	-	-	-	
Metal roofing	38.10	1.50	62.00	-	-	-	
Exterior air film					0.03	0.17	
TOTALS	**316.80**	**12.50**			**5.50**	**31.40**	**22.40**

R05: Embodied Carbon Emissions (A1 to A3 Life Stages) for 9m² Assembly Area

Category	Material	Description (from EPD)	Thickness	Material Volume	Carbon Emissions (A1-A3)	% of total
Units			mm	m^3	kgCO2e	%
Back-up structure	Steel stud framing with batt insulation	Steel stud framing for drywall/gypsum plasterboard per sq. meter of wall area (incl. air gaps per m3), C-profile: 152.4 x 76.2, gauge 20, 3 m height x 406.4 mm (400 mm) spacing (Generic)	-	*	160	14.5%
Exterior Insulation	Batt insulation	Mineral fiber batt insulation	152.4 (6")	1.029	31	2.80%
Sheathing	Roof structure sheathing	Roof cover board, fiberglass facing, 9.92 kg/m2, EVERBOARD™ - ½ fiberglass faced (Continuous Materials, plant Philadelphia)	12.7 (0.5")	*	37	3.4%
Membrane	Underlayment, butyl-based high temperature resistant sheet membrane, min. 30 mils	SBS polymer-modified bitumen membrane roofing, self-adhered, 6.69 kg/m2 (Certain Teed, Henry, IKO, Malarkey Roofing Products, Siplast, Soprema)	0.8 (0.03")	*	60	5.6%
Exterior Insulation	Fully adhered polyisocyanurate insulation board with coated composite facer, minimum 2-inches	Polyisocyanurate (PIR) roof insulation boards, coated glass faced (CGF), 0.941kg/m2 (2.07 lb/m2), 25 mm (0.984 in) (Atlas Roofing Corporation, Carlisle Construction Materials, Firestone Building Products, GAF, IKO, Johns Manville, Rmax - A Sika Brand, Soprema, Inc. (USA))	101.6 (4")	0.9144	110	9.9%
Insulation Protection	Cover Board	Roof cover board, fiberglass facing, 9.92 kg/m2, EVERBOARD™ - ½ fiberglass faced (Continuous Materials, plant Philadelphia)	6.35 (0.25")	*	37	3%
Membrane	Underlayment, high temperature resistant sheet membrane, 30 mil	SBS polymer-modified bitumen membrane roofing, self-adhered, 6.69 kg/m2 (Certain Teed, Henry, IKO, Malarkey Roofing Products, Siplast, Soprema)	0.8 (0.03")	0.0072	60	5.6%
Drainage	Drainage mat	Drainage mat and moisture barrier, 2.15 kg/m2, DrainScreen (Sto)	4 (0.16")	*	2.5	0.2%
Exterior finish	Metal Roof	Aluminum roofing, hot rolled plate, 2660-2840 kg/m3 (Aluminum Association)	38.1 (1.5")	0.3429	590	54.5%
				TOTAL	**1088**	

**Software auto-calculates the impact based on the area provided.*

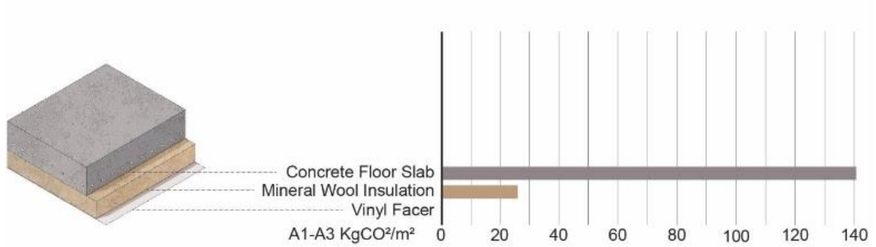
R05: Environmental Emissions (A1 to C4 Life Stages) for 9m² Assembly Area

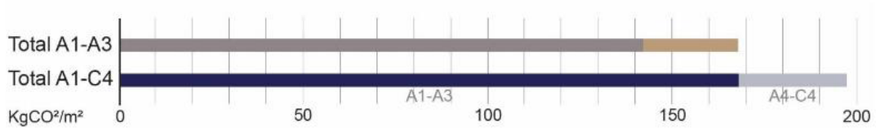
Lifecycle Stage		**A1 to C4**	A1-A3	A4-A5	B1-B5	C1-C4	A1-A3 Contribution to total
Category	Units	**Total**	Construction Materials	Transport to Site & Construction	Material Replacement & Refurbishment	Deconstruction	%
Global Warming	kg CO2e	**3711.58**	1090.07	25.84	739.88	1855.79	29.37%
Acidification	kg SO	**1.03E-04**	1.78E-05	6.81E-06	2.71E-05	5.17E-05	17.21%

APPENDIX A **FLOOR ASSEMBLY 01**

F01: Results Summary

Metrics	Results
Description	**Parking Garage Concrete Ceiling with Vinyl-Faced Mineral Wool**
Effective R-value	RSI-4.6 m^2K/W | R-26 $ft^{2\cdot}°F{\cdot}h/BTU$
Embodied Carbon per m^2 of Enclosure (A1-A3)	168.4 $kgCO_2/m^2$
Biogenic Carbon per m^2 of Enclosure	0 $kgCO_2/m^2$





F01: Assembly Effective R-value Calculation

Description	t_{SI}	t_{IP}	k	C (USI)	$RSI_{effective}$	$R_{effective}$	$R_{nominal}$
Units	mm	in	W/mK	W/m^2K	m^2K/W	$ft^{2\cdot}°F{\cdot}h/BTU$	$ft^{2\cdot}°F{\cdot}h/BTU$
Interior air film					0.11	0.61	
Concrete floor slab	254.00	10.00	1.60	6.30	0.16	0.90	
Semi-rigid mineral fiber exterior insulation	152.40	6.00	-	-	4.29	24.35	24.60
Vinyl facing	0.26	0.01	-	-	-	-	
Exterior air film					0.03	0.17	
TOTALS	**406.7**	**16.0**			**4.6**	**26.0**	**24.6**

F01: Embodied Carbon Emissions (A1 to A3 Life Stages) for 9m² Assembly Area

Category	Material	Description (from EPD)	Thickness	Material Volume	Carbon Emissions (A1-A3)	% of total
Units			mm	m^3	kgCO2e	%
Structure	Concrete Floor Slab	Ready-mix concrete, 35MPa GU cem. with air entr. 0-14% FA/SC (CRMCA)	254 (10")	2.29	1030.02	67.9%
	Interior gypsum board	Reinforcement steel (rebar), generic, 60% recycled content, A615	-	0.023	241.77	15.9%
Insulation	Exterior Insulation Mineral Wool (Semi-rigid)	Heavy density mineral wool board, 1 m2K/W, 34 mm, 4.2 kg/m2, 123.52 kg/m3, Industry average US (NAIMA)	152.4 (6")	1.37	242.18	16.0%
	Vinyl Facer	Polypropylene film (ASJ) used as insulation facing, 0.152 kg/m2, Micro-Lok® HP Ultra (Johns Manville)	0.26 (0.01 ")	0.0023	1.95	0.1%
				TOTAL	**1515.92**	100.0%

**Software auto-calculates the impact based on the area provided.*

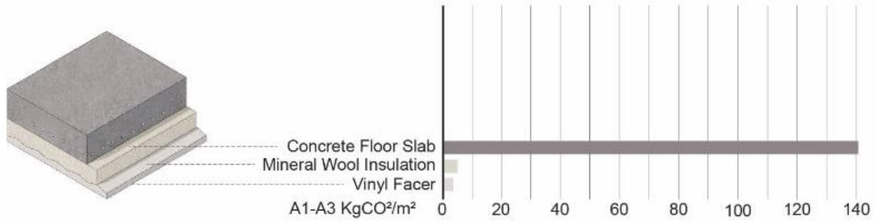
F01: Environmental Emissions (A1 to C4 Life Stages) for 9m² Assembly Area

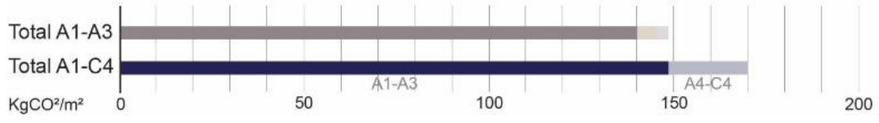
Lifecycle Stage		**A1 to C4**	A1-A3	A4-A5	B1-B5	C1-C4	A1-A3 Contribution to total
Category	Units	**Total**	Materials	Construction	Refurbishment	Deconstruction	%
Global Warming	kg CO2e	**1,775.99**	1,515.92	134.45	52.27	73.35	85.36%
Acidification	kg SO	**6.24**	5.74	0.20	0.04	0.26	91.92%
Eutrophication	kg Ne	**1.92**	1.75	0.09	0.01	0.07	91.31%
Ozone Depletion	kg CFC11e	**0.00008**	0.00003	0.00003	0.0000002	0.00002	40.18%
Formation of Tropospheric Ozone	kg O3e	**108.55**	98.58	2.37	1.20	6.40	90.81%
Fossil Fuel Primary Energy	MJ	**11,642.66**	8,600.65	1,981.67	20.15	1,040.19	73.87%
Biogenic Carbon Storage	kg CO2e	**0**	0	0	0	0	

APPENDIX A **FLOOR ASSEMBLY 02**

F02: Results Summary

Metrics	Results
Description	**Parking Garage Concrete Ceiling with Fire Resistant Spray Insulation**
Effective R-value	RSI-4.5 m^2K/W | R-25.7 $ft^2 \cdot °F \cdot h/BTU$
Embodied Carbon per m^2 of Enclosure (A1-A3)	148.4 $kgCO_2/m^2$
Biogenic Carbon per m^2 of Enclosure	0 $kgCO_2/m^2$





F02: Assembly Effective R-value Calculation

Description	t_{SI}	t_{IP}	k	C (USI)	$RSI_{effective}$	$R_{effective}$	$R_{nominal}$
Units	mm	in	W/mK	W/m^2K	m^2K/W	$ft^2 \cdot °F \cdot h/BTU$	$ft^2 \cdot °F \cdot h/BTU$
Interior air film					0.11	0.61	
Concrete floor slab	254.00	10.00	1.60	6.30	0.16	0.90	
Fire-resistant spray insulation	152.40	6.00	-	-	4.23	24.00	24.00
Exterior air film					0.03	0.17	
TOTALS	**406.4**	**16.0**			**4.50**	**25.70**	**24.00**

F02: Embodied Carbon Emissions (A1 to A3 Life Stages) for 9m² Assembly Area

Category	Material	Description (from EPD)	Thickness	Material Volume	Carbon Emissions (A1-A3)	% of total
Units			mm	m^3	kgCO2e	%
Structure	Concrete Floor Slab	Ready-mix concrete, 35MPa GU cem. with air entr. 0-14% FA/SC (CRMCA)	254 (10")	2.29	1030.02	77.15%
	Interior gypsum board	Reinforcement steel (rebar), generic, 60% recycled content, A615	-	0.023	241.77	18.11%
Insulation	Spray foam insulation (PU)	Spray polyurethane foam insulation for closed cell, with HFO blowing agent, 0.022 W/mK, 32 kg/m3 average density, (Spray Polyurethane Foam Association (SPFA)	152.4 (6")	1.37	37.45	2.80%
Fire Proofing	Fire resistant Spray	Spray-applied fire-resistive material, medium density, 352 kg/m3 (22 pcf) (GCP Applied Technologies (2022))	50.8 (2")	0.46	25.92	1.94%
				TOTAL	**1335.16**	100.0%

**Software auto-calculates the impact based on the area provided.*

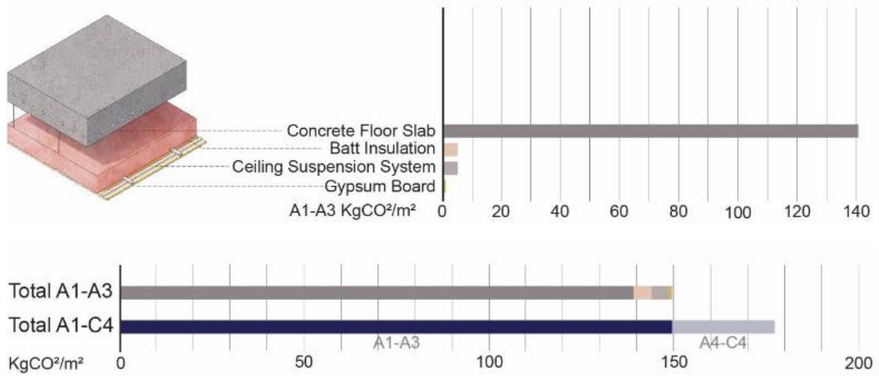
F02: Environmental Emissions (A1 to C4 Life Stages) for 9m² Assembly Area

Lifecycle Stage		**A1 to C4**	A1-A3	A4-A5	B1-B5	C1-C4	A1-A3 Contribution to total
Category	Units	**Total**	Materials	Construction	Refurbishment	Deconstruction	%
Global Warming	kg CO2e	**1,536.90**	1,335.16	135.76	0.00	65.98	86.87%
Acidification	kg SO	**6.37**	5.79	0.21	0.00	0.37	90.89%
Eutrophication	kg Ne	**1.93**	1.77	0.09	0.00	0.07	91.76%
Ozone Depletion	kg CFC11e	**0.00008**	0.000033	0.000031	0.00	0.00002	41.25%
Formation of Tropospheric Ozone	kg O3e	**110.48**	101.50	2.58	0.00	6.40	91.87%
Fossil Fuel Primary Energy	MJ	**11,741.34**	8,678.88	2,018.84	0.00	1,043.62	73.92%
Biogenic Carbon Storage	kg CO2e	**0**	0	0	0	0	

APPENDIX A **FLOOR ASSEMBLY 03**

F03: Results Summary

Metrics	Results
Description	**Parking Garage Insulated Dropped Ceiling (Heated Plenum)**
Effective R-value	RSI-4.6 m^2K/W | R-26.1 $ft^{2\cdot}°F\cdot h/BTU$
Embodied Carbon per m^2 of Enclosure (A1-A3)	149.8 $kgCO_2/m^2$
Biogenic Carbon per m^2 of Enclosure	0 $kgCO_2/m^2$



F03: Assembly Effective R-value Calculation

Description	t_{SI}	t_{IP}	k	C (USI)	$RSI_{effective}$	$R_{effective}$	$R_{nominal}$
Units	mm	in	W/mK	W/m^2K	m^2K/W	$ft^{2\cdot}°F\cdot h/BTU$	$ft^{2\cdot}°F\cdot h/BTU$
Interior air film					0.11	0.61	
Concrete floor slab	254.00	10.00	1.60	6.30	0.16	0.90	
Mineral fiber batt insulation	152.40	6.00	-	-	4.22	23.94	25.20
Metal ceiling tile suspension system	-	-	-	-	-	-	
Ceiling tile	12.70	0.50	0.16	-	0.08	0.45	
Exterior air film					0.03	0.17	
TOTALS	**419.1**	**16.50**			**4.60**	**26.10**	**25.20**

F03: Embodied Carbon Emissions (A1 to A3 Life Stages) for 9m² Assembly Area

Category	Material	Description (from EPD)	Thickness	Material Volume	Carbon Emissions (A1-A3)	% of total
Units			mm	m^3	kgCO2e	%
	Concrete Floor Slab	Ready-mix concrete, 35MPa GU cem. with air entr. 0-14% FA/SC (CRMCA)	254 (10")	2.29	1030.02	76.41%
Structure		Reinforcement steel (rebar), generic, 60% recycled content, A615	-	0.023	241.77	17.93%
Interior insulation	Batt Insulation	Mineral fiber batt insulation	152.4 (6")	1.37 m3	41.53	3.08%
Suspension system	Ceiling Tile Suspension System	Supraseal XL (Armstrong)	-	0.0041 m3	8.7	0.65%
Finish	Gypsum Board	Gypsum plaster board, regular, generic, 6.5-25 mm, 10.725 kg/m2 (for 12.5 mm), 858 kg/m3	12.7 (0.5")	0.114 m3	26.04	1.93%
				TOTAL	**1348.06**	100.0%

**Software auto-calculates the impact based on the area provided.*

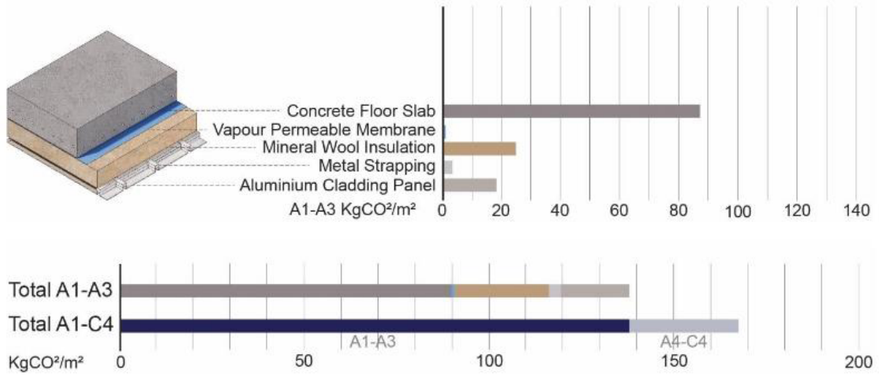
F03: Environmental Emissions (A1 to C4 Life Stages) for 9m² Assembly Area

Lifecycle Stage		**A1 to C4**	A1-A3	A4-A5	B1-B5	C1-C4	A1-A3 Contribution to total
Category	Units	**Total**	Construction Materials	Transport to Site & Construction	Material Replacement & Refurbishment	Deconstruction	%
Global Warming	kg CO2e	**1,593.13**	1,348.10	135.55	40.16	69.32	84.62%
Acidification	kg SO	**6.68**	6.03	0.21	0.18	0.26	90.32%
Eutrophication	kg Ne	**2.01**	1.84	0.09	0.01	0.063	91.63%
Ozone Depletion	kg CFC11e	**0.00008**	0.00003	0.000031	0.000002	0.000016	39.73%
Formation of Tropospheric Ozone	kg O3e	**108.84**	96.99	2.55	2.92	6.38	89.12%
Fossil Fuel Primary Energy	MJ	**540,188.81**	115,355.13	2,013.06	421,775.51	1045.11	21.35%
Biogenic Carbon Storage	kg CO2e	**0**	0	0	0	0	

APPENDIX A **FLOOR ASSEMBLY 04**

F04: Results Summary

Metrics	Results
Description	**Insulated Soffit with Mineral Wool**
Effective R-value	RSI-3.7 m^2K/W | R-21.1 $ft^2{\cdot}°F{\cdot}h/BTU$
Embodied Carbon per m^2 of Enclosure (A1-A3)	138.2 $kgCO_2/m^2$
Biogenic Carbon per m^2 of Enclosure	0 $kgCO_2/m^2$



F04: Assembly Effective R-value Calculation

Description	t_{SI}	t_{IP}	k	C (USI)	$RSI_{effective}$	$R_{effective}$	$R_{nominal}$
Units	mm	in	W/mK	W/m^2K	m^2K/W	$ft^2{\cdot}°F{\cdot}h/BTU$	$ft^2{\cdot}°F{\cdot}h/BTU$
Interior air film					0.11	0.61	
Concrete floor slab	254.00	10.00	1.60	6.30	0.16	0.90	
Self-adhered sheet-applied air barrier and WRB membrane (vapour permeable)	0.60	0.02	-	-	-	-	
Semi-rigid mineral fiber exterior insulation with intermittent proprietary fibreglass clips	152.40	6.00	0.03	0.22	3.41	19.35	25.80
Vertical or horizontal metal girts, air cavity	25.00	0.98	0.03	-	-	-	
Aluminum panel cladding	4.00	0.16	-	-	-	-	
Exterior air film					0.03	0.17	
TOTALS	**436.0**	**17.20**			**3.70**	**21.10**	**25.80**

F04: Embodied Carbon Emissions (A1 to A3 Life Stages) for 9m^2 Assembly Area

Category	Material	Description (from EPD)	Thickness	Material Volume	Carbon Emissions (A1-A3)	% of total
Units			mm	m^3	kgCO2e	%
Structure	Concrete Floor Slab	Ready-mix concrete, 35MPa GU cem. with air entr. 0-14% FA/SC (CRMCA)	254 (10")	2.29	1030.02	44.1%
		Reinforcement steel (rebar), generic, 60% recycled content, A615	-	0.023	241.77	19.5%
Exterior Membrane	Vapour permeable membrane	Latex-based membrane, vapor permeable, fluid-applied, fire resistant, 40 mils (1.016 mm), 1.17 lbs/gal (1.399 kg/L), Perm-A-Barrier® VPL (GCP Applied Technologies Inc., Corporate)	0.6 (0.024")	*	11	0.9%
Exterior Insulation	Exterior Insulation Mineral Wool	Heavy density mineral wool board, 1 m2K/W, 1.34 in (34 mm), 0.86 lb/ft2 (4.2 kg/m2), 7.71 lb/ft3 (123.52 kg/m3), Industry average US (NAIMA)	152.4 (6")	1.3716	240	19.4%
Metal strapping	1" metal z-girt strapping	Steel, structural, girts and purlins (NREL)	1.2 (0.047")	0.0018249	33	3%
Cladding	Aluminum Cladding Panel	Roll formed aluminum cladding, 4.91 kg/m2 (Metal Construction Association) (Generic)	4 (0.16")	0.036*	170	13.5%
				TOTAL	**1244.00**	

**Software auto-calculates the impact based on the area provided.*

F04: Environmental Emissions (A1 to C4 Life Stages) for 9m^2 Assembly Area

Lifecycle Stage		**A1 to C4**	A1-A3	A4-A5	B1-B5	C1-C4	A1-A3 Contribution to total
Category	Units	**Total**	Construction Materials	Transport to Site & Construction	Material Replacement & Refurbishment	Deconstruction	%
Global Warming	kg CO2e	**1504.957**	1239.78	134.34	56.06	74.777	82.38%
Acidification	kg SO	**8.28E-05**	4.27E-05	3.06E-05	2.70E-06	6.82E-06	51.56%
Eutrophication	kg Ne	**7.7165**	5.54	0.2159	0.1	1.8606	71.79%
Ozone Depletion	kg CFC11e	**2.140618**	1.9114	0.09299	0.094	0.042228	89.29%
Formation of Tropospheric Ozone	kg O3e	**92.373543**	87.57	2.58	1.56	0.663543	94.80%
Fossil Fuel Primary Energy	MJ	**7115.57**	4958.01	2000.28	81.63	75.65	69.68%
Biogenic Carbon Storage	kg CO2e	**0**					

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