# SUSTAINABILITY REPORT

## Life Cycle Assessment (LCA) background report for: SYMBIO™ Movable Walls System

**CONFIDENTIAL**


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# LIFE CYCLE ASSESSMENT (LCA) BACKGROUND REPORT FOR SYMBIO™ MOVABLE WALLS SYSTEM

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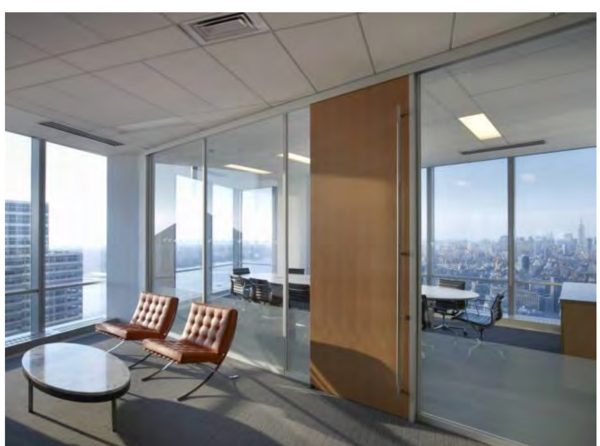
# Summary Information

| | |
|---|---|
| **Owner of the study** | Environamics Incorporated |
| **Practitioner of LCA (External)** | Intertek |
| **Purpose of the report** | Providing background LCA information on an Environmental Product Declaration |
| **Product system** | Symbio™ movable wall panels produced at the Environamics production facilities in Charlotte, North Carolina and Farmers Branch, Texas from cradle to grave |
| **Functional Unit** | 1m$^2$ of workspace (panels for division of space - no attached worksurface or storage) maintained for a 10-year period, including packaging materials used for the final assembled product. |
| **Underlying PCR** | BIFMA PCR for Office Furniture Workspace Products UNCPC 3814 |
| **Underlaying Standard(s)** | ISO 14040:2006/AMD 1:2020 and ISO 14044:2006+A1+A2:2020 |
| **Reference year** | 1st August 2019 – 31st July 2020 |
| **Date of study** | 2022-05-10 |



ENVIRONAMICS

# Life Cycle Assessment (LCA) background report for Symbio™ movable wall system

## 1.0 INTRODUCTION

Environamics Incorporated (hereinafter referred to as 'Environamics') is an interior specialty contracting company that fabricates and installs a floor to ceiling movable wall system, Symbio™. Environamics was founded in 1980, with manufacturing facilities in Charlotte, North Carolina and Farmers Branch, Texas. Environamics is interested in better understanding the environmental profile and impacts of their products. To this end, Environamics have commissioned Intertek (hereinafter referred to as 'Intertek') to undertake a Life Cycle Assessment (LCA) upon which an Environmental Product Declaration (EPD) can be generated for the Symbio™ movable wall system.

Life cycle assessment is a decision support tool that allows quantitative environmental profiles to be generated for different products systems. Environmental product declarations (EPD) and associated product category rules (PCR) allow LCAs of similar products to be carried out using a consistent approach with the aim of communication to interested stakeholders. This study has been performed in accordance with the requirements given in ISO 14025 for Type III EPD and the **BIFMA PCR for office furniture workspace products**. The methodology of this study is also underpinned by the international standards for LCA: ISO 14040:2006/AMD 1:2020 and ISO 14044:2006+A1+A2:2020.

This LCA background report is a comprehensive summary of the study carried out by Intertek and is not part of the public communication (i.e., the EPD). Rather, it is intended to present background documentation for Environamics internally and for the independent verification of the EPD generated from the study. In addition to a public communication document, the EPD can be viewed as an executive summary of this background LCA report.

The following LCA practitioners from Intertek were involved in this project:

- **Vijay Thakur –** Vijay is an LCA professional with 5+ years of experience. He has worked for various clients including Steel, Textile, Petrochemical products, automotive components, special steel products and others.

## 1.1. Introduction to Life Cycle Assessment

Life cycle assessment is a method of systematically assessing the environmental burdens associated with a product, process, or activity over the whole of its life cycle. The international standard for life cycle assessment, ISO 14040, states that:

> *'LCA addresses the environmental aspects and potential environmental impacts (e.g., use of resources and the environmental consequences of releases) throughout a product's life cycle from raw material acquisition through production, use, end-of-life treatment, recycling and final disposal (i.e. cradle-to-grave)'* (ISO, 2006b).

**Figure 1** below illustrates the life cycle system concept of natural resources and energy entering the system and product, emissions and waste leaving the system.

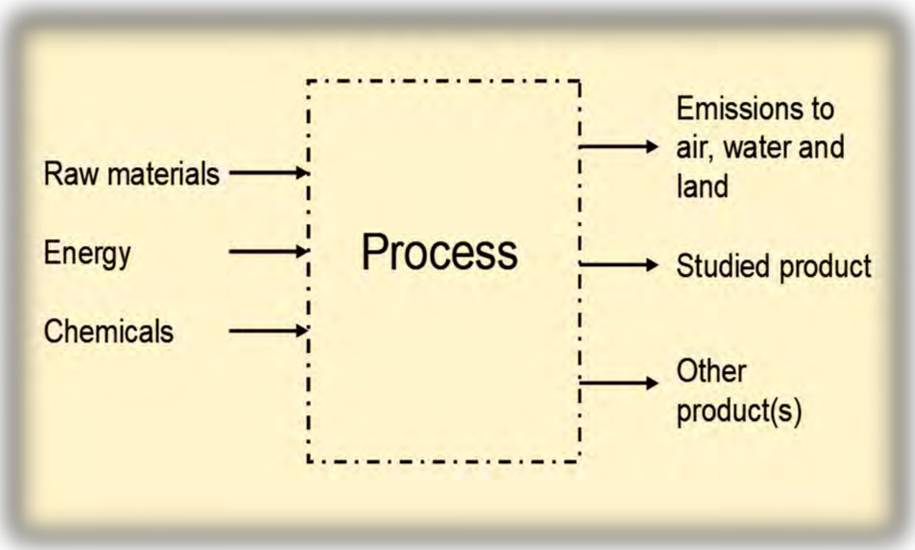



**Figure 1: Typical categories of data collected to describe processes in LCA terms**

Companies undertake an LCA to understand the environmental performance of their product for a variety of reasons including legislative pressures and supply chain issues. Another reason is the increasing number of environmentally conscious customers who are demanding products that combine the benefits of good functionality and low cost with high environmental performance. While LCA is a valuable tool, it should be emphasized that it is one of many factors, such as costs, consumer acceptance and production feasibility, which companies must consider during the decision-making process.

The technical framework for a life cycle assessment consists of four inter-related stages: goal and scope definition, inventory analysis, impact assessment and interpretation as shown in **Figure 2**. These four stages are used as a basis of the structure for this background LCA report. The whole process is usually iterative, with feedback loops between the interpretation and all other stages of the LCA, as was the case in this study.

The ISO standards set out the requirements associated with each stage.

The **goal and scope** definition involves identifying the purpose of the study and the systems to be studied, including setting the system boundaries and determining the level of detail included.

In the **inventory analysis** all materials, substances and energy used, and all emissions and waste released to the environment are identified and quantified over the whole life cycle of the product (from raw material extraction and processing, through manufacture, use and end of life).

The **impact assessment** is a technical, quantitative method used to assess the environmental significance of the inputs and outputs identified in the inventory analysis. The impacts considered can be divided into subject areas such as resource use, human health, and ecological consequences.

In the **interpretation** stage, results are analyzed, limitations explained, conclusions are made, and recommendations are provided.

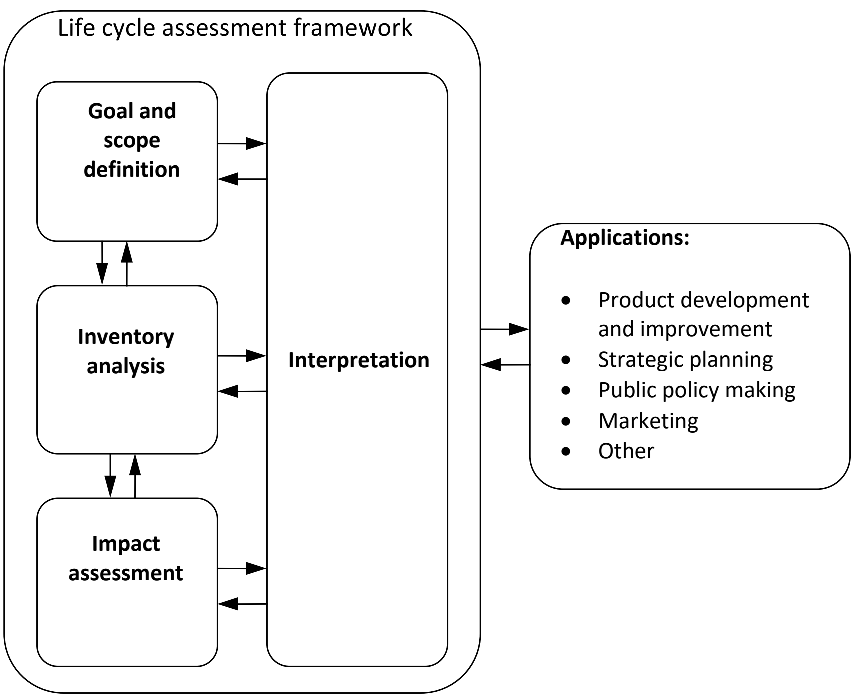



**Figure 2: Stages of an LCA (ISO, 2006b)**

# 2.0 GOAL AND SCOPE

The following sections describe the goal and scope of this assessment. This includes, but is not limited to, the objectives and intended application of the study, the EPD program operator information, identification of the specific product systems to be assessed, the product reference unit, the system boundaries and cut-off criteria of the study.

## 2.1 Goal of the study

The purpose of environmental profile declarations (EPD) is to provide quantitative environmental figures on products and resources for market information, environmental optimization and as part of a company's corporate responsibility program. An LCA assessment delivers an increased understanding of the sources of pollution and facilitates priority setting for sustainable business practices.

The main **objectives** of this LCA study were:

- Create an EPD that complies to internationally harmonized standards
- Communicates reliable and accurate quantitative environmental data to users downstream within the building supply chain.

The intended **applications** are:

- Identify significant contributions to the environmental impacts ("hotspots") across the product lifecycle.
- Identify possible improvement areas of the studied system that would be of interest for further analyses.

The outcomes of this study will be used for primarily for business-to-business communication. The intended audiences are a wide range of external and internal stakeholders, including customers, investors, process engineers, research and development scientists, and marketing teams.

The PCR from which this study and resulting EPD is based on was written to determine the potential environmental impacts of a furniture workspace product from cradle-to-grave. It was not written to support comparative assertions. EPDs based on different PCRs, or different calculation models, may not be comparable. When attempting to compare EPDs or life cycle impacts of products from different companies, the user should be aware of the uncertainty in the final results, due to and not limited to, the practitioner's assumptions, the source of the data used in the study, and the specifics of the product modeled.

## 2.2 EPD program operator details

The output of this LCA will be a Type III EPD that will be made public via the NSF Certification EPD program. The details of the program operator are provided in **Table 1**.

This report is to be verified by a qualified independent verifier experience in life cycle assessment.

**Table 1: EPD program operator details**

| |
|---|
| The NSF Certification EPD Program<br><br>NSF Certification, LLC<br>PO Box 130140,<br>Ann Arbor,<br>Michigan 48113-0140,<br>USA<br><br>http://info.nsf.org/Certified/Sustain/epd_search.asp |
| Product category rules (PCR): BIFMA PCR for Office Furniture Workspace Products UNCPC 3814 |
| PCR review was conducted by: Review Panel; Chaired by Dr. Thomas Gloria |
| Independent third-party verification of the declaration and data, according to ISO 14025:2006:<br><br>☐ EPD process certification ☒ EPD verification |
| Third party verifier: xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx |
| Procedure for follow-up of data during EPD validity involves third party verifier:<br><br>☐ Yes ☒ No |

## 2.3 Reference Unit

The reference unit is a key element of LCA which must be clearly defined. The reference unit can be presented in two ways: either as a functional unit or as a declared unit. A functional unit is a product unit that fulfils a specific function, e.g., a window, concrete beam, staircase, etc. A declared unit is a product unit that can fulfil multiple functions, e.g., a cubic meter of concrete, a square meter of wall paneling. The declared unit is used instead of the functional unit when the precise function of the product or scenarios at the building level, is not stated or is unknown.

In this assessment the cradle to grave life cycle of the product is covered and quantified and the **functional unit** for the study is defined based on “BIFMA PCR for office furniture workspace products” as:

- $1m^2$ of workspace (panels for division of space - no attached worksurface or storage) maintained for a 10-year period, including packaging materials used for the final assembled product.

There is no set figure for occupancy for the workspace as this is variable and therefore the occupancy has not been stated.

The representative configuration that was selected for this study is the SymbioTM Moveable Wall system using 9ft. aluminum framed panels that are typically supplied to customers office configuration projects and match the approximate percentage of panel types that the factory outputs annually. The panels will enclose a 9.92 $m^2$ area and consist of 6 hard panel units for 3 walls, 2 glass panels and 1 door frame with aluminum/glass door for the office 'front', and 4 corner connectors.

The details of the reference flow for the representative system are provided in the table below.

**Table 2: Reference flow details for the representative system (9ft. aluminum framed panels)**

| Flow | Item | Value |
|---|---|---|
| Reference system | Floorspace enclosed by walling system | 9.92 $m^2$ |
| | Total area of walls required to enclose a floor area of 9.92$m^2$ | 37.16$m^2$ |
| | Mass of materials required to enclose a floor area of 9.29$m^2$ | 839.4 kg (1848.9 lbs) |
| Normalized to functional unit | Workspace (floorspace) | 1$m^2$ |
| | Total area of walls required to enclose a floor area of 1$m^2$ | 3.75 $m^2$ (37.16 / 9.92) |
| | Mass of materials required to enclose a floor area of 1$m^2$ | 84.6 kg (839.2 / 9.92) |

The Symbio movable walling systems have a 12-year warranty period and have the self-certification & meet the requirements as specified in ANSI/BIFMA X5.5 & 5.6; therefore one reference unit is required to fulfil the functional unit.

## 2.4 Product description

Environamics is an interior specialty contracting company that fabricates and installs a floor to ceiling movable wall system, SymbioTM. They operate two manufacturing facilities in Charlotte, North Carolina and Farmers Branch, Texas. For further information see https: www.environamics-inc.com.

The Symbio Movable Wall System consist of Top and Bottom Track mounted 2-1/4" (57mm) wide modular aluminum framed architectural panels with a nearly unlimited finish design potential. The panels can be 'hard surface', (painted MDF, wood veneer, etc.) or 'glass panel' (1/4", 3/8" or ½" clear tempered, laminated or patterned). Additionally, each individual panel can consist of multiple hard surface or glass 'sections' separated by mullions. A full range of Sliding and Swing Doors are also offered with the same finish potential as the panels.

The product composition for the representative walling systems is provided in **Table 3a**. The aluminum used for the systems contains 33.9% recycled material, while the steel contains 25% recycled material. The systems contain 0% bio-based material and does not contain any substances hazardous to health or the environment (in particular, carcinogenic, mutagenic, toxic to reproduction, allergic, PBT5 or vPvB6 substances). No substances that are listed in the “Candidate List of Substances of very high concern for authorization” are contained in the curtain wall systems.

The movable wall system is packaged using crating wood, plastic wrap, cardboard and furniture drape prior to shipping to installation sites (**Table 3b**).

The wall systems are not expected to create exposure conditions that exceed safe thresholds for health impacts to humans or flora/fauna under normal operating conditions.

The CSI Specification for the Symbio moveable walls is provided within **Appendix A**.

**Table 3a: Product composition of walling system (materials required to enclose floor area of 9.92m$^2$)**

| Material | Contribution (%) | Recycled content (%) |
|---|---|---|
| Aluminum | 20.2% | 33.9% |
| Steel | 0.4% | 25% |
| Wood (MDF) | 58.4% | 0% |
| Glass | 19.5% | 0% |
| Vinyl | 1.5% | 0% |

**Table 3b: Packaging requirements for walling system (materials required to enclose floor area of 9.92m$^2$)**

| Material | Contribution (%) | Recycled content (%) |
|---|---|---|
| Packaging Film | 1-3% | 0% |
| Wood | 29-30% | 0% |
| OSB | 25-32% | 0% |
| Cardboard | 5-9% | 10% |
| Tape | 0.1% | 0% |
| Furniture Drape | 31-34% | 0% |

Two additional product combinations were evaluated based on environment footprint performance i.e., highest footprint & lowest footprint options. The product composition of walling system (materials required to enclose floor area of 9.92m2) for these two combinations are listed below –

**Table 3c: Product composition of walling system (materials required to enclose floor area of 9.92m$^2$) for highest & lowest environment footprint performance, compared with representative product**

| Material | Representative product | Lowest environment Footprint performance option (Glass) | Highest environment Footprint performance option (MDF) |
|---|---|---|---|
| Aluminum | 20.2% | 26% | 19% |
| Steel | 0.4% | 1% | 0% |
| Wood (MDF) | 58.4% | 0% | 75% |
| Glass | 19.5% | 73% | 0% |
| Vinyl | 1.5% | 0% | 5% |

These compositions were calculated using specific data collected for these three options, inventory data for representative product is shown in section 3.4.1. Inventory data for additional two scenarios is shown below –

**Table 3d: Product composition of walling system (materials required to enclose floor area of 9.92m$^2$) for highest & lowest environment footprint performance (in lbs. & kg)**

| Material | Lowest environment footprint option (Glass option) | | Highest environment footprint option (MDF option) | |
|---|---|---|---|---|
| | Lbs. | Kg | Lbs. | kg |
| Aluminum | 374.20 | 169.90 | 374.20 | 169.90 |
| Steel | 7.90 | 3.60 | 7.90 | 3.60 |
| Wood (MDF) | | | 1440 | 653.17 |
| Glass | 1051.60 | 477.00 | | |
| Vinyl | | | 100.4 | 45.54 |

*** It is assumed that mass of aluminum & steel remains same in all the product combinations, as they are used as support structures in frame, corners, and door handles etc.**

## 2.5 Process description

Raw materials, aluminum extrusions, MDF Board, and vinyl wall coverings, etc. are received at the production site and stored in the warehouse prior to going to the production floor. Per production orders, aluminum extrusions are cut to length, machined where necessary and fabricated into frames for panels and doors. MDF board is cut to size, fabric or vinyl covered where required and assembled into the aluminum frames.

In the case of glass panels and doors, the panes are purchased pre-cut and edge finished from local glass manufacturers, received in the warehouse then assembled into the corresponding frame for that individual panel or door. Finished panels and doors are wrapped with furniture drape for protection and stacked horizontally 3-4 ft. heigh on custom built pallets. The panels are fully enclosed with OSB wood for storage in the warehouse or immediate shipping to the jobsite. **Figure 3** provides the process flow for this system.

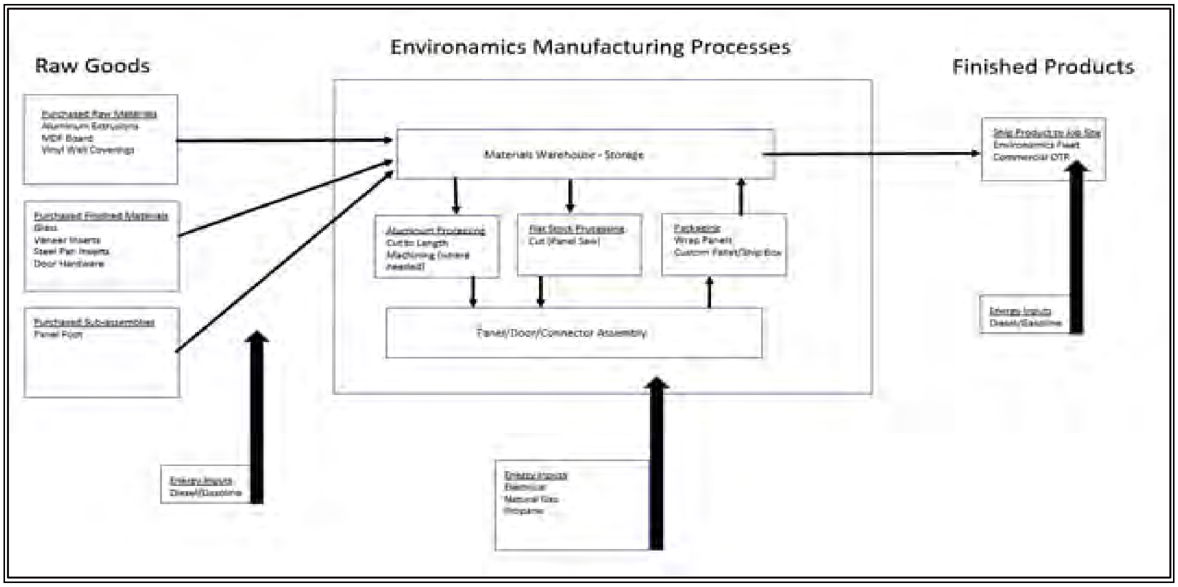



**Figure 3: Process flow diagram**

## 2.6 System boundary description

The system boundary of a product system determines the unit processes to be included in the LCA study and which data as inputs and/or outputs to/from the system can be omitted. In this LCA study the system boundary was defined as cradle-to-grave (**Figure 4**), which comprised extraction of raw materials, transportation of raw materials to manufacturing plant and the manufacturing of the product itself.

| Upstream (cradle-to-gate) | | Core (gate-to-gate) | Downstream (gate-to-grave) | | |
|---|---|---|---|---|---|
| Material acquisition and pre-processing | | Production | Distribution, use and end-of-life | | |
| Raw material supply | Transport | Manufacturing | Distribution and storage | Use | End-of-life (Disposal) |
| ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |

**Figure 4: System boundary**

The “Polluter Pays” principle has been assigned in this LCA to the product system that generates the waste until the end-of-waste stage has been reached. The end-of-waste state is determined by the economic cut-off method. This means that the environmental impacts of processes that cause costs for the initial product, like waste processing, are allocated to the initial product’s life cycle. When processes raise the value of materials, which is for example the case in certain recycling processes, the environmental impact of the recycling process is allocated to the life cycle of the reclaimed materials.

The modularity principles (as illustrated in the above system diagram, **Figure 4**) have been followed.

## 1. Material acquisition and pre-processing

This stage starts when the material is extracted from nature and ends when the material in component form reaches the gate of the production facility or services delivery operation. Materials and the related processing can be considered ‘primary’ of ‘secondary’.

- Primary materials are extracted from nature, examples include the iron ore and bauxite that are used to create basic materials used in the production of office furniture (e.g., steel, aluminum).
- Secondary materials are recovered, reclaimed, or recycled content that are used to create basic materials to be used in the production of office furniture (e.g. the recycled content in the aluminum and steel).
- Primary processing is the conversion of materials to a bulk form or a generic shape (materials or components that are not necessarily manufactured exclusively for the office furniture industry).
- Intermediate processing is the conversion of materials to components (e.g., steel coil, etc.).

Waste and scrap created during raw material acquisition and pre-processing, and emissions associated with transporting the material to recycling or landfill centers are accounted for using secondary data (**Section 3.5**).

Transportation prior to the material being shipped to the production stage has been included using secondary data (**Section 3.5**). Transport from the raw material stage to the production stage is included using primary data provided by the client.

## 2. Production

The production stage starts with the product components entering the production site and ends with the final product leaving the production gate. This stage is can also be termed “gate-to-gate”.

Gate-to-gate describes the product boundary encompassing the fabrication and assembly of the walling system. The walling system is manufactured fully at two sites, there is no transportation of semi-finished products between the sites. The production stage includes the following processes:

- Production of the finished product, including forming and machining.
- Materials used in packaging of the final product (including transportation of packaging materials).
- Transportation and disposal or recycling of waste created during the production.

Primary data has been used for transport distances of packaging materials (**Section 3.3.2**). No catalysts or other ancillary materials are used during production.

**3. Distribution, storage and use**

- Typical processes for distribution and use include:
- Transportation to the use location and during use;
- Storage at the use location, including disposal of packaging materials;
- Normal use;
- Repair and maintenance occurring during the usage time; and
- Assembly and installation of a product.

This module includes distribution to the customer, storage and assembly at the use location, disposal of packaging waste, use of the product, and repair and maintenance during the use of the product (10 years).

Transportation mode and distances to the use location are based on primary data (**Section 3.3.3**). Disposal routes for packaging materials have been based on secondary data (**Section 3.3.3**). No storage or use impacts have been included within this module as the walling system does not require energy or generate emissions during its storage or use. Furthermore, no repair or maintenance are required during the usage time as the product has a warranty period of twelve years. Energy required for the assembly and installation of the product is insignificant and is excluded from the study.

**4. End-of-life**

The end-of-life stage boundary begins when the used product is ready for disposal, recycling, reuse, etc. and ends when the product is landfilled, returned to nature, or transformed to be recycled or reused. Processes that occur as a result of the disposal are also included within the end-of-life stage. End-of-life processes include:

- Collection of end-of-life products;
- Incineration and sorting of bottom ash; and
- Landfilling, landfill maintenance, decomposition emissions

Primary data on the actual end of life treatment for the product was not available and, in its absence, the most current version of the USEPA Municipal Solid Waste (MSW9) data (2018) has been used to determine the percent of each material in the product that can be recycled versus landfilled (**Section 3.3.4).**

Transportation of materials to either recycling site or final disposal location have been included.

Quantitative and qualitative specific and generic data were collected for each flow, for all unit processes within the system boundary of the product system (apart from exclusions described in **Section 2.8**) and these data were used to compile the life cycle inventory (LCI). All LCI data used to model this product system are fully described and referenced in **Section 3**.

## 2.7 Cut-off Criteria

In the process of building an LCI it is typical to exclude items considered to have a negligible (aka relatively inconsequential or immaterial) contribution to results. To do this in a consistent and robust manner there must be confidence that the exclusion is fair and reasonable. To this end, cut-off criteria were defined in this study, which allow items to be neglected if they meet the criteria. In accordance with the PCR, exclusions could be made if they were expected to be within the below criteria and are deemed to be less than 1%, and the cumulative omitted mass or energy flows do not exceed 5%.

- **Mass**: when using mass as a cut-off criterion, it is appropriate to require the inclusion in the study of all inputs that cumulatively contribute more than a defined percentage to the mass input of the product system being modeled.

- **Energy**: similarly, an appropriate decision, when using energy as a criterion, is to require the inclusion in the study of those inputs that cumulatively contribute more than a defined percentage of the product system's energy inputs.

- **Environmental significance**: decisions on cut-off criteria should be made to include inputs that contribute more than an additional defined amount of the estimated quantity of individual data of the product system that are specially selected because of environmental relevance.

All the raw materials and energy inputs were modeled using processes and flows that closely follow actual production raw materials and processes. All the material and energy flows have been accounted. The only exclusion that has been made from the study is the energy required for the assembly and installation of the product as this is completed primarily by hand machines and is therefore deemed insignificant. All energy required for the manufacture of the product has been included.

The following general exclusions from the scope of the study were made:

- Human and animal energy inputs to processes;
- Production and disposal of infrastructure (machines, transport vehicles, roads, etc.) and their maintenance;
- Transport of employees to and from their normal place of work and business travel; and
- Environmental impacts associated with support functions (e.g., R&D, marketing, finance, management etc.).

# 3.0 Life Cycle Inventory Analysis

The life cycle inventory (LCI) analysis is defined by ISO as the 'phase of life cycle assessment involving the compilation and quantification of inputs and outputs for a product throughout its life cycle'. This section includes, but is not limited to, the data collection procedure, quantification of all relevant environmental impacts (inputs and outputs) of the product system, allocation methods, description of the background processes and databases and data validation.

## 3.1. Data Collection Procedure

Quantitative and qualitative data were collected for all processes within the system boundary (apart from exclusions described in **Section 2.8**) and these data were used to compile the LCI. Three categories of data are used in LCA:

1) Specific data (primary data)
2) Selected generic data (secondary data)
3) Proxy data (secondary data)

To explain the distinction between these categories, specific data directly refer to the product under investigation, for example the amount of electricity used by Environamics to manufacture the wall system.

Selected generic data do not directly refer to the product under investigation but refer to a similar process and fulfil the data quality criteria defined for the study (**Section 3.6**). Proxy data do not directly refer to the product under investigation and do not fulfil the data quality criteria defined for the study; they are therefore used only as a last resort in the absence of selected generic data.

Specific data were sought as a preference; however, they could not be collected for upstream and downstream lifecycle stages. Specific data for all core processes were collected from Environamics to produce the movable wall system using data collection sheets via an iterative process and represent a period of twelve months from 2019.08.01 to 2020.07.31. All specific data used in this study are described in **Section 3.4**.

Selected generic data were collected for the upstream lifecycle stages from the Ecoinvent v3.6 [cut-off] LCI database. All data sources are described in **Section 3.5**.

Note that no energy values were calculated from volumes or masses of fuels by the LCA practitioners as they were provided in units of energy, however, volume and mass to energy unit conversions have been carried out in the Ecoinvent v3.6 (cut-off) database and for this the lower heating value was used throughout.

## 3.2. Units and quantities

In this LCA background report the follow conventions were used for unit and quantities:

- The international System of Units (SI units) where used throughout, using reasonable multiples of SI units where impropriate, to improve readability;
- Three significant figures were adopted for all results;
- Thousand separators and the decimal mark follows the English version SI style i.e., 1,000.00;
- Dates and times following ISO 8601 i.e., YYYY-MM-DD

## 3.3 Allocation

Both the Charlotte and Farmers Branch manufacturing facilities produce a variety of movable walling system configurations. To determine the flow of materials and energy and the associated release of substances related exclusively to the representative configuration modeled for this study, allocation of the total plant primary data was performed based on $m^2$ of walling system produced (**Section 3.3.2**). All allocation was performed according to the basic rules from ISO 14044. No co-products were produced at either site.

In terms of generic data, the main database used, Ecoinvent v3.6 (cut-off), defaults to an economic allocation for most processes. However, in some cases a mass-based allocation is used, where there is a direct physical relationship. The allocation approach of specific Ecoinvent modules is documented on their website and method reports (see www.Ecoinvent.org).

In the case of end-of-life allocation of generic data, the Ecoinvent v3.6 with a cut-off by classification end-of-life allocation method was used. In this approach, environmental burdens and benefits of recycled/reused materials are given to the product system consuming them, rather than the system providing them, and are quantified based on recycling content of the material under investigation. This is a common approach in LCA for materials where there is a loss in inherent properties during recycling, the supply of recycled material exceeds demand and recycled content of the product is independent of whether it is recycled downstream. It follows the ISO standards on LCA.

## 3.4 Quantification of data

In this section the quantity and allocation of various material, energy streams and emissions by processes and products are outline. The system boundaries that have been adopted are in accordance with the modular approach described in **Section 2.7**.

### 3.4.1 Material acquisition and pre-processing

**Raw Materials**

The specific data collected from Environamics for the representative walling system is described in **Table 4a**. The raw material usage at both the Charlotte and Farmers Branch sites for the representative walling system are identical.

**Table 4a: Raw materials for the representative configuration required for the reference unit (37.16m$^2$ of wall area enclosing a floor area of 9.92m$^2$).**

| Material | Item | Quantification for Reference Unit (37.16m$^2$ of wall area enclosing a floor area of 9.92m$^2$) | |
|---|---|---|---|
| | | lbs | kg[1] |
| Aluminum | Modular Receiver 9' | 59.9 | 27.2 |
| | Flat Backup 9' | 0.8 | 0.4 |
| | Octogon 9' | 14.4 | 6.5 |
| | M-Panel Yoke x 10' | 64.9 | 29.5 |
| | Door Rail 2-1/8", 10' | 5.7 | 2.6 |
| | Ceiling Runner x 10' | 21.8 | 9.9 |
| | NoBase Floor Runner (3/4" Runner Cap)x 9' | 15.6 | 7.1 |
| | Full Height Header x 10 | 0.1 | 0.1 |
| | Doorjamb x 10' | 11.1 | 5.1 |
| | Glazed panel STILE x 10' | 80.6 | 36.6 |
| | Glazed panel RAIL x 12' | 67.4 | 30.6 |
| | Door Glass Stop x 12' | 5.7 | 2.6 |
| | Door Stile 2-1/8" Beveled | 16.8 | 7.6 |

[1] A factor 0.454 of has been used to convert weights from pounds to kilograms.

| Material | Item | Quantification for Reference Unit (37.16m² of wall area enclosing a floor area of 9.92m²) | |
|---|---|---|---|
| | | lbs | kg[1] |
| | Door Corner Mount x 12' | 2.1 | 0.9 |
| | Panel Foot Saddle | 6.9 | 3.2 |
| | Alum."B" Clip (each) | 0.3 | 0.1 |
| | ***Total Aluminum*** | ***374.2*** | ***169.9*** |
| Steel | "U" Clip (each) | 0.14 | 0.06 |
| | DOORFRAME CLIP (each) | 0.14 | 0.06 |
| | Hinge Rein. Plate (RAS Ind.) | 4.4 | 2.00 |
| | Flat .030 Step Mtg. Plate | 0.05 | 0.02 |
| | 5 3/4'' Bolts for Panel Foot | 3.2 | 1.45 |
| | ***Total Steel*** | ***7.9*** | **3.6** |
| Wood (MDF) | 1/2" MDF 4 x 10 | 1080 | 490.3 |
| | **Total Wood** | **1080** | **490.3** |
| Glass | GR 1/4"Clear Glass 116Ht x 59Wd | 278.0 | 126 |
| | Dr. Glass 31-36'', GR 1/4"Clear | 81.7 | 37.1 |
| | ***Total Glass*** | ***359.6*** | ***163.3*** |
| Vinyl | Hinge Mute – LF | 0.3 | 0.114 |
| | Strike Mute | 0.4 | 0.159 |
| | LF Small Bulb | 1.2 | 0.545 |
| | 1/4''Glazing Channel-Clear x 10' | 1.5 | 0.681 |
| | Polyfoam Tape 1/8x1/2 – LF | 1.4 | 0.654 |
| | MP Clips (5/UNIT) | 4.8 | 2.179 |
| | M-Wall Visual Seal LF | 17.6 | 7.990 |
| | ***Total Vinyl*** | ***27.1*** | ***12.3*** |
| | ***Total*** | ***1848.9*** | ***839.4*** |

Uplift factors have been applied to the following raw materials to account for the production losses, i.e., for example, loss of material when aluminum is cut to length.

- Aluminum – 6%
- Wood – 5%
- Glass - 1%
- Vinyl - 1%

Two additional product combinations were evaluated based on environmental footprint performance i.e., highest environment footprint & lowest environment footprint options. The product composition of walling system (materials required to enclose floor area of 9.92m2) for these two combinations are listed below in Table 4b –

**Table 4b: Product composition of walling system (materials required to enclose floor area of 9.92m$^2$) for highest & lowest environmental footprint performance (in lbs. & kg)**

| Material | Lowest environment footprint option (Glass) | | Highest environment footprint option (MDF) | |
|---|---|---|---|---|
| | Lbs. | Kg | Lbs. | kg |
| Aluminum | 374.20 | 169.90 | 374.20 | 169.90 |
| Steel | 7.90 | 3.60 | 7.90 | 3.60 |
| Wood (MDF) | 0 | 0 | 1440 | 653.17 |
| Glass | 1051.60 | 477.00 | 0 | 0 |
| Vinyl | 0 | 0 | 100.4 | 45.54 |

*** It is assumed that mass of aluminum & steel remains same in all the product combinations, as they are used as support structures in frame, corners, and door handles etc.**

**Transport of raw materials**

**Table 4c: Transport distances for raw materials**

| Raw material | Charlotte | | Farmers Branch | |
|---|---|---|---|---|
| | Distance (km) | Mode | Distance (km) | Mode |
| Aluminum | 1678 | Road | 6 | Road |
| Vinyl & Tape | 389 | Road | 5 | Road |
| Glass | 21 | Road | 24 | Road |
| Steel | 19 | Road | 26 | Road |
| Wood (MDF) | 15 | Road | 16 | Road |

### 3.4.2 Production

The Charlotte and the Farmers Branch production facilities manufacture walling systems to a variety of configurations. To correctly apportion the inventory values from total plant data to the representative configuration, an allocation based on area has been applied to the primary data (**Table 5a**). An area allocation is deemed appropriate as the production processes are the same for all walling systems and production output is recorded in area.

Furthermore, to assign the correct quantities required for the reference unit (37.16m$^2$ of walling) the values determined for the total production of the representative configuration have been calculated per m$^2$ then multiplied up for 37.16m$^2$ (**Table 5b / 5c**).

**Table 5a: Area based allocation factors**

| Site | Total Site Output (m$^2$) | Representative System (9ft Height Glass Wall) | |
|---|---|---|---|
| | | Output (m$^2$) | Percentage (%) |
| Charlotte | 13,552 | 4,156 | 30.7% |
| Farmers Branch | 5,414 | 1,350 | 24.9% |

**Table 5b**: **Resource and packaging requirements at Charlotte Site**

| Resource | Item | Total plant data | Quantity allocated to representative system (30.7% of total plant data) | Quantity per m$^2$ of representative walling system | Quantity per reference unit (37.16m$^2$ of representative walling unit) |
|---|---|---|---|---|---|
| Energy | **Electricity** | 146,556 kWh | 44,944 kWh | 10.81 kWh | 402 kWh |
| | **Natural gas** | 7,623 MJ | 2,338 MJ | 0.56 MJ | 20.9 MJ |
| | **Propane** | 73,553.22 MJ | 22,556 MJ | 5.43 MJ | 201.69 MJ |
| Waste | **Recycled waste**[2] | 19,000 kg | 5,827 kg | 1.4 kg | 52 kg (of which 36kg is production related) |
| | **General plant waste (solid waste**[3]**)** | 92,372 kg | 28,328 kg | 6.82 | 253.30 kg |
| Packaging | **Stretch film** | 321 kg | 98 kg | 0.024 kg | 0.88 kg |
| | **Yellow pine** | 8240 kg | 2526 kg | 0.608 kg | 22.59 kg |
| | **Spruce** | 5813 kg | 1783 kg | 0.429 kg | 15.9 kg |
| | **OSB** | 14014 kg | 4298 kg | 1.034kg | 38.4 kg |
| | **Corner guard** | 578 kg | 177 kg | 0.043 kg | 1.6 kg |
| | **Corrugated box** | 132 kg | 40 kg | 0.010 kg | 0.3 kg |

[2] Distance recycled waste transported from Charlotte site is 3.3 km
[3] Distance solid waste is transported to final disposal from Charlotte site is 4.3 km

| Resource | Item | Total plant data | Quantity allocated to representative system (30.7% of total plant data) | Quantity per m² of representative walling system | Quantity per reference unit (37.16m² of representative walling unit) |
|---|---|---|---|---|---|
| | Corrugated sheet | 1393 kg | 427 kg | 0.103 kg | 3.8 kg |
| | Corrugated pad | 2890 kg | 886 kg | 0.213 kg | 7.9 kg |
| | Strapping tape | 18 kg | 6 kg | 0.001 kg | 0.05 kg |
| | Masking tape | 19 kg | 6 kg | 0.001 kg | 0.05 kg |
| | Clear packing dape | 1 kg | 0.28 kg | 0.00007 kg | 0.002 kg |
| | 6" PolyTube | 1075 kg | 330 kg | 0.079 kg | 2.9 kg |
| | 48" Furniture drape | 16286 kg | 4994kg | 1.20 kg | 44.7 kg |
| | 60" Furniture drape | 2341 kg | 718 kg | 0.173 kg | 6.4 kg |
| | Vis-Queen | 73 kg | 22 kg | 0.005 kg | 0.2 kg |

**Table 5c: Resource and packaging requirements at Farmers Branch Site**

| Resource | Item | Total plant data | Quantity allocated to representative system (24.9% of total plant data) | Quantity per m² of representative walling system | Quantity per reference unit (37.16m² of representative walling unit) |
|---|---|---|---|---|---|
| Energy | Electricity | 42,514 kWh | 10,601 kWh | 7.85 kWh | 292 kWh |
| | Natural gas | 8,677 MJ | 1,302 MJ | 1.6 MJ | 59.6 MJ |
| | Propane | 13501 MJ | 4,141 MJ | 2.49 MJ | 92.67 MJ |
| Waste | Recycled waste)[4] | 13,696 kg | 3,415 kg | 2.5 kg | 94kg (of which 36 kg is production related) |
| | General plant waste (solid waste[5] | 65,580 kg | 16,352 kg | 12.11 kg | 450.12 kg |

[4] Distance recycled waste is transported from the Farmers Branch site is 30.4 km
[5] Distance solid waste transported to final disposal from the Farmers Branch site is 19 km

| Resource | Item | Total plant data | Quantity allocated to representative system (24.9% of total plant data) | Quantity per $m^2$ of representative walling system | Quantity per reference unit ($37.16m^2$ of representative walling unit) |
|---|---|---|---|---|---|
| **Packaging** | **Stretch film** | 92 kg | 22.8 kg | 0.017 kg | 0.63 kg |
| | **Yellow pine** | 5898 kg | 1471 kg | 1.089 kg | 40.48 kg |
| | **Spruce** | 4196 kg | 1046 kg | 0.775 kg | 28.80 kg |
| | **OSB** | 10630 kg | 2651 kg | 1.963 kg | 72.96 kg |
| | **Corner guard** | 96 kg | 24 kg | 0.018 kg | 0.66 kg |
| | **Corrugated box** | 60 kg | 14.9 kg | 0.011 kg | 0.41 kg |
| | **Corrugated sheet** | 1065 kg | 265.7 kg | 0.197 kg | 7.31 kg |
| | **Corrugated pad** | 497 kg | 124 kg | 0.092 kg | 3.41 kg |
| | **Strapping tape** | 10 kg | 2.5 kg | 0.002 kg | 0.07 kg |
| | **Masking tape** | 8 kg | 1.9 kg | 0.001 kg | 0.05 kg |
| | **Clear packing tape** | 0.45 kg | 0.1 kg | 0.00008 kg | 0.003 kg |
| | **6" PolyTube** | 163 kg | 40.6 kg | 0.030 kg | 1.12 kg |
| | **48" Furniture drape** | 2761 kg | 688.5 kg | 0.510 kg | 18.95 kg |
| | **60" Furniture drape** | 7628 kg | 1902 kg | 1.409 kg | 52.36 kg |
| | **Vis-Queen** | 45 kg | 11.3 kg | 0.008 kg | 0.31 kg |

In the absence of primary data, a conservative estimate of 500km has been used as a proxy for distance for the transportation of the packaging materials from suppliers to both sites. No water is consumed during the production process.

### 3.4.3 Distribution, storage and use

Transportation to the final use location and disposal of packaging waste are the only major process for this life cycle stage as the system does not require any energy or generate emissions during its storage or use. Furthermore, no repair or maintenance are required during the usage time as the product has a warranty period of twelve years.

#### Transportation to use location

Primary data was obtained for distribution of the representative configuration from both the Charlotte and Farmers Branch production facilities to the use location (**Table 6a**). An average distance travelled was derived from these values. All distances are by road.

**Table 6a: Distribution to final use location**

| Site | Percentage of Total | Distance (km) |
|---|---|---|
| Charlotte | 3.59% | 381 |
| | 0.26% | 1017 |
| | 0.77% | 660 |
| | 0.13% | 1004 |
| | 1.41% | 391 |
| | 0.51% | 245 |
| | 0.13% | 660 |
| | 0.13% | 703 |
| | 11.55% | 18 |
| | 1.93% | 1006 |
| | 14.12% | 994 |
| | 33.25% | 660 |
| | 3.34% | 471 |
| | 1.03% | 1006 |
| | 0.26% | 39 |
| | 0.90% | 669 |
| | 0.26% | 685 |
| | 0.13% | 1004 |
| | 1.03% | 267 |
| | 0.13% | 2240 |
| | 1.03% | 637 |
| | 0.77% | 626 |
| | 2.82% | 1195 |
| | 10.78% | 652 |
| | 0.77% | 698 |
| | **Average distance** | **664** |
| Farmers Branch | 0.62% | 1224 |
| | 1.23% | 2209 |
| | 28.40% | 51 |
| | 37.04% | 51 |
| | 1.23% | 3329 |
| | 1.23% | 788 |
| | 3.70% | 3321 |
| | 10.49% | 27 |
| | 1.85% | 3306 |
| | 1.85% | 51 |
| | 2.47% | 2240 |
| | 7.41% | 3358 |
| | 2.47% | 10 |
| | **Average** | **612** |

## Disposal of packaging materials at use location

The average mass of packaging required for the representative configuration (37.16m$^2$ of wall area enclosing a floor area of 9.92m$^2$) disposed at the use location has been calculated using the packaging weights described in **Table 5b** and **Table 5c** and the contribution of each site to average unit process (**Table 8**).

The disposal routes are based on secondary data derived from USEPA Municipal Solid Waste[6] to determine the amount of each material in the product that can be assumed to be recycled. The remaining materials that are not recycled, have been modeled for end of life using 80% landfill and 20% incineration[7].

Transport to landfill and incineration are embedded in the generic LCI datasets (**Section 3.5**) and a proxy of 150km to a recycling site has been assumed.

The end-of-life disposal scenario for the packaging materials at the use location are described in **Table 6b**.

**Table 6b**: **Disposal of packaging materials at use location**

| Material | Destination | | | | | |
|---|---|---|---|---|---|---|
| | Recycled / Reused | | Landfill | | Incineration | |
| | Weight (kg) | % | Weight (kg) | % | Weight (kg) | % |
| Packaging film (3.5kg) | 0.315 | 9% | 2.55 | 73% | 0.63 | 18% |
| Wood (50.7kg) | 8.62 | 17% | 33.5 | 66% | 8.62 | 17% |
| OSB (47.0kg) | 8.00 | 17% | 31.1 | 66% | 8.00 | 17% |
| Cardboard (13.1 kg) | 8.94 | 68% | 3.42 | 26% | 0.789 | 6% |
| Tape (0.1kg) | 0.0097 | 9% | 0.0784 | 73% | 0.0193 | 18% |
| Furniture drape (56.2kg) | 5.05 | 9% | 41.0 | 73% | 10.1 | 18% |

### 3.4.4 End-of-life

In the absence of primary data for the end-of-life disposal route for the walling system, in accordance with the PCR, secondary data derived from USEPA Municipal Solid Waste has been used to determine the amount of each material in the product that can be assumed to be recycled. The remaining materials that are not recycled, have been modeled for end of life using 80% landfill and 20% incineration. Transport to landfill and incineration are embedded in the generic LCI datasets (**Section 3.5**) and a proxy of 150km to a recycling site. The details for the end-of-life models are recorded in **Table 7a**.

[6] https://www.epa.gov/smm

[7] The usage of 80%/20% is a general disposition determined by the US EPA in the "Solid Waste Management and Greenhouse Gases: A Life-Cycle Assessment of Emissions and Sinks" document, page 111, and is deemed to be an acceptable disposition rate of final materials.

**Table 7a: End-of-life model**

| Material | Destination | | | | | |
|---|---|---|---|---|---|---|
| | Recycled / Reused | | Landfill | | Incineration | |
| | Weight (kg) | % | Weight (kg) | % | Weight (kg) | % |
| **Aluminum (169.9kg)** | 28.9 | 17% | 113 | 66.4% | 28 | 16.6% |
| **Steel (3.6kg)** | 1.2 | 33% | 1.9 | 53.5% | 0.5 | 13.5% |
| **Glass (163.3kg)** | 41 | 25% | 98 | 60% | 24 | 15% |
| **Vinyl (12.3kg)** | 1 | 8.7% | 9.0 | 73% | 2.3 | 18.3% |
| **Wood (490.3kg)** | 83.4 | 17% | 326 | 66.4% | 81.4 | 16.6% |

Similarly, end of life related calculations was done for the two additional scenarios i.e., highest environmental footprint option (MDF), and lowest environmental footprint option (Glass). The details for the end-of-life models are recorded in **Table 7b** & **Table 7c**

**Table 7b: End-of-life model for highest environment footprint option (MDF)**

| Material | Destination | | | | | |
|---|---|---|---|---|---|---|
| | Recycled / Reused | | Landfill | | Incineration | |
| | Weight (kg) | % | Weight (kg) | % | Weight (kg) | % |
| **Aluminum** | 28.88 | 17% | 112.81 | 66.4% | 28.20 | 16.6% |
| **Steel** | 1.19 | 33% | 1.93 | 53.5% | 0.49 | 13.5% |
| **Glass** | 119.25 | 25% | 286.20 | 60% | 71.55 | 15% |
| **Vinyl** | 0.00 | 8.7% | 0.00 | 73% | 0.00 | 18.3% |
| **Wood** | 0.00 | 17% | 0.00 | 66.4% | 0.00 | 16.6% |

**Table 7c: End-of-life model for lowest environment footprint option (Glass)**

| Material | Destination | | | | | |
|---|---|---|---|---|---|---|
| | Recycled / Reused | | Landfill | | Incineration | |
| | Weight (kg) | % | Weight (kg) | % | Weight (kg) | % |
| **Aluminum** | 28.88 | 17% | 112.81 | 66.4% | 28.20 | 16.6% |
| **Steel** | 1.19 | 33% | 1.93 | 53.5% | 0.49 | 13.5% |
| **Glass** | 0.00 | 25% | 0.00 | 60% | 0.00 | 15% |
| **Vinyl** | 3.96 | 8.7% | 33.24 | 73% | 8.33 | 18.3% |
| **Wood** | 111.04 | 17% | 433.71 | 66.4% | 108.43 | 16.6% |

The primary data from the two manufacturing facilities have been averaged for the unit process on an area weighted basis using the $m^2$ of output production values for the representative configuration (9ft. aluminum framed panel) produced from each site, as shown in the **Table 8**.

**Table 8: Contribution of each site to average unit process**

| Site | Production output of 9ft. aluminum framed panel ($m^2$) | Contribution to average model (%) |
|---|---|---|
| **Charlotte** | 4,156 | 75% |
| **Farmers Branch** | 1,350 | 25% |

## 3.5 Description of background datasets

Details of generic LCI data collected to model upstream and downstream processes for the representative system are provided in **Table 9**. All data are from Ecoinvent 3.6.

**Table 9: Generic data used for upstream and downstream processes**

| Dataset | Specific data name | Generic data category | Dataset date |
|---|---|---|---|
| **Aluminum**[8] | Aluminum, primary, ingot {RoW}\| production \| Cut-off, U<br><br>Metal working, average for aluminum product manufacturing {RoW}\| processing \| Cut-off, U<br><br>Anodizing, aluminum sheet {RoW}\| processing \| Cut-off, U | Selected generic data | 2015 (last updated: 2017)<br><br>2010 (last updated: 2020)<br><br>2010 (last updated: 2017) |
| **Vinyl** | Polyvinylchloride, bulk polymerized {RoW}\| polyvinylchloride production, bulk polymerization \| Cut-off, U<br><br>Injection molding {RoW} \| processing \| Cut-off, U | Selected generic data | 2010 (last updated: 2020)<br><br>2010 (last updated: 2020) |
| **Steel**[9] | Steel, low-alloyed {GLO}\| market for \| Cut-off, U | Selected generic data | 2011 (last updated: 2020) |

[8] Dataset has been adjusted to reflect stated recycled content (33.9%)
[9] Data has been adjusted to reflect stated recycled content (25%)

| Dataset | Specific data name | Generic data category | Dataset date |
|---|---|---|---|
| | Sheet rolling, steel {RoW}\| processing \| Cut-off, U | | 2011 (last updated: 2020) |
| **MDF** | Medium density fibreboard {RoW}\| medium density fibre board production, uncoated \| Cut-off, U | Selected generic data | 2014 (last updated 2020) |
| **Glass** | Flat glass, uncoated {RoW}\| production \| Cut-off, U | Selected generic data | 2010 (last updated 2020) |
| **Electricity (Charlotte)** | Electricity, medium voltage {SERC}\| market for \| Cut-off, U | Selected generic data | 2014 (last updated 2020) |
| **Electricity (Farmers Branch)** | Electricity, medium voltage {TRE}\| market for \| Cut-off, U | Selected generic data | 2014 (last updated 2020) |
| **Natural gas (Charlotte)** | Heat, district or industrial, natural gas {SERC}\| heat and power co-generation, natural gas, combined cycle power plant, 400MW electrical \| Cut-off, U | Selected generic data | 2015 (last updated 2020) |
| **Natural gas (Farmers Branch)** | Heat, district or industrial, natural gas {TRE}\| heat and power co-generation, natural gas, combined cycle power plant, 400MW electrical \| Cut-off, U | Selected generic data | 2015 (last updated 2020) |
| **Propane** | Propane {GLO}\| market for \| Cut-off, U | Selected generic data | 2013 (last updated 2020) |
| **Stretch film** | Packaging film, low density polyethylene {GLO}\| market for \| Cut-off, U | Selected generic data | 2011 (last updated 2020) |
| **Yellow pine** | Pine wood, timber, production mix, at sawmill, 40% water content DE S | Selected generic data | 2005 (last updated 2020) |
| **Spruce** | Spruce wood, timber, production mix, at sawmill, 40% water content DE S | Selected generic data | 2005 (last updated 2020) |
| **OSB** | Oriented strand board {GLO}\| market for \| Cut-off, U | Selected generic data | 2011 (last updated 2020) |
| **Corner guard**<br>**Corrugated box**<br>**Corrugated sheet**<br>**Corrugated pad** | Corrugated board box {RoW}\| market for corrugated board box \| Cut-off, U | Selected generic data | 2014 (last update: 2018) |

| Dataset | Specific data name | Generic data category | Dataset date |
|---|---|---|---|
| **Strapping tape** | Oriented polypropylene film E | Selected generic data | 2005 (last updated 2020) |
| **Masking tape** | Styrene-acrylonitrile copolymer {RoW}\| production \| Cut-off, U | | 2010 (last update: 2020) |
| **Clear packing tape** | Acrylic filler {RoW}\| market for acrylic filler \| Cut-off, U | | 2011 (last update: 2020) |
| | Chemical, organic {GLO}\| market for \| Cut-off, U | | 2011 (last update: 2020) |
| **6" PolyTube** | Packaging film, low density polyethylene {GLO}\| market for \| Cut-off, U | Selected generic data | 2010 (last updated 2020) |
| **48" Furniture drape** | Polyethylene terephthalate fibres (PET), via dimethyl terephthalate (DMT), prod. mix, EU-27 S | Selected generic data | 2005 (last updated 2020) |
| **60" Furniture drape** | Fiber, viscose {GLO}\| market for fiber, viscose \| Cut-off, U | | 2011 (last updated 2020 |
| **Vis-Queen** | Packaging film, low density polyethylene {GLO}\| market for \| Cut-off, U | Selected generic data | 2010 (last updated 2020) |
| **Transport of raw materials and packaging via road**[10] | Transport, freight, lorry 16-32 metric ton, euro5 {RoW}\| market for transport, freight, lorry 16-32 metric ton, EURO5 \| Cut-off, U | Selected generic data | 2018 (last updated 2020) |
| **Downstream Transport via road**[12] | Transport, freight, lorry 3.5-7.5 metric ton, euro5 {RoW}\| market for transport, freight, lorry 3.5-7.5 metric ton, EURO5 \| Cut-off, U | Selected generic data | 2018 (last updated 2020) |
| **Transport of recycled waste** | Municipal waste collection service by 21 metric ton lorry {GLO}\| market for \| Cut-off, U | Selected generic data | 2011 (last updated: 2020) |
| **Solid waste to landfill** | Municipal solid waste {RoW}\| treatment of, sanitary landfill \| Cut-off, U | Selected generic data | 2010 (last updated: 2020) |

[10] The Ecoinvent dataset for transport calculates with an average load factor of 50%, in other words it assumes fully loaded transport towards the customer with empty returns.

| Dataset | Specific data name | Generic data category | Dataset date |
|---|---|---|---|
| **Aluminum to landfill** | Waste aluminum {RoW}\| treatment of, sanitary landfill \| Cut-off, U | Selected generic data | 2010 (last updated: 2020) |
| **Aluminum to incineration** | Scrap aluminum {RoW}\| treatment of, municipal incineration \| Cut-off, U | Selected generic data | 2011 (last updated: 2020) |
| **Steel to landfill** | Scrap steel {RoW}\| treatment of, inert material landfill \| Cut-off, U | Selected generic data | 2010 (last updated: 2020) |
| **Steel to incineration** | Scrap steel {RoW}\| treatment of scrap steel, municipal incineration \| Cut-off, U | Selected generic data | 2011 (last updated: 2020) |
| **Glass to landfill** | Waste glass {RoW}\| treatment of, inert material landfill \| Cut-off, U | Selected generic data | 2010 (last updated: 2020) |
| **Glass to incineration** | Waste glass {RoW}\| treatment of, municipal incineration \| Cut-off, U | Selected generic data | 2011 (last updated: 2020) |
| **Vinyl to landfill** | Waste polyvinylchloride {RoW}\| treatment of waste polyvinylchloride, sanitary landfill \| Cut-off, U | Selected generic data | 2010 (last updated: 2020) |
| **Vinyl to incineration** | Waste polyvinylchloride {RoW}\| treatment of waste polyvinylchloride, municipal incineration \| Cut-off, U | Selected generic data | 2011 (last updated: 2020) |
| **MDF to landfill** | Waste wood, untreated {RoW}\| treatment of, sanitary landfill \| Cut-off, U | Selected generic data | 2010 (last updated: 2020) |
| **MDF to incineration** | Waste wood, untreated {RoW}\| treatment of waste wood, untreated, municipal incineration \| Cut-off, U | Selected generic data | 2011 (last updated: 2020) |

## 3.6. Data Validation

Data quality was monitored with the use of data quality requirements based on ISO14044 (**Table 10**). To ensure the quality of data were sufficient, data quality checks were completed on the first five data quality criteria of **Table 10** through the use of data quality indicators (DQIs). The other requirements are addressed through referencing the key data sources. Data quality indicators were applied using a data quality matrix whereby key data were assigned scores between 1 (best) and 5 (worst). The data quality matrix used in this study was adapted from Weidema et al. (2013) and is shown in **Table 11**. Data quality indicator scores for inventory data are provided in **Appendix B**.

**Table 10: Data quality requirements based on ISO 14044**

| Aspect | Description | Requirement in this study |
|---|---|---|
| **Time-related coverage** | Desired age of data and the minimum length of time over which data should be collected. | General data should represent the current situation of the date of study (2019/2020), or as close as possible. All data should be less than 10 years old. |
| **Geographical coverage** | Area from which data for unit processes should be collected. | Curtain wall manufacturing should be representative of Canada. End-of-life data should be representative of UK (final customer destination in scenario). |
| **Technology coverage** | Type of technology (specific or average mix). | Data should be representative of the technology used in production processes. |
| **Completeness** | Assessment of whether all relevant input and output data are included for each data set. | Specific data will be benchmarked with literature data. Simple validation checks (e.g. mass or energy balances) will be performed. |
| **Representativeness** | Degree to which the data set reflects the true population of interest. | The data should fulfill the defined time-related, geographical and technological scope. |
| **Precision** | Measure of the variability of the data values. | Data that is as representative as possible will be used. Data will be derived from credible sources, and references will be provided. |
| **Reproducibility** | Assessment of the method and data, and whether an independent practitioner will be able to reproduce the results. | Information about the method and data (reference source) should be provided. |
| **Sources of the data** | Assessment of the data sources used. | Data will be derived from credible sources, and references will be provided. |
| **Uncertainty of the information** | e.g. data, models, assumptions. | Data will be derived from credible sources, and references will be provided. |

**Table 11: data quality indicator matrix**

| Aspect | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| **Reliability of the source** | Verified data based on measurements | Verified data partly based on assumptions or non-verified data based on measurements | Non-verified data partly based on assumptions | Qualified estimate (e.g. by industrial expert) | Non-qualified estimate |
| **Representative** | Representative data from sufficient sample of sites over an adequate period to even out normal fluctuations | Representative data from a smaller number of sites but for adequate periods | Representative data from an adequate number of sites but from shorter periods | Representative data but from a smaller number of sites and shorter periods or incomplete data from an adequate number of sites and periods | Representation unknown or incomplete data from a smaller number of sites and/or from shorter periods |
| **Temporal correlation** | Less than three years of difference to year of study | Less than six years of difference | Less than 10 years of difference | Less than 15 years of difference | Age of data unknown or more than 15 years of difference |
| **Geographical correlation** | Data from area under study | Average data from larger area in which the area under study is included | Data from area with similar production conditions | Data from area with slightly similar production conditions | Data from unknown area or area with very different production conditions |
| **Technological correlation** | Data from enterprises, processes and materials under study | Data from processes and materials under study but from different enterprises | Data from processes and materials under study but from different technology | Data on related processes or materials but same technology | Data on related processes or materials but different technology |

## Reliability of the source

In this LCA the data relating to the manufacturing of the moveable walls system is from non-verified data based on measurements. All generic data has been assessed to have a data quality indicator of 3 or less and are derived from credible sources.

## Representativeness

The data relating to the manufacture of the moveable walls system is assessed to have a data quality indicator of 1 as production data has been provided from all sites that the boards are manufactured at. All generic data sets have been assessed with a data quality indicator of 3 or less, except for the following:

- Generic data for upstream manufacture of Strapping tape
- Generic data for upstream manufacture of Masking tape
- Generic data for upstream manufacture of Clear packing tape
- Generic data for upstream manufacture of 6" PolyTube
- Generic data for upstream manufacture of 48" Furniture drape
- Generic data for upstream manufacture of 60" Furniture drape
- Generic data for upstream manufacture of Vis-Queen

The above-named datasets have been assigned a data quality indicator result of 4 as the generic data is based on a small number of sites. The lower data quality assigned to these datasets is not deemed to have a significant impact on the study results as these materials are not shown to have a significant contribution to the overall results for the moveable walls system (see section 5.0).

#### Temporal Correlation

In this LCA the data relating to the manufacturing of the moveable walls system are recent (<2 years). The generic datasets are less than 6 years old.

#### Geographical Correlation

The data validation procedure indicates the processes used in the production of the systems is geographically representative, meaning that the production location lies within the region for which the relevant Ecoinvent environmental records have been selected.

#### Technological Correlation

The datasets have been assessed to be representative for the current technology used in the processes of manufacturing the product.

# 4.0 Life Cycle Impact Assessment (LCIA)

The impact assessment is a technical, quantitative method used to assess the environmental significance of the inputs and outputs identified in the inventory analysis. This section includes description of the impact assessment method, reporting parameters and results.

## 4.1 Impact Assessment Method and Reporting Parameters

In LCA, the life cycle impact assessment (LCIA) stage is where characterization factors are applied to LCI data to generate environmental impact results. There are several LCIA methods that can be chosen, all with slightly different characterization factors (both in terms of coverage and values) and different underlying characterization models used to generate these factors.

For this study we used the baseline characterization factors taken from IPPC for GWP and the TRACI 2.1 method for all other parameters, as prescribed by the PCR. The impact categories that the results will be reported against are shown in **Table 12** and a further description of these is provided within **Appendix C**. Furthermore, the following inventory assessment categories are reported:

- Net freshwater consumption (kg)
- Primary energy demand in total (renewable and non-renewable) (MJ)

The impact assessment method transformed data gathered in the inventory phase to several indicator scores for various impact categories, giving a broad range coverage of environmental issues. These indicator scores express the relative severity on an environmental impact category. In this study, LCIA results are shown at the 'mid-point' stage, whereby a score is given for each in the appropriate reference unit. This differs from LCIA results shown at the end-point stage, where the potential damage to ecosystems, human health and resources is shown.

To provide an example of the difference, at the mid-point level the contribution to global warming is measured in kg $CO_2e$, which tells us the amount of greenhouse gas equivalents that are released into the environment. To estimate the potential environmental damage caused by an amount of $CO_2e$ released into the environment, end-point characterization factors can be applied, and results expressed in terms of damage to ecosystems (species loss), human health (disability adjusted life years, DALY) or resources (USD). End-point results carry a higher degree of uncertainty, due to the multitude of assumptions required in the underlying damage models and therefore are not presented here.

**Table 12: Impact Category Parameters**

| Impact Category | Parameter | Unit |
|---|---|---|
| **Global Warming Potential (Climate Change)** | Global warming potential, GWP | Kg $CO_2$ equiv., 100 years |
| **Ozone Depletion Potential** | Depletion potential of the stratospheric ozone layer, ODP | Kg CFC 11 equiv. |
| **Acidification Potential** | Acidification potential of soil and water, AP | kg $SO_2$ equiv. |
| **Eutrophication Potential** | Eutrophication potential, EP | kg N equiv. |
| **Photochemical Ozone Creation (or 'smog')** | Formation potential of tropospheric ozone, POCP | kg $O_3$ equiv. |

The LCA software SimaPro (version 9) was used to build a model for the product system under investigation using specific and generic inventory data. The generic data was sourced from the LCI database Ecoinvent v3.6 (cut-off). In addition, SimaPro was used to apply characterization models and factors from the impact assessment methods to generate LCIA results. Characterization models and factors were used unaltered and as provided in this LCA. Microsoft Excel was subsequently used to format results exported from SimaPro into figures and tables for this background LCA report.

## 4.2 Environmental performance of the representative product

The environmental performance of the representative product manufactured as an average from both the Charlotte and Farmers Branch plants is declared and reported using the parameters and units shown in **Table 12**. These LCIA results and other environmental results are presented in **Table 13** per declared unit to three significant figures, and broken down into the following lifecycle stages:

- Material acquisition and pre-processing
- Production
- Distribution, storage and use
- End-of-life

The results for the representative product manufactured at the individual sites are presented in **Appendix D**.

**Table 13: Environmental performance of 1 m$^2$ of workspace for a period of 10 years (average of system from two production facilities)**

| Parameter | Unit | Material acquisition and pre-processing | Production | Distribution, storage and use | End-of-life | Total |
|---|---|---|---|---|---|---|
| **Global warming potential (GWP) - total** | kg $CO_2$ equiv. | 386.70 | 73.27 | 34.21 | 6.67 | 500.84 |
| **Global warming potential (GWP) -** Biogenic | kg $CO_2$ equiv. | 40.08 | 14.74 | 2.99 | 12.64 | 70.45 |
| **Ozone Depletion Potential (ODP)** | kg CFC-11 equiv. | 2.54E-05 | 7.30E-06 | 6.57E-06 | 9.36E-07 | 4.02E-05 |
| **Acidification potential (AP)** | kg $SO_2$ equiv. | 2.16 | 0.23 | 0.13 | 0.03 | 2.55 |
| **Eutrophication potential (EP)** | kg N equiv. | 1.09 | 0.41 | 0.15 | 0.25 | 1.89 |
| **Photochemical ozone creation potential (PCOP) or 'Smog'** | kg $0_3$ equiv. | 25.50 | 2.39 | 2.96 | 0.70 | 31.55 |
| **Inventory assessment categories** | | | | | | |
| **Total use of renewable and non-renewable primary energy resources** | MJ | 5492.03 | 1351.52 | 474.84 | 65.26 | 7383.65 |
| **Net use of fresh water** | m$^3$ | 2.96 | 0.40 | 0.05 | 0.04 | 3.44 |

Note that the LCIA results are relative expressions and do not predict impacts on category end-points, the exceeding of thresholds, safety margins or risks.

## 4.3. Environmental performance of the highest & lowest environmental footprint options

Additionally, the environmental performance of the highest & lowest environment footprint product combinations manufactured as an average from both the Charlotte and Farmers Branch plants are declared and reported in **Table 14** & **Table 15** per declared unit.

**Table 14: Environmental performance of 1 $m^2$ of workspace for a period of 10 years (lowest environment footprint combination – glass option)**

| Parameter | Unit | Material acquisition and pre-processing | Production | Distribution, storage and use | End-of-life | Total |
|---|---|---|---|---|---|---|
| **Global warming potential (GWP) - total** | kg $CO_2$ equiv. | 366.70 | 73.27 | 34.21 | 3.56 | 477.74 |
| **Global warming potential (GWP) -** Biogenic | kg $CO_2$ equiv. | 3.43 | 14.74 | 2.99 | 0.30 | 21.47 |
| **Ozone Depletion Potential (ODP)** | kg CFC-11 equiv. | 2.12E-05 | 7.30E-06 | 6.57E-06 | 8.21E-07 | 3.59E-05 |
| **Acidification potential (AP)** | kg $SO_2$ equiv. | 2.15 | 0.23 | 0.13 | 0.02 | 2.54 |
| **Eutrophication potential (EP)** | kg N equiv. | 1.00 | 0.41 | 0.15 | 0.00 | 1.56 |
| **Photochemical ozone creation potential (PCOP) or 'Smog'** | kg $0_3$ equiv. | 24.91 | 2.39 | 2.96 | 0.64 | 30.89 |
| **Inventory assessment categories** | | | | | | |
| **Total use of renewable and non-renewable primary energy resources** | MJ | 4236.07 | 1351.52 | 474.84 | 56.49 | 6118.92 |
| **Net use of fresh water** | $m^3$ | 1.84 | 0.40 | 0.05 | 0.02 | 2.30 |

**Table 15: Environmental performance of 1 $m^2$ of workspace for a period of 10 years (highest environment footprint combination – MDF option)**

| Parameter | Unit | Material acquisition and pre-processing | Production | Distribution, storage and use | End-of-life | Total |
|---|---|---|---|---|---|---|
| **Global warming potential (GWP) - total** | kg $CO_2$ equiv. | 398.95 | 73.27 | 34.21 | 8.71 | 515.13 |
| **Global warming potential (GWP) -** Biogenic | kg $CO_2$ equiv. | 52.34 | 14.74 | 2.99 | 16.79 | 86.86 |
| **Ozone Depletion Potential (ODP)** | kg CFC-11 equiv. | 3.01E-05 | 7.30E-06 | 6.57E-06 | 9.55E-07 | 4.49E-05 |
| **Acidification potential (AP)** | kg $SO_2$ equiv. | 2.15 | 0.23 | 0.13 | 0.03 | 2.55 |
| **Eutrophication potential (EP)** | kg N equiv. | 1.14 | 0.41 | 0.15 | 0.35 | 2.05 |
| **Photochemical ozone creation potential (PCOP) or 'Smog'** | kg $0_3$ equiv. | 25.67 | 2.39 | 2.96 | 0.69 | 31.71 |
| **Inventory assessment categories** | | | | | | |
| **Total use of renewable and non-renewable primary energy resources** | MJ | 6089.23 | 1351.52 | 474.84 | 66.52 | 7982.11 |
| **Net use of fresh water** | $m^3$ | 3.44 | 0.40 | 0.05 | 0.09 | 3.98 |

Note that the LCIA results are relative expressions and do not predict impacts on category end-points, the exceeding of thresholds, safety margins or risks

## 4.4. Comparison of environmental impacts for highest & lowest footprint with the representative product (cradle to grave)

Environmental impacts of highest and lowest environmental footprint product are compared against the representative product selected in the LCA study and % deviations are reported in Table 16.

**Table 15: Comparison of environmental performance for lowest & highest environment footprint product combination vs representative product**

| LCIA | Unit | Lowest Environment Footprint Product Combination | | Representative Product Combination | Highest Environment Footprint Product Combination | |
|---|---|---|---|---|---|---|
| | | Absolute | % | | Absolute | % |
| **Global warming potential (GWP) - total** | kg CO2 equiv. | 477.74 | -5% | 500.84 | 515.13 | 3% |
| **Global warming potential (GWP) - biogenic** | kg CO2 equiv. | 21.47 | -70% | 70.45 | 86.86 | 23% |
| **Ozone Depletion Potential (ODP)** | kg CFC-11 equiv. | 3.59E-05 | -11% | 4.02E-05 | 4.49E-05 | 12% |
| **Acidification potential (AP)** | kg SO2 equiv. | 2.54 | 0% | 2.55 | 2.55 | 0% |
| **Eutrophication potential (EP)** | kg N equiv. | 1.56 | -17% | 1.89 | 2.05 | 8% |
| **Photochemical ozone creation potential (PCOP) or 'Smog'** | kg O3 eq. | 30.89 | -2% | 31.55 | 31.71 | 1% |
| **Total use of renewable and non-renewable primary energy resources** | MJ | 6118.92 | -17% | 7383.65 | 7982.11 | 8% |
| **Net use of fresh water** | m3 | 2.30 | -33% | 3.44 | 3.98 | 16% |

# 5.0 Interpretation

This section includes analysis of the results, identification of environmental hot-spots, limitations of the study explained, and conclusions are made.

## 5.1. LCIA environmental hot spots

The results displayed in **Table 13** record the environmental performance results for the average system produced from both the Charlotte and Farmers Branch production facilities, while the site-specific results are provided within **Appendix D**. For general comparison purposes of the product under assessment, the global warming indicator result has been used as an indication of the relative impact of the other environmental performance indicators. This is because the GWP indicator is primarily related to energy use and given that the bill of materials for the system is the same at both sites, it has been used as an indication that, if one site has a higher global warming impact it will tend to have higher impacts in the other environmental performance impact categories as well.

Investigating the site specific GWP indicator result compared to the average result derived from the two sites (**Table 8**) reveals that the result for the average is within ten percent of the site-specific results (**Figure 5).** Furthermore, **Figure 5** reveals that the material acquisition and pre-processing is the stage contributing the greatest impacts over the systems life cycle.

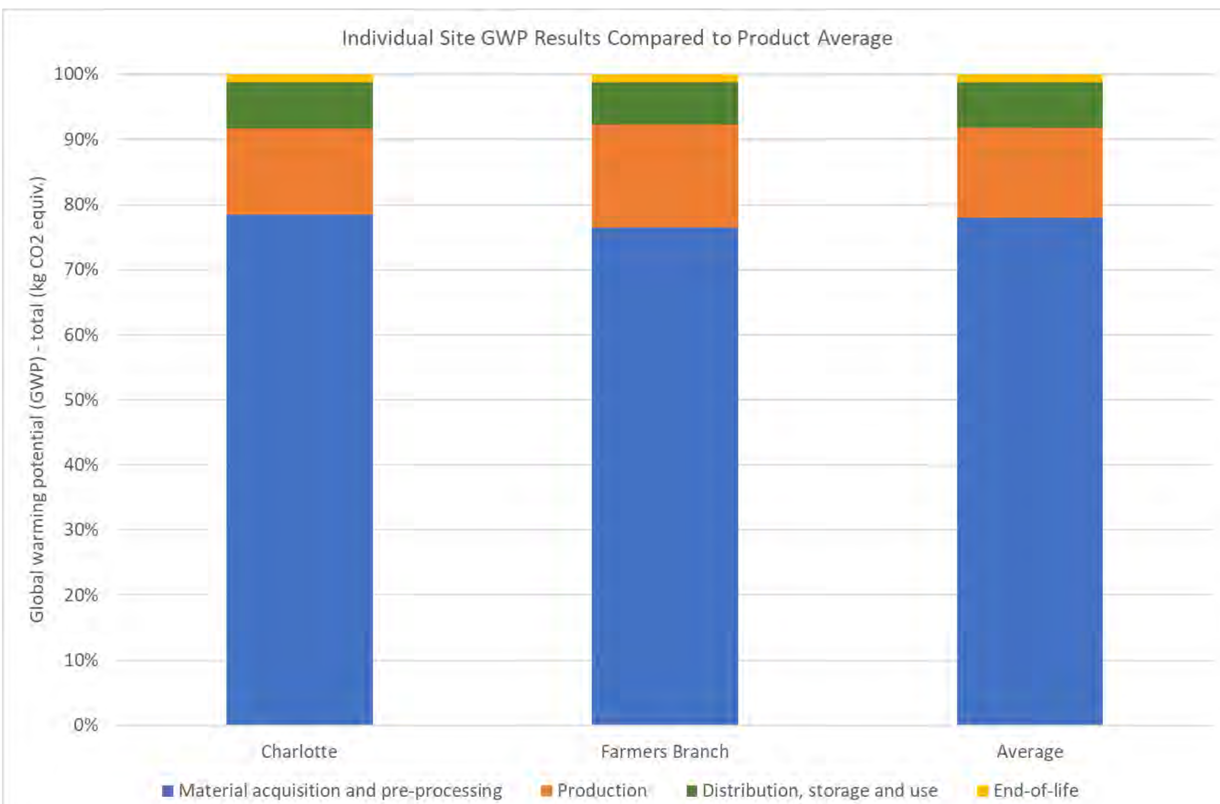



**Figure 5: GWP Indicator results for site specific results compared to average from both sites**

The following sections provide interpretation of the results for each stage of the average product's life cycle. **Figure 6 – Figure 10** show LCIA environmental hotspots as a percentage in 100% stacked bar charts for the five environmental parameters (global warming potential (GWP), ozone depletion potential (ODP), acidification potential (AP), eutrophication potential (EP) and smog formation potential) plus the two additional reporting parameters (total use of renewable and non-renewable primary energy resources and net use of fresh water) . These hotspots are shown in increasing levels of detail throughout this section as the primary drivers of the products environmental impact are revealed.

### 5.1.1 All lifecycle stages

**Figure 6** shows the breakdown of each parameter describing environmental impacts, as a percentage in a 100% stacked bar chart, for 1m$^2$ of workspace over a 10-year period. These environmental hotspot results show which life cycle stage contribute most (and least) to the cradle-to-grave system boundary.

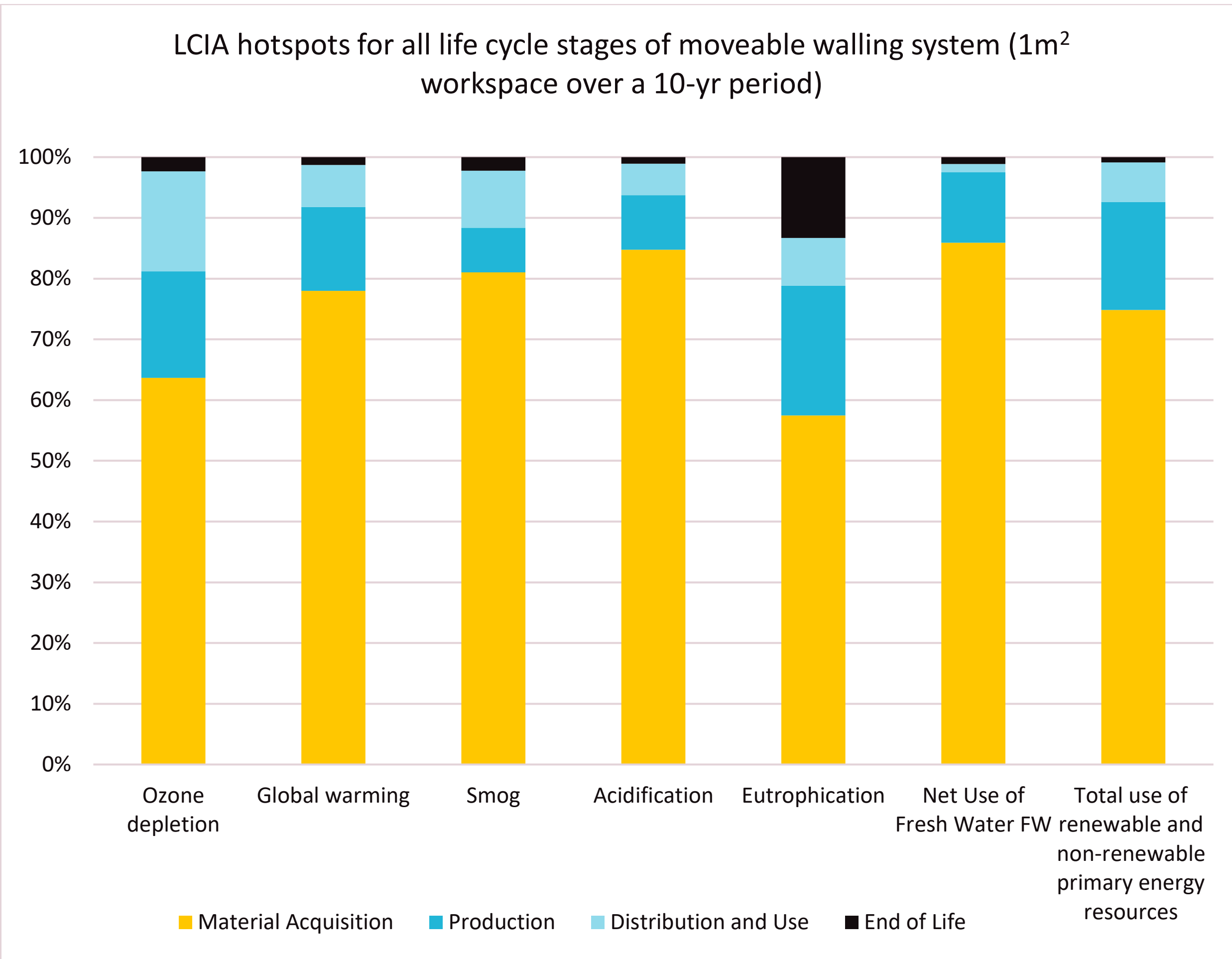



**Figure 6: LCIA hotspots for all life cycle stages of moveable walling system (1m$^2$ workspace over a 10-yr period)**

It is evident form **Figure 6** that the material acquisition stage dominates for all parameters describing environmental impacts. The production stage makes the next most noticeable contribution, while all other lifecycle stages make a minor to insignificant contribution.

This infers that making positive changes to the raw material supply of the product would result in the greatest potential reductions to environmental impact categories. For example, a reduction could be achieved by increasing the percentage of recycled material in the raw material supply and sourcing locally wherever possible.

### 5.1.2 Material acquisition and pre-processing

**Figure 7** shows the breakdown of each parameter describing environmental impact as a 100% stacked bar chart for the material acquisition and pre-processing life cycle stage of 1m$^2$ of workspace over a 10-year period.

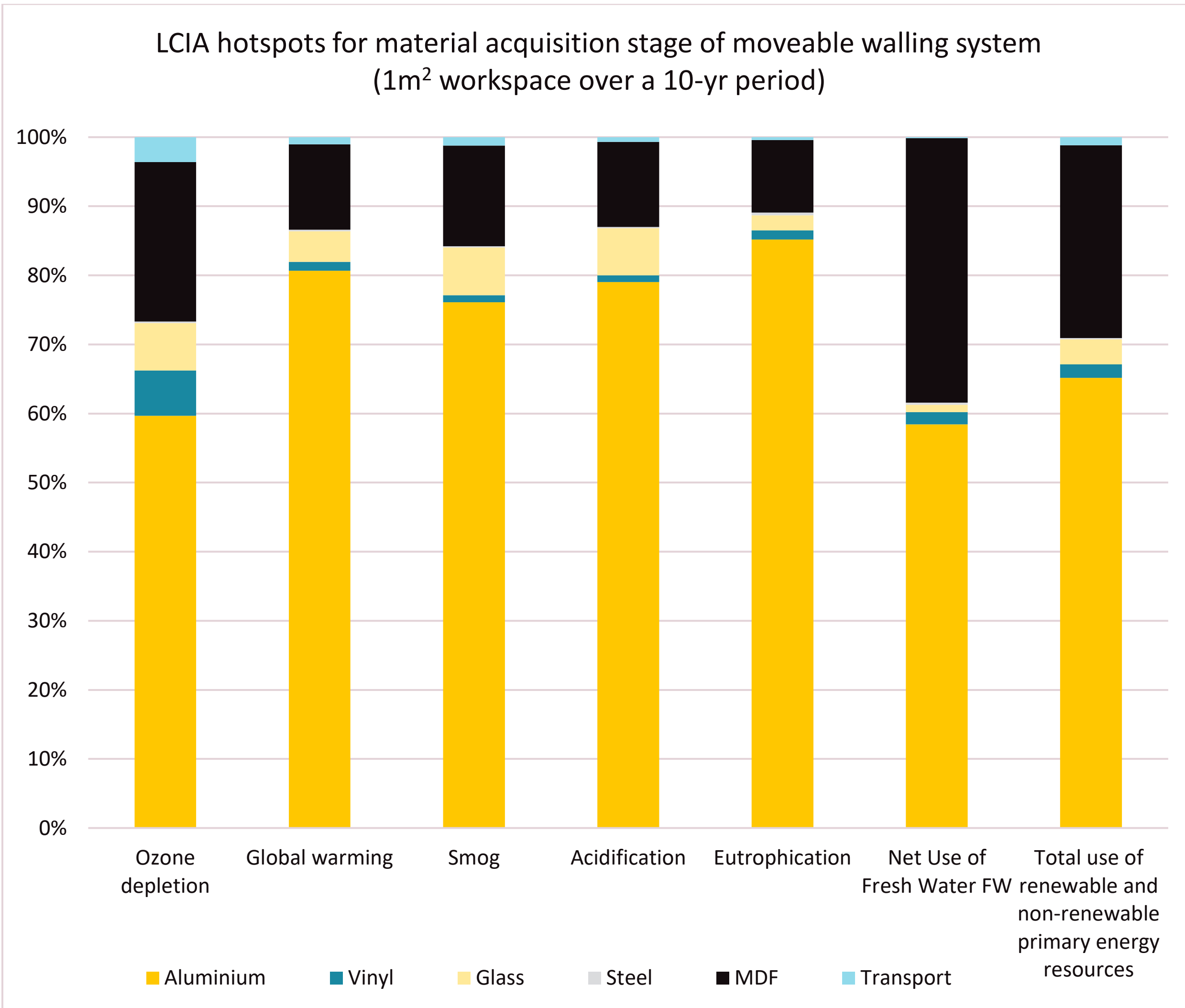



**Figure 7: LCIA hotspots for material acquisition stage of moveable walling system (1m$^2$ workspace over a 10-yr period)**

**Figure 7** reveals that the acquisition of aluminum dominates for all parameters describing environmental impacts. Although aluminum does not account for the greatest mass of the product, the high impact can be explained by the energy intensive production process. Aluminum is produced through mining, milling, electrolytic processing and casting using high temperatures and electrical currents. Souring aluminum with a higher recycled content could achieve lower impacts.

In comparison, the production of MDF, which accounts for the greatest mass of the product, makes a moderate contribution to parameters describing environmental impacts. This is to be expected since the production process to produce the raw material is less intensive.

### 5.1.3 Production

**Figure 8** shows the breakdown of each parameter describing environmental impact as a 100% stacked bar chart for the production life cycle stage of 1m$^2$ of workspace over a 10-year period.

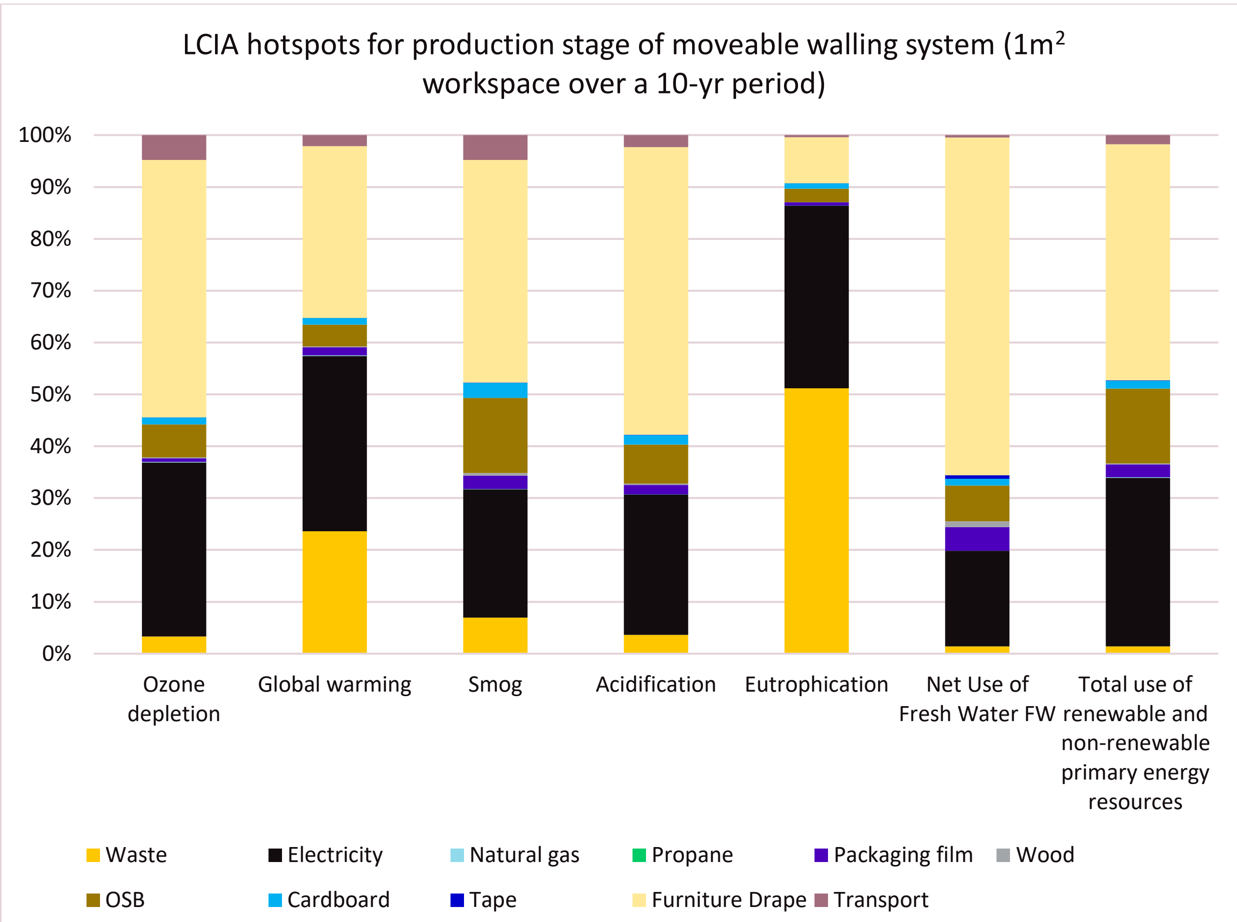



**Figure 8: LCIA hotspots for production stage of moveable walling system (1m$^2$ workspace over a 10-yr period)**

**Figure 8** reveals that no single source particularly dominates the production stage. The furniture drape and use of electricity make the most significant contribution to all parameters describing environmental impacts. Looking at the furniture drape, its impact contribution can be accounted for by the high mass of this packaging material used per functional unit of product (Table 3b). The significant impact that the electricity consumption makes can be attributed to the use of non-renewable sources of energy production. The possibility and ability to make changes to energy sources or reducing the mass of packaging per unit could bring reduction in these indicators in the future.

The disposal of waste makes a moderate contribution to the global warming and eutrophication indicators. This can be attributed to the dominant use of landfill for waste disposal, which is largely driven by biogenic methane releases and leaching into water sources from landfill sites.

### 5.1.3 Distribution and use

**Figure 9** shows the breakdown of each parameter describing environmental impact as a 100% stacked bar chart for the distribution and use life cycle stage of 1m$^2$ of workspace over a 10-year period.

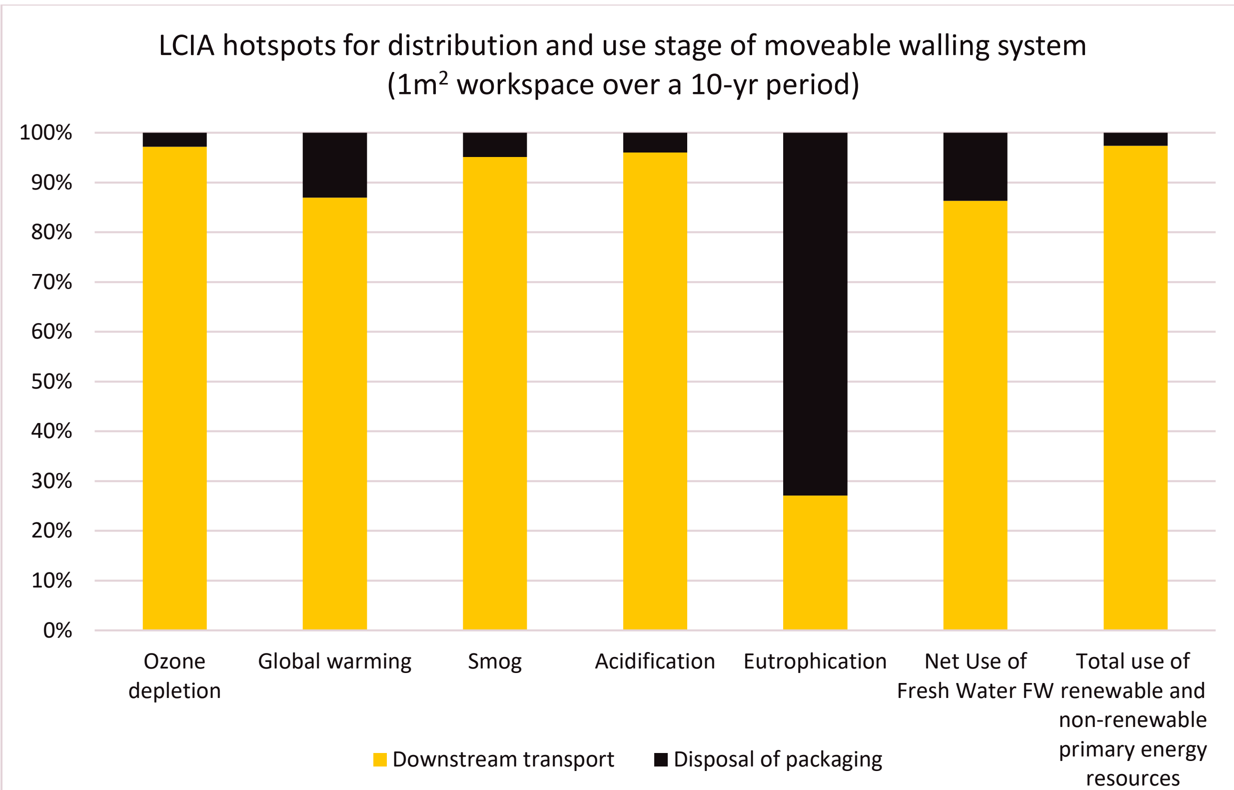



**Figure 9: LCIA hotspots for distribution and use stage of moveable walling system (1m$^2$ workspace over a 10-yr period)**

**Figure 9** demonstrates that downstream transport dominates for all parameters describing environmental impacts while the disposal of packaging dominates for eutrophication potential. Looking for opportunities to locally source materials where possible could lead to reductions for this life cycle stage.

The impact to the eutrophication potential impact category from the disposal of packaging can be attributed to the potential of leaching at landfill, thus contaminating nearby water sources and increasing eutrophication.

### 5.1.3 End of life

**Figure 10** shows the breakdown of each parameter describing environmental impact as a 100% stacked bar chart for the end-of-life phase of 1m$^2$ of workspace over a 10-year period.

It is evident form **Figure 10** that no single disposal routes particularly dominates this life cycle stage. The impact of landfilling dominates in the contribution to the eutrophication potential indicator, and this can be attributed to the potential of leaching at landfill, thus contaminating nearby water sources and increasing eutrophication. The incineration disposal route is the dominate contributor to the net use of fresh-water indicator.

The recycling disposal route shows a moderate contribute to most parameters describing environmental impacts, and this is solely attributed to the distance assumed for transporting of the waste to the recycling center.

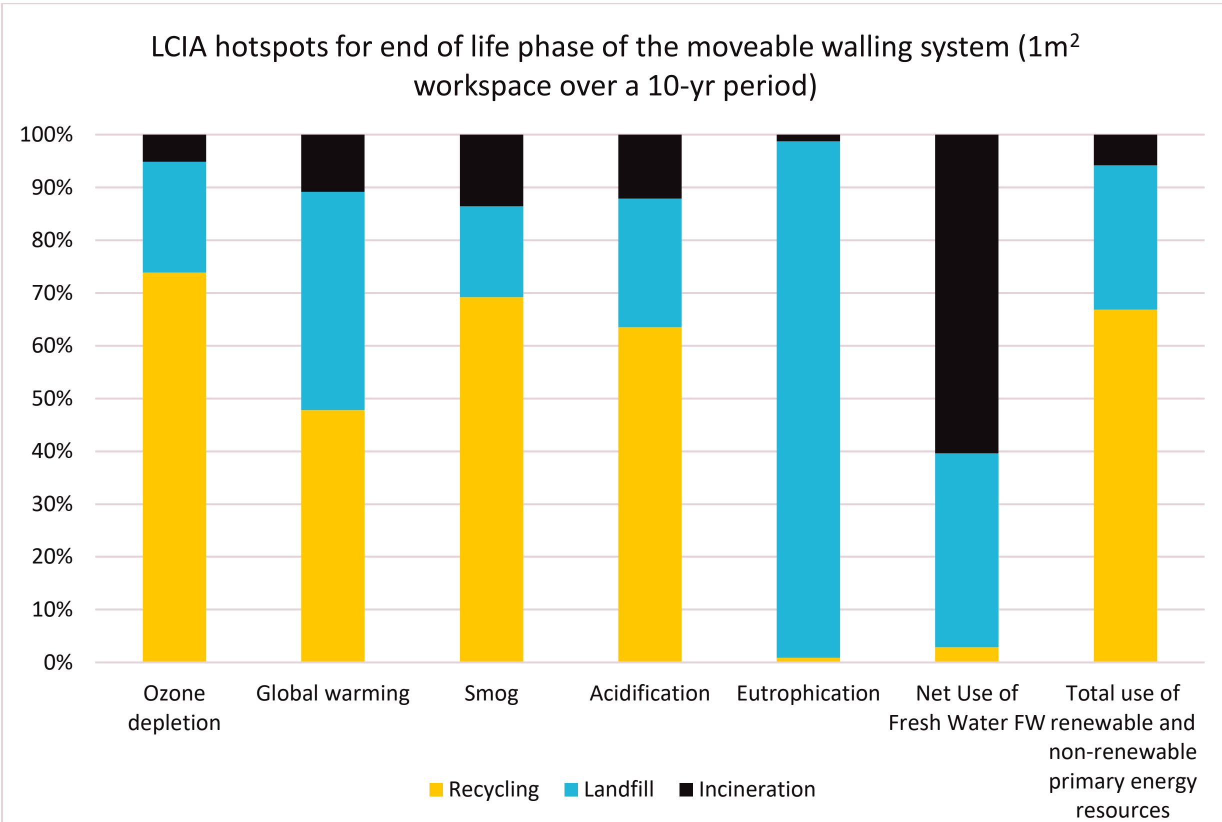



**Figure 10: LCIA hotspots for end-of-life phase of the moveable walling system (1m² workspace over a 10-yr period)**

## 5.2 Conclusions and limitations

The LCA study presented in this background report generated an environmental for the Symbio™ movable wall system to better understand the associated lifecycle environmental impacts. The declared unit for this study was defined "1m² of workspace over a 10-year period", the system boundary was set at cradle-to-grave, the underlying LCIA method used for parameters describing environmental impacts was IPCC and TRACI 2.1 and the LCA model was constructed in SimaPro v9 using Ecoinvent 3.6 datasets.

The following conclusions can be drawn from this study:

- The environmental impact results for the product manufactured at each site (**Appendix D**), compared to the of the results for the average product derived from the two sites (**Table 13**) are within ten percent of each other.

- The material acquisition and pre-processing stage is attributable for the largest portion of impact to the impact categories across the systems life cycle.
- Looking in detail at the material acquisition and pre-processing stage showed that the following sources are accountable for the largest portion of impact:
    - The aluminum
    - The MDF
- When considering the production stage, which has the next highest contribution over the products life cycle, the use of electricity and furniture drape (packaging) are significant.
- Potential reductions in environmental impacts could be achieve by sourcing raw materials with a greater recycled content or reducing the mass of packaging used per unit.
- Global Warming Potential (kg $CO_2$ eq.) is 477.54 kg $CO_2$ eq. for lowest environment footprint combination, 500.84 kg $CO_2$ eq. for representative product, & 515.13 kg CO2 eq. for highest environment footprint product combination.

The results within this LCA report are limited by:

- The scope, boundaries and reference period defined within this assessment.
- The generic data used for upstream and downstream processes.
- The data quality defined within this assessment (see **Appendix B**);
- The assumptions defined within this assessment specifically,
- Transport distances to recycling plants.
- The exclusions defined within this assessment (see **Section 2.7**).

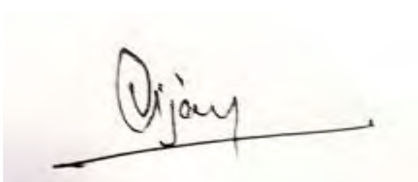
# 6.0 INTERNAL APPROVAL

Results were validated through:

a) internal QA/QC procedures at Intertek.

b) distribution of the draft report for comment to Environamics Ltd.

c) searching for other studies to compare results against.

| Intertek LCA Practitioner: | Intertek Internal Reviewer: |
| --- | --- |
| <br>Vijay Thakur<br>Sustainability Manager<br>Assuris<br>Intertek | <br>Gary Parker<br>Sustainability Director<br>Assuris<br>Intertek |

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# 8.0 Disclaimer

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# Appendix A – Specification for Symbio movable walling system

## MOVABLE WALLS
**Division 10, Section 10615**

### 1. RELATED DOCUMENTS
The drawings and general provisions of the contract, including GENERAL and SUPPLEMENTARY CONDITIONS, and all Specification Sections apply to the Work specified in this Section.

### 2. DESCRIPTION OF WORK
**A.** Movable walls as shown on the Drawings.
**B.** The work shall include:
1) Furnishing, delivering to the building, uncrating, setting in place and leveling all movable walls shown on the Drawings and listed in the Specifications.
2) Furnishing and installing raceway, boxes, connections and wiring for electrical power switches.
3) Furnishing and installing raceway and boxes for computer/data cabling and telecommunications.
4) Furnishing and installing doors, frames, hardware locksets and passage sets in movable walls.
5) Furnishing and installing glazing framing or pre-glazed panels in movable wall.

**C.** Work specified elsewhere in the general contract for construction of the project:
1) Furnishing and installing data/communications cable, cable wiring devices other than boxes, and coverplates.
2) Furnishing and installing electrical wiring devices other than boxes, and coverplates, and making connections of wiring in movable wall panels to building wiring systems.

### 3. QUALITY ASSURANCE
**A.** It is the intent of these Specifications and applicable Drawings to show and define the essential minimum requirements as to the quality of materials, construction, finish, and overall workmanship. Movable walls systems differing from that specified will not be considered unless ample proof is submitted in the form of drawings, descriptions, samples, and test results indicating all essential requirements of the Specifications are strictly adhered to.
**B.** The product warranty extends only to the original purchasers acquiring new products. Warranty shall cover all materials and labor for a period of twelve years.
**C.** The movable wall panel system shall be manufactured by a single firm specializing in the production of movable partitions and with a minimum of 5 years of successful experience in applications similar to the requirements of this project.
**D.** The movable wall panel system installer shall have a minimum of 5 years of successful experience in the installation of movable wall panel systems, shall have previous experience in projects of this approximate magnitude, and shall be authorized to do installation by the manufacturer of the movable wall system. Installation supervision shall be by an experienced supervisor trained in specialized methods of construction and approved by the movable wall system manufacturer.

### 4. CODES AND STANDARDS
Comply with the provisions of the following to the extent referenced:
1) ASTM C 36, Gypsum Wallboard.
2) ASTM C 442, Gypsum Backing Board and Coreboard.
3) ASTM E 90, Laboratory Measurement of Airborne Sound Transmission Loss of Building Partitions.

| Glass Type | Interlayer | STC |
|---|---|---|
| 1/4" Monolithic | 1/4" Overall | 31 |
| 1/4" Laminated | 1/4" Overall- 1/8" +.030 PVB+ 1/8" Glass | 35 |
| 1/2" Monolithic | 1/2" Overall | 36 |
| 1/2" Laminated | 1/2" Overall-1/4" + .030 PVB+ 1/4" Glass | 38 |

4) ASTM E 119, Fire Tests of Building construction and Materials.
5) ASTM E 84 Surface Burning Characteristics of Building Materials.
6) ASTM E 413, Classification for Determination of Sound Transmission Class.
7) Factory Mutual Publication, Specification Tested Building Materials Guide, 1985.
8) UL Publication, Fire Resistance Directory (January, 1985 with Quarterly Supplements.)

9) BIFMA Furniture Requirements.

## 5. SUBMITTALS

**A.** Submit product data, shop drawings, samples, fabrication specifications and installation instructions as specified in GENERAL REQUIREMENTS and as described herein.
**B.** Submit six (6) copies of manufacturer's data shop drawings and instructions. Two (2) copies will be retained by the Architect. Submit two sets of samples, both will be retained by the Architect.
**C.** Submit test data from independent testing agencies indicating that all performance characteristics specified in Paragraphs 9, 10, and 11 of this Section have been complied with.
**D.** Submit samples of each required finish and color. Prepare samples on same materials which will be used in wall assemblies.

## 6. DELIVERY, STORAGE AND HANDLING

**A.** Deliver movable wall system components boxed or crated to provide protection during transit and job storage.
**B.** Inspect wall components upon delivery for damage. Minor damages may be repaired provided finish items are equal to new work and acceptable to Architect. Remove and replace damaged items as directed.
**C.** Store materials in dry, protected areas in which it is possible to maintain a constant minimum temperature of 55°F.

## 7. GENERAL REQUIREMENTS

**A.** Floor to ceiling type with interchangeable standardized units which can be rearranged in any desired combination within a given wall space.
**B.** Extension in any direction without removing adjacent units (non-progressive).
**C.** Capable of relocation without unit disassembly (i.e., demountable products requiring complete disassembly for relocation or which suffer material damage to panels, framing or other components, are not acceptable).
**D.** Erected over finished floor materials including carpet.
**E.** Ability for leveling when installed over out-of-level floors.
**F.** Continuous installations with fasteners concealed.

## 8. MANUFACTURER

The movable wall system shall be Environamics Movable Walls by Environamics, Inc.

## 9. PARTITION SYSTEMS

**A.** Provide movable walls of type, size, materials and finishes indicated, or if not indicated, provide units as recommended by the manufacturer for the type of service indicated.
**B.** Provide movable walls complete with finished floor and ceiling channels, vertical support framing, glazing framing and stops, anchorage and accessories for complete, stable installation.

Partition Construction

1) Movable walls shall consist of unitized movable panels, factory laminated and factory assembled by the manufacturer under controlled conditions. Panel assembly not to exceed 250# per unit.
2) Maximum panel width to be 48". Maximum allowable ceiling height shall be 10 feet. Installations with ceiling heights greater than 10 feet or widths greater than 48" shall require prior approval by Environamics, Inc.
3) Panels shall be sized to be manufacturer's standard width as required to match furniture. Relative thickness of panels shall be 2¼", faced both sides with ⅝ " thick, beveled edge, firecode gypsum wallboard on 1" x 4"- 6" core board studs spaced 12" apart. Optional aluminum framed panel construction of 2¼" thick aluminum frame supported on two adjustable leveling feet, faced both sides with fire-retardant-treated-wood or tackable substrate with acoustical treatment interior.
4) Panels shall have been tested in an independent laboratory for screw holding ability and rated at an average resistance of not less than 190 pounds manual and 279 of shear for 1" R.H. No. 10 screw.
5) All panels shall be pre-finished with fabric-backed, 15 oz,. Type I vinyl wallcovering, color and pattern to be selected by the Architect from the manufacturer's current color line. Painted surfaces are not acceptable.
6) The movable wall system shall have non-progressive capabilities without damage to panel surfaces. Double-sided tape, Velcro or other non-mechanical attachments are not acceptable.

**D.** Aluminum Frames

1) All exposed aluminum shall be extruded from a controlled alloy billet and shall have a four-stage treatment prior to the electrostatic application of paint-like coating, then baked and cured to a 2H minimum hardness, a one mil. minimum thickness, and a gloss of 25 (±5) smooth finish. The paint-like coating shall conform to the Aluminum Association Specification R-10. Anodized finish options shall equal Medium Bronze Anodized "MK" AA-C22A34 and Clear Anodized "AN" AA-C22A213

2) Aluminum door frames shall be assembled plum and square. Frames are to be prepared for hardware including proper reinforcing, drilling and tapping. Miters at corners of frames shall be anchored with concealed clips. Frames must include soft vinyl bulb-type light and sound seal.
3) Aluminum glazing sections shall be installed plumb and square with all connections securely clipped. Intersections with head conditions shall be mitered where possible. Sill sections shall have removable, flush snap-on stops. Surface applied glazing stops will not be acceptable. The wall system shall be such that glazing can be placed anywhere within the wall without supplemental internal construction bracing. Pre-glazed panel sections shall have 1" or less profile trims.
4) Glazing mullions and jambs shall be available which include slotted inserts for furniture integration where indicated on Drawings, and must be capable of carrying the same loading as required of panel wall construction.

E. Furniture Support
1) The movable wall shall be capable of supporting the furniture components shown without requiring bracing other than the normal attachment to ceiling and floor. The wall shall exceed the test criteria of the "Panel Mounted Components" Section of BIFMA Panel System Standard.
2) The movable wall system shall be capable of receiving furniture integration splines at each point between panels and at each full module intersecting panel condition.
3) Splines are required only where needed by the furniture integration and shall be capable of being added or deleted as furniture requirements change without defacing or replacing the wall panels. Splines are to be a part of a connecting condition and not part of the wall panels.
4) Furniture components shall engage splines directly without the use of interfacing clips or supplemental hanger brackets.
5) System shall be capable of supporting connection to partial height panel systems and surface or cabinet components in any panel intersection configurations including corner worksurfaces across any combination of full or partial height wall and system panels.

F. Snap-On Base
This system shall include a rigid vinyl base matching in height to the furniture system base color, style and height that engage positively to the floor track throughout the partition run. Glue-on base is not acceptable. Pre-formed base conditions for corners, starts, ends, etc., will maintain a flush appearance throughout.

## 10. EXECUTION

**A.** The movable wall system shall interface readily with varying building conditions as shown on Drawings without requiring the manufacture of special fittings or modules that may require the Owner to maintain special inventories.
**B.** Movable walls shall be installed over existing floors, anchored to suspended ceiling and shall connect with existing masonry walls and new gypsum board walls.
**C.** Ceiling runners shall be fastened to the suspended ceiling grid with No. 6SMS or other approved fastener. All splices and intersections shall be held tight and aligned by manufacturer supplied concealed installation clips. The runner shall be pre-punched to provide access to wall panels for electrical drops.
**D.** Provide floor runners with pre-punched ¼" long gripper teeth which secure it against lateral movement while preventing crushing or carpet pile. No additional attachments are required except at door frames.
**E.** Intersections of movable walls shall be structurally sound without defacing the intersected surface by drilling or cutting.
**F.** Install snap-on base on all walls, both fixed and movable, and columns in every space where movable walls are installed even if only a portion of the room's walls is movable. On movable walls the base assembly shall engage positively to the floor track throughout the entire run of the partition. For fixed drywall, attach the base to the wall using a J-Clip which mechanically attaches to the wall, and accepts the snap-on base, similarly to the floor runner, allowing use of snap-on base throughout the facility.
**G.** Electrical
1) All movable wall panels shall have a vertical chase capable of accepting electrical outlets, switches, data/communication outlets, and the conduit serving the outlets.
2) Electrical receptacle boxes and switch boxes shall be UL labeled and meet all NEC codes for designated uses. All outlet and switch boxes shall be assembled into the panels at the point of manufacture with flexible steel conduit extending from the boxes up through the panel chaseway. Locations of outlets and switches are shown on the Drawings.
3) Electrical conduit for receptacles and switches shall contain 120 volt, 4 color coded #12 wire with an additional 12" of wire extending from the box, and 12" of conduit extending from the top of the panel and connected to a pre-manufactured UL listed component to accommodate hook-up to the building power system. The movable wall contractor shall furnish to the General Contractor a mating pre-manufactured UL listed component for each conduit, with a 6' length of flexible steel conduit and 4 color coded #12 wire for use by the electrical contractor.
4) Conduit for data/communication cable shall terminate at a point 12" above the top of the panel.
5) Receptacles, switches, data/communications outlets, and all coverplates will be furnished and installed by others in panel mounted electrical system.

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6) A UL 183 listed 8-wire 4-circuit electrical system must be available standard. A power adapter connecting cable must be available to connect manufacturers UL listed furniture system electrical system with identical capacities and circuitry.

**H.** Wood Doors and Hardware

1) Install wood doors in all door openings in movable walls.
2) Doors shall be 1¾" thick, solid core wood doors of size and design as shown on the Drawings. Doors shall be of stile and rail construction, manufactured according to the Architectural Woodwork Institute (AWI) Specification #1400, Custom Grade, for stile and rail wood doors. Exposed surfaces shall be plain sliced natural birch or other veneer suitable for painting or staining.
3) Each door shall be hung with two pair of 4½" x 4½" x 0.134" five knuckle non rising loose pin, button tipped, ball-bearing, full mortise, wrought steel hinges conforming to ANSI A156.1 and BHMA No. A8112.
4) Locksets and passage sets.
   a. Lever Passage Set shall conform to ANSI A156.2 1976 Grade 1 requirements; brass ½" throw latch bolt projects to 1" throw with Delrin AF insert hardened steel insert; 4 ⅞ " curved lip ASA strike; cast bronze and stainless steel trim with precision machined internal parts of hardened steel; 2¾" back set; 1⅛ " x 2 " brass front.
   b. Lever or lockset shall conform to ANSI A156.2 1976 Grade 1 requirements, Fed. Spec. FF-H-00106B; brass ½" throw latch bolt projects to 1" throw with Delrin AF insert and hardened steel insert; 4 ⅞ " curved lip ASA strike cast bronze and stainless steel trim with precision machined internal parts of hardened steel; 2¾" back set; 1⅛ " x 2¼" brass front. Finishes to be manufacturer's standards.
5) Doors shall be pre-fit, pre-machined, sanded and finished at the factory. Bevel doors ⅛" in 2" at lock edge. Comply with hardware templates.
6) Install doors in accordance with NFPA No. 80 with ½" minimum latch throw. Clearances shall be ⅛ " at jambs and heads and ½" from bottom of door to top of floor finish.
7) Install floor mounted door stops, 2" diameter, low rise, dome type, cast units, No. 10 finish, with molded rubber bumper insert. Unit shall be provided with a non-rotational positioning stud to penetrate into floor with screws.

## 11. PERFORMANCE CHARACTERISTICS

**A.** All movable wall panels shall be Class A fire rated as defined by ASTM Procedure C-36. All laminated gypsum panel surfacing materials shall have a Flame Spread Rating of 25 (or less) when tested in accordance with ASTM Procedure E 84.

**B.** Depending on configuration, standard movable wall panels shall provide an STC rating of 33-38 when tested in accordance with ASTM E 90 without aid of acoustical batting in conformance with "full-wall" tests as opposed to "point on panel" tests. An STC rating of 38 for laminated gypsum panels and 41 for aluminum framed panels shall be achieved with sound batten option installed in panels.

**C.** Movable wall panels shall be capable of supporting a hang-on component weight capacity of no less than 2,000 pounds per wall panel spline, single or double side loaded, regardless of its width.

## 12. PREPARATION FOR INSTALLATION

Do not begin erection of movable walls until building is suitably enclosed to provide complete protection from weather and until temperature within the building can be maintained at a constant minimum of 55° F.

## 13. INSTALLATION

**A.** Install partitions after permanent partitions, floor coverings, suspended ceiling panels, data/communications cable, and final electrical connections.

**B.** Install movable walls to be fully movable, rigid, level, plumb, and in alignment with components secured together in accordance with manufacturer's instructions. Partitions shall be clean and free from defects and ready for use.

**C.** Aluminum floor runners not over carpet shall be secured to the floor as required by the use of power driven pins or other approved fasteners. Where partitions are installed over carpeting and carpet teeth are used in the floor runner, fasteners shall only be required at door openings.

**D.** Where splines for furniture integration are shown to be installed on permanent partitions or on existing masonry walls, install plywood over the existing wall surface to receive the splines as detailed on Drawings. Then, fill space between splines with pre-finished gypsum wallboard with wallcovering to match the movable wall panels. On existing masonry walls edge plywood and gypsum wallboard assembly with wood trim as detailed on Drawings.

**E.** Where columns occur close to movable wall, provide fillers between the movable wall and the column. Where the space is greater than 4", a wall start shall be applied to the movable wall and the column. A pre-finished gypsum board panel shall then be attached, flush with the column.

**F.** Install continuous and positive seal to prevent light and sound transmissions at partition contacts with floor, ceiling, wall, and other abutting surfaces.

G. Repair damaged or defaced work or replace with new work, as acceptable to the Architect. Completely refinish defaced partition components with factory-finish materials or replace defaced components.

H. Adjust hardware and leave doors in proper operating condition.

## INDEX TO DRAWINGS

# Appendix B – data quality assessment

**Table 14: data quality indicator matrix (repeat of Table 11 for convenience)**

| Aspect | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| **Reliability of the source** | Verified data based on measurements | Verified data partly based on assumptions or non-verified data based on measurements | Non-verified data partly based on assumptions | Qualified estimate (e.g. by industrial expert) | Non-qualified estimate |
| **Representative** | Representative data from sufficient sample of sites over an adequate period to even out normal fluctuations | Representative data from a smaller number of sites but for adequate periods | Representative data from an adequate number of sites but from shorter periods | Representative data but from a smaller number of sites and shorter periods or incomplete data from an adequate number of sites and periods | Representation unknown or incomplete data from a smaller number of sites and/or from shorter periods |
| **Temporal correlation** | Less than three years of difference to year of study | Less than six years of difference | Less than 10 years of difference | Less than 15 years of difference | Age of data unknown or more than 15 years of difference |
| **Geographical correlation** | Data from area under study | Average data from larger area in which the area under study is included | Data from area with similar production conditions | Data from area with slightly similar production conditions | Data from unknown area or area with very different production conditions |
| **Technological correlation** | Data from enterprises, processes and materials under study | Data from processes and materials under study but from different enterprises | Data from processes and materials under study but from different technology | Data on related processes or materials but same technology | Data on related processes or materials but different technology |

**Table 15: data quality indicator scores**

| Data description | Reliability of the source | Representative-ness | Temporal correlation | Geographical correlation | Technological correlation |
|---|---|---|---|---|---|
| Generic data for the upstream manufacture of aluminum | 2 | 2 | 2 | 3 | 2 |
| Generic data for the upstream manufacture of vinyl | 2 | 2 | 2 | 3 | 2 |
| Generic data for the upstream manufacture of steel | 2 | 2 | 2 | 3 | 2 |
| Generic data for the upstream manufacture of Glass | 2 | 2 | 2 | 3 | 2 |
| Generic data for the upstream manufacture of MDF | 2 | 2 | 2 | 3 | 2 |
| Generic data for the upstream generation of Electricity (used at Charlotte) | 2 | 2 | 2 | 1 | 2 |
| Generic data for the upstream generation of Electricity (used at Farmers Branch) | 2 | 2 | 2 | 1 | 2 |
| Generic data for the upstream generation of Natural gas (Charlotte) | 2 | 2 | 2 | 1 | 2 |
| Generic data for the upstream generation of Natural gas (Farmers Branch) | 2 | 2 | 2 | 1 | 2 |
| Generic data for the upstream manufacture of Propane | 2 | 2 | 2 | 2 | 2 |
| Generic data for transportation of materials / packaging by road | 2 | 2 | 2 | 3 | 2 |
| Generic data for upstream manufacture of stretch film | 2 | 2 | 2 | 3 | 2 |
| Generic data for upstream manufacture of yellow pine | 2 | 2 | 2 | 3 | 2 |
| Generic data for upstream manufacture of spruce | 2 | 2 | 2 | 3 | 2 |

| Data description | Reliability of the source | Representative-ness | Temporal correlation | Geographical correlation | Technological correlation |
|---|---|---|---|---|---|
| **Generic data for upstream manufacture of OSB** | 2 | 2 | 2 | 3 | 2 |
| **Generic data for upstream manufacture of Corner guard** | 2 | 2 | 2 | 3 | 2 |
| **Generic data for upstream manufacture of Corrugated box** | 2 | 2 | 2 | 3 | 2 |
| **Generic data for upstream manufacture of Corrugated sheet** | 2 | 2 | 2 | 3 | 2 |
| **Generic data for upstream manufacture of Corrugated pad** | 2 | 2 | 2 | 3 | 2 |
| **Generic data for upstream manufacture of Strapping tape** | 2 | 4 | 2 | 3 | 2 |
| **Generic data for upstream manufacture of Masking tape** | 2 | 4 | 2 | 3 | 2 |
| **Generic data for upstream manufacture of Clear packing tape** | 2 | 4 | 2 | 3 | 2 |
| **Generic data for upstream manufacture of 6" PolyTube** | 2 | 4 | 2 | 3 | 2 |
| **Generic data for upstream manufacture of 48" Furniture drape** | 2 | 4 | 2 | 3 | 2 |
| **Generic data for upstream manufacture of 60" Furniture drape** | 2 | 4 | 2 | 3 | 2 |
| **Generic data for upstream manufacture of Vis-Queen** | 2 | 4 | 2 | 3 | 2 |
| **Generic data for transportation of waste by road** | 2 | 2 | 2 | 3 | 2 |
| **Generic data for downstream transportation of product by road** | 2 | 2 | 2 | 3 | 2 |

| Data description | Reliability of the source | Representative-ness | Temporal correlation | Geographical correlation | Technological correlation |
|---|---|---|---|---|---|
| **Generic data for downstream treatment of solid waste to landfill** | 2 | 2 | 2 | 2 | 2 |
| **Generic data for downstream treatment of aluminum to landfill** | 2 | 2 | 2 | 2 | 2 |
| **Generic data for downstream treatment of aluminum to incineration** | 2 | 2 | 2 | 2 | 2 |
| **Generic data for downstream treatment of steel to landfill** | 2 | 2 | 2 | 2 | 2 |
| **Generic data for downstream treatment of teel to incineration** | 2 | 2 | 2 | 2 | 2 |
| **Generic data for downstream treatment of glass to landfill** | 2 | 2 | 2 | 2 | 2 |
| **Generic data for downstream treatment of glass to incineration** | 2 | 2 | 2 | 2 | 2 |
| **Generic data for downstream treatment of vinyl to landfill** | 2 | 2 | 2 | 2 | 2 |
| **Generic data for downstream treatment of vinyl to incineration** | 2 | 2 | 2 | 2 | 2 |
| **Generic data for downstream treatment of MDF to landfill** | 2 | 2 | 2 | 2 | 2 |
| **Generic data for downstream treatment of MDF to incineration** | 2 | 2 | 2 | 2 | 2 |

# Appendix C - Impact Categories Description

## Global warming potential

Global warming potential is a measure for the adverse environmental effect caused by man-made emissions of greenhouse gases that cause heat to be trapped in the atmosphere and so result in a temperature rise of the Earth's surface. The Intergovernmental Panel on Climate Change (IPCC) has developed a characterization model to quantify the climate change impact of emissions released to the atmosphere. Emissions of different gases are given characterization factors, expressing the release of a gas in terms of its carbon dioxide equivalent ($CO_2e$), depending upon its radiating force in relation to that of $CO_2$. On calculating $CO_2$ equivalents, the residence time of the gases in the troposphere is considered and models for time periods of 20, 50 and 100 years have been developed. Commonly, a time horizon of 100 years is used, as this better reflects the long-term impacts of climate change. A 100-year time horizon was used for this project.

## Ozone depletion

Ozone depletion refers to the destruction of stratospheric ozone. This layer of ozone is crucial to life as it absorbs harmful solar ultraviolet radiation that can cause increased human health risk and have negative impacts on plant life and aquatic ecosystems if it reaches the troposphere. Ozone depleting substances such as chlorine from chlorofluorocarbons (CFCs) and bromine from halons can decrease the concentration of ozone in the stratosphere, resulting in the potential for less ultraviolet radiation to be absorbed.

Ozone depletion is measured in terms of the capacity for an emission to reduce ozone in the stratosphere relative to the ozone reduction potential of trichlorofluoromethane (CFC-11) as a baseline. This is commonly expressed in terms of kilograms of CFC-11 per kilogram of emission of a substance. The significance of ozone layer depletion has reduced with the effectiveness of the Montreal protocol in reducing emissions of ozone depleting substances.

## Acidification potential

Terrestrial acidification refers to processes that increase the hydrogen ion concentration ($[H^+]$) and soil systems, such as atmospheric deposition of sulfur, nitrogen and phosphorous compounds. Any change from the natural pH can have detrimental effects on plant and aquatic life. Some common emissions that contribute to acidification potential include nitrogen oxides (NOx), Sulphur dioxide ($SO_2$) and ammonia ($NH_4$). In terrestrial ecosystems, the effects result in softwood forests (e.g. spruce) inefficient growth and as a final consequence in dieback of the forest. These effects are mainly seen in Scandinavia and in the central and eastern parts of Europe. In aquatic ecosystems, the effects are (clear) acid lakes without any wildlife. These effects are mainly seen in Scandinavia. Buildings, constructions, sculptures and other objects worthy of preservation may be damaged by acid rain. The impact category is regional.

## Eutrophication potential

Nutrient enrichment (eutrophication) can be defined as the enrichment of aquatic ecosystems with nutrients leading to increased production of plankton, algae and higher aquatic plants leading to a deterioration of the water quality and a reduction in the value of the utilization of aquatic ecosystems. The primary effect of surplus nitrogen and phosphorus in aquatic ecosystems is growth of algae. The secondary effect is decomposition of dead organic material (e.g. algae) and anthropogenic organic substances. The decomposition of organic material is an oxygen consuming process, leading to decreasing oxygen saturation and sometimes to anaerobic conditions. Anaerobic conditions in the sediment at the bottom of lakes or other inland waters may furthermore result in production of hydrogen sulfide ($H_2S$) which may lead to “bottom up” incidents and liberation of toxic hydrogen sulphide to the surrounding water. The effects of nutrient enrichment of terrestrial ecosystems include changes in function and diversity of species in nutrient poor ecosystems as heaths, dune heaths, raised bogs, and so on, and they are caused by atmospheric deposition of nitrogen compounds. Nutrient enrichment can be considered as a regional as well as local effect.

## Smog formation

Ozone formation (or photochemical oxidants formation, or smog) is a product of reactions that take place between NOx and volatile organic compounds (VOCs) in the presence of UV radiation. Low-level $O_3$ is a key photochemical oxidant of concern as it is toxic to humans. Ozone formation is a measure of the adverse effects from the formation of low-level ozone and other photo-oxidants. Models are used to calculate photochemical oxidation, and they are based on the mass of each released substance and the photochemical ozone creation potential (POCP) of the substance. This is a measure of how likely it is that the substance will contribute towards smog formation and are calculated from the change in ozone concentration in a set volume of air with the introduction of the emission of a substance relative to the change in emission of ethylene. The impact category is regional.

# Appendix D – LCIA per site

## Charlotte Facility

**Table 16: Environmental performance of 1 $m^2$ of workspace for a period of 10 years (from Charlotte)**

| Parameter | Unit | Material acquisition and pre-processing | Production | Distribution, storage and use | End-of-life | Total |
|---|---|---|---|---|---|---|
| **Global warming potential (GWP) - total** | kg $CO_2$ equiv. | 387.94 | 69.52 | 34.80 | 6.67 | 498.93 |
| **Global warming potential (GWP) -** Biogenic | kg $CO_2$ equiv. | 40.09 | 13.34 | 2.99 | 12.64 | 69.06 |
| **Ozone Depletion Potential (ODP)** | kg CFC-11 equiv. | 2.57E-05 | 7.15E-06 | 6.70E-06 | 9.36E-07 | 4.05E-05 |
| **Acidification potential (AP)** | kg $SO_2$ equiv. | 2.16 | 0.22 | 0.14 | 0.03 | 2.55 |
| **Eutrophication potential (EP)** | kg N equiv. | 1.09 | 0.36 | 0.15 | 0.25 | 1.85 |
| **Photochemical ozone creation potential (PCOP) or 'Smog'** | kg $0_3$ equiv. | 25.59 | 2.27 | 3.02 | 0.70 | 31.58 |
| **Inventory assessment categories** | | | | | | |
| **Total use of renewable and non-renewable primary energy resources** | MJ | 5511.84 | 1309.81 | 484.07 | 65.26 | 7370.99 |
| **Net use of fresh water** | $m^3$ | 2.96 | 0.39 | 0.05 | 0.04 | 3.44 |

Note that the LCIA results are relative expressions and do not predict impacts on category end-points, the exceeding of thresholds, safety margins or risks.

Farmers Branch Facility

**Table 17: Environmental performance of 1 $m^2$ of workspace for a period of 10 years (from Farmers Branch)**

| Parameter | Unit | Material acquisition and pre-processing | Production | Distribution, storage and use | End-of-life | Total |
|---|---|---|---|---|---|---|
| **Global warming potential (GWP) - total** | kg $CO_2$ equiv. | 382.95 | 32.43 | 84.50 | 6.67 | 506.56 |
| **Global warming potential (GWP) -** Biogenic | kg $CO_2$ equiv. | 40.07 | 2.98 | 18.95 | 12.64 | 74.63 |
| **Ozone Depletion Potential (ODP)** | kg CFC-11 equiv. | 2.45E-05 | 6.19E-06 | 7.74E-06 | 9.36E-07 | 0.00 |
| **Acidification potential (AP)** | kg $SO_2$ equiv. | 2.14 | 0.13 | 0.26 | 0.03 | 2.56 |
| **Eutrophication potential (EP)** | kg N equiv. | 1.08 | 0.15 | 0.55 | 0.25 | 2.03 |
| **Photochemical ozone creation potential (PCOP) or 'Smog'** | kg $0_3$ equiv. | 25.21 | 2.79 | 2.74 | 0.70 | 31.44 |
| **Inventory assessment categories** | | | | | | |
| **Total use of renewable and non-renewable primary energy resources** | MJ | 5432.23 | 447.15 | 1476.65 | 65.26 | 7421.28 |
| **Net use of fresh water** | $m^3$ | 2.95 | 0.04 | 0.42 | 0.04 | 3.46 |

Note that the LCIA results are relative expressions and do not predict impacts on category end-points, the exceeding of thresholds, safety margins or risks.