Metal Cladding and Panel Products

EPD Background Report

On behalf of Metal Construction Association

Client:	**Metal Construction Association**
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On behalf of thinkstep AG and its subsidiaries

Document prepared by

Erin Mulholland		emulholland@sphera.com
	October 23, 2019	+1 617 247 4477
Malcolm Hegeman		

Quality assurance by

Trisha Montalbo, ScD	
Senior Consultant, Americas	October 23, 2019

Under the supervision of

Susan Murphy	Director of Consulting & Innovation, Americas

Table of Contents

List of Figures

List of Tables

List of Acronyms

ADP	Abiotic Depletion Potential
AP	Acidification Potential
EoL	End-of-Life
EP	Eutrophication Potential
FU	Functional Unit
GaBi	Ganzheitliche Bilanzierung (German for holistic balancing)
GWP	Global Warming Potential
HFC	Hydrofluorocarbon
HFO	Hydrofluoroolefin
ILCD	International Cycle Data System
IMP	Insulated Metal Panel
ISO	International Organization for Standardization
LCA	Life Cycle Assessment
LCI	Life Cycle Inventory
LCIA	Life Cycle Impact Assessment
MCM	Metal Composite Material
NMVOC	Non-Methane Volatile Organic Compound
ODP	Ozone Depletion Potential
PCR	Product Category Rules
POCP	Photochemical Ozone Creation Potential
SFP	Smog Formation Potential
TRACI	Tool for the Reduction and Assessment of Chemical and Other Environmental Impacts
VOC	Volatile Organic Compound

Glossary

Life cycle

A view of a product system as "consecutive and interlinked stages … from raw material acquisition or generation from natural resources to final disposal" (ISO 14040:2006, section 3.1). This includes all material and energy inputs as well as emissions to air, land and water.

Life Cycle Assessment (LCA)

"Compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle" (ISO 14040:2006, section 3.2)

Life Cycle Inventory (LCI)

"Phase of life cycle assessment involving the compilation and quantification of inputs and outputs for a product throughout its life cycle" (ISO 14040:2006, section 3.3)

Life Cycle Impact Assessment (LCIA)

"Phase of life cycle assessment aimed at understanding and evaluating the magnitude and significance of the potential environmental impacts for a product system throughout the life cycle of the product" (ISO 14040:2006, section 3.4)

Life cycle interpretation

"Phase of life cycle assessment in which the findings of either the inventory analysis or the impact assessment, or both, are evaluated in relation to the defined goal and scope in order to reach conclusions and recommendations" (ISO 14040:2006, section 3.5)

Functional unit

"Quantified performance of a product system for use as a reference unit" (ISO 14040:2006, section 3.20)

Allocation

"Partitioning the input or output flows of a process or a product system between the product system under study and one or more other product systems" (ISO 14040:2006, section 3.17)

Closed-loop and open-loop allocation of recycled material

"An open-loop allocation procedure applies to open-loop product systems where the material is recycled into other product systems and the material undergoes a change to its inherent properties."

"A closed-loop allocation procedure applies to closed-loop product systems. It also applies to open-loop product systems where no changes occur in the inherent properties of the recycled material. In such cases, the need for allocation is avoided since the use of secondary material displaces the use of virgin (primary) materials."

(ISO 14044:2006, section 4.3.4.3.3)

Foreground system

“Those processes of the system that are specific to it … and/or directly affected by decisions analyzed in the study.” (JRC 2010, p. 97) This typically includes first-tier suppliers, the manufacturer itself and any downstream life cycle stages where the manufacturer can exert significant influence. As a general rule, specific (primary) data should be used for the foreground system.

Background system

“Those processes, where due to the averaging effect across the suppliers, a homogenous market with average (or equivalent, generic data) can be assumed to appropriately represent the respective process … and/or those processes that are operated as part of the system but that are not under direct control or decisive influence of the producer of the good….” (JRC 2010, pp. 97-98) As a general rule, secondary data are appropriate for the background system, particularly where primary data are difficult to collect.

Critical Review

“Process intended to ensure consistency between a life cycle assessment and the principles and requirements of the International Standards on life cycle assessment” (ISO 14044:2006, section 3.45).

1. Goal of the Study

The Metal Construction Association (MCA) is recognized as the leading advocate for the architectural metal products industry. In addition to representing companies who manufacture and supply metal products used in structures around the world, MCA also supports third-party metal product research and testing. MCA and its members are committed to creating a cleaner, safer environment evidenced by the association's LCA program and support of similar initiatives. Aware of the increasing interest in transparent reporting of products' environmental performance, MCA seeks to demonstrate its sustainability leadership and leverage business value through evaluating the environmental profiles of member companies' non-structural metal façade products and communicating the results via industry average Environmental Product Declarations (EPDs).

The goal of the study is to assess the cradle-to-gate environmental impacts of four metal products produced in North America: insulated metal panels (IMP), metal composite material panel (MCM), steel roll formed cladding, and aluminum roll formed cladding. The analyses were conducted according to ULE's Product Category Rule: "Part B: Insulated Metal Panels, Metal Composite Panels, and Metal Cladding: Roof and Wall Panels" (UL Environment, 2018). Note that this study is an update to the MCA industry-wide EPD issued in 2014 (MCA, 2014).

The intended audience for this report includes the program operator, UL Environment, the reviewer who will be assessing the life cycle assessment (LCA) for conformance to the Product Category Rule (PCR), and MCA member companies. In addition, thinkstep recommends making this report available upon request to all third parties to whom the EPD is communicated for conformance with ISO 14044, Section 5.2. The resulting EPDs are intended to support business-to-business communication.

Results presented in this document do not constitute comparative assertions. However, these results will be disclosed to the public in EPDs, which architects and builders can potentially use to compare MCA member companies' products with similar products presented in other EPDs that follow the same PCR. In order to be published by a program operator, the EPD will undergo a verification for conformance to the PCR.

2. Scope of the Study

The following sections describe the general scope of the project to achieve the stated goals. This includes, but is not limited to, the identification of specific product systems to be assessed, the product function(s), functional unit and reference flows, the system boundary, allocation procedures, and cut-off criteria of the study.

2.1. Product Systems

MCA products are used in a multitude of building coverage applications and offer a wide range of benefits, including aesthetics, durability, rain screening, fireproofing, and reduced energy costs, with each product type offering its own unique properties. This declaration covers four metal cladding and panel product types, manufactured by 11 different participating MCA member companies, representing a significant majority of annual production in the US and Canada.

Since MCA's primary goal is to develop EPDs and thus promote its member companies' products under the LEED certification system, this LCA will focus on four cladding and panel products that are considered representative of common products manufactured by member companies, as seen Table 2-1.

Table 2-1: Metal cladding and panel products under study

Product	Description	Primary processes
Insulated metal panel (IMP)	Coil gauge: 22 – 26 Gauge Foam thickness: 2 – 6 inches Primary product: 2" Insulated metal panel (IMP) with polyurethane/polyisocyanurate foam core and 24 gauge steel coil	• Continuous coil coating • IMP continuous foaming
Metal composite material panel (MCM)	Metal substrate thickness: 0.01 and 0.02 inches Polyethylene core thickness: 3, 4, and 6 mm Primary product: 0.02 inches aluminum cladding skins with 4mm thick polyethylene core	• Continuous coil coating • MCM sheet manufacturing • MCM panel fabrication
Roll formed steel cladding	Steel gauge: 18 – 29 Gauge Primary product: 0.028 inches (24 Gauge) steel coil	• Continuous coil coating • Roll forming
Roll formed aluminum cladding	Aluminum gauge: 16 – 29 Gauge Primary product: 0.025 inches (22 Gauge) aluminum coil	• Continuous coil coating • Roll forming

The following participating companies and products will be represented by EPDs and are shown below in Table 2-1. Note that only companies listed here may claim to be represented by the EPDs.

Table 2-2: Products by manufacturer

Company	IMP	MCM	Roll form, steel	Roll form, Al	# of products
3A Composites, USA		X			**1**
Arconic / Alcoa Architectural Products		X			**1**
All Weather Insulated Panels	X				**1**
ATAS International, Inc.			X	X	**2**
Dimensional Metals, Inc.			X	X	**2**
Englert			X	X	**2**
Fabral			X	X	**2**
Kingspan	X				**1**
McElroy / Green Span Profiles	X		X		**2**
Mitsubishi Chemical Composites America		X			**1**
NCI (Metl-Span/MBCI, CENTRIA)	X				**1**
Petersen Aluminum Corporation			X	X	**2**
Total	**4**	**3**	**6**	**5**	

2.2. Product Function and Functional Unit

The main purpose of metal cladding and panels is to provide thermal insulation and weather protection for building walls and roofs. The panels create barriers that control noise, water, air, and thermal transmission between an external environment and interior building space. Accordingly, the PCR's functional unit for metal panels, metal composite panels, and metal cladding is the coverage of 100 square meters (1076.4 square feet) of building area. The coverage area refers to the projected flat area covered by the product as output by the final manufacturing process step and does not account for losses due to overlap and scrap during installation.

Table 2-3: Reference flows

Name	IMP	MCM	Roll form, steel	Roll form, Al
Product mass [kg / 100 m^2]	1276	756	491	277

2.3. System Boundaries

As with the functional unit, system boundaries are defined by the PCR. The production stage (i.e., cradle-to-gate) is required, including raw material extraction and processing, processing of secondary material, transport to the manufacturer, and manufacturing. The PCR considers installation, use, end-of-life, and recovery stages (Modules A4 through D) as optional. As such, this study excludes installation, use, end-of-life, and recovery stage. Since this is a "cradle-to-gate" study, the products are not declared as fulfilling a building reference service life. This study also excludes construction of capital equipment, including tools used to produce, install and maintain the products, maintenance and operation of support equipment, human labor and commute, building energy consumption, all other impacts associated with the use phase relative to energy use, the building in which the product is installed. The included and excluded life cycle stages are summarized in Table 2-4.

Table 2-4:Life cycle modules included in EPD

Production			Installation		Use stage							End-of-Life				Next product system
Raw material supply (extraction, processing, recycled material)	Transport to manufacturer	Manufacturing	Transport to building site	Installation into building	Use / application	Maintenance	Repair	Replacement	Refurbishment	Operational energy use	Operational water use	Deconstruction / demolition	Transport to EoL	Waste processing for reuse, recovery or recycling	Disposal	Reuse, recovery or recycling potential
A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	D
X	X	X	MND	MND	MND	MND	MND	MND	MND	MND	MND	MND	MND	MND	MND	MND

X = declared module; MND = module not declared

2.3.1. Time Coverage

The data are intended to represent metal cladding and panel production during the 2017 calendar year. As such, each participating MCA member company provided primary data for the 2017 calendar year. These data were then used to calculate the weighted average production of MCA members.

2.3.2. Technology Coverage

Data were collected for the four metal cladding and panel products under study. Manufacturing data were collected directly from MCA members. Waste, emissions, and energy use are calculated from reported annual production during the reference year from MCA member companies. Section 3.2 gives more detail on the sources for the data used.

2.3.3. Geographical Coverage

This background LCA represents MCA members' products produced in the United States and Canada. Primary data are representative of these countries, with exceptions noted in Section 3.2.

Regionally specific datasets were used to represent each manufacturing location's energy consumption. Proxy datasets were used as needed for raw material inputs to address lack of data for a specific material or for a specific geographical region. These proxy datasets were chosen for their technological representativeness of the actual materials.

2.4. Allocation

2.4.1. Multi-output Allocation

Multi-output allocation generally follows the requirements of ISO 14044, section 4.3.4.2. When allocation becomes necessary during the data collection phase, the allocation rule most suitable for the respective process step is applied and documented along with the process in Section 3.

Allocation of background data (energy and materials) taken from the GaBi 2019 database is documented online at http://www.gabi-software.com/support/gabi/gabi-database-2019-lci-documentation/.

2.4.2. End-of-Life Allocation

The cut-off allocation approach is adopted in the case of any post-consumer and post-industrial recycled content, which is assumed to enter the system burden-free. Only environmental impacts from the point of recovery and forward (e.g., inbound transports, grinding, processing, etc.) are considered.

As this is a cradle-to-gate study, product disposal is not within the system boundaries. Waste from manufacturing is the only disposal considered in this study. Plastic waste is assumed to be inert in landfills so no landfill gas is produced from it. In the case of bio-based waste, waste flows are linked to inventories that account for waste composition and heating value as well as for regional efficiencies and heat-to-power output ratios; output electricity and thermal energy is assumed to have a benefit beyond the system boundary equivalent to convetional regional methods of producing these respective energy types. No credits were assigned to these output energy flows.

2.5. Cut-off Criteria

Data were included whenever possible. If it was necessary to exclude materials in order to facilitate the analysis, only flows representing less than 1% of the cumulative mass of the product system were excluded, providing their environmental relevance was judged not to be a concern.

Packaging of incoming raw materials (e.g. pallets, totes, super-sacks) are excluded as they represent less than 1% of the product mass and are not environmentally relevant. Capital goods and infrastructure required to produce metal panel and cladding products are presumed to produce millions of units to over the course of their life, so impact of a single functional unit attributed to this equipment is negligible; therefore, capital goods and infrastructure were excluded from this study.

2.6. Selection of LCIA Methodology and Impact Categories

According to the PCR, the following environmental indicators shall be calculated and declared:

Table 2-5: North American LCIA Results

Parameter	Impact indicator	TRACI 2.1 unit
GWP	Global warming potential	[kg CO_2 eq.]
ODP	Depletion potential of the stratospheric ozone layer	[kg CFC-11 eq.]
AP	Acidification potential of land and water	[kg SO_2 eq.]

Parameter	Impact indicator	TRACI 2.1 unit
EP	Eutrophication potential	[kg N eq.]
SFP	Smog formation potential	[kg O_3 eq.]
ADPF	Abiotic depletion potential of fossil energy resources	[MJ, LHV]

The North Americans impact assessment results are calculated using characterization factors published by the United States Environmental Protection Agency through its Tool for Reduction and Assessment of Chemical and Other Environmental Impacts (TRACI 2.1). Since there is very little material derived from biomass within the evaluated products, the GWP, including biogenic carbon impact category was excluded from the global warming potential calculations. Additionally, excluding biogenic carbon from GWP ensures that the reader does not mistakenly infer that overall environmental impact can be reduced by using more material derived from biomass. As such, carbon emissions and removals are not reported, as permitted by Part A.

Table 2-6: LCI Results - Resource Use

Parameter	Parameter	Unit
RPR_E	Renewable primary energy as energy carrier	[MJ, LHV]
RPR_M	Renewable primary energy resources as material utilization	[MJ, LHV]
$NRPR_E$	Non-renewable primary energy as energy carrier	[MJ, LHV]
$NRPR_M$	Non-renewable primary energy as material utilization	[MJ, LHV]
SM	Use of secondary material	[kg]
RSF	Use of renewable secondary fuels	[MJ, LHV]
NRSF	Use of non-renewable secondary fuels	[MJ, LHV]
RE	Recovered Energy	[MJ, LHV]
FW	Use of net fresh water	[m^3]

Table 2-7: LCI Results - Output Flows and Waste Categories

Parameter	Parameter	Unit
HWD	Hazardous waste disposed	[kg]
NHWD	Non-hazardous waste disposed	[kg]
HLRW	High-level radioactive waste, conditioned, to final repository	[kg]
ILLRW	Intermediate- and low-level radioactive waste, conditioned, to final repository	[kg]
CRU	Components for re-use	[kg]
MR	Materials for recycling	[kg]
MER	Materials for energy recovery	[kg]
EE	Exported energy	[MJ]

It shall be noted that the above impact categories represent impact potentials, i.e., they are approximations of environmental impacts that could occur if the emitted molecules would (a) actually follow the underlying impact pathway and (b) meet certain conditions in the receiving environment while doing so. In addition, the reported emissions represent only that fraction of the total environmental load that corresponds to the declared unit.

LCIA results are therefore relative expressions only and do not predict actual impacts, the exceeding of thresholds, safety margins, or risks.

2.7. Data Quality Requirements

The data used to create the inventory model shall be as precise, complete, consistent, and representative as possible with regards to the goal and scope of the study under given time and budget constraints.

- Measured primary data are considered to be of the highest precision, followed by calculated data, literature data, and estimated data. The goal is to model all relevant foreground processes using measured or calculated primary data.
- Completeness is judged based on the completeness of the inputs and outputs per unit process and the completeness of the unit processes themselves. The goal is to capture all relevant data in this regard.
- Consistency refers to modeling choices and data sources. The goal is to ensure that differences in results reflect actual differences between product systems and are not due to inconsistencies in modeling choices, data sources, emission factors, or other artifacts.
- Reproducibility expresses the degree to which third parties would be able to reproduce the results of the study based on the information contained in this report. The goal is to provide enough transparency with this report so that third parties are able to approximate the reported results. This ability may be limited by the exclusion of confidential primary data and access to the same background data sources
- Representativeness expresses the degree to which the data matches the geographical, temporal, and technological requirements defined in the study's goal and scope. The goal is to use the most representative primary data for all foreground processes and the most representative industry-average data for all background processes. Whenever such data were not available (e.g., no industry-average data available for a certain country), best-available proxy data were employed.

An evaluation of the data quality with regard to these requirements is provided in Section 5 of this report.

2.8. Software and Database

The LCA model was created using the GaBi 9.2 software system for life cycle engineering, developed by thinkstep AG. The GaBi 2019 SP37 LCI database provides the life cycle inventory data for several of the raw and process materials obtained from the background system.

2.9. Verification

The background LCA report and EPD must be verified before publication. Report verification was conducted by Thomas Gloria, Ph.D., of Industrial Ecology Consultants, on behalf of UL Environment. This verification was performed against ISO 14040/44 (ISO, 2006a; ISO, 2006b), ISO 21930 (ISO, 2017), and the selected PCR for insulated metal panels, metal composite panels, and metal cladding (UL Environment, 2018).

3. Life Cycle Inventory Analysis

3.1. Data Collection Procedure

All primary data were collected using customized data collection templates, which were sent out by email to the respective data providers in the participating companies. The majority of manufacturers only operate one site per product type, and therefore that site was selected to participate. If data from additional sites was available, it was included. Data providers were asked to provide annual data for 2017. MCA members provided gate-to-gate data on production volume, product characteristics, packaging materials, energy use, wastes, and emissions, as well as inbound and outbound transportation. Upon receipt, each questionnaire was cross-checked for completeness and plausibility using mass balance, stoichiometry, as well as internal and external benchmarking. If gaps, outliers, or other inconsistencies occurred, thinkstep engaged with the data provider to resolve any open issues. Data was combined based on a area-weighted average.

The energy inputs and outputs were modeled according to data provided by each site. The electricity grid and natural gas mix were chosen based on the locations of each manufacturer's production facilities.

Material inbound transportation distances, product outbound distances, packaging details, and installation details were calculated based on primary data or estimations from participating MCA companies.

The project was further subjected to a comprehensive quality assurance process at every major milestone in the project to analyze and ensure model integrity, data accounting and consistency with the goal and scope.

3.2. Metal cladding and panel products

3.2.1. Manufacturing

Metal cladding and panel products (IMP, MCM, roll formed steel, roll formed aluminum), while each offering their own set of properties and attributes, generally all have similar functions and—to a degree—similar manufacturing processes. Figure 3-1, below shows the processes associated with the cradle-to-gate system boundary.

Raw materials and manufacturing (A1 – A3) represent the cradle-to-gate portion of a metal panel's life cycle and are required by the PCR. Metal coil (either coated or bare), containing recycled content, is transported to MCA member company manufacturing facilities. Depending on the metal product offering, companies also purchase foam chemicals, thermoplastics, and packaging / auxiliary materials. Inbound steel is transported via a combination of ship, rail, and truck from the coil suppliers manufacturing facilities. All other materials are transported solely via truck from within North America to member company facilities. At manufacturing facilities, metal coil is trimmed and formed according to product requirements.

All finished cladding and panel products are packaged on wooden pallets with a variety of protective materials, including expanded polystyrene sheets, engineered wood board, plastic banding, and plastic film shrink wrap.

Ancillary materials were also used to facilitate operations, such as lubricants and sealants. Utilities including municipal water, natural gas, propane, and diesel were also used on site at manufacturing facilities. Waste and emissions from metal coil, core materials, ancillary materials, combustible materials, and blowing agents were also accounted for. Any recycled material leaving the facility was cut-off and no credit was given.

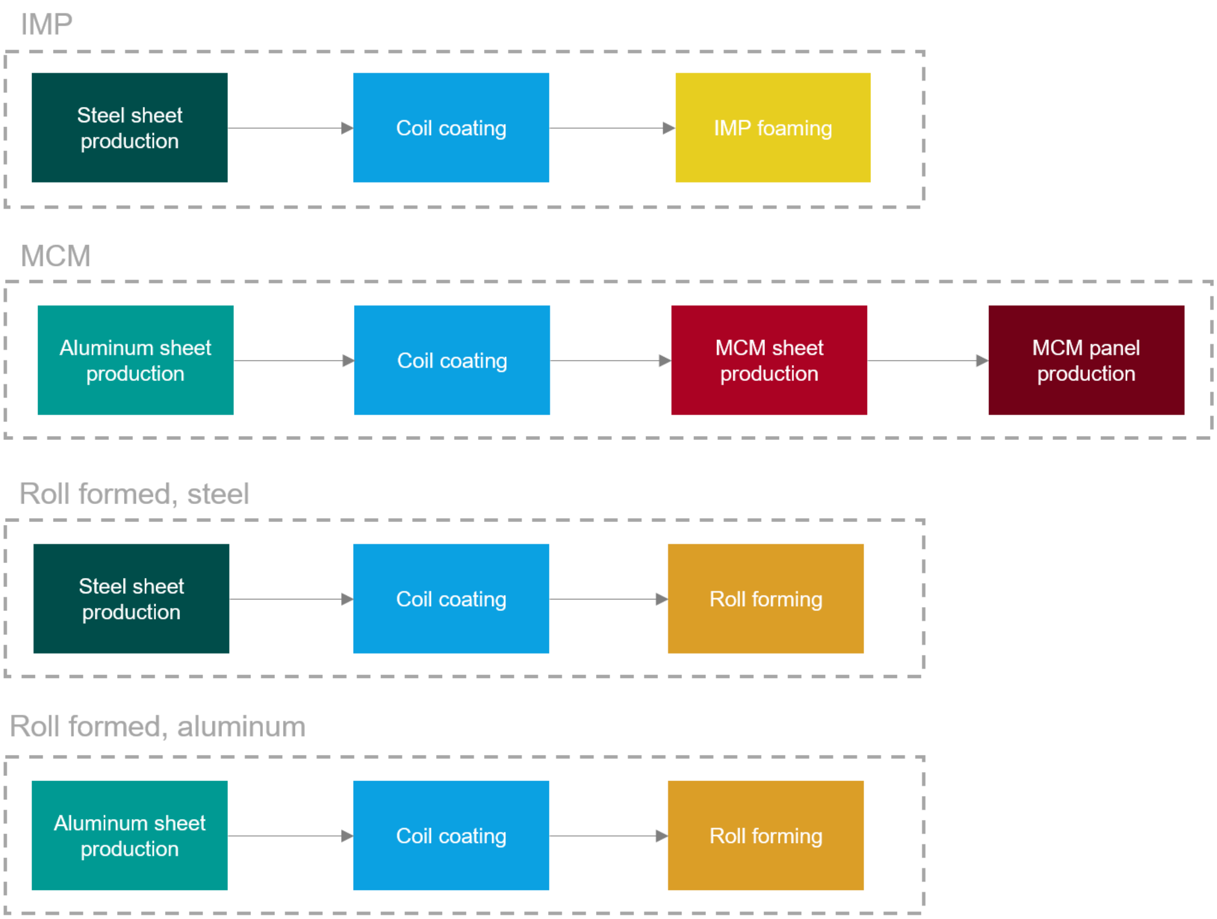

Figure 3-1: Metal cladding and panel cradle-to-gate processes

Insulated metal panel (IMP)

IMPs consist of a polyurethane foam core sandwiched between two sheets of steel. These panels are manufactured on a continuous production line. In IMP panel production, foam chemicals are mixed and injected in-line between the two steel sheets. MCA member companies use a variety of blowing agents, including HFCs, HFOs, and hydrocarbons. Emissions mainly occur during foam injection between metal sheets. Blowing agent loss rate during manufacturing ranges from 5 – 27% and is based on experiments performed by member companies. If no primary data on loss rate was provided by a company, then a the most conservative value (27%) was applied. Once the foam has cured, panels are cut to length, packaged, and distributed to construction sites. Figure 3-2, below, shows a detailed IMP manufacturing process.

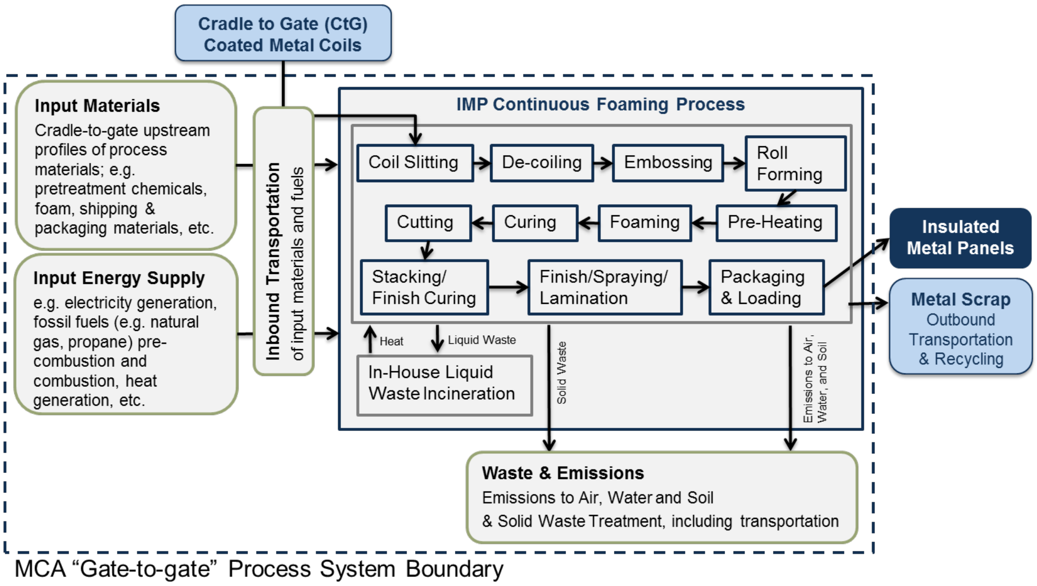

Figure 3-2: IMP manufacturing process

Metal Composite Panel (MCM)

Much like IMPs, MCMs consist of a core sandwiched between two sheets of aluminum. MCMs, however, utilize extruded polyethylene (PE) or fire-retardant thermoplastic (FR) as the core material, which is bonded to the metal layers via lamination. Figure 3-3, below, shows a detailed MCM manufacturing process.

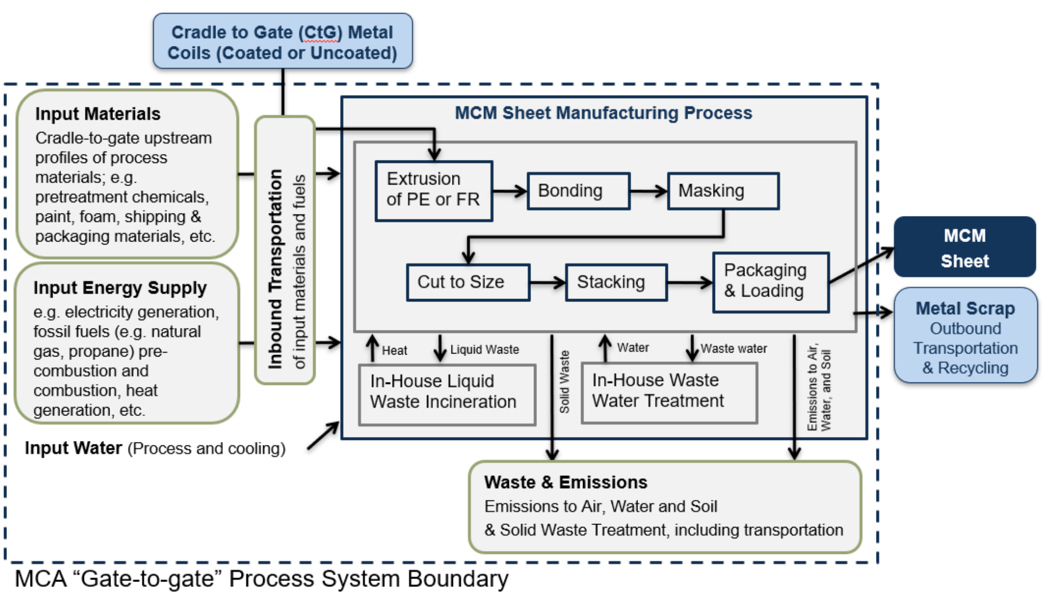

Figure 3-3: MCM manufacturing process

Roll formed steel and aluminum

Roll formed steel and aluminum products undergo the simplest production process of the evaluated products as no core is used. Steel and aluminum coated coils are formed into the desired profile using a factory roller. Figure 3-4, below, shows a detailed roll formed metal manufacturing process.

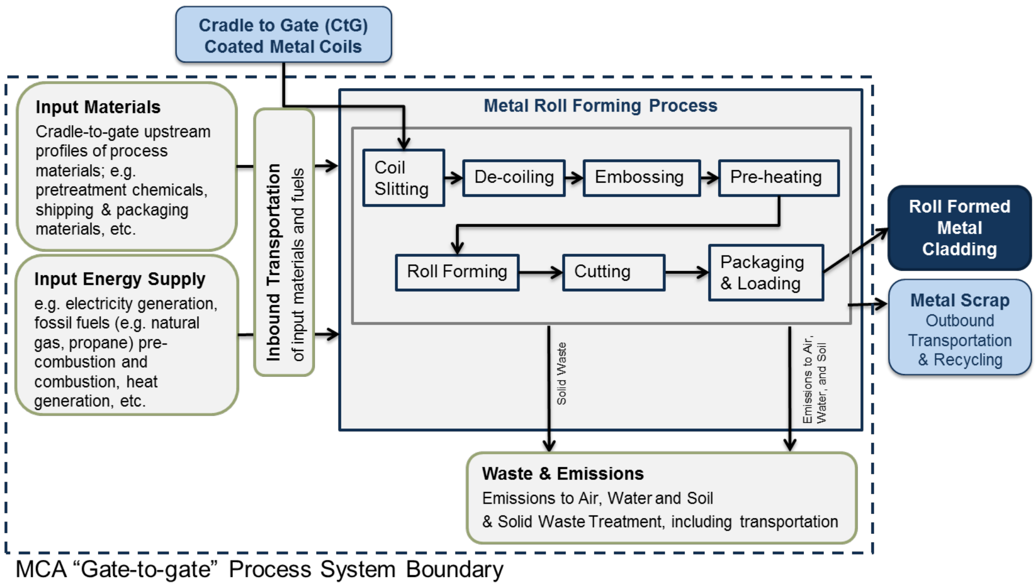

Figure 3-4: Roll formed metal manufacturing process

Annex A details unit process data for production weighted by mass output, at MCA member company facilities.

3.2.2. Distribution, Installation, Use, End-of-Life

As this is a cradle-to-gate study, all downstream life cycle phases (i.e. distribution, installation, use, and end-of-life) are excluded. This study only evaluates the impacts associated with raw material supply, inbound transportation, and manufacturing, as defined by the PCR.

3.3. Background Data

This section details the GaBi 2019 datasets used in the MCA LCA model. Datasets are grouped by energy, materials, transportation, and disposal. Documentation for all GaBi datasets can be found at http://www.gabi-software.com/support/gabi/gabi-database-2019-lci-documentation/.

3.3.1. Energy and fuels

National averages for fuel inputs and electricity grid mixes were obtained from the GaBi 2019 databases. Table 3-7 shows the key life cycle inventory (LCI) datasets used in modeling energy generation and consumption for the product system.

Table 3-1: Energy and fuel datasets

Geography	Dataset	Data Provider	Reference Year
US	Diesel mix at filling station	ts	2016
US	Electricity grid mix	ts	2016
US	Electricity grid mix – AZNM	ts	2016
US	Electricity grid mix – CAMX	ts	2016
US	Electricity grid mix – ERCT	ts	2016
US	Electricity grid mix – FRCC	ts	2016
US	Electricity grid mix – RFCE	ts	2016
US	Electricity grid mix – RFCM	ts	2016
US	Electricity grid mix – RFCW	ts	2016
US	Electricity grid mix – SRMV	ts	2016
US	Electricity grid mix – SRSO	ts	2016
US	Electricity grid mix – SRTV	ts	2016
US	Electricity grid mix – SRVC	ts	2016
US	Heavy fuel oil at refinery (0.3wt.% S)	ts	2016
US	Heavy fuel oil at refinery (2.5wt.% S)	ts	2016
US	Light fuel oil at refinery	ts	2016
US	Lubricants at refinery	ts	2016
US	Naphtha at refinery	ts	2016
US	Thermal energy from LPG	ts	2016
US	Thermal energy from natural gas	ts	2016
US	Thermal energy from propane	ts	2016

3.3.2. Raw Materials and Processes

Data for upstream and downstream raw materials and unit processes were obtained from the GaBi 2019 database. Table 3-2, below, shows the most relevant material and process datasets used in modeling the product systems.

Table 3-2: Raw material and process datasets

Geography	Dataset	Data Provider	Reference Year
EU-28	Aluminium sheet mix	ts	2018
US	Average Corrugated Product (Cradle-to-Gate, 2014)	CPA	2017
DE	BF Steel billet / slab / bloom	ts	2018
DE	Chipboard P5 (8.5% moisture) 1m3	ts	2018
US	Coil coating	MCA	2010
US	Dipropylene glycol by product propylene glycol via PO hydrogenation	ts	2018
EU-28	Expanded Polystyrene (PS 30) (EN15804 A1-A3)	ts	2018
EU-28	Expanded polystyrene foam (PS 20) (A1-A3)	ts	2018

Geography	Dataset	Data Provider	Reference Year
EU-28	Expanded polystyrene foam (PS 25) (A1-A3)	ts	2018
RNA	Hot Rolled Aluminum	AA/ts	2010
US	Kaolin (mining and processing)	ts	2018
EU-28	Kraft paper (EN15804 A1-A3)	ts	2018
US	Limestone (CaCO3; washed)	ts	2018
US	Methylene diisocyanate (MDI), by-product hydrochloric acid, methanol	ts	2018
DE	Mineral wool (Facades)	ts	2018
EU-28	Mineral wool (Flat roofs) (EN15804 A1-A3)	ts	2018
RNA	Oriented strand board (OSB)	CORRIM	2011
US	Pentane (estimation)	ts	2017
GLO	Plastic Film (PE, PP, PVC)	ts	2018
US	Polybutadiene granulate (PB)	ts	2018
US	Polyether Polyol (from PO+EO)	ts	2018
US	Polyethylene film (LDPE/PE-LD)	ts	2018
US	Polyethylene High Density Granulate (HDPE/PE-HD)	ts	2018
EU-28	Polyethylene Linear Low Density Granulate (LLDPE/PE-LLD)	ts	2018
DE	Polypropylene Film (PP) without additives	ts	2018
US	Polypropylene granulate (PP)	ts	2018
US	Polyvinyl chloride granulate (Suspension, S-PVC)	ts	2018
US	Silica sand (Excavation and processing)	ts	2018
RNA	Softwood lumber	CORRIM	2011
RNA	Softwood plywood	CORRIM	2011
GLO	Steel hot dip galvanized	worldsteel	2014
DE	Steel wire rod - open input steel billet	ts	2018
US	Tap water from surface water	ts	2018
DE	Tetrafluoroethane (R134a)	ts	2017
US	Titanium dioxide pigment (sulphate process)	ts	2018

3.3.3. Transportation

Average transportation distances and modes of transport are included for the transport of the raw materials, operating materials, and auxiliary materials to production and assembly facilities.

The GaBi 2019 database was used to model transportation. Truck transportation within the United States was modeled using the GaBi US truck transportation datasets. The vehicle types, fuel usage, and emissions for these transportation processes were developed using a GaBi model based on the most recent US Census Bureau Vehicle Inventory and Use Survey (2002) and US EPA emissions standards for heavy trucks in 2007. The 2002 VIUS survey is the latest available data source describing truck fleet fuel consumption and utilization ratios in the US based on field data (Langer, 2013), and the 2007 EPA emissions standards are considered to be the appropriate data available for describing current US truck emissions.

Table 3-3: Transportation and road fuel datasets

Geography	Name	Data Provider	Reference Year
GLO	Bulk commodity carrier, average, ocean going	ts	2018
GLO	Container ship, 5,000 to 200,000 dwt payload capacity, ocean going	ts	2018
GLO	Rail transport cargo - Diesel, average train, gross tonne weight 1,000t / 726t payload capacity	ts	2018
US	Truck - Flatbed, platform, etc. / 49,000 lb payload - 8b	ts	2018
US	Truck - Medium Heavy-duty Diesel Truck / 17,333 lb payload - 6	ts	2018
US	Truck - Medium Heavy-duty Diesel Truck / 9,333 lb payload - 3	ts	2018
US	Truck - Tank, liquid or gas / 50,000 lb payload - 8b	ts	2018
US	Truck - Trailer, basic enclosed / 45,000 lb payload - 8b	ts	2018

3.3.4. Disposal

Disposal of manufacturing waste is modeled primarily using landfill datasets, classified according to the Resource Conservation and Recovery Act (RCRA), Subtitle 3. Recycled material is modeled as leaving the system boundary burden free. Table 3-9 shows datasets used into model waste disposal.

Table 3-4: End-of-life datasets

Geography	Name	Data Provider	Reference Year
US	Ferro metals on landfill, post-consumer	ts	2018
US	Glass/inert on landfill	ts	2018
US	Municipal waste water treatment (mix)	ts	2018
US	Plastic recycling (clean scrap)	ts	2018

4. Life Cycle Inventory and Impact Assessment

This section presents both inventory and impact assessment results for the declared modules of cladding and panel products. Inventory metrics include different forms of resource use as well as environmental impact indicators as shown in Section 2.6. The impact assessment results are calculated using the US EPA's TRACI 2.1 (Tool for Reduction and Assessment of Chemical and Environmental Impacts). Each section shows tabulated results for TRACI 2.1 impact categories, resource use, output flow and waste categories, and carbon emission and removals, followed by relative results for A1-A3 for each impact category, as required by the PCR.

It shall be reiterated at this point that the reported impact categories represent impact potentials, i.e., they are approximations of environmental impacts that could occur if the emissions would (a) follow the underlying impact pathway and (b) meet certain conditions in the receiving environment while doing so. In addition, the inventory only captures that fraction of the total environmental load that corresponds to the chosen functional unit (relative approach). LCIA results are therefore relative expressions only and do not predict actual impacts, the exceeding of thresholds, safety margins, or risks.

Life cycle impact assessment and inventory results are summarized in this section. Each of the four cladding and panel product assessments consists of cradle-to-gate contribution analysis, followed by tabulated results, to provide a sense of which modules are driving environmental burden.

Please note that results are normalized to the declared unit of 100m^2 of product.

4.1. Insulated Metal Panel (IMP)

Figure 4-1 and Table 4-1, below, show life cycle impact assessment results for the IMP product. The majority of burdens for categories fall within module A1 (production of raw materials), with the exception of GWP. Within GWP, blowing agent emissions are the largest driver. AP, EP, and POCP all see more pronounced contributions from inbound transportation (A2) due to tailpipe emissions of nitrogen compounds and NMVOCs during transport.

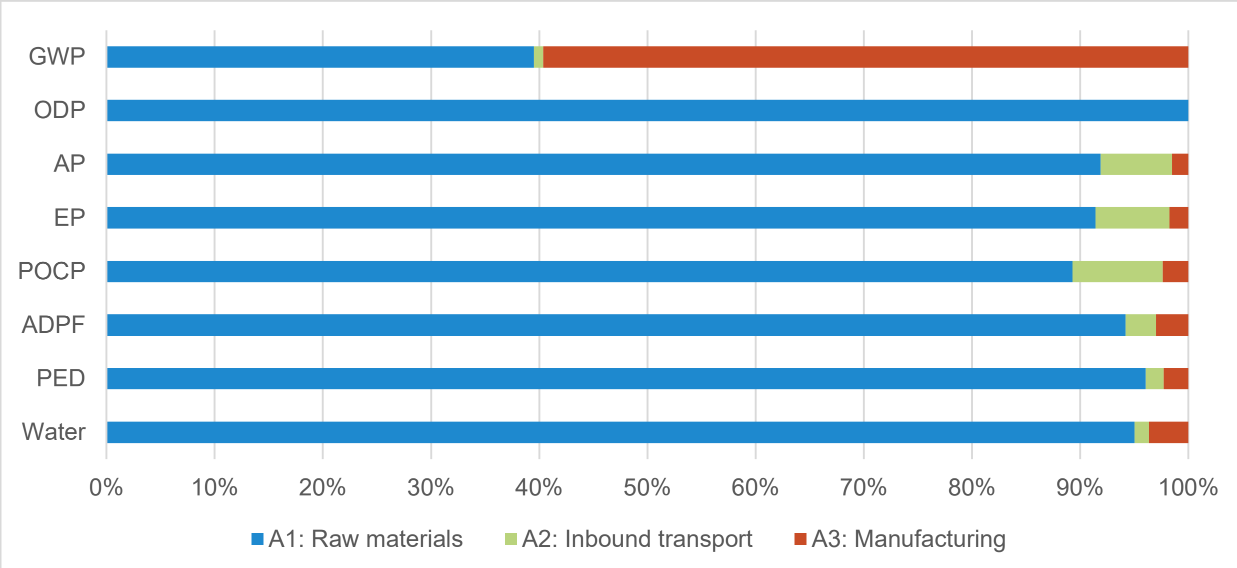

Figure 4-1: A1-A3 contribution analysis - IMP

Table 4-1: IMP results

Parameter	Unit	Total	A1	A2	A3
LCIA					
GWP	[kg CO_2 eq.]	**1.07E+04**	4.23E+03	9.15E+01	6.39E+03
ODP	[kg CFC-11 eq.]	**4.03E-05**	4.03E-05	0.00E+00	0.00E+00
AP	[kg SO_2 eq.]	**1.06E+01**	9.74E+00	7.00E-01	1.61E-01
EP	[kg N eq.]	**6.47E-01**	5.91E-01	4.42E-02	1.13E-02
SFP	[kg O_3 eq.]	**1.79E+02**	1.60E+02	1.49E+01	4.27E+00
ADPF	[Surplus MJ]	**6.34E+03**	5.97E+03	1.77E+02	1.90E+02
Resource					
RPRE	[MJ, LHV]	**2.83E+03**	2.56E+03	3.82E+01	2.33E+02
RPRM	[MJ, LHV]	**9.47E+02**	9.47E+02	0.00E+00	0.00E+00
RPRT	[MJ, LHV]	**3.78E+03**	3.51E+03	3.82E+01	2.33E+02
NRPRE	[MJ, LHV]	**6.81E+04**	6.49E+04	1.33E+03	1.84E+03
NRPRM	[MJ, LHV]	**1.21E+04**	1.21E+04	0.00E+00	0.00E+00
NRPRT	[MJ, LHV]	**8.01E+04**	7.70E+04	1.33E+03	1.84E+03
SM	[kg]	**5.39E+01**	5.39E+01	0.00E+00	0.00E+00
RSF	[MJ, LHV]	**0.00E+00**	0.00E+00	0.00E+00	0.00E+00
NRSF	[MJ, LHV]	**0.00E+00**	0.00E+00	0.00E+00	0.00E+00
RE	[MJ, LHV]	**0.00E+00**	0.00E+00	0.00E+00	0.00E+00
FW	[m^3]	**1.11E+01**	1.06E+01	1.48E-01	4.06E-01
Waste					
HWD	[kg]	**2.27E-03**	2.26E-03	9.92E-06	1.10E-06
NHWD	[kg]	**1.40E+02**	1.36E+02	4.75E-02	4.56E+00
HLRW	[kg]	**1.09E-03**	9.75E-04	3.52E-06	1.14E-04
ILLRW	[kg]	**2.53E-02**	2.21E-02	9.51E-05	3.14E-03
CRU	[kg]	**0.00E+00**	0.00E+00	0.00E+00	0.00E+00
MFR	[kg]	**5.06E+01**	0.00E+00	0.00E+00	5.06E+01
MER	[kg]	**0.00E+00**	0.00E+00	0.00E+00	0.00E+00
EET	[MJ]	**4.31E-03**	4.31E-03	0.00E+00	0.00E+00

4.2. Metal Composite Material Panel (MCM)

Figure 4-2 and Table 4-2, below, show life cycle impact assessment results for the MCM product. The majority of burdens for categories fall within module A1 (production of raw materials). Within raw materials production, the majority of impact categories are driven by the production of aluminum and masking material. EP and SFP have more pronounced contribution in inbound transportation due to tailpipe emissions of nitrogen compounds.

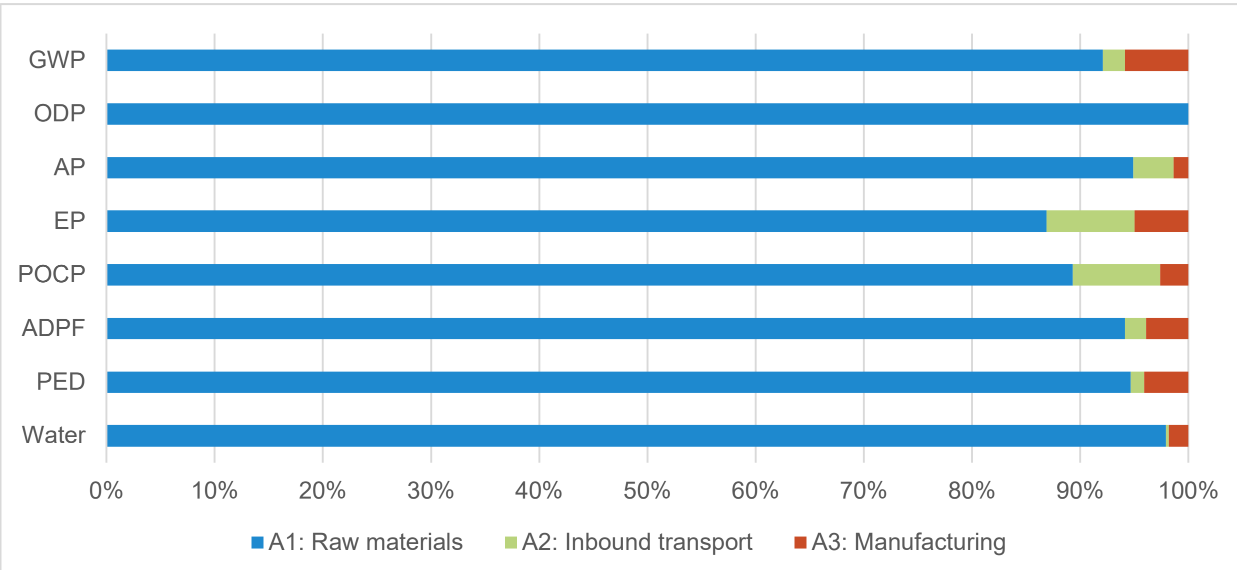

Figure 4-2: A1-A3 contribution analysis - MCM

Table 4-2: MCM results

Parameter	Unit	Total	A1	A2	A3
LCIA					
GWP	[kg CO_2 eq.]	**2.80E+03**	2.58E+03	5.71E+01	1.64E+02
ODP	[kg CFC-11 eq.]	**1.10E-07**	1.10E-07	0.00E+00	0.00E+00
AP	[kg SO_2 eq.]	**1.16E+01**	1.11E+01	4.32E-01	1.61E-01
EP	[kg N eq.]	**3.61E-01**	3.13E-01	2.94E-02	1.79E-02
SFP	[kg O_3 eq.]	**1.29E+02**	1.15E+02	1.04E+01	3.39E+00
ADPF	[Surplus MJ]	**5.70E+03**	5.37E+03	1.11E+02	2.23E+02
Resource					
RPRE	[MJ, LHV]	**7.79E+03**	7.61E+03	2.46E+01	1.58E+02
RPRM	[MJ, LHV]	**1.32E+03**	1.32E+03	0.00E+00	0.00E+00
RPRT	[MJ, LHV]	**9.11E+03**	8.93E+03	2.46E+01	1.58E+02
NRPRE	[MJ, LHV]	**4.93E+04**	4.58E+04	8.33E+02	2.72E+03
NRPRM	[MJ, LHV]	**1.72E+04**	1.72E+04	0.00E+00	0.00E+00
NRPRT	[MJ, LHV]	**6.65E+04**	6.29E+04	8.33E+02	2.72E+03
SM	[kg]	**3.48E+02**	3.48E+02	0.00E+00	0.00E+00
RSF	[MJ, LHV]	**0.00E+00**	0.00E+00	0.00E+00	0.00E+00
NRSF	[MJ, LHV]	**0.00E+00**	0.00E+00	0.00E+00	0.00E+00
RE	[MJ, LHV]	**0.00E+00**	0.00E+00	0.00E+00	0.00E+00
FW	[m^3]	**3.70E+01**	3.63E+01	9.52E-02	6.72E-01

Waste					
HWD	[kg]	**1.64E-01**	1.64E-01	6.41E-06	1.22E-06
NHWD	[kg]	**4.67E+02**	4.66E+02	3.04E-02	6.95E-01
HLRW	[kg]	**7.60E-04**	5.31E-04	2.21E-06	2.27E-04
ILLRW	[kg]	**1.99E-02**	1.36E-02	5.97E-05	6.26E-03
CRU	[kg]	**0.00E+00**	0.00E+00	0.00E+00	0.00E+00
MFR	[kg]	**0.00E+00**	0.00E+00	0.00E+00	0.00E+00
MER	[kg]	**0.00E+00**	0.00E+00	0.00E+00	0.00E+00
EET	[MJ]	**0.00E+00**	0.00E+00	0.00E+00	0.00E+00

4.3. Roll formed steel cladding

Figure 4-3 and Table 4-3, below, show life cycle impact assessment results for steel roll formed cladding. Nearly the entirety of burdens for all categories fall within module A1 (production of raw materials). Within raw materials production, the majority of impact categories are driven by the production of steel.

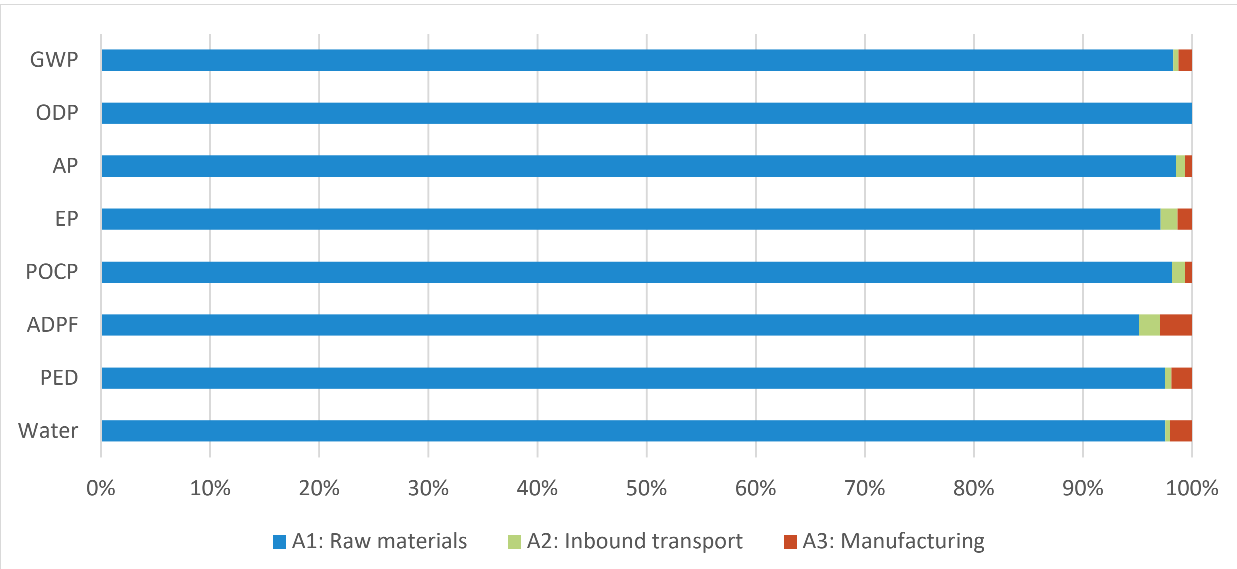

Figure 4-3: A1-A3 contribution analysis – steel roll formed cladding

Table 4-3: Steel roll formed cladding results

Parameter	Unit	Total	A1	A2	A3
LCIA					
GWP	[kg CO_2 eq.]	**1.53E+03**	1.51E+03	7.07E+00	1.93E+01
ODP	[kg CFC-11 eq.]	**1.88E-05**	1.88E-05	0.00E+00	0.00E+00
AP	[kg SO_2 eq.]	**4.00E+00**	3.95E+00	3.36E-02	2.60E-02
EP	[kg N eq.]	**1.80E-01**	1.75E-01	2.81E-03	2.43E-03
SFP	[kg O_3 eq.]	**6.49E+01**	6.37E+01	7.65E-01	4.27E-01
ADPF	[Surplus MJ]	**7.20E+02**	6.85E+02	1.39E+01	2.12E+01
Resource					
RPRE	[MJ, LHV]	**7.26E+02**	7.05E+02	3.23E+00	1.82E+01
RPRM	[MJ, LHV]	**7.92E+02**	7.92E+02	0.00E+00	0.00E+00
RPRT	[MJ, LHV]	**1.52E+03**	1.50E+03	3.23E+00	1.82E+01
NRPRE	[MJ, LHV]	**1.73E+04**	1.69E+04	1.04E+02	3.29E+02
NRPRM	[MJ, LHV]	**5.53E+01**	5.53E+01	0.00E+00	0.00E+00
NRPRT	[MJ, LHV]	**1.74E+04**	1.69E+04	1.04E+02	3.29E+02
SM	[kg]	**3.57E+01**	3.57E+01	0.00E+00	0.00E+00
RSF	[MJ, LHV]	**0.00E+00**	0.00E+00	0.00E+00	0.00E+00
NRSF	[MJ, LHV]	**0.00E+00**	0.00E+00	0.00E+00	0.00E+00
RE	[MJ, LHV]	**0.00E+00**	0.00E+00	0.00E+00	0.00E+00
FW	[m^3]	**3.17E+00**	3.09E+00	1.25E-02	6.48E-02
Waste					
HWD	[kg]	**1.62E-03**	1.61E-03	8.45E-07	1.40E-07
NHWD	[kg]	**6.68E+01**	6.67E+01	3.93E-03	1.01E-01
HLRW	[kg]	**1.20E-04**	8.25E-05	2.79E-07	3.73E-05
ILLRW	[kg]	**1.70E-03**	6.64E-04	7.52E-06	1.03E-03
CRU	[kg]	**0.00E+00**	0.00E+00	0.00E+00	0.00E+00
MFR	[kg]	**0.00E+00**	0.00E+00	0.00E+00	0.00E+00
MER	[kg]	**0.00E+00**	0.00E+00	0.00E+00	0.00E+00
EET	[MJ]	**2.17E-03**	2.17E-03	0.00E+00	0.00E+00

4.4. Roll formed aluminum cladding

Figure 4-4 and Table 4-4, below, show life cycle impact assessment results for aluminum roll formed cladding. Nearly the entirety of burdens for all categories fall within module A1 (production of raw materials). Within raw materials production, the majority of impact categories are driven by the production of aluminum.

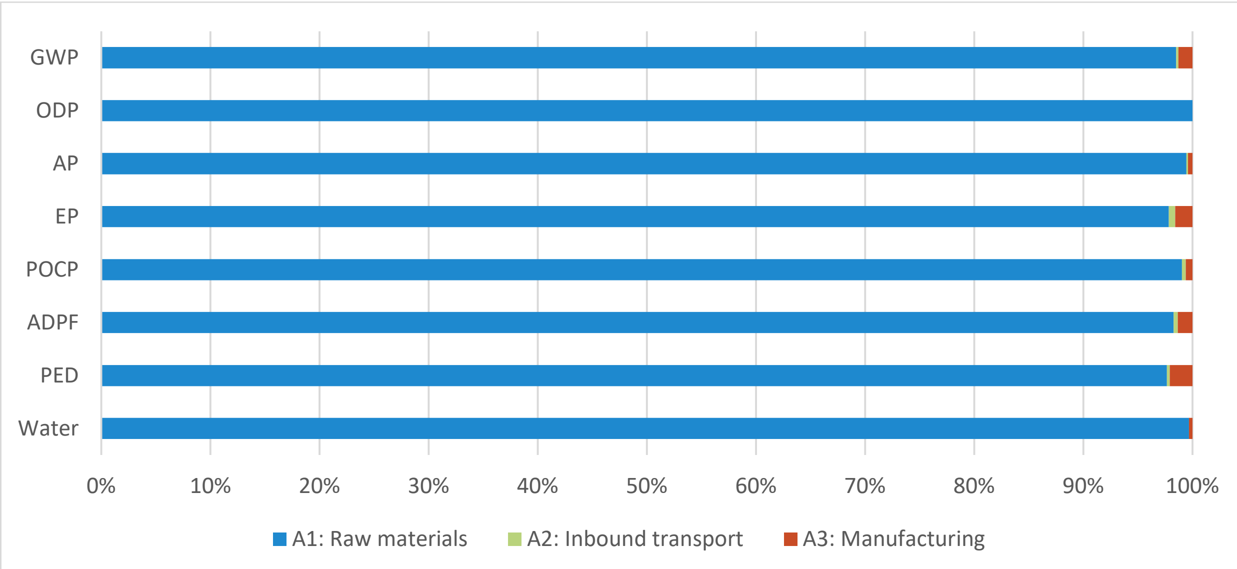

Figure 4-4: A1-A3 contribution analysis – aluminum roll formed cladding

Table 4-4: Aluminum roll formed cladding results

Parameter	Unit	Total	A1	A2	A3
LCIA					
GWP	[kg CO_2 eq.]	**1.86E+03**	1.83E+03	3.91E+00	2.35E+01
ODP	[kg CFC-11 eq.]	**1.86E-05**	1.86E-05	0.00E+00	0.00E+00
AP	[kg SO_2 eq.]	**9.12E+00**	9.07E+00	1.44E-02	3.57E-02
EP	[kg N eq.]	**2.27E-01**	2.23E-01	1.29E-03	3.60E-03
SFP	[kg O_3 eq.]	**9.17E+01**	9.08E+01	3.24E-01	5.62E-01
ADPF	[Surplus MJ]	**2.10E+03**	2.06E+03	7.69E+00	2.82E+01
Resource					
RPRE	[MJ, LHV]	**9.29E+03**	9.26E+03	1.79E+00	2.39E+01
RPRM	[MJ, LHV]	**9.09E+02**	9.09E+02	0.00E+00	0.00E+00
RPRT	[MJ, LHV]	**1.02E+04**	1.02E+04	1.79E+00	2.39E+01
NRPRE	[MJ, LHV]	**2.36E+04**	2.31E+04	5.78E+01	4.95E+02
NRPRM	[MJ, LHV]	**1.49E+02**	1.49E+02	0.00E+00	0.00E+00
NRPRT	[MJ, LHV]	**2.38E+04**	2.32E+04	5.78E+01	4.95E+02
SM	[kg]	**2.06E+02**	2.06E+02	0.00E+00	0.00E+00
RSF	[MJ, LHV]	**0.00E+00**	0.00E+00	0.00E+00	0.00E+00
NRSF	[MJ, LHV]	**0.00E+00**	0.00E+00	0.00E+00	0.00E+00
RE	[MJ, LHV]	**0.00E+00**	0.00E+00	0.00E+00	0.00E+00
FW	[m^3]	**3.57E+01**	3.56E+01	6.93E-03	1.07E-01
Waste					
HWD	[kg]	**7.52E-02**	7.52E-02	4.68E-07	1.65E-07
NHWD	[kg]	**4.89E+02**	4.88E+02	2.18E-03	2.20E-01
HLRW	[kg]	**1.76E-03**	1.67E-03	1.54E-07	8.80E-05
ILLRW	[kg]	**2.97E-02**	2.72E-02	4.16E-06	2.43E-03
CRU	[kg]	**0.00E+00**	0.00E+00	0.00E+00	0.00E+00
MFR	[kg]	**0.00E+00**	0.00E+00	0.00E+00	0.00E+00
MER	[kg]	**0.00E+00**	0.00E+00	0.00E+00	0.00E+00
EET	[MJ]	**1.58E-03**	1.58E-03	0.00E+00	0.00E+00

5. Interpretation

5.1. Identification of Relevant Findings

The results in Section 4 represent the cradle-to-gate life cycle performance of 100 m^2 metal cladding and panel products. These results are consistent with metal panel characteristics, listed in Table 2-1, with products using more material and thicker gauge metal corresponding to higher potential environmental impact (i.e. IMP and MCM are associated with higher potential impact than steel and aluminum cladding).

For all products, raw materials production (A1) is the greatest contributor to the majority of impact categories and is primarily driven by metal production. Inbound transportation (A2) tends to have a slightly more pronounced, though overall negligible, contribution in EP, AP, and SFP. GWP of the IMP product is the only metric not dominated by raw materials production; the majority of impact contribution comes from manufacturing (A3), which is driven by the emissions of blowing agent.

5.2. Data Quality Assessment

Inventory data quality is judged by its precision (measured, calculated or estimated), completeness (e.g., unreported emissions), consistency (degree of uniformity of the methodology applied) and representativeness (geographical, temporal, and technological).

To cover these requirements and to ensure reliable results, first-hand industry data in combination with consistent background LCA information from the GaBi 2019 database were used. The LCI datasets from the GaBi 2019 database are widely distributed and used with the GaBi 8.7 Software. The datasets have been used in LCA models worldwide in industrial and scientific applications in internal as well as in many critically reviewed and published studies. In the process of providing these datasets they are cross-checked with other databases and values from industry and science.

5.2.1. Precision and Completeness

- ✓ **Precision:** As the majority of the relevant foreground data are measured data or calculated based on primary information sources of the owner of the technology, precision is considered to be high. Seasonal variations were balanced out by using yearly averages. All background data are sourced from GaBi databases with the documented precision.
- ✓ **Completeness:** Each foreground process was checked for mass balance and completeness of the emission inventory. This study omits the use of raw materials packaging, as it represents less than 1% of overall inputs to the product system and is not environmentally relevant. Capital goods and infrastructure were also excluded, as they produce millions of units over the course of their life and the impacts attributed to each functional unit of metal panel or cladding is negligible. No other data were knowingly omitted. Completeness of foreground unit process data is considered to be high. All background data are sourced from GaBi databases with the documented completeness.

5.2.2. Consistency and Reproducibility

- ✓ **Consistency:** To ensure data consistency, all primary data were collected with the same level of detail, while all background data were sourced from the GaBi databases.
- ✓ **Reproducibility:** Reproducibility is supported as much as possible through the disclosure of input-output data, dataset choices, and modeling approaches in this report. Based on this information, any third party should be able to approximate the results of this study using the same data and modeling approaches.

5.2.3. Representativeness

- ✓ **Temporal:** All of the primary data is taken from 12 months of continuous operation in the 2017 calendar year. All secondary data were obtained from the GaBi 2019 databases and published EPDs. Data are representative of the years 2006 to 2018.
- ✓ **Geographical:** All primary and secondary data were collected specific to the countries or regions under study. Where country-specific or region-specific data were unavailable, proxy data were used. Participating members represent a significant majority of annual production for the region under study. Geographical representativeness is considered to be high.
- ✓ **Technological:** All primary and secondary data were modeled to be specific to the technologies or technology mixes under study. Where technology-specific data were unavailable, proxy data were used. Participating members represent a significant majority of annual production for the region under study. Technological representativeness is considered to be high.

5.3. Model Completeness and Consistency

5.3.1. Completeness

All relevant process steps for each product system were considered and modeled to represent each specific situation. The process chain is considered sufficiently complete and detailed with regard to the goal and scope of this study.

5.3.2. Consistency

All assumptions, methods and data are consistent with each other and with the study's goal and scope. Differences in background data quality were minimized by exclusively using LCI data from the GaBi 2019 databases. System boundaries, allocation rules, and impact assessment methods have been applied consistently throughout the study.

5.4. Conclusions, Limitations, and Recommendations

5.4.1. Conclusions

The goal of this study was to conduct a cradle-to-gate LCA of metal panel and cladding products in order to develop EPDs that cover IMP, MCM, roll formed steel cladding, and roll formed aluminum cladding. The creation of these EPDs will allow consumers or architects in the building and construction industry to make better-informed decisions about the environmental impacts associated with the products they choose. Overall, the study found that environmental performance is driven primarily by raw materials, with the majority of raw material impact from the production of metal coil. Unlike other impact categories, IMP global warming potential is driven by the emissions of blowing agent during manufacturing.

5.4.2. Assumptions and Limitations

This study was carried out for MCA with the goal of quantifying the environmental performance of the four metal products. This will, in turn, enable them to communicate results via EPDs, as well as to gain understanding and identify opportunities for improvement. The intent of this study was not to conduct a comparative assessment of MCA member company products. Additionally, the results from this analysis are specifically for the aforementioned metal products and are not intended to be applied to other adjacent insulation products on the market.

This study was based on primary data collected at MCA member company facilities. Datasets selected to represent the production of raw materials by upstream suppliers are based on regional or global averages rather than on primary data collected directly from member company supply chains. When selecting these datasets, a conservative approach was applied in that datasets associated with higher impacts are used when there are multiple possible options.

Global warming potential for IMP products is overwhelmingly being driven by the emission of blowing agent. Based on discussions with industry experts, this study assumes that 5 - 27% of blowing agents are emitted during manufacturing. However, actual blowing agent release may vary, thus affecting global warming potential impacts.

Lastly, this study was conducted in accordance with a PCR. While this guidance document has been developed by industry experts to best represent this product system, real life environmental impacts of metal panel and cladding products may extend beyond those defined in this document.

5.4.3. Recommendations

As technologies improve and process innovations emerge, efficiencies and overall environmental impacts should improve over time. For the IMP foaming process, an improved carbon-footprint profile can be realized if all companies move away from HFC blowing agents such as R-134a, to lower GWP blowing agents, such as HFOs or pentane, though either of these substitutes may come at the expense of higher environmental impacts in other categories Since most impact assessment categories are driven by raw material production (A1), MCA could aim to minimize high impact raw materials such as steel and aluminum. Additionally, MCA could work with suppliers to source material that is produced in low-impact grid mixes.

References

Bare, J. (2012). *Tool for the Reduction and Assessment of Chemical and other Environmental Impacts (TRACI) - Software Name and Version Number: TRACI version 2.1 - User's Manual.* Washington, D.C.: U.S. EPA.

EPA. (2012). *Tool for the Reduction and Assessment of Chemical and other Environmental Impacts (TRACI) – User's Manual.* Washington, D.C.: U.S. EPA.

IPCC. (2013). *Climate Change 2013: The Physical Science Basis.* Genf, Schweiz: IPCC.

ISO. (2006a). *ISO 14040: Environmental management – Life cycle assessment – Principles and framework.* Geneva: International Organization for Standardization.

ISO. (2006b). *ISO 14044: Environmental management – Life cycle assessment – Requirements and guidelines.* Geneva: International Organization for Standardization.

ISO. (2017). *ISO 21930: Sustainability in buildings and civil engineering works -- Core rules for environmental product declarations of construction products and services.* Geneva: International Organization for Standardization.

Langer, T. (2013). *Heavy-Duty Vehicle Fuel Efficiency Data in the United States.* Washington, DC: American Council for an Energy -Efficient Economy.

MCA. (2014). *Environmental Product Declaration: Metal Composite Mataerial Panels, Industry-wide EPD.* UL Environment.

thinkstep. (2014). *GaBi LCA Database Documentation*. Retrieved from thinkstep AG: http://database-documentation.gabi-software.com

UL Environment. (2018). *Product Category Rules for Building-Related Products and Services - Part A: Life Cycle Assessment Calculation Rules and Report Requirements, UL 10010 (v3.1).*

UL Environment. (2018). *Product Category Rules for Part B: Insulated Metal Panels, Metal Composite Panels, and Metal Cladding: UL 10010-5.* UL Environment.

A. Annex – Unit process data

Table A-1: Unit process data - IMP

Parameter	Unit	Total
Input		
Steel coil	kg	**7.80E+02**
MDI	kg	**1.75E+02**
Polyol	kg	**1.26E+02**
Mineral wool	kg	**2.77E+01**
Blowing agent	kg	**2.42E+01**
Catalyst	kg	**1.16E+00**
Electricity	MJ	**5.20E+02**
Natural gas	MJ	**4.32E+02**
Propane	MJ	**5.60E+01**
Wood pallet	kg	**3.93E+01**
Particle board	kg	**6.23E-01**
OSB	kg	**2.68E+01**
EPS	kg	**1.69E+01**
PE film	kg	**1.64E+01**
Output		
Insulated metal panel	kg	**1.28E+03**
Steel scrap	kg	**5.06E+01**
Foam scrap	kg	**2.44E+00**
Mineral wool scrap	kg	**1.66E+00**
Blowing agent emissions	kg	**6.53E+00**

Table A-2: Unit process data - MCM

Parameter	Unit	Total
Input		
Aluminum coil	kg	**3.10E+02**
PE core	kg	**2.26E+02**
PE core, recycled	kg	**1.03E+02**
FR core	kg	**1.87E+02**
FR core, recycled	kg	**2.27E+01**
Masking material	kg	**6.99E+00**
Bonding material	kg	**7.61E+00**
Water	L	**1.27E+02**
Electricity	MJ	**7.38E+02**
Natural gas	MJ	**3.25E+02**
Propane	MJ	**1.43E+01**
Lubricant	kg	**2.05E-01**
Wood pallet	kg	**6.73E+01**
OSB	kg	**1.31E+01**
EPS	kg	**1.86E-04**
Output		
Metal composite material panel	kg	**7.56E+02**
Aluminum scrap	kg	**1.98E+01**
Manufacturing waste	kg	**5.38E+01**

Table A-3: Unit process data - steel roll formed cladding

Parameter	Unit	Total
Input		
Steel coil	kg	**5.16E+02**
Sealant	kg	**7.75E-02**
Water	L	**9.52E+00**
Electricity	MJ	**1.05E+02**
Natural gas	MJ	**1.04E+01**
Propane	MJ	**1.68E+01**
Lubricant	kg	**8.72E-02**
Wood pallet	kg	**5.16E+01**
Corrugated material	kg	**1.04E+00**
Paper	kg	**2.46E-02**
EPS	kg	**7.90E-03**
Plastic film	kg	**1.28E+00**
Steel banding	kg	**8.09E-01**
Output		
Steel roll formed cladding	kg	**4.91E+02**
Steel scrap	kg	**1.96E+01**

Table A-4: Unit process data - aluminum roll formed cladding

Parameter	Unit	Total
Input		
Aluminum coil	kg	**2.86E+02**
Sealant	kg	**2.06E-02**
Water	L	**5.67E+01**
Electricity	MJ	**1.76E+02**
Natural gas	MJ	**8.88E-01**
Propane	MJ	**4.33E+00**
Lubricant	kg	**5.89E-02**
Wood pallet	kg	**5.69E+01**
Corrugated material	kg	**3.22E+00**
Paper	kg	**5.51E-03**
EPS	kg	**1.77E-03**
Plastic film	kg	**3.47E+00**
Steel banding	kg	**2.26E-01**
Output		
Aluminum roll formed cladding	kg	**2.77E+02**
Aluminum scrap	kg	**1.01E+01**
Manufacturing waste	kg	**9.35E-01**