ENVIRONMENTAL PRODUCT DECLARATION

ROLL-FORMED CLADDING

ALUMINUM PANELS
STEEL PANELS

PAC-CLAD
PETERSEN

For more than 50 years, Petersen Aluminum Corporation (also known by the brand name PAC-CLAD®) based in Elk Grove Village, IL, with branches in Georgia, Texas, Maryland and Minnesota, has been a leading provider of architectural metal products. PAC-CLAD products provide unmatched aesthetics, performance and sustainability to any project. Where possible, Petersen products include a high percentage of recycled material. Additionally, these products offer a long life span, and at the end of their extended service life are 100% recyclable. Most of the PAC-CLAD colors meet LEED®, ENERGY STAR® and Cool Roof Rating Council certification requirements.

For more information visit www.pac-clad.com or www.pacgreeninfo.com for the most current information on sustainable metal roofing.

UL CERTIFIED
ENVIRONMENTAL PRODUCT DECLARATION
UL.COM/EPD

PAC-CLAD PETERSEN

Roll-Formed Steel and Aluminum Panels

According to ISO 14025

This document is an environmental product declaration in accordance with ISO 14025. This EPD does not guarantee that any performance benchmarks, including environmental performance benchmarks, are met. EPDs are intended to complement Type I environmental performance labels. EPDs provide LCA-based information and additional information on the environmental aspects of products and assist purchasers and users to make informed comparisons between products. EPDs are not comparative assertions. EPDs encourage improvement of environmental performance and provide information for assessing the environmental impacts of products over their life cycles. EPDs not based on an LCA covering all life cycle stages, or based on a different PCR, are examples of declarations that have limited comparability. EPDs from different programs may not be comparable.

CERTIFIED ENVIRONMENTAL PRODUCT DECLARATION

PROGRAM OPERATOR	UL Environment
DECLARATION HOLDER	Petersen Aluminum Corporation
DECLARATION NUMBER	4786652606.101.1
DECLARED PRODUCT	Roll Formed Steel and Aluminum Panels
REFERENCE PCR	Metal Cladding: Roof and Wall Panels (UL, October 2012)

DATE OF ISSUE	March 10, 2015
PERIOD OF VALIDITY	5 Years

CONTENTS OF THE DECLARATION	Product definition and information about building physics Information about basic material and the material's origin Description of the product's manufacture Indication of product processing Information about the in-use conditions Life cycle assessment results Testing results and verifications

The PCR review was conducted by:	UL Environment Review Panel Thomas Gloria (Chairperson)
This declaration was independently verified in accordance with ISO 14025 by Underwriters Laboratories ☐ INTERNAL ☐ EXTERNAL	[signature] Tom Gloria, Industrial Ecology Consultants
This life cycle assessment was independently verified in accordance with ISO 14044 and the reference PCR by:	[signature] Britt Willingham, UL Environment

Description of organization and product

Organization Description

The product configurations offered herein use ranges representative of all types of roll-formed metal panels based on specific products from Petersen Aluminum.

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Product Benefits

For decades, roll-formed metal wall and roof panels have served building owners and architects as one of the best combinations of economy, service and design; the reasons for this are many. They offer a wide selection of profiles and a multitude of design options. Preformed metal wall panels are manufactured from a variety of metals, including steel, aluminum, copper and zinc. Ongoing development of coating technology continues to provide longer life spans for the metal panels, making them a particularly important part of mainstream commercial building design.

Higher education facilities are commonly roofed with metal panels, as seen here on a science building in Georgia.

Metal is used for coping, trim and similar functions other than cladding roofs and walls, like on this fueling station in Illinois.

A variety of flush wall panel colors can be used to create unique mosaic designs such as on this casino in Oklahoma.

High solar reflectivity and the use of recycled materials to manufacture roofing panels help earn LEED points for residential buildings like this single-family home in Illinois.

A high degree of customization possibilities encourages architects to specify metal roof panels for education facilities such as this elementary school in Connecticut.

More color options translates to more stimulating visual appeal as seen at this water park in Georgia.

Metal roof panels can support solar power panels such as those on the roof of this store in Illinois that produces as much energy as it consumes for a net-zero result.

Metal roof panels can be curved to create architecturally creative and visually appealing roof designs, such as this museum in Tennessee.

Product Description

Roll-formed metal panels are designed and produced for commercial and residential applications. This declaration is intended for business-to-business applications (B2B).

Panels are custom roll-formed from coils of steel or aluminum to fit a variety of roof and wall applications. The panels can be factory-formed (Figure 1) or formed on the job site using a mobile roll former (Figure 2) or a combination of both. The metal panels offer long-term durability and come in a broad pallette of colors and finishes to maximize design options. A wide range of panel profiles is available to meet building code and aesthetic requirements, as illustrated in Figure 3.

Figure 1: Inline Roll Former (Photo courtesy The Bradbury Co.)

Figure 2: Mobile Roll Former (Photo courtesy Schlebach Machines)

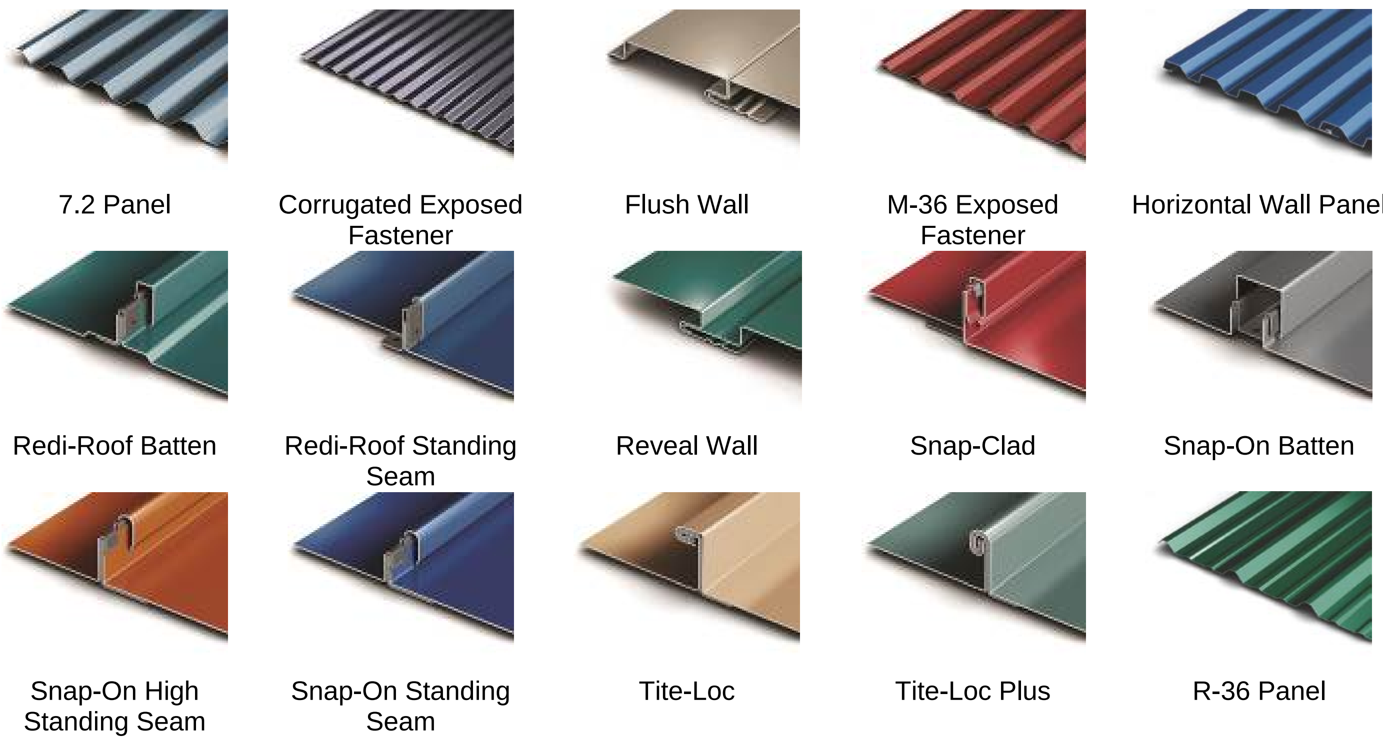

Figure 3: Images representing the range of panel profiles

Range of Applications

Steel and aluminum panels are selected for a variety of roof and wall applications because of their long-term durability, low maintenance, wide variety of color and finish options, and their ability to help improve energy efficiency such as with solar roof and wall systems, and rainscreen applications. Metal panels require less maintenance than other exterior systems and meet the most demanding performance requirements. Many designers and building owners also choose metal panels for the environmental value derived from being made with recycled content and being recyclable or reusable at the end of a building's useful life. Common applications include these structure types:

Banking	Hospitality
Commercial	Institutional
Healthcare	Light commercial and industrial
Municipal	Residential
Public venues, such as sports complexes, museums and convention centers	Retail
Religious	Schools and Universities
	Transportation

Table 1: Examples of the types of structures using steel panels for roofs and walls

Materials

The LCA results in this document represent aluminum and steel roll-formed cladding panels. Standing-seam roofing panels and some wall-cladding panels are roll formed to create interlocking joints which accommodate the fastener and concealed clip system to achieve panel-to-panel engagement. Roll-formed exposed-fastener roof and wall panels feature overlapping edges which are mechanically fastened to the substrate. A variety of profiles in various widths are available for metal roof systems. Profile depth range is 2 inches or less.

Raw materials/primary products

Component	Material	Availability	Origin	Mass (%)
Galvanized/ Galvalume panels	Steel coil, hot-dip coated	Fossil resource, limited	North America	>99%
Anti-corrosion coating	Spray applied thermoplastic	Fossil resource, limited	North America	<1%
Aluminum panels	Aluminum coil	Fossil resource, limited	North America	>99%
Anti-corrosion coating	Spray applied thermoplastic	Fossil resource, limited	North America	<1%

Table 2: Base material mass by percentage; Petersen average

Raw Material Extraction and Origin

Steel coil represents steel that has been hot-dip coated (e.g. zinc, aluminum-zinc coated) and rolled to from 18 to 29 gauge thickness. The hot-dip coating provides corrosion protection and improved aesthetics before and after the roll-forming process is applied. For aesthetic reasons, steel coil may be pre-painted using a continuous coil coating process whereby durable exterior primers and finish coats are applied to the metal surface. Light striations, pencil-ribbing (also known as stiffening beads) may be applied to reduce oil-canning.

Aluminum coils are rolled in thicknesses up to 18 gauge (.040” thickness) and undergo the same intermediate processes before undergoing the roll-forming process.

The mining location and upstream transportation distances are not specified, as this EPD considered information from multiple suppliers considered to be industry-typical. Aluminum coil production and coating are known to be performed in the same facility. For steel coils, there is a very short haul, 1 mile, from the site of coil production to the site of coil coating. Following the coil coating process, the average inbound transportation to the Petersen roll forming facility in Elk Grove, Illinois is 87 miles for steel coil and 565 miles for aluminum.

Availability of Raw Materials

All raw materials are produced from fossil resources and thus are of limited availability. Hot-dip coated steel coil production in North America, however, consumes around 0.44 kg of scrap steel per kilogram of output. Similarly, aluminum coil used by Petersen is of 0.77 kg secondary sources per 1 kg of output.

Roll Forming Process

The roll forming facilities are located in five branches—Georgia, Maryland, Illinois, Minnesota, and Texas. Roll forming is a continuous bending operation in which a strip of metal (steel or aluminum) is passed through consecutive sets of rolls, or stands, each performing only an incremental part of the bend, until the desired cross-section profile is obtained. Roll forming is ideal for producing parts with long lengths or in large quantities with a minimum amount of handling as compared to other types of forming (i.e. press brake). A variety of cross-section profiles can be produced, but each profile requires a carefully crafted set of roll tools. Roll forming can be performed in factories with permanently positioned machines, or in the field will mobile roll formers.

Producing the panels is a five-stage process, as follows: (1) The metal coils are introduced from an uncoiler. (2) A flattener ensures an even, consistent surface for shaping. (3) Any punching is done by presses prior to forming. (4) The coil then enters a series of rolls designed to incrementally shape the steel or aluminum sheet into the desired profile. (5) Finally, the roll-formed panel is sheared to the required length, and stacked for inspection and final packaging. Scrap metal generated are sent to external recyclers.

Delivery Conditions and Properties

The delivery conditions can vary highly depending on the needs of the building structure and design. Panel width can range from approximately 10 inches to 36 inches (0.25 meters to 1 meter, approximately). As characteristic of continuous production methods, panels can be sheared to the required length, but can range from 4 feet to 64 feet (1 meters to 20 meters, approximately) depending on panel profile.

Roll-formed metal panels can be produced with different skin metals such as zinc and copper. Steel and aluminum, however, remains the dominant material.

Panel thickness can range from 29 gauge to 18 gauge. Thickness of the panels themselves can vary due to different corrugated profile designs.

Packaging

The finished metal cladding panels are stacked, bundled, and secured with wooden pallets and plastic film wrap, as shown in Figure 4.

Figure 4: Metal roof and wall systems are generally transported by truck from the factory to a job site as shown in this picture. They can also be loaded into closed containers for transport by rail or ship.

Installation

Depending on the application of the panels, installation hardware varies. For standing seam roof panels, a clip is used for every 0.9 m (36 in) of panel with two fasteners. For the wall panels, only fasteners are used every 0.45 m to 0.6 m (18” to 24”).

Singular Effects

Key Product Standards for Roofs and Walls (Latest Edition Governs Unless Noted)

The following standards are provided as examples of standards which generally apply to all roll-formed metal panels.

Substrate Performance
AISI S100 – North American Specification for the Design of Cold-Formed Steel Structural Members
Specifications for Aluminum Structures, the Aluminum Association

ASTM

- A463 - Standard Specification for Steel Sheet, Aluminum-Coated, by the Hot-Dip Process
- A653 - Standard Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process
- A792 - Standard Specification for Steel Sheet, 55 % Aluminum-Zinc Alloy-Coated by the Hot-Dip Process
- A924 - Standard Specification for General Requirements for Steel Sheet, Metallic-Coated by the Hot-Dip Process
- B209 - Standard Specification for Aluminum and Aluminum-Alloy Sheet and Plate

Metal Roof Performance
ASTM

- E283 - Standard Test Method for Determining Rate of Air Leakage Through Exterior Windows, Curtain Walls and Doors Under Specified Pressure Differences Across the Specimen
- E330- Standard Test Method for Structural Performance of Exterior Windows, Doors, Skylights and Curtain Walls by Uniform Static Air Pressure Difference
- E413 - Classification for Rating Sound Insulation
- E795 - Standard Practices for Mounting Test Specimens During Sound Absorption Tests
- E1514 - Specification for Structural Standing Seam Steel Roof Panel Systems
- E1592- Standard Test Method for Structural Performance of Sheet Metal Roof and Siding Systems by Uniform Static Air Pressure Difference
- E1637 - Specification for Structural Standing Seam Aluminum Roof Panel Systems
- E1646- Standard Test Method for Water Penetration of Exterior Metal Roof Panel Systems by Uniform Static Air Pressure Difference
- E1680 – Standard Test Method for Rate of Air Leakage Through Exterior Metal Roof Panel Systems
- E2140 - Test Method for Water Penetration of Metal Roof Panel Systems by Static Water Pressure Head
- UL2218 - Impact Resistance of Prepared Roof Covering Materials

Metal Wall Performance

ASTM

E283- Standard Test Method for Determining Rate of Air Leakage Through Exterior Windows, Curtain Walls, and Doors Under Specified Pressure Differences Across the

E330- Standard Test Method for Structural Performance of Exterior Windows, Doors, Skylights and Curtain Walls by Uniform Static Air Pressure Difference

E331 - Standard Test Method for Water Penetration of Exterior Windows, Skylights, Doors, and Curtain Walls by Uniform Static Air Pressure Difference

Paint Finish Performance

ASTM

B117 - Standard Practice for Operating Salt Spray (Fog) Apparatus

D523 - Standard Test Method for Specular Gloss

D522 - Standard Test Methods for Mandrel Bend Test of Attached Organic Coatings

D968 - Standard Test Methods for Abrasion Resistance of Organic Coatings by Falling Abrasive

D1308 - Standard Test Method for Effect of Household Chemicals on Clear and Pigmented Organic Finishes

D2244 -Standard Practice for Calculation of Color Tolerances and Color Differences from Instrumentally Measured Color Coordinates

D2247 -Standard Practice for Testing Water Resistance of Coatings in 100% Relative Humidity

D2794 -Standard Test Method for Resistance of Organic Coatings to the Effects of Rapid Deformation (Impact)

D4214 -Standard Test Methods for Evaluating the Degree of Chalking of Exterior Paint Films

D3359 - Standard Test Methods for Measuring Adhesion by Tape Test

D3363 - Standard Test Method for Film Hardness by Pencil Test

D4145 - Standard Test Method for Coating Flexibility of Prepainted Sheet

E 84 - Standard Test Method for Surface Burning Characteristics of Building Materials

Fire Performance

ASTM

E84 - Standard Test Method for Surface Burning Characteristics of Building Materials

E119 - Standard Test Methods for Fire Tests of Building Construction and Materials

E631 - Standard Terminology of Building Constructions

UL263- Fire Tests of Building Construction and Materials

UL790- Standard Test Method for Fire Tests of Roof Coverings

Model Codes or Standards

International Building Code

Local Building Code

ASCE/SEI 7 – Minimum Design Loads for Buildings and Other Structures

UL-Building Materials Directory

UL- Fire Resistance Directory

ASHRAE, TIMA –[Handbook of Fundamentals & Insulation Requirements]

SMACNA, [Architectural Sheet Metal Manual – Gutter design and flashing details]

(FS HH-I-521)(FS HH-I-558b)-[Fiberglass Insulation]
FS HH-I-1972)-([Insulation Board Thermal Faced, Polyurethane or Polyisocyanurate])
FMRC-Approval Guide
FMRC-Specification Tested Products Guide
ANSI B18.6.4 –[Steel Self-Tapping Screw Standard]
SAE J78 Self Drilling Tapping Screws
MCA Technical Bulletin, Fastener Selection Guidelines, 2008
AAMA 501-[Method of Test for Metal Curtain Walls]

Thermal Effects

Thermal expansion or contraction of roll-formed panels can occur in any direction on the panel and is always greatest along the longest panel dimension. Roll-formed panels will thermally expand and contract according to their coefficient of thermal expansion. Metal roof and wall systems need to be designed to account for thermal movement of the panels.

Quality Control

Quality control is a major emphasis for Petersen Aluminum. Petersen has both internal and third-party programs that validate the consistency of the processes involved in manufacturing these high-quality metal products. Petersen works under the following guidelines:

Description	Tolerance
Panel Length	+/- 1/4 inches
Panel End Squareness	+/- 1/4 inches
Viewed from Panel Front (Measured across sheet)	0.5% of width and no more than 1/8 inch at one end
Viewed from Panel Side (Measured across sheet)	2% of panel depth and no more than 1/16 inch
Camber (Lateral bow of panel viewed from panel front)	3/16 inch per 10 feet length Accumulation allowed (e.g., 40 ft panel) Length maximum camber = 3/4 inch

Table 3: Allowable Fabrication Tolerances

Environment, Health, and Safety in Manufacturing

Petersen warehouse and production personnel utilize the basic PPE (personal protective equipment). This includes but is not limited to: gloves for handling metal; protective eyewear, especially when cutting of metal is involved; ear protection for use near machines, and also steel-toe boots. In addition, a hazard communication program is in effect for chemicals primarily used for maintenance of machines.

Requirements for the Underlying Life Cycle Assessment

The LCA study and analysis were conducted according to the Product Category Rule (PCR) created by UL Environment for insulated metal panels, metal composite panels, and metal cladding, published on October 9, 2012 and valid through October 9, 2017.

Functional Unit/Reference Flow

The functional unit for this study is defined as "coverage of 93 square meters (1,000 square feet) with metal product." The coverage area refers to the projected flat area covered by the product as output by the final step in the manufacturing process, and does not account for losses due to overlap and scrap during installation.

To achieve the functional unit of 93 square meters (1,000 square feet) coverage, a reference flow of 434 kg (957 lbs) for steel or 192 kg (423 lbs) for aluminum is required for an industry-average roll-formed metal cladding. Table 4 summarizes the key Petersen primary products, substrates and processes for which Primary LCI data was collected from Petersen.

Primary Product	Metal Substrate of Interest	Petersen Primary Processes
Roll formed steel cladding	High performance coated 0.028" (24 gauge) steel coil	• Continuous Coil Coating • Roll forming
Roll formed aluminum cladding	Aluminum coated (20 gauge) coil	• Continuous Coil Coating • Roll forming

Table 4: Roll formed metal cladding, key metal substrates and processing

System Boundaries

The defined system boundary is a 'cradle-to-grave' LCA, which correlates to the Product Stage modules A1 – A5, B2, C4, and D as defined by EN 15804:

- A1 – Raw materials
- A2 – Transport
- A3 – Manufacturing
- A4 – Transportation to installation site
- A5 – Installation
- B2 – Panel maintenance (re-painting)
- C4 – Disposal of unrecycled panels at end-of-life
- D – Credit

The reference service life (RSL) is declared as 60 years, equivalent to the building itself. Figure 5 below illustrates the system boundary for the metal cladding product system.

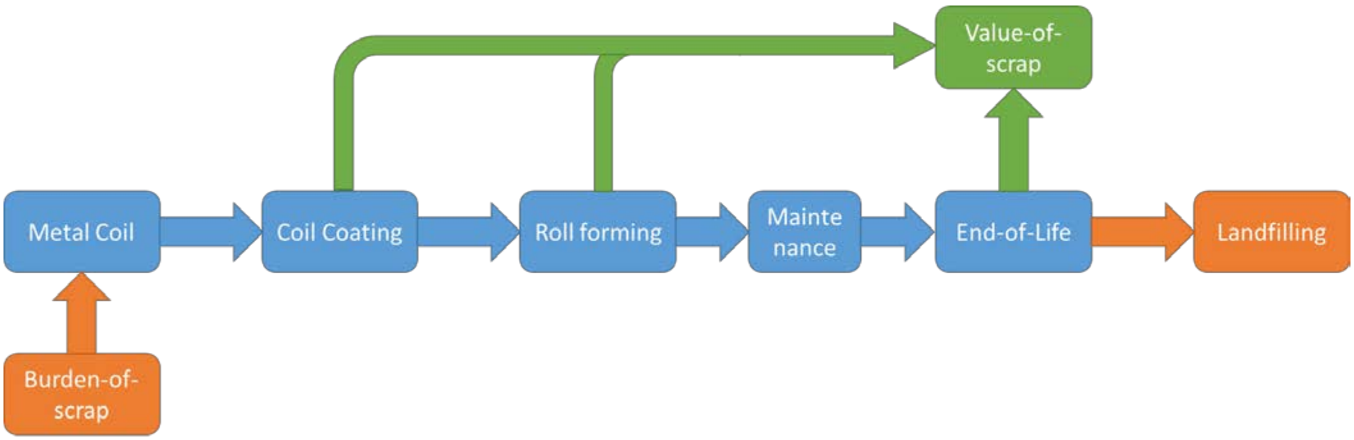

Figure 5: Cradle-to-grave system boundaries of roll-formed metal cladding

In accordance to EN15804, life cycle stages where there is no reliable data and a reasonable scenario cannot be modeled were excluded from the study. These life cycle stages include: use stage, indirect energy use, refurbishment, repair and deconstruction for the panels.

Scope

The scoping stage considers all elements identified as contributing to the production of metal cladding products and then evaluated for their inclusion or exclusion from the LCA study. Table 5 summarizes the elements included and excluded from this study.

Included	Excluded
✓ Extraction of input raw materials, transportation and production of the metal sheet used in the product ✓ Energy supply ✓ Overhead (heating, lighting) of manufacturing facilities ✓ In-bound transportation of all materials, intermediate products and fuels ✓ Operation of primary production equipment ✓ Operation of mobile support equipment ✓ Input water (for process and cooling) ✓ Waste and on-site waste water treatment ✓ Manufacture and transport of product packaging ✓ Process ancillary materials (e.g. fasteners) ✓ Transportation to installation site ✓ Maintenance through re-painting ✓ Transportation & recycling of metal sheet scrap ✓ Disposal of non-recycled panels ✓ Recycling of panels at end-of-life	× Maintenance and manufacture of fixed capital equipment × Maintenance of mobile support equipment × Outbound transportation of the main product/process output × Hygiene related water use × Employee commuting × Human labor

Table 5: System boundaries description for cradle-to-grave process

Temporal Scope

According to the guiding PCR, the primary data collected from the involved facilities should be average values from a period of 12 months. The 12-month period is to begin no later than 5 years prior to the date of the LCA calculations.

Geographic Scope

According to the PCR, the geographic region of the production sites included in the calculation of representative data was documented.

Background Data

The LCA model was created using the GaBi 6 Software system for life cycle engineering, developed by thinkstep AG. The GaBi 2013 LCI database provides the life cycle inventory data for several of the raw and process materials obtained from the background system. North American background data were used whenever possible; if such data were not available, European data were used as a proxy. The worldsteel North American average data were used for galvanized steel coil, with coil coating data obtained from the Metal Construction Association (MCA). The aluminum coil was modeled using data created by Aluminum Association.

Life Cycle Assessment Results and Analysis

Cradle-to-grave life cycle impact assessment results are shown for both TRACI 2.0 and CML (November 2010) characterization factors. Due to the relative approach of LCA, which is based on a functional unit, these results are relative expressions only and do not predict impacts on category endpoints (such as Human Health or Ecosystem Quality), the exceeding of thresholds, safety margins or risks.

With respect to global warming potential, no credit was given for the sequestration of biogenic carbon during the growth of biomass used in plant-derived packaging materials. Any carbon temporarily sequestered during the use of bio-based materials is assumed to be re-released to the atmosphere upon their decomposition. Since the lifetime of plant-derived packaging materials is shorter than the 100-year time horizon of this impact category (GWP 100), biogenic carbon was excluded from the global warming potential calculations.

The impacts will be reported with and without credits from recycling the panels at end-of-life (module D).

Total Environmental Impacts, Including Module D

The total, net impacts of the declared life cycle modules are presented in Table 6 and Table 7 for both steel and aluminum panels, respectively.

Steel	Unit	Steel
CML		
GWP	$kgCO_2$-eq	1,320
AP	$kgSO_2$-eq	6.67
EP	$kgPO_4^{3-}$-eq	0.765
ODP	kgR11-eq	1.10E-04
POCP	kgC_2H_4-eq	1.11
ADPe	kgSb-eq	0.0229
ADPf	MJ	14,700
TRACI 2.0		
GWP	$kgCO_2$-eq	1,320
AP	mol H^+-eq	374
EP	kgN-eq	0.397
ODP	kgCFC11-eq	7.62E-05
SFP	kgO_3-eq	113

Table 6: Total life cycle impacts of 93 square meters (1,000 sq ft) of steel roll-formed cladding, TRACI 2.0 and CML 2001 (Nov 2010) including module D

Aluminum	Unit	Aluminum
CML		
GWP	$kgCO_2$-eq	1,000
AP	$kgSO_2$-eq	4.41
EP	$kgPO_4^{3-}$-eq	0.398
ODP	kgR11-eq	8.26E-05
POCP	kgC_2H_4-eq	0.959
ADPe	kgSb-eq	0.000517
ADPf	MJ	9,930
TRACI 2.0		
GWP	$kgCO_2$-eq	1,000
AP	mol H^+-eq	232
EP	kgN-eq	0.197
ODP	kgCFC11-eq	4.64E-05
SFP	kgO_3-eq	49.6

Table 7: Total life cycle impacts of 93 square meters (1,000 sq ft) of aluminum roll-formed cladding, TRACI 2.0 and CML 2001 (Nov 2010) including module D

Declared CML 2001 – November 2010 and TRACI 2.0 impacts are subdivided by product stages for steel and aluminum panels, as shown in Table 8 and Table 9, respectively.

Steel	Total	A1	A2	A3	A4	A5	B2	C4	D
CML									
GWP	1,320	1,780	9.45	111	24.6	132	59.4	2.9	-798
AP	6.67	6.94	0.0383	0.796	0.0998	0.39	0.29	0.013	-1.9
EP	0.765	0.622	0.00865	0.0334	0.0226	0.108	0.0203	0.00152	-0.0524
ODP	1.10E-04	8.46E-05	6.41E-11	3.18E-08	1.67E-10	-2.43E-07	2.56E-09	5.99E-11	2.54E-05
POCP	1.11	0.779	0.00459	0.065	0.012	0.145	0.532	0.00127	-0.424
ADPe	0.0229	0.0309	1.24E-06	6.12E-06	3.23E-06	-6.85E-06	0.000107	1.12E-06	-0.0081
ADPf	14,700	21,000	139	1,170	362	-740	1,150	43.9	-8,390
TRACI 2.0									
GWP	1,320	1,780	9.45	111	24.6	132	59.4	2.9	-798
AP	374	384	2.77	37.5	7.21	25.2	14.5	0.752	-97.3
EP	0.397	0.219	0.00312	0.0215	0.00815	0.0602	0.0116	0.000594	0.073
ODP	7.62E-05	4.88E-05	6.82E-11	3.44E-08	1.78E-10	-2.65E-07	2.72E-09	6.37E-11	2.77E-05
SFP	113	116	1.5	4.99	3.91	1.37	3.2	0.259	-18.4

Table 8: Total LCIA results for steel roll formed cladding in CML and TRACI 2.0 impacts subdivided by life cycle modules including module D

Aluminum	Total	A1	A2	A3	A4	A5	B2	C4	D
CML									
GWP	1,000	3,340	41.7	111	24.6	132	59.4	1.21	-2,710
AP	4.41	15.7	0.169	0.796	0.0998	0.39	0.29	0.00542	-13.1
EP	0.398	0.765	0.0382	0.0334	0.0226	0.108	0.0203	0.000633	-0.59
ODP	8.26E-05	1.11E-04	2.83E-10	3.18E-08	1.67E-10	-2.43E-07	2.56E-09	2.50E-11	-2.82E-05
POCP	0.959	0.911	0.0203	0.065	0.012	0.145	0.532	0.000528	-0.727
ADPe	0.000517	0.00138	5.47E-06	6.12E-06	3.23E-06	-6.85E-06	0.000107	4.67E-07	-0.000976
ADPf	9,930	30,700	613	1,170	362	-740	1,150	18.3	-23,300
TRACI 2.0									
GWP	1,000	3,340	41.7	111	24.6	132	59.4	1.21	-2,710
AP	232	770	12.2	37.5	7.21	25.2	14.5	0.313	-635
EP	0.197	0.323	0.0138	0.0215	0.00815	0.0602	0.0116	0.000247	-0.241
ODP	4.64E-05	7.73E-05	3.01E-10	3.44E-08	1.78E-10	-2.65E-07	2.72E-09	2.66E-11	-3.07E-05
SFP	49.6	135	6.62	4.99	3.91	1.37	3.2	0.108	-106

Table 9: Total LCIA results for aluminum roll formed cladding in CML and TRACI 2.0 impacts subdivided by life cycle modules including module D

Energy and Material Resources, Including Module D

Primary energy resources, secondary material and water use for steel and aluminum panels are presented in Table 10 and Table 11, respectively. Energy and material indicators not relevant to the products are declared as 0.

Steel	Total	A1	A2	A3	A4	A5	B2	C4	D
Total primary energy demand, renewable [MJ]	3,850	3,310	0.816	62.2	2.13	-37.2	72.7	2.09	432
Use of renewable primary energy excluding renewable primary energy resources used as raw materials	2,840	2,840	0	0	0	0	0	0	0
Use of renewable primary energy resources used as raw materials	1,010	474	0.816	62.2	2.13	-37.2	72.7	2.09	432
Total primary energy demand, fossil [MJ]	16,400	21,700	139	1,250	363	-857	1,240	45.3	-7,470
Use of non-renewable primary energy excluding non-renewable primary energy resources used as raw materials	0	0	0	0	0	0	0	0	0
Use of non-renewable primary energy resources used as raw materials	16,400	21,700	139	1,250	363	-857	1,240	45.3	-7,470
Use of Secondary Material [kg]	261	261	0	0	0	0	0	0	0
Use of renewable secondary fuels	0	0	0	0	0	0	0	0	0
Use of non-renewable secondary fuels	0	0	0	0	0	0	0	0	0
Use of Fresh Water [m3]	179	88.2	0.243	42.6	0.633	-17	62.5	1.24	0.25

Table 10: Energy and material resource input indicators per 1,000 sqft of steel panel in accordance to guiding PCR including module D

Aluminum	Total	A1	A2	A3	A4	A5	B2	C4	D
Total primary energy demand, renewable [MJ]	4,530	16,800	3.6	62.2	2.13	-37.2	72.7	0.872	-12,300
Use of renewable primary energy excluding renewable primary energy resources used as raw materials	2,840	2,840	0	0	0	0	0	0	0
Use of renewable primary energy resources used as raw materials	1,690	13,900	3.6	62.2	2.13	-37.2	72.7	0.872	-12,300
Total primary energy demand, fossil [MJ]	10,900	32,600	615	1250	363	-857	1,240	18.9	-24,300
Use of non-renewable primary energy excluding non-renewable primary energy resources used as raw materials	0	0	0	0	0	0	0	0	0
Use of non-renewable primary energy resources used as raw materials	10,900	32,600	615	1,250	363	-857	1,240	18.9	-24,300
Use of Secondary Material [kg]	212	212	0	0	0	0	0	0	0
Use of renewable secondary fuels	0	0	0	0	0	0	0	0	0
Use of non-renewable secondary fuels	0	0	0	0	0	0	0	0	0
Use of Fresh Water [m3]	479	309	1.07	42.6	0.633	-17	62.5	0.518	79.4

Table 11: Energy and material resource input per 1,000 sqft of aluminum panel including module D

Waste and Output Flows, Including Module D

Additional environmental information, including hazardous, non-hazardous and radioactive waste disposed; materials for recycling; and materials for energy recovery are shown Table 12 and Table 13 for steel and aluminum panels, respecitvely. There are no known re-use of materials, and no data on the portion of generated waste is sent specifically to power plants utilizing secondary materials. Therefore, the indicators "Components for re-use" and "Materials for energy recovery" are reported as 0.

Steel	Total	A1	A2	A3	A4	A5	B2	C4	D
Hazardous Waste Disposed [kg]	10.6	11.0	0	1.15E-04	0	0	0	0	-0.429
Non-Hazardous Waste Disposed [kg]	24.3	4.38	0	5.78E-05	0	0	0	0	19.9
Radioactive Waste Disposed [kg]	0.568	0.27	0.000222	0.0327	0.000578	-0.0447	0.0366	0.000551	0.272
Components for re-use	0	0	0	0	0	0	0	0	0
Materials for Recycling [kg]	591	0	0	0	0	0	0	0	591
Materials for energy recovery [MJ]	0	0	0	0	0	0	0	0	0
Exported Energy [MJ]	599	0	0	8.57	0	590	0	0	0

Table 12: Waste and output flows per functional unit of 1,000 sqft of steel Roll formed panels including module D

Aluminum	Total	A1	A2	A3	A4	A5	B2	C4	D
Hazardous Waste Disposed [kg]	59.6	593	0	1.15E-04	0	0	0	0	-533
Non-Hazardous Waste Disposed [kg]	1.83	23.3	0	5.78E-05	0	0	0	0	-21.4
Radioactive Waste Disposed [kg]	0.38	0.67	0.00098	0.0327	0.000578	-0.0447	0.0366	0.00023	-0.316
Components for re-use	0	0	0	0	0	0	0	0	0
Materials for Recycling [kg]	300	0	0	0	0	0	0	0	300
Materials for energy recovery [MJ]	0	0	0	0	0	0	0	0	0
Exported Energy [MJ]	599	0	0	8.57	0	590	0	0	0

Table 13: Waste and output flows per functional unit of 1,000 sqft of aluminum Roll formed panels including module D

Total Environmental Impacts, Excluding Module D

The total of the declared life cycle modules are presented in Table 14 and Table 15 for both steel and aluminum panels, respectively.

Steel	Unit	Steel
CML		
GWP	$kgCO_2$-eq	2,030
AP	$kgSO_2$-eq	8.34
EP	$kgPO_4^{3-}$-eq	0.811
ODP	kgR11-eq	8.74E-05
POCP	kgC_2H_4-eq	1.49
ADPe	kgSb-eq	0.0301
ADPf	MJ	22,100
TRACI 2.0		
GWP	$kgCO_2$-eq	2030
AP	mol H^+-eq	460
EP	kgN-eq	0.333
ODP	kgCFC11-eq	5.18E-05
SFP	kgO_3-eq	129

Table 14: Total life cycle impacts of 93 square meters (1,000 sq ft) of steel roll-formed cladding, TRACI 2.0 and CML 2001 (Nov 2010) excluding module D

Aluminum	Unit	Aluminum
CML		
GWP	$kgCO_2$-eq	3,410
AP	$kgSO_2$-eq	16.1
EP	$kgPO_4^{3-}$-eq	0.923
ODP	kgR11-eq	1.08E-04
POCP	kgC_2H_4-eq	1.61
ADPe	kgSb-eq	0.00139
ADPf	MJ	30,700
TRACI 2.0		
GWP	$kgCO_2$-eq	3,410
AP	mol H^+-eq	797
EP	kgN-eq	0.412
ODP	kgCFC11-eq	7.37E-05
SFP	kgO_3-eq	144

Table 15: Total life cycle impacts of 93 square meters (1,000 sq ft) of aluminum roll-formed cladding, TRACI 2.0 and CML 2001 (Nov 2010) excluding module D

Declared CML 2001 – November 2010 and TRACI 2.0 impacts are subdivided by product stages for steel and aluminum panels, as shown in Table 16 and Table 17, respectively.

Steel	Total	A1	A2	A3	A4	A5	B2	C4
CML								
GWP	2,030	1,690	9.45	111	24.6	132	59.4	2.9
AP	8.34	6.71	0.0383	0.796	0.0998	0.39	0.29	0.013
EP	0.811	0.616	0.00865	0.0334	0.0226	0.108	0.0203	0.00152
ODP	8.74E-05	8.76E-05	6.41E-11	3.18E-08	1.67E-10	-2.43E-07	2.56E-09	5.99E-11
POCP	1.49	0.729	0.00459	0.065	0.012	0.145	0.532	0.00127
ADPe	0.0301	0.0299	1.24E-06	6.12E-06	3.23E-06	-6.85E-06	0.000107	1.12E-06
ADPf	22,100	20,000	139	1,170	362	-740	1,150	43.9
TRACI 2.0								
GWP	2030	1690	9.45	111	24.6	132	59.4	2.9
AP	460	372	2.77	37.5	7.21	25.2	14.5	0.752
EP	0.333	0.228	0.00312	0.0215	0.00815	0.0602	0.0116	0.000594
ODP	5.18E-05	5.20E-05	6.82E-11	3.44E-08	1.78E-10	-2.65E-07	2.72E-09	6.37E-11
SFP	129	114	1.5	4.99	3.91	1.37	3.2	0.259

Table 16: Total LCIA results for steel roll formed cladding in CML and TRACI 2.0 impacts subdivided by life cycle modules excluding module D

Aluminum	Total	A1	A2	A3	A4	A5	B2	C4
CML								
GWP	3,410	3,040	41.7	111	24.6	132	59.4	1.21
AP	16.1	14.3	0.169	0.796	0.0998	0.39	0.29	0.00542
EP	0.923	0.7	0.0382	0.0334	0.0226	0.108	0.0203	0.000633
ODP	1.08E-04	1.08E-04	2.83E-10	3.18E-08	1.67E-10	-2.43E-07	2.56E-09	2.50E-11
POCP	1.61	0.831	0.0203	0.065	0.012	0.145	0.532	0.000528
ADPe	0.00139	0.00127	5.47E-06	6.12E-06	3.23E-06	-6.85E-06	0.000107	4.67E-07
ADPf	30,700	28,100	613	1,170	362	-740	1,150	18.3
TRACI 2.0								
GWP	3,410	3,040	41.7	111	24.6	132	59.4	1.21
AP	797	700	12.2	37.5	7.21	25.2	14.5	0.313
EP	0.412	0.296	0.0138	0.0215	0.00815	0.0602	0.0116	0.000247
ODP	7.37E-05	7.40E-05	3.01E-10	3.44E-08	1.78E-10	-2.65E-07	2.72E-09	2.66E-11
SFP	144	124	6.62	4.99	3.91	1.37	3.2	0.108

Table 17: Total LCIA results for aluminum roll formed cladding in CML and TRACI 2.0 impacts subdivided by life cycle modules excluding module D

Energy and Material Resources, Excluding Module D

Primary energy resources, secondary material and water use for steel and aluminum panels are presented in Table 18 and Table 19, respectively. Energy and material indicators not relevant to the products are declared as 0.

Steel	Total	A1	A2	A3	A4	A5	B2	C4
Total primary energy demand, renewable [MJ]	3,470	3,360	0.816	62.2	2.13	-37.2	72.7	2.09
Use of renewable primary energy excluding renewable primary energy resources used as raw materials	2,840	2,840	0	0	0	0	0	0
Use of renewable primary energy resources used as raw materials	627	524	0.816	62.2	2.13	-37.2	72.7	2.09
Total primary energy demand, fossil [MJ]	23,000	20,800	139	1,250	363	-857	1,240	45.3
Use of non-renewable primary energy excluding non-renewable primary energy resources used as raw materials	0	0	0	0	0	0	0	0
Use of non-renewable primary energy resources used as raw materials	23,000	20,800	139	1,250	363	-857	1,240	45.3
Use of Secondary Material [kg]	261	261	0	0	0	0	0	0
Use of renewable secondary fuels	0	0	0	0	0	0	0	0
Use of non-renewable secondary fuels	0	0	0	0	0	0	0	0
Use of Fresh Water [m3]	179	88.3	0.243	42.6	0.633	-17	62.5	1.24

Table 18: Energy and material resource input indicators per 1,000 sqft of steel panel in accordance to guiding PCR excluding module D

Aluminum	Total	A1	A2	A3	A4	A5	B2	C4
Total primary energy demand, renewable [MJ]	15,500	15,400	3.6	62.2	2.13	-37.2	72.7	0.872
Use of renewable primary energy excluding renewable primary energy resources used as raw materials	2,840	2,840	0	0	0	0	0	0
Use of renewable primary energy resources used as raw materials	12,700	12,600	3.6	62.2	2.13	-37.2	72.7	0.872
Total primary energy demand, fossil [MJ]	32,600	30,000	615	1250	363	-857	1,240	18.9
Use of non-renewable primary energy excluding non-renewable primary energy resources used as raw materials	0	0	0	0	0	0	0	0
Use of non-renewable primary energy resources used as raw materials	32,600	30,000	615	1,250	363	-857	1,240	18.9
Use of Secondary Material [kg]	212	212	0	0	0	0	0	0
Use of renewable secondary fuels	0	0	0	0	0	0	0	0
Use of non-renewable secondary fuels	0	0	0	0	0	0	0	0
Use of Fresh Water [m3]	408	318	1.07	42.6	0.633	-17	62.5	0.518

Table 19: Energy and material resource input indicators per 1,000 sqft of aluminum panel in accordance to guiding PCR excluding module D

Waste and Output Flows, Excluding Module D

Additional environmental information, including hazardous, non-hazardous and radioactive waste disposed; materials for recycling; and materials for energy recovery are shown Table 20 and Table 21 for steel and aluminum panels, respecitvely. There are no known re-use of materials, and no data on the portion of generated waste is sent specifically to power plants utilizing secondary materials. Therefore, the indicators “Components for re-use” and “Materials for energy recovery” are reported as 0.

Steel	Total	A1	A2	A3	A4	A5	B2	C4
Hazardous Waste Disposed [kg]	11.0	11.0	0	0.000115	0	0	0	0
Non-Hazardous Waste Disposed [kg]	6.72	6.72	0	0.0000578	0	0	0	0
Radioactive Waste Disposed [kg]	0.328	0.302	0.000222	0.0327	0.000578	-0.0447	0.0366	0.000551
Components for re-use	0	0	0	0	0	0	0	0
Materials for Recycling [kg]	0	0	0	0	0	0	0	0
Materials for energy recovery [MJ]	0	0	0	0	0	0	0	0
Exported Energy [MJ]	599	0	0	8.57	0	590	0	0

Table 20: Waste and output flows per functional unit of 1,000 sqft of steel Roll formed panels excluding module D

Aluminum	Total	A1	A2	A3	A4	A5	B2	C4
Hazardous Waste Disposed [kg]	549	549	0	0.000115	0	0	0	0
Non-Hazardous Waste Disposed [kg]	21.1	21.1	0	0.0000578	0	0	0	0
Radioactive Waste Disposed [kg]	0.662	0.635	0.00098	0.0327	0.000578	-0.0447	0.0366	0.00023
Components for re-use	0	0	0	0	0	0	0	0
Materials for Recycling [kg]	0	0	0	0	0	0	0	0
Materials for energy recovery [MJ]	0	0	0	0	0	0	0	0
Exported Energy [MJ]	599	0	0	8.57	0	590	0	0

Table 21: Waste and output flows per functional unit of 1,000 sqft of aluminum Roll formed panels excluding module D

Scenarios and Additional Technical Information

The declared technical information for transportation to installation, installation and reference service life as required by the PCR are identical for steel and aluminum panels; therefore, one table is shown to represent both cases. Technical information is presented from Table 22 to Table 25.

The panels typically are shipped within 400 miles (644 km) to the installation site by truck, assuming an average of 78% capacity utilization. GaBi data calculates fuel consumption rate by mass and distance. Therefore, fuel consumption is presented by liter per *mass-distance*; bulk density and volume capacity are not considered in the calculation.

	Units	Value
Fuel type and consumption of vehicle type used for transport	liter/t*km by truck	0.0242
Distance	km	644
Capacity utilization	%	78
Bulk density of transported products	kg/m3	N/A
Volume capacity utilization	N/A	N/A

Table 22: Technical information of transportation to building site

The only environmentally relevant activities at this stage are the disposal of packaging materials upon arrival at the site.

	Units	Value
Ancillary materials for installation		
Clips and fasteners for roof panels	kg	43
Fasteners for exposed wall panels and wall panels	kg	3 - 9
Water use	m3	0
Other resource use	kg	0
Quantitative description of energy type	MJ	0
Wastage of materials on the building site (total)	kg	229
Wood packaging	kg	227
Plastic packaging	kg	0.249
Paper packaging	kg	2.13
Direct emissions to ambient air, soil, and water	kg	0

Table 23: Technical information of transportation to installation

Refurbishment and replacement are not considered to take place over the reference service life. Upstream and direct emissions from production and application of paint is considered in aggregate by the GaBi dataset.

	Units	Value
Maintenance cycle	# per RSL	2
Ancillary materials for maintenance	kg/cycle	15
Wastage material during maintenance	kg	0
Net fresh water consumption during maintenance	m3	0
Energy input during maintenance	kWh	0
Direct emissions to ambient air, soil, and water	kg	0

Table 24: Technical information of transportation of maintenance cycle

The relevant conditions are the declared service life, 60 years, and maintenance.

	Value
Reference service life	60 years
Declared product properties and finishes	Factory coated finish
Design application parameters	N/A
An assumed quality of work when installed	N/A
Outdoor environment	N/A
Output materials as a result of waste processing at building	N/A
Indoor environment	N/A
Usage conditions	N/A

Table 25: Reference service life and relevant reference conditions

Process	Units	Value
Collection process specified by type	kg collected separately	
	kg collected with mixed construction waste	434
Recovery system specified by type	kg for re-use	
	kg for recycling	382
	kg for energy recovery	
Disposal specified by type	kg product or material for final deposition	52
Assumptions for scenario development	Recycling rate	88%

Table 26: End-of-life scenarios for steel roll formed panels

Process	Units	Value
Collection process specified by type	kg collected separately	
	kg collected with mixed construction waste	192
Recovery system specified by type	kg for re-use	
	kg for recycling	182
	kg for energy recovery	
Disposal specified by type	kg product or material for final deposition	10
Assumptions for scenario development	Recycling rate	95%

Table 27: End-of-life scenarios for aluminum roll formed panels

Interpretation

The above results represent a cradle-to-grave assessment of roll-formed steel and aluminum cladding produced by Petersen. The study was conducted for the functional unit of coverage of 93 square meters (1,000 square feet) with roll-formed panels. The cradle-to-grave system boundary (stages A1 – A5, B2, C4, and D) includes the production as well as credit back to the system through recovery of recyclable materials as “value-of-scrap.”

The Global Warming Potential impact is dominated by stages A1 (materials) as well as moderate burdens at manufacturing (A3). In the raw material stage (A1), metal coil production is the major contributor at approximately 84% of the Global Warming Potential for steel (Table 16) and 90% for aluminum (Table 17). The moderate impacts at manufacturing (A3) comes from energy use, primarily electricity. The transportation stage (A2) included all known inbound transportation as well as delivery of coated steel and aluminum coil to the Petersen roll-forming facility. The burden to Global Warming Potential from stage A2 and A4 are marginal (1.6% for steel and 1.8% for aluminum) and are mainly from tailpipe emissions. The installation stage (A5) have moderate impacts due to methane emissions from the disposal of pallet wood waste to landfill. Additionally, due to the estimation of re-painting one to two additional times after installation, the maintenance stage (B2) also has minor impact contributions to Global Warming Potential.

The impacts from raw material input of metal coil comes from the burden of virgin material production as well as the burden of utilizing scrap in the “value-of-scrap” approach required by the guiding PCR. However, there is a large credit back to the system due to generation of recyclable scrap that is generated at the end-of-life (module D). Therefore, the net impact is substantially lower than the sum of the cradle-to-gate (A1 – A3) burdens.

With respect to the other environmental indicators, the metal coil production is again the main contributor. Photochemical Ozone Creation Potential CML 2001 – November 2010 impact methodology results in a moderate impact contribution at the maintenance stage (B2) due to the consideration of the elementary emission flow *NMVOC (unspecified)*, which is not considered in the Smog Formation Potential in the TRACI 2.0 impact methodology. The production and application of anti-corrosion chemicals lead to a dominant contribution of Ozone Depletion Potential at raw material stage (A1). The exceptions were Eutrophication and Photochemical Ozone Creation Potentials. The landfilling of used pallets at the installation stage (stage A5) lead to emissions which substantially contribute to Eutrophication Potentials.

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