

## ENVIRONMENTAL PRODUCT DECLARATION

# ALUMINUM CURTAIN WALL SYSTEMS

YKK AP AMERICA, ENERGIFACADE® ENERGY EFFICIENT BUILDING SOLUTIONS, PROTEK® HURRICANE MITIGATION AND BLAST MITIGATION SYSTEMS



*YKK AP® curtain walls are used in many applications, shown here at One Crescent Drive.*

*All YKK AP® products are manufactured, finished and inspected for quality in the YKK AP environmentally certified, state-of-the-art facility in Dublin, GA.*



YKK AP America is taking positive steps toward sustainable manufacturing helping to balance ecology and economy—improving the environment and society over the long term. YKK AP® is the proud manufacturer of architectural products, including aluminum curtain wall systems, which provide safe and comfortable environments for building occupants and help reduce energy usage.

A dedicated partner in green building design and sustainability, YKK AP helps create innovative, high quality architectural systems that add to the strength, energy efficiency and longevity of the building envelope.

All YKK AP® products are created in a facility that is a model of environmental responsibility. YKK AP's U.S. manufacturing plant in Dublin, GA, is ISO 14001 certified and has been recognized by the U.S. Department of Energy for exceptional leadership in industrial energy efficiency.

For additional information, visit [commercial.ykkap.com](http://commercial.ykkap.com).



# ENVIRONMENTAL PRODUCT DECLARATION





YKK AP America  
Aluminum Curtain Wall Systems

According to ISO 14025 and EN 15804

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



PROGRAM OPERATOR	UL Environment	
DECLARATION HOLDER	YKK AP America	
DECLARATION NUMBER	4786832322.101.1	
DECLARED PRODUCT	Aluminum Curtain Wall Systems	
REFERENCE PCR	Part A: Calculation Rules for the LCA and Requirements Project Report, (IBU/UL E, V1.3, 06.19.2014), Part B: Requirements on the EPD for Curtain Walling (IBU, V1.6, Jul. 2014), Part B Addendum: IBU PCR for Curtain Walling (UL E, V1.0 Nov. 2015). Berlin: Institut Bauen & Umwelt.	
DATE OF ISSUE	November 13, 2015	
PERIOD OF VALIDITY	5 Years	
EXTENSION DATE	September 10, 2022	
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:	IBU	
	The Independent Expert Committee	
This declaration was independently verified in accordance with ISO 14025 by Underwriters Laboratories <input type="checkbox"/> INTERNAL <input checked="" type="checkbox"/> EXTERNAL	 Wade Stout, UL Environment	
	 Thomas Gloria, Industrial Ecology Consultants	

Conforms with EN 15804

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YKK AP America  
Aluminum Curtain Wall Systems

According to ISO 14025

## Product Definition

### Category Description

Curtain wall systems clad a building envelope with glass and aluminum to protect the interior from the elements and create a safe and comfortable work environment for the building occupants. Curtain walls are designed to only carry their own weight. The wall transfers wind loads to the main building structure, also known as the main wind force resisting system (MWFRS), at connection points in the floors or columns of the building. A curtain wall is designed to resist air and water infiltration, as well as sway created by wind and seismic forces and its own weight.

Curtain walls may span from floor to floor, used in punched opening applications, or span multiple floors, and take into consideration design requirements such as: thermal expansion and contraction; building sway and movement; water diversion; and thermal efficiency for cost-effective heating, cooling and lighting in the building.

YKK AP offers a range of installation and aesthetic options to meet your project needs. Curtain wall systems are available with inside, outside or structurally glazed options. Stick built, unitized and cassette (carrier frame) system options are available with many sightlines and mullion depths allowing you to control cost by selecting the ideal mullion depth for your opening size and design pressure requirements. Optional face covers expand design flexibility.

All YKK AP® products are manufactured, finished and inspected for quality in YKK AP's environmentally certified, state-of-the-art facility in Dublin, GA. As a result, YKK AP products fit together without a lot of jobsite re-work. YKK AP offers a complete suite of tools and engineering services to assist in proper system selection, specification and installation.

#### Materials & Coatings

Aluminum Alloys:  
6063 T5, 6063 T6,  
6061 T6

Available Finishes:  
ANODIZED  
PLUS®, AAMA  
2604/2605 Painted  
Finishes

### Product Description

The following YKK AP America aluminum curtain wall systems are covered by this EPD (glazing is excluded from this study):



#### YCW 700 2-1/4" x 7" Thermally Improved Outside Glazed Curtain Wall System

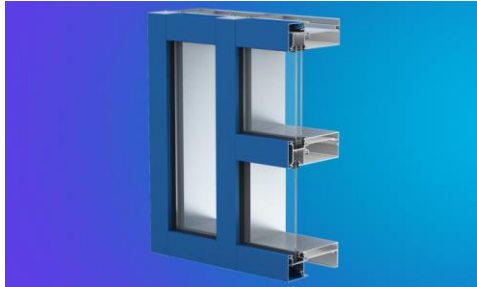
YCW 700 combines the strength and flexibility of a curtain wall with the excellent thermal characteristics of a thermal clip system.

# ENVIRONMENTAL PRODUCT DECLARATION



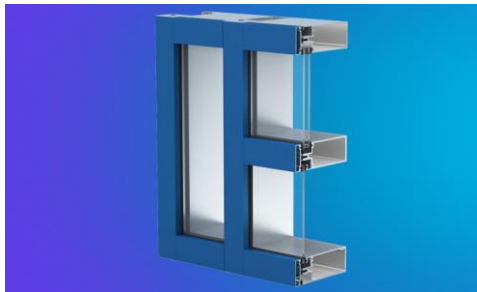
YKK AP America  
Aluminum Curtain Wall Systems

According to ISO 14025



### **YCW 750 IG 2-1/2" x 5-1/4", 6", 6-3/4", 7-1/2" Inside Glazed curtain wall system**

YCW 750 IG is primarily an inside glazed curtain wall system designed for low to mid-rise applications.



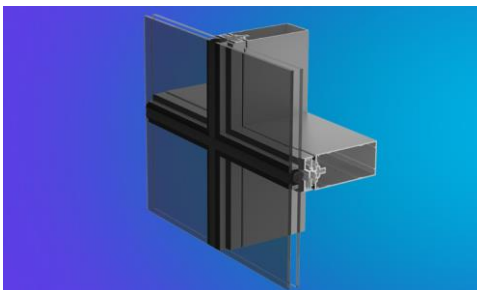
### **YCW 750 OG 2-1/2" x 5-1/4", 6", 6-3/4", 7-1/2" Outside Glazed Open Back Curtain Wall system**

YCW 750 OG (Outside Glazed) is a pressure wall system that provides the flexibility required for today's projects. With a typical 3/16" wall thickness providing exceptional durability making it ideal for use in high traffic areas.



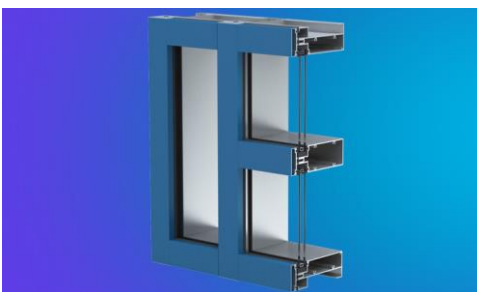
### **YCW 750 OGP 2-1/2" x 5-1/4", 6", 6-3/4", 7-1/2" Outside Glazed Open Back Curtain Wall system with Polyamide Pressure Plates**

YCW 750 OGP reduces temperature transfer from the exterior to the interior creating more comfortable interior space. The system utilizes a low conductivity pressure plate made from an industry proven material, Polyamide 6/6.



### **YCW 750 SSG 2-1/2" x 5-1/16" to 10-1/2" Two and Four-Side Silicone Glazed Curtain Wall System**

The popular YCW 750 family of products has been expanded to include 4-side structural silicone glazing. This stick built system is designed for glazing either in the field or in a climate controlled environment for increased quality assurance of critical seals.



### **YCW 750 SplineTech® 2-1/2" x 5-1/4", 6", 6-3/4", 7-1/2" Outside Glazed Screw Spline Curtain Wall System**

YCW 750 SplineTech is the latest addition to YKK AP's very successful line of curtain wall glazing systems. The new system shares many of the same features, options, and accessories with the YCW 750 outside glazed curtain wall system, but it is designed to simplify fabrication and assembly.

**Environment**



# ENVIRONMENTAL PRODUCT DECLARATION



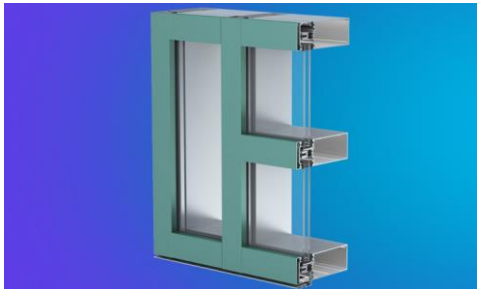
YKK AP America  
Aluminum Curtain Wall Systems

According to ISO 14025



## **YCW 750 XT/XTP enerGfacade® 2-1/2" x 6", 6-3/4", 7-1/2", 8", 8-1/4", 8-1/2", 9", 9- 3/4", 10" High Performance Curtain Wall Featuring Dual Thermal Barriers**

YCW 750 XT/XTP yields best-in-class thermal performance and exceeds not only current codes, but also exceeds the most stringent green building codes and standards in the market today.



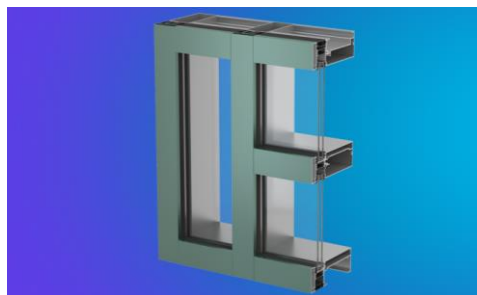
## **YCW 750 XT IG enerGfacade® 2-1/2" x 6", 7-1/2" Inside Glazed High Performance Curtain Wall System**

YCW 750 XT IG is an inside glazed curtain wall system that yields best-in-class thermal performance and exceeds, not only current codes, but also exceeds the most stringent green building codes and standards in the industry today.



## **YCW 752 2" x 4-7/8", 6-5/8", 7-3/8" Outside Glazed Pressure Wall System**

The YCW 752 is an outside glazed pressure wall system that offers a sight line of a mere 2" wide. The system offers a wide variety of face covers and back members of several different depths that may be steel reinforced to suit design requirements. YCW 752 also provides improved thermal performance to conserve energy and lower operating costs.



## **YCW Veneer Wall 2" x 1-7/8", 2-3/8" or 2-1/2" x 3"**

YCW Veneer Wall is a low to mid rise gutter system that is designed to be anchored to the steel structure of a building. Available in either a 2" or 2-1/2" gutter width, YCW Veneer Wall accepts both monolithic and insulated glazing. Optional snap-on battens or face covers are available, depending on the requirements of the architect/designer.





# ENVIRONMENTAL PRODUCT DECLARATION



YKK AP America  
Aluminum Curtain Wall Systems

According to ISO 14025



## **YHC 300 IG 3" x 7-1/16", 7-13/16" ProTek® Impact Resistant and Blast Mitigation Inside Glazed Curtain Wall System**

YHC 300 IG (Inside Glazed) is a high performance curtain wall system designed and tested to meet the most demanding conditions. With varied infill and components, YHC 300 IG can meet the requirements for Impact Resistance, Blast Mitigation or both. Outside or inside glaze



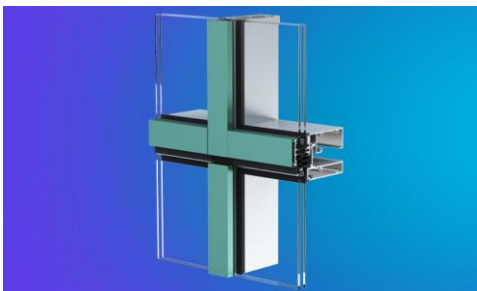
## **YHC 300 OG 3" x 7-11/16", 10-1/2" ProTek® Hurricane Impact and Blast Mitigation Curtain Wall System**

YHC 300 OG is a high performance curtain wall system designed and tested to provide innovative impact and blast solutions for a wide range of applications and design pressures from 45 PSF all the way to 130 PSF.



## **YHC 300 SSG 3" x 6-15/16", 7-11/16" ProTek® Impact Resistant and Blast Mitigating Structural Silicone Glazed Curtain Wall System**

YHC 300 SSG (Structural Silicone Glazed) is a high performance curtain wall system designed and tested to meet the most demanding conditions. With varied infill and components, YHC 300 SSG can meet the requirements for Impact Resistance, Blast Mitigation or both. Outside or inside glaze



## **YUW 750 XT 2-1/2" x 6", 7-1/2" enerGfacade® Unitized Wall System with Superior Performance**

YUW 750 XT is a unique and versatile unitized wall system designed to curb a building's energy appetite and protect against interior moisture. The system is designed to be assembled and glazed in a climate controlled environment for increased quality assurance of critical seals.



# ENVIRONMENTAL PRODUCT DECLARATION



YKK AP America  
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## Technical Performance

Name	Notes*	Value	Unit
Thermal Transmittance (U-Factor) AAMA 1503.1, AAMA 507, and NFRC 100	1, 2, 4	0.28 – 0.40	Btu/hr•ft <sup>2</sup> •°F
Solar Heat-Gain Coefficient (SHGC) NFRC 200	1, 2, 4	0.23 – 0.28	
Condensation Resistance Factor (CRFf) AAMA 1503.1	2, 3, 4	59 – 82	
<b>Water Infiltration**</b> <b>ASTM E 331 and AAMA 501.1</b>	<b>2</b>	<b>12 – 20</b>	<b>psf</b>
<b>Air Infiltration**</b> <b>ASTM E283 at 6.24 psf</b>	<b>2</b>	<b>0.06</b>	<b>cfm/ft<sup>2</sup></b>
Impact Resistance ASTM E1886/1996, Testing Application Standard 201/202/203	2, 3, 4	A, D, E	

\* (1) Calculated based on U (Center of Glass) = 0.20 and SHGC (COG) = 0.25 (2) Varies by product type (3) Dependent on glazing specified  
(4) Based on products tested

\*\* Predominantly describes the framing

## Industry Standards

AAMA 1801, ASTM E1425, ASTM E90, ASTM E413, ASTM E1332, ASTM E2235, ASTM E283, AAMA 501.4, AAMA 501.6, ASTM E330, AAMA 507, AAMA 1503, NFRC 100, NFRC 102, NFRC 200, NFRC 500, AAMA 501.5, ASTM E331, ASTM E547, AAMA 501.1

ProTek® hurricane and blast mitigation products: TAS 201, TAS 202, TAS 203, ASTM E1886, ASTM E1996, ASTM F1642, UFC 4-010-01

YKK AP® does not test or rate the declared products for extraordinary effects, i.e., performance under unforeseeable influence of fire, water or mechanical destruction.

## Delivery Status

YKK AP® curtain wall systems vary in size depending on the application. They may span from floor to floor, used in punched opening applications, or span multiple floors.



# ENVIRONMENTAL PRODUCT DECLARATION



YKK AP America  
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## Base and Ancillary Materials

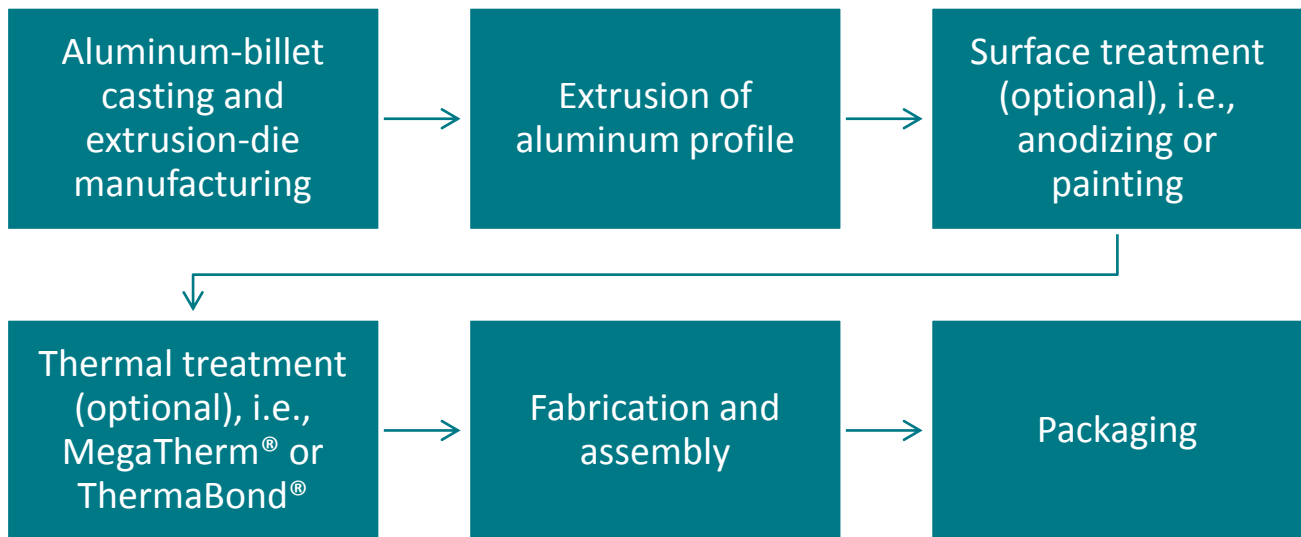
Material	Mass [kg]	Mass [%]
Aluminum 6063	7.03 – 7.10	89.6 – 90.5
Anodizing coat, optional	0 – 4.31E-02	<1
Paint coat, optional	0 – 2.34E-02	<1
MegaTherm® (Nylon 6.6/Glass fiber)	1.62E-02	<1
ThermaBond® (Polyurethane)	5.49E-04	<1
EPDM	4.37E-01	5.6
Nylon 6	1.59E-01	2.0
Polyacetal (POM)	1.28E-03	<1
PVC	1.57E-02	<1
Rubber (SBR)	1.05E-03	<1
Silicone	3.72E-02	<1
Stainless Steel	1.51E-02	<1
Steel	6.63E-02	<1

Note: Glazing is excluded from this study.

## Manufacturing

All YKK AP® products are manufactured, finished and inspected for quality in YKK AP's environmentally certified, state-of-the-art facility in Dublin, GA.

The manufacturing process comprises the following production stages:





# ENVIRONMENTAL PRODUCT DECLARATION



YKK AP America  
Aluminum Curtain Wall Systems

According to ISO 14025

The main material input into the YKK AP manufacturing process is aluminum ingot. The ingot is first alloyed to the desired grade and cast into billets. Subsequently, the billets are extruded into profiles using steel dies that are manufactured on-site. The extruded profiles may then be anodized or painted. Optional thermal treatment, whereby a system is thermally broken, leads into the product's fabrication and assembly. In a last step, the complete assemblies are packed for shipment.

## Packaging

YKK AP® products are primarily packaged using corrugated cardboard and wood components prior to shipping to installation sites.

## Product Processing/Installation

Outside of the scope of this EPD (installation stage excluded).

## Reference Service Life, Condition of Use

Outside of the scope of this EPD (use stage excluded).

## End of Life: Recycling and Disposal (C4)

Name	Value	Unit
Recycling	6.40E+00	kg
Landfilling (non-recycled Aluminum, other materials)	1.45E+00	kg

Aluminum extrusions are a highly efficient sustainable building material. Aluminum is 100% recyclable and can be recycled repeatedly. Recycled aluminum is identical to smelted aluminum but requires only 1/20 of the energy to manufacture. In building and construction, aluminum scrap has a recycling rate of 95% [AA]. The remaining 5% is sent to landfill.

AA. (2013). *The Environmental Footprint of Semi-finished Aluminum Products in North America: A Life Cycle Assessment Report*. Aluminum Association.

## Environment and Health

**Product manufacturing:** Plant emissions to air/soil/water are monitored (if applicable) and comply with local laws.

**Product use:** YKK AP® products are not expected to create exposure conditions that exceed safe thresholds for health impacts to humans or flora/fauna under normal operating conditions. Use stage is outside of the scope of this EPD.



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## Life Cycle Assessment – Product System and Modeling

A “cradle-to-gate with options” analysis using life cycle assessment (LCA) techniques was conducted for this EPD. The analysis was done according to the product category rule (PCR) for Curtain Walling and followed LCA principles, requirements and guidelines laid out in the ISO 14040/14044 standards. As such, EPDs of construction products may not be comparable if they do not comply with the same PCR. While the intent of the PCR is to increase comparability, there may still be differences among EPDs that comply with the same PCR (e.g., due to differences in system boundaries, background data, etc.).

### Declared Unit

The declared unit for an EPD is one square meter (1 m<sup>2</sup>) of curtain wall product.

Name	Value	Unit
Declared unit	1	m <sup>2</sup>
Conversion factor to 1 kg	1/7.9	-

### System Boundaries

Per the PCR, this “cradle-to-gate with options” analysis provides information on the Product Stage of the aluminum product life cycle, comprising modules A1–A3, and on the “options” Disposal and Credits, i.e., modules C4 and D:

DESCRIPTION OF THE SYSTEM BOUNDARY (X = INCLUDED IN LCA; MND = MODULE NOT DECLARED)																	
PRODUCT STAGE			CONSTRUCTION PROCESS STAGE		USE STAGE							END OF LIFE STAGE			BENEFITS AND LOADS BEYOND THE SYSTEM BOUNDARIES		
Raw material supply	Transport	Manufacturing	Transport	Construction-in-stallation process	Use	Maintenance	Repair	Replacement	Refurbishment	Operational energy use	Operational water use	De-construction demolition	Transport	Waste processing	Disposal	Reuse-Recovery-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	X	X

**Time coverage:** Primary data were collected on production within calendar year 2014. Background data for upstream and downstream processes (i.e., raw materials, energy resources, transportation and ancillary materials) were obtained from the GaBi 2014 databases.

**Technology coverage:** Data were collected for the production of aluminum curtain wall products at YKK AP’s manufacturing facility in the United States.

**Geographical coverage:** All YKK AP® products are manufactured in Dublin, Georgia, USA. As such, the geographical coverage for this study is based on United States system boundaries for all processes and products. Whenever US background data were not readily available, European data or global data were used as proxies.



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## Assumptions

This study was performed based on primary YKK AP data for the production of a production-weighted average curtain wall system. However, up to fabrication and assembly, where a bill of materials (BoM) specifies the parts which comprise an individual product, the underlying model was created to describe YKK AP® aluminum extrusions as generic intermediates. Thus, it was assumed that the same annual average split for surface treatments—i.e., 50% anodized, 18% painted, 32% remain mill finish—apply to extrusions going into curtain wall products as well as extrusions going into other products, e.g., windows (see separate EPD).

Another assumption was made in accounting for packaging materials, i.e., wood and corrugated cardboard. Due to a lack of data granularity, which is, at least partially, owed to the realities on the factory floor, packaging materials were scaled with the aluminum content as identified in the BoM.

Beyond that, no significant assumptions have been made. All of the raw materials and energy inputs were modeled using processes and flows that closely follow actual production raw materials and processes. All of the material and energy flows have been accounted.

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## Allocation

No multi-output (i.e., co-product) allocation was performed in this study. Allocation of background data (energy and materials) taken from the GaBi 2014 databases is documented online at <http://www.gabi-software.com/support/gabi/gabi-6-lci-documentation/>.

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## Cut-off Criteria

As required by EN 15804, in case of insufficient input data or data gaps for a unit process, the cut-off criteria were 1% of renewable and non-renewable primary energy usage and 1% of the total mass input of that unit process. The total of neglected input flows per module was a maximum of 5% of energy usage and mass.

In practice, all inputs and outputs, for which data are available, have been included in the calculation. Data gaps have been filled by conservative assumptions with average or generic data. Capital items for the production processes (machines, buildings, etc.) were not taken into consideration.

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## Background Data

In order to model the life cycle for the production and recycling of the extruded aluminum, the GaBi Professional software system developed by thinkstep AG was used. All relevant background data necessary for the production of extruded aluminum were taken from the GaBi 2014 databases.

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## LCA Practitioner

This EPD and the underlying LCA model were developed by thinkstep, Inc.



thinkstep

**Environment**



# ENVIRONMENTAL PRODUCT DECLARATION



YKK AP America  
Aluminum Curtain Wall Systems

According to ISO 14025

## Life Cycle Assessment – Results and Analysis

Results given per declared unit: 1m<sup>2</sup> of curtain wall system.

### ENVIRONMENTAL IMPACTS

CML 2001 (Apr 2013)

Parameter	Unit	Manufacturing	Disposal	Credits
		A1-A3	C4	D
GWP	kg CO <sub>2</sub> eq	5.27E+01	4.44E-02	-3.93E+01
ODP	kg CFC-11 eq	3.75E-09	1.02E-12	-1.66E-09
AP	kg SO <sub>2</sub> eq	3.49E-01	1.97E-04	-2.81E-01
EP	kg PO <sub>4</sub> <sup>3</sup> eq	1.85E-02	2.50E-05	-1.16E-02
POCP	kg C <sub>2</sub> H <sub>4</sub> eq	2.42E-02	1.98E-05	-1.41E-02
ADPE	kg Sb eq	6.07E-05	1.75E-08	-2.11E-05
ADPF	MJ	5.99E+02	6.91E-01	-3.62E+02

TRACI 2.1

Parameter	Unit	Manufacturing	Disposal	Credits
		A1-A3	C4	D
GWP	kg CO <sub>2</sub> eq	5.27E+01	4.44E-02	-3.93E+01
ODP	kg CFC-11 eq	3.99E-09	1.08E-12	-1.77E-09
AP	kg SO <sub>2</sub> eq	3.36E-01	2.12E-04	-2.59E-01
EP	kg N eq	7.79E-03	1.16E-05	-4.15E-03
SP	kg O <sub>3</sub> eq	3.17E+00	4.12E-03	-2.00E+00
FF	MJ	4.93E+01	8.91E-02	-2.39E+01

### RESOURCE USE

Parameter	Unit	Manufacturing	Disposal	Credits
		A1-A3	C4	D
PERE	[MJ]	2.49E+02	3.87E-02	-2.33E+02
PERM	[MJ]	-	-	-
PERT	[MJ]	2.49E+02	3.87E-02	-2.33E+02
PENRE	[MJ]	6.30E+02	7.11E-01	-3.71E+02
PENRM	[MJ]	-	-	-
PENRT	[MJ]	6.30E+02	7.11E-01	-3.71E+02
SM	[kg]	2.43E-01	-	-
RSF	[MJ]	-	-	-
NRSF	[MJ]	-	-	-
FW	[m <sup>3</sup> ]	1.08E+00	-6.59E-04	-1.01E+00

### OUTPUT FLOWS AND WASTE CATEGORIES

Parameter	Unit	Manufacturing	Disposal	Credits
		A1-A3	C4	D
HWD	[kg]	3.94E-03	1.37E-07	-3.72E-03
NHWD	[kg]	1.37E+01	1.00E+00	-1.25E+01
RWD	[kg]	1.22E-02	7.91E-06	-3.91E-03
CRU	[kg]	-	-	-
MFR	[kg]	-	5.21E+00	-
MER	[kg]	-	-	-
EEE	[MJ]	-	-	-
EET	[MJ]	-	-	-

### Glossary

#### Environmental Impacts

GWP	Global warming potential
ODP	Depletion potential of the stratospheric ozone layer
AP	Acidification potential of land and water
EP	Eutrophication potential
POCP	Formation potential of tropospheric ozone photochemical oxidants
ADPE	Abiotic depletion potential for non-fossil resources
ADPF	Abiotic depletion potential for fossil resources
FF	Fossil fuel consumption

#### Resource Use

PERE	Use of renewable primary energy excluding renewable primary energy resources used as raw materials;
PERM	Use of renewable primary energy resources used as raw materials
PERT	Total use of renewable primary energy resources
PENRE	Use of non-renewable primary energy excluding non-renewable primary energy resources used as raw materials
PENRM	Use of non-renewable primary energy resources used as raw materials
PENRT	Total use of non-renewable primary energy resources
SM	Use of secondary material
RSF	Use of renewable secondary fuels
NRSF	Use of non-renewable secondary fuels
FW	Use of net fresh water

#### Output Flows and Waste Categories

HWD	Hazardous waste disposed
NHWD	Non-hazardous waste disposed
RWD	Radioactive waste disposed
CRU	Components for re-use
MFR	Materials for recycling
MER	Materials for energy recovery
EE	Exported energy per energy carrier



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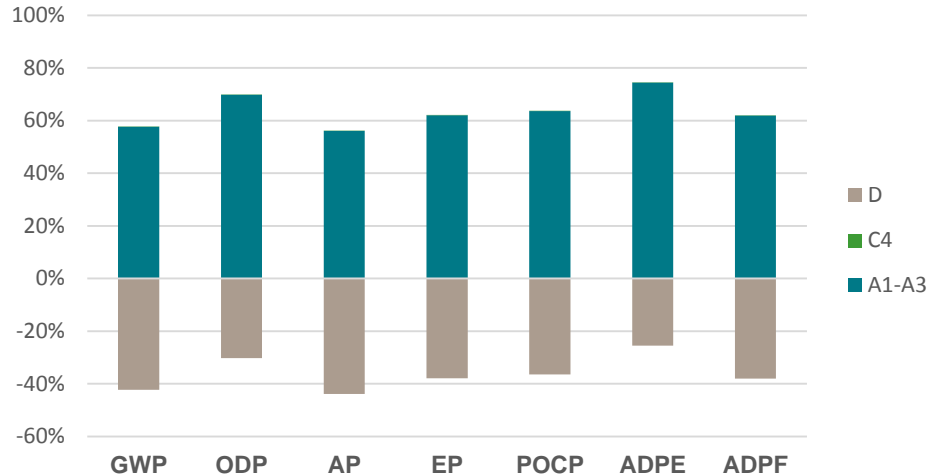
According to ISO 14025

## Interpretation

The results represent the cradle-to-gate and disposal environmental performance of the evaluated curtain wall system. As shown in the figure to the right, the results indicate that the impacts are driven by the product stage (modules A1-A3). The primary impact is derived from upstream aluminum production in module A1 (raw material supply). The YKK AP manufacturing processes account for a relatively small part of the manufacturing impact in comparison.

As module D (material credit at the end of life) clearly impacts the results, it is important to note that the applied recycling rate of 95% represents a defensible rate for aluminum extrusion products in the building and transportation sector. This is based on a conservative calculation for global aluminum recycling from these sectors. If a higher rate is used, the credit will increase, thus lowering the total life-cycle impacts. Similarly, a lower recycling rate would raise the total life cycle impacts. As new information becomes available (e.g., the Aluminum Association publishes regional-specific recycling rates), this EPD should be modified to reflect the most current industry conditions.

### CML Impact Categories



## Data Quality Assessment

**Temporal representativeness:** All primary data were collected for the year 2014. All secondary data come from the GaBi 2014 databases and are representative of the years 2010-2013. Therefore, temporal representativeness is warranted. **Geographical representativeness:** 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. Geographical representativeness is considered to be high. **Technological representativeness:** 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. Technological representativeness is considered to be high. **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. All background data are sourced from GaBi databases with the documented precision.

## References

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