(Aluminum Association, 2022)

EPD Background Report

North American Semi-Fabricated Aluminum Products for Building & Construction

On behalf of The Aluminum Association

Client: Aluminum Association

Title: EPD Background Report – North American Semi-Fabricated Aluminum Products for Building and Construction

Report version: v1.0

Report date: September 13, 2022

On behalf of Sphera Solutions GmbH and its subsidiaries

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List of Acronyms

AA	Aluminum Association
ADP	Abiotic Depletion Potential
ADPE	Abiotic Depletion Potential (elementary)
ADPF	Abiotic Depletion Potential (fossil)
AP	Acidification Potential
CA	Canada
CN	China
CRU	Components for Re-use
EEE	Exported Electrical Energy
EET	Exported Thermal Energy
EPD	Environmental Product Declaration
EoL	End-of-Life
EP	Eutrophication Potential
FW	Use of net Fresh Water
GaBi	Ganzheitliche Bilanzierung (German for holistic balancing)
GHG	Greenhouse Gas
GWP	Global Warming Potential
HWD	Hazardous Waste Disposed
IPCC	International Panel on Climate Change
ISO	International Organization for Standardization
LCA	Life Cycle Assessment
LCI	Life Cycle Inventory
LCIA	Life Cycle Impact Assessment
MER	Materials for Energy Recovery
MFR	Materials for Recycling
NCV	Net Calorific Value (a.k.a. Lower Heating Value, LVH)
NHWD	Non Hazardous Waste Disposed
NMVOC	Non-Methane Volatile Organic Compound
NRSF	Use of Non-renewable Secondary Fuels
ODP	Ozone Depletion Potential
PCR	Product Category Rules
PED	Primary Energy Demand

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
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
POCP	Photochemical Ozone Creation Potential
R1-value	Factor for the efficiency evaluation of a waste incineration plant according European Waste Framework Directive
RME	Region Middle East
RNA	Region North America
RSF	Use of Renewable Secondary Fuels
RSL	Reference Service Life
RWD	Radioactive Waste Disposed
SETAC	Society of Environmental Toxicology And Chemistry
SFP	Smog Formation Potential
SM	Use of Secondary Material
TRACI	Tool for the Reduction and Assessment of Chemical and Other Environmental Impacts
VOC	Volatile Organic Compound
WHO	World Health Organization
WIP	Waste Incineration Plant

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).

Executive Summary

This report documents the average life cycle inventory (LCI) and life cycle impact assessment (LCIA) results of four aluminum construction products manufactured in North America (U.S. and Canada) in the reference year 2016. The study was commissioned by the Aluminum Association (AA) to build on the full life cycle assessment study published earlier in the year (Aluminum Association, 2022) to respond to increasing market demand for up-to-date life cycle data on the environmental performance of building and construction products. The goal of this study is to provide updated life cycle inventory (LCI) and life cycle impact assessment (LCIA) data for aluminum ingots and aluminum semi-fabricated products to align with the requirements laid out in the recently published product category rules (UL Environment, 2022).

The functional unit of the study is 1 tonne (1,000 kg) of aluminum product in the form of either ingot, extrusion or sheet. As mandated by the PCR, the scope of the study is "cradle-to-gate with end-of-life option", i.e., starting with the extraction of bauxite ore up to the production process steps with the addition of recycling and recovery of aluminum construction products at their end-of-life.

"Cradle-to-gate" refers to the stages of the life cycle starting with raw material extraction and ending here with a semi-fabricated product at the manufacturing facility.

Both approaches used primary production data for the reference year 2016 to assess the same baseline scenario for the following aluminum ingots and semi-fabricated products:

- Primary aluminum ingot (100% primary aluminum content)
- Recycled aluminum ingot (100% recycled aluminum content)
- Industry-average aluminum extrusion
- Industry-average sheet aluminum

The data and results for the above products as presented in the full environmental footprint report (Aluminum Association, 2022) have been updated to include transportation (100 km by truck) in this report, as mandated by the PCR. A comparison to the original LCIA results showed that the impact of the addition of the transportation is minimal and doesn't change the conclusions and recommendations laid out in the full report published by AA earlier this year. For further information, please refer to the full report titled "The Environmental Footprint of Semi-Fabricated Aluminum Products (Aluminum Association, 2022).

Table ES-1-1. Life cycle impact assessment results summary

		Primary aluminum ingot	Recycled aluminum ingot	Aluminum extrusion	Sheet aluminum
GWP	[kg CO2-Eq.]	9.74E+02	9.67E+02	2.71E+03	2.93E+03
ODP	[kg CFC11-Eq.]	3.79E-13	3.53E-13	3.48E-07	4.47E-08
AP	[kg SO2-Eq.]	2.87E+00	2.94E+00	7.10E+00	8.81E+00
EP	[kg (PO4)3--Eq.]	8.87E-02	8.89E-02	2.84E-01	2.91E-01
SFP	[kg O3-Eq.]	3.31E+01	3.31E+01	9.07E+01	1.00E+02
ADPf	[MJ]	1.50E+03	1.45E+03	4.26E+03	4.06E+03

1 General Aspects

1.1 Commissioner of the LCA Study

The commissioner of the EPD and the underlying LCA study is the Aluminum Association (“client”). The LCA was performed externally by LCA practitioners at Sphera Solutions Inc. (“Sphera”).

1.2 Declaration of Conformity

This EPD project report was prepared in accordance with ISO 14044, ISO 14040 and ISO 21930 (ISO, 2006) (ISO, 2006) (ISO, 2017).

The project report provides the systematic and comprehensive summary of the project documentation supporting the verification of an EPD. The EPD was registered and published at the program operator UL Environment.

The present LCA study was conducted according to the requirements of the following product category rules (PCR):

- PCR Part A: Product Category Rules for Building-Related Products (UL Environment, 2022).
- PCR Part B: Aluminum Construction Product EPD Requirements (UL Environment, 2022).

The project report will be accessible to the verifier under the conditions of confidentiality of ISO 14025 (ISO, 2006). Sphera further recommends making this project report (minus any confidential contents) available to third parties upon request to meet the requirements of ISO 14044:2006, clause 5.2.

2 Goal of the Study

The Aluminum Association (AA) represents aluminum producers in the United States, ranging from primary production to value added products to recycling as well as suppliers to the industry. The association is the industry's leading voice, representing companies that make the majority of the aluminum ingots and aluminum construction products shipped in North America.

AA seeks to align with the additional requirements laid out in the recently published product category rule (UL Environment, 2022) through the addition of transportation and to update the existing Environmental Product Declarations (EPDs) for the following products:

- Primary aluminum ingot
- Recycled aluminum ingot
- Aluminum extrusion
- Sheet aluminum (hot-rolled, cold-rolled and semi-finished)

This life cycle assessment (LCA) will enable AA to demonstrate sustainability leadership and leverage business value through participation in voluntary product environmental performance standards. The AA engaged Sphera to conduct an LCA on aluminum ingots and semi-finished products.

The main purpose of EPDs is for business-to-business communication. The intended use of the EPD is to communicate environmentally relevant information and LCA results to support the assessment of the sustainable use of resources and of the impact of construction works on the environment.

Results presented in this document do not constitute comparative assertions. Please refer to the disclaimer in the EPDs with regards to the comparability of EPDs.

This LCA study has been carried out in accordance with the International Standard ISO 14044. It has been critically reviewed by an independent expert in accordance with ISO 14044, clause 6.1 to conform with all ISO requirements.

3 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.

3.1 Product Systems

This life cycle assessment study evaluates the potential environmental impacts of the following aluminum products typically used in the construction sector:

Aluminum ingots:

- Primary aluminum ingot
- Recycled aluminum ingot

Semi-fabricated aluminum:

- Aluminum extrusion
- Sheet aluminum

The product and technical specifications are described in more detail in each individual EPD and are also available in the recently published report titled “The Environmental Footprint of Semi-Fabricated Aluminum Products in North America” (Aluminum Association, 2022).

The above cited documents also contain a description of applications and manufacturing processes.

3.2 Declared Unit

The declared unit specified by the PCR and evaluated for all products covered by this study is:

1 metric ton (1 tonne or 1,000 kg) of aluminum product.

A “declared unit” is used in cradle-to-gate with options studies, such as this, in place of a “functional unit” because the precise function of the product is unknown. Also, for this reason, no reference service life (RSL) has been specified.

3.3 System Boundary

This is a cradle-to-gate (A1-A3) study with end-of-life option (C1-C4, D) as mandated by the PCR so it includes raw material acquisition and manufacturing of the semi-finished products in addition to final disposal of product (UL Environment, 2022). Raw material transport to the manufacturing facility has been accounted for.

Table 3-1 summarizes the inclusions and exclusions from the system boundary. The reference service life of each product is not specified. Transportation to project finishing and to the job site (A4), construction (A5), and the use stage (B1-B7) are excluded from the LCA and EPD scope as described in Table 3-2.

In accordance with the PCR, deconstruction (C1) and waste processing (C3) are reported as zero. Transport to the disposal site (C2) is assumed as 100 km (62 miles) by truck.

Module D is defined as benefits and loads beyond the product system boundary. Any production scrap generated during the extrusion and surface treatment processes as well as the scrap collected for recycling in end-of-life is used to provide the aluminum scrap consumed in module A1 before the remaining net scrap is recycled and credited in module D. For more details on the EoL allocation approach, see section 5.1.1 of the underlying LCA report (Aluminum Association, 2022).

Production and maintenance of capital goods and infrastructure have been excluded from the study and are not considered in the system boundary described by the PCR (UL Environment, 2022).

Table 3-1. System boundaries - "cradle-to-gate with options"

Included	Excluded
✓ Raw material production and transportation (A1) ✓ Inbound transportation of materials or components to assembly facility (A2) ✓ Manufacturing processes of the semi-finished products (A3) ✓ De-construction demolition (C1) ✓ Transport (C2) ✓ Waste processing (C3) ✓ End-of-life (disposal or recycling) (C4) ✓ Transportation at end-of-life	✗ Finishing and treatment of final products ✗ Construction and maintenance of infrastructure and capital equipment ✗ Outbound transportation of finished product

Table 3-2. Modules of the production life cycle included in the EPD

Production			Installation		Use stage							End-of-Life				Next product system
Raw material supply (extraction, processing, recycled material)	Transport to manufacturer	Manufacturing	Transport to finishing / 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	X	X	X	X	X

(X = declared module; MND = module not declared)

3.3.1 Time Coverage

AA primary data are to represent production within calendar year 2016. Refer to the 2022 Semi-fab LCA report for more information on temporal coverage (AA, 2022). Background data for upstream and downstream processes (i.e., raw materials, energy resources, transportation, and ancillary materials) were obtained from the GaBi 2020 (CUP 2020.1) databases with reference years between 2016 and 2021.

3.3.2 Technology Coverage

Data is to represent the production of semi-finished aluminum products and aluminum ingots at AA members across the United States and Canada.

3.3.3 Geographical Coverage

Aluminum semi-finished products manufactured by AA members in North America. More information on the geographical coverage is available in section 3.8 of the full report from AA (Aluminum Association, 2022).

3.4 Allocation

3.4.1 Multi-output Allocation

No multi-output (i.e., co-product) allocation was performed in the foreground system of this study.

Allocation of background data (energy and materials) taken from the GaBi 2020 databases is documented online at https://sphera.com/wp-content/uploads/2020/04/Modelling-Principles-GaBi-Databases-2021.pdf.

3.4.2 End-of-Life Allocation

End-of-Life allocation generally follows the requirements of ISO 14044, and ISO 21930.

Closed loop recycling approach was used in this study. The net scrap was looped back into the system as making up for part of the raw material needed for the process. The associated impacts and credits are reported in module D.

3.5 Cut-off Criteria

No cut-off criteria are applied in this study. All reported data were incorporated and modelled using best available LCI data. For use of proxy data, refer to the full AA report (Aluminum Association, 2022).

3.6 Selection of LCIA Methodology and Impact Categories

The life cycle impact assessment (LCIA) categories and other indicators as mandated by the PCR are listed in this chapter. TRACI and IPCC AR5 impact assessment methodology frameworks are used for results reporting for this EPD. The impact assessment categories and other metrics required by the PCR are shown in Table 3-3. GWP excludes biogenic carbon as there are no relevant biogenic carbon removals or emissions in the life cycle. There is no calcination, carbonation and combustion of waste from non-renewable sources.

Table 3-3. Required declaration of environmental impacts, use of resources, and generation of waste.

Indicator	Unit	Methodology
Life Cycle Impact Assessment Results		
Global warming potential, excluding biogenic carbon (GWP 100)	kg CO_2 eq	IPCC AR5 (IPCC, 2013)
Ozone depletion potential (ODP)	kg CFC-11 eq	TRACI 2.1 (Bare, 2012) (EPA, 2012)
Acidification potential (AP)	kg SO_2 eq	
Eutrophication potential (EP)	kg N eq	
Smog formation potential (SFP)	kg O_3 eq	
Resources, Fossil fuels	MJ LHV	
Resource Use		
Renewable primary resources used as energy carrier (fuel) (RPR_E)	MJ LHV	ISO 21930 (ISO, 2017), informed by the ACLCA Guidance document (ACLCA, 2019)
Renewable primary resources with energy content used as material (RPR_M)	MJ LHV	
Non-renewable primary resources used as an energy carrier (fuel) ($NRPR_E$)	MJ LHV	
Non-renewable primary resources with energy content used as material ($NRPR_M$)	MJ LHV	
Secondary materials (SM)	kg	
Renewable secondary fuels (RSF)	MJ LHV	
Non-renewable secondary fuels (NRSF)	MJ LHV	
Recovered energy (RE)	MJ LHV	
Use of net fresh water resources (FW)	m^3	
Output Flows and Waste Categories		
Hazardous waste disposed (HWD)	kg	ISO 21930 (ISO, 2017), informed by the ACLCA Guidance document (ACLCA, 2019)
Non-hazardous waste disposed (NHWD)	kg	
High-level radioactive waste, conditioned, to final repository (HLRW)	kg	
Intermediate- and low-level radioactive waste, conditioned, to final repository (ILLRW)	kg	
Components for re-use (CRU)	kg	
Materials for recycling (MR)	kg	
Materials for energy recovery (MER)	kg	
Recovered energy exported from the product system (EE)	MJ LHV	

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 emissions would (a) actually 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 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.

3.7 Interpretation to Be Used

The results of the LCI and LCIA were interpreted according to the Goal and Scope. The interpretation addresses the following topics:

- Identification of significant findings, such as the main process step(s), material(s), and/or emission(s) contributing to the overall results.
- Evaluation of completeness, sensitivity, and consistency to justify the exclusion of data from the system boundaries as well as the use of proxy data.
- Conclusions, limitations, and recommendations.

3.8 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.

An evaluation of the data quality with regard to these requirements is provided in the AA report produced earlier this year (Aluminum Association, 2022).

3.9 Software and Database

The LCA model was created using the GaBi 10 Software system for life cycle engineering, developed by Sphera Solutions, Inc. The GaBi 2020 LCI database (service pack 40) provides the life cycle inventory data for several of the raw and process materials obtained from the background system.

3.10 Critical Review

The EPD development process requires verification by or organized by the selected program operator, UL Environment. Verification was conducted by James Mellentine, Thrive ESG, in accordance with ISO 14025, ISO 14044, and ISO 21930 requirements and the referenced PCR.

4 Life Cycle Inventory Analysis

4.1 Data Collection Procedure

The data collection procedure is described in section 4.1 of The Environmental Footprint of Semi-Fabricated Aluminum Products in North America report (Aluminum Association, 2022).

4.2 LCA Model

The following figures show the GaBi plans of the product systems under study that have been slightly modified since the publication of the AA report (Aluminum Association, 2022): the primary aluminum ingot (Figure 4-1 and Figure 4-2), the recycled aluminum ingot (Figure 4-3), the aluminum extrusion (Figure 4-4 and Figure 4-5) and sheet aluminum (Figure 4-6 to Figure 4-8) plans experienced the following minor changes:

- Modules C and D added for aluminum ingots as required by the PCR (UL Environment, 2022)
- Transportation modules have been added (A2, A4 and C2).
- Additional processes and flows have been added to help with results calculation of non-LCIA indicators.

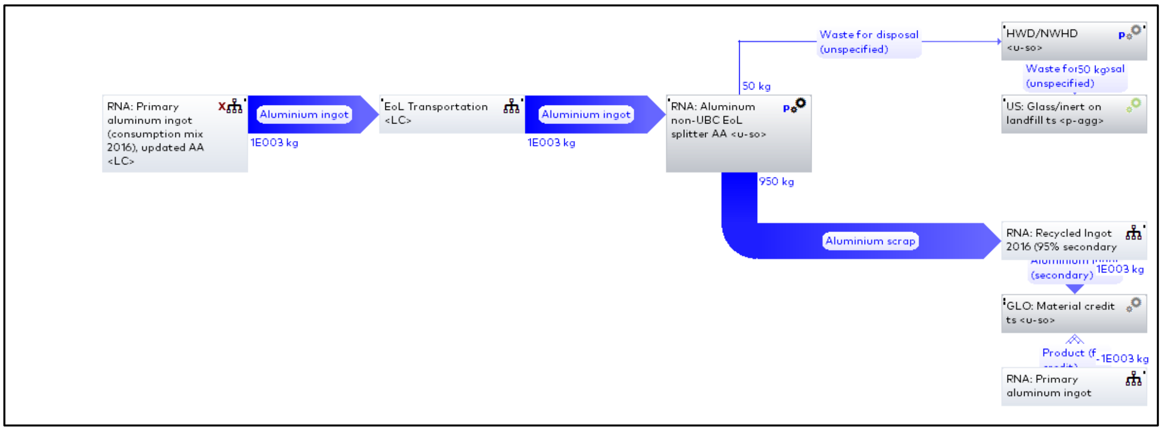

Figure 4-1. GaBi plan for the product life cycle for primary aluminum ingot (cradle-to-gate with EoL option)

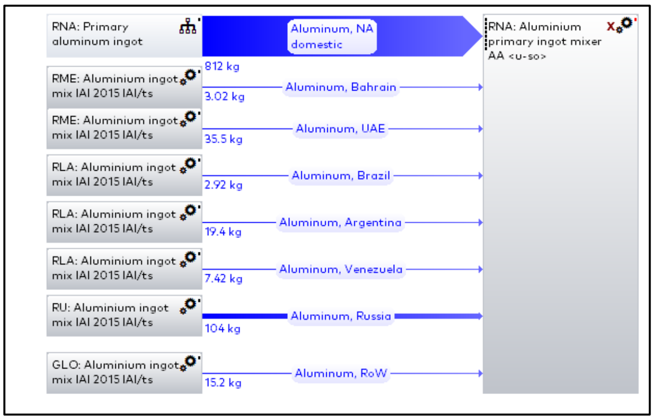

Figure 4-2. GaBi plan for the primary aluminum ingot consumption mix provenance

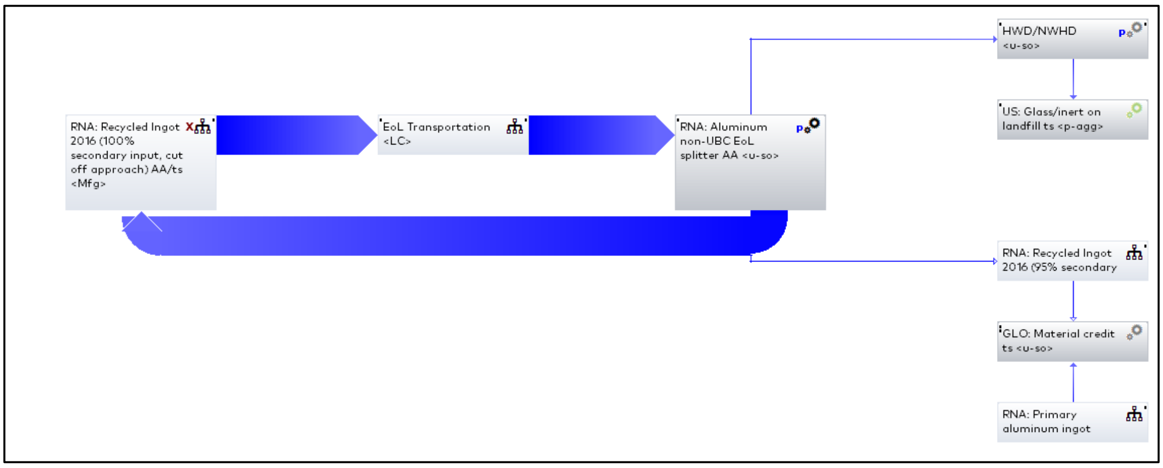

Figure 4-3. GaBi plan for the product life cycle for recycled aluminum ingot (cradle-to-gate with EoL option)

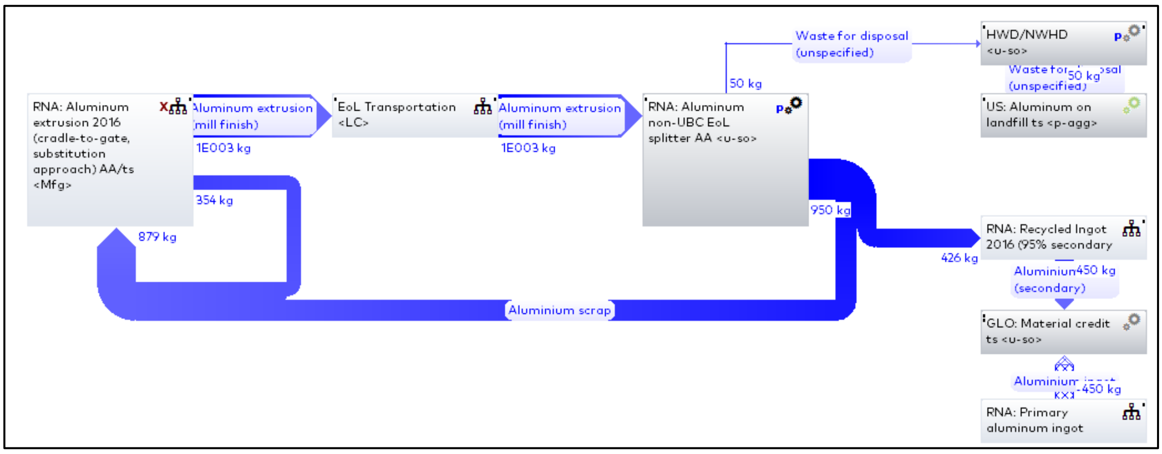

Figure 4-4. GaBi plan of the product life cycle for aluminum extrusion (cradle-to-gate with EoL option)

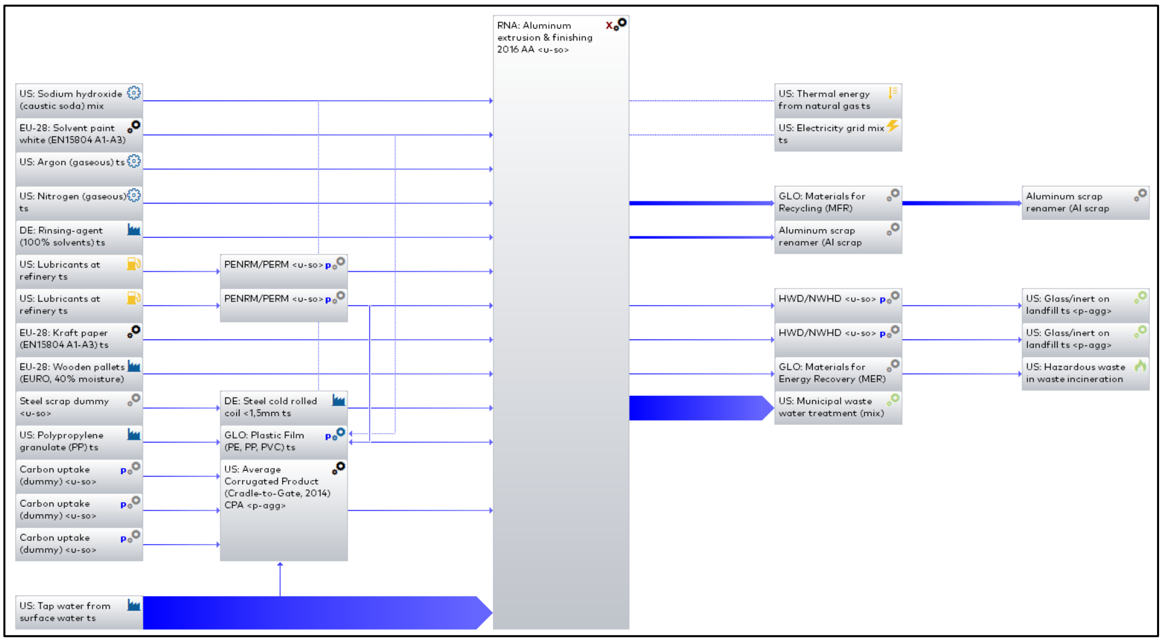

Figure 4-5. GaBi plan of the extrusion and finishing process steps for extruded aluminum

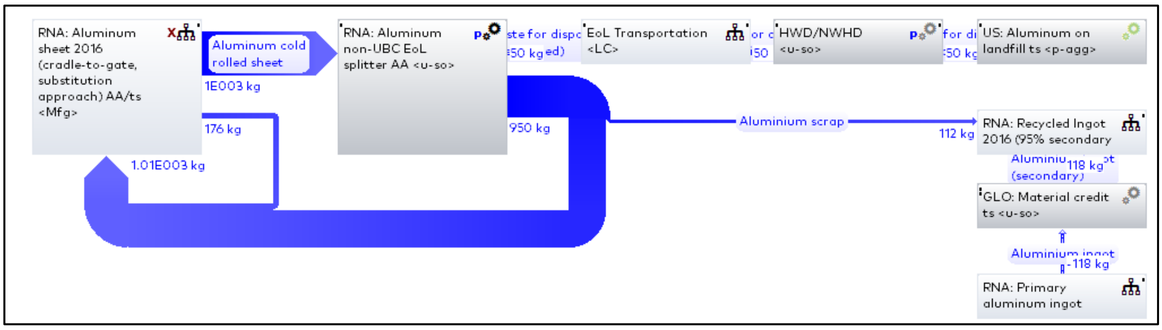

Figure 4-6. GaBi plan of the product life cycle for aluminum sheet (cradle-to-gate with EoL option)

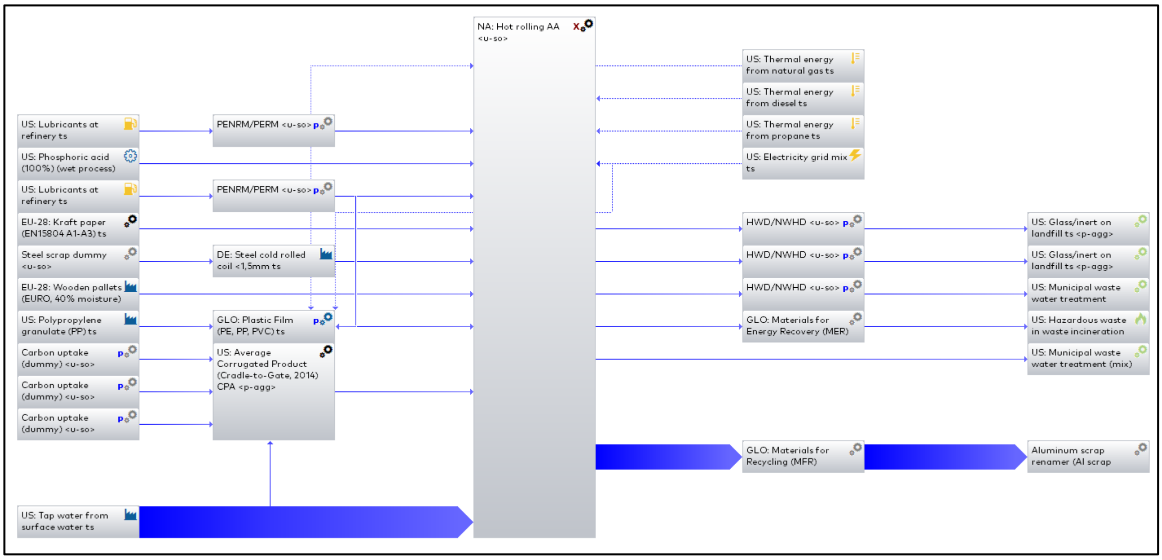

Figure 4-7. GaBi plan of hot rolling step for aluminum sheet

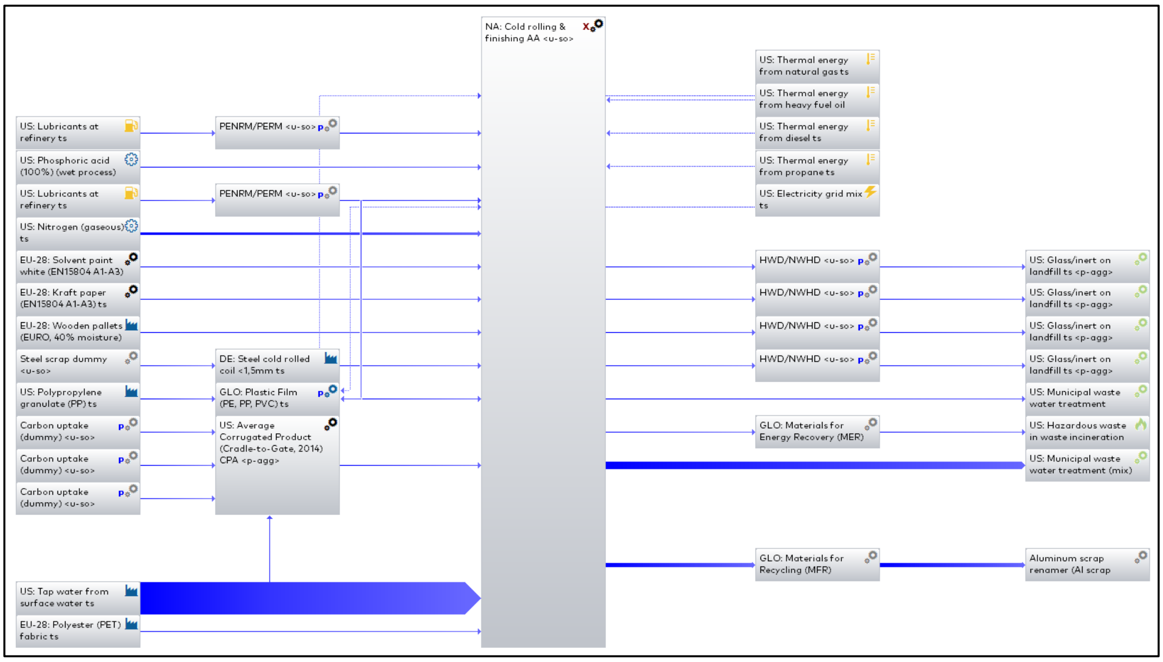

Figure 4-8. GaBi plan for cold rolling and finishing steps for aluminum sheet

At the life cycle level, aluminum was modelled as part of a closed-loop recycling approach. A 95% recycling rate was used for the aluminum extrusion and a credit was assigned to the life cycle equal to the substituted burden of primary production, accounting for the burden from scrap collection, processing, re-melting and casting. This net credit was reported in module D. The 95% recycling rate is a global estimate for aluminum in the building and transportation sectors (EAA, 2021) which has been supported by minimum values published in a United Nations report (UNEP, 2011). The remaining 5% not captured in the recycling loop are landfilled and are reported in module C4.

For unit processes and detailed input and output information for each of the above products, please refer to the report (Aluminum Association, 2022).

4.3 Background Data

Information on the background datasets used is available in the latest published AA report on semi-fabricated products (Aluminum Association, 2022).

In addition, the primary aluminum used in North America is sourced domestically and from other geographic regions, for which carbon intensity information is shared in the below Table 4-1:

Table 4-1. Data sources, origin and carbon intensity for primary aluminum

Geographic Origin	Dataset	Electricity sources (IAI, 2017)	Carbon intensity (kg CO2 eq/kWh)
Domestic (North America)	RNA: Primary aluminum ingot	Hydro (80%), lignite (17%), natural gas (3%), nuclear and fuel oil: <1%	0.214
Argentina	RLA: Aluminum ingot mix IAI 2015	Hydro (64%), natural gas (35%), coal <1%	0.393
Bahrain	RME: Aluminum ingot mix IAI 2015	Natural gas (100%)	0.45
Brazil	RLA: Aluminum ingot mix IAI 2015	Hydro (64%), natural gas (35%), coal <1%	0.393
Russia	RU: Aluminum ingot mix IAI 2015	Hydro (98%), coal (2%)	0.0421
United Arab Emirates	RME: Aluminum ingot mix IAI 2015	Natural gas (100%)	0.45
Venezuela	RLA: Aluminum ingot mix IAI 2015	Hydro (64%), natural gas (35%), coal <1%	0.393
Rest of the World	GLO: Aluminum ingot mix IAI 2015	Hydro (25%), coal (64%), natural gas (10%), nuclear (1%), oil <1%	0.778

Other additional data sets that have been used in modelling the transportation systems are detailed in Table 4-2. Average transportation distances and modes of transport are included for the transport of major raw materials to production and assembly facilities as per the full report (Aluminum Association, 2022).

The GaBi 2020 database was used to model transportation. The truck vehicle modelled is described by the fuel efficiency data from 2002 US Census Bureau Vehicle Inventory Use Survey (VIUS) and emissions data from Environmental Protection Agency (EPA Moves).

Documentation for all GaBi datasets can be found at http://www.gabi-software.com/america/support/gabi/.

Table 4-2. Data sets used in transportation modelling

Geographic Reference	Dataset	Data Provider	Ref. Year
US	Truck – Dump Truck / 52,000 lb payload – 8b	Sphera	2019
US	Diesel mix at refinery	Sphera	2016

4.4 Biogenic Carbon

GWP results exclude biogenic carbon as there are no relevant biogenic carbon removals or emissions in the life cycle. There is no calcination, carbonation and combustion of waste from non-renewable sources.

5 Life Cycle Impact Assessment

This chapter contains the results for the impact categories and additional metrics defined in Section 3.6. 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.

5.1 LCIA Results

5.1.1 Primary Aluminum Ingot

The LCIA results presented in this section are for primary aluminum ingot. Table 5-1 and Table 5-2 summarize the environmental impact results. Most of the associated environmental impact can be attributed to the input alumina and the electricity use at the electrolysis step as detailed in Table 5-3 and Figure 5-1.

Table 5-1. North American life cycle impact assessment results for 1,000 kg of primary aluminum ingot

TRACI v2.1	Unit	A1-A3	C1	C2	C3	C4	D
GWP 100	kg CO_2 eq	8.51E+03	-	9.90E+00	-	2.17E+00	-7.55E+03
ODP	kg CFC-11 eq	-1.99E-13	-	1.05E-15	-	7.02E-15	5.70E-13
AP	kg SO_2 eq	3.86E+01	-	2.85E-02	-	9.49E-03	-3.58E+01
EP	kg N eq	8.78E-01	-	3.36E-03	-	5.35E-04	-7.93E-01
SFP	kg O_3 eq	3.26E+02	-	6.40E-01	-	1.67E-01	-2.94E+02
ADP_{fossil}*	MJ, LHV	6.56E+03	-	1.86E+01	-	4.25E+00	-5.08E+03

** Resource depletion metric based on EI99 [MJ surplus energy]*

Table 5-2. EU life cycle impact assessment results for 1,000 kg of primary aluminum ingot

CML v4.2	Unit	A1-A3	C1	C2	C3	C4	D
GWP	kg CO_2 eq	8.49E+03	-	9.88E+00	-	2.16E+00	-7.54E+03
ODP	kg CFC-11 eq	3.13E-12	-	1.05E-15	-	7.02E-15	-2.57E-12
AP	kg SO_2 eq	4.14E+01	-	2.12E-02	-	8.75E-03	-3.85E+01
EP	kg $(PO_4)^{3-}$ eq	2.53E+00	-	6.49E-03	-	1.17E-03	-2.31E+00
POCP	kg Eth. Eq	2.08E+00	-	-7.13E-03	-	7.64E-05	-1.91E+00
ADP_{fossil}	MJ, LVH	8.12E+04	-	1.39E+02	-	3.27E+01	-6.87E+04
$ADP_{element}$	kg Sb-eq	4.03E-06	-	1.60E-09	-	1.80E-09	-3.08E-06

Table 5-3. TRACI 2.1 contributions per manufacturing stage for 1,000 kg of primary aluminum ingot

Parameter	Unit	Alumina	Bauxite	Cast House	Electrolysis	EoL	Primary Ingot	Recycling Credit	Transport
GWP	kg CO_2 eq	2.27E+03	3.94E+01	9.39E+01	4.46E+03	2.17E+00	1.65E+03	-7.55E+03	9.90E+00
ODP	kg CFC-11 eq	1.01E-12	9.08E-15	3.99E-14	-1.92E-12	7.02E-15	6.64E-13	5.70E-13	1.05E-15
AP	kg SO_2 eq	8.90E+00	1.91E-01	2.03E-01	2.07E+01	9.49E-03	8.58E+00	-3.58E+01	2.85E-02
EP	kg N eq	3.79E-01	4.96E-03	1.02E-02	2.71E-01	5.35E-04	2.12E-01	-7.93E-01	3.36E-03
SFP	kg O_3 eq	1.50E+02	2.28E+00	4.39E+00	6.61E+01	1.67E-01	1.04E+02	-2.94E+02	6.40E-01
ADP_{fossil}	MJ, LHV	2.49E+03	6.41E+01	1.84E+02	1.93E+03	4.25E+00	1.90E+03	-5.08E+03	1.86E+01

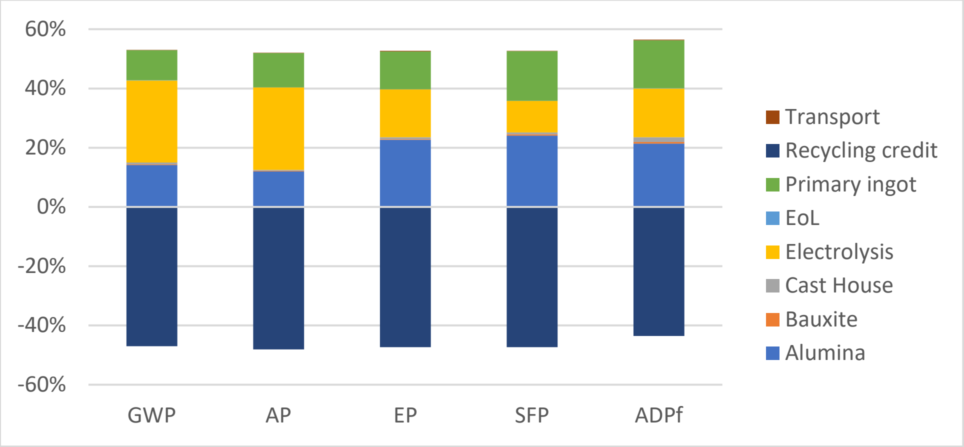

Figure 5-1. TRACI 2.1 contributions per manufacturing stage for primary aluminum ingot

Resource use LCIA indicators and output flows are required by the chosen PCR and thus are presented in Table 5-4 and Table 5-5 below.

Table 5-4. Resource use indicators for 1,000 kg of primary aluminum ingot

Parameter	Unit	A1-A3	C1	C2	C3	C4	D
RPR_E	MJ, LHV	5.29E+04	-	5.82E+00	-	2.71E+00	-4.96E+04
RPR_M	MJ, LHV	-	-	-	-	-	-
RPR_T	MJ, LHV	5.29E+04	-	5.82E+00	-	2.71E+00	-4.96E+04
$NRPR_E$	MJ, LHV	8.27E+04	-	1.40E+02	-	3.35E+01	-6.98E+04
$NRPR_M$	MJ, LHV	-	-	-	-	-	-
$NRPR_T$	MJ, LHV	8.27E+04	-	1.40E+02	-	3.35E+01	-6.98E+04
SM	kg	-	-	-	-	-	-
RSF	MJ, LHV	-	-	-	-	-	-
NRSF	MJ, LHV	-	-	-	-	-	-
RE	MJ, LHV	-	-	-	-	-	-
FW	m^3	1.75E+02	-	2.62E-02	-	4.75E-03	-1.65E+02

Table 5-5. Output flows and waste categories for 1,000 kg of primary aluminum ingot

Parameter	Unit	A1-A3	C1	C2	C3	C4	D
HWD	kg	4.87E-05	-	2.40E-06	-	2.24E-07	-4.25E-05
NHWD	kg	2.40E+03	-	-	-	5.00E+01	-2.25E+03
HLRW	kg	7.77E-04	-	3.05E-07	-	3.30E-07	-5.98E-04
ILLRW	kg	2.00E-02	-	8.16E-06	-	8.70E-06	-1.51E-02
CRU	kg	-	-	-	-	-	-
MFR	kg	5.48E+00	-	-	9.50E+02	-	-5.17E+00
MER	kg	1.39E+01	-	-	-	-	-1.31E+01
EE	MJ, LHV	-	-	-	-	-	-

5.1.2 Recycled Aluminum Ingot

The LCIA results presented in this section are for recycled aluminum ingot. GWP excludes biogenic carbon as there are no relevant biogenic carbon removals or emissions in the life cycle. There is no calcination, carbonation and combustion of waste from non-renewable sources.

Resource use LCIA indicators and output flows are required by the chosen PCR and thus are presented in Table 5-9 and Table 5-10. Modules C1 and C3 are not associated with any impact and are therefore declared as zero.

Table 5-6. North American life cycle impact assessment results for 1,000 kg of recycled ingot

TRACI v2.1	Unit	A1-A3	C1	C2	C3	C4	D
GWP 100	kg CO_2 eq	5.26E+02	-	9.90E+00	-	2.17E+00	4.29E+02
ODP	kg CFC-11 eq	3.78E-13	-	1.05E-15	-	7.02E-15	-3.24E-14
AP	kg SO_2 eq	8.65E-01	-	2.85E-02	-	9.49E-03	2.03E+00
EP	kg N eq	3.99E-02	-	3.36E-03	-	5.35E-04	4.51E-02
SFP	kg O_3 eq	1.56E+01	-	6.40E-01	-	1.67E-01	1.67E+01
ADP_{fossil}*	MJ, LHV	1.14E+03	-	1.86E+01	-	4.25E+00	2.88E+02

** Resource depletion metric based on EI99 [MJ surplus energy]*

Table 5-7. EU life cycle impact assessment results for 1,000 kg of recycled ingot

CML v4.2	Unit	A1-A3	C1	C2	C3	C4	D
GWP 100	kg CO_2 eq	5.23E+02	-	9.88E+00	-	2.16E+00	4.28E+02
ODP	kg CFC-11 eq	3.99E-13	-	1.05E-15	-	7.02E-15	1.46E-13
AP	kg SO_2 eq	7.86E-01	-	2.12E-02	-	8.75E-03	2.19E+00
EP	kg $(PO_4)^{3-}$ eq	9.47E-02	-	6.49E-03	-	1.17E-03	1.31E-01
POCP	kg Eth. eq	7.08E-02	-	-7.13E-03	-	7.64E-05	1.08E-01
ADP_{fossil}	MJ, LVH	8.32E+03	-	1.39E+02	-	3.27E+01	3.90E+03
$ADP_{element}$	kg Sb eq	7.38E-07	-	1.60E-09	-	1.80E-09	1.75E-07

Table 5-8. TRACI 2.1 contributions per manufacturing stage for 1,000 kg of recycled aluminum ingot

Parameter	Unit	EoL	Recycling Credit	Remelting and Casting	Transport
GWP	kg CO_2 eq	2.17E+00	4.29E+02	5.26E+02	9.90E+00
ODP	kg CFC-11 eq	7.02E-15	-3.24E-14	3.78E-13	1.05E-15
AP	kg SO_2 eq	9.49E-03	2.03E+00	8.65E-01	2.85E-02
EP	kg N eq	5.35E-04	4.51E-02	3.99E-02	3.36E-03
SFP	kg O_3 eq	1.67E-01	1.67E+01	1.56E+01	6.40E-01
ADPf	MJ, LHV	4.25E+00	2.88E+02	1.14E+03	1.86E+01

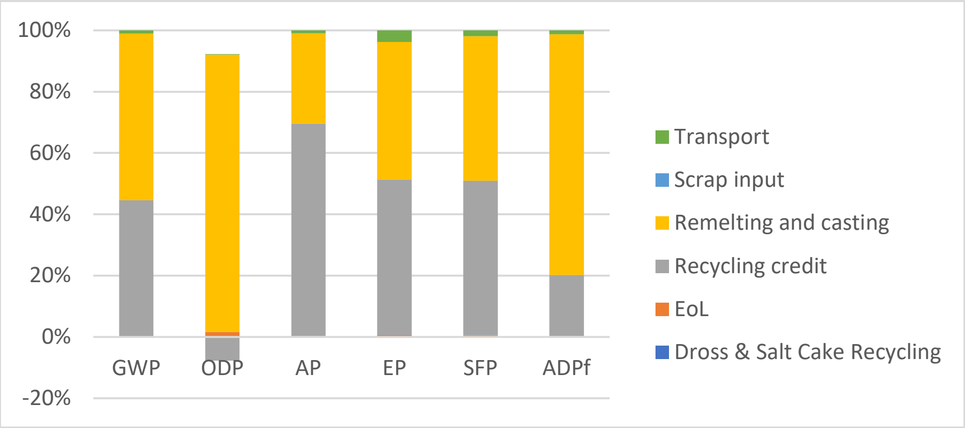

Figure 5-2. TRACI 2.1 contributions per manufacturing stage for recycled aluminum ingot

As seen in Table 5-8 and Figure 5-2 above, most of the associated environmental impact can be attributed to the energy required for aluminum scrap remelting and casting.

Table 5-9. Resource use indicators for 1,000 kg of recycled ingot

Parameter	Unit	A1-A3	C1	C2	C3	C4	D
RPR$_E$	MJ, LHV	5.46E+02	-	5.82E+00	-	2.71E+00	2.82E+03
RPR$_M$	MJ, LHV	-	-	-	-	-	-
RPR$_T$	MJ, LHV	5.46E+02	-	5.82E+00	-	2.71E+00	2.82E+03
NRPR$_E$	MJ, LHV	8.62E+03	-	1.40E+02	-	3.35E+01	3.96E+03
NRPR$_M$	MJ, LHV	1.49E+00	-	-	-	-	8.01E+00
NRPR$_T$	MJ, LHV	8.62E+03	-	1.40E+02	-	3.35E+01	3.98E+03
SM	kg	1.00E+03	-	-	-	-	-5.40E+01
RSF	MJ, LHV	-	-	-	-	-	-
NRSF	MJ, LHV	-	-	-	-	-	-
RE	MJ, LHV	-	-	-	-	-	-
FW	m^3	1.69E+00	-	2.62E-02	-	4.75E-03	9.35E+00

Table 5-10. Output flows and waste categories for 1,000 kg of recycled ingot

Parameter	Unit	A1-A3	C1	C2	C3	C4	D
HWD	kg	3.76E-06	-	2.40E-06	-	2.24E-07	2.41E-06
NHWD	kg	2.18E+01	-	-	-	5.00E+01	1.28E+02
HLRW	kg	1.39E-04	-	3.05E-07	-	3.30E-07	3.40E-05
ILLRW	kg	3.81E-03	-	8.16E-06	-	8.70E-06	8.60E-04
CRU	kg	-	-	-	-	-	-
MFR	kg	3.54E-02	-	-	9.50E+02	-	2.94E-01
MER	kg	1.66E-01	-	-	-	-	7.43E-01
EE	MJ, LHV	-	-	-	-	-	-

5.1.3 Aluminum Extrusion

The LCIA results presented in this section are for aluminum extrusions. GWP excludes biogenic carbon as there are no relevant biogenic carbon removals or emissions in the life cycle. There is no calcination, carbonation and combustion of waste from non-renewable sources.

Resource use LCIA indicators and output flows are required by the chosen PCR and thus are presented in Table 5-14 and Table 5-15. Modules C1 and C3 are not associated with any impact and are therefore declared as zero.

Table 5-11. North American life cycle impact assessment results for 1,000 kg of aluminum extrusion

TRACI v2.1	Unit	A1-A3	C1	C2	C3	C4	D
GWP 100	kg CO$_2$ eq	6.08E+03	-	9.90E+00	-	2.17E+00	-3.39E+03
ODP	kg CFC-11 eq	3.48E-07	-	1.05E-15	-	7.02E-15	2.55E-13
AP	kg SO$_2$ eq	2.31E+01	-	2.85E-02	-	9.49E-03	-1.60E+01
EP	kg N eq	6.36E-01	-	3.36E-03	-	5.35E-04	-3.56E-01
SFP	kg O$_3$ eq	2.22E+02	-	6.40E-01	-	1.67E-01	-1.32E+02
ADP$_{fossil}$*	MJ, LHV	6.51E+03	-	1.86E+01	-	4.25E+00	-2.28E+03

** Resource depletion metric based on EI99 [MJ surplus energy]*

Table 5-12. EU life cycle impact assessment results for 1,000 kg of aluminum extrusion

CML v4.2	Unit	A1-A3	C1	C2	C3	C4	D
GWP 100	kg CO$_2$ eq	6.06E+03	-	9.88E+00	-	2.16E+00	-3.38E+03
ODP	kg CFC-11 eq	3.01E-07	-	1.05E-15	-	7.02E-15	-1.15E-12
AP	kg SO$_2$ eq	2.43E+01	-	2.12E-02	-	8.75E-03	-1.73E+01
EP	kg (PO$_4$)$^{3-}$ eq	1.67E+00	-	6.49E-03	-	1.17E-03	-1.04E+00
POCP	kg Eth. eq	1.32E+00	-	-7.13E-03	-	7.64E-05	-8.55E-01
ADP$_{fossil}$	MJ, LVH	6.70E+04	-	1.39E+02	-	3.27E+01	-3.08E+04
ADP$_{element}$	kg Sb eq	2.41E-03	-	1.79E-06	-	8.18E-07	-1.27E-03

Table 5-13. TRACI 2.1 contributions per manufacturing stage for 1,000 kg of aluminum extrusion

Parameter	Unit	Primary ingot	Secondary ingot	Scrap input	Billet casting	Extrusion	Transport	EoL
GWP	kg CO$_2$ eq	4.60E+03	2.30E+01	9.37E+01	7.45E+02	7.52E+02	4.06E+01	-3.55E+03
ODP	kg CFC11 eq	-1.07E-13	8.44E-15	4.37E-14	4.47E-09	3.44E-07	4.32E-15	2.94E-13
AP	kg SO$_2$ eq	2.09E+01	6.92E-02	9.51E-02	1.48E+00	1.26E+00	1.17E-01	-1.68E+01
EP	kg (PO$_4$)$^{3-}$ eq	4.74E-01	2.04E-03	8.06E-03	6.53E-02	9.22E-02	1.38E-02	-3.72E-01
SFP	kg O$_3$ eq	1.76E+02	7.76E-01	2.06E+00	2.37E+01	2.30E+01	2.62E+00	-1.38E+02
ADPf	MJ	3.54E+03	3.46E+01	2.01E+02	1.42E+03	1.36E+03	7.64E+01	-2.37E+03

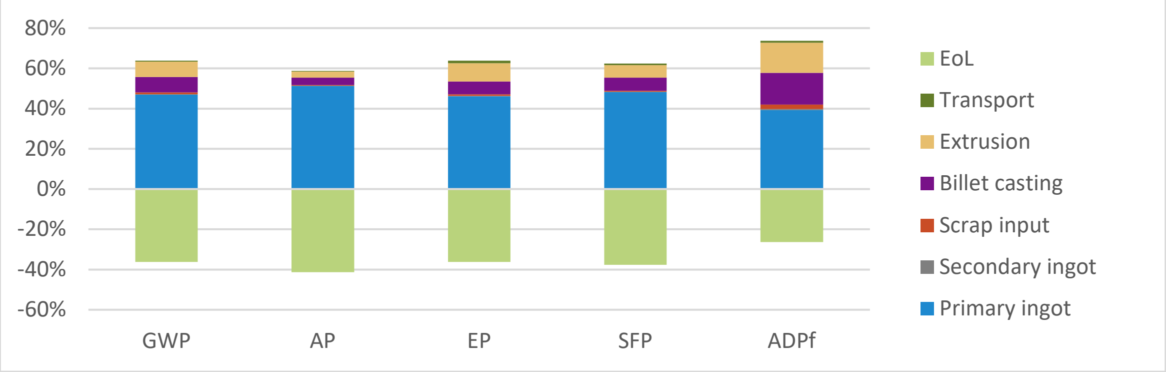

Figure 5-3. TRACI 2.1 contributions per manufacturing stage for aluminum extrusion

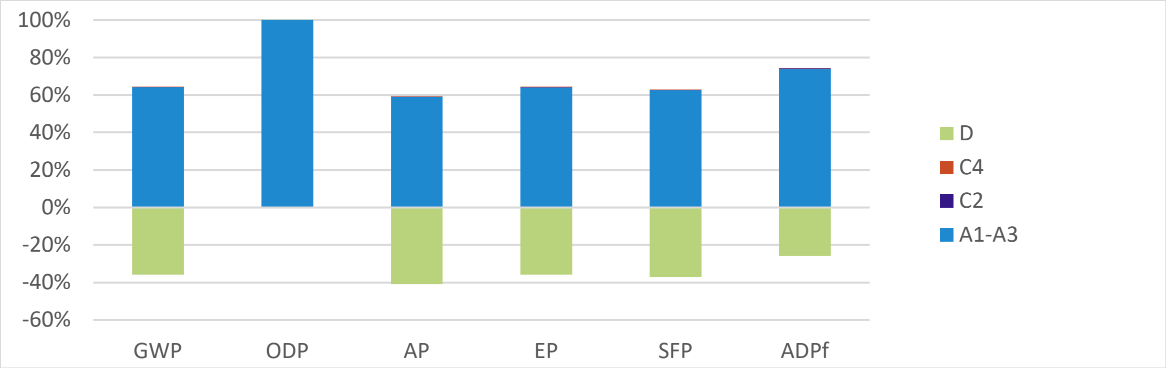

Figure 5-4. TRACI 2.1 contributions per declared module for aluminum extrusion

Table 5-14. Resource use for 1,000 kg aluminum extrusion

Parameter	Unit	A1-A3	C1	C2	C3	C4	D
RPR$_E$	MJ, LHV	3.04E+04	-	5.82E+00	-	2.71E+00	-2.22E+04
RPR$_M$	MJ, LHV	-	-	-	-	-	-
RPR$_T$	MJ, LHV	3.04E+04	-	5.82E+00	-	2.71E+00	-2.22E+04
NRPR$_E$	MJ, LHV	6.99E+04	-	1.40E+02	-	3.35E+01	-3.14E+04
NRPR$_M$	MJ, LHV	1.20E+02	-	-	-	-	-6.33E+01
NRPR$_T$	MJ, LHV	-	-	-	-	-	-
SM	kg	8.79E+02	-	-	-	-	4.26E+02
RSF	MJ, LHV	-	-	-	-	-	-
NRSF	MJ, LHV	-	-	-	-	-	-
RE	MJ, LHV	-	-	-	-	-	-
FW	m^3	6.95E+03	-	2.55E+01	-	4.43E+00	-3.04E+03

Table 5-15. Output flows and waste categories for 1,000 kg of aluminum extrusion

Parameter	Unit	A1-A3	C1	C2	C3	C4	D
HWD	kg	7.34E-04	-	2.40E-06	-	2.24E-07	-1.90E-05
NHWD	kg	1.34E+03	-	-	-	5.00E+01	-1.01E+03
HLRW	kg	1.39E-03	-	3.05E-07	-	3.30E-07	-2.68E-04
ILLRW	kg	3.75E-02	-	8.16E-06	-	8.70E-06	-6.79E-03
CRU	kg	-	-	-	-	-	-
MFR	kg	2.50E+02	-	-	9.50E+02	-	-2.32E+00
MER	kg	1.00E+01	-	-	-	-	-5.86E+00
EE	MJ, LHV	-	-	-	-	-	-

5.1.4 Sheet Aluminum

The LCIA results presented in this section are for aluminum sheet . Most of the associated environmental impact can be attributed to the use of primary aluminum as a raw material. GWP excludes biogenic carbon as there are no relevant biogenic carbon removals or emissions in the life cycle. There is no calcination, carbonation and combustion of waste from non-renewable sources.

Resource use LCIA indicators and output flows are required by the chosen PCR and thus are presented in Table 5-19 and Table 5-20. Modules C1 and C3 are not associated with any impact and are therefore declared as zero.

Table 5-16. North American life cycle impact assessment results for 1,000 kg of sheet aluminum

TRACI v2.1	Unit	A1-A3	C1	C2	C3	C4	D
GWP 100	kg CO_2 eq	3.82E+03	-	9.90E+00	-	2.17E+00	-8.90E+02
ODP	kg CFC-11 eq	4.47E-08	-	1.05E-15	-	7.02E-15	6.71E-14
AP	kg SO_2 eq	1.30E+01	-	2.85E-02	-	9.49E-03	-4.22E+00
EP	kg N eq	3.83E-01	-	3.36E-03	-	5.35E-04	-9.35E-02
SFP	kg O_3 eq	1.35E+02	-	6.40E-01	-	1.67E-01	-3.46E+01
ADP_{fossil}*	MJ, LHV	4.66E+03	-	1.86E+01	-	4.25E+00	-5.98E+02

** Resource depletion metric based on EI99 [MJ surplus energy]*

Table 5-17. EU life cycle impact assessment results for 1,000 kg of sheet aluminum

CML v4.2	Unit	A1-A3	C1	C2	C3	C4	D
GWP 100	kg CO_2 eq	3.80E+03	-	9.88E+00	-	2.16E+00	-8.88E+02
ODP	kg CFC-11 eq	3.86E-08	-	1.05E-15	-	7.02E-15	-3.03E-13
AP	kg SO_2 eq	1.35E+01	-	2.12E-02	-	8.75E-03	-4.54E+00
EP	kg $(PO_4)^{3-}$ eq	9.88E-01	-	6.49E-03	-	1.17E-03	-2.72E-01
POCP	kg Eth. eq	7.96E-01	-	-7.13E-03	-	7.64E-05	-2.25E-01
ADP_{fossil}	MJ, LVH	4.50E+04	-	1.39E+02	-	3.27E+01	-8.10E+03
$ADP_{element}$	kg Sb eq	1.43E-03	-	1.79E-06	-	8.18E-07	-3.34E-04

Table 5-18. TRACI 2.1 contributions per manufacturing stage for 1,000 kg of aluminum sheet

Parameter	Unit	Primary ingot	Secondary ingot	Scrap input	Remelting & casting	Sheet rolling	Transport	EoL
GWP	kg CO_2 eq.	2.52E+03	5.17E+01	1.06E+02	6.89E+02	6.16E+02	2.55E+01	-1.07E+03
ODP	kg CFC11 eq.	-5.88E-14	1.90E-14	4.92E-14	6.68E-13	4.47E-08	3.71E-15	1.30E-13
AP	kg SO_2 eq.	1.14E+01	1.56E-01	1.07E-01	1.20E+00	9.37E-01	1.01E-01	-5.07E+00
EP	kg $(PO_4)^{3-}$ eq	2.59E-01	4.59E-03	9.07E-03	5.76E-02	6.32E-02	1.19E-02	-1.12E-01
SFP	kg O_3 eq.	9.64E+01	1.75E+00	2.32E+00	2.18E+01	1.80E+01	2.25E+00	-4.15E+01
ADPf	MJ	1.94E+03	7.79E+01	2.26E+02	1.42E+03	1.06E+03	6.57E+01	-7.08E+02

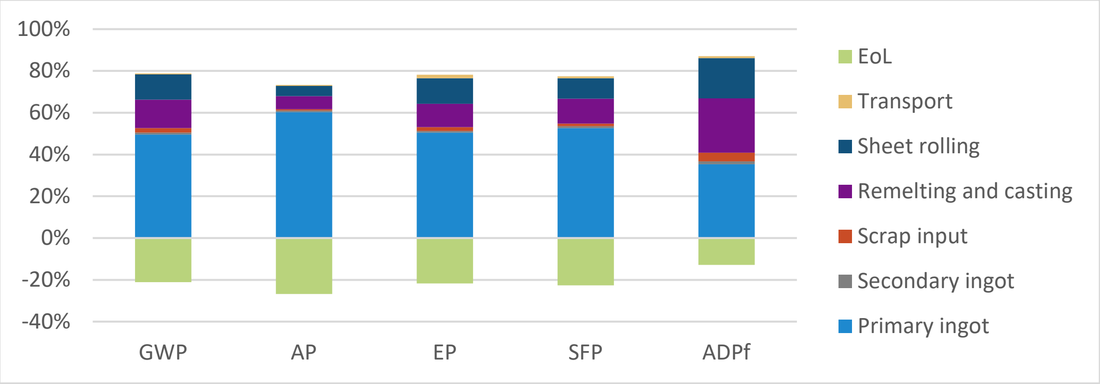

Figure 5-5. TRACI 2.1 contributions per manufacturing stage for 1,000 kg of aluminum sheet

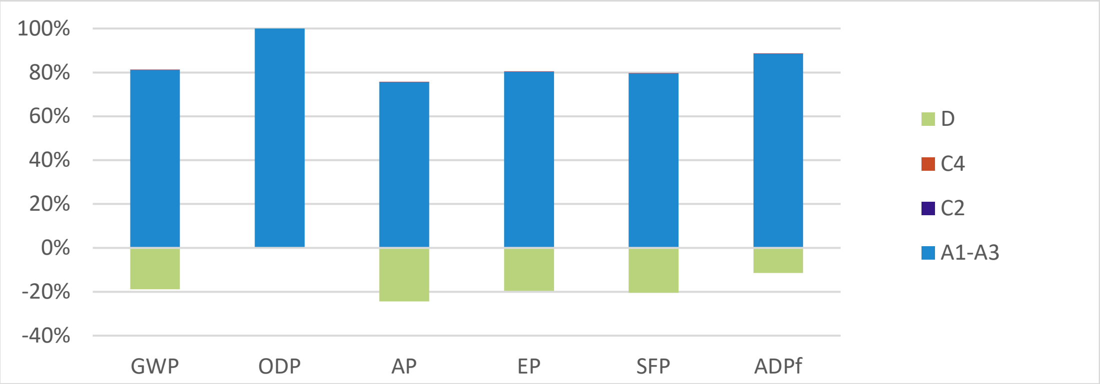

Figure 5-6. TRACI 2.1 contributions per declared module for 1,000 kg of aluminum sheet

Table 5-19. Resource use for 1,000 kg of sheet aluminum

Parameter	Unit	A1-A3	C1	C2	C3	C4	D
RPR_E	MJ, LHV	1.67E+04	-	5.82E+00	-	2.71E+00	-5.85E+03
RPR_M	MJ, LHV	-	-	-	-	-	-
RPR_T	MJ, LHV	-	-	5.82E+00	-	-	-
$NRPR_E$	MJ, LHV	4.75E+04	-	1.40E+02	-	3.35E+01	-8.24E+03
$NRPR_M$	MJ, LHV	2.88E+02	-	-	-	-	-1.66E+01
$NRPR_T$	MJ, LHV	-	-	1.40E+02	-	-	-
SM	kg	1.01E+03	-	-	-	-	1.12E+02
RSF	MJ, LHV	-	-	-	-	-	-
NRSF	MJ, LHV	-	-	-	-	-	-
RE	MJ, LHV	-	-	-	-	-	-
FW	m^3	4.20E+03	-	2.55E+01	-	4.43E+00	-7.99E+02

Table 5-20. Output flows and waste categories for 1,000 kg of sheet aluminum

Parameter	Unit	A1-A3	C1	C2	C3	C4	D
HWD	kg	1.15E-04	-	2.40E-06	-	2.24E-07	-5.00E-06
NHWD	kg	7.07E+02	-	-	-	5.00E+01	-2.66E+02
HLRW	kg	1.21E-03	-	3.05E-07	-	3.30E-07	-7.05E-05
ILLRW	kg	3.28E-02	-	8.16E-06	-	8.70E-06	-1.78E-03
CRU	kg	-	-	-	-	-	-
MFR	kg	1.77E+02	-	-	9.50E+02	-	-6.09E-01
MER	kg	4.47E+00	-	-	-	-	-1.54E+00
EE	MJ, LHV	-	-	-	-	-	-

5.2 Sensitivity Analysis

A sensitivity analysis has been conducted to examine the impact of increasing primary aluminum content in semi-finished products. Given the significant influence of primary aluminum on the cradle-to-gate footprint, one way to address it is to reduce the use of primary aluminum and increase the use of recycled metal. A sensitivity analysis was conducted to examine the effect of increasing primary aluminum content in the products. As shown in Figure 5-7 and Figure 5-8, a one percent increase in primary aluminum content in the products will increase the cradle-to-gate primary energy demand and global warming potential by as much as 1856 MJ and 117 kg CO2e, respectively, for 1,000 kg semi-finished products. This is equal to say that a one percentage point increase in recycled aluminum content will reduce the energy demand and carbon footprint by the same amount.

For additional sensitivity analysis information for each of the above products, please refer to the report (Aluminum Association, 2022).

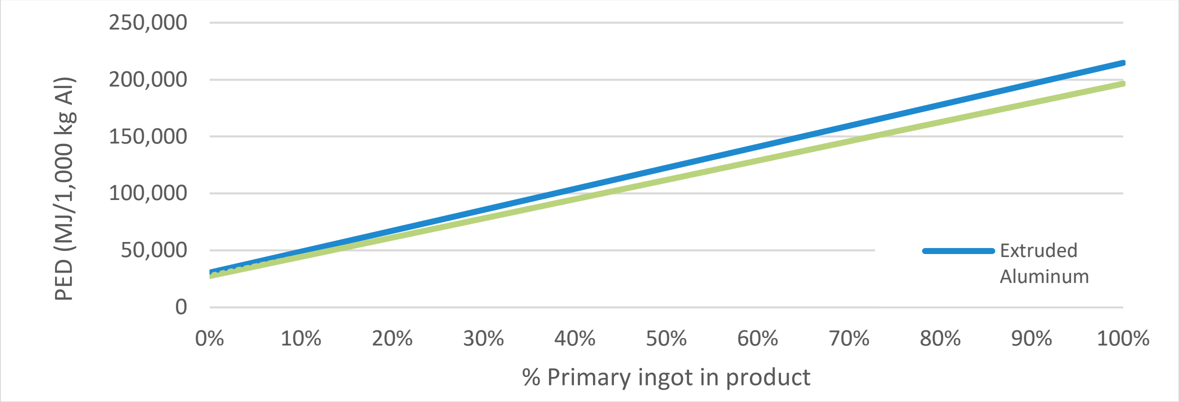

Figure 5-7. Impact of primary and recycled metal use on cradle-to-gate primary energy demand of semi-finished aluminum products

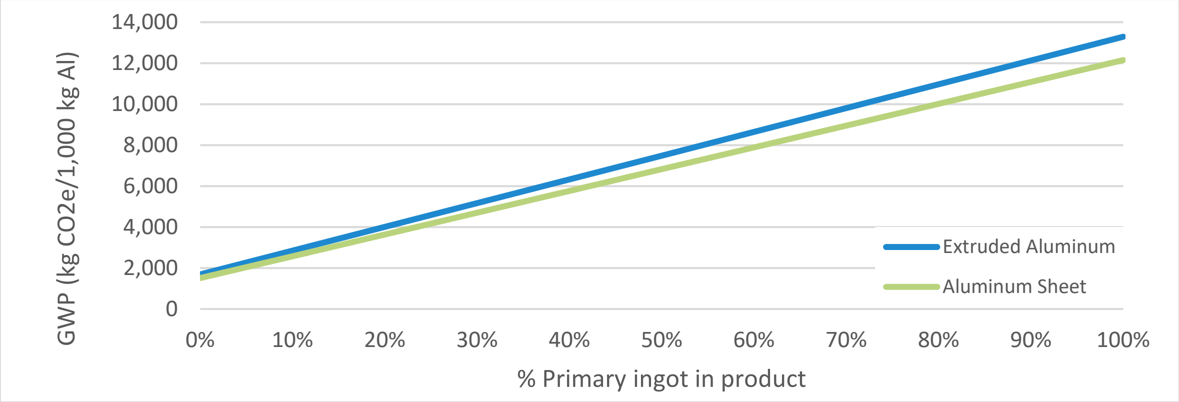

Figure 5-8. Impact of primary and recycled metal use on cradle-to-gate carbon footprint of semi-finished aluminum products

5.3 Scenario Analysis

To see the effect of primary aluminum sourcing, a scenario analysis was conducted to alternate the sourcing from different regions or countries other than the baseline case of the North American consumption mix. The metal compositions – shares of primary and recycled metal in the products, are kept unchanged for the scenario analysis. Figure 5-9 and Figure 5-10 show the effects of primary aluminum sourcing on cradle-to-gate primary energy demand and global warming potential, respectively. The regions and countries included in the scenario analysis are:

- RNA represents the weighted average of primary aluminum consumption mix in North America, which is the baseline case;
- CA represents Canada where primary aluminum is exclusively smelted with hydropower electricity;
- CN represents China where primary aluminum is mainly smelted with coal-fired electricity;
- RME represents the Middle East where primary aluminum is mainly smelted with natural gas fired electricity.

Clearly, the scale of difference is dependent both on impact category (e.g., PED or GWP) and on how much primary aluminum content is in the products. The more primary aluminum is in the product, the more striking the difference between hydropower smelted aluminum and coal-power smelted aluminum. The difference is more prominent for GWP than it is for PED. The cradle-to-gate carbon footprint of automotive aluminum sheet made of Chinese primary aluminum would be 3.2 times higher than it is made of Canadian primary aluminum under the same share of primary and recycled content as the baseline case.

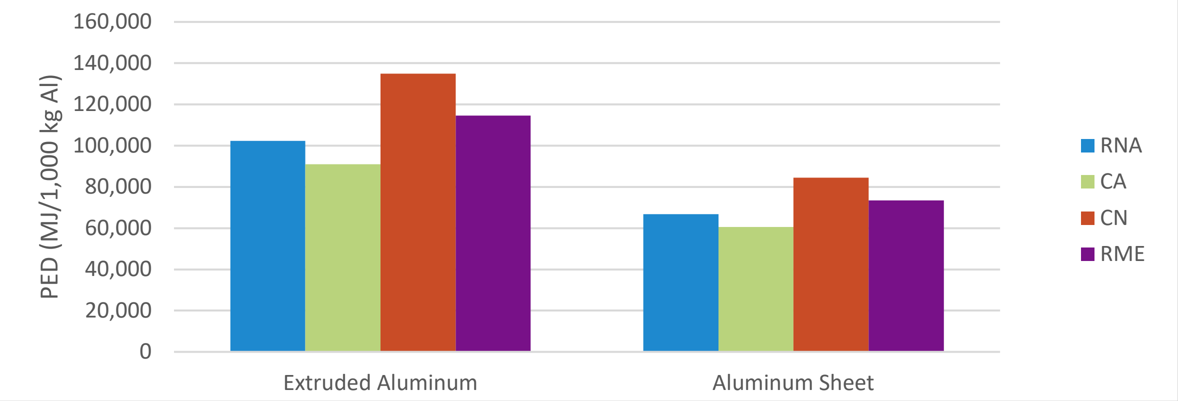

Figure 5-9. Effect of source of primary aluminum on cradle-to-gate primary energy demand (RNA: North America, CA: Canada, CN: China, RME: Middle East)

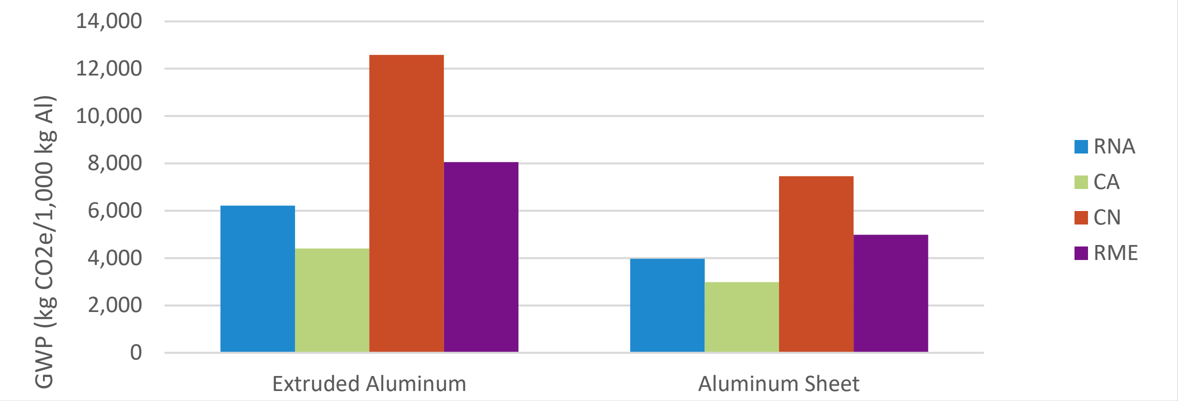

Figure 5-10. Effect of source of primary aluminum on cradle-to-gate carbon footprint (RNA: North America, CA: Canada, CN: China, RME: Middle East)

For additional scenario analysis information for each of the above products, please refer to the report (Aluminum Association, 2022).

6 Life Cycle Interpretation

The results in Section 5.1 throughout Section 5.4 represented the cradle-to-gate and end-of-life environmental performance of aluminum ingots and the two semi-fabricated products:

- Primary aluminum ingot (100% primary aluminum content)
- Recycled aluminum ingot (100% recycled aluminum content)
- Aluminum extrusion
- Sheet aluminum (cold-rolled)

6.1 Life Cycle Overview

The interpretation is based on the assumptions and limitations described in this background report and the recently published AA report from which the data used here is derived (Aluminum Association, 2022).

The manufacturing phases are dominant in the life cycle (Modules A1-A3), with recycling playing a secondary role (Module D). Disposal (Module C4) plays a relatively small role overall in the overall life cycle. Amongst all, majority of impacts are coming from primary aluminum ingot and its processing.

As previously noted above, the main change to the data and results reported previously in The Environmental Footprint of Semi-Fabricated Aluminum Products in North America (Aluminum Association, 2022), is the addition on transportation modules as required by the new PCR (UL Environment, 2022).

Transportation to manufacturing sites and at end of life have a minimal impact on the overall LCIA results obtained as seen in the previous section 5. Table 6-1 illustrates the percentage difference between the previous set of reported LCIA results and the new results that now take the impact of transportation into account. The results for primary and recycled aluminum ingots for modules A1-A3 saw virtually no major changes, however the reporting requirements mandated the inclusion of modules C and D, which were not required when the full report was generated (UL Environment, 2022).

Table 6-1. Percentage difference in TRACI 2.1 compared to AA report (Aluminum Association, 2022)

	Primary aluminum ingot (A1-A3)	Recycled aluminum ingot (A1-A3)	Aluminum extrusion	Sheet aluminum
GWP	0.00%	0.00%	1.52%	0.88%
AP	-0.01%	-0.46%	1.63%	0.85%
EP	-0.02%	-0.03%	5.20%	3.82%
SFP	0.00%	-0.02%	2.98%	1.67%
PED	0.00%	-0.14%	1.30%	0.75%

The addition of transportation to the life cycle impact assessment of these products does not impact the conclusions previously obtained in the latest January 2022 AA report, where more detailed life cycle interpretation information is available (Aluminum Association, 2022).

6.2 Data Quality Assessment

Please refer to The Environmental Footprint for Semi-Fabricated Aluminum Products in North America for more information on quality assessment for data used in this study (Aluminum Association, 2022)

6.3 Conclusions, Limitations, and Recommendations

6.3.1 Conclusions

As discussed in Section 6.1, manufacturing constitutes the largest driver of impacts across all impact categories. The credit attained for manufacturing highly recyclable aluminum products reduces the overall environmental impacts.

The addition of transportation to the life cycle assessment of these products had a minimal impact across all impact categories and the conclusions of this study are consistent with the previous remarks shared in the full AA report (Aluminum Association, 2022).

6.3.2 Recommendations

The recycling rate for aluminum from building and transportation sectors is estimated to be 95% (Aluminum Association, 2022). As the credits at the end-of-life are significant in the life cycle, a change in this recycling rate will, in turn, affect the environmental impact results of the aluminum extrusions. As such, as new information on aluminum recycling rates becomes available, this report and the accompanying EPD should be modified to reflect industry conditions.

Other recommendations are available in the full report published by AA in January 2022 (Aluminum Association, 2022).

Bibliography

ACLCA. (2019). *ACLCA Guidance to Calculating Non-LCIA Inventory Metrics in Accordance with ISO 21930:2017.*

Aluminum Association. (2022, January). *The Environmental Footprint of Semi-Fabricated Aluminum Products in North America.* Retrieved from https://www.aluminum.org/sites/default/files/2022-01/2022_Semi-Fab_LCA_Report.pdf

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.

EAA. (2021). *https://www.european-aluminium.eu/*. Retrieved from European Aluminum Website.

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

IAI. (2017, June). Life Cycle Inventory Data and Environmental Metrics for the Primary Aluminium Industry. London, World Aluminium, 2015 Data.

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

ISO. (2006). *ISO 14025:2006 Environmental labels and declarations - Type III environmental declarations - Principles and procedures.* Retrieved from https://www.iso.org/standard/38131.html

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

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

ISO. (2017). *ISO 21930 Sustainability in building construction - Environmental declaration of building products.*

Sphera Solutions Inc. (2020). *GaBi LCA Database Documentation*. Retrieved from GaBi Solutions: https://www.gabi-software.com/databases/gabi-databases/

UL Environment. (2022, March 28). Part A: Life Cycle Assessment Calculation Rules and Report Requirements, UL 10010 version 4.0.

UL Environment. (2022, February 16). Part B: Aluminum Construction Product EPD Requirements, UL 10010-38.

UNEP. (2011). *Recycling Rates of Metals : A Status Report.* Retrieved from UNE Document Repository: https://wedocs.unep.org/bitstream/handle/20.500.11822/8702/Recycling_Metals.pdf?sequence=1&isAllowed=y

Annex A: Participating Companies

No.	Company	Note
1	Alcoa Corporation	Primary aluminum
2	Arconic Corporation	Recycling, sheet, extrusion
3	Century Aluminum	Primary aluminum
4	Commonwealth Rolled Products	Formally Aleris International, recycling, sheet
5	Constellium	Recycling, sheet, extrusion
6	Howmet	Formally part of Arconic, recycling, sheet, extrusion
7	Hydro Extrusions North America	Recycling, extrusion
8	Hydro Metals North America	Recycling, extrusion billet
9	Jupiter Aluminum	Recycling, sheet
10	JW Aluminum	Recycling, sheet, foil
11	Kaiser Aluminum	Recycling, sheet, extrusion
12	Keymark	Recycling, extrusion
13	Novelis Inc.	Recycling, sheet, foil
14	Real Alloys	Recycling, RSI
15	Rio Tinto	Primary aluminum
16	Reynolds	Foil
17	Scepter Inc.	Recycling, RSI
18	Skana	Recycling, sheet
19	Smelter Service Corporation	Recycling, RSI
20	United Aluminum	Recycling, sheet