LCA Background Report for Environmental Product Declaration of Cold Rolled Aluminium Sheet and Painted Aluminium Sheet

in accordance with ISO 14040:2006, ISO 14044:2006, ISO 14025:2006 and EN 15804:2012+A2:2019

Asaş Alüminyum

Date

11.04.22

Prepared by

Semtrio

SEMTRIO

Contents

1. GENERAL ASPECTS

1.1 General information about the applicant company and the product

Founded in Gebze in 1990, Asaş Alüminyum Sanayi ve Ticaret A.Ş. will be mentioned as ASAŞ is one of the most remarkable industrial enterprises in Turkey with its 5 state-of-the-art production facilities in Akyazı, Sakarya region and over 2400 employees and export to over 90 countries. Based on its stable financial growth trend since its establishment in 1990, Asaş was listed No 63 out of Top 100 companies in İSO 500 Turkey in 2020 and became one of the leading manufacturers in Europe. ASAS generates solutions and adds value to all sectors where it operates, thanks to its innovative products, technology, R&D Center which is a first in its sector, and its services.

Believing that not only science but also art makes contribution to the development of societies, ASAŞ decided to be found ASAŞSANAT in 2015 to further improve its support in art. ASAŞSANAT operates as a learning+ sharing+ designing+ production platform that brings art and design students together with academics and professionals. Asaş aims to revive the change created by art in societies as well as the skill of having different point of view in its own organization by courses and seminars for the spouses and children of its employees, at the Art Workshop to be constructed in Akyazı/Sakarya Region. Additionally, in line with its social responsibility activities, another target of ASAŞ is, to develop projects that will enable our handicapped friends to create art works in parallel to corporate social responsibility activities.

ASAŞ provides services for its clients at its Aluminium Profile, Composite Panel, Aluminium ColdRolled Product, PVC Profile and Roller Shutter production facilities which are located in a total of 923.000 m² area, of which 300.000 m² is enclosed, in Akyazı and Karapürçek complex.

As ASAŞ, we serve many sectors such as construction, automotive, railway, commercial vehicles, energy, packaging, consumer products and maritime. We produce finished and semi-finished products to meet our customers' needs in their own projects. Besides this, we enrich our knowledge in the field of production with design & product development studies and offer our products that we produce with our own brand to the market. Aluminium architectural systems (door, window, and curtain wall systems), aluminium composite panels, u-PVC door and window systems, aluminium design products (aluminium flag and lighting poles, aluminium furniture etc), roller shutter systems, garage doors and motor control systems are product groups that we sell with our own brand.

With cold rolled products which are produced in the most modern and highest technology facility in Europe, ASAŞ has been providing services to packaging, construction, durable consumption and automotive sectors with its high-quality product groups since its foundation in 2014. Aluminium Cold Products Production Facilities were founded within ASAŞ organization in Sakarya – Karapürçek in 2014 to meet the growing demand for high quality products in Turkey and in world markets. The facility provides services in a total 310.000 m² area, of which 135.000 m² is enclosed, and has total annual capacity of 120.000 tons of coldrolled products, of which 45.000 tons are coated products.

1.2 Commissioner of the LCA study, internal or external practitioner of the LCA study

This LCA study is commissioned by Asaş Alüminyum and prepared by Sustainability Consultant Mr. Bekir Cetin, Ms. Gülşen Tuncer, Ms. Gülşah Uzun and Ms. Beyza Nur Hoşgör of Semtrio Sustainability Consulting. This report has been carried out for coldrolled products - coldrolled aluminium sheet and painted aluminium sheet at Asaş Alüminyum manufacturing plant in Sakarya Yazılıgürgen Mahallesi Fabrikalar Cad. No. 50, 54400 Karapürçek - Sakarya / Turkey.

1.3 Contact Details

This report was issued in April 2022, participant details are present in the table below.

Table 1: Contact information for the participants

Company	Address	Participant	Contact
Asaş Alüminyum San. Ve Tic. A.Ş.	Yazılıgürgen Mahallesi Fabrikalar Cad. No. 50, 54400 Karapürçek - Sakarya / Türkiye	Hasan Basri Taşkın Nurcan Alaca Zeynep Kahya	hasan.taskin@asastr.com nurcan.alaca@asastr.com zeynep.kahya@asastr.com
Semtrio	Budotek Teknopark Umraniye / İstanbul	Mr. Bekir Cetin	bekircetin@semtrio.com
Semtrio	Budotek Teknopark Umraniye / İstanbul	Ms. Gülşen Tuncer	gulsentuncer@semtrio.com
Semtrio	Budotek Teknopark Umraniye / İstanbul	Ms. Gülşah Uzun	gulsahuzun@semtrio.com
Semtrio	Budotek Teknopark Umraniye / İstanbul	Ms. Beyza Nur Hoşgör	beyzahosgor@semtrio.com

1.4 Requirements and Standards

This study is conducted according to the guidelines of ISO 14040:2006, ISO 14044:2006, ISO 14025:2006, ISO 14020:2006 and the requirements given in the General Program Instructions v3.01; PCR Construction products 2019:14, version 1.11, by The International EPD® System and EN 15804:2012+A2:2019.

The inventory for the LCA study is based on the period of 1st January 2021 and 30st June 2021 production figures from Sakarya manufacturing plant. This LCA was modelled with SimaPro LCA v9.2.0.2 software with Ecoinvent v3.7.1 database for secondary data.

2. GOAL OF THE STUDY

This LCA study aims to evaluate the environmental impacts for 1 kg of cold rolled aluminium sheet and 1 kg painted cold rolled aluminium sheet, cradle to gate with options, modules, C1-C4, D (A1–A3 + C + D) approach to be awarded Environmental Product Declarations (EPDs) certified by The International EPD System through third-party verification. This LCA study aims to be used as business-to-business communication.

3. SCOPE OF THE STUDY

3.1 Production Process

Production process of cold rolled and painted aluminium sheet comprises the product stages A1-A3, which includes the acquisition of all raw materials, additives products and energy, transport to the production site, packaging, and waste processing up to the” end-of-waste” state or final disposal.

3.1.1. Product Stage A1-A2: Raw Materials Supply and Transport to the Manufacturer

In the cold rolled plant, the process starts from gathering the primer aluminium, external seconder, internal and external scrap, chemicals, and other additives.

Primer aluminium is supplied from Russia, Tajikistan and Kazakhstan by seaway and roadway to Asaş cold rolled production facility. External secondary materials and scraps are supplied by road from an average distance of 200 km to Asaş cold rolled production plant. Internal scrap is the materials obtained as waste from production facility which has no shipping.

Some of the chemicals and additives used in production are supplied from Europe (Belgium, Spain, Italy, Netherlands, Switzerland) and Turkey by roadway at maximum distance 1,292.7 km and seaway at maximum distance 5,913.4 km from supplier to Asaş cold rolled production plant. The rest is supplied from Turkey at a maximum distance of 507 km from the supplier to Asaş cold rolled production plant.

3.1.2. Product Stage A3: Manufacturing

In the cold rolled production plant, the process starts with induction and casting. Cast rolled aluminium is produced by mixing primary aluminium, secondary aluminium and pre-consumer recycled materials with other additives in the casting process. After the casting process, aluminium alloys are treated in cold rolling, plate annealing, plate stretching and cutting processes.

The cast rolled aluminium is after sent to cold rolling and annealing processes. Cast rolled aluminium is treated coldtened into different thicknesses in cold rolling mill. Electricity, water, and some lubricants are consumed in this stage. After passing through the cold rolling mill, aluminium sheet is subjected to the annealing for softening the aluminium sheet. As the last process before cutting, the coils are stretched to make the coil product smoother. As a result of all these processes, aluminium sheet is produced. After the cutting process is completed, the cold rolled aluminium sheet is ready and packaged to be delivered to the customer.

In addition to the processes mentioned for cold rolled aluminium sheet, dyeing process is applied for the production of painted aluminium sheet. For the production of painted aluminium sheet, the stretched cold rolled aluminium product is processed in the dyeing process. After the cutting process is completed, the painted aluminium sheet is ready and packaged to be delivered to the customer.

3.2 End of Life Stage

The end-of-life stage includes module C2-C4 and D:

C2 - transport to waste processing

C3 - waste processing for reuse, recovery and/or recycling

C4 – disposal

D - reuse, recovery and/or recycling potentials

For both products which are mentioned as the cold rolled aluminium sheet and painted aluminium sheet have the same C1, C2, C3, c4 and D module scenarios.

In module C1, it is assumed that demolition of the cold rolled aluminium sheet and painted aluminium sheet from base construction material is done manually. Given the scenario that is assumed, any impact will not occur from this module.

After demolition, the cold rolled aluminium sheet and painted aluminium sheet can be recycled or used as aggregate in other construction materials.

In module C2, 95% of the products that has finished their utilizable lifetime, are considered to be sent to a sorting facility to be recycled, granted to cover 200 km ground on land for transport from demolition area to the sorting facility. 5% of de-constructed products is sent to landfill, where 5% is approximately calculated as the portion of cold rolled aluminium sheet and painted aluminium sheet products inseparable from the base construction material which the cold rolled products are mounted on to.

The aforementioned portion is inseparable from the base material and therefore is unsuitable for recycling. The separable portion of the product, 95% of the used products, is sent for recycling to a sorting facility, and 5% of 95% of the sent material is considered to be suitable for recycling; recycled to be used in another construction project or construction material manufacture process. A total of 5.48% of end-of-life product are sent to landfill and a total of 94.52% of end-of-life product is completely recycled.

3.3 Specification and Description of the Products

This LCA study evaluates the potential environmental impacts for 1 kg of Cold Rolled Aluminium Sheet Product and 1 kg of Painted Aluminium Sheet with Cradle to gate with options, modules A1–A2–A3, C2–C3–C4, D approach.

UN CPC Code: 41534 – Plates, sheets and strip, of aluminium, of a thickness exceeding 0.2 mm

3.3.1. Cold Rolled and Painted Aluminium Sheet

Cold rolled aluminium sheet products production facilities were established in Sakarya-Karapürçek in 2014 within the body of ASAŞ in order to meet the growing demand for high quality products in the Turkish and world markets. The facility provides services in a total area of 310,000 m^2, of which 135,000 m^2 is closed, with a total cold product capacity of 120,000 tons, of which 45,000 tons are painted annually. In the facility, plates and foils are produced in different alloys (1000-3000-5000-8000 series) and tempers, in requested sizes and surface properties (embossed, painted).

Aluminium coil and sheet products, consist of embossing, step plate and roll coating are all stretched in different alloys and sizes. The product surfaces can be produced completely oil-free or low-oil, upon request, film coating on the surface or paper between the plates is applied.

Aluminium painted sheets are all stretched aluminium sheet products of different sizes and colours. Painted aluminium is the product that comes out by colouring aluminium sheets and plates. Painted plates are covered with a protective film.

Intended use of the products: Aluminium sheets have a wide range of applications due to superior corrosion properties, welding capabilities, electrical and thermal conductivity characteristics. They are highly resistant to external environment due to corrosion resistance. This and many other features make it available in many industries, especially construction, automotive, and transport. In addition, they benefit from energy efficiency with light-weight features in many areas.

Figure 1: Picture of Cold Rolled Product

The technical specification of the cold rolled aluminium products is provided in the table below.

Table 2: Cold Rolled Alüminium Sheet Product Technical Specifications

Product	Standards	Description
Cold Rolled Aluminium Sheet	TS EN 485-1:2016	Aluminium and Aluminium Alloys - Sheet, strip and plate - Part 1: Technical conditions for inspection and delivery
	DS/EN 485-2	Aluminium and Aluminium Alloys - Sheet, strip and plate - Part 2: Mechanical Properties
	DS/EN 485-3	Aluminium and Aluminium Alloys - Sheet, strip and plate - Part 3: Tolerances on dimensions and form for hot-rolled products
	DIN EN 485-4	Aluminium and Aluminium Alloys - Sheet, strip and plate - Part 4: Tolerances on shape and dimensions for cold-rolled products
	ASTM B209M-10	Standard Specification for Aluminum and Aluminum-Alloy Sheet and Plate (Metric)

Table 2: Cold Rolled Aluminium Sheet Technical Specifications - Continued

Cold Rolled Aluminium Sheet	BS EN 1715-2:2008	Aluminium and aluminium alloys - Drawing stock- Part 2: Specific requirements for electrical applications
	DS/EN 1386	Aluminium and aluminium alloys - Trade plate - Specifications
	DIN EN ISO 7438	Metallic materials - Bend test
	TS 205-3 EN ISO 7799	Metallic materials - Sheet and strip 3 mm thick or less - Reverse bend test
	DS/EN ISO 20482	Metallic Materials - Sheet and Strip - Erichsen Cupping Test
	TS 10525 EN 1669	Aluminium and aluminium alloys-Test methods-Earing test for sheet and strip
	TS EN ISO 6507-1	Metallic materials - Vickers hardness test - Part 1: Test method
	TS EN ISO 6506-1	Metallic materials - Brinell hardness test - Part 1: Test method
	TS EN ISO 6892-1	Metallic materials - Tensile testing - Part 1: Method of test at room temperature

Table 3: Painted Aluminium Sheet Technical Specifications

Product	Standards	Description
Painted Aluminium Sheet	TS EN 9260 ISO 4628-2	Paints and varnishes - Evaluation of degradation of coatings; Designation of quantity and size of defects, and of intensity of uniform changes in appearance - Part 2: Assessment of degree of blistering
	DS EN ISO 4628-3	Paints and varnishes - Evaluation of degradation of coatings - Designation of quantity and size of defects, and of intensity of uniform changes in appearance - Part 3: Assessment of degree of rusting
	DS EN ISO 4628-4	Paints and varnishes - Evaluation of degradation of coatings; Designation of quantity and size of defects, and of intensity of uniform changes in appearance - Part 4: Assessment of degree of cracking
	DS EN ISO 4628-5	Paints and varnishes - Evaluation of degradation of coatings; Designation of quantity and size of defects, and of intensity of uniform changes in appearance - Part 5: Assessment of degree of flaking
	DS EN ISO 4628-10	Paints and varnishes. Evaluation of degradation of coatings. Designation of quantity and size of defects, and of intensity of uniform changes in appearance Assessment of degree of filiform corrosion.

	TS EN ISO 1520	Paints and varnishes - Cupping test
	TS EN ISO 6270-1	Paints and varnishes - Determination of resistance to humidity - Part 1: Condensation (single-sided exposure)
	DIN EN ISO 2808	Paint and Varnishes -Determintion of film thickness
	DS/EN ISO 2409	Paint and Varnishes -Cross cut test
	ISO 3251	Paints, varnishes and plastics - Determination of non-volatile-matter content
	ISO 1519	Paints and varnishes - Bend test (cylindirical mandrel)
	ASTM D 4214-07	Standard Test Methods for Evaluating the Degree of Chalking of Exterior Paint Films

3.4 Declared Unit

The declared unit is a 1 kg of Cold Rolled Aluminium Sheet and Painted Aluminium Sheet manufactured from primer aluminium, external seconder, pre- and post-consumed materials, chemicals, and other additives ready to deliver at the factory gate.

3.4.1 Reference Service Life (RSL)

According to PCR 2019:14, as this LCA is cradle to gate with options, modules, C1-C4, D (A1–A3 + C + D) the declaration of the RSL is not possible. The RSL is declared as: “not specified”.

3.5 Content Declaration

Table 4: Content declaration of Cold Rolled Aluminium Sheet

Product	Primer Aluminium, kg	Post-consumer recycled materials, kg	Pre-consumer recycled materials, kg	Additives, kg	Post-consumer material, weight-%	Renewable material, weight-%	Biogenic carbon, kg
Cold Rolled Aluminium Sheet	0.647	0.121	0.222	0.010	12	0	0

Table 5: Content declaration of Painted Aluminium Sheet

Product	Primer Aluminium, kg	Post-consumer scrap, kg	Internal Scrap, kg	Additives, kg	Colourant, kg	Post-consumer material, weight-%	Renewable material, weight-%	Biogenic carbon, kg

Painted Aluminium Sheet	0.595	0.111	0.204	0.009	0.081	11	0	0

Table 6: Content declaration of Packaging Material, for 1 kg of Cold Rolled Aluminium Sheet

Cold Rolled Aluminium Sheet	Weight, kg	Weight, %	Biogenic carbon, kg
LDPE	0.004	0.433	-
Paper	0.003	0.315	-
Wood	0.011	1.15	-0.010
Metal	0.004	0.403	-

Table 7: Content declaration of Packaging Material, for 1 kg of Painted Aluminium Sheet

Painted Aluminium Sheet	Weight	Weight, %	Biogenic carbon, kg
LDPE, kg	0.004	0.424	-
Paper, kg	0.003	0.303	-
Wood, kg	0.009	0.918	-0.113
Metal, kg	0.003	0.322	-

3.6 System Boundary

According to the PCR Construction products 2019:14, the system boundary of both products is shown in the tables below.

Table 8: Reporting modules declared, geography, share of specific data (in GWP-GHG indicator) and data variation for Cold Rolled Aluminium Sheet

	Product stage		Construction process stage			Use stage							End of life stage				Resource recovery stage
	Raw material supply	Transport	Manufacturing	Transport	Construction installation	Use	Maintenance	Repair	Replacement	Refurbishment	Operational energy use	Operational water use	De-construction demolition	Transport	Waste processing	Disposal	Recycling potential
Module	**A1**	**A2**	**A3**	**A4**	**A5**	**B1**	**B2**	**B3**	**B4**	**B5**	**B6**	**B7**	**C1**	**C2**	**C3**	**C4**	**D**
Modules declared	X	X	X	ND	ND	ND	ND	ND	ND	ND	ND	ND	X	X	X	X	X
Geography	GLO	GLO	TR	-	-	-	-	-	-	-	-	-	GLO	GLO	GLO	GLO	GLO
Specific data used	>99%			-	-	-	-	-	-	-	-	-	-	-	-	-	-
Variation – products	Not relevant			-	-	-	-	-	-	-	-	-	-	-	-	-	-
Variation – sites	Not relevant			-	-	-	-	-	-	-	-	-	-	-	-	-	-

X: Declared

ND: Not declared.

Table 9: Reporting modules declared, geography, share of specific data (in GWP-GHG indicator) and data variation for Painted Aluminium Sheet

	Product stage			Construction process stage		Use stage							End of life stage				Resource recovery stage
	Raw material supply	Transport	Manufacturing	Transport	Construction installation	Use	Maintenance	Repair	Replacement	Refurbishment	Operational energy use	Operational water use	De-construction demolition	Transport	Waste processing	Disposal	Recycling potential
Module	**A1**	**A2**	**A3**	**A4**	**A5**	**B1**	**B2**	**B3**	**B4**	**B5**	**B6**	**B7**	**C1**	**C2**	**C3**	**C4**	**D**
Modules declared	X	X	X	ND	ND	ND	ND	ND	ND	ND	ND	ND	X	X	X	X	X
Geography	GLO	GLO	TR	-	-	-	-	-	-	-	-	-	GLO	GLO	GLO	GLO	GLO
Specific data used	>99%			-	-	-	-	-	-	-	-	-	-	-	-	-	-
Variation – products	Not relevant			-	-	-	-	-	-	-	-	-	-	-	-	-	-
Variation – sites	Not relevant			-	-	-	-	-	-	-	-	-	-	-	-	-	-

X: Declared

ND: Not declared.

A1-A3 - Cradle to gate – *Mandatory Module*

The aggregation of the modules A1, A2 and A3 is allowed by EN 15804:2012+A2:2019. This rule is applied in this EPD and denoted by A1-3. This module represents the extraction and processing of raw materials, transport to production sites and the manufacture and packaging.

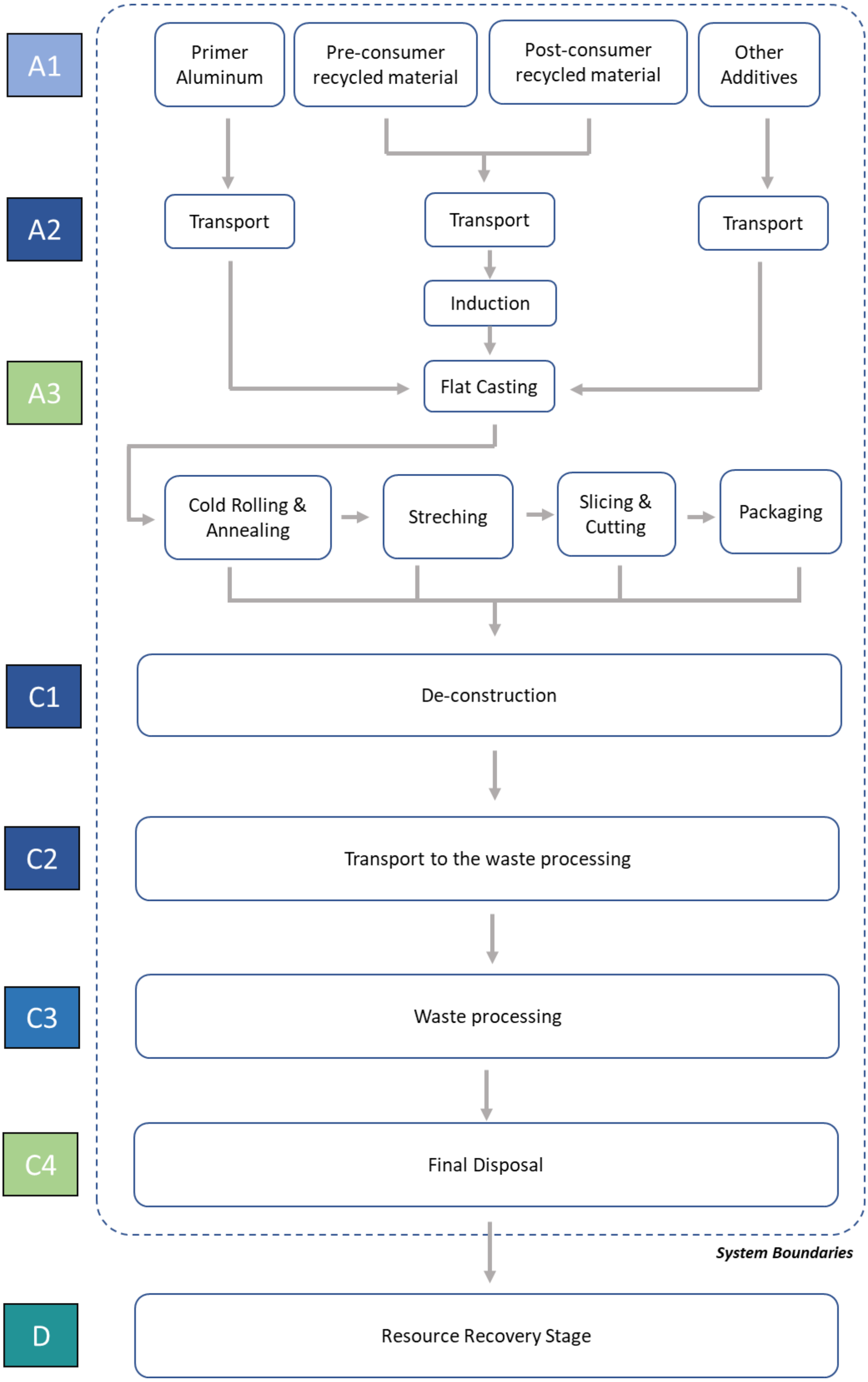

Figure 2: System Boundaries for Cold Rolled Aluminium Sheet

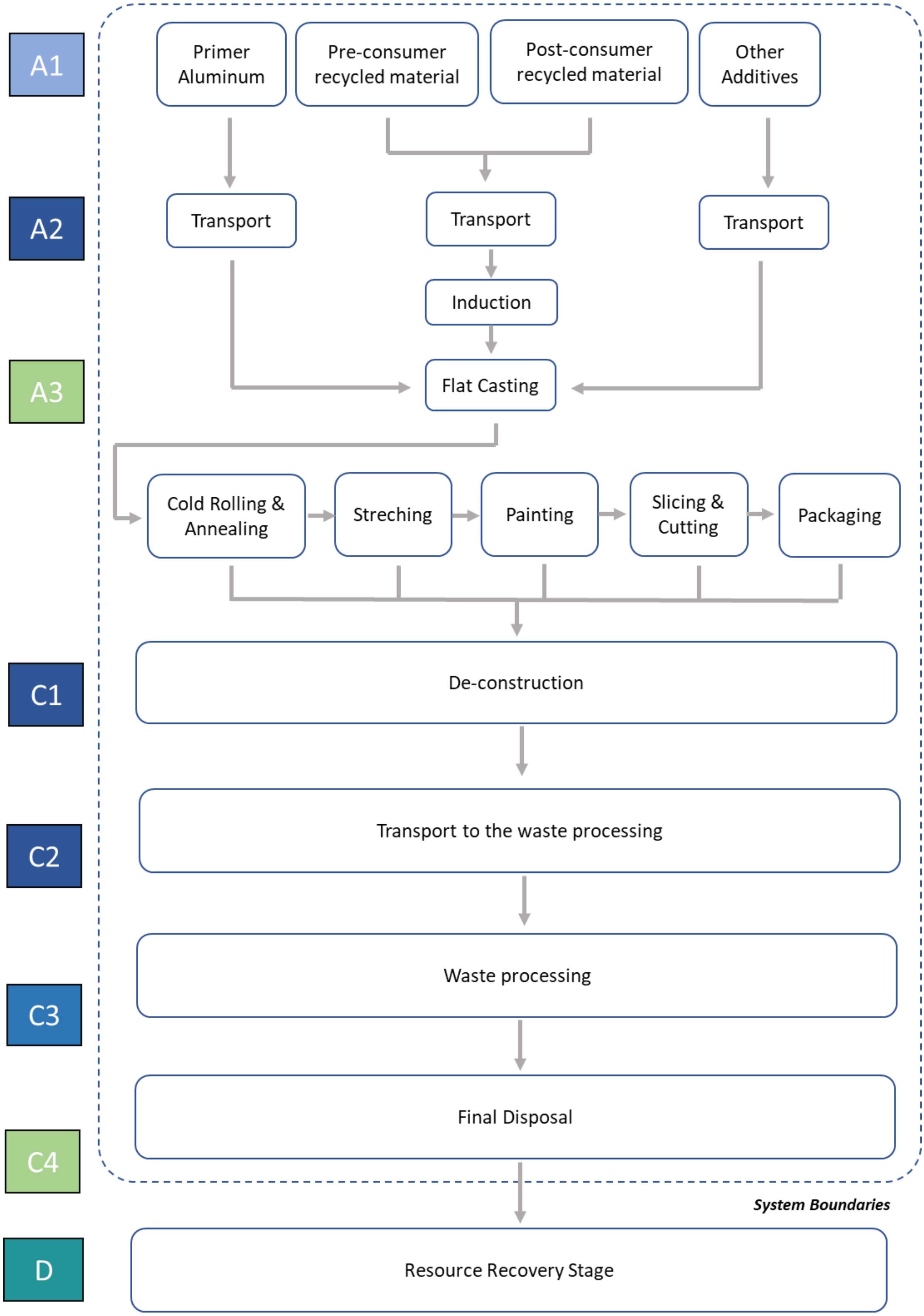

Figure 3: System Boundaries for Painted Aluminium Sheet

C1 - De-construction

In module C1, it is assumed that demolition of the cold rolled aluminium sheet and painted aluminium sheet from base construction material is done manually. Given the scenario that is assumed, environmental impact of de-construction process is not considered in this study.

C2 - Transport to waste processing

An average distance of 200 km has been assumed for the transport to sorting facility. Transport is calculated on the basis of a scenario with the parameters described in the attached table.

Table 10: Parameters C2 Module

Parameters C2 Module	
Transport by road*	Lorry, 16-32 metric ton
Distance (km)	200
Database	Ecoinvent v3.7.1

**Technology is Euro 6*

C3 - Waste processing for reuse, recovery and/or recycling

This module includes the energy consumption required for the sorting of cold rolled products in the recycling process.

C4 - Final disposal

95% of the products after their lifetime will be collected and recycled into the manufacturing system. It is assumed that 5% of the product is lost during de-construction and 95% reached the sorting/recycling facility. The recycling rate of cold rolled and painted aluminium sheet products are assumed to be 95%; making up a total of 90% of end-of-life products recycled to be used again in construction projects or construction material manufacture process, and the remaining 10% of end-of-life products being sent to landfill.

D - Reuse, recovery or recycling

Cold Rolled Aluminium Sheet and Painted Aluminium Sheet inputs to the production stage are subtracted from the construction to be recycled at end-of-life in order to obtain the cold rolled aluminium sheet and painted aluminium sheet from the product system. This remaining net cold rolled aluminium sheet and net painted aluminium sheet are then sent to recycling. Module D reports the environmental aspects of recycled scrap generated at the end of life minus that used at the production stage.

In the manufacturing system, at this LCA study period, some of the inputs are post-consumer material that entering the manufacturing system.

$M_{MR\ in}$:amount of input material to the product system that has been recovered (recycled or reused) from a previous system (determined at the system boundary); in this LCA study pre- and post-consumer recycled materials.

$M_{MR\ out}$:amount of material exiting the system that will be recovered (recycled and reused) in a subsequent system. This amount is determined at end-of-waste point and is therefore equal to the output flow of "materials to recycling [kg]" reported for modules A4, A5, B and C; in this LCA study it is the 64.7% for cold rolled aluminium product and 59.5% for painted aluminium sheet in the end-of-life section, According to the PCR; Y is a process-specific material yield calculated as follows;

- Y the material yield, between point of end-of-waste (M-EoW) in stage C and point of substitution (M-DoS) in module D (when the material has been upgraded)
- Y = M-DoS / M-EoW

This LCA and the EPD only cover the Cradle to Gate with options A1-3 and C1-4 and D stages because other stages are very dependent on particular scenarios and are better developed for specific building or construction works.

4. LIFE CYCLE INVENTORY ANALYSIS

4.1 Data Collection

Data collection for this LCA study has been carried out in accordance with data requirement stated in ISO 14040-44, ISO 14025, ISO 14020, and the requirements given in the General Program Instructions v3.01; PCR Construction products 2019:14, version 1.11 by The International EPD® System and EN 15804:2012+A2:2019.

There are two different data classifications has been used as primary (specific) and secondary (selected generic) data. All primary data has been collected from the manufacturing plant. For secondary data Ecoinvent v3.7.1 database has been used.

Upstream data, raw materials production, transportation, fossil fuels and electricity mix data have been obtained from Ecoinvent v3.7.1 as secondary data. All manufacturing data in core processes has been gathered from the manufacturing plant. The manufacturing data are collected based on a mass balance. The production data in this LCA study represents the period of 1st January 2021 and 30th June 2021.

Mileage and tonnage figures for transport data to the core processes were provided by Asaş procurement department specifically per origin of departures, however roadway and seaway upstream data per ton per kilometres were taken from Ecoinvent v3.7.1.

Main life cycle inventory data information is given in Appendix III.

Table 11: Province of raw materials by city & country per functional unit

Raw Material	Departure	Destination
Primer Aluminium	Russia	Karapürçek, Sakarya, Turkey
Primer Aluminium	Tajikistan	Karapürçek, Sakarya, Turkey
Primer Aluminium	Kazakhstan	Karapürçek, Sakarya, Turkey
External Scrap	Tekirdağ, Turkey	Karapürçek, Sakarya, Turkey
External Seconder	Düzce, Turkey	Karapürçek, Sakarya, Turkey
External Seconder	İzmir, Turkey	Karapürçek, Sakarya, Turkey
External Seconder	Ankara, Turkey	Karapürçek, Sakarya, Turkey
External Seconder	Bilecik, Turkey	Karapürçek, Sakarya, Turkey
Additives	Biscay, Spain	Karapürçek, Sakarya, Turkey
Additives	İstanbul, Turkey	Karapürçek, Sakarya, Turkey
Additives	Ossana, Italy	Karapürçek, Sakarya, Turkey
Additives	Kocaeli, Turkey	Karapürçek, Sakarya, Turkey
Additives	Oss, Holland	Karapürçek, Sakarya, Turkey
Additives	Geneva, Switzerland	Karapürçek, Sakarya, Turkey
Additives	Belgium, Bruxelles	Karapürçek, Sakarya, Turkey
Colourant	İzmir, Turkey	Karapürçek, Sakarya, Turkey
Colourant	Kocaeli, Turkey	Karapürçek, Sakarya, Turkey
Colourant	İstanbul, Turkey	Karapürçek, Sakarya, Turkey

Entire life cycle inventory data are presented in Appendix III.

4.2 Calculation Methods

The indicators, disclaimers, and other requirements in Section 7.2.3 (for environmental impacts based on the LCIA) and Section 7.2.4 (for resource use, waste, etc.) of EN 15804:2012+A2:2019 have been used and calculated in SimaPro v9.2.0.2.

4.3 Cut-off Rules

Life Cycle Inventory data for a minimum of 99 % of total inflows to the three life cycle stages have been included and a cut-off rule of 1% regarding energy, mass, and environmental relevance was applied.

4.4 Allocation

Mass allocation applied for waste generated during the production of the cold products. The waste data has been allocated to cold rolled aluminium sheet, painted aluminium sheet and aluminium foil, taking into account the total production in the relevant time period.

It has been calculated that 30% of the total waste produced in the facility will be on the cold rolled, 24% on the painted board and 46% on the aluminium foil.

The same percentages were used to allocate the packaging products for three products.

4.5 Assumptions and Limitations

The assumptions of the data obtained from SimapPro database are shown for below.

For additives:

- Calcium was calculated Calcium carbonate, precipitated {RER}| calcium carbonate production, precipitated | Cut-off, S,
- Chromium, Chromium oxide, flakes {RER}| production | Cut-off, S
- Copper, Copper carbonate {RER}| production | Cut-off, S
- Iron, Cast iron {RER}| production | Cut-off, S
- Magnesium, Magnesium oxide {RER}| production | Cut-off, S
- Manganese 99% and manganese 75%, Manganese {RER}| production | Cut-off, S
- Silicon metal, Silicon carbide {RER}| production | Cut-off, S
- Zinc, Zinc oxide {RER}| production | Cut-off, S
- Magnesium, Magnesium oxide {RER}| production | Cut-off, S
- For 1 kg of thinner, calculated as 0.75 kg of "Chemical, organic {GLO}| market for | Cut-off, S" and 0.25 kg of "Benzyl alcohol {RoW}| production | Cut-off, S" as additives
- For colour, the amount of chemicals used, according to MSDS sheets and CAS numbers that obtained, was assumed as "Chemical, organic {GLO}| production | Cut-off, S".

All these data above were obtained from Ecoinvent v3.7.1.

4.6 Data Quality

According to EN 15804:2012+A2:2019 specific data was used for module A3 (Processes the manufacturer has influence over) and was gathered from the manufacturing plant. Specific data includes actual product weights, amounts of raw materials used, product content, energy consumption, transport figures, water consumption and amounts of wastes.

There is two manufacturing plant in Sakarya and Akyazı, Turkey. However, cold rolled products are manufactured in Sakarya.

The manufacturing data (specific) are monitored and recorded by Asaş Cold Rolled manufacturing responsible people. Specific energy and chemical consumption values and raw materials/chemicals are collected from Asaş.

For A1 and A2 modules, According to EN 15804:2012+A2:2019, generic data was applied and was obtained from Ecoinvent v3.7.1.

Specific data used in this LCA study is less than 1 year old. Generic data used in the study was obtained from Ecoinvent v3.7.1 which is less than 10 years old.

Cut-off criteria for the upstream generic data is at least 99%, according to the General Programme Requirement in terms of the energy, the mass, and the overall environmental relevance of the flows. Inventory data covers all elementary flows and are obtained from Ecoinvent v3.7.1. Technological and geographical references are presented in Appendix II.

-- **Internal Data Management**

Specific data are collected from Asaş for Cold Rolled Production Plant. Ecoinvent v3.7.1 is used for the upstream and downstream data as selected generic data. No other database is used. Ecoinvent data is updated automatically when SimaPro provides updates. For the core processes data, manufacturing responsible people record the data. If input materials amount and/or process routes change, the EPD will be updated. For data collection contact name are provided in the EPD and in section 1.3.

-- Data collection procedures

All raw materials, suppliers, chemicals, recipes, energy/fuel consumption data are monitored and recorded in the company's system. Recipes include the trade secrets and special chemicals, CAS numbers, and consumption amounts. All raw materials, chemicals, chemical amounts, suppliers' distances, electricity consumption, natural gas are provided by the responsible person in section 1.3.

Follow-up procedures during the validity period of the EPD: In the computer system, all data regarding 100% of manufacturing are monitored and recorded up to date. If more than 10% change occurs, the EPDs will be updated as required by the PCR.

All electricity is supplied from the grid. However, for the whole electricity consumption in the production facility the I-REC certificate was purchased which also represents the time period for the LCA study. Thus, the energy sources behind the electricity grid in module A3 are not documented. The renewable electricity chosen in Ecoinvent database is as follows "Electricity, high voltage {TR}| electricity production, hydro, run-of-river | Cut-off, S".

5. ENVIRONMENTAL PERFORMANCE RELATED INFORMATION

5.1. Cold Rolled Aluminium Sheet and Painted Aluminium Sheet

The characterization factors and calculation methods are described in Appendix I.

Table 12: Potential environmental impact for 1 kg of Cold Rolled Aluminium Sheet – mandatory indicators according to EN 15804:2012+A2:2019

Results for 1 kg of Cold Rolled Aluminium Sheet										
Indicator	**Unit**	**A1**	**A2**	**A3**	**Tot.A1-A3**	**C1**	**C2**	**C3**	**C4**	**D**
GWP-fossil	kg CO_2 eq.	12.6	0.408	0.39	13.4	0	0.031	0.006	0.004	-9.44
GWP-biogenic	kg CO_2 eq.	-0.026	7.19E-04	-0.033	-0.058	0	7.50E-05	2.35E-04	1.06E-04	0.022
GWP-luluc	kg CO_2 eq.	0.124	1.27E-04	6.90E-05	0.124	0	1.06E-05	8.45E-06	3.62E-06	-0.094
GWP-total	kg CO_2 eq.	12.68	0.408	3.53E-01	13.4	0	0.031	0.006	0.004	-9.51
ODP	kg CFC 11 eq.	5.57E-07	9.60E-08	3.52E-08	6.88E-07	0	7.03E-09	5.32E-10	4.22E-10	-4.14E-07
AP	mol H^+ eq.	0.088	0.001	5.11E-04	0.090	0	8.59E-05	3.75E-05	2.53E-05	-0.067
EP-freshwater	kg PO_4^{3-} eq.	6.25E-03	1.55E-04	4.55E-05	0.006	0	9.19E-06	4.89E-06	2.62E-06	-0.005
	kg P eq	6.26E-04	3.56E-06	1.82E-06	0.001	0	2.32E-07	4.31E-07	1.29E-07	-4.71E-04
EP-marine	kg N eq.	0.012	3.23E-04	1.06E-04	0.012	0	1.75E-05	9.94E-06	6.05E-06	-0.009
EP-terrestrial	mol N eq.	0.135	3.59E-03	1.13E-03	0.140	0	1.95E-04	1.10E-04	6.76E-05	-0.101
POCP	kg NMVOC eq.	0.041	0.001	5.16E-04	0.043	0	7.45E-05	3.03E-05	2.00E-05	-0.031
ADP-minerals&metals*	kg Sb eq.	3.31E-05	9.80E-07	2.02E-07	3.43E-05	0	1.13E-07	9.81E-09	8.53E-09	-1.22E-05
ADP-fossil*	MJ	126.4	6.48	5.8	139	0	4.69E-01	0.105	0.054	-94.6
WDP	m^3	2.36	0.024	0.018	2.40	0	0.001	0.001	0.001	-1.676
Acronyms	GWP-fossil = Global Warming Potential fossil fuels; GWP-biogenic = Global Warming Potential biogenic; GWP-luluc = Global Warming Potential land use and land use change; ODP = Depletion potential of the stratospheric ozone layer; AP = Acidification potential, Accumulated Exceedance; EP-freshwater = Eutrophication potential, fraction of nutrients reaching freshwater end compartment; EP-marine = Eutrophication potential, fraction of nutrients reaching marine end compartment; EP-terrestrial = Eutrophication potential, Accumulated Exceedance; POCP = Formation potential of tropospheric ozone; ADP-minerals&metals = Abiotic depletion potential for non-fossil resources; ADP-fossil = Abiotic depletion for fossil resources potential; WDP = Water (user) deprivation potential, deprivation-weighted water consumption									

** Disclaimer: The results of this environmental impact indicator shall be used with care as the uncertainties of these results are high or as there is limited experience with the indicator.*

Table 13: Potential environmental impact for 1 kg of Painted Aluminium Sheet – mandatory indicators according to EN 15804:2012+A2:2019

Results for 1 kg of Painted Aluminium Sheet										
Indicator	**Unit**	**A1**	**A2**	**A3**	**Tot.A1-A3**	**C1**	**C2**	**C3**	**C4**	**D**
GWP-fossil	kg CO_2 eq.	13.3	0.425	0.606	14.4	0	0.031	0.006	0.004	-9.44
GWP-biogenic	kg CO_2 eq.	-0.027	7.49E-04	-0.027	-0.053	0	7.50E-05	2.35E-04	1.06E-04	0.022
GWP-luluc	kg CO_2 eq.	0.129	1.33E-04	7.86E-05	0.129	0	1.06E-05	8.45E-06	3.62E-06	-0.094
GWP-total	kg CO_2 eq.	13.4	0.426	5.79E-01	14.4	0	0.031	0.006	0.004	-9.51
ODP	kg CFC 11 eq.	5.99E-07	1.00E-07	5.61E-08	7.55E-07	0	7.03E-09	5.32E-10	4.22E-10	-4.14E-07
AP	mol H^+ eq.	0.093	0.002	7.53E-04	0.095	0	8.59E-05	3.75E-05	2.53E-05	-0.067
EP-freshwater	kg PO_4^{3-} eq.	0.007	1.62E-04	6.41E-05	0.007	0	9.19E-06	4.89E-06	2.62E-06	-0.005
	kg P eq	0.001	3.71E-06	2.15E-06	0.001	0	2.32E-07	4.31E-07	1.29E-07	-4.71E-04
EP-marine	kg N eq.	0.013	3.37E-04	1.55E-04	0.013	0	1.75E-05	9.94E-06	6.05E-06	-0.009
EP-terrestrial	mol N eq.	0.143	3.74E-03	1.66E-03	0.148	0	1.95E-04	1.10E-04	6.76E-05	-0.101
POCP	kg NMVOC eq.	0.044	0.001	7.56E-04	0.046	0	7.45E-05	3.03E-05	2.00E-05	-0.031
ADP-minerals&metals*	kg Sb eq.	3.59E-05	1.02E-06	2.39E-07	3.72E-05	0	1.13E-07	9.81E-09	8.53E-09	-1.22E-05
ADP-fossil*	MJ	138	6.76	9.02	153	0	4.69E-01	0.105	0.054	-94.6
WDP	m^3	2.60	0.025	1.19E-01	2.74	0	0.001	0.001	0.001	-1.68
Acronyms	GWP-fossil = Global Warming Potential fossil fuels; GWP-biogenic = Global Warming Potential biogenic; GWP-luluc = Global Warming Potential land use and land use change; ODP = Depletion potential of the stratospheric ozone layer; AP = Acidification potential, Accumulated Exceedance; EP-freshwater = Eutrophication potential, fraction of nutrients reaching freshwater end compartment; EP-marine = Eutrophication potential, fraction of nutrients reaching marine end compartment; EP-terrestrial = Eutrophication potential, Accumulated Exceedance; POCP = Formation potential of tropospheric ozone; ADP-minerals&metals = Abiotic depletion potential for non-fossil resources; ADP-fossil = Abiotic depletion for fossil resources potential; WDP = Water (user) deprivation potential, deprivation-weighted water consumption									

** Disclaimer: The results of this environmental impact indicator shall be used with care as the uncertainties of these results are high or as there is limited experience with the indicator.*

Table 14: Potential environmental impact – additional mandatory and voluntary indicators for 1 kg of Cold Rolled Aluminium Sheet

Results according to PCR2019:14 for 1 kg of Cold Rolled Aluminium Sheet										
Indicator	**Unit**	**A1**	**A2**	**A3**	**Tot.A1-A3**	**C1**	**C2**	**C3**	**C4**	**D**
GWP-GHG[1]	kg CO_2 eq.	12.5	0.404	0.34	13.2	0	0.031	0.005	0.004	-9.38
Results according to EN 15804+A2 for 1 kg of Cold Rolled Aluminium Sheet										
PM/RI	[disease inc.]	5.26E-07	3.46E-08	3.20E-07	8.80E-07	0	1.95E-09	4.75E-10	3.58E-10	-6.34E-07
IRP	[kBq U235 eq]	0.294	0.027	4.28E-02	0.364	0	0.002	0.001	1.84E-04	-0.250
ET-freshwater	[CTUe]	165	5.38	193	364	0	0.360	0.056	60.4	-259
HT-cancer	[CTUh]	1.71E-08	1.56E-10	6.69E-09	2.39E-08	0	1.28E-11	1.73E-12	3.62E-12	-1.64E-08
HT-non-cancer	[CTUh]	2.31E-07	5.18E-09	1.49E-07	3.85E-07	0	3.52E-10	4.33E-11	9.15E-11	-2.81E-07
SQP	[pt]	10.1	7.25	15.2	32.6	0	3.27E-01	0.014	6.97E-02	-16.5
Acronyms	GWP-GHG = Global Warming Potential total excl. biogenic carbon following IPCC AR5 methodology; IRP = Ionizing radiation, human health; ET-freshwater = Eco-toxicity (freshwater); HT-cancer = Human toxicity, cancer effects; HT-non-cancer = Human toxicity, non-cancer effects; ; PM: Particulate matter; SQP = Potential soil quality index (SQP)									

[1] The indicator includes all greenhouse gases included in GWP-total but excludes biogenic carbon dioxide uptake and emissions and biogenic carbon stored in the product. This indicator is thus equal to the GWP indicator originally defined in EN 15804:2012+A1:2013.

Table 15: Potential environmental impact – additional mandatory and voluntary indicators for 1 kg of Painted Aluminium Sheet

Results according to PCR2019:14 for 1 kg of Painted Aluminium Sheet										
Indicator	**Unit**	**A1**	**A2**	**A3**	**Tot.A1-A3**	**C1**	**C2**	**C3**	**C4**	**D**
GWP-GHG[2]	kg CO_2 eq.	13.2	0.421	0.561	14.2	0	0.031	0.005	0.004	-9.38
Results according to EN 15804+A2 for 1 kg of Painted Aluminium Sheet										
PM/RI	[disease inc.]	8.87E-07	3.61E-08	4.67E-09	9.28E-07	0	1.95E-09	4.75E-10	3.58E-10	-6.34E-07
IRP	[kBq U235 eq]	0.353	0.029	2.19E-03	0.384	0	0.002	0.001	1.84E-04	-0.250
ET-freshwater	[CTUe]	369	5.62	1,641	2,016	0	0.360	0.056	60.4	-259
HT-cancer	[CTUh]	2.43E-08	1.62E-10	1.77E-07	2.01E-07	0	1.28E-11	1.73E-12	3.62E-12	-1.64E-08
HT-non-cancer	[CTUh]	3.95E-07	5.41E-09	2.75E-07	6.75E-07	0	3.52E-10	4.33E-11	9.15E-11	-2.81E-07
SQP	[pt]	23.9	7.57	2.51	34.0	0	3.27E-01	0.014	6.97E-02	-16.5
Acronyms	GWP-GHG = Global Warming Potential total excl. biogenic carbon following IPCC AR5 methodology; IRP = Ionizing radiation, human health; ET-freshwater = Eco-toxicity (freshwater); HT-cancer = Human toxicity, cancer effects; HT-non-cancer = Human toxicity, non-cancer effects; PM: Particulate matter; SQP = Potential soil quality index (SQP)									

[2] The indicator includes all greenhouse gases included in GWP-total but excludes biogenic carbon dioxide uptake and emissions and biogenic carbon stored in the product. This indicator is thus equal to the GWP indicator originally defined in EN 15804:2012+A1:2013.

Table 16: Use of resources for 1 kg of Cold Rolled Aluminium Sheet

Results for 1 kg of Cold Rolled Aluminium Sheet										
Indicator	**Unit**	**A1**	**A2**	**A3**	**Tot.A1-A3**	**C1**	**C2**	**C3**	**C4**	**D**
PERE	MJ	41.9	0.070	2.75	44.7	0	0.006	0	0.003	-31.7
PERM	MJ	0	0	0	0	0	0	0	0	0
PERT	MJ	41.9	0.070	2.75	44.7	0	0.006	0	0.003	-31.7
PENRE	MJ	133.7	6.88	6.4	147	0	0.498	0	0.058	-100
PENRM	MJ.	0	0	0	0	0	0	0	0	0
PENRT	MJ	134	6.88	6.4	147	0	0.498	0	0.058	-100
SM	kg	0.156	0	0	0.156	0	0	0	0	0
RSF	MJ	0	0	0	0	0	0	0	0	0
NRSF	MJ	0	0	0	0	0	0	0	0	0
FW	m^3	0.526	0.006	0.003	0.534	0	4.27E-04	0.001	1.82E-04	-0.390
Acronyms	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 re-sources; SM = Use of secondary material; RSF = Use of renewable secondary fuels; NRSF = Use of non-renewable secondary fuels; FW = Use of net fresh water									

Table 17: Use of resources for 1 kg of Painted Aluminium Sheet

Results for 1 kg of Painted Aluminium Sheet										
Indicator	**Unit**	**A1**	**A2**	**A3**	**Tot.A1-A3**	**C1**	**C2**	**C3**	**C4**	**D**
PERE	MJ	43.8	0.073	4.54	48.4	0	0.006	0	0.003	-31.7
PERM	MJ	0	0	0	0	0	0	0	0	0
PERT	MJ	43.8	0.07	4.54	48.4	0	0.006	0	0.003	-31.7
PENRE	MJ	146	7.18	9.98	163	0	0.498	0	0.058	-100
PENRM	MJ.	0	0	0	0	0	0	0	0	0
PENRT	MJ	146	7.18	9.98	163	0	0.498	0	0.058	-100
SM	kg	0.163	0	0	0.163	0	0	0	0	0
RSF	MJ	0	0	0	0	0	0	0	0	0
NRSF	MJ	0	0	0	0	0	0	0	0	0
FW	m^3	0.561	0.006	0.006	0.572	0	4.27E-04	0.001	1.82E-04	-0.390
Acronyms	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 re-sources; SM = Use of secondary material; RSF = Use of renewable secondary fuels; NRSF = Use of non-renewable secondary fuels; FW = Use of net fresh water									

Table 18: Waste production for 1 kg of Cold Rolled Aluminium Sheet

Results for 1 kg of Cold Rolled Aluminium Sheet										
Indicator	**Unit**	**A1**	**A2**	**A3**	**Tot.A1-A3**	**C1**	**C2**	**C3**	**C4**	**D**
Hazardous waste disposed	kg	0.014	0	0	0.014	0	0	0	0	0
Non-hazardous waste disposed	kg	0	0	0.001	0.001	0	0	0	0.098	0
Radioactive waste disposed	kg	0	0	0	0	0	0	0	0	0

Table 19: Output flows for 1 kg of Cold Rolled Aluminium Sheet

Results for 1 kg of Cold Rolled Aluminium Sheet										
Indicator	**Unit**	**A1**	**A2**	**A3**	**Tot.A1-A3**	**C1**	**C2**	**C3**	**C4**	**D**
Components for re-use	kg	0	0	0	0	0	0	0	0	0
Material for recycling	kg	0	0	0.003	0.003	0	0	0	0	0
Materials for energy recovery	kg	0	0	0	0	0	0	0	0	0
Exported energy, electricity	MJ	0	0	0	0	0	0	0	0	0
Exported energy, thermal	MJ	0	0	0	0	0	0	0	0	0

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Table 20: Waste production for 1 kg of Painted Aluminium Sheet

Results for 1 kg of Painted Aluminium Sheet										
Indicator	**Unit**	**A1**	**A2**	**A3**	**Tot.A1-A3**	**C1**	**C2**	**C3**	**C4**	**D**
Hazardous waste disposed	kg	0.014	0	0	0.014	0	0	0	0	0
Non-hazardous waste disposed	kg	0	0	0.002	0.002	0	0	0	0.098	0
Radioactive waste disposed	kg	0	0	0	0	0	0	0	0	0

Table 21: Output flows for 1 kg of Painted Aluminium Sheet

Results for 1 kg of Painted Aluminium Sheet										
Indicator	**Unit**	**A1**	**A2**	**A3**	**Tot.A1-A3**	**C1**	**C2**	**C3**	**C4**	**D**
Components for re-use	kg	0	0	0	0	0	0	0	0	0
Material for recycling	kg	0	0	0.009	0.009	0	0	0	0	0
Materials for energy recovery	kg	0	0	0	0	0	0	0	0	0
Exported energy, electricity	MJ	0	0	0	0	0	0	0	0	0
Exported energy, thermal	MJ	0	0	0	0	0	0	0	0	0

6. LIFE CYCLE INTERPRETATION

6.1 Cold Rolled Aluminium Sheet and Painted Aluminium Sheet

The Process flow of SimaPro network is presented in **Error! Reference source not found.** for Global Warming Potential impact.

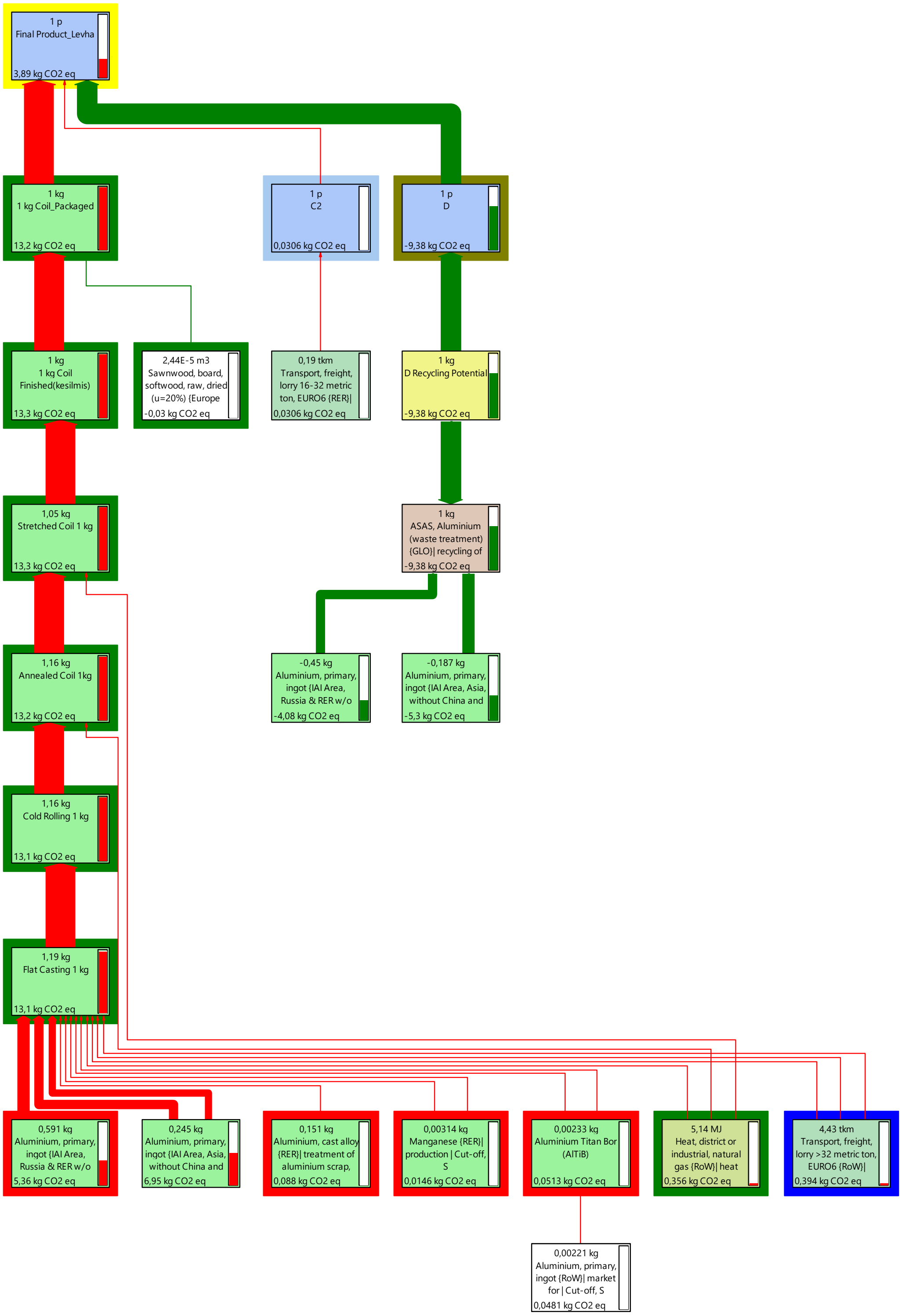

Figure 4: GWP-GHG network flow for 1 kg of Cold Rolled Aluminium Sheet

The relative impacts of all life cycle stages for 1 kg of Cold Rolled Aluminium Sheet are presented in Figure 4 for each impact category. Primer aluminium of the product life cycle appears as the highest impact contributor.

Long-term emissions (>100 years) are not taken into consideration in the impact estimate. In this interpretation section, SimaPro LCA model is presented for only considering GWP-GHG results as kg CO2 eq. All other LCIA results are also presented as bar charts in the Figure 6.

The GWP-GHG value of the final cold rolled aluminium sheet is 3.89 kg CO_2 eq. The final packaged product is 13.2 kg CO_2 eq. However, with the Module D scenario avoided emissions calculated as -9.38 kg CO_2 eq the final product's GWP-GHG value became 3.89 kg CO_2 eq.

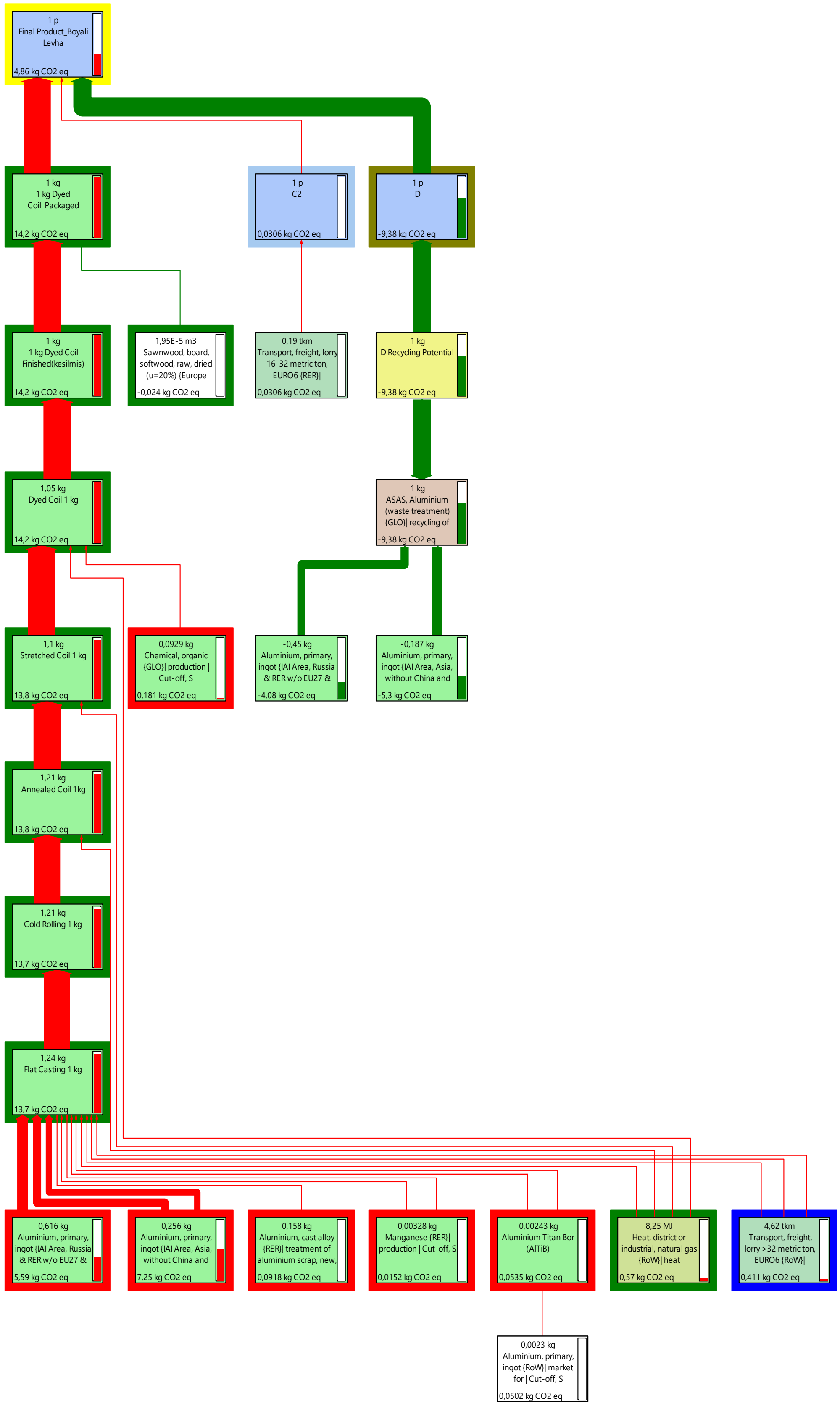

Figure 5: GWP-GHG network flow for 1 kg of Painted Aluminium Sheet

The relative impacts of all life cycle stages for 1 kg of Cold Rolled Aluminium Sheet are presented in Figure 5Figure 4 for each impact category. Primer aluminium of the product life cycle appears as the highest impact contributor.

Long-term emissions (>100 years) are not taken into consideration in the impact estimate. In this interpretation section, SimaPro LCA model is presented for only considering GWP-GHG results as kg CO2 eq. All other LCIA results are also presented as bar charts in the Figure 6.

The GWP-GHG value of the final cold rolled aluminium sheet is 3.89 kg CO_2 eq. The final packaged product is 13.2 kg CO_2 eq. However, with the Module D scenario avoided emissions calculated as -9.38 kg CO_2 eq the final product's GWP-GHG value became 3.89 kg CO_2 eq.

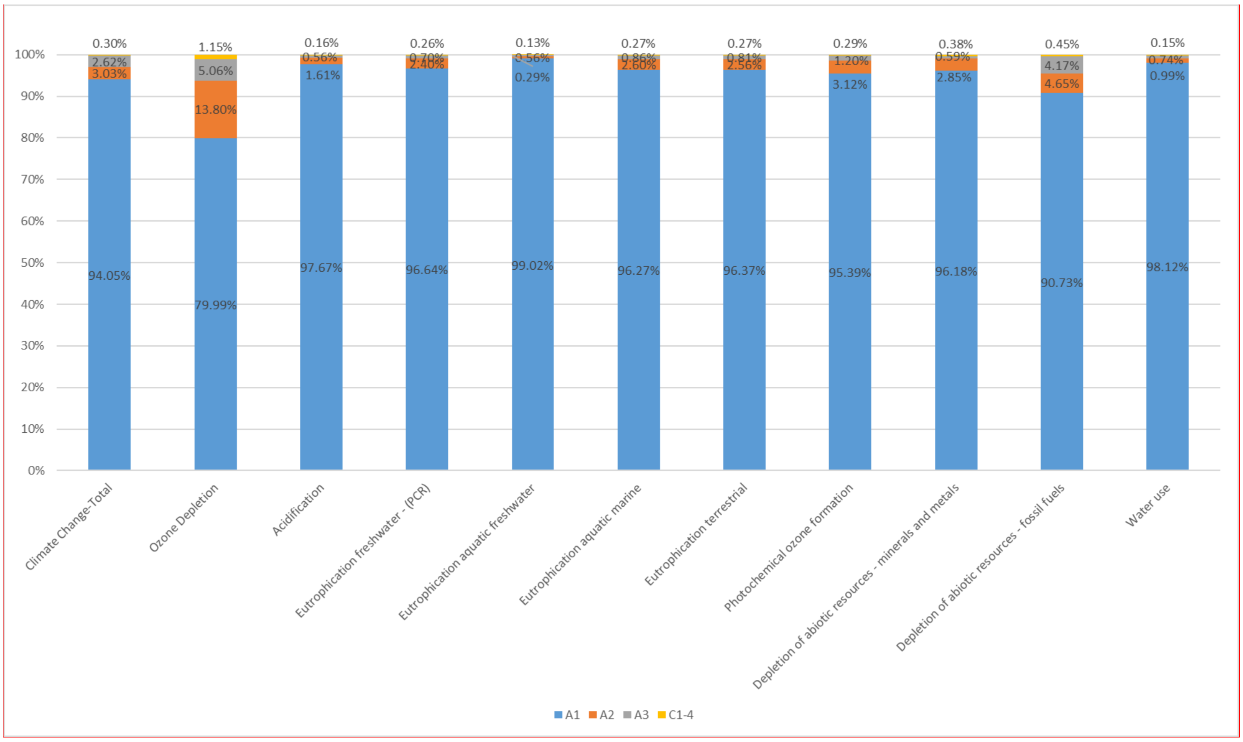

Figure 6: Potential environmental impact per module for 1 kg of Cold Rolled Aluminium Sheet

Environmental indicators caused by per life cycle module for the cold rolled aluminium sheet are presented in Figure 6. Environmental impacts caused by A1 Module is appeared to be dominant for climate change and it is the main hotspot in all environmental impact indicators.

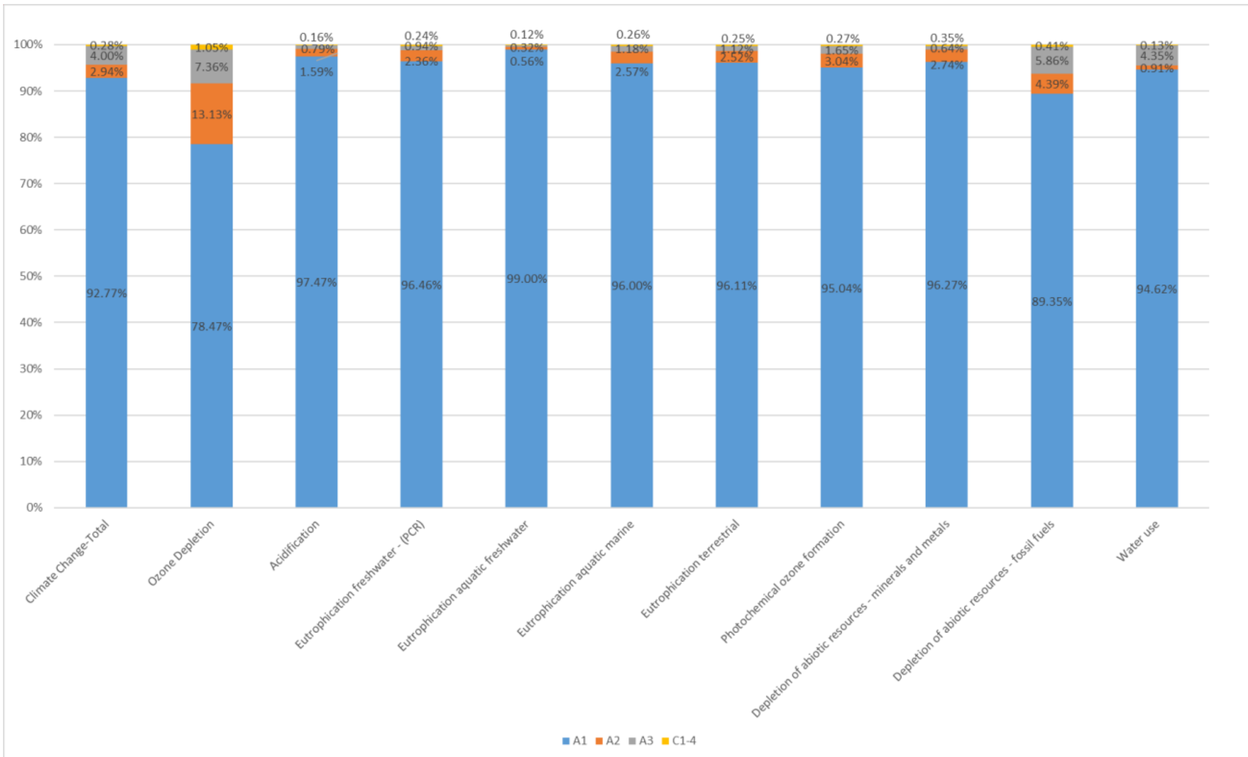

Figure 7: Potential environmental impact per module for 1 kg of Painted Aluminium Sheet

Environmental indicators caused by per life cycle module for the painted aluminium sheet are presented in Figure 7. Environmental impacts caused by A1 Module is appeared to be dominant for climate change and it is the main hotspot in all environmental impact indicators.

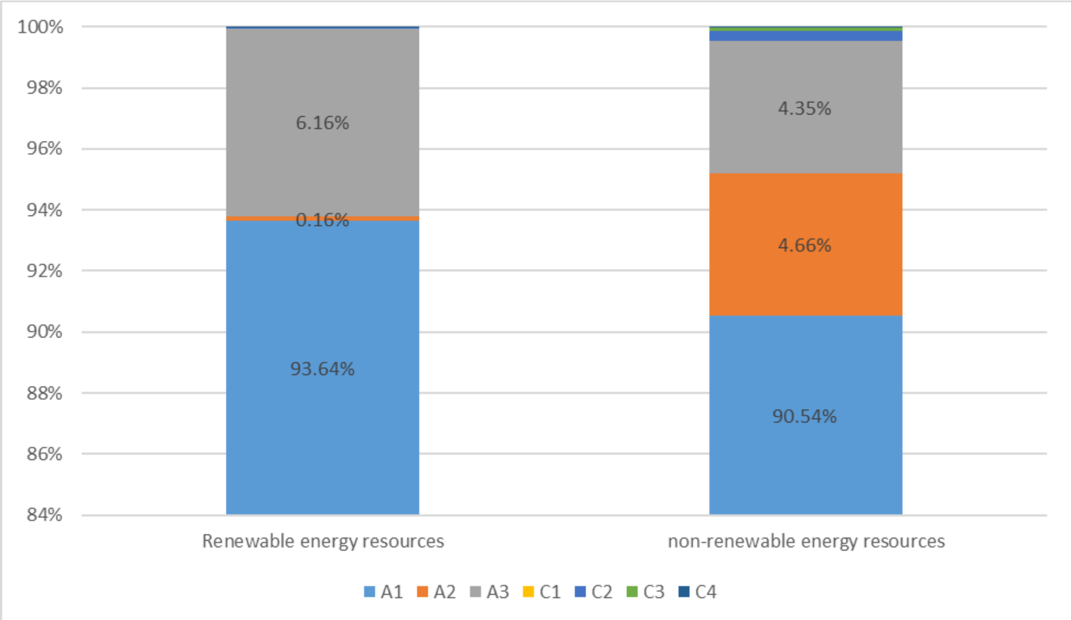

Figure 8: Energy consumption per module for 1 kg of Cold Rolled Aluminium Sheet

Figure 9 shows the energy consumption at each module of the life cycle by source (renewable or non-renewable). Fossil energy sources are the most dominant at A1 life cycle stage. For the A3 the renewable energy resources is the highest, as the manufacturing processes' electricity consumption is chosen as renewable energy.

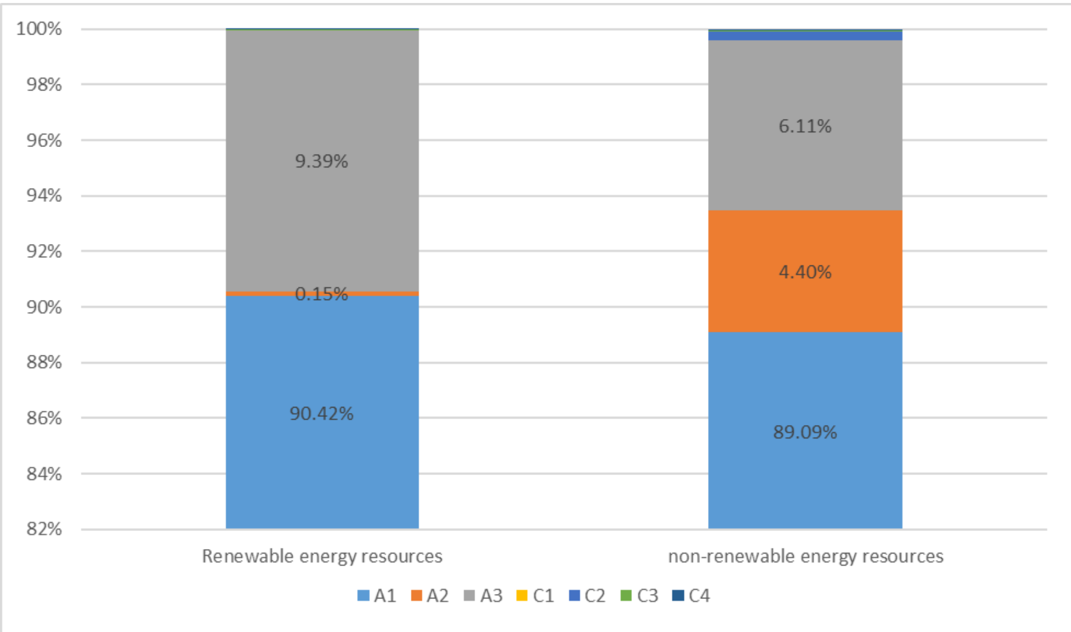

Figure 9: Energy consumption per module for 1 kg of Painted Aluminium sheet

Figure 5 shows the energy consumption at each module of the life cycle by source (renewable or non-renewable). Fossil energy sources are the most dominant at A1 life cycle stage. For the A3 the renewable energy resources is the highest, as the manufacturing processes' electricity consumption is chosen as renewable energy.

7. REFERENCES

ISO 14020:2000 Environmental labels and declarations -- General principles

ISO 14025: 2006 Environmental labels and declarations -- Type III environmental declarations -- Principles and procedures

ISO 14040: 2006 Environmental management -- Life cycle assessment -- Principles and framework

ISO 14044: 2006 Environmental management -- Life cycle assessment -- Requirements and guidelines

EN 15804:2012+A2:2019 Sustainability of construction works – Environmental product declarations - Core rules for the product category of construction products

The International EPD® System / www.environdec.com

The International EPD® System / The General Programme Instructions v3.01 / https://www.environdec.com/contentassets/95ee9211a9614f1faa7461ff32cecc91/general-programme-instructions-v3.01.pdf

The International EPD® System / PCR 2019:14 Construction products v1.1 (EN 15804:A2) / https://www.environdec.com/PCR/Detail/?Pcr=%2014759

Product Environmental Footprint Category Rules Guidance / https://ec.europa.eu/environment/eussd/smgp/pdf/PEFCR_guidance_v6.3.pdf

Ecoinvent 3.7.1 / http://www.ecoinvent.org/

SimaPro LCA Software / https://simapro.com/

Asaş Website, https://www.asastr.com/

APPENDIX I: CALCULATION METHODS

IPCC 2013 GWP 100a (incl. CO2 uptake) v1.0

IPCC 2013 is the successor of the IPCC 2007 method, which was developed by the Intergovernmental Panel on Climate Change. It contains the climate change factors of IPCC with a timeframe of 100 years, including CO_2 uptake. Accounting for CO_2 uptake is relevant for the following standards: Greenhouse Gas Protocol, ISO 14067, PAS 2050.

The results can be calculated cumulatively as Climate change (select Damage assessment in your results) or per category:

- Climate change - fossil
- Climate change - biogenic
- Climate change - CO2 uptake
- Climate change - land use and land transformation

IPCC characterisation factors for the direct (except CH_4) global warming potential of air emissions. They are:

- not including indirect formation of dinitrogen monoxide from nitrogen emissions.
- not accounting for radiative forcing due to emissions of NOx, water, sulphate, etc. in the lower stratosphere + upper troposphere.
- not considering the range of indirect effects given by IPCC.
- not including indirect effects of CO emissions.

Cumulative Energy Demand (LHV) v1.0

The Cumulative Energy Demand (LHV) method was created by PRé Consultants based on data published by ecoinvents for raw materials available in the SimaPro database. The method calculates Lower Heating Values (LHV); for higher heating values (HHV) use the Cumulative Energy Demand method.

Ratio between lower and higher heating value for each fuel type was derived from Overview and methodology - Data quality guideline for the ecoinvent database version 3 (Table 5.1). It was then used to convert the higher heating values from the default Cumulative Energy Demand method into lower heating values. For peat this ratio was not available in the Data quality guideline, therefore we assume a slightly lower ratio than what was calculated for lignite (0.85).

ReCiPe 2016 Midpoint (H) v1.04

ReCiPe 2016 v1.1 midpoint method, Hierarchist version. This is the default ReCiPe midpoint method.

The ReCiPe 2016 method is a new version of ReCiPe 2008 and it was created by RIVM, Radboud University, Norwegian University of Science and Technology and PRé Consultants. Due to significant methodological differences, the results of ReCiPe 2008 and ReCipe 2016 cannot and should not be compared. In ReCiPe you can choose to use midpoint indicators or endpoint indicators. Each method has been created for three different perspectives. The method includes global normalisation factors for reference year 2010.

In case the original method only reported a characterisation value for one specific subcompartment, this value is taken as the characterisation value for all subcompartments in this compartment. The characterisation values of the subcompartments "fresh water" under water, "high population density" under air and "industrial soil" under soil were chosen as factor for the subcompartment "unspecified". Please mind that the factors in Global warming differ from the 100a time horizon in IPCC 2013 because climate-carbon feedback for non-CO2 GHGs is included. For further details see the method's documentation.

ReCiPe Midpoint (H) 2008

The ReCiPe method was created by RIVM, CML, PRé Consultants, Radboud Universiteit Nijmegen and CE Delft. In ReCiPe you can choose to use midpoint indicators or endpoint indicators. Each method has been created for three different perspectives. More information on the method via www.lcia-ReCiPe.net.

Evaluation:

"Europe ReCiPe H" refers to the normalisation values of Europe.

"World ReCiPe H" refers to the normalisation values of the world.

In case the original method only reported a characterisation value for one specific subcompartment, this value is taken as the characterisation value for all subcompartments in this compartment.

The characterisation values of the subcompartments "fresh water", "high population density" and "industrial soil" were used for the subcompartment "unspecified".

CML-IA baseline v3.06

CML-IA is a LCA methodology developed by the Center of Environmental Science (CML) of Leiden University in The Netherlands.

More information on: http://cml.leiden.edu/software/data-cmlia.html

This method is an update of the CML 2 baseline 2000 and corresponds to the files published by CML in August 2016 (version 4.7). The CML 2 baseline 2000 version can be found in the 'superseded' list. For most impact categories, substances have been added and removed and/or characterisation factors were updated, according to new scientific insight. Only the impact category Photochemical oxidation did not undergo any changes.

The CML-IA (baseline) method elaborates the problem-oriented (midpoint) approach. The CML Guide provides a list of impact assessment categories grouped into:

A: Obligatory impact categories (Category indicators used in most LCAs)

B: Additional impact categories (operational indicators exist, but are not often included in LCA studies)

C: Other impact categories (no operational indicators available, therefore impossible to include quantitatively in LCA)

In case several methods are available for obligatory impact categories a baseline indicator is selected, based on the principle of best available practice. These baseline indicators are category indicators at "mid-point level" (problem oriented approach)". Baseline indicators are recommended for simplified studies. The guide provides guidelines for inclusion of other methods and impact category indicators in case of detailed studies and extended studies.

Only baseline indicators are available in the CML method in SimaPro (based on CML Excel spreadsheet with characterisation and normalisation factors). In general, these indicators do not deviate from the ones in the spreadsheet. In case the spreadsheet contained synonyms of substance names already available in the substance list of the SimaPro database, the existing names are used. A distinction is made for emissions to agricultural soil and industrial soil. Emissions to agricultural soil are made clear by placing 'agricultural' in the column 'subcompartment' while emissions to industrial soil are blank. Emissions to seawater are indicated with 'ocean', while emissions to fresh water are blank (we assume that all emissions to water in existing process records are emissions to fresh water).

Depletion of abiotic resources

Two impact categories: Abiotic depletion (elements, ultimate reserves) and abiotic depletion (fossil fuels)

Abiotic depletion (elements, ultimate reserves) is related to extraction of minerals due to inputs in the system. The Abiotic Depletion Factor (ADF) is determined for each extraction of minerals (kg antimony equivalents/kg extraction) based on concentration reserves and rate of deaccumulation. Abiotic depletion of fossil fuels is related to the Lower Heating Value (LHV) expressed in MJ per kg of m3 fossil fuel. The reason for taking the LHV is that fossil fuels are considered to be fully substitutable.

Global warming

The characterisation model as developed by the Intergovernmental Panel on Climate Change (IPCC) is selected for development of characterisation factors. Factors are expressed as Global Warming Potential for time horizon 100 years (GWP100), in kg carbon dioxide equivalent/kg emission.

Ozone layer depletion (steady state)

The characterisation model is developed by the World Meteorological Organisation (WMO) and defines ozone depletion potential of different gases (kg CFC-11 equivalent/ kg emission).

Human toxicity (HTP inf), Freshwater aquatic ecotoxicity (FAETP inf), Marine aquatic ecotoxicology (MAETP inf) and Terrestrial ecotoxicity (TETP inf)

Characterisation factors, expressed as Human Toxicity Potentials (HTP), are calculated with USES-LCA, describing fate, exposure and effects of toxic substances for an infinite time horizon. For each toxic substance HTP's are expressed as 1,4-dichlorobenzene equivalents/ kg emission.

Photochemical oxidation (high NOx)

The model is developed by Jenkin & Hayman and Derwent and defines photochemical oxidation expressed in kg ethylene equivalents per kg emission.

Acidification (incl. fate, average Europe total, A&B)

Acifidication potential expressed in kg SO2 equivalents per kg emission. Model is developed by Huijbregts.

Eutrophication (fate not included)

Eutrophication potential developed by Heijungs et al and expressed in kg PO4 equivalents per kg emission.

AWARE v1.03

AWARE (Available WAter REmaining) is the recommended method from WULCA to assess water consumption impact assessment in LCA. In May 2016, the method was also endorsed by the EU Joint Research Center. Current implementation corresponds to AWARE version 1.2c.

AWARE is to be used as a water use midpoint indicator representing the relative Available WAter REmaining per area in a watershed after the demand of humans and aquatic ecosystems has been met. It assesses the potential of water deprivation, to either humans or ecosystems, building on the assumption that the less water remaining available per area, the more likely another user will be deprived.

It is first calculated as the water Availability Minus the Demand (AMD) of humans and aquatic ecosystems and is relative to the area (m3 m-2 month-1). In a second step, the value is normalized with the world average result (AMD = 0.0136m3 m-2 month-1) and inverted. The result represents the relative value in comparison with the average m3 consumed in the world (the world average is calculated as a consumption-weighted average). The indicator is limited to a range from 0.1 to 100, with a value of 1 corresponding to the world average, and a value of 10, for example, representing a region where there is 10 times less available water remaining per area than the world average.

Documentation is available from: http://www.wulca-waterlca.org

EF 3.0 Method (adapted) v1.0

The EF method is the impact assessment method of Environmental Footprint initiative. The implementation is based on EF method 3.0 published for use during the EF transition phase. It includes the normalization and weighting factors published in November 2019.

PLEASE NOTE! This implementation of the EF method was adapted to better correspond with the substances used in the SimaPro data libraries:

i) additional flows have been included as they are extensively used by the background databases and their synonyms are part of the original EF method;

ii) flows not used by the background databases have been removed from the method.

Since the method was modified, it is not strictly confined to the EF 3.0 package. The original version of the method will be distributed in a dedicated SimaPro EF 3.0 database or made available as a .csv file to users upon request.

Changes from the EF 2.0 v1.01 method:

- Human toxicity and ecotoxicity impact categories have been replaced

- Land use factors have been recalculated

- Smaller changes to Climate Change (carbon storage), Ozone depletion, Photochemical ozone formation, respiratory inorganics and water scarcity

- Impact category names follow the original EF 3.0 method names

Adaptations by PRé Consultants:

- this implementation of EF 3.0 impact assessment method does not include any substances, which would be new to SimaPro, e.g. regionalized land use flows. None of those flows is used in the SimaPro libraries and would not contribute to the results.

- additional substances have been included as they are extensively used by the background databases and their synonyms are part of the original EF method:

Resource use, energy carriers - flows expressed in mass units (not only in net calorific value as in EF); characterization factor corresponds to the lower heating values of given fuel;

Resource use, mineral and metals - additional flows for already characterized mineral and metals;

Water scarcity - for flows representing geographies not covered in the original EF method the global factor was applied;

Climate change:

- carbon dioxide (emission to air) is included with factor 1 (like carbon dioxide, fossil in the original method);

- carbon dioxide, to soil or biomass stock (emission to soil) is included with factor -1 (this flow is necessary for the correct modeling of land use in ecoinvent);

- carbon dioxide, in air (raw material) is included with factor 0 (like carbon dioxide, fossil and carbon dioxide, biogenic in the original method).

Sources: https://eplca.jrc.ec.europa.eu/permalink/EF_3.0_Complete.zip

- Fazio, S. Castellani, V. Sala, S., Schau, EM. Secchi, M. Zampori, L., Supporting information to the characterisation factors of recommended EF Life Cycle Impact Assessment methods, EUR 28888 EN, European Commission, Ispra, 2018, ISBN 978-92-79-76742-5, doi:10.2760/671368, JRC109369.

- Normalization and weighting sets from Annex 2 of the Product Environmental Footprint Category Rules Guidance.

- Normalization: World population used to calculate the NF per person: 6895889018 people; Source: United Nations, Department of Economic and Social Affairs, Population Division (2011). World Population Prospects: The 2010 Revision, DVD Edition – Extended Dataset (United Nations publication, Sales No. E.11.XIII.7).

- Weighting: Sala S., Cerutti A.K., Pant R., Development of a weighting approach for the Environmental Footprint, Publications Office of the European Union, Luxembourg, 2018, ISBN 978-92-79-68041-0.

Contact: http://eplca.jrc.ec.europa.eu/LCDN/developerEF.xhtml

EF-Climate Change.

Impact indicator: Radiative forcing as Global Warming Potential (GWP100)

Baseline model of the IPCC 2013 + some factors adapted from EF guidance

EF-Ozone depletion

Impact indicator: Ozone Depletion Potential (ODP) calculating the destructive effects on the stratospheric ozone layer over a time horizon of 100 years.

EF-Ionising radiation

Impact indicator: Ionizing Radiation Potentials: Quantification of the impact of ionizing radiation on the population, in comparison to Uranium 235.

EF-Photochemical ozone formation

Impact indicator: Photochemical ozone creation potential (POCP): Expression of the potential contribution to photochemical ozone formation.

Only for Europe. Includes spatial differentiation. Considering a marginal increase in ozone formation, the LOTOS-EUROS spatially differentiated model averages over 14000 grid cells to define European factors.

EF-Particulate matter

Impact indicator: Disease incidence due to kg of PM2.5 emitted

The indicator is calculated applying the average slope between the Emission Response Function (ERF) working point and the theoretical minimum-risk level. Exposure model based on archetypes that include urban environments, rural environments, and indoor environments within urban and rural areas.

EF-Human toxicity, non-cancer

Impact indicator: Comparative Toxic Unit for human (CTUh)

USEtox consensus multimedia model. It spans two spatial scales: continental scale consisting of six compartment (urban air, rural air, agricultural soil natural soil, freshwater, costal marine water), and the global scale with the same structure but without the urban air. Specific groups of chemicals requires further work.

EF-Human toxicity, cancer

Impact indicator: Comparative Toxic Unit for human (CTUh)

USEtox consensus multimedia model. It spans two spatial scales: continental scale consisting of six compartment (urban air, rural air, agricultural soil natural soil, freshwater, costal marine water), and the global scale with the same structure but without the urban air. Specific groups of chemicals requires further work .

EF-Acidification

Impact indicator: Accumulated Exceedance (AE) characterizing the change in critical load exceedance of the sensitive area in terrestrial and main freshwater ecosystems, to which acidifying substances deposit.

EF-Eutrophication freshwater

Impact indicator: Phosphorus equivalents: Expression of the degree to which the emitted nutrients reaches the freshwater end compartment (phosphorus considered as limiting factor in freshwater).

European validity. Averaged characterization factors from country dependent characterization factors.

EF-Eutrophication marine

Impact indicator: Nitrogen equivalents: Expression of the degree to which the emitted nutrients reaches the marine end compartment (nitrogen considered as limiting factor in marine water).

EF-Eutrophication terrestrial

Impact indicator: Accumulated Exceedance (AE) characterizing the change in critical load exceedance of the sensitive area, to which eutrophying substances deposit.

EF-Ecotoxicity freshwater

Impact indicator: Comparative Toxic Unit for ecosystems (CTUe)

USEtox consensus multimedia model. It spans two spatial scales: continental scale consisting of six compartment (urban air, rural air, agricultural soil natural soil, freshwater, costal marine water), and the global scale with the same structure but without the urban air. Specific groups of chemicals requires further work.

EF-Land Use

Impact indicator: Soil quality index

CFs set was re-Calculated by JRC starting from LANCA® v 2.2 as baseline model. Out of 5 original indicators only 4 have been included in the aggregation (physico-chemical filtration was excluded due to the high correlation with the mechanical filtration).

EF-Water use

Impact indicator: User deprivation potential (deprivation-weighted water consumption)

Relative Available WAter REmaining (AWARE) per area in a watershed, after the demand of humans and aquatic ecosystems has been met. CF are recommended for characterization of blue water consumption only, where consumption is defined as the difference between withdrawal and release of blue water. Therefore, green water, fossil water, sea water and rainwater are not to be characterized with this CFs set. The following features of AWARE100 are not included: agricultural/non-agricultural distinction at country level, temporal (monthly) specification, characterization factors at watershed level.

EF-Resource use, energy carriers

Impact indicator: Abiotic resource depletion fossil fuels (ADP-fossil); based on lower heating value

ADP for energy carriers, based on van Oers et al. 2002 as implemented in CML, v. 4.8 (2016). Depletion model based on use-to-availability ratio. Full substitution among fossil energy carriers is assumed.

EF-Resource use, mineral and metals

Impact indicator: Abiotic resource depletion (ADP ultimate reserve)

ADP for mineral and metal resources, based on van Oers et al. 2002 as implemented in CML, v. 4.8 (2016). Depletion model based on use-to-availability ratio. Full substitution among fossil energy carriers is assumed.

EN 15804 +A2 Method v1.0

The EN 15804 standard covers Environmental Product Declarations (EPDs) of Construction Products. The 2019 A2 revision of this standard has aligned their methodology with the EF 3.0 method, except for their approach on biogenic carbon. According to the EN 15804, biogenic carbon emissions cause the same amount of Climate Change as fossil carbon, but can be neutralized by removing this carbon from the atmosphere again.

EF 3.0 normalization values, published November 2019, were used.

PLEASE NOTE! This implementation of this method was adapted to better correspond with the substances used in the SimaPro data libraries. This method is identical to the EF 3.0 method, except for a few characterization factors (CF) in both the Climate Change and Climate Change – Biogenic impact categories:

Substance	Compartment	Characterization factor
carbon dioxide (biogenic)	Emission	1
carbon monoxide (biogenic)	Emission	1.57
methane (biogenic)	Emission	36.75
carbon dioxide	Resource	-1

Adaptations by PRé Consultants:

- this implementation of EN 15804 impact assessment method does not include any substances, which would be new to SimaPro, e.g. regionalized land use flows. None of those flows is used in the SimaPro libraries and would not contribute to the results.

- additional substances have been included as they are extensively used by the background databases and their synonyms are part of the original EN 15804 method:

Resource use, energy carriers - flows expressed in mass units (not only in net calorific value as in the EN 15804); characterization factor corresponds to the lower heating values of given fuel;

Resource use, mineral and metals - additional flows for already characterized mineral and metals;

Water scarcity - for flows representing geographies not covered in the original EN 15804 method the global factor was applied;

Climate change:

- carbon dioxide (emission to air) is included with factor 1 (like carbon dioxide, fossil in the original method);

- carbon dioxide, to soil or biomass stock (emission to soil) is included with factor -1 (this flow is necessary for the correct modeling of land use in ecoinvent);

- carbon dioxide, in air (raw material) is included with factor -1 (like carbon dioxide, biogenic in the original method).

APPENDIX II: BACKGROUND DATA DESCRIPTION

Table 22: Background Data Description

Module per EN 15804	DATABASE	DESCRIPTION
	Data available in Ecoinvent	
A1	Chemical, organic {GLO}| market for | Cut-off, S	Geography: The inventory is modelled for Global Technology level: 0 Technology: Start date: 01/01/2011 End date: 31/12/2020
A1	Aluminium, primary, ingot {IAI Area, Asia, without China and GCC}| aluminium production, primary, ingot | Cut-off, S	Geography: The inventory is modelled for IAI Area, Asia, without China and GCC Technology level: 3 Technology: Start date: 01/01/2015 End date: 31/12/2020
A1	Aluminium, primary, ingot {IAI Area, Russia & RER w/o EU27 & EFTA}| aluminium production, primary, ingot | Cut-off, S	Geography: The inventory is modelled for IAI Area, Russia & RER w/o EU27 & EFTA Technology level: 3 Technology: Start date: 01/01/2015 End date: 31/12/2020
A1	Calcium carbonate, precipitated {RER}| calcium carbonate production, precipitated | Cut-off, S	Geography: The inventory is modelled for Europe Technology level: 3 Technology: For more information on the model please refer to the dedicate ecoinvent report, access it in the Report section of ecoQuery (http://www.ecoinvent.org/login-databases.html);Hischier, R. (2005) Establishing Life Cycle Inventories of Chemicals Based on Differing Data Availability (9 pp). The International Journal of Life Cycle Assessment, Volume 10, Issue 1, pp 59–67. 10.1065/lca2004.10.181.7;CAMEO Chemicals version 2.7. CALCIUM CARBONATE. Retrieved from: https://cameochemicals.noaa.gov/chemical/25005, accessed 25 January 2017;Gendorf (2016) Umwelterklärung 2015, Werk Gendorf Industriepark, www.gendorf.de;Kenny, M. and Oates, T. 2007. Lime and Limestone. In Ullmann's Encyclopedia of Industrial Chemistry, Electronic Release, Vol.21, pp.61. Wiley-VCH, Weinheim.;In the model, unreacted fractions are treated in a waste treatment process, and emissions reported are after a waste treatment process that is included in the scope of this dataset. For volatile reactants, a small level of evaporation is assumed. Solvents and catalysts are mostly recycled in closed-loop systems within the scope of the dataset and reported flows are for losses from this system.;This inventory representing production of a particular chemical compound is at least partially based on a generic model on the production of chemicals. The data generated by this model have been improved by compound-specific data when available.;Chemical reaction:;The model on production of chemicals is using specific industry or literature data wherever possible and more generic data on chemical production processes to fill compound-specific data gaps when necessary. The basic principles of the model have been published in literature (Hischier 2005, Establishing Life Cycle Inventories of Chemicals Based on Differing Data Availability). The model has been updated and extended with newly available data from the chemical industry.;The main source of information for the values for heat, electricity, water (process and cooling), nitrogen, chemical factory is industry data from Gendorf. The values are a 5-year average of data (2011 - 2015) published by the Gendorf factory (Gendorf, 2016, Umwelterklärung, www.gendorf.de), (Gendorf, 2015, Umwelterklärung, www.gendorf.de), (Gendorf, 2014, Umwelterklärung, www.gendorf.de). The Gendorf factory is based in Germany, it produces a wide range of chemical substances. The factory produced 1657400 tonnes of chemical substances in the year 2015 (Gendorf, 2016, Umwelterklärung, www.gendorf.de) and 740000 tonnes of intermediate products.;CaO2H2 + CO2 -> CaCO3? + H2O;Reference(s):;Precipitated calcium carbonate is produced from the reaction of hydrated lime with carbon dioxide. With controlled reaction conditions the result is a product with size of 0.02 to 0.2 micrometer and

		with high reflectivity (Kenny and Oates 2007). An alternative route to produce precipitate calcium carbonate is through the Solvay process (Kenny and Oates 2007). Start date: 01/01/2015 End date: 31/12/2020
A1	Chromium oxide, flakes {RER}| production | Cut-off, S	Geography: The inventory is modelled for Europe Technology level: 3 Technology: Althaus H.-J., Chudacoff M., Hischier R., Jungbluth N., Osses M. and Primas A. (2007) Life Cycle Inventories of Chemicals. ecoinvent report No. 8, v2.0. EMPA Dübendorf, Swiss Centre for Life Cycle Inventories, Dübendorf, CH.;References:;Production from sodium dichromate and sulphuric acid according to the wet process scheme, with a process yield of 98%. The inventory is based on stoechiometric calculations. The emissions to air (0.2 wt% of raw material input) and water were estimated using mass balance. Treatment of the waste water in an internal waste water treatment plant assumed (elimination efficiency of 50% for Cr-compounds).;Anger, G., Halstenberg, J., Hochgeschwender, K., Scherhag, C., Korallus, U., Knopf, H., Schmidt, P. and Ohlinger, M. 2000. Chromium Compounds. Ullmann's Encyclopedia of Industrial Chemistry. Start date: 01/01/2000 End date: 31/12/2020
A1	Copper carbonate {RER}| production | Cut-off, S	Geography: The inventory is modelled for Europe Technology level: 3 Technology: Production out of copper sulphate and sodium carbonate with an overall process yield is of 98%. Inventory bases on stoechiometric calculations. The emissions to air (0.2 wt.% of raw material input) and water were estimated using mass balance. Treatment of the waste water in a internal waste water treatment plant assumed (elimination efficiency of 90% for C). Start date: 01/01/2000 End date: 31/12/2020
A1	Cast iron {RER}| production | Cut-off, S	Geography: The inventory is modelled for Europe Technology level: 3 Technology: Electric arc furnace for melting. Energy consumption and emissions from EAF steel making Start date: 01/01/2001 End date: 31/12/2020
A1	Magnesium oxide {RER}| production | Cut-off, S	Geography: The inventory is modelled for Europe Technology level: 3 Technology: Classen M., Althaus H.-J., Blaser S., Doka G., Jungbluth N. and Tuchschmid M. (2007) Life Cycle Inventories of Metals. Final report ecoinvent data v2.0 No.10. EMPA Dübendorf, Swiss Centre for Life Cycle Inventories, Dübendorf, CH, Online-Version under: www.ecoinvent.ch.;- Caustic magnesium oxide production: The data from lime calcination are used as a first approximation due to the fact that this process uses also a kiln. This process has a yield of 58% - a value that, due to a lack of more specific data, is used here as well.;- Mining: the data for the mining operation are taken from iron mining (Classen et al. 2007). As resource "magnesite, in ground" with a yield of 90% (assumption due to lack of respective information) is used while all other inputs and outputs are taken 1:1 from iron mining. Due to a lack of data, a magnesite content in the crude ore of 60% is assumed here.;- Crushing: The data from limestone crushing are used as a first approximation. Therefore, the data are taken from the dataset "primary crushing of limestone" in Kellenberger et al. (2007).;References:;Seeger M., Otto W., Flick W., Bickelhaupt F. and Akkerman O. S. (2000) Magnesium Compounds. In: Ullmann's Encyclopedia of Industrial Chemistry, Sixth Edition, June-2001 Electronic Release (ed. Häussinger P., Leitgeb P. and Schmücker B.), 6 th Electronic Release Edition. Wiley InterScience, New York, Online-Version under: http://www.mrw.interscience.wiley.com/ueic/ull_search_fs.html.;Caustic magnesium oxide is obtained by burning $MgCO_3$ or $Mg(OH)_2$ (brucite) slightly above the decomposition temperature. In both cases, first there is a mining and crushing step and then there is a calcination step with a temperature of about 800 - 1000 °C, for which rotary kilns or hearth furncaces techniques are used.;Due to missing production data and no quantitative information in Seeger et al. (2000), process data from similar processes within the ecoinvent project are used as a first approximation for the caustic magnesium oxide production:;Kellenberger D., Althaus H.-J., Jungbluth N. and Künniger T. (2007) Life Cycle Inventories of Building

		Products. Final report ecoinvent data v2.0 No. 7. Swiss Centre for Life Cycle Inventories, Empa - TSL, Dübendorf, CH, Online-Version under: www.ecoinvent.ch.;- Benefication: No process specific information are available - therefore the input and output data from the iron benefication process of the ecoinvent project (shown in Classen et al. 2007) are used as a first approximation. This process has a yield of 85% - a value that, due to a lack of more specific data for magnesium oxide, is used here as well. Start date: 01/01/2000 End date: 31/12/2020
A1	Manganese {RER}| production | Cut-off, S	Geography: The inventory is modelled for Europe Technology level: 3 Technology: IPPC (2001) Integrated Pollution Prevention and Control (IPPC); Reference Document on Best Available Techniques in the Non Ferrous Metals Industries. European Commission. Retrieved from http://www.jrc.es/pub/english.cgi/ 0/733169;ELECTROLYSIS OF AQUEOUS MANGANESE SALTS;Wellbeloved D. B., Craven P. M. and Waudby J. W. (1997) Manganese and Manganese Alloys. In: Ullmann's encyclopedia of industrial chemistry (ed. Anonymous). 5th edition on CD-ROM Edition. Wiley & Sons, London.;ELECTROTHERMAL DECOMPOSITION OF MANGANESE ORES;References:;Overall emissions and waste: Emissions to air consist of dust and fume emissions from smelting, hard metal and carbide production; Other emissions to air are ammonia (NH_3), acid fume (HCl), hydrogen fluoride (HF), VOC and heavy metals. Effluents are composed of overflow water from wet scrubbing systems, wastewater from slag and metal granulation, and blow down from cooling water cycles. Waste includes dust, fume, sludge and slag.;The electrothermal process is the second important process to produce manganese metal in an industrial scale. The electrothermal process takes place as a multistage process. In the first stage manganese ore is smelted with only a small amount of reductant in order to reduce mostly the iron oxide. This produces a low-grade ferro-manganese and a slag that is rich in Mn-oxide. The slag is then smelted in the second stage with silicon to produce silicomanganese. The molten silicomanganese can be treated with liquid slag from the fist stage to obtain relatively pure manganese metal. For the last step a ladle or shaking ladle can be used. The manganese metal produced by the electrothermal process contains up to 98% of Mn.;The production of manganese metal by the electrolysis of aqueous manganese salts requires at first a milling of the manganese ore. Milling increases the active surface and ensures sufficient reactivity in both the reduction and the subsequent leaching steps. After milling the manganese ore is fed to a rotary kiln where the reduction and calcination takes place. This process is carried out at about 850 - 1000 ºC in a reducing atmosphere. As a reducing agent, several carbon sources can be used e.g. anthracite, coal, charcoal and hydrocarbon oil or natural gas. The cal-cined ore needs to be cooled below 100 ºC to avoid a further re-oxidation. The subsequent leaching process is carried out with recycled electrolyte, mainly sulphuric acid. After leaching and filtration the iron content is removed from the solution by oxidative precipitation and the nickel and cobalt are removed by sulphide precipitation. The purified electrolyte is then treated with SO_2 in order to ensure plating of gamma-Mn during electrolysis. Electrolysis is carried out in diaphragm cells. The cathode is normally made of stainless steel or titanium. For the anode lead-calcium or lead-silver alloy can be used. After an appropriate reaction time the cathodes are removed from the electrolysis bath. The manganese that is deposited on the cathode starter-sheet is stripped off mechanically and then washed and dried. The metal is crushed to produce metal flakes or powder or granulated, depending on the end use.;The metal is won by electrolysis (25%) and electrothermic processes (75%). Start date: 01/01/2003 End date: 31/12/2020
A1	Reinforcing steel {RoW}| production | Cut-off, U	Geography: The inventory is modelled for Europe Technology level: 3 Technology: Represents average European technology; furnace with 4th hole and secondary metallurgy Start date: 01/01/2013 End date: 31/12/2023
	Silicon carbide {RER}| production | Cut-off, S	Geography: The inventory is modelled for Europe Technology level: 3

A1		Technology: Liethschmidt, K. and Garbes, J. 2008. Silicon Carbide. Ullmann's Encyclopedia of Industrial Chemistry.;Reference:;Silicon carbide is manufactured through reaction of silicon dioxide and carbon, yielding silicon carbide and carbon monoxide. This dataset represents the average technology used by 4 companies. Start date: 01/01/2000 End date: 31/12/2020
A1	Titanium, primary {GLO}| market for | Cut-off, S	Geography: The inventory is modelled for Global Technology level: 0 Technology: Start date: 01/01/2004 End date: 31/12/2020
A1	Borax, anhydrous, powder {GLO}| market for | Cut-off, S	Geography: The inventory is modelled for Global Technology level: 0 Technology: Start date: 01/01/2011 End date: 31/12/2020
A1	Aluminium, primary, ingot {RoW}| market for | Cut-off, S	Geography: The inventory is modelled for Rest-of-World Technology level: 0 Technology: Start date: 01/01/2010 End date: 31/12/2020
A1	Zinc oxide {RER}| production | Cut-off, S	Geography: The inventory is modelled for Europe Technology level: 3 Technology: References:;Schwab, B., Ruh, A., Manthey, J. and Drosik, M. 2015. Zinc. Ullmann's Encyclopedia of Industrial Chemistry. 1–25.;Hischier R., Classen M., Lehmann M. and Scharnhorst W. (2007) Life cycle inventories of Electric and Electronic Equipment: Production, Use and Disposal. ecoinvent report No. 18. Empa / Technology & Society Lab, Swiss Centre for Life Cycle Inventories, Dübendorf, 2007.;Zinc oxide is mainly produced from residues and secondary zinc by means of the indirect (or French) way. The demand for chemical purity imposed by the users means that a number of purification techniques are required. About 1 – 2 % of zinc oxide is produced by the wet process, 10 – 20 % by the direct process, and the remainder by the indirect process.;Auer, G., Woditsch, P., Westerhaus, A., Kischkewitz, J., Griebler, W.-D. and De Liedekerke, M. 2009. Pigments, Inorganic, 2. White Pigments. Ullmann's Encyclopedia of Industrial Chemistry. Start date: 01/01/2005 End date: 31/12/2020
A1	Zircon, 50% zirconium {GLO}| market for | Cut-off, S	Geography: The inventory is modelled for Global Technology level: 0 Technology: Start date: 01/01/2011 End date: 31/12/2020
A1	Aluminium, primary, ingot {RoW}| market for | Cut-off, S	Geography: The inventory is modelled for Rest-of-World Technology level: 0 Technology: Start date: 01/01/2010 End date: 31/12/2020
A1	Cast iron {RER}| production | Cut-off, S	Geography: The inventory is modelled for Europe Technology level: 3 Technology: Electric arc furnace for melting. Energy consumption and emissions from EAF steel making Start date: 01/01/2001 End date: 31/12/2020
A1	Magnesium oxide {RER}| production | Cut-off, S	Geography: The inventory is modelled for Europe Technology level: 3 Technology: Classen M., Althaus H.-J., Blaser S., Doka G., Jungbluth N. and Tuchschmid M. (2007) Life Cycle Inventories of Metals. Final report ecoinvent data v2.0 No.10. EMPA Dübendorf, Swiss Centre for Life Cycle Inventories, Dübendorf, CH, Online-Version under: www.ecoinvent.ch.;- Caustic magnesium oxide production: The data from lime calcination are used as a first approximation due to the fact that this process uses also a kiln. This process has a yield of 58% - a value that, due to a lack of more specific data, is used here as well.;- Mining: the data for the mining operation are taken from iron mining (Classen et al. 2007). As resource "magnesite, in ground" with a yield of 90% (assumption due to lack of respective information) is used while all other inputs and outputs are taken 1:1 from iron mining. Due to a lack of data, a magnesite content in the crude ore of 60% is assumed here.;- Crushing: The data from

		limestone crushing are used as a first approximation. Therefore, the data are taken from the dataset “primary crushing of limestone” in Kellenberger et al. (2007).;References:;Seeger M., Otto W., Flick W., Bickelhaupt F. and Akkerman O. S. (2000) Magnesium Compounds. In: Ullmann's Encyclopedia of Industrial Chemistry, Sixth Edition, June-2001 Electronic Release (ed. Häussinger P., Leitgeb P. and Schmücker B.), 6 th Electronic Release Edition. Wiley InterScience, New York, Online-Version under: http://www.mrw.interscience.wiley.com/ueic/ull_search_fs.html.;Caustic magnesium oxide is obtained by burning MgCO3 or Mg(OH)2 (brucite) slightly above the decomposition temperature. In both cases, first there is a mining and crushing step and then there is a calcination step with a temperature of about 800 - 1000 °C, for which rotary kilns or hearth furncaces techniques are used.;Due to missing production data and no quantitative information in Seeger et al. (2000), process data from similar processes within the ecoinvent project are used as a first approximation for the caustic magnesium oxide production:;Kellenberger D., Althaus H.-J., Jungbluth N. and Künniger T. (2007) Life Cycle Inventories of Building Products. Final report ecoinvent data v2.0 No. 7. Swiss Centre for Life Cycle Inventories, Empa - TSL, Dübendorf, CH, Online-Version under: www.ecoinvent.ch.;- Benefication: No process specific information are available - therefore the input and output data from the iron benefication process of the ecoinvent project (shown in Classen et al. 2007) are used as a first approximation. This process has a yield of 85% - a value that, due to a lack of more specific data for magnesium oxide, is used here as well. Start date: 01/01/2000 End date: 31/12/2020
A1	Aluminium scrap, new {GLO}| aluminium scrap, new, Recycled Content cut-off | Cut-off, S	Geography: The inventory is modelled for Global Technology level: 0 Technology: Start date: 01/01/2011 End date: 31/12/2020
A1	Benzyl alcohol {RoW}| production | Cut-off, S	Geography: The inventory is modelled for Rest-of-World Technology level: 3 Technology: Brühne, F., Wright: Benzyl alcohol. In: Ullmann's Encyclopedia of Industrial Chemistry, Seventh Edition, 2004 Electronic Release (ed. Fiedler E., Grossmann G., Kersebohm D., Weiss G. and Witte C.). 7 th Electronic Release Edition. Wiley InterScience, New York, Online-Version under: http://www.mrw.interscience.wiley.com/ueic/articles/;Reference:;Benzyl alcohol can be produced in many ways. At present there are only two processes of substantial industrial importance: the hydrolysis of benzyl chloride and the hydrogenation of benzaldehyde. Other processes, like the oxidation of toluene, the hydrogenation of benzoic acid esters, the electrochemical reduction of benzoic acid, the hydrolysis of benzylsulfonic acid, and the decarboxylation of benzyl formate, have no importance in the industrial production of benzyl alcohol. The hydrolysis of benzyl chloride is a reversible reaction which leads to the almost quantitative formation of benzyl alcohol only in the presence of alkaline saponifying agents that combine with the hydrogen chloride as it is formed. It is therefore carried out by heating benzyl chloride with stoichiometric excesses of aqueous solutions of oxides, hydroxides, or carbonates of the alkali or alkaline earth metals. ;To 610 parts of boiling 10 % soda solution 126.5 parts of benzyl chloride is added with stirring. The reaction mixture is refluxed and stirred until carbon dioxide no longer escapes; this takes an average of five to six hours. An alkali-resistant steel reactor with brick walls is used. The stirrer and heating coil are made of an alloy with a high nickel content. After the reaction mixture has cooled, the upper layer, consisting of crude benzyl alcohol, is removed. The sodium chloride solution below still contains some soda. Dissolved benzyl alcohol can be obtained from it by adding salt or by extracting with benzene or toluene. The crude benzyl alcohol is carefully fractionated at a reduced pressure in an efficient column. The yield is 85 parts of benzyl alcohol and 10 parts of dibenzyl ether. Start date: 01/01/1998 End date: 31/12/2020
A2	Transport, freight, lorry >32 metric ton, EURO6 {RoW}| transport, freight, lorry >32 metric ton, EURO6 | Cut-off, S	Geography: The inventory is modelled for Rest-of-World Technology level: 1 Technology: Diesel and diesel engine. Lorry transport is further differentiated with respect to vehicle weight and emission technology

		standard (EURO-standard). ;Technology classifications are based on those used widely within the works of the European Environment Agency, particularly in the Emissions Inventory Guidebook. Start date: 01/01/2009 End date: 31/12/2020
A2	Transport, freight, sea, bulk carrier for dry goods {GLO}| transport, freight, sea, bulk carrier for dry goods | Cut-off, S	Geography: The inventory is modelled for Global Technology level: 3 Technology: Fuel consumption and emissions are representative of the current technology (used in 2012 and considering the age distribution of global fleet). Load capacity ({{capacity}} tonnes), fuel consumption and emissions are global weighted averages on tkms over the size classes from IMO (2015).;capacity Start date: 01/01/2007 End date: 31/12/2020
A2	Transport, freight, lorry 16-32 metric ton, EURO6 {RoW}| transport, freight, lorry 16-32 metric ton, EURO6 | Cut-off, S	Geography: The inventory is modelled for Rest-of-World Technology level: 1 Technology: Diesel and diesel engine. Lorry transport is further differentiated with respect to vehicle weight and emission technology standard (EURO-standard). ;Technology classifications are based on those used widely within the works of the European Environment Agency, particularly in the Emissions Inventory Guidebook. Start date: 01/01/2009 End date: 31/12/2020
A3	Tap water {RER}| market group for | Cut-off, S	Geography: The inventory is modelled for Europe Technology level: 3 Technology: Start date: 01/01/2015 End date: 31/12/2020
A3	Electricity, high voltage {TR}| electricity production, hydro, run-of-river | Cut-off, S	Geography: The inventory is modelled for Turkey Technology level: 2 Technology: The efficiency of generators depends on the output, the rotation speed of the generator and the cooling system. For today's power plants an efficiency of approximately 96% is assumed, modern generators show an efficiency of about 98%. The efficiency of transformers amounts to 98%, respectively 99%.;König F., von (1985) Bau von Wasserkraftanlagen. C.F. Müller, Karlsruhe.;The technology used in the dataset has an overall efficiency of 82%, more modern technologies show an overall efficiency of about 88%. The overall efficiency (current: 0,82; modern: 0,88) is composed of the efficiency of the works water channel (current: 1,00; modern: 1,00), the turbine (current: 0,87; modern: 0,91), the generator (current: 0,96; modern: 0,98) and the transformer (current: 0,98; modern: 0,99). For the calculation of the works water channel of run-of-river plants an efficiency of 100% is assumed.;References:;Run-of-river power plants are hydro power plants without important reservoirs. Depending on the net head of the power plant, high-pressure, medium-pressure and low-pressure systems can be distinguished. Low-pressure power plants including river power stations and canal power plants are very common; therefore these two types of run-of-river power stations are covered in the dataset. To some extent, high-pressure as well as medium-pressure run-of-river systems can be considered as reservoir power stations, e.g. as unit in plant groups that are dominated by storage power plants, but also include alpine run power stations.;The efficiency losses in turbines depend on the turbine type (Kaplan, Francis, Pelton, etc.), the turbine output and on the ratio between turbined water amount and the rated water amount. In König, examples for curve progressions of the relationship between these variables are shown. For current power plants an efficiency of 87% is assumed, more modern turbines show an efficiency of about 91%. Start date: 01/01/1945 End date: 31/12/2020
A3	Heat, district or industrial, natural gas {RoW}| heat production, natural gas, at industrial furnace >100kW | Cut-off, S	Geography: The inventory is modelled for Rest-of-World Technology level: 3 Technology: Fan burners on market (modulating or non-modulating, non-condensing) Start date: 01/01/2000 End date: 31/12/2020
A3	Aluminium, cast alloy {RER}| treatment of aluminium scrap, new, at refiner | Cut-off, S	Geography: The inventory is modelled for Europe Technology level: 3 Technology: Average technology for the aluminium recycled (refined) in Europe Start date: 01/01/2005

		End date: 31/12/2020
A3	Aluminium scrap, new {GLO}| aluminium scrap, new, Recycled Content cut-off | Cut-off, S	Geography: The inventory is modelled for Global Technology level: 3 Technology: Start date: 01/01/2020 End date: 31/12/2020
A3	Aluminium scrap, post-consumer {GLO}| aluminium scrap, post-consumer, Recycled Content cut-off | Cut-off, S	Geography: The inventory is modelled for Global Technology level: 3 Technology: Start date: 01/01/2020 End date: 31/12/2020
A3	Packaging film, low density polyethylene {RER}| production | Cut-off, S	Geography: The inventory is modelled for Europe Technology level: 3 Technology: present technologies Start date: 01/01/1993 End date: 31/12/2020
A3	Kraft paper {RER}| market for kraft paper | Cut-off, S	Geography: The inventory is modelled for Europe Technology level: 0 Technology: Start date: 01/01/2015 End date: 31/12/2020
A3	Sawnwood, board, softwood, raw, dried (u=20%) {Europe without Switzerland}| market for sawnwood, board, softwood, raw, dried (u=20%) | Cut-off, S	Geography: The inventory is modelled for Europe without Switzerland Technology level: 3 Technology: Start date: 01/01/2019 End date: 31/12/2020
A3	Water, completely softened {RER}| water production, completely softened | Cut-off, S	Geography: The inventory is modelled for Europe Technology level: 3 Technology: Water completely soften consists in the removal of cations mainly calcium and magnesium which are exchanged or replaced for another cation that cannot form scale as it is much more soluble such as sodium or chloride ions. The most common means for reduction of hard water relies on ion exchange resins or reverse osmosis; in limited circumstances, it is performed through the use of chemicals additives specially, lime softening (WaterProfessionals, 2017). Start date: 01/01/2015 End date: 31/12/2020
C2	Transport, freight, lorry 16-32 metric ton, EURO6 {RER}| transport, freight, lorry 16-32 metric ton, EURO6 | Cut-off, S	Included activities start: From combustion of fuel in the engine. The dataset takes as input the infrastructure of the lorry and road network, the materials and efforts needed for maintenance of these and the fuel consumed in the vehicle for the journey. Included activities end: The activity ends with the transport service of 1tkm and the emissions of exhaust and non-exhaust emissions into air, water and soil. Energy values: 0 Geography: The inventory is modelled for Europe Technology level: 1 Technology: Technology classifications are based on those used widely within the works of the European Environment Agency, particularly in the Emissions Inventory Guidebook.;Diesel and diesel engine. Lorry transport is further differentiated with respect to vehicle weight and emission technology standard (EURO-standard). Start date: 01/01/2009 End date: 31/12/2020 Is data valid for entire period: True Time period: Macro-economic scenario name: Business-as-Usual
C3	Diesel, burned in building machine {GLO}| market for | Cut-off, S	Geography: The inventory is modelled for Global Technology level: 0 Technology: Start date: 01/01/2011 End date: 31/12/2020
C3	Electricity, medium voltage {Europe without Switzerland}| market group for | Cut-off, S	Geography: The inventory is modelled for Europe without Switzerland Technology level: 3 Technology: Start date: 01/01/2015 End date: 31/12/2020
C4	Waste aluminium {RoW}| treatment of, sanitary landfill | Cut-off, S	Production volume: 3.96633243560791 kg Included activities start:

		Included activities end: Waste-specific short-term emissions to air via landfill gas incineration and landfill leachate. Burdens from treatment of short-term leachate (0-100a) in wastewater treatment plant (including WWTP sludge disposal in municipal incinerator). Long-term emissions from landfill to groundwater (after base lining failure). Energy values: 0 Geography: The inventory is modelled for Rest-of-World Technology level: 3 Technology: Swiss municipal sanitary landfill for biogenic or untreated municipal waste ('reactive organic landfill'). Landfill gas and leachate collection system. Recultivation and monitoring for 150 years after closure. Start date: 01/01/1994 End date: 31/12/2020 Is data valid for entire period: True Time period: Macro-economic scenario name: Business-as-Usual
D	Aluminium, primary, ingot {IAI Area, Russia & RER w/o EU27 & EFTA}| aluminium production, primary, ingot | Cut-off, S, Avoided	Geography: The inventory is modelled for IAI Area, Russia & RER w/o EU27 & EFTA Technology level: 3 Technology: Start date: 01/01/2015 End date: 31/12/2020 Is data valid for entire period: True Time period: Macro-economic scenario name: Business-as-Usual
D	Aluminium, primary, ingot {IAI Area, Asia, without China and GCC}| aluminium production, primary, ingot | Cut-off, S, Avoided	Geography: The inventory is modelled for IAI Area, Asia, without China and GCC Technology level: 3 Technology: Start date: 01/01/2015 End date: 31/12/2020 Is data valid for entire period: True Time period: Macro-economic scenario name: Business-as-Usual

APPENDIX III: INVENTORY DATA USED IN THE LCA MODEL

Table 23: Inventory Data Used in LCA Model of Induction Furnace

Inputs - Induction				
Material/Process	**Amount**	**Unit**	**Secondary Data/New Created Data**	**Source**
Internal Scrap	0.895	kg	Aluminium scrap, new {GLO}| aluminium scrap, new, Recycled Content cut-off | Cut-off, S	ASAŞ
Outsource Scrap	0.114	kg	Aluminium scrap, post-consumer {GLO}| aluminium scrap, post-consumer, Recycled Content cut-off | Cut-off, S	ASAŞ
Water, well	6.66E-06	m3	Water, well, TR	ASAŞ
Tap Water	0.012	kg	Tap water {RER}| market group for | Cut-off, S	ASAŞ
Electricity	0.773	kWh	Electricity, high voltage {TR}| electricity production, hydro, run-of-river | Cut-off, S	ASAŞ
Transport to Core - Road	0.504	tkm	Transport, freight, lorry 16-32 metric ton, EURO6 {RoW}| transport, freight, lorry 16-32 metric ton, EURO6 | Cut-off, S	ASAŞ
Outputs				
Material/Process	**Amount**	**Unit**	**Secondary Data/New Created Data**	**Source**
Induction Internal Seconder 1 kg	1.00	kg	Induction Internal Seconder 1 kg	ASAŞ
Wastewater	0.000011	m3	Wastewater ASAS 1 m3	ASAŞ
Particulates, unspecified	2.01E-07	kg	Particulates, unspecified	ASAŞ
Hydrogen chloride	2.45E-06	kg	Hydrogen chloride	ASAŞ
Hydrogen fluoride	5.02E-07	kg	Hydrogen fluoride	ASAŞ
PAH, polycyclic aromatic hydrocarbons	6E-09	kg	PAH, polycyclic aromatic hydrocarbons	ASAŞ
Arsenic	1E-09	kg	Arsenic	ASAŞ
PAH, polycyclic aromatic hydrocarbons, carcinogenic	1E-09	kg	PAH, polycyclic aromatic hydrocarbons, carcinogenic	ASAŞ
Chrysene	6.2E-08	kg	Chrysene	ASAŞ
Copper	6.2E-08	kg	Copper	ASAŞ
Manganese	3.1E-08	kg	Manganese	ASAŞ
PAH, polycyclic aromatic hydrocarbons, carcinogenic	6.2E-08	kg	PAH, polycyclic aromatic hydrocarbons, carcinogenic	ASAŞ
m-Xylene	1.73E-07	kg	m-Xylene	ASAŞ
p-Xylene	1.73E-07	kg	p-Xylene	ASAŞ

Toluene	1.73E-07	kg	Toluene	ASAŞ
o-Xylene	1.73E-07	kg	o-Xylene	ASAŞ
Benzene, ethyl-	1.73E-07	kg	Benzene, ethyl-	ASAŞ
VOC, volatile organic compounds, unspecified origin	1.73E-07	kg	VOC, volatile organic compounds, unspecified origin	ASAŞ
VOC, volatile organic compounds, unspecified origin	3.47E-07	kg	VOC, volatile organic compounds, unspecified origin	ASAŞ
Benzene	1.73E-07	kg	Benzene	ASAŞ

1 m3 Wastewater				
Pollutant	Amount	Unit	Secondary Data/New Created Data	Source
Suspended solids, unspecified	125	kg	Suspended solids, unspecified	ASAŞ
COD (Chemical Oxygen Demand), TR	800	kg	COD (Chemical Oxygen Demand), TR	ASAŞ
Oils, unspecified	20.0	kg	Oils, unspecified	ASAŞ
Chromium VI	0.500	kg	Chromium VI	ASAŞ
Aluminium	3.00	kg	Aluminium	ASAŞ
Copper	2.00	kg	Copper	ASAŞ
Zinc	3.00	kg	Zinc	ASAŞ
Iron	3.00	kg	Iron	ASAŞ
Cadmium	0.500	kg	Cadmium	ASAŞ
Nickel	1.00	kg	Nickel	ASAŞ
Lead	1.00	kg	Lead	ASAŞ
Chromium	1.00	kg	Chromium	ASAŞ

Table 24: Inventory Data Used in LCA Model of Casting

Inputs - Casting				
Material/Process	Amount	Unit	Secondary Data/New Created Data	Source
Water, Well	2.27E-06	m3	Water, well, TR	ASAŞ
Water, tap	0.005	kg	Tap water {RER}| market group for | Cut-off, S	ASAŞ
Primer Tajikistan	0.088	kg	Aluminium, primary, ingot {IAI Area, Asia, without China and GCC}| aluminium production, primary, ingot | Cut-off, S	ASAŞ

Primer Russia	0.498	kg	Aluminium, primary, ingot {IAI Area, Russia & RER w/o EU27 & EFTA}| aluminium production, primary, ingot | Cut-off, S	ASAŞ
Primer Kazakhstan	0.119	kg	Aluminium, primary, ingot {IAI Area, Asia, without China and GCC}| aluminium production, primary, ingot | Cut-off, S	ASAŞ
External Seconder	0.128	kg	Aluminium, cast alloy {RER}| treatment of aluminium scrap, new, at refiner | Cut-off, S	ASAŞ
Internal Scrap	0.209	kg	Aluminium scrap, new {GLO}| aluminium scrap, new, Recycled Content cut-off | Cut-off, S	ASAŞ
Internal Seconder	0.037	kg	Induction Internal Seconder 1 kg	ASAŞ
Additive Calcium	6.6E-06	kg	Calcium carbonate, precipitated {RER}| calcium carbonate production, precipitated | Cut-off, S	ASAŞ
Additive Chromium	4.47E-05	kg	Chromium oxide, flakes {RER}| production | Cut-off, S	ASAŞ
Additive Copper	3.30E-04	kg	Copper carbonate {RER}| production | Cut-off, S	ASAŞ
Additive iron	0.005	kg	Cast iron {RER}| production | Cut-off, S	ASAŞ
Additive Magnesium	0.001	kg	Magnesium oxide {RER}| production | Cut-off, S	ASAŞ
Additive manganese, 99%	0.001	kg	Manganese {RER}| production | Cut-off, S	ASAŞ
Additive manganese, 75%	0.002	kg	Manganese {RER}| production | Cut-off, S	ASAŞ
Additive silicon metal	2.12E-04	kg	Silicon carbide {RER}| production | Cut-off, S	ASAŞ
Additive aluminium, titanium and boron	0.002	kg	Aluminium Titan Bor (AlTiB)	ASAŞ
Additive aluminium, titanium and boron	2.14E-04	kg	Aluminium Titan Bor (AlTiB)	ASAŞ
Additive Zinc	2.75E-05	kg	Zinc oxide {RER}| production | Cut-off, S	ASAŞ
Additive aluminium, zirconium	0.000014	kg	Aluminium_Zirconium	ASAŞ
Additive iron	1.42E-05	kg	Cast iron {RER}| production | Cut-off, S	ASAŞ
Additive Magnesium	1.35E-04	kg	Magnesium oxide {RER}| production | Cut-off, S	ASAŞ
Lubricant	2.07E-04	kg	Chemical, organic {GLO}| market for | Cut-off, S	ASAŞ
Heat	3.06	MJ	Heat, district or industrial, natural gas {RoW}| heat production, natural gas, at industrial furnace >100kW | Cut-off, S	ASAŞ
Electricity	0.170	kWh	Electricity, high voltage {TR}| electricity production, hydro, run-of-river | Cut-off, S	ASAŞ
Transport to Core - Road	3.70	tkm	Transport, freight, lorry >32 metric ton, EURO6 {RoW}| transport, freight, lorry >32 metric ton, EURO6 | Cut-off, S	ASAŞ
Transport to Core - Seaway	0.661	tkm	Transport, freight, sea, bulk carrier for dry goods {GLO}| transport, freight, sea, bulk carrier for dry goods | Cut-off, S	ASAŞ
Transport to Core - Road	0.007	tkm	Transport, freight, lorry >32 metric ton, EURO6 {RoW}| transport, freight, lorry >32 metric ton, EURO6 | Cut-off, S	ASAŞ
Transport to Core - Road	0.034	tkm	Transport, freight, lorry >32 metric ton, EURO6 {RoW}| transport, freight, lorry >32 metric ton, EURO6 | Cut-off, S	ASAŞ
Transport to Core - Road	0.005	tkm	Transport, freight, lorry 16-32 metric ton, EURO6 {RoW}| transport, freight, lorry 16-32 metric ton, EURO6 | Cut-off, S	ASAŞ
Transport to Core - Seaway	0.010	tkm	Transport, freight, sea, bulk carrier for dry goods {GLO}| transport, freight, sea, bulk carrier for dry goods | Cut-off, S	ASAŞ
Outputs				

Material/Process	Amount	Unit	Secondary Data/New Created Data	Source
Cold Casting 1 kg	1.00	kg	Cold Casting 1 kg	ASAŞ
Wastewater	5.07E-06	m3	Wastewater ASAS 1 m3	ASAŞ
Particulates, unspecified	9.16E-06	kg	Particulates, unspecified	ASAŞ
Benzene	1.94E-06	kg	Benzene	ASAŞ
PAH, polycyclic aromatic hydrocarbons	6.1E-08	kg	PAH, polycyclic aromatic hydrocarbons	ASAŞ
Carbon monoxide	6.72E-06	kg	Carbon monoxide	ASAŞ
Sulfur dioxide, TR	8.41E-06	kg	Sulfur dioxide, TR	ASAŞ
Nitrogen monoxide, TR	0.001	kg	Nitrogen monoxide, TR	ASAŞ
Nitrogen dioxide, TR	0.002	kg	Nitrogen dioxide, TR	ASAŞ
Hydrogen chloride	5.49E-05	kg	Hydrogen chloride	ASAŞ
Hydrogen fluoride	1.13E-05	kg	Hydrogen fluoride	ASAŞ
VOC, volatile organic compounds, unspecified origin	8.33E-06	kg	VOC, volatile organic compounds, unspecified origin	ASAŞ
m-Xylene	4.16E-06	kg	m-Xylene	ASAŞ
p-Xylene	4.16E-06	kg	p-Xylene	ASAŞ
o-Xylene	4.19E-06	kg	o-Xylene	ASAŞ
Toluene	4.19E-06	kg	Toluene	ASAŞ
Benzene, ethyl-	4.19E-06	kg	Benzene, ethyl-	ASAŞ
VOC, volatile organic compounds, unspecified origin	4.19E-06	kg	VOC, volatile organic compounds, unspecified origin	ASAŞ
Chromium	2.1E-08	kg	Chromium	ASAŞ
Copper	1.19E-06	kg	Copper	ASAŞ
Manganese	6.55E-07	kg	Manganese	ASAŞ
Arsenic	1.0E-08	kg	Arsenic	ASAŞ
Chrysene	1.17E-06	kg	Chrysene	ASAŞ
PAH, polycyclic aromatic hydrocarbons, carcinogenic	1.0E-06	kg	PAH, polycyclic aromatic hydrocarbons, carcinogenic	ASAŞ
1 kg Aluminium Titan Bor (AlTiB)				
Material/Process	Amount	Unit	Secondary Data/New Created Data	Source
Titanium, primary {GLO}| market for | Cut-off, S	0.050	kg	Titanium, primary {GLO}| market for | Cut-off, S	ASAŞ

Borax, anhydrous, powder {GLO}| market for | Cut-off, S	0.010	kg	Borax, anhydrous, powder {GLO}| market for | Cut-off, S	ASAŞ
Aluminium, primary, ingot {RoW}| market for | Cut-off, S	0.940	kg	Aluminium, primary, ingot {RoW}| market for | Cut-off, S	ASAŞ
1 kg Aluminium_Zirconium				
Material/Process	Amount	Unit	Secondary Data/New Created Data	Source
Zircon, 50% zirconium {GLO}| market for | Cut-off, S	0.100	kg	Zircon, 50% zirconium {GLO}| market for | Cut-off, S	ASAŞ
Aluminium, primary, ingot {RoW}| market for | Cut-off, S	0.900	kg	Aluminium, primary, ingot {RoW}| market for | Cut-off, S	ASAŞ

Table 25: Inventory Data Used in LCA Model of Cold Rolling

Inputs - Cold Rolling				
Material/Process	Amount	Unit	Secondary Data/New Created Data	Source
Casted Roll	1.02	kg	Cold Casting 1 kg	ASAŞ
Lubricant	0.002	kg	Chemical, organic {GLO}| market for | Cut-off, S	ASAŞ
Water, tap	2.18E-04	kg	Tap water {RER}| market group for | Cut-off, S	ASAŞ
Electricity	0.199	kWh	Electricity, high voltage {TR}| electricity production, hydro, run-of-river | Cut-off, S	ASAŞ
Outputs				
Material/Process	Amount	Unit	Secondary Data/New Created Data	Source
Cold Rolled Sheet	1.00	kg	Cold Rolled Sheet 1 kg	ASAŞ
Wastewater	8.0E-08	m3	Wastewater ASAS 1 m3	ASAŞ
m-Xylene	4.09E-07	kg	m-Xylene	ASAŞ
p-Xylene	4.09E-07	kg	p-Xylene	ASAŞ
Toluene	4.09E-07	kg	Toluene	ASAŞ
o-Xylene	4.09E-07	kg	o-Xylene	ASAŞ
Benzene, ethyl-	4.09E-07	kg	Benzene, ethyl-	ASAŞ
VOC, volatile organic compounds, unspecified origin	4.09E-07	kg	VOC, volatile organic compounds, unspecified origin	ASAŞ
VOC, volatile organic compounds, unspecified origin	8.19E-07	kg	VOC, volatile organic compounds, unspecified origin	ASAŞ

Benzene	4,09E-07	kg	Benzene	ASAŞ

Table 26: Inventory Data Used in LCA Model of Annealing

Inputs - Annealing				
Material/Process	Amount	Unit	Secondary Data/New Created Data	Source
Cold Rolled Sheet	1.00	kg	Cold Rolled Sheet 1 kg	ASAŞ
Water, tap	2.18E-04	kg	Tap water {RER}| market group for | Cut-off, S	ASAŞ
Electricity	0.033	kWh	Electricity, high voltage {TR}| electricity production, hydro, run-of-river | Cut-off, S	ASAŞ
Heat	0.827	MJ	Heat, district or industrial, natural gas {RoW}| heat production, natural gas, at industrial furnace >100kW | Cut-off, S	ASAŞ
Outputs				
Material/Process	Amount	Unit	Secondary Data/New Created Data	Source
Annealed Coil	1.00	kg	Annealed Coil 1kg	ASAŞ
Wastewater ASAS 1 m3	6.9E-08	m3	Wastewater ASAS 1 m3	ASAŞ
Particulates, unspecified	2.37E-05	kg	Particulates, unspecified	ASAŞ
Benzene	4.0E-07	kg	Benzene	ASAŞ
Benzene, ethyl-	4.0E-07	kg	Benzene, ethyl-	ASAŞ
m-Xylene	4.19E-07	kg	m-Xylene	ASAŞ
p-Xylene	4.19E-07	kg	p-Xylene	ASAŞ
o-Xylene	4.0E-07	kg	o-Xylene	ASAŞ
Toluene	4.0E-07	kg	Toluene	ASAŞ
VOC, volatile organic compounds, unspecified origin	4.0E-07	kg	VOC, volatile organic compounds, unspecified origin	ASAŞ
VOC, volatile organic compounds, unspecified origin	6.0E-07	kg	VOC, volatile organic compounds, unspecified origin	ASAŞ

Table 27: Inventory Data Used in LCA Model of Streching

Inputs - Streching				
Material/Process	**Amount**	**Unit**	**Secondary Data/New Created Data**	**Source**
Annealed Coil	1.10	kg	Annealed Coil 1kg	ASAŞ
Water, tap	0.004	kg	Tap water {RER}| market group for | Cut-off, S	ASAŞ
Heat	0.534	MJ	Heat, district or industrial, natural gas {RoW}| heat production, natural gas, at industrial furnace >100kW | Cut-off, S	ASAŞ
Electricity	0.071	kWh	Electricity, high voltage {TR}| electricity production, hydro, run-of-river | Cut-off, S	ASAŞ
Outputs				
Material/Process	**Amount**	**Unit**	**Secondary Data/New Created Data**	**Source**
Stretched Coil	1.00	kg	Stretched Coil 1 kg	ASAŞ
Wastewater ASAS 1 m3	1.29E-06	m3	Wastewater ASAS 1 m3	ASAŞ

Table 28: Inventory Data Used in LCA Model of Finished Coil

Inputs - Finished Coil				
Material/Process	**Amount**	**Unit**	**Secondary Data/New Created Data**	**Source**
Stretched Coil	1.05	kg	Stretched Coil 1 kg	ASAŞ
Coil Cutting Process	1.00	kg	Coil Cutting Process (Dyed or undyed)	ASAŞ
Outputs				
Material/Process	**Amount**	**Unit**	**Secondary Data/New Created Data**	**Source**
Finished Coil	1.00	kg	1 kg Coil Finished(kesilmis)	ASAŞ

Table 29: Inventory Data Used in LCA Model of Packaged Coil

Inputs - Packaged Coil				
Material/Process	Amount	Unit	Secondary Data/New Created Data	Source
Finished Coil	1.00	kg	1 kg Coil Finished	ASAŞ
Packaging Material, LDPE	0.004	kg	Packaging film, low density polyethylene {RER}| production | Cut-off, S	ASAŞ
Packaging Material, paper	0.003	kg	Kraft paper {RER}| market for kraft paper | Cut-off, S	ASAŞ
Packaging Material, wood	2.44E-05	m3	Sawnwood, board, softwood, raw, dried (u=20%) {Europe without Switzerland}| market for sawnwood, board, softwood, raw, dried (u=20%) | Cut-off, S	ASAŞ
Packaging Material, metal	0.004	kg	Steel, low-alloyed, hot rolled {GLO}| market for | Cut-off, S	ASAŞ
Outputs				
Material/Process	Amount	Unit	Secondary Data/New Created Data	Source
Packaged Coil	1.00	kg	1 kg Coil_Packaged	ASAŞ
Hazardous waste	0.001	kg	Hazardous waste, for underground deposit {RoW}| market for hazardous waste, for underground deposit | Cut-off, S	ASAŞ

Table 30: Inventory Data Used in LCA Model of Dyed Coil

Inputs - Dyed Coil				
Material/Process	Amount	Unit	Secondary Data/New Created Data	Source
Stretched Coil	1.04	kg	Stretched Coil 1 kg	ASAŞ
Color	0.088	kg	Chemical, organic {GLO}| production | Cut-off, S	ASAŞ
Thinner	0.004	kg	Thinner	ASAŞ
Water, softened	1.94	kg	Water, completely softened {RER}| water production, completely softened | Cut-off, S	ASAŞ
Water, tap	0.025	kg	Tap water {RER}| market group for | Cut-off, S	ASAŞ
Electricity	0.442	kWh	Electricity, high voltage {TR}| electricity production, hydro, run-of-river | Cut-off, S	ASAŞ
Heat	2.74	MJ	Heat, district or industrial, natural gas {RoW}| heat production, natural gas, at industrial furnace >100kW | Cut-off, S	ASAŞ
Outputs				
Material/Process	Amount	Unit	Secondary Data/New Created Data	Source

Dyed Coil	1.00	kg	Dyed Coil 1 kg	ASAŞ
Wastewater ASAS 1 m3	0.002	m3	Wastewater ASAS 1 m3	ASAŞ
Particulates, unspecified	1.34E-06	kg	Particulates, unspecified	ASAŞ
Benzene	2.70E-06	kg	Benzene	ASAŞ
Carbon monoxide	5.39E-06	kg	Carbon monoxide	ASAŞ
Benzene, ethyl-	2.70E-06	kg	Benzene, ethyl-	ASAŞ
m-Xylene	2.70E-06	kg	m-Xylene	ASAŞ
p-Xylene	2.70E-06	kg	p-Xylene	ASAŞ
Nitrogen monoxide, TR	0.001	kg	Nitrogen monoxide, TR	ASAŞ
Nitrogen dioxide, TR	0.011	kg	Nitrogen dioxide, TR	ASAŞ
o-Xylene	2.70E-06	kg	o-Xylene	ASAŞ
Sulfur dioxide, TR	1.53E-04	kg	Sulfur dioxide, TR	ASAŞ
Toluene	2.70E-06	kg	Toluene	ASAŞ
VOC, volatile organic compounds, unspecified origin	5.40E-06	kg	VOC, volatile organic compounds, unspecified origin	ASAŞ
VOC, volatile organic compounds, unspecified origin	2.70E-06	kg	VOC, volatile organic compounds, unspecified origin	ASAŞ
1 kg Thinner				
Material/Process	**Amount**	**Unit**	**Secondary Data/New Created Data**	**Source**
Chemical, organic {GLO}| market for | Cut-off, S	0.750	kg	Chemical, organic {GLO}| market for | Cut-off, S	ASAŞ
Benzyl alcohol {RoW}| production | Cut-off, S	0.250	kg	Benzyl alcohol {RoW}| production | Cut-off, S	ASAŞ

Table 31: Inventory Data Used in LCA Model of Finished Dyed Coil

Inputs - Finished Dyed Coil				
Material/Process	**Amount**	**Unit**	**Secondary Data/New Created Data**	**Source**
Dyed Coil	1.05	kg	Dyed Coil 1 kg	ASAŞ
Coil Cutting Process	1.00	kg	Coil Cutting Process (Dyed or undyed)	ASAŞ
Outputs				

Material/Process	Amount	Unit	Secondary Data/New Created Data	Source
Dyed Coil Finished	1.00	kg	1 kg Dyed Coil Finished	ASAŞ

Table 32: Inventory Data Used in LCA Model of Dyed Packaged Coil

Inputs - Dyed Packaged Coil				
Material/Process	Amount	Unit	Secondary Data/New Created Data	Source
Dyed Coil Finished	1.00	kg	1 kg Dyed Coil Finished	ASAŞ
Packaging Material, LDPE	0.004	kg	Packaging film, low density polyethylene {RER}| production | Cut-off, S	ASAŞ
Packaging Material, paper	0.003	kg	Kraft paper {RER}| market for kraft paper | Cut-off, S	ASAŞ
Packaging Material, wood	1.95E-05	m3	Sawnwood, board, softwood, raw, dried (u=20%) {Europe without Switzerland}| market for sawnwood, board, softwood, raw, dried (u=20%) | Cut-off, S	ASAŞ
Packaging Material, metal	0.003	kg	Steel, low-alloyed, hot rolled {GLO}| market for | Cut-off, S	ASAŞ
Outputs				
Material/Process	Amount	Unit	Secondary Data/New Created Data	Source
Dyed Packaged Coil	1	kg	1 kg Dyed Coil - Packaged	ASAŞ
Hazardous waste	0.002	kg	Hazardous waste, for underground deposit {RoW}| market for hazardous waste, for underground deposit | Cut-off, S	ASAŞ

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