Aluminium Carbon Footprint Methodology

Good Practice for Calculation of Primary Aluminium and Precursor Product Carbon Footprints

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This guidance is prepared by International Aluminium Institute on behalf of its member companies.

Contents

1 Introduction

This guidance addresses the life cycle environmental impact category "climate change". It specifies the principles, requirements and methodologies for quantifying and communicating greenhouse gas (GHG) emissions from primary aluminium production processes and the associated cradle-to-gate partial[1] carbon footprints of their products and pre-cursors (e.g. bauxite, alumina).

This guidance is aligned with international (ISO) standards for environmental management and greenhouse gas emissions calculation and the communication of carbon footprint information, but represents a specified approach to the aluminium sector and its products. Employment of this best practice guidance enables bauxite and/or other ores, alumina and aluminium producers (their customers and other stakeholders) to calculate and communicate harmonized and comparable carbon footprints of a product or set of products.

While there is significant cross-over with corporate accounting principles (greenhouse gas inventories of an entity, company or set of companies) – including default data, calculation methodologies and relevant processes – the scope of emissions accounting can differ between CORPORATE and PRODUCT carbon footprint metrics (even within given companies). This guidance is applicable to the development of product carbon footprints – for guidance on corporate accounting, alternative sources should be used.

2 Normative references

ISO 14044:2006/Amd 2:2020, Environmental management — Life cycle assessment — Requirements and guidelines — Amendment 2 (https://www.iso.org/standard/76122.html)

ISO 14064-1:2018, Greenhouse gases — Part 1: Specification with guidance at the organization level for quantification and reporting of greenhouse gas emissions and removals (https://www.iso.org/standard/66453.html)

[1] According to ISO 14067, the term "product carbon footprint" refers to the full life cycle of the product, including production, use and end-of-life.

ISO/DIS 19694-4, Stationary source emissions — Determination of greenhouse gas (GHG) emissions in energy-intensive industries — Part 4: Aluminium industry (https://www.iso.org/standard/73182.html)

ISO 14067:2018, Greenhouse gases — Carbon footprint of products — Requirements and guidelines for quantification (https://www.iso.org/standard/71206.html)

ISO 14026 :2017 Environmental labels and declarations — Principles, requirements and guidelines for communication of footprint information (https://www.iso.org/standard/67401.html)

2019 IPCC Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 3: Industrial Processes and Product Use, Chapter 4: Metal Industry Emissions, Section 4.4 Primary Aluminium Production(https://www.ipccnggip.iges.or.jp/public/2019rf/pdf/3_Volume3/19R_V3_Ch04_Metal_Industry.pdf)

Greenhouse Gas Protocol Product Life Cycle Accounting and Reporting Standard (2011) (https://ghgprotocol.org/product-standard)

Greenhouse Gas Protocol Corporate Value Chain (Scope 3) Accounting and Reporting Standard (2011) (http://www.ghgprotocol.org/standards/scope-3-standard)

Greenhouse Gas Protocol Technical Guidance for Calculation Scope 3 Emissions (2013) (http://ghgprotocol.org/feature/scope-3-calculation-guidance)

Greenhouse Gas Protocol Calculation tools:

The Aluminium Sector Greenhouse Gas Protocol (2006)

- Guidance: www.ghgprotocol.org/sites/default/files/ghgp/aluminium_1.pdf
- Worksheet: http://www.ghgprotocol.org/sites/default/files/ghgp/Aluminium%20Sector%20GHG%20Workbook%20-%20version%202_1_0.xls

Allocation of GHG Emissions from a Combined Heat and Power (CHP) Plant (2006)

- Guidance: https://ghgprotocol.org/sites/default/files/CHP_guidance_v1.0.pdf
- Worksheet: https://ghgprotocol.org/sites/default/files/CHP_tool_v1.0.xls

GHG Emissions from Stationary Combustion (2005)

- Guidance: http://www.ghgprotocol.org/sites/default/files/ghgp/Stationary_Combustion_Guidance_final_1.pdf
- Worksheet: http://www.ghgprotocol.org/sites/default/files/ghgp/Stationary_combustion_tool_%28Version4-1%29.xlsx

GHG Emissions from Purchased Electricity (2015)

- Worksheet: http://www.ghgprotocol.org/sites/default/files/ghgp/Purchased_Electricity_Tool_Version-4_8_0.xlsx

GHG Emissions from Transport or Mobile Sources (2015)

- Worksheet: http://ghgprotocol.org/sites/default/files/ghgp/Transport_Tool_v2_6.xlsx

J. Atherton. Declaration by the Metals Industry on Recycling Principles. The International Journal of Life Cycle Assessment volume 12, page 59–60 (2007). (http://dx.doi.org/10.1065/lca2006.11.283)

3 Terms and definitions

Aluminium related terms and definitions follow "ISO/DIS 19694-4, Stationary source emissions — Determination of greenhouse gas (GHG) emissions in energy-intensive industries — Part 4: Aluminium industry (3. Terms & Definitions)", while primary aluminium unit processes follow "International Aluminium Institute (2018) Life Cycle Inventory Data and Environmental Metrics for the Primary Aluminium Industry".

4 Goal and scope

4.1 General

The climate change impact of a product, expressed as carbon dioxide equivalents (CO_2e), is the summation of all GHG emissions and removals[2] over the partial (cradle-to-gate) life cycle of the product (or process). This guidance does not address avoided emissions or actions taken to mitigate released emissions. This guidance is also not

[2] Removals from the atmosphere typically occur when CO_2 is absorbed by biogenic sources (i.e. plants) and converted to energy during photosynthesis. However, removals may also occur when a product absorbs atmospheric CO_2 during use, or when CO_2 from the atmosphere is used during a processing step.

designed to be used for quantifying GHG reductions from offsets or claims of carbon neutrality.

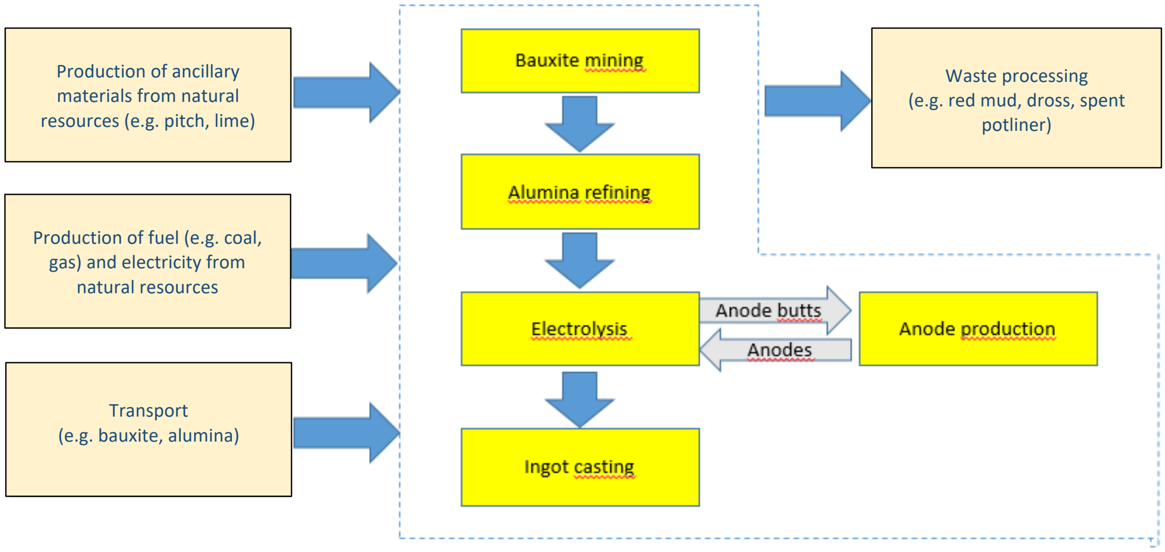
4.2 Product category

The goal of this guidance is to provide practitioners with a standardised approach to the calculation of climate change impact of a given mass of primary aluminium and precursor products, including:

- dry bauxite and/or other ores
- aluminium hydroxide ($Al(OH)_3$, commonly known as "hydrate")
- aluminium oxide (Al_2O_3, commonly known as "alumina")
- primary aluminium tapped from electrolytic cells or pots during the electrolytic reduction of metallurgical alumina, excluding alloying additives and recycled aluminium.
- alloyed and unalloyed primary[3] aluminium in different forms produced in the cast-house of aluminium smelters from liquid primary aluminium

4.3 System boundary

The system boundary can be illustrated by the following flow-chart. The yellow boxes refer to the core processes which are under the responsibility of the aluminium industry.



[3] According to Global Advisory Group (GAG) Guidance Document 001, unalloyed aluminium is defined as aluminium without alloying elements where the minimum aluminium content is specified to be greater than 99,00%.

For primary aluminium this includes the unit processes bauxite and/or other ores mining, alumina production (hydrate production & calcination), anode production, electrolysis, ingot casting, raw materials transport, electricity generation, and waste processing. It also includes the production of ancillary materials and fuels required for primary aluminium production.

It does not include the stages of “production of semi-finished products from raw material”, “use” and “end-of-life”.

5 Greenhouse gas emission sources

The predominant greenhouse gas emitted from primary aluminium production processes is carbon dioxide (CO_2), although other, high global warming potential (GWP) gases are also – or have the potential to be – released. These emissions can be categorised as follows.

Broadly equivalent corporate accounting scope is included for information, but it should be noted that product (portfolio) carbon footprints do not necessarily align exactly with corporate scopes, given they may represent a subset of a corporation’s inventory or a combination of multiple corporate inventories. A cradle-to-gate carbon footprint should include all emissions sources (A-H) for a given product or set of products.

Table 1. Greenhouse gas emission sources for aluminium industry

	Emission source	**Predominant GHGs**	**Broadly equivalent corporate accounting “scope”**
A	Direct emissions from fuel combustion in production, waste* and emissions management & ancillary processes	CO_2, CH_4, N_2O	1
B	Direct production process emissions	CO_2 CF_4 & C_2F_6 (electrolysis only)	1
C	Ancillary process emissions	CO_2, SF_6	1 (where entity-controlled) or 3 (category 1) (where purchased)

D	Indirect emissions from the consumption of purchased electricity, heat and steam in production, waste and emissions management & ancillary processes	CO_2, CH_4, N_2O	2
E	Emissions from electricity generation and distribution to power-consuming processes (production, waste and emissions management & ancillary)	CO_2, CH_4, N_2O	1 (where entity-controlled) or 2 (where purchased)
F	Emissions (cradle-to-gate) from (purchased) material inputs	CO_2, CH_4, N_2O, SF_6 CF_4 & C_2F_6 (where primary aluminium purchased)	1 (where entity-controlled) or 3 (category 1) (where purchased)
G	Indirect (cradle-to-gate) emissions from the production of fuels (and other related activities) combusted directly (A) or indirectly (B/E)	CO_2, CH_4, N_2O	1 (where entity controls upstream processes) and/or 3 (category 3) (where purchased)
H	Other indirect (cradle-to-gate) emissions from purchased services, upstream third-party transportation and distribution and third-party waste treatment	CO_2, CH_4, N_2O	3 (categories 1, 4 and 5)

* including wastewater

6 Life cycle impact assessment

This carbon footprint study uses only one impact category: climate change. The different substances which have been considered as GHG emissions and the selected characterization factors shall be reported.

6.1 Climate change impact category characterisation factor

The Intergovernmental Panel on Climate Change (IPCC) published value of a 100-year global warming potential (GWP) for different greenhouse gases (see Annex A). GWP used in the national inventory reporting, is recommended to be used to convert life cycle inventory results to an indicator of climate change impact (CO_2e). At time of writing, GWPs published in the IPCC Fourth Assessment Report (IPCC, 2007) are adopted by International Aluminium Institute.

The potential climate change impact of each GHG emitted and removed by the system under study shall be calculated by multiplying the mass of GHG released or removed by the 100-year GWP given by the IPCC in units of kg CO_2e per kg emission. The (partial) carbon footprint of the system under study is the sum of these calculated impacts.

When comparing impacts across time, the characterisation factors applied to emissions inventories should be the same for all periods under study.

6.2 Applicable time series

Carbon footprints should be updated whenever a significant change occurs in the emissions intensity of the product(s) under study [(+/- 10%)], or every 5 years, whichever is shorter.

The following situations, as stipulated in the GHG Protocol, shall trigger a significant change:

1. Structural changes in operation, including significant process change in operation, technology advancement, raw material or energy changes.
2. Changes in calculation methodology or improvements in the accuracy of emission factors or activity data or inclusion of new types of sources that result in a significant impact on the emissions data.
3. Discovery of significant errors, or a number of cumulative errors that are collectively significant.

Frequency of inventory data collection should be informed by the frequency of significant change in emissions intensity of the process(es) under study. These may be different for different emission sources.

All inventory data shall refer to a one-year period, prior to application of the characterisation factor (GWP).

6.3 Emissions inventory calculations: Direct emissions from process

Guidance for direct emissions calculation for significant aluminium production processes[4] are included below. Emissions from fuel combustion, waste (including

[4] LIFE CYCLE INVENTORY DATA AND ENVIRONMENTAL METRICS FOR THE PRIMARY ALUMINIUM INDUSTRY Appendix B: https://www.world-aluminium.org/media/filer_public/2017/07/04/appendix_b_c_d_FWVbEo2.pdf

wastewater) treatment and disposal, emission control and ancillary processes should be included in the inventory.

Across all processes, fuel combustion in stationary or mobile equipment (such as haul trucks, molten metal transfer crucibles or support vehicles) should be calculated following the GHG Protocol calculation tools “GHG Emissions from Stationary Combustion (2005)” and “GHG Emissions from Transport or Mobile Sources (2015)”.

6.3.1 Bauxite and/or other ores mining

Mining direct emissions are evolved in the combustion of fossil fuels for stationary and mobile equipment, with calculation following the GHG Protocol calculation tools “GHG Emissions from Stationary Combustion (2005)” and “GHG Emissions from Transport or Mobile Sources (2015)”.

6.3.2 Alumina production

Alumina production can be further categorised as 2 sub-unit processes by product:

1. aluminium hydroxide production from bauxite and/or other ores[5]
2. calcination of aluminium hydroxide to produce aluminium oxide

The majority of direct emissions from both processes is from the combustion of fossil fuels for heat and steam, with calculation following the GHG Protocol calculation tool “GHG Emissions from Stationary Combustion (2005)”.

a) Stationary combustion to sustain the requested condition in a digester
b) Stationary combustion in kilns for the production of calcined alumina (calciners);
c) Stationary combustion in kilns/ovens for the production of dried speciality alumina (dryers);
d) Stationary combustion in auxiliary, emergency or pollution control equipment (boilers, heaters, diesel generators, incinerators, thermal oxidizers, thermal engines).

Also,

e) Mobile combustion in transportation equipment (ships, trucks, trains, cars, conveyors) for raw material, products, wastes residues and employees, with calculation following

[5] The Bayer Process is the most economic means of obtaining alumina from bauxite. Other processes for obtaining alumina from metal ores are also in use in some refineries, although these make up a relatively small percentage of global production: “2019 IPCC Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 3: Industrial Processes and Product Use, Chapter 4: Metal Industry Emissions, Section 4.4.5.methodological issues for alumina production”.

the GHG Protocol calculation tools “GHG Emissions from Stationary Combustion (2005)” and “GHG Emissions from Transport or Mobile Sources (2015)”.

Other possible direct process emissions, such as flue gas desulphurization, acid cleaning of process equipment, organic carbon in bauxite and/or in other ores, liquor burning, are not a main source of GHG emissions (<1%), therefore, currently considered to be negligible by following “2019 IPCC Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 3: Industrial Processes and Product Use, Chapter 4: Metal Industry Emissions, Section 4.4 Primary Aluminium”.

6.3.3 Anode production

Direct emissions from operation of an anode or paste production facility and/or anode baking plant.

6.3.3.1 Paste production / Green anode production

Most direct emissions are from the combustion of fossil fuels for heat and steam, with calculation following the GHG Protocol calculation tool “GHG Emissions from Stationary Combustion (2005)”.

Where coke calcination is present as an ancillary process, direct emissions calculation should follow the “Aluminium Sector Greenhouse Gas Protocol (2006) - 1.6.1 Coke Calcination”.

6.3.3.2 Anode baking

Direct emissions are from three sources: bake furnace fuel combustion, combustion of volatiles evolved from the anode during baking and combustion of baking furnace packing material.

The first of these should be calculated following the GHG Protocol calculation tool “GHG Emissions from Stationary Combustion (2005)”.

For the others, calculation follows “The Aluminium Sector Greenhouse Gas Protocol (2006) 1.3.2 Baking furnace carbon dioxide emissions”

6.3.4 Electrolysis

Calculation of emissions from the electrolysis process is according to the following sections of “The Aluminium Sector Greenhouse Gas Protocol (2006)”:

1.3 calculation of carbon dioxide emissions from prebake processes

1.4 calculation of carbon dioxide emissions from Søderberg processes

Calculation of perfluorocarbon emissions follows, instead, International Aluminium Institute (2020) Good Practice Guidance: Measuring Perfluorocarbon, being consistent with the 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, which covers both high voltage (HV) and low voltage (LV) PFC emissions.

6.3.5 Gas treatment centres

Direct CO_2 emissions may be evolved where sodium carbonate (soda ash) is used as a reagent in SO_2 scrubbing facilities. Calculation follows “The Aluminium Sector Greenhouse Gas Protocol (2006) 1.6.2 Soda Ash Use”

6.3.6 Aluminium casting

Calculation of CO_2e emissions from fuels used in the cast-house follows the calculation tool “GHG Emissions from Stationary Combustion (2005)”.

6.4 Emissions inventory calculations: Emissions from the production of energy, consumed by unit processes

Emissions related to the production of fuels and electricity and consumed in unit processes, including production, waste/wastewater treatment and disposal, emission control and ancillary processes, should be included in the inventory.

Table 2. Activities included in Emissions from the production of energy

Activity	Description	Broadly equivalent corporate accounting “scope”
A. Upstream emissions of fuels	Extraction, production, and transportation of fuels consumed by the reporting product	3 (category 3)

B. Upstream emissions of electricity, steam and heat	For both conventional and renewable energy: • Raw Materials Extraction • Construction Materials Manufacture • Power Plant Construction	3 (category 3)
C. Generation of electricity, steam and heat	the emissions from the combustion of fuels to generate electricity, steam, heating, and cooling that is consumed by the reporting product; also emissions from operations and maintenance at the power plant	1 or 2
D. Transmission and distribution (T&D) losses	Generated (upstream activities and combustion) electricity, steam, heating, and cooling that is consumed (i.e., lost) in a T&D system – reported by end user	3 (category 3)

Calculation of emissions from the activities A/B/D follows [Category 3: Fuel- and Energy-Related Activities Not Included in Scope 1 or Scope 2] in "Greenhouse Gas Protocol Technical Guidance for Calculation Scope 3 Emissions (2013)"

Calculation of emissions from the activity B is based on the emission factor methodology, which estimates CO_2 emissions by multiplying a level of activity data (e.g. MWh of electricity consumed) by a combustion emission factor (e.g. kilograms of CO_2 per MWh).

Activity data x Combustion Emission Factor = CO_2 emissions

The activity data that should be collected is the quantity of consumed energy. Emissions factors may vary with season, time of the day and supplier. For practical reasons, this guidance recommends the use of average rates over a full year and over a relevant selection of sources. If the life cycle emission factor is known to the consumed electricity,

life cycle emission factor = upstream emission factor + combustion emissions factor +T&D losses

Combined Emissions from Activities B,C,D can be simply calculated as:

Activity data x Life Cycle Emission Factor = CO_2 emissions

6.4.1 Selection of Emission Factors

Several options for selecting emission factors are provided below in order of preference. It is important to express emission factors in the same measurement units as the activity data. It is also important to document and justify the choice of emission factors used in the inventory. Contractual purchase agreements are the best piece of justification.

a) Site-specific emission factors provided by the supplier. In this case, the emission factors should be based on the actual fuel fired and/or the technology employed by the supplier and provided to the customer on a frequent basis.
b) Site-specific estimate custom emission factors. If the supplier is not able or willing to provide emission factors of dedicated production units, then a method based on the assumed fuel fired and derived from the efficiency method for can be used to estimate custom emission factors. It is described here after in paragraph 6.4.2.
c) Regional emission factors. If site-specific emission factors are not available or appropriate (no dedicated source), generic regional or power pool emissions factors that have been publicly published can be used.
d) National average emission factors. If regional or power pool emission factors are not available, an appropriate generic national average factor for the entire country's grid can be used. If the type of fuel fired by the supplier is known, International Energy Agency (IEA) and UN Environment Programme (UNEP) provide emission factors for different fuels.

6.4.2 Custom emission factors estimate

6.4.2.1 Energy supply from conventional boilers

It is only necessary to know the type of fuel combusted and to determine the assumed thermal efficiency of the energy production unit. The CO_2 emission factor of the supplied energy is calculated from the CO_2 emission factor of the combusted fuel, both related to the same energy unit (eg.MWh), by dividing the latter by the actual or assumed thermal efficiency:

Equation Estimating CO_2 emission factor for energy from conventional boilers

$$EF_H = F_{c,h} \cdot F_{ox} \cdot (44/12) / e_H$$

Where:

EF_H = CO_2 emission factor of supplied energy in kg CO2 per energy unit (e.g. MWh)
$F_{c,h}$ = Carbon content of fuel on a heating value basis in kg C per energy unit (e.g. MWh)
F_{ox} = Oxidation factor to account for fraction of carbon in fuel that remains as soot or ash
(44/12) = The ratio of the molecular weight of CO_2 to that of carbon
e_H = assumed efficiency of energy production (fraction)

Care should be taken to ensure consistency between the thermal efficiency value and the basis of underlying fuel heating value (GCV or NCV).

6.4.2.2 Energy supply from CHP units

For CHP units, the estimation method is based on the "efficiency method" described in section 7.2.2. However, in the case of CHP units out of control of the reporting company, some data such as actual fuel fired may not be available and a surrogate method is then needed.

To apply the surrogate efficiency method, it is only necessary to know the type of fuel combusted, the energy balance of the unit in standard operating conditions (fuel input, steam output, electricity output, all expressed in the same energy or power unit, e.g. MW) and assumed thermal efficiencies of reference units producing steam and electricity separately.

The following equations can be applied to calculate two conventional factors which have the dimension of energy efficiencies and can then be used to estimate the CO_2 emission factors of supplied steam and electricity from the CO_2 emission factor of the type of fuel combusted, exactly as in the previous paragraph, with E_H or E_P replacing e_H.

Equation Determining efficiency factors for steam and electricity purchased from a CHP unit

$E_H = (e_H / A_f) \, . \, (H / e_H + P / e_P)$

$E_P = (e_P / A_f) \, . \, (H / e_H + P / e_P)$

Where

E_H = Conventional efficiency factor for steam produced from the CHP unit

E_P = Conventional efficiency factor for electricity produced from the CHP unit

e_H = Assumed efficiency of steam production from a conventional unit (fraction)

e_P = Assumed efficiency of electricity production from a conventional unit (fraction)

H = Standard steam output of the CHP plant in energy or power unit (e.g. MW)

P = Standard electricity output of the CHP plant in energy or power unit (e.g. MW)

A_f = Standard fuel energy input of the CHP plant in energy or power unit (e.g. MW)

Care should be taken to ensure consistency between the assumed efficiency values and the basis of underlying fuel heating value (GCV or NCV).

E_H and E_P are purely conventional values. They may be higher than 100% for steam since they reflect the far better global efficiency of CHP compared with traditional power plants and the low efficiency of electricity production compared with steam production.

6.4.3 Purchased energy

The operator shall obtain the relevant emission factor for purchased electricity and heat from the supplier based on section 6.4 considerations. If the operator has a contract with a supplier with a defined energy generation facility, the emissions factor for the contractual amount of energy from the specific generation facility, and the energy mix and emissions factor for the residual purchased power shall be calculated separately, with a principle of transparency and avoidance of double counting. If relevant data are not available from the supplier, the operator shall select emission factors by following 6.4.1.

A record shall be maintained of the reference factors and their source in the supporting evidence. If contract used for physical supply of power from a particular power generation plant via grid, the renewable energy certificates/guarantees of origin can be used to confirm the origin of received power.

6.4.4 Self-generated energy

Consumers of energy which are also generators of such energy carriers, shall possess the relevant emission factor for self-generated energy considering upstream emissions of fuel production as described in 6.4.

The operator should allocate to the product emissions inventory the consuming aluminium (or precursor) process(es), including ancillary processes, share of total energy transformation emissions, calculated according to the calculation tool “GHG Emissions from Stationary Combustion (2005)”.

6.5 Emissions inventory calculations: Other emissions

All GHG emissions over the partial (cradle-to-gate) life cycle of the product (or process), excluding those aforementioned in section 6.3 and 6.4, are under this category.

The Greenhouse Gas Protocol Corporate Value Chain (Scope 3) Accounting and Reporting Standard (2013) offers an internationally accepted method to enable GHG management of companies' value chains. The 8 categories of emissions from upstream activities are the most relevant to the emissions under this category.

The "Greenhouse Gas Protocol Technical Guidance for Calculation Scope 3 Emissions (2013)" serves as a companion to the aforementioned GHG Protocol Scope 3 Standard to offer companies practical guidance on calculating their scope 3 emissions. It provides information not contained in the Scope 3 Standard, such as methods for calculating GHG emissions for each category, data sources, and worked examples.

7 Modelling parameters and assumptions, allocation issues

7.1 General

Inputs and outputs shall be allocated to different products according to a clearly stated and justified allocation procedure.

The sum of allocated inputs and outputs of a unit process shall be equal to the inputs and outputs of the unit process before allocation.

Whenever several alternative allocation procedures seem applicable, a sensitivity analysis shall be conducted to illustrate the consequences of the departure from the selected approach.

7.2 Allocation procedure

7.2.1 Alumina production

An allocation issue occurs for alumina refineries which sell both calcined metallurgical alumina to aluminium smelters and non-calcined hydrate, as co-products, to other users. It is proposed to solve this allocation issue as follows:

1. The refinery shall report the mass P_1 of calcined metallurgical alumina produced in a given time period and the mass P_2 of non-calcined hydrate over the same period as separate figures

2. The refinery shall report the GHG emissions E_c of the calcination and the GHG emissions E_r of all the other operations in the refinery as separate figures
3. The mass $P_{1.0}$ of metallurgical alumina before calcination shall be determined by using the relevant stoichiometric formulas
4. Allocation by mass is applied to the GHG emissions E_r of all the other operations in the refinery according to the ratio of the mass $P_{1.0}$ of metallurgical alumina before calcination and the mass P_2 of the annually produced non-calcined hydrate.

7.2.2 Allocation of CO_2 emissions from a CHP (co-generation) plant

When a CHP plant (or cogeneration unit) is owned by the reporting company and operated in an alumina refinery site, the most likely situation is that a significant fraction of the produced electricity output is sold to other users or power companies (steam in excess may also be sold, e.g. for district heating). In this case, the sold energy should be deducted from the internal energy consumption and corresponding CO_2 emissions should be reported separately. This is done by determining emission factors for the electricity and steam outputs and multiplying those emission factors by the energy outputs sold.

The most common method to allocate emissions from a CHP plant is the efficiency method whereby CO_2 emissions are allocated based on the fuel energy inputs needed to produce the separate steam and electricity products from the same type of fuel. The efficiency method is the preferred method of this guidance document. It assumes that converting fuel energy to steam energy is more efficient than converting fuel to electricity, which optimizes the CO_2 emissions savings for the steam consumers, i.e. the alumina refineries. Actual efficiencies of steam and electricity production will not be precisely characterized, necessitating the use of assumed values. If national fuel or emissions allocation procedure applies, the allocation shall be in accordance with the national procedure.

The efficiency method is referred from 'Allocation of GHG Emissions from a Combined Heat and Power (CHP) Plant '.

7.2.3 Primary cast-house products

7.2.3.1 Allocation of cast-house emissions to unalloyed primary aluminium from liquid metal

The following example shows how the partial carbon footprint of a DC-cast unalloyed primary aluminium ingot from liquid metal is calculated if the plant uses liquid aluminium and purchased scrap. For alloyed ingots, the carbon footprint of the relevant alloying elements must be added.

Typically, the cast-house of a smelter transforms liquid primary aluminium from the pot-room and run-around scrap from the sawing of ingots into the different forms of primary aluminium ingots. In this case, the primary aluminium ingot carries all the GHG emissions of the cast-house. Here liquid metal of about 900˚C is filled into the holding furnace and the run-around scrap is used to cool down the melt to the casting temperature of 700˚C Therefore, run-around scrap does not need additional fuel for remelting.

If the cast-house of a smelter remelts additional quantities of purchased solid metal, as described additional fuel is needed to melt this solid metal. All the other processes, e.g. casting, ingot handling, ingot sawing and infrastructure will be identical and have the same GHG emissions per tonne.

GHG emissions tied to the remelting of the scrap (excluding internal scrap) can be obtained by determining the fuel demand and the resulting GHG emissions related to the remelting of a furnace batch consisting of 100% scrap metal. If such data are not available, default data from European Aluminium and Aluminum Association should be used. The same method should be applied for alloying elements and remelt ingots.

In order to obtain the GHG emissions of unalloyed primary aluminium from liquid metal, excluding purchased solid metal, the total GHG emissions tied to all cast-house operations has to be reduced by the emissions tied to the remelting of the purchased solid metal.

7.2.3.2 Transparency requirement if input material includes scrap

As a complement to the carbon footprint of the cast-house product, operators should communicate:

- the method used for their CF calculation
- the targeted product
- The aluminium sourcing for this product:
  - share of primary aluminium (%)
  - share of pre-consumer scrap (%)
  - share of post-consumer scrap (%)
  - share of unknown scrap (%)

It is advised to use professional Life Cycle Analysis software as well as expert advice to develop appropriate and consistent models and for detailed documentation, explanation, and reporting of all processes.

7.2.3.3 Full carbon footprint (CFP) study

The reporter of the cradle-to-gate partial carbon footprint should advise the customer to add the partial carbon footprint of this information module to the carbon footprint of the remaining information modules, i.e. fabrication, use and end-of-life recycling, to obtain the carbon footprint of the product system under study.

8 Communication of carbon footprint result

8.1 General

Guidance on how to communicate carbon footprint of products is given in ISO 14026. Chapter 11 of the “Greenhouse Gas Protocol Product Life Cycle Accounting and Reporting Standard (2011)” also provide general communication guidelines.

In general, the carbon footprint is communicated cradle-to-gate by the producer of the product. According to ISO 14067 cradle-to-gate carbon footprints cannot be considered as product carbon footprints (CFPs), because CFPs include the whole life cycle of the product.

8.2 Data Quality

Primary data are defined as quantified values of a process or an activity obtained from a direct measurement or a calculation based on direct measurements. Data from databases or other sources which fulfil the criteria of primary data are also primary data. Secondary data are defined as data from sources other than primary data.

Table 3 summarises the components, as well as required data quality when calculating a carbon footprint by following the approach articulated in this guidance.

Table 3. Required quality data

Category	Required Data	Note
4.3.1 Direct emissions	Primary	a) Unit processes to be included in calculation are listed in Annex B; b) Data sources must be specified at communication.
4.3.2 Emissions from energy production	Primary or secondary	
4.3.3 Other emissions	Primary or secondary	

Preference should be given to site-specific data from suppliers. If such data are not available, regional averages from the IAI's latest life cycle inventory dataset should be used.

8.3 Additional information

At the communication stage, along with the carbon footprint result, the following information should be provided:

1) Specified product to which the calculated cradle-to-gate carbon footprint relates and declared unit, e.g. 1 tonne
2) The percentage of climate change impact that is derived from secondary data, if any
3) Source of global warming potential (GWP) values used
4) If input materials include scrap, elements contained in section 7.2.3.2 are recommended to be disclosed

The product in question covered by this guidance is listed under section 4.2. A schematic of included GHG emissions by product category is included as Annex C.

9 Bibliography

International Aluminium Institute (2018) Life Cycle Inventory Data and Environmental Metrics for the Primary Aluminium Industry (https://www.world-aluminium.org/media/filer_public/2018/02/19/lca_report_2015_final_26_june_2017.pdf)

International Aluminium Institute (2020) Good Practice Guidance: Measuring Perfluorocarbons (https://www.world-aluminium.org/media/filer_public/2020/12/23/iai_good_practice_guidance_measuring_perfluorocarbons_2020.pdf)

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Annex A: Global warming potential values

The following table includes the 100-year time horizon global warming potentials (GWP) relative to CO_2. This table is adapted from the IPCC Fifth Assessment Report, 2014 (AR5)[i]. The AR5 values are the most recent, but the second assessment report (1995) and fourth assessment report (2007) values are also listed because they are sometimes used for inventory and reporting purposes. For more information, please see the IPCC website (www.ipcc.ch). The use of the latest (AR5) values is recommended. Please note that the GWP values provided here from the AR5 for non-CO_2 gases do not include climate-carbon feedbacks.

Global warming potential (GWP) values relative to CO_2

Industrial designation or common name	Chemical formula	GWP values for 100-year time horizon		
		Second Assessment Report (SAR)	Fourth Assessment Report (AR4)	Fifth Assessment Report (AR5)
Carbon dioxide	CO_2	1	1	1
Methane	CH_4	21	25	28
Nitrous oxide	N_2O	310	298	265
Substances controlled by the Montreal Protocol				
CFC-11	CCl_3F	3,800	4,750	4,660
CFC-12	CCl_2F_2	8,100	10,900	10,200
CFC-13	$CClF_3$		14,400	13,900
CFC-113	CCl_2FCClF_2	4,800	6,130	5,820
CFC-114	$CClF_2CClF_2$		10,000	8,590
CFC-115	$CClF_2CF_3$		7,370	7,670
Halon-1301	$CBrF_3$	5,400	7,140	6,290
Halon-1211	$CBrClF_2$		1,890	1,750
Halon-2402	$CBrF_2CBrF_2$		1,640	1,470
Carbon tetrachloride	CCl_4	1,400	1,400	1,730
Methyl bromide	CH_3Br		5	2
Methyl chloroform	CH_3CCl_3	100	146	160

Industrial designation or common name	Chemical formula	GWP values for 100-year time horizon		
		Second assessment report (SAR)	Fourth Assessment Report (AR4)	Fifth Assessment Report (AR5)
HCFC-21	$CHCl_2F$			148
HCFC-22	$CHCLF_2$	1,500	1,810	1,760
HCFC-123	$CHCl_2CF_3$	90	77	79
HCFC-124	$CHClFCF_3$	470	609	527
HCFC-141b	CH_3CCl_2F	600	725	782
HCFC-142b	CH_3CClF_2	1,800	2,310	1,980
HCFC-225ca	$CHCl_2CF_2CF_3$		122	127
HCFC-225cb	$CHClFCF_2CClF_2$		595	525
Hydrofluorocarbons (HFCs)				
HFC-23	CHF_3	11,700	14,800	12,400
HFC-32	CH_2F_2	650	675	677
HFC-41	CH_3F_2	150		116
HFC-125	CHF_2CF_3	2,800	3,500	3,170
HFC-134	CHF_2CHF_2	1000		1,120
HFC-134a	CH_2FCF_3	1,300	1,430	1,300
HFC-143	CH_2FCHF_2	300		328
HFC-143a	CH_3CF_3	3,800	4,470	4,800
HFC-152	CH_2FCH_2F			16
HFC-152a	CH_3CHF_2	140	124	138
HFC-161	CH_3CH_2F			4
HFC-227ea	CF_3CHFCF_3	2,900	3,220	3,350
HFC-236cb	$CH_2FCF_2CF_3$			1,210
HFC-236ea	CHF_2CHFCF_3			1,330
HFC-236fa	$CF_3CH_2CF_3$	6,300	9,810	8,060
HFC-245ca	$CH_2FCF_2CHF_2$	560		716
HFC-245fa	CHF2CH2CF3		1,030	858
HFC-365mfc	CH3CF2CH2CF3		794	804
HFC-43-10mee	CF3CHFCHFCF2CF3	1,300	1,640	1,650

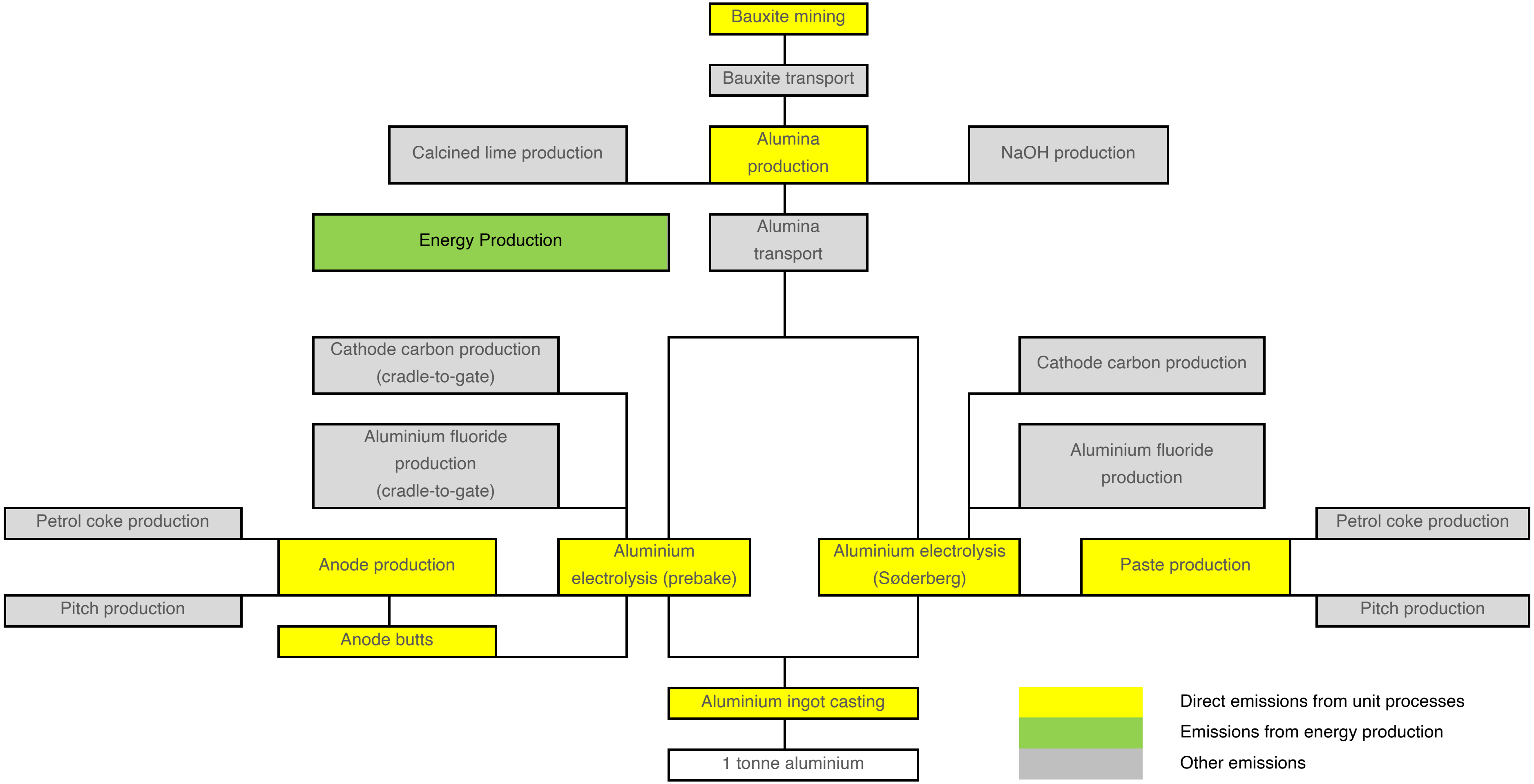
Industrial designation or common name	Chemical formula	GWP values for 100-year time horizon		
		Second assessment report (SAR)	Fourth Assessment Report (AR4)	Fifth Assessment Report (AR5)
Perfluorinated compounds				
Sulfur hexafluoride	SF_6	23,900	22,800	23,500
Nitrogen trifluoride	NF_3		17,200	16,100
PFC-14	CF_4	6,500	7,390	6,630
PFC-116	C_2F_6	9,200	12,200	11,100
PFC-218	C_3F_8	7,000	8,830	8,900
PFC-318	$c-C_4F_8$	8,700	10,300	9,540
PFC-31-10	C_4F_{10}	7,000	8,860	9,200
PFC-41-12	C_5F_{12}	7,500	9,160	8,550
PFC-51-14	C_6F_{14}	7,400	9,300	7,910
PCF-91-18	$C_{10}F_{18}$		>7,500	7,190
Trifluoromethyl sulfur pentafluoride	SF_5CF_3		17,700	17,400
Perfluorocyclopropane	$c-C_3F_6$			9,200
Fluorinated ethers				
HFE-125	CHF_2OCF_3		14,900	12,400
HFE-134	CHF_2OCHF_2		6,320	5,560
HFE-143a	CH_3OCF_3		756	523
HCFE-235da2	$CHF_2OCHClCF_3$		350	491
HFE-245cb2	$CH_3OCF_2CF_3$		708	654
HFE-245fa2	$CHF_2OCH_2CF_3$		659	812
HFE-347mcc3	CH3OCF2CF2CF3		575	530
HFE-347pcf2	CHF2CF2OCH2CF3		580	889
HFE-356pcc3	CH3OCF2CF2CHF2		110	413
HFE-449sl (HFE-7100)	C4F9OCH3		297	421
HFE-569sf2 (HFE-7200)	C4F9OC2H5		59	57
HFE-43-10pccc124 (H-Galden 1040x)	$CHF_2OCF_2OC_2F_4OCHF_2$		1,870	2,820
HFE-236ca12 (HG-10)	CHF2OCF2OCHF2		2,800	5,350

Industrial designation or common name	Chemical formula	GWP values for 100-year time horizon		
		Second assessment report (SAR)	Fourth Assessment Report (AR4)	Fifth Assessment Report (AR5)
HFE-338pcc13 (HG-01)	$CHF_2OCF_2CF_2OCHF_2$		1,500	2,910
HFE-227ea	$CF_3CHFOCF_3$			6,450
HFE-236ea2	$CHF_2OCHFCF_3$			1,790
HFE-236fa	$CF_3CH_2OCF_3$			979
HFE-245fa1	$CHF_2CH_2OCF_3$			828
HFE 263fb2	$CF_3CH_2OCH_3$			1
HFE-329mcc2	$CHF_2CF_2OCF_2CF_3$			3,070
HFE-338mcf2	$CF_3CH_2OCF_2CF_3$			929
HFE-347mcf2	$CHF_2CH_2OCF_2CF_3$			854
HFE-356mec3	$CH_3OCF_2CHFCF_3$			387
HFE-356pcf2	$CHF_2CH_2OCF_2CHF_2$			719
HFE-356pcf3	$CHF_2OCH_2CF_2CHF_2$			446
HFE 365mcf3	$CF_3CF_2CH_2OCH_3$			<1
HFE-374pc2	$CHF_2CF_2OCH_2CH_3$			627
Perfluoropolyethers				
PFPMIE	$CF_3OCF(CF_3)CF_2OCF_2OCF_3$		10,300	9,710
Hydrocarbons and other compounds - direct effects				
Chloroform	$CHCl_3$	4		16
Methylene chloride	CH_2Cl_2	9	8.7	9
Methyl chloride	CH_3Cl		13	12
Halon-1201	$CHBrF_2$			376

IPCC data sources for more information:

- AR4 values: https://www.ipcc.ch/publications_and_data/ar4/wg1/en/ch2s2-10-2.html
- AR5 values: https://www.ipcc.ch/pdf/assessment-report/ar5/wg1/WG1AR5_Chapter08_FINAL.pdf (p. 73-79)

Annex B: Life Cycle flow chart (Cradle-to-Gate)



Annex C: Level of Disclosure

Product Carbon Footprint – Cradle-to-Gate			Broadly equivalent corporate accounting "scope"
Product	**Emission Category**	**Emission source**	**Bauxite** and/or other ores **Mine**
Bauxite and/or other ores	Direct Process	Combustion of fossil fuels for stationary and mobile equipment,	1
		Stationary combustion in auxiliary, emergency or pollution control equipment	1
	Energy Production	Fuel	3 (cat 3)
		Electricity, steam, heat - purchased	2 & 3 (cat 3)
		Electricity, steam, heat - self generated	1 & 3 (cat 3)
	Others	Purchased goods and services	3 (cat 1)
		Capital goods	3 (cat 2)
		Waste Generated in operations	3 (cat 5)
		Employee commuting	3 (cat 7)
		Upstream leased assets	3 (cat 8)

Product Carbon Footprint - Cradle-to-Gate			Broadly equivalent corporate accounting "scope"
Product	**Emission Category**	**Emission source**	**Alumina Refinery**
Aluminium Hydroxide	Direct Process	Stationary combustion to sustain the requested condition in a digester	1
		Stationary combustion in auxiliary, emergency or pollution control equipment	1
		Use of limestone as sorbent material for flue gas desulphurization (FGD);	1
		Fugitive emissions of non CO2 GHG from unintentional releases	1
		Emissions from organic carbon content of bauxite and/or other ores and residue	1
		Emissions from acid cleaning of apparatus	1
		combustion of fossil fuels for stationary and mobile equipment,	1
	Energy Production	Fuel	3 (cat 3)
		Electricity, steam, heat - purchased	2 & 3 (cat 3)
		Electricity, steam, heat - self generated	1 & 3 (cat 3)
	Others	Purchased goods and services	3 (cat 1)
		Capital goods	3 (cat 2)
		Upstream transportation and distribution of bauxite and/or other ores	3 (cat 4)
		Waste Generated in operations	3 (cat 5)
		Employee commuting	3 (cat 7)
		Upstream leased assets	3 (cat 8)

Product Carbon Footprint - Cradle-to-Gate			Broadly equivalent corporate accounting "scope"
Product	**Emission Category**	**Emission source**	**Alumina Refinery**
Aluminium Oxide	Direct Process	Stationary combustion in kilns for the production of calcined alumina (calciners);	1
		Stationary combustion in kilns/ovens for the production of dried speciality alumina (dryers);	1
		Stationary combustion in auxiliary, emergency or pollution control equipment	1
		combustion of fossil fuels for stationary and mobile equipment,	1
	Energy Production	Fuel	3 (cat 3)
		Electricity, steam, heat - purchased	2 & 3 (cat 3)
		Electricity, steam, heat - self generated	1 & 3 (cat 3)
	Others	Purchased goods and services	3 (cat 1)
		Capital goods	3 (cat 2)
		Upstream transportation and distribution of aluminium hydroxide	3 (cat 4)
		Waste Generated in operations	3 (cat 5)
		Employee commuting	3 (cat 7)
		Upstream leased assets	3 (cat 8)

Product Carbon Footprint - Cradle-to-Gate			Broadly equivalent corporate accounting “scope”
Product	**Emission Category**	**Emission source**	**Primary aluminium smelter**
Primary Aluminium	Direct Process	Anode/Paste Production - self produced	1
		Anode/Paste Production - purchased	3
		Emissions from Anode/Paste consumption	1
		Perfluorcarbon emissions	1
		Stationary combustion in casthouse	1
		Stationary combustion in auxiliary, emergency or pollution control equipment	1
		combustion of fossil fuels for stationary and mobile equipment,	1
	Energy Production	Fuel	3 (cat 3)
		Electricity, steam, heat - purchased	2 & 3 (cat 3)
		Electricity, steam, heat - self generated	1 & 3 (cat 3)
	Others	Purchased goods and services	3 (cat 1)
		Capital goods	3 (cat 2)
		Upstream transportation and distribution of aluminium oxide	3 (cat 4)
		Waste Generated in operations	3 (cat 5)
		Employee commuting	3 (cat 7)
		Upstream leased assets	3 (cat 8)