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Stationary source emissions — Determination of greenhouse gas emissions in energy-intensive industries —

Part 4: Aluminium industry

Emissions de sources fixes — Détermination des émissions de gaz à effet de serre dans les industries énergo-intensives —

Partie 4: Industrie de l'aluminium

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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This document was prepared by Technical Committee ISO/TC 146, *Air quality*, Subcommittee SC 1, *Stationary source emissions.*

A list of all parts in the ISO 19694 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user’s national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

This document serves the following purposes:

— to measure, test and quantify GHG emissions from the aluminium industry;

— to assess the level of GHG emissions performance of production processes over time at production sites;

— to establish and provide reliable, accurate and quality information for reporting and verification purposes.

This document can be used to measure, report and compare the GHG emissions of an aluminium production facility. Data for individual facilities, sites or works can be combined to measure, report and compare GHG emissions for a company, corporation or group.

Direct fuel-based emissions are not included; for calculation of this part of the GHG emissions, see ISO 19694-1.

This document deals with sector-specific aspects for the determination of greenhouse gas (GHG) emissions from aluminium production and is based on documents mentioned under tier 3 of Section 4.4.2.4 of the 2006 IPCC guidelines[6].

Stationary source emissions — Determination of greenhouse gas emissions in energy-intensive industries —

Part 4: Aluminium industry

1 Scope

This document specifies a harmonized method for calculating the emissions of greenhouse gases from the electrolysis section of primary aluminium smelters and aluminium anode baking plants. This document also specifies key performance indicators for the purpose of benchmarking of aluminium and boundaries.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 19694-1, *Stationary source emissions — Determination of greenhouse gas emissions in energy-intensive industries — Part 1: General aspects*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 19694-1 and the following apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1
aluminium electrolysis
section of an aluminium primary smelter where aluminium is converted from aluminium oxide to aluminium metal in electrolysis cells

3.2
anode baking plant
production of carbon anodes for use in aluminium prebake electrolysis cells

3.3
PFC gas
gas emitted from *aluminium electrolysis* (3.1) consisting of CF_4 and C_2F_6

3.4
grid specific CO_2 factor
CO_2 factor (t CO_2/MWh) associated with the electricity delivered to a specific aluminium smelter from their supplier

Note 1 to entry: The unit for grid specific CO_2 factor is t CO_2/MWh.

4 Symbols and abbreviated terms

4.1 Abbreviated terms

AE	Anode effect
CWPB	Centre-worked prebake
DAE	Direct anode emissions
DEE	Direct electrolysis emissions
GHG	Green house gas
HSS	Horizontal stud Søderberg
IPCC	Intergovernmental Panel on Climate Change
PFC	Perfluorocarbon
PFPB	Point feeder prebake
SWPB	Side-worked prebake
TIE	Electrolysis electricity consumption
VSS	Vertical stud Søderberg
WBCSD	World Business Council for Sustainable Development
WRI	World Resources Institute

4.2 Symbols and chemical formulae

4.2.1 Symbols

A_{EM}	Anode effect minutes per cell-day (equals to frequency multiplied by average duration)
A_{EO}	Anode effect overvoltage
A_{NC}	Net anode consumption
A_{sha}	Ash content in baked anodes
A_{shp}	Ash content in pitch, % mass fraction
A_{shpc}	Ash content in packing coke, % mass fraction
B_A	Baked anode production
B_{AW}	Baked anode mass
B_C	typical binder content in paste, % mass fraction
C_{BA}	Carbon content of baked anodes
C_{Butt}	Carbon content of anode butts
C_E	Current efficiency for aluminium production

C_D Carbon in skimmed dust from anode from Søderberg cells, tonnes carbon per tonne aluminium

C_{SM} Emissions of cyclohexane soluble matter, kilograms per tonnes aluminium

E_{CF_4} Emissions of tetrafluoromethane, kg CF_4 per year

$E_{C_2F_6}$ Emissions of hexafluoroethane, kg C_2F_6 per year

E_{CO_2} CO_2 emissions, tonnes per year

E_{FPC} Emission factor of packing coke, tCO_2/t of packing coke

$F_{\frac{C_2F_6}{CF_4}}$ Mass fraction of $\frac{C_2F_6}{CF_4}$

G_A Mass of loaded green anodes, $G_A = \left(\frac{G_{AW}}{B_{AW}}\right)B_A$

G_{AW} Green anode mass

G_{WP} Global warming potential; use latest G_{WP} data from IPCC

H_w Hydrogen content in green anode

H_p Hydrogen content in pitch, % mass fraction

M_{BA} Total mass of baked anodes

M_{Butt} Total mass of anode butts

M_P Total metal production, tonnes aluminium per year

N_{AC} Net anode consumption, tonnes per tonnes aluminium

O_{FPC} Oxidation factor of packing coke (typically 1 for this stream)

O_{VC} Overvoltage coefficient for CF_4

P_C Paste consumption, tonnes per tonnes aluminium

P_{CC} Packing coke consumed per tonnes of baked anode

P_{CW} Packing coke mass

R_{CF_4} Emission rates of CF_4, kg per tonne of aluminium produced

$R_{C_2F_6}$ Emission rates of C_2F_6, kg per tonne of aluminium produced

S_a Sulfur content in baked anodes

S_c Sulfur content in calcined coke, % mass fraction

S_p Sulfur content in pitch, % mass fraction

S_{pc} Sulfur content in packing coke, % mass fraction

S_{CF_4} Slope coefficient for CF_4, kg CF_4 per tonne aluminium per anode effect minute per cell day

W_T Waste tar collected

4.2.2 Chemical formulae

Al	Aluminium
Al_2O_3	Aluminium oxide (alumina)
C	Carbon
CF_4	Tetrafluoromethane
C_2F_6	Hexafluoroethane
CO	Carbon monoxide
CO_2	Carbon dioxide
$NaAlF_6$	Sodium aluminium hexafluoride (cryolite)
NaF	Sodium fluoride

5 Calculation methods — General remarks

5.1 General

This document shall be used in conjunction with ISO 19694-1 which contains generic, overall requirements, definitions and rules applicable to the determination of GHG emissions for all energy-intensive sectors, provides common methodological issues and specifies the details for applying the rules. The application of this document to the sector-specific standards ensures accuracy, precision and reproducibility of the results.

5.2 Calculation methods for process GHG emissions from primary aluminium production

Figure 1 gives sources of process emissions and references to where in the standard calculation methods are specified.

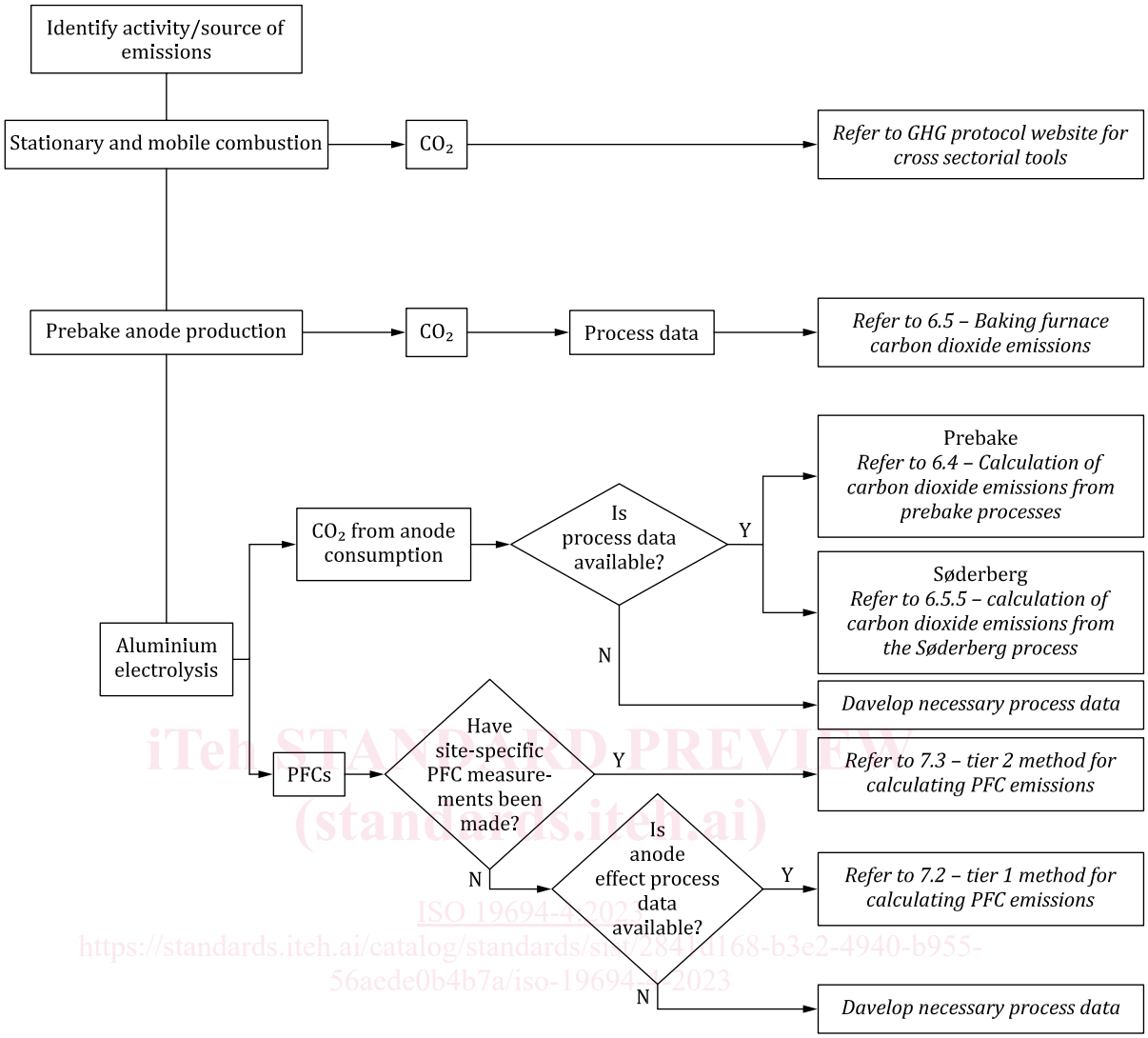

Figure 1 — Decision tree for process carbon dioxide and perfluorocarbon emissions from primary aluminium production

Process CO_2 emissions in state-of-the-art aluminium smelters comprise around 90 % of total direct CO_2 equivalent emissions, with the balance of emissions consisting of CO_2 from fossil fuel combustion and PFC emissions. Guidance on CO_2 emissions from fuel combustion is not included in this document. Methodology for calculating CO_2 emissions from the combustion of fuel in anode baking furnaces is described elsewhere[6],[7], while methodology for calculating process CO_2 emissions is given in Clause 7.

5.3 Sources of greenhouse gases

5.3.1 Electrolysis

Most of the CO_2 emissions result from the electrolytic reaction of the carbon anode with alumina as given in Formula (1):

$$2Al_2O_3 + 3C \rightarrow 4Al + 3CO_2 \quad (1)$$

Carbon dioxide is also emitted during the electrolysis reaction as the carbon anode reacts with other sources of oxygen, primarily from the air. Carbon dioxide is also formed as a result of the Boudouard reaction where CO_2 reacts with the carbon anode forming carbon monoxide, which is then oxidized to