Protocol
2C3: PFC EMISSIONS DURING PRIMARY ALUMINIUM PRODUCTION

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NFR Code:	n.a.
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FOREWORD
Under the Kyoto Protocol, the Netherlands is required to set up and maintain a national system to monitor its greenhouse gas emissions. One of the elements of this system is a transparent and verifiable description of the methods and processes used in this monitoring system. These methods must meet international guideline criteria, which have been defined by the United Nations (UN) and the European Union (EU).

The Netherlands meets the aforementioned requirement, for example, by defining a series of Monitoring Protocols, which describe the methods and work processes used to determine greenhouse gas emissions and the amounts of carbon sinks available. Protocols have been written for about 40 greenhouse gas sources or sinks. This document describes the protocol for one of these sources or sinks.

The protocols have been compiled in close collaboration with experts from various sectors of society in the Netherlands, particularly experts from the Emissions Registration (ER). The ER is a collaborative group that includes institutions such as CBS, WUR, RIVM and PBL. Until 31 December 2009 this was coordinated by PBL (Planbureau for the Leefomgeving, or the Netherlands Environmental Assessment Agency), but on 1 January 2010 this coordination task was taken over by RIVM (the Netherlands institute for public health and the environment). Other institutions that have contributed to the protocols include NL Agency; Ministry of Agriculture, Nature and Food Quality; and the Ministry of VROM (Housing, Spatial Planning and the Environment).

1 SCOPE AND SIGNIFICANCE OF EMISSION SOURCES/ACTIVITIES

1.1 Scope and definition
This protocol describes the monitoring of the PFC (perfluorocarbon) emissions (CF_4 and C_2F_6) that are released during the primary industrial production of aluminium (IPCC code 2C3). This concerns the industrial SBI code 2442 (aluminium production).

The Netherlands has two aluminium manufacturers, each using a single production location.

Several types of PFCs are emitted during primary aluminium production, e.g. (80-90%) tetrafluoromethane (CF_4) and, to a lesser extent, (10-20%) hexafluoroethane (C_2F_6). Other PFCs are also mentioned in the literature, e.g. C_3F_8, which can also be released during the production process, though in much smaller quantities.

PFCs are formed during the so-called ‘anode effect’, when the concentration of aluminium-oxide in the electrolyte smelt bath is too low. The anode effect produces sparks whereby the temperature increases so much that PFCs are formed. The frequency and duration of the anode effect depends on the type of process used (Søderberg or Prebake), the method of dosing the alumina, and the extent of the process automation.

1.2 Significance and influences

1.2.1 Contribution to total national emissions

The PFC emissions by the aluminium industry contribute about 1% to the total annual greenhouse gas emissions from the Netherlands.

1.2.2 Developments that infuence emissions

Anode effects and related PFC emissions can both be prevented by dosing the alumina as steadily as possible. Using an alumina dosing system from the centre, the so-called central input of Centre Worked Prebaked (CWPB), PFC emissions are 95% less than when using a dosing system that inputs the alumina from the side (Side Worked Prebaked, or SWPB).

Both Dutch aluminium manufacturers use Prebake anodes, and both originally used the SWPB dosing system. However, the first company switched to central dosing (CWPB) in 1999, and the second company also began using this system in 2003.

2 METHOD, EMISSION FACTORS AND ACTIVITY DATA

2.1 Calculation method

The two aluminium manufacturers in the Netherlands each use their own methodology for calculating PFC emissions. Company 1 uses a method that complies with the Tier-2 method, with the exception of the following points:

- only CF_4 emissions are calculated, not C_2F_6;
- a different slope is used to calculate the emission factor.

The method used by Company 2 complies entirely with the Tier-2 method, as described in the Good Practice Guidance published by the IPCC (IPCC, 2001, p. 3.39 onwards).

Company 1

Emissions from company 1 are calculated using the following formulas:

$$Emission_{CF4} = Emission\ factor_{CF4} * Production / 1000$$

$$Emission_{C2F6} = Weight\ fraction\ \mathrm{C_2F_6}/\mathrm{CF_4} * Emission_{CF4}$$

Where:

$Emissions_{CF4\ /\ C2F6}$:	emissions of CF_4 or C_2F_6 (ton/year)
$Emission\ factor_{CF4}$:	emission factor for CF_4 (kg/ton aluminium)
Weight fraction C2F6/ CF4:	up to 1999 (for side feed) this amounted to 0.10; after 1999 (for centre feed) this figure is 0.121.

The emission factor for CF_4 is therefore calculated as follows:

$$Emission\ factor_{CF4} = Slope_{CF4} * AEF * AED$$

Where:

$Slope_{CF4}$:	The 'slope' of CF_4 refers to a technology-specific value for CF_4 (IPCC, 2001, p. 3.39 and the following); Company 1 uses its own specific value, which deviates from the IPCC Tier-2 method.
AEF:	number of anode effects per day (anode effects/oven/day)
AED:	duration of the anode effects (minutes).

Company 2

The emissions of the second company are calculated with the following formulas:

$$Emission_{CF4} = Emission\ factor_{CF4} * Production / 1000$$

$$Emission_{C2F6} = Emission\ factor_{C2F6} * Production / 1000$$

The emission factors are determined by the Overvoltage method:

$$Emission\ factor_{CF4} = Overvoltage\_coefficient_{CF4} * AEO / CE$$

$$Emission\ factor_{C2F6} = Overvoltage\_coefficient_{C2F6} * AEO / CE$$

Where:

Emission $factor_{CF4 / C2F6}$:	the emission factor for CF_4 or C_2F_6 (kg/ton aluminium)
Overvoltage coefficient:	this is a technology-specific (IPCC, 2001, p.3.39 onwards) value per ton of aluminium per mV per oven/day.
AEO:	anode effect overvoltage (mV/oven day)
CE:	current efficiency of the aluminium production (as fraction)

2.2 Emission factors

See Section 2.1.

2.3 Activity data

Not applicable

3 WORKING PROCESSES

Process for estimating (t-1)

If preliminary figures are required at any point, the following process is used to estimate the figure for t-1. The preliminary data for the work package leader are calculated by extrapolating them from the previous years' figures, based on prognoses for the developments in the most important activity data (taken from CBS (Statistics Netherlands) or other statistical sources).

INPUT	PROCESS	OUTPUT	BY WHOM
Preliminary data work package leader (t-1)	Include t-1 data in ER database	ER-db with (t-1) data	Work package leader
ER-db with (t-1) data	Check emission figures: compare with previous years (trend), modify if required and document everything	ER-db (t-1) with any modified figures	Task force

Process for final determination of (t-2)
The final emission figures (as described in this protocol) are calculated using the following process.

INPUT	PROCESS	OUTPUT	BY WHOM
Internally defined emission figures	Reported in Annual Environmental Reports	AER/MJV	Company
Annual Environmental Reports (AER/MJV)	Validate in AER/MJV	Validated AER/MJV	Competent Authority (Provincial government)
Validated AER/MJV	Include in FO-I file	FO-I file	FO-I (Facilitary Organisation – Industry)
FOI file	Checking emission figures: - Comparing MJVs with MJVs from previous years (trend) If non-substantiated deviations in MJV text found, contact the Province and/or Company→ If necessary modify emission figures and document everything.	Final data Work package leader (t-2)	Work package leader
Final data Work package leader (t-2)	Include (t-2) data in ER database	ER-db with (t-2) data	Work package leader
ER-db with (t-2) data	Check, and trend analysis of air emissions: explain deviations or modify figures	Final defined emission figures (t-2)	Task forces and PBL experts

Supplying data via the AER/MJV
Companies are required to report emissions per plant as a part of their annual environmental reports (AER/MJV), separating the confidential data from the public information. Reports must be submitted to the Competent Authority for each plant before 1 April of the year following the reporting year.

Data are stored per company, i.e. methods used, measurement results and frequencies, calibration records, characteristics and (possibly the) efficiency of the technologies used for PFC reduction, as well as other important data or information. Confidential information concerning the technologies used within the company is also stored, but this is only made available to the Competent Authority, the ENINA working group and possibly to review teams.

4 UNCERTAINTY AND QUALITY

4.1 Estimating uncertainties

A Tier-1 uncertainty analysis is implemented every year before the NIR is submitted by the ER, based on the greenhouse gas inventory and in compliance with IPCC guidelines. The assumptions used and the results thereof are described in a background report to the NIR. In addition to this, where included in the QA/QC programme for the relevant period, extra analyses are implemented regularly in specific situations, which include any updating of the Tier-2 uncertainty analyses.

The Tier-2 uncertainty assessment was last updated in 2006. This assessment showed that a Tier-1 uncertainty assessment is sufficiently reliable and that Tier-2 uncertainty assessments need only be implemented at periodic intervals of around 5 years, unless a major change in an important source is sufficient to require earlier reassessment.

- Source-specific uncertainty

The uncertainty estimate-totaal concerns the root of the sum of uncertainty in the data sources used (AD_{onz}) in the square and the uncertainty of the emission factor (EF_{onz}) in the square. The extent of the total uncertainty is here primarily determined by the greatest AD or EF uncertainty.

$$\text{Uncertainty estimate}_{\text{total}} = \sqrt{EF_{onz.}^{\ 2} + AD_{onz.}^{\ 2}}$$

The uncertainty estimates concerning the data sources (AD) and emission factors (EF) used, and the total uncertainty estimate, are listed in the following table.

IPCC	Category	Gas	AD $_{onz.}$	EF $_{onz.}$	Uncertainty estimates $_{tot}$
2C3	PFC from aluminium production	PFC	2	20	20

The uncertainty in PFC emissions from aluminium production was estimated to be about 20% (2% in activity data and 20% in the PFC emission factor) [Olivier et al, 2009].

4.2 Quality assurance and quality control (QA/QC)

The ER work package leaders check that:

1. the basic data are well documented and adopted (check for typing errors, use of the correct unit sizes and correct conversion);
2. the calculations have been implemented correctly;
3. assumptions are consistent, also whether specific parameters (e.g. activity data) are used consistently;
4. complete and consistent data sets have been supplied.

Any actions that result from these checks are noted on an ‘action list’. Before defining the data, supervisors check whether the relevant actions on this list, plus the QC checks, have all been completed. Defining the data is carried out by the WEM (working group on emissions monitoring), and confirmed in writing via an e-mail from the institute representatives to the ER project leader at PBL.

The work package leaders fill out a new documentation sheet when adding new data. For reasons of efficiency a minimum level has been set for obligatory documentation, i.e. 5% changes at target group level, and 0.5% at levels concerning the national total. These documentation sheets form part of the trend analysis, as well as the eventual definition of the data set.

The ER work package leaders communicate by e-mail regarding these QC checks, results and actions. They send a printed copy to the ER secretary, who keeps a logbook and compiles these e-mails into an ‘action list’. This shows explicitly that the required checks and corrections have been carried out.

4.3 Verification

In order to check the quality of the emission figures for the sources in this protocol, general QA/QC procedures have been followed that are in line with the IPCC guidelines. These are described further in the QAQC programme used by the National System, and the annual working plans published by the ER.

- Sector-specific QC
No additional specific verification procedures are implemented for the sources defined in this protocol.

4.4 Possibilities for improvement compared to the current calculation method

4.4.1 History

Company 1
Only CF_4 emissions are determined for Company 1. This was only made public at the end of 2005 – before this the information was given as total PFC emissions. Therefore, up to and including 2005, the CF_4 and CF_6 emissions were determined as follows:

CF_4 emissions: 0.9 * of total PFC emissions;
C_2F_6 emissions: 0.1 * of total PFC emissions.
This is corrected in de NIR 2006 (Brandes *et al.*, 2006) and the missing C_2F_6 emissions were added from 1990 onwards.
A C_2F_6,/ CF_4 *Weight fraction* of 0.10 was used for the entire period.

Company 2
Up to and including 2006 Company 2 used a fixed ratio between CF_4 and CF_6 to determine emissions for the years up to and including 2002, with 0.1 kg C_2F_6 being emitted for every kg CF_4. Emissions after 2002 were determined via measurements.

Emissions based on periodic measurements taken in 1999 were recalculated under the NIR 2006 (Brandes *et al.*, 2006). These measurements, which did not become available until later, resulted in a C_2F_6,/ CF_4 weight fraction of 0.24. Recalculations were carried out for the period 1990-1998 and the years 2000 and 2001.

4.4.2 Future

Not applicable

5 REMAINING ASPECTS

5.1 Point source criteria
Not applicable

5.2 Component profiles
Not applicable

5.3 Regionalisation
Not applicable

5.4 Time-based variations in source strength
Not applicable

6 REFERENCES AND ADDITIONAL INFORMATION

6.1 References

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6.2 Additional information

Not applicable