Approved baseline and monitoring methodology AM0059

"Reduction in GHGs emission from primary aluminium smelters"

I. SOURCE AND APPLICABILITY

Source

This methodology is based on the case NM0209-rev "Reduction in GHGs emission from primary aluminium smelter at Hindalco, Hirakud India", proposed by Hindalco Industries Limited, whose baseline and monitoring methodology and project design document were prepared by PricewaterhouseCoopers (P) Ltd, India.

This methodology also refers to the latest version of:

- Combined tool to identify the baseline scenario and demonstrate additionality;
- Tool to calculate project emissions from consumption of electricity and
- Tool to calculate emission factor for electricity system.

For more information regarding the proposed new methodology, approved methodologies and the tools as well as their consideration by the Executive Board please refer to http://cdm.unfccc.int/goto/MPappmeth.

Selected approach from paragraph 48 of the CDM modalities and procedures

- "Actual or historical emissions, as applicable", or
- "Emissions from a technology that represents an economically attractive course of action, taking into account barriers to investment"

The methodology determines baseline from historical and actual data for the current capacity and a technology that represents an economically attractive course of action, taking into account barriers to investment, for the expansion of capacity.

Definitions

For the purpose of this methodology, the following definitions apply:

- Smelting technology refers to the type of electrolysis process used to produce primary aluminium. The following categories of smelting technologies are considered for the purpose of this methodology:
    - Point Feed Prebake (PFPB);
    - Bar Broken Center Work Prebake (CWPB);
    - Side Work Prebake (SWPB);
    - Vertical Stud Søderberg (VSS);
    - Horizontal Stud Søderberg (HSS).

Applicability

This methodology is applicable to project activities implemented in an existing facility to:

- Upgrade the smelting technology which results in reduction of perfluorocarbon (PFCs) emissions; and/or
- Improve the electrical energy use efficiency in primary aluminum smelters.

The following conditions apply to the methodology:

- The methodology is restricted to project activities where only changes in the smelting technology[1] are implemented (and not to any general improvement practices i.e. improvement in the feeding system or metal tapping) with the primary purpose of reducing PFC emissions and/or improving electrical energy efficiency and not with the primary objective of increasing aluminium production;
- At least three years of historical data prior to the implementation of the project activity for the calculations of baseline emissions are available;

This methodology is not applicable to:

- Projects that reduce PFC emissions by means of general improvements in energy efficiency without undertaking changes in the current smelting technology (e.g. improvement in the feeding system or metal tapping, improvements in bath chemistry to lower smelting temperature and increase efficiency of electricity use, insulation to reduce heat losses, etc.)
- Project activities where the main objective is to reduce the carbon anode consumption.

II. BASELINE METHODOLOGY

Project boundary

Table 1: Summary of gases and sources included in the project boundary, and justification / explanation where gases and sources are not included.

	Source	Gas	Included?	Justification / Explanation
Baseline	Anode effect in pots	CF_4	Yes	Main source of emissions
		C_2F_6	Yes	Main source of emissions
	Use of Na_2CO_3	CO2	No	Excluded for simplification
	Use of Cover Gas	SF_6	No	Excluded for simplification
	Anode Consumption	CO_2	No	Excluded for simplification
	Anode baking	CO_2	No	Excluded for simplification
	Electricity consumption	CO_2	Yes	Main source of emissions
		CH_4	No	Excluded for simplification

[1] Changes in smelting technology, when replacing the Hall-Héroult process, could lead to perfluorocarbon emission reductions through modification / retrofitting existing cells and using advanced technologies. Currently available perfluorocarbon mitigation technologies and practices include computerized controls, as well as improved operating practices that minimize the frequency and duration of anode effects and associated emissions. These changes lead to both PFC emission reduction as well as efficiency in smelting electrical energy

	Source	Gas	Included?	Justification / Explanation
		N_2O	No	Excluded for simplification
Project Activity	Anode effect in pots	CF_4	Yes	Main source of emissions
		C_2F_6	Yes	Main source of emissions
	Use of Na_2CO_3	CO_2	No	Excluded for simplification
	Use of Cover Gas	SF_6	No	Excluded for simplification
	Anode Consumption	CO_2	No	Excluded for simplification
	Anode baking	CO_2	No	Excluded for simplification
	Electricity consumption	CO_2	Yes	Main source of emissions
		CH_4	No	Excluded for simplification
		N_2O	No	Excluded for simplification

Procedure for estimating the remaining lifetime of the existing smelting technology included in the project boundary.

The following approaches should be used to estimate the remaining lifetime of the existing smelting technology or its parts:

(a) The typical average technical lifetime of the existing smelting technology, taking into account common practices in the sector, e.g., based on industry surveys, statistics, technical literature, etc. in the relevant geographical area.
(b) The practices regarding replacement schedules e.g. based on historical replacement records for parts that will be replaced as part of the project activity, in similar equipment.

The remaining lifetime of the existing smelting technologies should be chosen in a conservative manner, i.e., the smallest value of remaining lifetime should be chosen in cases where the life time is estimated as a time range rather than single value.

Procedure for the identification of the most plausible baseline scenario and the demonstration of additionality

As per the guidance of CDM Executive Board, only the investment analysis, and not barrier analysis, will be used for the identification of baseline scenario and demonstration of additionality.

Step 1: Identification of alternative scenarios

This step shall be implemented as described in the latest version of the "Combined tool to identify the baseline scenario and demonstrate additionality" approved by the Executive Board. The following guidance is supplementary to that provided in tool.

Project participant shall identify all realistic and credible baseline scenario candidates for the project activity (choice of smelting technology) that delivers outputs (i.e. aluminium production) with comparable quality, properties, and application areas.

If the project activity also leads to an expansion of the aluminum production capacity within the potlines that existed prior to the start of the project activity then alternative scenarios for current capacity and expanded capacity should be determined separately. In other words, project proponent should consider the capacity of the currently installed potlines undergoing technology change under the CDM project activity. For identification of relevant alternative scenarios, project proponent shall provide an overview of other smelting technologies or practices that provide outputs (i.e. aluminium production) of comparable quality, properties and application areas as the proposed CDM project activity and that have been implemented previously or are currently underway in the relevant geographical area or in the aluminium sector.

In determining the relevant geographical area, a size should be chosen which ensures that at least 5 primary aluminum plants are included. The minimum size considered should be the host country. If there are less than 5 primary aluminum plants in the host country, the geographical area should be extended by including all neighboring non-Annex I countries. If the number remains to be less than 5, all non-Annex I countries in the continent should be considered. If the necessary data on plants in the relevant geographical area is not available, or if there are less than 5 primary aluminum plants in all non-Annex I countries in the continent, then data from all plants included in the annual statistics of the International Aluminium Institute should be used.

The expanded capacity is the difference between the actual production and the historically existing production[2]. Therefore, the expanded capacity will be determined ex post. For ex-ante calculations of emission reductions, the estimated nominal capacity expansion in the capacity can be used.

Alternative scenarios for the **project activity** shall include, *inter alia*, the following:

<table>
<tr><th></th><th>Historic capacity</th><th>Expanded capacity</th></tr>
<tr><td rowspan="2">Alternative scenarios for smelting technologies</td><td>• Continuation of current technology without the implementation of control measures to improve efficiency and reduce PFCs emissions.
• Continuation of current technology with the implementation of control measures to improve efficiency and reduce PFCs emissions.</td><td>• Use of the same technology as for the current capacity.
• Use of new technology for expanded capacity, other than common practice technology in the region.
• Use new technology, which is common practice in the region.</td></tr>
<tr><td colspan="2">• Proposed project activity undertaken without being registered as a CDM project (with or without expansion of capacity as applicable).
• All capacity (current and expanded) supplied with a new technology other than project technology</td></tr>
</table>

Further, if project activity leads to expansion of capacity (without the inclusion of the new potlines) due to change in technology, a separate baseline electricity consumption should be determined for the expanded capacity based on the alternative selected for that capacity.

Step 2: Investment Analysis

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[2] Historic capacity is the maximum value of annual production achieved during three years preceding the start of operation of project activity. The expanded capacity is the additional production achieved as a result of project activity that is over and above the *historic capacity* .

This step shall be implemented as described Step 3 of the latest version of the “Combined tool to identify the baseline scenario and demonstrate additionality” approved by the Executive Board. The following guidance is supplementary to that provided in tool.

The investment analysis for the projects with extended production capacity must consider the profits achieved due to higher production, among all other cash flows and investments during the lifetime of project activity, as one of the input cash streams for determination of financial performance of project by suitable methods (IRR, NPV etc.).

Step 3: Common practice analysis

This step shall be implemented as described in Step 4 of the latest version of the “Combined tool to identify the baseline scenario and demonstrate additionality” approved by the Executive Board. The following guidance is supplementary to that provided in tool.

In addition to the common practice test as provided in the “Combined tool to identify the baseline scenario and demonstrate additionality”, for the purpose of this methodology, a “common practice” smelting technology is defined as the smelting technology type (using the differentiation as provided in the definition above) that is most frequently used among the all plants in the relevant geographical area, as defined in Step 1.

<u>The methodology is only applicable if the identified baseline scenario is the continuation of the current practice for the historic capacity without the implementation of any control measures. For the expanded capacity the baseline scenario is the common practice technology based in the IAI statistics and surveys.</u>

Baseline emissions

Baseline GHG emissions are calculated as the summation of the GHGs emitted due to anode effect and electricity consumption during the aluminium smelting process:

$$BE_{GHG,y} = BE_{PFC,y} + BE_{elec,y} \quad (1)$$

Where:

$BE_{GHG,y}$	=	GHG baseline emissions from smelting process (tCO_{2e}/year) in project year y
$BE_{PFC,y}$	=	Baseline PFC (CF_4 & C_2F_6) emissions from anode effects (tCO_{2e}/year) in project year y
$BE_{elec,y}$	=	Emissions due to electricity consumption in the aluminium smelting process in the baseline scenario (tCO_{2e}/year) in project year y

1. Baseline emission calculation for PFC emission from anode effects (AE):

The baseline emissions of PFCs are to be determined for the historical capacity and expanded capacity.

$$BE_{PFC,y} = BE_{PFCE,HC} \times MP_{HC} + BE_{IAI,EC} \times MP_{EC,y} \quad (2)$$

Where:

$BE_{PFCE,HC}$ = PFC emission rate per tonne of aluminium produced (tCO_{2e}/tAl) of historical capacity

$BE_{IAI,EC}$ = Average value of "PFC emission factor per tonne of aluminium produced" for the top 20% [3] aluminium plants using the common practice technology [4] identified for the expanded capacity according to the most recent published IAI Survey ($t\ CO_2e/tAl$) as project alternative. The average PFC emission factor should be updated every year with the most recent values published by IAI.

MP_{HC} = Maximum annual historic aluminium production based on recent 3 years production (tAl/year) prior to the implementation of the project activity

$MP_{EC,y}$ = Metal production of expanded capacity (tAl/year) in year 'y'

$$MP_{EC,y} = MP_y - MP_{HC} \qquad \textbf{(2.1)}$$

Where:

MP_y = Total aluminium production in year 'y'

The baseline levels of PFCs emissions shall be calculated using IPCC guidance on tier 2 method or tier 3 method using the available data. To determine the baseline emission level using tier 3, data shall be selected for a period of measurement corresponding to the most stable and lowest anode effect frequency-duration product or over-voltage (anode effect frequency, duration and/or over voltage) of the potlines included in the project boundary. The minimum period shall be from recent 3 years prior to the implementation of the project, with the number of measurements statistically representative for that period.

Baseline emissions per tonne of aluminium are estimated as follows:

$$BE_{PFCE,HC} = EF_{CF4} \times GWP_{CF4} + EF_{C2F6} \times GWP_{C2F6} \qquad \textbf{(2.2)}$$

If: $BE_{PFCE,HC} \leq BE_{IAI,HC}$, then $BE_{PFCE,CC}$ is as estimated by above equation

If: $BE_{PFCE,HC} > BE_{IAI,HC}$, then $BE_{PFCE,HC} = BE_{IAI,HC}$

Where:

BE_{PFCE} = Baseline PFCs emissions per tonne of Aluminium produced ($t\ CO_2e/tAl$)

$BE_{IAI,CC}$ = Average value of "PFC emission per tonne of Aluminium produced" according to the most recent published IAI Survey for the current technology ($t\ CO_2e/tAl$). Baseline should be updated every year with the most recent values published by IAI.

EF_{CF_4} = Emission factor of CF_4 ($t\ CF_4/t\ Al$), discounted by the uncertainty range as specified by the IAI/USEPA Protocol

$EF_{C_2F_6}$ = Emission factor of C_2F_6 ($t\ C_2F_6/t\ Al$) = weight mentioned in table 2 below multiplied by EF_{CF_4}, discounted by the uncertainty range as specified by the IAI/USEPA Protocol.

GWP_{CF_4} = Global Warming Potential of CF_4 as per IPCC Second Assessment Report = 6500

[3] Top 20% in terms of minimum PFC emission rates (ton PFC/tAl produced).

[4] Currently Point Feeder Pre Baked (PFPB) is the common practice technology for new plants or for the expanded capacity of existing plants).

$GWP_{C_2F_6}$ = Global Warming Potential of C_2F_6 as per IPCC Second Assessment report = 9200

The 2006 IPCC Guidelines describe three general methods for estimating PFCs emission factors from aluminium production (Vol. 3, Section 4.4.2.3, Choice of method for PFCs from primary aluminium production).

To monitor smelter emissions, project developer can use the following IPCC methods[5]:

1. Tier 3 Method
2. Tier 2 Method

The method to be adopted is dependent on whether anode effects are terminated manually prior to the implementation of the project activity or not, consistent with the EPA-IAI protocol[6]. Tier 2 is applicable if it can be proven and documented that 95% of the anode effects are manually terminated (cell hood must be opened during termination of the anode effect), while in all other cases, tier 3 is applicable.

Tier 3 Method: based on anode effect performance

This method uses measurements to establish a smelter-specific relationship between operating parameters (i.e. frequency and duration of anode effects or Anode Effect Over-voltage) and emissions of CF_4 and C_2F_6. These emission factors are multiplied by smelter-specific production (tonnes of aluminium) to estimate smelter emissions.

The optimum calculation method, (slope vs. over-voltage) depends largely on the type of anode effect kill practices used in plants.
1. The slope method should be used with aggressive fast kill anode effect practices.
2. The over-voltage method should be used with slow, repetitive anode effect kill practices.

Slope Method:

This method uses a regression analysis to estimate a linear relationship between anode effect (AE) and PFC emissions. The measurement could be periodic or continuous measurements and should be done as per the International Aluminium Institute GHG Protocol (IAI, 2005). The emission factor is then estimated as, expressed as an emission factor (EF):

$$EF = Slope \times AE \text{ min}/ cell.day \quad \textbf{(3)}$$

Where:

EF	=	Emission factor of CF_4 (kg CF_4/t Al) or C_2F_6 (kg C_2F_6/t Al)
$Slope$	=	Slope coefficient (kg PFC/t Al)/(AE-minute/cell.day)
AE	=	Anode Effect (min/cell.day[7]) estimated as per equation 3.1

[5] Tier 1 approach provides default emission factors by technology type. The level of uncertainty in the Tier 1 method is much larger than for estimations using Tier II or Tier III methods.
[6] This Protocol is recommended in the corresponding monitoring methodology.
[7] The 'cell.day' term really means 'the number of cells operating multiplied by the number of days of operation.' At a smelter this would more usually be calculated (for a certain period of time, e.g. a month or a year) using 'the average

To develop an accurate estimate of the slope, simultaneous measurements of CF_4 or C_2F_6 emissions and anode effect data over an appropriate period of time are collected.

$$AEmin/\,cell.day = AEF.\,AED$$

(3.

1)

Where:

AE	=	Anode effect (min/cell.day)[8]
AEF	=	Number of anode effects per cell.day, measured as per details provided in the monitoring section
AED	=	Anode effect duration in minutes (min), measured as per details provided in the monitoring section

Over-voltage Method:

This method uses the anode effect over-voltage as the relevant process parameter. The anode effect over-voltage is the cell voltage above 8V caused by anodeffects, summed over a 24-hour period (mV/day).

$$EF = \frac{OVC \times AEO}{CE} \tag{4}$$

Where:

EF	=	Emission factor for CF_4 (kg CF_4/t Al) or C_2F_6 (kg C_2F_6/t Al)
OVC	=	Over-voltage coefficient (kg PFC/t Al)/(mV/cell.day), measured as per details provided in the monitoring section for the existing capacity
AEO	=	Anode effect over-voltage (mV/cell.day), measured as per details provided in the monitoring section for the existing capacity
CE	=	Aluminium production process current efficiency (%), measured as per details provided in the monitoring section for the existing capacity

The CF_4 and C_2F_6 emission factors determined using above value will remain constant throughout all the crediting period. The emission factors and the results of the measurements should be documented transparently in the CDM-PDD.

<u>Tier 2 Method: based on anode effect performance</u>

If measurement data are not available to determine smelter-specific slope or over-voltage coefficients, default coefficients may be used together with smelter-specific operating parameters (CE, AVO, AED, and AEF). Good practice default coefficients are listed in Table 1, Default coefficients for the calculation of PFC emissions from aluminium production (Tier 2 Methods).

number of cells operating across the smelter over a certain period of days multiplied by the number of days in the period.'

[8] The 'cell.day' term really means 'the number of cells operating multiplied by the number of days of operation.' At a smelter this would more usually be calculated (for a certain period of time, e.g. a month or a year) using 'the average number of cells operating across the smelter over a certain period of days multiplied by the number of days in the period.'

Table 2: Technology-specific relationship between emissions & operating parameters based on default technology-based slope and over-voltage coefficients based on 2006 IPCC Guidelines for National Greenhouse Gas Inventories (***to be updated as when new guideline is available***)						
Technology	**Slope Coefficient [(kg PFC/tAl) / (AE-Mins/cellday)**		**Overvoltage Coefficient [(kg CF4/tAl) / (mV)]**		**Weight Fraction C_2F_6 / CF_4**	
	CF_4	**Uncertainty (+/-%)**	**CF_4**	**Uncertainty (+/-%)**	**C_2F_6/CF_4**	**Uncertainty (+/-%)**
CWPB	0.143	6	1.16	24	0.121	11
SWPB	0.272	15	2.65	43	0.252	23
VSS	0.0 - 92	17	NR	NR	0.053	15
HSS	0.099	44	NR	NR	0.085	48

Note 1: In order to determine the emission factor, along with the data from above table, the historic data on over-voltage (AEO) and CE or duration (AED), frequency (AEF) and CE, would be needed to estimate emission factor. The historic data is used to estimate the average of a quantity of values (corresponding to weekly or monthly data of the cells working all days in average and with, commonly, three shifts per day) and its standard deviation. To account for uncertainty use the 95% confidence interval (applying a Student's t-distribution for á degrees of freedom) values to estimate the emission factors. The lower or upper bound of 95% for a particular variable should be so chosen to result in conservative value of the emission factor. The uncertainty associated with AEF and AED or AEO, when measured, is expected to be low but will depend on computer scan rates (e.g. long scan rates will yield higher uncertainties) and data collection systems at each site. However, statistical error estimates for AEF and AED or AEO should be reported in the CDM-PDD.

Note 2: If tier 2 method is used, in order to ensure conservativeness, the lower limit for the emission factor should be chosen. For example, if using slope method for HSS technology the value of slope chosen from the able should be 0.05544 (= 0.099*(1-0.44)).

Thus, the following list of references is provided:

- IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories (http://www.ipccnggip.iges.or.jp/public/gp/english/3_Industry.pdf). The baseline methodology should always consider the most recent recommendations from IPCC.
- 2006 IPCC Guidelines for National Greenhouse Gas Inventories – Reference Manual Volume 3 (http://www.ipccggip.iges.or.jp/public/gl/invs6b.htm). The methodology should always consider the most recent recommendations from IPCC.
- Draft 2006 IPCC Guidelines for National Greenhouse Gas Inventories.
- USEPA and IAI (2003), Protocol for Measurement of Tetrafluoromethane and Hexafluoroethane from Primary Aluminium Production. U.S. EPA Climate Protection Partnerships Division, Washington, DC (called "Protocol" in this methodology).
- The International Aluminium Institute's report on the aluminium industry's global perfluorocarbon gas emissions reduction programme – results of the 2003 anode effect survey.

2. Baseline emission calculation for GHG emission from power plants supplying electricity:

Baseline emissions due to electric energy consumption are to be determined considering the emissions due to current capacity and expanded capacity.

$$BE_{elec} = (E_{elec,HC} \times MP_{HC} . + E_{benchmark,EC} \times MP_{EC,y} .)\ EF_y \quad \textbf{(5)}$$

If: $E_{consumption,HC} \leq E_{benchmark,HC}$, $E_{elec,CC} = E_{consumption,HC}$

If: $E_{consumption,HC} > E_{benchmark,HC}$, $E_{elec,CC} = E_{benchmark,HC}$

Where:

BE_{elec}	=	GHG emissions due to generation of electricity used in smelting process (tCO_2e/year)
$E_{elec,HC}$	=	Specific electricity consumption for the baseline scenario (MWh/t Al)
$E_{consumption,HC}$	=	Average specific electricity consumption of electrolysis process in smelter based on three years data prior to implementation of project activity (MWh/t Al)
$E_{benchmark,HC}$	=	Benchmark average specific electricity consumption of electrolysis process in smelter for existing technology from IAI energy benchmarking statistics (MWh/t Al)
$E_{benchmark,EC}$	=	Benchmark average specific electricity consumption of electrolysis process in smelter for common practice technology option identified for the extended capacity from IAI energy benchmarking statistics (MWh/t Al)
MP_{HC}	=	Historic aluminium production (t Al/year)
$MP_{EC,y}$	=	Aluminium production over and above historic production (t Al/year) in year 'y', estimated using equation 2.1 above.
EF_y	=	Emission factor of the electricity supply source (tCO_2/kWh) in year 'y'. In case the source of Electricity is grid, this factor is termed as $EF_{y,grid}$. If the supply of source is captive power plant, this factor is termed as $EF_{y,CAP}$. Where the supply is from both the sources, use equation 8 to calculate the emission factor.

In case the supply source is single power plant/ captive power plant then $EF_{y,CAP}$ is calculated as:

$$EF_{y,CAP} = \frac{\sum_i F_{i,y}.COEF_i}{GEN_y} \quad \textbf{(6)}$$

Where:

$EF_{y,CAP}$		Emission factor of the electricity supply source (tCO2/MWh)
$F_{i,y}$	=	Amount of fuel i (in a mass or volume unit) consumed by power source in the year 'y'
$COEF_i$	=	CO2 emission coefficient of fuel i (tCO_2/ mass or volume unit of the fuel),
GEN_y	=	Electricity (MWh) generated in the year 'y'

The CO2 emission coefficient $COEF_i$ is obtained as

$$COEF_i = NCV_i \times EF_{CO2,i} \quad \textbf{(7)}$$

Where:

NCV_i	Net calorific value (energy content) per mass or volume unit of a fuel *i*
$EF_{CO2,i}$	CO2 emission factor per unit of energy of the fuel i.

In case the supply source is grid then EF_y is calculated as defined in latest version of approved "tool for estimating grid emission factor".

For units where both grid and captive generation are used, EF_y would be calculated as follows :

$$EF_y = \frac{\left(EF_{y,grid} \times EC_{y,grid} + EF_{y,CAP} \times EC_{y,CAP}\right)}{EC_{y,grid} + EC_{y,CAP}} \quad \textbf{(8)}$$

Where:

$EF_{y,grid}$	=	Emission factor of the grid (tCO_2/MWh) in year 'y'
$EC_{y,grid}$	=	Electricity consumption from the grid in the unit (MWh) in year 'y'
$EF_{y,CAP}$	=	Emission factor for captive power generated as determined by equation (5) above (tCO_2/MWh) in year 'y'
$EF_{y,CAP}$	=	Electricity consumption from captive power in the unit (MWh) in year 'y'

The ex post baseline calculation would be done based on ex post monitoring of *aluminium production, emission factors* and measured value of *energy consumption*. The ex post estimates would be arrived at using one year average data before start of the project activity.

Project Emissions

The project emissions PE, (tCO_2e/year) are given as follows:

$$PE_{GHG} = PE_{PFC} + PE_{elec} \quad \textbf{(9)}$$

Where:

PE_{GHG}	=	Project emission of GHGs from smelting process (tCO_{2e}/year)
PE_{PFC}	=	Project emissions of PFC (CF_4 & C_2F_6) from anode effects (tCO_{2e}/year)
PE_{elec}	=	Emissions of the power plants supplying electricity to the pots under project scenario (tCO_{2e}/year)

3. Project emission calculation for PFC emission from anode effects:

$$PE_{PFC} = (EF_{CF_4} \times GWP_{CF_4} + EF_{C_2F_6} \times GWP_{C_2F_6})MP_y \quad \textbf{(10)}$$

Where:

PE_{PFC}	=	Project emissions of PFC (CF_4 & C_2F_6) from anode effects (tCO_{2e}/year)
EF_{CF_4}	=	Emission factor of CF_4 (tCF_4/t Al), adjusted by the uncertainty range as specified by the IAI/USEPA Protocol
$EF_{C_2F_6}$	=	Emission factor of C_2F_6 (tC_2F_6/t Al) = weight as expressed in table 2 above multiplied by EF_{CF_4}, adjusted by the uncertainty range as specified by the IAI/USEPA Protocol.
GWP_{CF_4}	=	Global Warming Potential of CF_4 = 6,500
$GWP_{C_2F_6}$	=	Global Warming Potential of C_2F_6 = 9,200

MP_y = Total aluminium production of the project activity (t Al/year) in year 'y'

The Tier 3 method (slope or over voltage) shall be used to estimate the project emissions. The corresponding data needed is described in the monitoring section.

4. Project emission calculation for GHG emission from power plants supplying electricity:

PE_{elec} Is estimated using the "tool to calculate project emissions from consumption of electricity".

Leakage

Reductions in process emissions at the aluminium plant is not expected to cause any leakage unless the project involves purchase of green anode (prebake) from outside the project boundary, in which case transport emission should be identified.

$$LE_y = L_{An\_trans} \quad \textbf{(11)}$$

Where:

L_{An_trans} = Leakage due to transportation of the green anode

$$L_{An\_trans,y} = \left(\sum_i \frac{D_{An\_source,i,y} * TEF * AN_y}{Q_{An,y} \times 1000} \right) \quad \textbf{(12)}$$

Where:

$L_{An\_trans,y}$ = Transport related emissions per tonne of green anode consumed (tCO_2 in year y)

$D_{An\_source,i,y}$ = Round trip distance by transport mode *i* between the source of green anode and the project activity plant (km/trip)

=

TEF = Emission factor for transport fuel (kg CO2/km) (IPCC default values)

$Q_{An,y}$ = Quantity of green anode carried in one trip per transport mode (ton of anode) in year 'y'

AN_y = Annual consumption of green anode in year y. (ton of Anode)

Emission reductions

Assessment of emission reductions should be calculated ex ante, using an estimated value for BE_{GHG} corresponding to emissions prior to project implementation, and shall be reported in the PDD submitted for validation.

Emission reductions are calculated as follows:

$$ER_y = BE_y - PE_y - LE_y \quad \textbf{(13)}$$

Where:

ER_y	=	Emission reductions during the year *y* (tCO_2/yr)
BE_y	=	Baseline emissions during the year *y* (tCO_2/yr)
PE_y	=	Project emissions during the year *y* (tCO_2/yr)
LE_y	=	Leakage emissions during the year *y* (tCO_2/yr)

Changes required for methodology implementation in 2nd and 3rd crediting periods

Baseline selection and alternatives available to project participants taking into account national and/or sectoral policies in host countries, IPCC default values and the methodological approach need to be rechecked and defined for implementation on 2nd and 3rd crediting periods. Further, end of lifetime of the potlines included within the project boundary should also be considered while selecting the crediting period. This needs to be done for assessing the continued validity of the baseline and updating the baseline

Data and parameters not monitored

To obtain the baseline scenario slope coefficient [(kg PFC/t Al)/(AE-minute/cell.day)] or over-voltage coefficient [(kg PFC/t Al)/(mV/cell.day)] a measurement as per the IAI protocol shall be performed prior to project implementation (tier 3 method). In using the method historical data of the plant (AEO and CE or AEF and AED) shall be used to estimate CF4 and C2F6 emission factors and reported in the PDD, which shall be validated by the DOE. These emissions factors shall remain constant throughout all the crediting period.

To determine baseline emissions, if measurement data are not available to determine smelter-specific Slope or Over-voltage coefficients, default coefficients may be used together with smelter-specific operating parameters. Good practice default coefficients are listed in Table 2 above, Default Coefficients for the Calculation of PFC Emissions from Aluminium Production (tier 2 method).

Data/ Parameter:	$BE_{IAI,HC}$
Data unit:	(tCO2e/tAl)
Description:	Average value of "PFC emission per tonne of Aluminium produced" according to the most recent published IAI Survey for the current technology (t CO_2e/tAl). Baseline should be updated every year with the most recent values published by IAI.
Source of data:	The International aluminium Institutes' Report On The Aluminium Industry's Global Perflurocarbon Gas Emissions Reduction Programme, available at www.world-aluminium.org.
Measurement procedures (if any):	
Any comment:	Most recent IAI survey should be referred

Data/ Parameter:	$BE_{IAI,EC}$
Data unit:	(tCO2e/tAl)
Description:	Average value of "PFC emission per tonne of aluminium produced" according to the most recent published IAI Survey for the identified technology for the expanded capacity as project alternative. Baseline should be updated every year with the most recent values published by IAI.
Source of data:	The International aluminium Institutes' Report On The Aluminium Industry's Global Perflurocarbon Gas Emissions Reduction Programme, available at www.world-aluminium.org.
Measurement procedures (if any):	
Any comment:	Most recent IAI survey should be referred

Data/ Parameter:	$E_{benchmark,EC}$
Data unit:	(MWh/t Al)
Description:	Benchmark specific electricity consumption of electrolysis process in smelter for technology option for the extended capacity from IAI energy benchmarking statistics.
Source of data:	The International aluminium Institutes' Report On The Aluminium Industry's Global Perflurocarbon Gas Emissions Reduction Programme, available at www.world-aluminium.org.
Measurement procedures (if any):	
Any comment:	Most recent IAI survey should be referred

Data/ Parameter:	$E_{benchmark,HC}$
Data unit:	(MWh/t Al)
Description:	Benchmark specific electricity consumption of electrolysis process in smelter for existing technology from IAI energy benchmarking statistics (kWh/t Al)
Source of data:	The International aluminium Institutes' Report On The Aluminium Industry's Global Perflurocarbon Gas Emissions Reduction Programme, available at www.world-aluminium.org.
Measurement procedures (if any):	
Any comment:	Most recent IAI survey should be referred

Data/ Parameter:	$E_{consumption,HC}$
Data unit:	(MWh/t Al)
Description:	Average specific electricity consumption of electrolysis process in smelter based on three years data prior to implementation of project activity (MWh/t Al)
Source of data:	Plant Records
Measurement procedures (if any):	
Any comment:	

Parameter:	$EF_{CO2,i}$
Data unit:	tCO_2/ unit of energy of fuel *i*
Description:	CO2 emission factor per unit of energy of the fuel *i*.
Source of data:	National data or most recent IPCC guidelines should be referred
Measurement procedures (if any):	
Any comment:	Preference should be give to national data, if available.

Parameter:	NCV_i
Data unit:	Unit of energy/unit mass or volume of fuel *i*
Description:	Net calorific value (energy content) per mass or volume unit of a fuel *i*
Source of data:	National data or most recent IPCC guidelines should be referred
Measurement procedures (if any):	
Any comment:	Preference should be give to national data, if available.

Parameter:	GWP_{CF_4}
Data unit:	
Description:	Global Warming Potential of CF_4
Source of data:	IPCC Second Assessment Report
Measurement procedures (if any):	
Any comment:	

Parameter:	$GWP_{C_2F_6}$
Data unit:	
Description:	Global Warming Potential of C_2F_6
Source of data:	IPCC Second Assessment Report
Measurement procedures (if any):	
Any comment:	

Data / Parameter:	TEF
Data unit:	(tCO2/kM)
Description:	Emission factor for transport fuel (kg CO2/km)
Source of data:	IPCC default values
Measurement procedures (if any):	IPCC default value would be cross-checked from records of vehicle km and fuel consumption based on a sample of vehicles. In case the actual value is higher than IPCC default value, the actual value shall be used.
Monitoring frequency:	Yearly
QA/QC procedures:	
Any comment:	Most recent IPCC guidelines

Data / Parameter:	MP_{HC}
Data unit:	(tAl/year)
Description:	Maximum annual historic Aluminium production based on 3 years production (tAl/year)
Source of data:	Plant records/ balance sheets
Measurement procedures (if any):	
Monitoring frequency:	Yearly
QA/QC procedures:	
Any comment:	

III. MONITORING METHODOLOGY

Monitoring procedures

All monitoring procedures must be in accordance with references as follows :

- For PFC measurements - the USEPA and IAI "Protocol for Measurement of Tetrafluoromethane and Hexafluoroethane from Primary Aluminium Production".
- For all other Aluminium smelter related emissions with the exception of emissions from power consumption the WRI/WBCSD, GHG protocol has been used. For data sources, quality control and uncertainty assessment, the methodology refers to Section 8 "Managing Inventory Quality", Section 9 Reporting GHG emissions and Section 10 Verification of GHG emissions, Appendices A and B of the "Greenhouse Gas Emissions Monitoring and Reporting by the Aluminium Industry" of The Aluminium Sector Greenhouse Gas Protocol (Addendum to the WBCSD/WRI Greenhouse Gas Protocol), May 2003 - Greenhouse Gas Emissions Monitoring and Reporting by the Aluminium Industry. Source - http://www.ghgprotocol.org/
- IPCC, Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories, Sources, http://www.ipccnggip.iges.or.jp/public/gp/pdf/3_Industry.pdf.

Project emissions are determined by multiplying aluminium production with the post-project implementation emission factors for PFCs. Post project emission factors are determined by measuring Current Efficiency (CE) and Anode Effect Frequency and Duration (AEF and AED) or Anode Effect Over-voltage (AEO) and using slope coefficients or over-voltage coefficients based on PFC on-site measurements.

To obtain the project activity slope coefficient [(kg PFC/t Al)/(AE-minute/cell.day)] or over-voltage coefficient [(kg PFC/t Al)/(mV/cell.day)] a measurement shall be performed each three years (tier 3 method). By using historical data of the plant (AEO — or AEF and AED — and CE) and the coefficient measured, ex-ante CF_4 and C_2F_6 emission factors are set and will remain constant until a new measurement is conducted (every three years or less).

Data and parameters monitored

Data / Parameter:	**MP_y**
Data unit:	tAl/year
Description:	Total aluminium production per year
Source of data:	Smelter
Measurement procedures (if any):	Measured and checked with financial accounting figures and MIS
Monitoring frequency:	Daily
QA/QC procedures:	100% data would be measured and monitored. The aluminium smelting plant should of series of internal check procedures including scheduled calibration to ensure low uncertainties of the data produced during monitoring.
Any comment:	

Data / Parameter:	**CE**
Data unit:	Unit used for slope method is fraction and for overvoltage method is %
Description:	Current efficiency of Aluminium production process
Source of data:	Smelter plant
Measurement procedures (if any):	In accordance with Protocol for measurement of Tetrafluoromethane (CF4) and Hexafluoroethane (C2F6) Emissions from Primary AluminiumAluminium Production, USEPA and IAI, May 2003
Monitoring frequency:	Monthly
QA/QC procedures:	100% data would be measured and monitored, The aluminium plant should have a series of internal procedures that ensures data have low uncertainties during monitoring process
Any comment:	

Data / Parameter:	**AEO**
Data unit:	Mv/Cell.day
Description:	Anode effect over voltage
Source of data:	Smelter plant
Measurement procedures (if any):	In accordance with Protocol for measurement of Tetrafluoromethane (CF4) and Hexafluoroethane (C2F6) Emissions from Primary Aluminium Production, USEPA and IAI, May 2003
Monitoring frequency:	Daily
QA/QC procedures:	100% data would be measured and monitored, The aluminium plant should have a series of internal procedures that ensures data have low uncertainties during monitoring process
Any comment:	Required when overvoltage method is used for PFC estimation

Data / Parameter:	**AEF**
Data unit:	Number of anode effects per cell.day
Description:	Anode effect frequency
Source of data:	Smelter plant
Measurement procedures (if any):	In accordance with Protocol for measurement of Tetrafluoromethane (CF4) and Hexafluoroethane (C2F6) Emissions from Primary Aluminium Production, USEPA and IAI, May 2003
Monitoring frequency:	Daily
QA/QC procedures:	100% data would be measured and monitored, The aluminium plant should have a series of internal procedures that ensures data have low uncertainties during monitoring process
Any comment:	Required when slope method is used for PFC estimation

Data / Parameter:	**AED**
Data unit:	(min)
Description:	Anode effect duration
Source of data:	Smelter plant
Measurement procedures (if any):	In accordance with Protocol for measurement of Tetrafluoromethane (CF4) and Hexafluoroethane (C2F6) Emissions from Primary Aluminium Production, USEPA and IAI, May 2003
Monitoring frequency:	Daily
QA/QC procedures:	100% data would be measured and monitored. The aluminium plant should have a series of internal procedures that ensures data have low uncertainties during monitoring process
Any comment:	Required when slope method is used for PFC estimation

Data / Parameter:	**Slope coefficient**
Data unit:	[(kg PFC/t Al)/(AE- minutes/cell.day)
Description:	Slope Coefficient
Source of data:	Smelter plant
Measurement procedures (if any):	In accordance with Protocol for measurement of Tetrafluoromethane (CF4) and Hexafluoroethane (C2F6) Emissions from Primary Aluminium Production, USEPA and IAI, May 2003
Monitoring frequency:	Every 3 year, or less according to the "protocol"
QA/QC procedures:	At least 15 anode effects should be measured and monitored. The uncertainity level of data is medium. The aluminium plant should follow QA/QC procedures described in page 32, section 8 of the Protocol.
Any comment:	Refer to instruction in page 34, section 10 of the protocol.

Data / Parameter:	**Over-voltage coefficient**
Data unit:	[(kg PFC/t Al)/(mV/cell.day)]
Description:	Over-voltage Coefficient
Source of data:	Aluminium/ Smelter plant
Measurement procedures (if any):	In accordance with Protocol for measurement of Tetrafluoromethane (CF4) and Hexafluoroethane (C2F6) Emissions from Primary Aluminium Production, USEPA and IAI, May 2003
Monitoring frequency:	Every 3 year, or as per "protocol"
QA/QC procedures:	The aluminium plant should follow QA/QC procedures described in page 32, section 8 of the Protocol.
Any comment:	Refer to instruction in page 34, section 10 of the protocol.

Data / Parameter:	$\mathbf{EF_{CF4}}$
Data unit:	Kg CF_4/t Al
Description:	Emission factor of CF_4
Source of data:	Anode effect over voltage (AEO), Anode Effect Frequency (AEF) and Anode Effect Duration (AED) onsite measurements in order to introduce in the corresponding equations of IPCC Methods.
Measurement procedures (if any):	In accordance with Protocol for measurement of Tetrafluoromethane (CF4) Emissions from Primary Aluminium Production, USEPA and IAI, May 2003
Monitoring frequency:	Every 3 year, or as per "protocol Monthly
QA/QC procedures:	Uncertainty level of data is Low. The aluminium smelting plant should of series of internal check procedures including scheduled calibration to ensure low uncertainties of the data produced during monitoring.
Any comment:	

Data / Parameter:	$\mathbf{EF_{C2F6}}$
Data unit:	Kg C_2F_6/t Al
Description:	Emission factor of C2F6
Source of data:	AEO, AEF and AED on-site measurements in order to introduce in the corresponding equations of IPCC Methods. IPCC suggests using 1/10 of $\mathbf{EF_{CF4}}$
Measurement procedures (if any):	In accordance with Protocol for measurement of Hexafluoroethane (C_2F_6) Emissions from Primary Aluminium Production, USEPA and IAI, May 2003
Monitoring frequency:	Every 3 year, or as per "protocol"
QA/QC procedures:	Uncertainty level of data is Low. The aluminium smelting plant should of series of internal check procedures including scheduled calibration to ensure low uncertainties of the data produced during monitoring.
Any comment:	

Data / Parameter:	$E_{consumption,y}$
Data unit:	(MWh/t Al)
Description:	Yearly Specific electricity consumption
Source of data:	Smelter
Measurement procedures (if any):	Calculated from measured kWh consumption of alternating current and tonnes of aluminium
Monitoring frequency:	Monthly
QA/QC procedures:	The aluminium plant should have a series of internal procedures that ensures data have low uncertainties during monitoring process.
Any comment:	

Data / Parameter:	$EC_{y,cap}$
Data unit:	MWh
Description:	consumption from captive power in the unit (MWh)
Source of data:	Power plant
Measurement procedures (if any):	Calculated from measured kWh consumption
Monitoring frequency:	Monthly
QA/QC procedures:	The aluminium plant should have a series of internal procedures that ensures data have low uncertainties during monitoring process.
Any comment:	

Data / Parameter:	$EC_{y,grid}$
Data unit:	MWh
Description:	Electricity consumption from the grid in the unit (MWh)
Source of data:	Grid Data
Measurement procedures (if any):	Calculated from measured kWh consumption
Monitoring frequency:	Monthly
QA/QC procedures:	The aluminium plant should have a series of internal procedures that ensures data have low uncertainties during monitoring process.
Any comment:	

Data / Parameter:	$EC_{y,CAP}$
Data unit:	MWh
Description:	Electricity consumption from captive power in the unit (MWh) in year ‘y’
Source of data:	Power plant
Measurement procedures (if any):	Calculated from measured kWh consumption
Monitoring frequency:	Monthly
QA/QC procedures:	The aluminium plant should have a series of internal procedures that ensures data have low uncertainties during monitoring process.
Any comment:	

Data / Parameter:	$\mathbf{EF_{y\ (grid)}}$
Data unit:	(tCO_2/MWh)
Description:	CO_2 emission factor for grid electricity during the year y
Source of data:	Use the latest approved "Tool to calculate emission factor for electricity systems".
Measurement procedures (if any):	Calculated
Monitoring frequency:	Either once at the start of the project activity or updated annually, consistent with guidance in "tool for estimating of grid emission factor".
QA/QC procedures:	Apply procedures in "Tool for calculation of emission factor for electricity systems"
Any comment:	All data and parameters to determine the grid electricity emission factor, as "Tool for calculation of emission factor for electricity systems" shall be included in the monitoring plan.

Data / Parameter:	$\mathbf{EF_{y,cap}}$
Data unit:	(tCO2/MWh)
Description:	Emission factor of the electricity supply source
Source of data:	Power plant supplying electricity to smelter
Measurement procedures (if any):	In case of only captive power, calculated based on total fuel consumption at the captive power plant, and the total generation.
Monitoring frequency:	Yearly
QA/QC procedures:	This data would be calculated. The aluminium smelting plant should of series of internal check procedures including scheduled calibration to ensure low uncertainties of the data produced during monitoring.
Any comment:	For supply from grid, data available in public domain to be used for calculation

Data / Parameter:	$\mathbf{F_{i,y}}$
Data unit:	(tCO2/MWh)
Description:	Amount of fuel i (in a mass or volume unit) consumed by power source in the year 'y'
Source of data:	Power plant supplying electricity to smelter
Measurement procedures (if any):	In case of only captive power total fuel consumption at the captive power plant, is measured on mass or volume basis.
Monitoring frequency:	Yearly
QA/QC procedures:	This data would be calculated. The aluminium smelting plant should of series of internal check procedures including scheduled calibration to ensure low uncertainties of the data produced during monitoring.
Any comment:	For supply from grid, data available in public domain to be used for calculation

Data / Parameter:	GEN_y
Data unit:	(MWh/yr)
Description:	Electricity (MWh) generated in the year 'y'
Source of data:	Power plant supplying electricity to smelter
Measurement procedures (if any):	In case of only captive powertotal electricity generation recorded by energy meter continuously.
Monitoring frequency:	Yearly
QA/QC procedures:	This data would be calculated. The aluminium smelting plant should of series of internal check procedures including scheduled calibration to ensure low uncertainties of the data produced during monitoring.
Any comment:	For supply from grid, data available in public domain to be used for calculation

Data / Parameter:	$\mathbf{AN_y}$
Data unit:	(Ton Anode/year)
Description:	Annual consumption of green anode in year y. (ton of Anode)
Source of data:	Smelter
Measurement procedures (if any):	Measured
Monitoring frequency:	Yearly
QA/QC procedures:	100% data would be monitored. The aluminium smelting plant should conduct of series of internal check procedures including scheduled calibration to ensure low uncertainties of the data produced during monitoring.
Any comment:	Data to be crossed check with material supply, production and material receipt data.

Data / Parameter:	$\mathbf{Q_{AN,y}}$
Data unit:	Ton Anode/vehicle/ rail/ ship
Description:	Quantity of green anode carried in one trip per transport mode (ton of anode) in year 'y'
Source of data:	Smelter
Measurement procedures (if any):	Estimated
Monitoring frequency:	Yearly
QA/QC procedures:	100% data would be monitored. The aluminium smelting plant should conduct of series of internal check procedures including scheduled calibration to ensure low uncertainties of the data produced during monitoring.
Any comment:	

Data / Parameter:	$D_{An\ source,i,y}$
Data unit:	Km
Description:	Round trip distance covered by transport mode *i* between the source of green anode and the project activity plant (km/trip)
Source of data:	Smelter.
Measurement procedures (if any):	Estimated
Monitoring frequency:	Yearly
QA/QC procedures:	100% data would be monitored.
Any comment:	Crossed check with transporters if external.

References and any other information

IPCC (1996a), Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories, Greenhouse Gas Inventory Reporting Instructions
IPCC (1996b), Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories, Greenhouse Gas Inventory Workbook
IPCC (1996c), Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories, Greenhouse Gas Inventory Reference Manual
IPCC (2002), Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories, Section 3.3, PFC Emissions from Aluminium Production, http://www.ipccnggip.iges.or.jp/public/gp/pdf/3_Industry.pdf
IPCC (2006), 2006 IPCC Guidelines for National Greenhouse Gas Inventories
USEPA (1999), International Efforts to Reduce Perfluorocarbon (PFC) Emissions from Primary Aluminium Production. Air and Radiation Office. USEPA 430-R-99-001
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IAI (2002), The Aluminium Sector Greenhouse Gas Protocol, Greenhouse Gas Emissions Monitoring And Reporting by the Aluminium Industry, International Aluminium Institute, London, UK
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History of the document

Version	Date	Nature of revision(s)
01	EB 35, Annex 3, 19 October 2007	Initial adoption