



**CLEAN DEVELOPMENT MECHANISM  
PROPOSED NEW METHODOLOGY: BASELINE (CDM-NMB)  
Version 01 - in effect as of: 1 July 2004**

**CONTENTS**

- A. Identification of methodology
- B. Overall summary description
- C. Choice of and justification as of baseline approach
- D. Explanation and justification of the proposed new baseline methodology.
- E. Data sources and assumptions
- F. Assessment of uncertainties
- G. Explanation of how the baseline methodology allows for the development of baselines in a transparent and conservative manner

**SECTION A. Identification of methodology****A.1. Proposed methodology title:**

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Changes in industrial processes, energy efficiency, fuel switching, self-generation, and cogeneration equipment at an aluminium smelting facility.

**A.2. List of category(ies) of project activity to which the methodology may apply:**

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The UNFCCC CDM web site appears not to provide a list of categories of project activities, from which one might choose that applicable for this proposed new methodology.

Using the “Sectoral Scope” classification as applied to Designated Operational Entities, the category would be (9) Metal production.

A more specific category of project activity might be as indicated in the proposed methodology title.

**A.3. Conditions under which the methodology is applicable to CDM project activities:**

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This methodology would apply to the case where the project activity involves any one or any combination of the following activities at an aluminium smelting facility:

- Improvements in the smelting process
- Changes in the energy efficiency of any equipment using electricity
- Fuel switching involved with any on-site power generation equipment
- Addition of, or changes in, electricity self-generation equipment
- Addition of, or changes in, electricity cogeneration equipment
- Changes in energy efficiency (fuel saving) of any equipment using fuels

**A.4. What are the potential strengths and weaknesses of this proposed new methodology?**

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The potential strengths of the proposed new methodology include the following:

- It is applicable to a number of types of possible mitigation activities in aluminium smelting
- It is straightforward to apply

The potential weaknesses of the proposed new methodology include the following:

- The uncertainty associated with Anode Effect Frequency (AEF) and Anode Effect Duration (AED) or Anode Effect Over-voltage (AEO) measurements is expected to be low, but it 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 shall be reported in the PDD.

**SECTION B. Overall summary description:**

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The methodology considers process emissions of all GHGs at an aluminium smelting facility or a specific part of the facility where project activities are implemented, both in the baseline and the project scenarios. Two PFCs, tetrafluoromethane (CF<sub>4</sub>), and hexafluoroethane (C<sub>2</sub>F<sub>6</sub>) are known to be emitted from the process of primary aluminium smelting. These PFCs are formed during the phenomenon known as anode effect (AE), when the aluminium oxide concentration in the reduction cell electrolyte is low.



SF<sub>6</sub> is infrequently used as a cover gas only for special foundry products. Since SF<sub>6</sub> is assumed to be inert, SF<sub>6</sub> emissions should equal consumption at the industrial facility.

Carbon dioxide emissions are the result of reactions at the carbon anode, Na<sub>2</sub>CO<sub>3</sub> used in the process, and internal transport at the industrial facility. Electricity purchased from the grid results in emissions elsewhere in the power grid and any electricity sold from the industrial facility through the grid reduces such emissions. If the project activities include either: (a) improvements in electricity efficiency in the manufacture of aluminium or (b) increased electricity generation or cogeneration at the industrial site, or both, power plant emissions would decrease as a result of the project activity. Thus power plant emissions are proportional to *net* electricity purchases in the baseline and project scenarios. Any fuels used at the industrial facility to generate electricity or prebake anode production would produce emissions from combustion. Any such emissions would be included in the baseline and project scenarios. This new methodology incorporates the following procedures and methodologies:

- Draft consolidated tools for the demonstration of additionality (Version 3 Sept. 2004, published as Annex 3 to EB 15 Report).
- Approved consolidated baseline methodology ACM0002 “Consolidated baseline methodology for grid-connected electricity generation from renewable sources.”

**SECTION C. Choice of and justification as to why one of the baseline approaches listed in paragraph 48 of CDM modalities and procedures is considered to be the most appropriate:**

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**C.1. General baseline approach:**

- ☒ Existing actual or historical emissions, as applicable;
- ☐ Emissions from a technology that represents an economically attractive course of action, taking into account barriers to investment;
- ☐ The average emissions of similar project activities undertaken in the previous five years, in similar social, economic, environmental and technological circumstances, and whose performance is among the top 20 per cent of their category.

**C.2. Justification of why the approach chosen in C.1 above is considered the most appropriate:**

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The approach chosen is more appropriate since the methodology may be applied to facilities using any one of several technologies commonly used in aluminium smelting (CWPB, SWPB, PFPB, HSS, and VSS) comprising both prebake and Söderberg technologies. Moreover, project activities may involve a combination of technologies so that no single technology can be used as a reference, as required in the second option. For the same reason, each project within the proposed set of applicable project activities is likely to be unique and cannot be readily identified with “similar” project activities elsewhere. The first option “existing actual or historical emissions” involves data that are uniquely determined.

**SECTION D. Explanation and justification of the proposed new baseline methodology:**



**D.1. Explanation of how the methodology determines the baseline scenario (that is, indicate the scenario that reasonably represents the anthropogenic emissions by sources of greenhouse gases (GHG) that would occur in the absence of the proposed project activity):**

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The basic assumptions of the baseline methodology are:

- The project activity may involve measures that improve the smelting processes.
- The project activity may involve measures that change energy efficiency of equipment at the industrial facility. These changes are reflected in fuel and electricity savings, use of process heat to self-generate electricity, cogeneration to cover process heat and electricity demand, and fuel switching of the overall aluminium plant.

The first step in determining the baseline scenario is to analyse all options available to project participants. These include the business-as-usual case (considering sectoral policies, usual practices and market circumstances to determine whether this case corresponds to the continuation or not of the current operation of the aluminium industry), the project scenario, and any other scenario that might be applicable.

On the one hand, the project may involve improvements in the smelting process, mainly leading to PFC emission reductions related to anode effect mitigation. For example, the project could introduce technology or process changes. In this specific case, some of the available possibilities include:

- Continuing with the current equipment or pieces of the electrolytic cell without any modification.
- Replacing, adding or modifying equipment used in the electrolytic cell (e.g. technology replacement, anode improvement, external magnetic compensation loop installation, cell current increase, point breaking and feeding system improvement, alumina quality improvement, computer control algorithm implementation, anode/cathode current distribution improvement, metal tapping, anode change operation, anode shape modification, scheduled anode effect elimination, point feeder mechanical reliability improvement, plugged feeder hole improvement) without any other change in the existing aluminium plant.

On the other hand, the project may involve energy efficiency, self-generation, cogeneration, and fuel switching measures, mainly leading to CO<sub>2</sub> emission reductions. Thus, some of the available possibilities include:

- Continuing with fuels currently being used at the aluminium plant and maintaining all equipment currently in use. Existing energy-intensive equipment is expected to have a lifetime exceeding that of the crediting period.
- Making any combination of the above-mentioned measures (e.g. switching fuels without replacing any equipment; replacing, adding or modifying equipment used to generate energy at the aluminium plant without any other change, and so on).
- Replacing, adding or modifying pieces of the electrolytic cell leading to improved energy efficiency.

Finally, combinations of the measures mentioned above give rise to the whole set of possible alternatives. In order to determine the baseline, candidate scenarios to the project activity will be selected from this set and analysed according to the consolidated tools for demonstration of additionality.

Therefore, the choice of the baseline scenario is determined after considering the additionality test described in Section D.3. Legal requirements, economic and financial considerations, and barriers that may favour one or other alternative would affect choice of baseline and project alternatives. In Step 1 of the additionality test, different alternative scenarios shall be considered. The rest of the Steps will give the



possibility to select the most likely scenario as the baseline one. In this way, the same steps used to prove additionality shall be used to determine the baseline scenario.

Once the baseline scenario is selected (whatever it is), baseline emissions are those corresponding to existing actual or historical emissions by sources in the baseline scenario and are consistently calculated according to the processes involved. General considerations were given in Section B above.

## **D.2. Criteria used in developing the proposed baseline methodology:**

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The proposed methodology incorporates a consolidated baseline methodology that has already been approved and a revised draft of consolidated tools for demonstration of additionality:

- ACM0002 “Consolidated baseline methodology for grid-connected electricity generation from renewable sources.”
- Draft consolidated tools for demonstration of additionality (Version 3 Sept. 2004, published as Annex 3 to EB 15 Report).

These procedures and methodologies are applicable without changes and are only referenced in this methodology.

The proposed new methodology also incorporates the following approved methodology:

- AM0008 “Industrial fuel switching from coal and petroleum fuels to natural gas without extension of capacity and lifetime of the facility.”

However, this approved methodology included its own test for additionality. Moreover, it was applicable to fuel switching only to natural gas. Thus, essential aspects of AM0008 have been taken, made more general, and included explicitly within this methodology.

One major aspect of the proposed methodology refers to GHG emissions in the aluminium manufacturing process. Such emissions include:

- Perfluorocarbons (PFCs) from the anode effect,
- Carbon dioxide emissions from reactions at the carbon anode (prebake anode production and anode consumption),
- Carbon dioxide from  $\text{Na}_2\text{CO}_3$  used to correct the ratio of  $\text{AlF}_3/\text{NaF}$  concentrations in the electrolytic bath,
- Sulphur hexafluoride ( $\text{SF}_6$ ) used as a cover gas, as well as
- Carbon dioxide for transport of anode and aluminium within the industrial plant.

The proposed methodology is also applicable to activities that could improve electricity efficiency, as well as electricity self-generation and cogeneration. The impact of such activities on an interconnected power system is similar to that from CDM projects involving renewable electricity generation connected to the grid. The Approved Consolidated Methodology ACM0002 would thus be applicable even though the project does not involve renewable energy. Indeed, this methodology was recommended to be used as part of AM0014, which involves cogeneration of electricity at an industrial facility using a non-renewable fuel.

Finally, electricity generation on site could involve fossil fuels, producing emissions on site from fuel combustion. Any such emissions, and changes from fuel switching and/or changes in electricity generating equipment, are also considered in this methodology. The formulae related to fuel combustion emissions are similar to those in AM0008, which refers to fuel switching at an industrial site.



The proposed methodology also widens the additionality tests incorporated in AM0008, by recommending the use of the Consolidated tools for demonstration of additionality.

We believe that the proposed methodology would be applicable to several types of mitigation options in aluminium smelting industries while remaining simple to use.

**D.3. Explanation of how, through the methodology, it can be demonstrated that a project activity is additional and therefore not the baseline scenario (section B.3 of the CDM-PDD):**

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The methodology proposed here recommends the use of the Draft consolidated tools for demonstration of additionality (Annex 3 to the report of the 15th meeting of the CDM Executive Board, Sept. 2004). While this is still a Draft at the time of preparing this methodology, it should be noted that these tools are based on a review and consolidation of additionality tools presented in a number of new methodologies approved by the CDM Executive Board. Moreover, a previous draft was published and the tools were modified taking into consideration most of the key issues. We expect the final version to be similar to the Draft cited here, and the definitive version should be applied to determine additionality.

**D.4. How national and/or sectoral policies and circumstances can be taken into account by the methodology:**

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The type of activity involves process and equipment changes at aluminium smelting facility. Such changes generally must meet legal requirements, including environmental impact assessment. If the proposed project activity is required by the laws or regulations, it would not be additional. Similarly if there were special incentives to promote project activities similar to those proposed, the activity may not be additional. All these issues are taken into consideration in the Consolidated tools for demonstration of additionality mentioned in section D.3. As a part of that determination, the project proponents are required to:

- Analyse legal requirements and obligations with respect to the project activities.
- Analyse national incentives to promote similar project activities.
- Analyse sectoral policies to promote similar project activities.

**D.5. Project boundary (gases and sources included, physical delineation):**

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The project boundary could encompass the physical, geographical site of the aluminium manufacturing plant including any power plants located on site. Schematically, Figure D.5.1 shows the project boundary, indicating energy flows into the boundary and GHG emissions associated with the manufacturing process as well as fuel combustion within the project boundary. We consider all fuels used to generate electricity both in the baseline scenario and in the project case. The project boundary would be applicable both to the baseline and project scenarios.

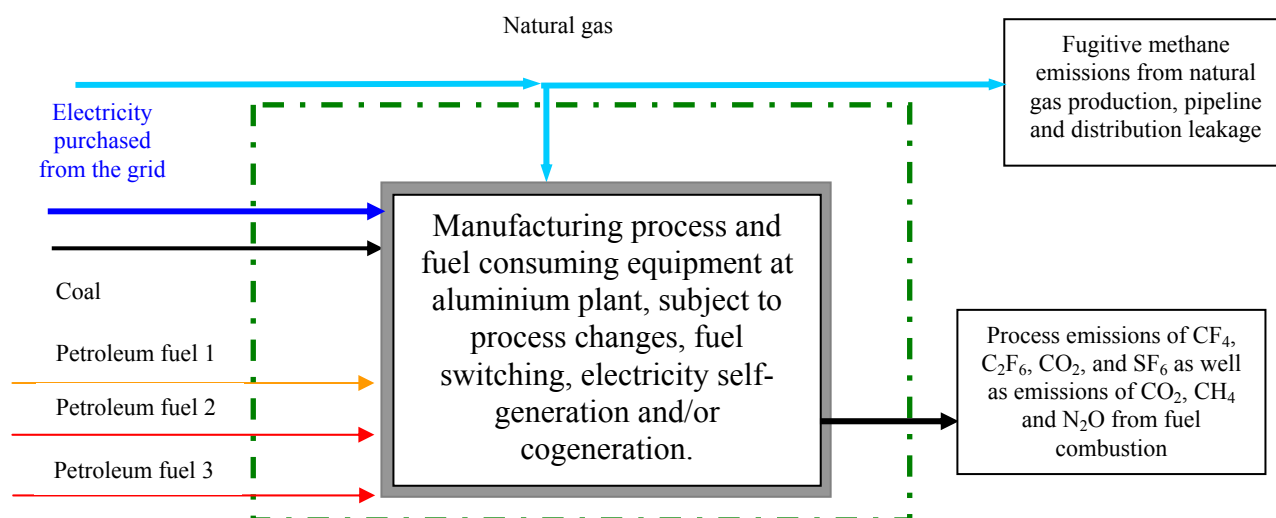


Fig. D.5.1. Project boundary

Alternative project boundaries that are subsets of (i.e. contained within) the project boundary indicated above may also be chosen under certain circumstances. If the project only affects one or two of the mitigation options covered by this methodology, such a smaller project boundary may be applicable. For instance, if the project involves only certain modules of aluminium manufacturing process, then the project boundary can be limited to these modules, provided process emissions from these modules and energy flows in and out of these modules can be accounted for and monitored. In this case, any process changes made in other modules or elsewhere at the plant site, e.g. fuel switching or power plant changes, cannot be included within the CDM project under question. Such other process changes might be presented as a future CDM project provided it meets additionality and other requirements.

**D.6. Elaborate and justify formulae/algorithms used to determine the baseline scenario. Variables, fixed parameters and values have to be reported (e.g. fuel(s) used, fuel consumption rates):**

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The candidates to baseline scenario, which are potentially eligible to use this methodology, are all of scenarios mentioned above in section D.1.

Therefore, baseline emissions  $BE$  (expressed in tonne  $CO_2$  equivalent per year,  $tCO_2e/year$ ) are given by Eq. (1):

$$BE = \sum_i BFC_i (EF_i + MEF_i \cdot GWP(CH_4) + NEF_i \cdot GWP(N_2O)) + (NBEP + NPES) \cdot EF_{elec\ gen} + BE_{PFC} + BE_{CO_2 transport} + BE_{SF_6} + BE_{Na_2CO_3} + \sum_j BE_{CO_2 anode\ j}$$

where:

$BE$	baseline emissions ( $tCO_2e/year$ )
$BFC_i$	consumption of fuel $i$ used in the baseline scenario, measured in energy units (e.g. GJ)
$EF_i$	carbon dioxide emission factor per unit energy of fuel $i$ (e.g. $tCO_2/GJ$ ) (combustion)
$MEF_i$	methane emission factor per unit energy of fuel $i$ (e.g. $tCH_4/GJ$ ) (combustion)



$GWP(CH_4)$	global warming potential of $CH_4$ set as 21 tCO <sub>2</sub> e/tCH <sub>4</sub> for the 1 <sup>st</sup> commitment period
$NEF_i$	nitrous oxide emission factor per unit of energy of fuel $i$ (e.g. tN <sub>2</sub> O/GJ) (combustion)
$GWP(N_2O)$	global warming potential of $N_2O$ set as 310 tCO <sub>2</sub> e/tN <sub>2</sub> O for the 1 <sup>st</sup> commitment period
$NBEP$	net electricity purchased (electricity purchased less electricity sold) through the grid in the baseline (e.g. MWh)
$NPES$	net electricity sold (electricity sold less electricity purchased) through the grid in the <i>project</i> (e.g. MWh)
$EF_{elec\ gen}$	baseline emission factor for grid electricity generation (e.g. kg CO <sub>2</sub> e/MWh)
$BE_{PFC}$	baseline emissions from CF <sub>4</sub> and C <sub>2</sub> F <sub>6</sub> (tCO <sub>2</sub> e)
$BE_{CO_2,transport}$	baseline emissions from internal transport at the industrial facility (tCO <sub>2</sub> e)
$BE_{SF_6}$	baseline emissions from SF <sub>6</sub> consumption (tCO <sub>2</sub> e)
$BE_{Na_2CO_3}$	baseline emissions of CO <sub>2</sub> e from Na <sub>2</sub> CO <sub>3</sub> (tCO <sub>2</sub> e)
$\sum_j BE_{CO_2,anode\ j}$	Prebake technology = $BE_{CO_2,anode} + BE_{CO_2\ from\ pitch\ cooking} + BE_{CO_2\ from\ packing\ coke}$
	Söderberg technology = $BE_{CO_2,anode\ Soderberg}$
$BE_{CO_2,anode}$	baseline emission from anode consumption (Prebake technology) (tCO <sub>2</sub> e)
$BE_{CO_2\ from\ pitch\ cooking}$	baseline emission from pitch cooking (tCO <sub>2</sub> e)
$BE_{CO_2\ from\ packing\ coke}$	baseline emission from packing coke (tCO <sub>2</sub> e)
$BE_{CO_2,anode\ Soderberg}$	baseline emission from anode consumption (Söderberg technology) (tCO <sub>2</sub> e)

Eq. (2)

A part of baseline emissions correspond to the emissions from fuels burnt at the aluminium plant in the baseline scenario. Electricity purchased through the connected power grid to meet a part or all of the demand at the plant would cause emissions elsewhere in the power grid. Such emissions are included. The emissions associated with grid electric power generation depend on  $NBEP$  and  $EF_{elec\ gen}$ , the emissions factor for electricity generation in the connected power grid. Electricity sales in the project scenario would increase baseline emissions elsewhere in the grid. Thus net electricity sales in the project scenario need to be included in the baseline emissions.

The CDM Executive Board has already approved a consolidated methodology for determining  $EF_{elec\ gen}$ . We recommend the incorporation of this methodology denominated ACM0002 as a component of the proposed new methodology, for the purpose of determining  $EF_{elec\ gen}$ . ACM0002 offers some alternative pathways for determining  $EF_{elec\ gen}$ , and each specific PDD should adopt a specific procedure, according to its circumstances.

Note that ACM0002 is actually designated “Consolidated baseline methodology for grid-connected electricity generation from renewable sources.” When the project involves electricity generation from renewable sources, project emissions for electricity generation are negligible, and the baseline emissions are emissions avoided elsewhere in the power grid. The new methodology being proposed here is related to electricity generation at an aluminium plant using fuels, which need not be renewable. However, the emissions from these fuels are being estimated and counted as part of project emissions, and thus, as far as the baseline is concerned, ACM0002 should be perfectly applicable.





AM0014 offers an alternative procedure for estimating  $EF_{elec\ gen}$ , namely the “Simplified Methodology for Small-scale CDM Project Activities,” which would be applicable in case electricity displaced is less than or equal to 15 MW equivalent.

Thus, this proposed new methodology recommends the use of either ACM0002 or the simplified methodology for small-scale projects, as appropriate.

Process emissions are discussed in detail below.

### **Baseline CO<sub>2</sub> emissions from reactions at the carbon anode: Prebake anode production and Anode consumption**

To calculate the CO<sub>2</sub> emissions evolved from aluminium production processes for Prebake cells, the methodology described in Part A, below, should be used. For Söderberg cells, Part B should be used if the quantity of carbon contained in anode materials is known (weight per reporting period or per unit of production in metric tonnes).<sup>1</sup>

#### **Part A - Carbon dioxide emissions from Prebake cells**

##### **Part A.1 - CO<sub>2</sub> emissions from anode consumption**

Aluminium is produced by the electrolytic reduction of alumina (Al<sub>2</sub>O<sub>3</sub>). During the reduction process the aluminium smelting pot acts as the electrolytic cell. The pot itself forms the cathode, while the anode consists of one or more carbon blocks suspended in it. In the pot, Al<sub>2</sub>O<sub>3</sub> is dissolved in a bath of fluoride salts, consisting primarily of cryolite, Na<sub>3</sub>AlF<sub>6</sub>. Passing electrolysis current through the cell also causes Ohmic heating, which maintains the electrolyte in a liquid state. Molten aluminium is produced while the anode is consumed in the reaction. The aluminium forms at the cathode and gathers at the bottom of the pot. Most carbon dioxide is formed in the reaction of the carbon anode with the oxygen from alumina, but some is also formed by anode oxidation with other sources of oxygen (especially air). The proposed project activity is expected to reduce CO<sub>2</sub> emissions from anode consumption by increasing current efficiency.

Estimated baseline anode CO<sub>2</sub> emissions,  $BE_{CO_2\ anode}$ , are given by:

$$BE_{CO_2\ anode} (tCO_2/year) = BE_{CO_2\ MRA} (tCO_2/year) = Mass\ Reducing\ Agent \cdot 44/12 \quad Eq. (3)$$

where:

$$Mass\ Reducing\ Agent = SCC_{Total} \cdot P_{Al} \quad Eq. (4)$$

$$SCC_{Total} (tCO_2/year) = SCC_{Stoichiometric} + SCC_{CE} + SCC_{Non-electrochemical\ oxidation} \quad Eq. (5)$$

$P_{Al}$  = annual aluminium production (tAl/year)

$SCC_{Stoichiometric}$  = Specific carbon consumption, given by the following reaction:

<sup>1</sup> For the sake of simplicity in order to avoid complex notation, some variables and parameters, which are used for calculating variables of interest, are denoted with the same symbol in the baseline as well as the project scenario.



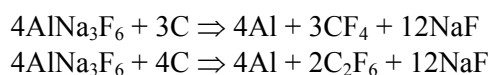
This value is: 333 kgC/tAl.

$SCC_{CE}$  = Specific carbon consumption generated by the current passing through an anode without producing aluminium. Such a value may be estimated by means of the following formula:

$$SCC_{CE} (t\text{CO}_2/\text{year}) = SCC_{\text{Stoichiometric}} (1 - CE)/CE \quad \text{Eq. (7)}$$

Where  $CE$  = current efficiency.

This value includes specific carbon consumption during the anode effect ( $SCC_{AE}$ ), given by the following reactions:



Carbon consumption during the anode effect is determined from the specific generation of  $\text{CF}_4$  and  $\text{C}_2\text{F}_6$  (kgPFC/tAl). This value is extremely low and is accounted for in the PFC emissions. Thus, these values need to be discounted from  $SCC_{CE}$ . The redefined value ( $SCC_{CE*}$ ) is given by the following formula:

$$SCC_{CE*} (t\text{CO}_2/\text{year}) = SCC_{CE} - SCC_{AE} \quad \text{Eq. (8)}$$

$SCC_{\text{Non-electrochemical oxidation}}$  = Carbon consumption produced by air oxidation of the anode. Current circulation causes anode temperature increase, favouring anode oxidation and break-up. Thus there is an additional carbon consumption that is not involved in aluminium production.

Three terms contribute to  $SCC_{\text{Total}}$ , but if the project activity involves only changes in the  $CE$ , only  $SCC_{CE}$  would be affected by it. In this case, *ex ante* calculations of  $\text{CO}_2$  baseline emissions could be obtained from Eq. (3), but since  $SCC_{\text{Stoichiometric}}$  and  $SCC_{\text{Non-electrochemical oxidation}}$  will not change through project implementation, we could redefine baseline  $\text{CO}_2$  emissions as:

$$BE_{\text{CO}_2 \text{ anode}} (t\text{CO}_2/\text{year}) = SCC_{CE*} \cdot P_{Al} \cdot 44/12 \quad \text{Eq. (9)}$$

*Ex ante* baseline emissions will be determined from historical data of  $SCC_{\text{Total}}$  and  $CE$  (these values are set and will remain constant throughout the crediting period). The aluminium company has to indicate how the measurement of  $SCC_{\text{Total}}$  was conducted. The *ex ante* annual aluminium production ( $P_{Al}$ ) will be estimated by the plant for the crediting period.

During the project  $P_{Al}$  will be monitored and then *ex post* baseline emissions will be obtained from Eq. (9).

## Part A.2 - Process carbon dioxide emissions from anode baking furnace

### Part A.2.1. Pitch volatile matter oxidation from pitch cooking



$$BE_{CO_2 \text{ from pitch cooking}} (tCO_2e) = (GWA - BAP - HW - RT / 1000) \cdot 44 / 12$$

and

Eq. (10)

$$HW(t) = H_2 / 100 \cdot PC / 100 \cdot GWA$$

where:

$GWA$  = green anode tonnage (t)

$BAP$  = baked anode production (t)

$HW$  = weight of hydrogen from pitch (t)

$H_2$  = hydrogen content in pitch (wt%) = 4.45

$PC$  = average pitch content (wt%) in green anode = 15

$RT$  = recovered tar (t) = 5 kg/t  $BAP$  for Riedheimer furnace and  
0 kg/t for other furnaces

The baseline emissions will be determined from historical data of  $GWA$ ,  $BAP$  and  $HW$  (these values are set and will remain constant throughout the crediting period).

#### Part A.2.2. Bake pitch volatile matter oxidation from pitch cooking

$$BE_{CO_2 \text{ from packing coke}} (tCO_2e) = [PCC \cdot BAP \cdot (100 - \% Ash_{pc} - \% S_{pc}) / 100] \cdot 44 / 12$$

Eq. (11)

where:

$PCC$  = packing coke consumption per tonne of baked anode ( $t_{coke}/t_{anodes}$ ) = 0.050

$BAP$  = baked anode production (t)

$Ash_{pc}$  = ash content in packing coke (wt%) = 5

$S_{pc}$  = sulphur content in packing coke (wt%) = 3

The baseline emissions will be determined from historical data of  $BAP$  (these values are set and will remain constant throughout the project activity).

**Part B - Søderberg CO<sub>2</sub> emissions from anode consumption (  $BE_{CO_2 \text{ anode Søderberg}}$  )**

$$\begin{aligned}
BE_{CO_2 \text{ anode Søderberg}} (tCO_2e / year) = & [(PC \cdot P_{Al}) - (BSM \cdot P_{Al} / 1000)] \\
& - \{ \%BC / 100 \cdot PC \cdot P_{Al} \cdot [\%S_p + \%Ash_p + (H_2 / 100)] \} \\
& - \{ [(100 - \%BC) / 100] \cdot PC \cdot P_{Al} \cdot [(\%S_c + \%Ash_c) / 100] \} \cdot 44 / 12
\end{aligned} \tag{Eq. (12)}$$

where:

$PC$  = paste consumption (tPaste/tAl)

$BSM$  = emissions of benzene soluble matter (kg/tAl) = 0.5 (VSS)  
= 4.0 (HSS)

$BC$  = average binder content (wt %) in paste = 25 – 30

$S_p$  = sulphur content in pitch (wt %) = 0.55

$Ash_p$  = ash content in pitch (wt %) = 0.15

$H_2$  = hydrogen content (wt %) in pitch = 4.5

$S_c$  = sulphur content in calcinated coke (wt %) = 1.8

$Ash_c$  = ash content in calcinated coke (wt %) = 0.1

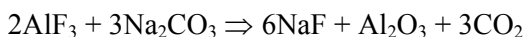
*Ex-ante* baseline emissions will be determined through historical data of  $PC$  (tPaste/tAl, fixing its value for the entire crediting period) and annual aluminium production ( $P_{Al}$ ) from Eq. (12). The plant will estimate *ex-ante*  $P_{Al}$  for the crediting period. During the project,  $P_{Al}$  will be monitored and then *ex post* baseline emissions will be obtained from Eq. (12).

**Note:** Parts A.2 and B of the new methodology are based on “Calculating Direct GHG Emissions from Primary Aluminium Metal Production,” GHG Protocol.

**Emissions of CO<sub>2</sub> from Na<sub>2</sub>CO<sub>3</sub> used in aluminium production processes**

Na<sub>2</sub>CO<sub>3</sub> is used to correct the ratio of AlF<sub>3</sub>/NaF concentrations in the electrolytic bath. The objective is for AlF<sub>3</sub> to be 11% above NaF. After reconstruction of the cathodic coating, pot bottom absorbs NaF increasing AlF<sub>3</sub> proportion in the bath. Na<sub>2</sub>CO<sub>3</sub> is added when surplus of AlF<sub>3</sub> increases for some reason and it is necessary to correct deviation. However, this last cause is not frequent since there are other measures to control deviation.

This circumstance (i.e. high surplus of AlF<sub>3</sub> in the bath) has an effect on the thermal balance of the pot. The temperature of the bath goes down and current performance also decreases. Less aluminium produced per kA passed through the pot. Then Na<sub>2</sub>CO<sub>3</sub> is added to transform AlF<sub>3</sub> into NaF according to the following reaction:



Estimated CO<sub>2</sub> emissions of the baseline,  $BE_{Na_2CO_3}$ , are given by:

$$BE_{Na_2CO_3} (tCO_2) = SC \cdot 44/106 \tag{Eq. (13)}$$

Where:

$SC$  = quantity of soda consumed (t)



The baseline emission will be determined from historic data of  $\text{Na}_2\text{CO}_3$  consumption,  $SC$  (this value is set and will remain constant throughout the project activity).

### **CO<sub>2</sub> emissions from transport**

There are CO<sub>2</sub> emissions from internal transport of anodes and aluminium within the plant location. For each year  $y$ , these emissions are expressed as:

$$BE_{CO_2 \text{ transport}_y} = FT_y \cdot E_{F_y} \quad \text{Eq. (14)}$$

where:

$BE_{CO_2 \text{ transport}_y}$  = CO<sub>2</sub> baseline emissions from internal transport (tCO<sub>2</sub>e/year)

$FT_y$  = Quantity of fuel consumed by the heavy-duty vehicles (MJ/year)

$E_{F_y}$  = Emission factor of fuel consumed by heavy-duty vehicles (tCO<sub>2</sub>e/MJ of fuel)

Where  $FT_y$  can be obtained from:

- (1) Volume of fuel consumed by heavy-duty vehicles (litres/year)
- (2) Fuel density (kg/litre)
- (3) Lower heating value of fuel (MJ/kg)

$$FT_y = (1) \times (2) \times (3) \text{ in MJ/year}$$

The baseline emissions will be determined from historical data of fuel consumption (these values are set and will remain constant throughout the crediting period).

### **Baseline SF<sub>6</sub> emissions**

In the aluminium industry SF<sub>6</sub> is infrequently used as a cover gas only for special foundry products. Since SF<sub>6</sub> is assumed to be inert, SF<sub>6</sub> emissions should equal consumption.

Estimated CO<sub>2</sub>e emissions of the baseline,  $BE_{SF_6}$ , are given by:

$$BE_{SF_6} = \text{Consumption of } SF_6 \quad \text{Eq. (15)}$$

$$\text{Emission of } SF_6 \text{ (tCO}_2\text{e)} = \text{Consumption of } SF_6 \text{ (kg)} \cdot \text{CO}_2 \text{ Conversion Factor (tCO}_2\text{/kgSF}_6\text{)}$$

$$BE_{SF_6} \text{ (tCO}_2\text{e)} = \text{Consumption of } SF_6 \text{ (kg)} \cdot 23.9 \text{ tCO}_2\text{/kgSF}_6$$

The baseline emissions will be determined from historic data of SF<sub>6</sub> consumption (this value is set and will remain constant throughout the crediting period).

### **Baseline PFC emissions**



Estimated baseline PFC emissions,  $BE_{PFC}$ , are given by:

$$BE_{PFC} (tCO_2e / year) = \left( \frac{EF_{CF_4} \cdot GWP_{CF_4} + EF_{C_2F_6} \cdot GWP_{C_2F_6}}{1000} \right) \cdot P_{Al} \quad Eq. (16)$$

where:

- $EF_{CF_4}$  = Emission factor of  $CF_4$  (kg $CF_4$ /tAl)
- $EF_{C_2F_6}$  = Emission factor of  $C_2F_6$  (kg $C_2F_6$ /tAl) = 1/10 of  $BEF_{CF_4}$
- $GWP_{CF_4}$  = Global Warming Potential of  $CF_4$  = 6,500
- $GWP_{C_2F_6}$  = Global Warming Potential of  $C_2F_6$  = 9,200
- $P_{Al}$  = Total aluminium production of the company (tAl/year)

The *IPCC Guidelines* describe three general methods for estimating PFC emission factors from aluminium production (Vol.3, Section 2.13.6, PFCs from Aluminium Production). These three methods correspond to tiers, but are not identified as such. To be consistent with other sections of the *IPCC Guidelines* and the *Good Practice Guidance*, the methods presented in the *IPCC Guidelines* are referred to as tiers in this section. The most accurate method is either to monitor smelter emissions continuously (Tier 3a) or to develop a smelter specific long-term relationship between measured emissions and operating parameters and to apply this relationship using activity data (Tier 3b). The Tier 3b method requires comprehensive measurements to develop the smelter-specific relationship and on-going collection of operating parameter data (e.g. frequency and duration of anode effects and the Anode Effect Over-voltage) and production data. Where a smelter-specific relationship has not been developed but information on operating parameters and production is available, default technology specific slope and over-voltage coefficients may be used (Tier 2). Where the only information available is the annual quantity of aluminium produced, default emission factors by technology type may be used (Tier 1). The level of uncertainty in the Tier 1 method will be much greater than for estimations produced using Tier 3 or Tier 2 methods. For this reason Tier 3 or Tier 2 Methods will be used in this methodology.

### Tier 3a Method – Continuous emission monitoring

Continuous monitoring of emissions is possible and is the most accurate means of determining emissions. Given likely cost and other resource considerations, however, it is not regarded as necessary for *good practice*. For details, see Direct Measurement Techniques, below.

### Direct measurement techniques

Sampling and measurement must be performed to a *good-practice* standard to ensure the accuracy of the data, which means that:

- Measurements of PFCs at smelters should account for both emissions captured by the reduction cell hooding and extracted by the fume exhaust duct, and also fugitive emissions released into the



potroom<sup>2</sup> atmosphere. Ideally, these data can be obtained by direct measurement of PFCs in duct and fugitive emissions. Otherwise, direct measurement of PFCs in duct emissions can be conducted along with careful measurement of the cell hooding capture efficiency, allowing fugitive emissions to be calculated.

- The analytical technology used should be capable of measuring both CF<sub>4</sub> and C<sub>2</sub>F<sub>6</sub> gases simultaneously. Several suitable analytical technologies are available. The technology chosen must have a suitable dynamic range for the measurement of expected concentrations of duct emissions and fugitive emissions. The sensitivity of the detection should be capable of reliable measurement at the lowest levels expected in electrolysis cell exhaust ducts and for fugitive emissions where fugitive emissions account for 5% or more of total PFC emissions. The dynamic range of the measurement device should be capable of reliable measurement to the highest concentration to be measured. For duct emissions, this means a concentration measurement range of 0 to 1000 ppmv (parts per million by volume). Measurements should be normalised for temperature and pressure and these measurement conditions must be reported and recorded with the concentration measurements that will be used when calculating mass emissions.
- Duct volumetric gas flow measurements should be performed according to nationally or internationally recognised standards. Gas flow measurements should be performed during the course of the concentration measurement program at sufficient intervals to ensure accurate representation of the volumetric gas flow. Measurements should be normalised for temperature and pressure and these measurement conditions must be reported and recorded with the flow measurements that will be used when calculating mass emissions.
- Calibration of analytical instruments should be performed at regular intervals during the measurement campaign. The required schedule for calibrations will vary according to the type and known stability of the analytical instrumentation used but must be sufficient to minimise the effect of instrument calibration drift. The results of all calibrations should be reported and recorded with the concentration measurement. Measurements affected by drift should be omitted from emission estimations. Calibration gases should be traceable to recognised national or international standards. The calibration method should be thoroughly documented and recorded with the emission measurements.

### **Tier 3b Method – Smelter-specific relationship between emissions and operating parameters based on field measurements**

This method uses periodic 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<sub>4</sub> and C<sub>2</sub>F<sub>6</sub>. Once established, the relationship can be used along with process data collected on an ongoing basis, to estimate emissions factors over time. These emission factors are multiplied by smelter-specific production (tonnes) to estimate smelter emissions.

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<sup>2</sup> The potroom is the standard industry term for the large room in which the reduction cells or ‘pots’ are housed. The smelting cells have hooding which, depending on the smelter design, age etc., will have varying fume collection efficiency. The collected fume is transported via ducts to a fume scrubbing facility where other pollutants are removed. Fume that escapes from the hooding may either be collected in a fume manifold and also transported to the fume scrubbing facility or exhausted to atmosphere through the potroom roof. Since the potrooms may be up to a kilometre long and 20 metres or more in width, accurate measurements of fugitive emissions may not be feasible. Therefore, measurements of PFCs in collected fume and fugitive fume are required or else measurements of collected fume along with a comprehensive understanding of the fume collection efficiency is required to ensure that PFCs captured by the scrubbing system along with fugitive emissions are included in estimations.



The following estimation relationships can be used:

**Slope Method:** This method uses a linear least squares relationship between anode effect (*AE*) minutes per cell.day<sup>3</sup> and emissions, expressed as an emission factor (*EF*):

$$EF (kg CF_4 \text{ or } C_2F_6 \text{ per tonne of Al}) = Slope \cdot AE \text{ min/cell.day} \quad Eq. (17)$$

To develop an accurate estimate of the slope, simultaneous measurements of emissions and collection of anode effect data over an appropriate period of time are required. The Slope Method is a variant of the **Tabereaux approach** described in the *IPCC Guidelines*. It is recommended that specific CF<sub>4</sub> emissions for anode effects longer than 2 minutes be calculated as follows:

### Tabereaux Approach

$$EF (kg CF_4 \text{ or } C_2F_6 \text{ per tonne of Al}) = Slope \cdot AE \text{ min/cell.day} \quad Eq. (18)$$

$$Slope = 1.698 (p/CE) \quad \text{and} \quad AE \text{ min/cell.day} = AEF \cdot AED$$

where:

*p* = Average fraction of CF<sub>4</sub> in the cell gas during anode effects for the CF<sub>4</sub> slope or Average fraction of C<sub>2</sub>F<sub>6</sub> in the cell gas during anode effects for the C<sub>2</sub>F<sub>6</sub> slope

Prebake: *p* = 0.08 (8%)

Söderberg: *p* = 0.04 (4%)

*CE* = Current Efficiency for the aluminium production process, expressed as a fraction rather than as a percentage

*AEF* = Number of anode effects per cell.day

*AED* = Anode effect duration in minutes

**Pechiney Overvoltage Method:** This method uses the Anode Effect Over-voltage as the relevant process parameter. The Anode Effect Over-voltage is the extra cell voltage, above 8V, caused by anode effects, when averaged over a 24-hour period (mV/day). The correlation formula was derived from measurements of PFC generation at smelters with Pechiney technology, expressed as an emission factor (*EF*):

$$EF (kg CF_4 \text{ or } C_2F_6 \text{ per tonne of Al}) = OVC \cdot AEO/CE \quad Eq. (19)$$

where:

*OVC* = Over-Voltage Coefficient

*AEO* = Anode effect over-voltage in mV/cell.day

*CE* = Aluminium production process current efficiency expressed in percent

<sup>3</sup> 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.'



**Tier 2 Method – Smelter-specific relationship between emissions & operating parameters based on default technology-based slope and over-voltage coefficients**

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 1, Default Coefficients for the Calculation of PFC Emissions from Aluminium Production (Tier 2 Methods).

**Default Coefficients for the Calculation of PFC Emissions form Aluminium Production  
(TIER 2 Methods)**

Technology <sup>a</sup>	Slope <sup>b,d</sup> [(kg <sub>PFC</sub> /tAl)/(AE-Minutes/cell.day)]				Over-voltage coefficient <sup>b</sup> [(kg <sub>PFC</sub> /tAl)/(mV/cell.day)]	
	CF <sub>4</sub>	Uncertainty	C <sub>2</sub> F <sub>6</sub>	Uncertainty	CF <sub>4</sub>	C <sub>2</sub> F <sub>6</sub>
CWPB	0.14	±0.009	0.018	±0.004	1.9	NA
SWPB	0.29	±0.02	0.029	±0.01	1.9	NA
VSS	0.068 <sup>g</sup>	±0.02	0.003	±0.001	See note e	-
HSS	0.18 <sup>f</sup>		0.018		-	-

a Centre Worked Prebaked (CWPB), Side Worked Prebaked (SWPB), Vertical Stud Søderberg (VSS), Horizontal Stud Søderberg (HSS).  
b Source: IPAI, EPA field measurements, and other company measurement data.  
c There is inadequate data for establishing a slope coefficient for C<sub>2</sub>F<sub>6</sub> emissions from SWPB cells based on measurement data; therefore a default of one-tenth of the CF<sub>4</sub> coefficient is *good practice*, consistent with the *IPCC Guidelines*.  
d Embedded in each Slope coefficient is an assumed emissions collection efficiency as follows: CWPB 95%, SWPB 90%, VSS 85%, HSS 90%. These collection efficiencies have been assumed based on expert opinion. While collection efficiency for HSS cells may vary, the company measurement data used for calculation of these coefficients are consistent with a collection efficiency of at least 90%.  
e Overvoltage coefficients are not relevant to VSS and HSS technologies.  
f The HSS Slope coefficients are based on 1991 IPAI survey data.  
g Further work on emission measurement and uncertainty analysis should be pursued for VSS. These default coefficients are based on a small number of data, and it is expected that the uncertainty might be higher than for other coefficients (Bjerke, 1999a, and Bjerke *et al.*, 1999b).  
NA = not available.

By using historical data of the plant (*AEO* –or *AEF* and *AED*– and *CE*), *ex ante* CF<sub>4</sub> and C<sub>2</sub>F<sub>6</sub> emission factors are set and will remain constant through the crediting period. *Ex ante* baseline emissions will be estimated from Eq. (16) using the *ex ante* aluminium production data estimated by the plant for the crediting period.

Following the project  $P_{Al}$  will be monitored and then *ex post* baseline emissions will be obtained from Eq. (16).

**Note:** 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 PDD.

**D.7. Elaborate and justify formulae/algorithms used to determine the emissions from the project activity. Variables, fixed parameters and values have to be reported (e.g. fuel(s) used, fuel consumption rates):**

>>

The project activity could involve a variety of mitigation measures. It could involve changes in order to reduce process PFC or carbon dioxide emissions. Process activities could also involve improved energy efficiency in aluminium production. The project activity may also include increased electricity generation

at the facility with increased export to the connected power grid. Finally, the project activity could involve replacing some or all fossil fuels currently being used by other lower carbon fuels for providing heat and electricity at the industrial facility. Any of these components would reduce GHG emissions compared to the baseline.

The project emissions  $PE$  (tCO<sub>2</sub>e/year) are given by Eq. (20):

$$PE = \sum_i FC_i (EF_i + MEF_i \cdot GWP(CH_4) + NEF_i \cdot GWP(N_2O)) \\ + PE_{PFC} + PE_{Na_2CO_3} + PE_{CO_2 transport} + PE_{SF_6} + \sum_j PE_{CO_2 anode j}$$

$PE$	baseline emissions (tCO <sub>2</sub> e/year)
$FC_i$	consumption of fuel $i$ used in the project scenario, measured in energy units (e.g. GJ)
$EF_i$	carbon dioxide emission factor per unit energy of fuel $i$ (e.g. tCO <sub>2</sub> e/GJ) (combustion)
$MEF_i$	methane emission factor per unit energy of fuel $i$ (e.g. tCH <sub>4</sub> /GJ) (combustion)
$GWP(CH_4)$	global warming potential of CH <sub>4</sub> set as 21 tCO <sub>2</sub> e/tCH <sub>4</sub> for the 1 <sup>st</sup> commitment period
$NEF_i$	nitrous oxide emission factor per unit energy of fuel $i$ (e.g. tN <sub>2</sub> O/GJ) (combustion)
$GWP(N_2O)$	global warming potential of N <sub>2</sub> O set as 310 tCO <sub>2</sub> e/tN <sub>2</sub> O for the 1 <sup>st</sup> commitment period
$PE_{PFC}$	project emissions from CF <sub>4</sub> and C <sub>2</sub> F <sub>6</sub> (tCO <sub>2</sub> e)
$PE_{Na_2CO_3}$	project emissions of CO <sub>2</sub> e from Na <sub>2</sub> CO <sub>3</sub> (tCO <sub>2</sub> e)
$PE_{CO_2 transport}$	project emissions from internal transport in the industrial facility (tCO <sub>2</sub> e)
$PE_{SF_6}$	project emissions from SF <sub>6</sub> consumption (tCO <sub>2</sub> e)
$\sum_j PE_{CO_2 anode j}$	Prebake Technology = $PE_{CO_2 anode} + PE_{CO_2 from pitch cooking} + PE_{CO_2 from packing coke}$ Söderberg technology = $PE_{CO_2 anode Söderberg}$
$PE_{CO_2 anode}$	project emissions from anode consumption (Prebake technology) (tCO <sub>2</sub> e)
$PE_{CO_2 from pitch cooking}$	project emissions from pitch coking (tCO <sub>2</sub> e)
$PE_{CO_2 from packing coke}$	project emissions from packing coke (tCO <sub>2</sub> e)
$PE_{CO_2 anode Söderberg}$	project emissions from anode consumption (tCO <sub>2</sub> e) (Söderberg technology)

The formula for project emissions is very similar to that for baseline emissions, extensively discussed in Section D.6. The main difference is that emissions associated with electricity purchase or sale from the aluminium plant to the power grid are not included in project emissions. While any fuels burnt at the project site may generate electricity, if any electricity were exported from the facility through the connected grid, this would offset emissions elsewhere in the grid. Such emissions are counted in baseline emissions, as also emissions associated with net electricity purchases from the grid in the baseline scenario. Additional details on emissions associated with electricity generation in the power grid outside the project facility, including the methodology to be used in order to estimate such emissions, were presented in D.6.

**Project CO<sub>2</sub> emissions from reactions at the carbon anode: Prebake anode production and Anode consumption****Part A - Electrolysis carbon dioxide emissions from Prebake cells****Part A.1 - CO<sub>2</sub> emissions from anode consumption**

Estimated anode CO<sub>2</sub> emissions of the project,  $PE_{CO_2 \text{ anode}}$ , are given by:

$$PE_{CO_2 \text{ anode}} (tCO_2/year) = PE_{CO_2 \text{ MRA}} (tCO_2/year) = \text{Mass Reducing Agent} \cdot 44/12 \quad \text{Eq. (21)}$$

Three terms contributes to  $SCC_{Total}$ , but if the project activity involves changes in the  $CE$ , only  $SCC_{CE}$  is affected by it. *Ex ante* calculations of project emissions could be obtained from Eq. (21), but  $SCC_{Stoichiometric}$  and  $SCC_{Non-electrochemical \text{ oxidation}}$  will not change over the project life. Thus, only  $SCC_{CE}$  and  $SCC_{AE}$  will need to be monitored. Thus we redefine CO<sub>2</sub> baseline emissions as:

$$PE_{CO_2 \text{ anode}} (tCO_2/year) = SCC_{CE*} \cdot 44/12 \cdot P_{Al} \quad \text{Eq. (22)}$$

*Ex ante* project emissions will be determined from data of  $SCC_{Total}$  and  $CE$  estimated *ex ante* by the plant. *Ex ante* total aluminium production ( $P_{Al}$ ) will be determined by the plant during the crediting period. Following project implementation  $SCC_{Total}$ ,  $CE$ , and  $P_{Al}$  will be monitored, and then *ex post* project emissions will be obtained from Eq. (21) or Eq. (22).

**Part A.2 - Process carbon dioxide emissions from anode baking furnace****Part A.2.1. Pitch volatile matter oxidation from pitch cooking**

$$PE_{CO_2 \text{ from pitch cooking}} (tCO_2e) = (GWA - BAP - HW - RT/1000) \cdot 44/12$$

and Eq. (23)

$$HW(t) = H_2/100 \cdot PC/100 \cdot GWA$$

*Ex ante* project emissions will be determined from data of  $GWA$ ,  $BAP$  and  $HW$  estimated *ex ante* by the plant. Following project implementation  $GWA$ ,  $BAP$  and  $HW$  will be monitored, and then *ex post* project emissions will be obtained from Eq. (23).

**Part A.1.2. Bake pitch volatile matter oxidation from pitch cooking**

$$PE_{CO_2 \text{ from packing coke}} (tCO_2e) = [PCC \cdot BAP \cdot (100 - \%Ash_{pc} - \%S_{pc})/100] \cdot 44/12 \quad \text{Eq. (24)}$$

*Ex ante* project emissions will be determined from data of  $BAP$  estimated *ex ante* by the plant. Following project implementation  $BAP$  will be monitored, and then *ex post* project emissions will be obtained from Eq. (24).

**Part B - Söderberg CO<sub>2</sub> emissions from anode consumption ( $BE_{CO_2 \text{ anode Söderberg}}$ )**



$$\begin{aligned}
PE_{CO_2 \text{ anode Söderberg}} (tCO_2e / year) = & [(PC \cdot P_{Al}) - (BSM \cdot P_{Al} / 1000)] - \\
& \{ \%BC / 100 \cdot PC \cdot P_{Al} \cdot [\%S_p + \%Ash_p + (H_2 / 100)] \} - \\
& - \{ [(100 - \%BC) / 100] \cdot PC \cdot P_{Al} \cdot [(\%S_c + \%Ash_c) / 100] \} \cdot 44 / 12
\end{aligned}
\tag{Eq. (25)}$$

*Ex ante* project emissions will be determined through data of PC ( $tPaste/P_{Al}$ ) and annual aluminium production ( $P_{Al}$ ). The plant will determine *ex ante*  $P_{Al}$  and  $tPaste$  for the crediting period. Following project implementation  $P_{Al}$  and PC ( $tPaste/P_{Al}$ ) will be monitored, and then *ex post* project emissions will be obtained from Eq. (25).

### **Project emissions of CO<sub>2</sub> from Na<sub>2</sub>CO<sub>3</sub> used in aluminium production processes**

Estimated CO<sub>2</sub> emissions of the baseline,  $PE_{Na_2CO_3}$ , are given by:

$$PE_{Na_2CO_3} (tCO_2) = SC \cdot 44 / 106 \tag{Eq. (26)}$$

where:

SC = quantity of soda consumed ( $t$ )

*Ex ante* project emissions will be determined through data of Na<sub>2</sub>CO<sub>3</sub> consumption estimated *ex ante* by the plant. Following project implementation Na<sub>2</sub>CO<sub>3</sub> consumption will be monitored, and then *ex post* project emissions will be obtained from Eq. (26).

### **Project CO<sub>2</sub> emissions from transport**

$$PE_{CO_2 \text{ transport}_y} = FT_y \cdot E - F_y \tag{Eq. (27)}$$

*Ex ante* project emissions will be determined through fuel consumption data estimated *ex ante* by the plant. Following project implementation fuel consumption will be monitored, and *ex post* project emissions will be obtained from Eq. (27).

### **Project SF<sub>6</sub> emissions**

Estimated project CO<sub>2e</sub> emissions,  $PE_{SF_6}$ , are given by:

$$PE_{SF_6} = \text{Consumption of } SF_6 \tag{Eq. (28)}$$

$$\text{Emission of } SF_6 (tCO_2e) = \text{Consumption of } SF_6 (kg) \cdot CO_2 \text{ Conversion Factor } (tCO_2/kgSF_6)$$

$$PE_{SF_6} (tCO_2e) = \text{Consumption of } SF_6 (kg) \cdot 23.9 tCO_2/kgSF_6$$

*Ex-ante* project emissions will be determined through data of SF<sub>6</sub> consumption estimated *ex ante* by the plant. Following project implementation SF<sub>6</sub> consumption will be monitored, and *ex-post* project emissions will be obtained from Eq. (28).

**Project PFC emissions**

Estimated PFC emissions of the project,  $PE_{PFC}$ , are given by:

$$PE_{PFC} (tCO_{2e} / year) = \left( \frac{EF_{CF_4} \cdot GWP_{CF_4} + EF_{C_2F_6} \cdot GWP_{C_2F_6}}{1000} \right) \cdot P_{Al} \quad Eq. (29)$$

where the terms have the same meaning as in Eq. (16).

For *ex-ante* calculation of project PFC emissions, the PDD will have to provide a justified estimation of the future values of *AEO* (or *AEF* and *AED*) and *CE*. The future production of aluminum will be estimated for the crediting period by the plant. *Ex-post* emissions of the project are obtained by placing the monitored values, *AEO*, *CE* and  $P_{Al}$ , in the Eq. (29).

**D.8. Description of how the baseline methodology addresses any potential leakage of the project activity:**

>>

Reductions in process emissions at the aluminium plant will not cause any leakage.

One possible source of leakage is in changes in fuel use patterns whereby there is increased fugitive emissions associated with increased fuel use at the industrial site and/or where there are increased energy consumption associated with fuel transport. These are considered below, in a manner similar to that in AM0008.

Fugitive  $CH_4$  emissions from fuel production and  $CO_2$  emissions from fuel transportation are categorized as leakage. Emissions from fuel production/transportation is counted only if the fuel is produced/transported in a non-Annex I country.

The leakage  $LE_y$  is expressed as

$$LE = (FC_i - BFC_i) \cdot FE_i(CH_4) \cdot GWP(CH_4) + \sum_j TF_j \cdot EF_j - \sum_k BTF_k \cdot EF_k \quad Eq. (30)$$

where  $FE_i(CH_4)$  is the IPCC default methane emission factor of fuel  $i$  associated with fugitive emissions. Typical fuels might be natural gas and coal. Fugitive methane emissions are associated with natural gas production and pipeline leakage. Fugitive methane emissions are also associated with coal mining. In case that the effect of these methane emissions cannot be neglected, they should be included here.

The second line in the above formula refers to emissions from fuel transportation, shown as a product of the transportation fuels used and the corresponding  $CO_2$  emissions factor for the fuel. The first sum applies to transport fuels used in the project scenario while the second sum corresponds to the baseline scenario (such as marine, railroad or truck). In case those information and data are not available due to uncertainties and diversities in energy market, the IPCC default value could apply. Otherwise, it could be estimated qualitatively in view of the relatively small magnitude of  $CO_2$  emissions from fuel transportation in typical industrial fuels, and in potential CDM projects at aluminium manufacturing plants.



**D.9. Elaborate and justify formulae/algorithms used to determine the emissions reductions from the project activity. Variables, fixed parameters and values have to be reported (e.g. fuel(s) used, fuel consumption rates):**

>>

The emission reduction  $ER$  by the project activity is given by:

$$ER = BE - PE - LE \quad \text{Eq. (31)}$$

expressed in tonnes of CO<sub>2</sub> equivalent (tCO<sub>2</sub>e/year).

Total emission reductions should be calculated *ex ante*, using an estimated value for  $BE$ , corresponding to emissions prior to project implementation. The estimation of total emission reductions shall be reported in the PDD submitted for validation.

## SECTION E. Data sources and assumptions:

**E.1. Describe parameters and or assumptions (including emission factors and activity levels):**

>>

The parameters are listed together with data sources in section E.2, below.

**E.2. List of data used indicating sources (e.g. official statistics, expert judgement, proprietary data, IPCC, commercial and scientific literature) and precise references and justify the appropriateness of the choice of such data:**

>>

Moreover, the determination of baseline and project emissions depends on the values of the following parameters, whose sources are given below:

Symbol	Definition	Data source (in order of preference) and justification
$EF_i$	carbon dioxide emission factor per unit energy of fuel $i$ (e.g. tCO <sub>2</sub> /GJ) (combustion)	<ol style="list-style-type: none"> <li>1. National inventory of GHG emissions, prepared as part of National Communications to the UNFCCC or other official documents. This is the most important emissions factor and thus needs to be based on the most reliable and specific data source as possible.</li> <li>2. On-site measurements of carbon content and calorific value of fuels. This would be recommended for fuels where there is significant variation in properties and/or when the fuel is not widely commercialised.</li> <li>3. IPCC default emissions factors. This is the last choice, and should be used only where data from other sources are not available.</li> </ol>
$MEF_i$	methane emission factor per unit energy of fuel $i$ (e.g. tCH <sub>4</sub> /GJ) (combustion)	IPCC default values. Methane emissions from fuel combustion are likely to be insignificant so that standard values should suffice to provide an adequate estimate.



$NEF_i$	nitrous oxide emission factor per unit of energy of fuel $i$ (e.g. tN <sub>2</sub> O/GJ) (combustion)	IPCC default values. Nitrous oxide emissions from fuel combustion are likely to be insignificant so that standard values should suffice to provide an adequate estimate.
$EF_{elec\ gen}$	baseline emission factor for grid electricity generation (e.g. kg CO <sub>2</sub> e/MWh)	Determined using either: <ul style="list-style-type: none"> <li>▪ ACM0002 Approved consolidated methodology for grid-connected renewable electricity generation from renewable sources.</li> <li>▪ (for generation less than 15 MW) Simplified methodology for small-scale CDM project activities.</li> </ul>
$EF_{CF_4}$	Emission factor of CF <sub>4</sub> (kgCF <sub>4</sub> /tAl)	<ol style="list-style-type: none"> <li>1. CF<sub>4</sub> on-site measurements</li> <li>2. AEO, AEF and AED on-site measurements in order to introduce in the corresponding equations of IPCC Methods.</li> <li>3. IPCC default emissions factors. This is the last choice, and should be used only where data from other sources are not available.</li> </ol>
$EF_{C_2F_6}$	Emission factor of C <sub>2</sub> F <sub>6</sub> (kgC <sub>2</sub> F <sub>6</sub> /tAl)	<ol style="list-style-type: none"> <li>1. CF<sub>4</sub> on-site measurements</li> <li>2. AEO, AEF and AED on-site measurements in order to introduce in the corresponding equations of IPCC Methods. IPCC suggest to use 1/10 of <math>EF_{CF_4}</math></li> <li>3. IPCC default emissions factors. This is the last choice, and should be used only where data from other sources are not available.</li> </ol>
$OVC$	Over-voltage coefficient [(kgPFC/tAl)/(mV/cell.day)]	<ol style="list-style-type: none"> <li>1. OVC on-site measurements</li> <li>2. IPCC default emissions factors</li> </ol>
$Slope$	Slope [(kgPFC/tAl)/(AE-Minutes/cell.day)]	<ol style="list-style-type: none"> <li>1. OVC on-site measurements</li> <li>2. IPCC default emissions factors</li> </ol>

Emissions from grid-connected electricity generation require data that are specified in ACM0002, and depend on the specific methodological option chosen among various alternatives proposed therein.

Leakage calculations require estimates of fugitive methane emissions from fuel production. Since these are likely to be small compared to other components of baseline and project emissions, default values from IPCC may be chosen to make these estimates.

Leakage calculations also require estimates of fuel consumption for fuel transport, where applicable. These need to be estimated on the basis of fuel intensity of the transport mode and distances involved, and fuel-specific CO<sub>2</sub> emissions factors, all based on IPCC default values. Again, this is justified since these emissions are likely to be small.

### **E.3. Vintage of data (e.g. relative to starting date of the project activity):**

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Aluminium production, electricity and fuel consumption data are required for three years prior to project implementation in order to determine *ex ante* baseline emissions.

**E.4. Spatial level of data (local, regional, national):**

&gt;&gt;

Production data, process parameters, fuel consumption and equipment efficiency data all correspond to the industrial facility. Parameters needed to determine the emissions factor for grid-connected electricity generation depend on the power plants connected to the grid in question.

**SECTION F. Assessment of uncertainties (sensitivity to key factors and assumptions):**

&gt;&gt;

The most important components of emissions are associated with the manufacturing process. Where the project activity involves process changes, these emissions need to be determined with reliable methods. Section D.6 has indicated preferable and acceptable methods for estimating PFC and process CO<sub>2</sub> emissions. Fuel CO<sub>2</sub> emissions depend on fuel consumption at the industrial facility prior to and following project implementation, and the CO<sub>2</sub> emissions factor of the fuels involved. These variables and parameters are very well known.

One potentially large source of emissions and emissions reductions is associated with grid-connected power generation. The methodology proposed here is the approved consolidated methodology ACM0002. This ACM includes multiple options for determining the emissions factor for grid-connected electricity. The result is likely to be sensitive to the option chosen.

**SECTION G. Explanation of how the baseline methodology allows for the development of baselines in a transparent and conservative manner:**

&gt;&gt;

All equations that make up the determination of baseline emissions are straightforward and transparent.

The uncertainty associated with Anode Effect Frequency (*AEF*) and Anode Effect Duration (*AED*) or Anode Effect Over-voltage (*AEO*) measurements is expected to be low, but it 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* shall be reported in the PDD.

Wherever data limitations might exist, this methodology proposes alternative procedures and, in case of doubt, how to make conservative assumptions.

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