



## Approved baseline methodology ACM0003

### “Emissions reduction through partial substitution of fossil fuels with alternative fuels in cement manufacture”

#### Source

This methodology is based on two cases “Replacement of Fossil Fuel by Palm Kernel Shell biomass in the production of Portland cement” NM0040, prepared by Lafarge Asia, and “Indocement’s Sustainable cement Production Project” NM0048-rev, prepared by Indocement. For more information regarding the proposals and their consideration by the Executive Board please refer to cases NM0040 and NM0048-rev on <http://cdm.unfccc.int/methodologies/PAmethodologies/approved.html>.

#### Selected approach from paragraph 48 of the CDM modalities and procedures

“Emissions from a technology that represents an economically attractive course of action, taking into account barriers to investment”

#### Applicability

The methodology is applicable to the cement industry with the following conditions:

- Fossil fuel(s) used in cement manufacture are partially replaced by alternative fuels, including renewable biomass<sup>1</sup>, where renewable biomass residues are in surplus and leakages in other uses of the renewable biomass will not occur;
- CO<sub>2</sub> emissions reduction relates to CO<sub>2</sub> emissions generated from fuel burning requirements only and is unrelated to the CO<sub>2</sub> emissions from decarbonisation of raw materials (i.e. CaCO<sub>3</sub> and MgCO<sub>3</sub> bearing minerals);
- The methodology is applicable only for installed capacity (expressed in tonnes clinker/year) that exists by the time of validation of the project activity;
- The amount of alternative fuels available for the project is at least 1.5 times the amount required to meet the consumption of all users consuming the same alternative fuels, i.e. the project and other alternative fuel users.

This baseline methodology shall be used in conjunction with the approved monitoring methodology ACM0003 (“Monitoring methodology for emissions reduction through partial substitution of fossil fuels with alternative fuels in cement manufacture”).

#### Project boundary

The physical project boundary covers all production processes related to clinker production. The specific production step associated with GHG emissions that will define the project boundary primarily includes pyro-processing. In terms of gases covered, within the project boundary only CO<sub>2</sub> emissions from the combustion of fuels are considered, because the cement manufacturing process involves high combustion temperatures and long residence times that would limit production of other GHG emissions.

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<sup>1</sup> Renewable biomass residues are such that they do not contribute to global warming. The Executive Board may further define renewable biomass based on recommendations from the Meth Panel and the AR WG.

## Baseline scenario selection

### 1. *Define alternative scenarios for the fuel mix*

- Define a continuation of current practice scenario, i.e. a scenario in which the company continues cement production using the existing technology, materials and fuel mix. Quantify the amount of fossil fuel(s) that would be used for clinker production over the project period.
- Define scenario(s) reflecting the likely evolving fuel mix portfolios, and relative prices of fuels available.<sup>2</sup> The scenario(s) may be based on one fuel or a different mixes of fuels. Quantify the amount of fossil fuel(s) that is expected to be used for clinker production over the project period.
- Define a scenario in which traditional fuels are partially substituted with alternative fuels (i.e. the proposed project). If relevant, develop different scenarios with different mix of alternative fuels and varying degrees of fuel-switch from traditional to alternative fuels. These scenarios should reflect all relevant policies and regulations<sup>3</sup>. Quantify the amounts of fossil fuels and alternative fuels that would be used for clinker production over the project period.

### 2. *Option 1: Select baseline scenario through financial analysis*

The baseline scenario defines the most likely situation in the absence of the proposed project. A key assumption of this methodology is that the cement company is taking decisions to maximise its revenues. The baseline scenario for a fuel-switch project implemented in the cement sector, therefore, should be selected from among the alternative scenarios by conducting the following financial tests:

- Calculate the financial costs (e.g. capital and variable costs) of the different alternatives.
- For all relevant project scenarios, compare the scenarios on the basis of NPV, IRR, or an alternative indicator of financial attractiveness of investment. Compute the financial indicator using net incremental cash flow but excluding potential CER revenue.
- Based upon this comparison, select the most cost-effective scenario from the list of alternative scenarios. The scenario with the most attractive economics, as measured by the chosen financial indicator (e.g. highest IRR, highest NPV), should be selected as the baseline scenario.
- A sensitivity analysis should be performed to assess the robustness of the selection of the most likely future scenario to reasonable variations in critical assumptions and to establish that the project is not the baseline. The financial indicator is calculated conservatively if assumptions tend to make the CDM project's indicators more attractive and the alternatives' indicators less attractive.

The baseline scenario should take into account relevant national/local and sectoral policies and circumstances, and the proponent should demonstrate that the key factors, assumptions and parameters of the baseline scenario are conservative.

### *Option 2: Select baseline scenario through barriers analysis*

The baseline scenario defines the most likely situation in the absence of the proposed project.

Each fuel selection scenario should be processed via the barriers analysis step of the latest version of the "**Tool for demonstration assessment and of additionality**" agreed by the CDM Executive Board, which is available on the UNFCCC CDM web site<sup>4</sup>.

<sup>2</sup> If relevant, construction of a new cement kiln or plant using alternative fuels could be included as a possible scenario. Note that the clinker production capacity should remain constant.

<sup>3</sup> Please refer to Executive Board guidance on national policies

<<http://cdm.unfccc.int/EB/Meetings/016/eb16repan3.pdf>>

<sup>4</sup> Please refer to: <<http://cdm.unfccc.int/methodologies/PAmethodologies/approved.html>>



The baseline scenario should take into account relevant national/local and sectoral policies and circumstances, and the proponent should demonstrate that the key factors, assumptions and parameters of the baseline scenario are conservative.

### Additionality

*The additionality of the project activity shall be demonstrated and assessed using the latest version of the “Tool for the demonstration and assessment of additionality” agreed by the CDM Executive Board, which is available on the UNFCCC CDM web site<sup>5</sup>.*

### Baseline and project emissions calculations

The project reduces CO<sub>2</sub> emissions from burning fossil fuel in cement kilns.

CH<sub>4</sub> emissions from kilns are negligible and are ignored. The project activity also generates CO<sub>2</sub>, CH<sub>4</sub>, and N<sub>2</sub>O emissions due to on-site transportation of biomass and other alternative fuels.

Other emissions outside of the project boundary include CH<sub>4</sub> emissions from burning of biomass in open fields and CH<sub>4</sub> emissions due to anaerobic decomposition of wastes in landfills in the baseline. These are covered under the section on leakage. Emissions of CO<sub>2</sub>, CH<sub>4</sub>, and N<sub>2</sub>O due to off-site transport and preparation of alternative fuels and fossil fuels to the cement plants are also addressed in the leakage section below.

#### **Step 1.** Calculate project heat input from alternative fuels

Heat input from alternative fuels with significant moisture content is calculated first to allow for the calculation of a project-specific moisture “penalty” for alternative fuel heat input requirements.

$$HI_{AF} = \sum Q_{AF} \times HV_{AF} \quad (1)$$

where:

HI<sub>AF</sub> = heat input from alternative fuels (TJ/yr)

Q<sub>AF</sub> = quantity of each alternative fuel (tonnes/yr)

HV<sub>AF</sub> = lower heating value of the alternative fuel(s) used (TJ/tonne fuel).

#### **Step 2.** Calculate alternative heat input as a share of total baseline fossil fuel heat input

(2)

$$S_{AF} = \frac{HI_{AF}}{(\sum Q_{FF} \times HV_{FF}) + HI_{AF}}$$

where:

S<sub>AF</sub> = alternative heat input share of total baseline fossil fuel heat input

HI<sub>AF</sub> = heat input from alternative fuels (TJ/yr)

Q<sub>FF</sub> = quantity of each fossil fuel used in baseline (tonnes/yr)

HV<sub>FF</sub> = lower heating value of the fossil fuel(s) used in baseline (TJ/tonne fuel).

<sup>5</sup> Please refer to: < <http://cdm.unfccc.int/methodologies/PAmethodologies/approved.html> >

**Step 3.** Application of project specific moisture “penalty”

A project specific “penalty” is applied, because the combustion of typically coarser biomass and other alternative fuels, as opposed to more finely ground coal, will reduce the heat transfer efficiency in the cement manufacturing process. This will therefore require a greater heat input to produce the same quantity and quality of cement clinker. The chemical content and ease of absorption into cement clinker of all fuel ashes also differs, and this also contributes to the need for a project specific penalty.

This project specific penalty (*mp*) should be determined by a comparison heat and mass balance for the cement manufacturing equipment when producing equal quantity and quality of cement clinker with and

without alternative fuels. This penalty can be determined at an average % alternative fuel replacement and expressed as a relationship between the amounts of alternative fuel fired as % of total fuel input vs. amount of cement clinker produced. For example, for cement process requiring 3.3 MJ/kg cement clinker during baseline conditions and 3.4 MJ/kg cement clinker when using 10% of alternative fuel, the penalty is 0.1 MJ/kg clinker per 10% alternative fuel used. The product of this and the mass of clinker produced results in an absolute heat penalty per 10% alternative fuel for this specific alternative fuel in this specific process.

(3)

$$mp = \frac{HC_{AF}(i) - HC_{FF}}{S_i} \times 10$$

where:

*mp* = moisture penalty (MJ/tonne/10% alternative fuel share of total heat input)  
 $HC_{AF}(i)$  = specific heat consumption using *i* % alternative fuel (MJ/tonne clinker)  
 $HC_{FF}$  = specific heat consumption using fossil fuels only (MJ/tonne clinker)  
 $S_i$  = alternative fuel heat input share of total baseline heat input in the moisture penalty test

The total moisture penalty is therefore calculated as follows:

(4)

$$MP_{Total} = \frac{S_{AF}}{10\%} \times C \times mp$$

where:

$MP_{total}$  = total moisture penalty (TJ/yr)  
 $S_{AF}$  = alternative fuel heat input share of total baseline heat input  
*C* = total clinker production (tonnes/yr)  
*mp* = moisture penalty (MJ/tonne-10% alternative fuel share of total heat input)

**Step 4** Calculate GHG emissions from the use of alternative fuels in kilns:

$$AF_{GHG} = \sum(Q_{AF} * HV_{AF} * EF_{AF}) \quad (5)$$

where:

$AF_{GHG}$  = GHG emissions from alternative fuels (tCO<sub>2e</sub>/yr)  
 $Q_{AF}$  = monitored alternative fuels input in clinker production (tonnes/yr).  
 $HV_{AF}$  = heating value(s) of the alternative fuel(s) used (TJ/tonne fuel).  
 $EF_{AF}$  = emission factor(s) of alternative fuel(s) used (tCO<sub>2e</sub>/TJ).



When several alternative fuels are burned, the GHG emissions from each fuel are aggregated to determine  $AF_{GHG}$  using respective heating values and emission factors.

For biomass fuels, unless it is clearly demonstrated and documented that biomass consumed by the project will decompose anaerobically, it should be assumed that the biomass would be burned.  $CO_2$  emissions from biomass burning should be considered  $CO_2$ -neutral, i.e. these emissions are part of the natural carbon cycle because the carbon released to the atmosphere during burning is reabsorbed during the next growing season. To be conservative,  $N_2O$  and  $CH_4$  emissions from stockpiled biomass should be ignored.

For non-biogenic carbon (e.g. tires, plastics, textiles, and rubber/leather), unless it can be clearly demonstrated that incineration of these alternative fuels is the dominant practice in the area(s) from which the alternative fuels in the project activity are sourced,  $CO_2$  emissions from these fuels should be included in project emissions. If these wastes are incinerated in the host country (in the baseline scenario), then they should be considered as  $CO_2$ -neutral fuels, unless the heat generated in the incineration plant is used for heating or electricity generation purposes. In this latter case,  $CO_2$  emissions from these fuels are to be included in project emissions.

**Step 5.** Calculate the baseline GHG emissions from the fossil fuel(s) displaced by the alternative fuel(s)

$$FF_{GHG} = [(Q_{AF} * HV_{AF}) - MP_{total}] * EF_{FF} \quad (6)$$

where:

|                    |   |  |
|--------------------|---|--|
| $FF_{GHG}$         | = | GHG emissions from fossil fuels displaced by the alternatives (tCO <sub>2</sub> /yr) |
| $Q_{AF} * HV_{AF}$ | = | total actual heat provided by all alternative fuels (TJ/yr)                          |
| $MP_{total}$       | = | total moisture penalty (TJ/yr)   |
| $EF_{FF}$          | = | emissions factor(s) for fossil fuel(s) displaced (tCO <sub>2</sub> /TJ).             |

$EF_{FF}$  is the estimated baseline value and would be the lowest of the following  $CO_2$  emission factors :

- the weighted average annual  $CO_2$  emission factor for the fossil fuel(s) consumed and monitored ex ante during the year before the validation,
- the weighted average annual  $CO_2$  emission factor for the fossil fuel(s) consumed and monitored during the corresponding verification period (e.g. the period during which the emission reductions to be certified have been achieved),
- the weighted average annual  $CO_2$  emission factor for the fossil fuel(s) that would have been consumed according to the baseline scenario determined in section 1 and 2 of the “Additionality and baseline scenario selection” section above.

**Step 6.** Calculate GHG emissions due to on-site transportation and drying of alternative fuels

(7)

$$OT_{GHG} = OF_{AF} * (VEF_{CO_2} + VEF_{CH_4} * GWP_{CH_4}/1000 + VEF_{N_2O} * GWP_{N_2O}/1000) + (FD * FD_{HV} * VEF_D)$$

where:

|              |   |  |
|--------------|---|--|
| $OT_{GHG}$   | = | GHG emissions from on-site transport and drying of alternative fuels (tCO <sub>2e</sub> /yr) |
| $OF_{AF}$    | = | transportation fuel used for alternative fuels on-site during the year (t/yr),               |
| $VEF_{CO_2}$ | = | $CO_2$ emission factor for the transportation fuel (tCO <sub>2</sub> /tonne),                |
| $VEF_{CH_4}$ | = | $CH_4$ emission factor for the transportation fuel (kg $CH_4$ /tonne),                       |
| $VEF_{N_2O}$ | = | $N_2O$ emission factor for the transportation fuel (kg $N_2O$ /tonne),                       |
| $GWP_{CH_4}$ | = | global warming potential for $CH_4$ (21),  |



|                               |   |  |
|-------------------------------|---|--|
| GWP <sub>N<sub>2</sub>O</sub> | = | global warming potential for N <sub>2</sub> O (310),               |
| FD                            | = | fuel used for drying alternative fuels (t/yr),                     |
| FD <sub>HV</sub>              | = | heating value of the fuel used for drying (TJ/t fuel), and         |
| VEF <sub>D</sub>              | = | emission factor of the fuel used for drying (tCO <sub>2</sub> /TJ) |

**Step 7.** Calculate emission savings from reduction of on-site transport of fossil fuels

$$OT\_GHG_{FF} = OF_{FF} * EF_{T\ CO_2e} \quad (8)$$

where:

|                                 |   |  |
|---------------------------------|---|--|
| OT-GHG <sub>FF</sub>            | = | emissions from reduction of on-site transport of fossil fuels (tCO <sub>2e</sub> ) |
| OF <sub>FF</sub>                | = | fuel saving from on-site transportation of fossil fuels (t/yr)                     |
| EF <sub>T CO<sub>2e</sub></sub> | = | emission factor of fuel used for transportation (tCO <sub>2e</sub> /t fuel),       |

### Leakage

Leakage emissions considered are methane emissions due to biomass that would be burned or decomposed anaerobically in landfills in the absence of the project, as well as CO<sub>2</sub> emissions from off-site transport of fuels to the cement plant and off-site preparation of alternative fuels.

Another potential source of leakage is that the project may deprive other users of alternative fuels and thereby increase fossil fuel use. To ensure that the proposed project activity will not reduce the amount of alternative fuels available to other alternative fuels users, the project proponent should demonstrate that the amount of alternative fuels is 1.5 times the amount required to meet the consumption of all users consuming the same alternative fuels, i.e. the project and other alternative fuel users.

**Step 1.** Calculate CH<sub>4</sub> emissions due to biomass that would be burned in the absence of the project

$$BB_{CH_4} = Q_{AF-B} * BCF * CH_4F * CH_4/C * GWP_{CH_4} \quad (9)$$

where:

|                               |   |   |
|-------------------------------|---|---|
| BB <sub>CH<sub>4</sub></sub>  | = | GHG emissions due to burning of biomass that is used as alternative fuel (tCO <sub>2e</sub> /yr)                              |
| Q <sub>AF-B</sub>             | = | amount of biomass used as alternative fuel that would have been burned in the open field in the absence of the project (t/yr) |
| BCF                           | = | carbon fraction of the biomass fuel (tC/t biomass) estimated on basis of default values,                                      |
| CH <sub>4</sub> F             | = | fraction of the carbon released as CH <sub>4</sub> in open air burning (expressed as a fraction), <sup>6</sup>                |
| CH <sub>4</sub> /C            | = | mass conversion factor for carbon to methane (16 tCH <sub>4</sub> /12 tC), and  |
| GWP <sub>CH<sub>4</sub></sub> | = | global warming potential of methane (21).   |

**Step 2.** Calculate the CH<sub>4</sub> emissions due to anaerobic decomposition of wastes in landfills

This step will only be relevant for a project activity that burns waste that would otherwise be landfilled. The emission reductions are achieved by avoiding CH<sub>4</sub> emissions from anaerobic decomposition of waste. There is a possibility that the methane is completely or partially flared in the baseline scenario. If all landfill gas is being flared, then CH<sub>4</sub> emission reductions cannot be claimed. If a portion of the methane is flared, then only the non-flared portion (NFL) of the CH<sub>4</sub> can be claimed by the project proponent.

$$LW_{CH_4} = Q_{AF-L} * DOC * DOC_F * MCF * F * C * (1-OX) * NFL * GWP_{CH_4} \quad (10)$$

<sup>6</sup> The IPCC 1996 guidelines recommend using 0.005% as a default value.



where:

$LW_{CH_4}$  = baseline GHG emissions due to anaerobic decomposition of biomass wastes in landfills (tCO<sub>2e</sub>/yr)

$Q_{AF-L}$  = amount of wastes (e.g. biomass) used as alternative fuel that would be landfilled in the absence of the project (t/yr)

DOC = degradable organic carbon content of the waste (%)

$DOC_F$  = portion of DOC that is converted to landfill gas (0.77 default value)

MCF = methane conversion factor for landfill (%)

F = fraction of CH<sub>4</sub> in landfill gas (0.5 default value)

C = carbon to methane conversion factor (16/12)

OX = oxidation factor (fraction – default is 0)

NFL = non-flared portion of the landfill gas produced (%)

$GWP_{CH_4}$  = global warming potential of methane (21).

### Step 3. Calculate emissions from off-site transport of alternative and fossil fuels

The emissions from transportation should be calculated as follows:

$$LK_{trans} = LK_{AF} - LK_{FF} \quad (11)$$

$$LK_{AF} = (Q_{AF}/CT_{AF}) * D_{AF} * EF_{CO_2e}/1000 \quad (12)$$

$$LK_{FF} = (RQ_{FF}/CT_{FF}) * D_{FF} * EF_{CO_2e}/1000 \quad (13)$$

where:

$LK_{trans}$  = leakage from transport of alternative fuel less leakage due to reduced transport of fossil fuels (tCO<sub>2</sub>/yr)

$LK_{AF}$  = leakage resulting from transport of alternative fuel (tCO<sub>2</sub>/yr)

$LK_{FF}$  = leakage due to reduced transport of fossil fuels (tCO<sub>2</sub>/yr)

$Q_{AF}$  = quantity of alternative fuels (tonnes)

$CT_{AF}$  = average truck or ship capacity (tonnes/truck or ship)

$D_{AF}$  = average round-trip distance between the alternative fuels supply sites and the cement plant sites (km/truck or ship)

$RQ_{FF}$  = quantity of fossil fuel (tonnes) that is reduced due to consumption of alternative fuels estimated as:

$CT_{FF}$  = average truck or ship capacity (tonnes/truck or ship)

$D_{FF}$  = average round-trip distance between the fossil fuels supply sites and the cement plant sites (km/truck or ship)

$EF_{CO_2e}$  = emission factor from fuel use due to transportation (kg CO<sub>2e</sub>/km) estimated as:

$$EF_{CO_2e} = EF_{T\ CO_2} + (EF_{T\ CH_4} * 21) + (EF_{T\ N_2O} * 310) \quad (14)$$

where:

$EF_{T\ CO_2}$  = emission factor of CO<sub>2</sub> in transport (kg CO<sub>2</sub>/km)

$EF_{T\ CH_4}$  = emission factor of CH<sub>4</sub> in transport (kg CH<sub>4</sub>/km)

$EF_{T\ N_2O}$  = emission factor of N<sub>2</sub>O in transport (kg N<sub>2</sub>O/km)

21 and 310 are the Global Warming Potential (GWP) of CH<sub>4</sub> and N<sub>2</sub>O respectively

**Step 4.** Calculate emissions from off-site preparation of alternative fuels

The GHG emissions generated during the preparation of alternative fuels outside the project site are estimated as follows:

$$GHG_{PAFO} = FD_{AFO} * HV_{FDAFO} * EF_{FDAFO} + PD_{AFO} * EF_{pO} \quad (15)$$

where:

$GHG_{PAFO}$  = GHG emissions that could be generated during the preparation of alternative fuels outside the project site (tCO<sub>2</sub>/yr)

$FD_{AFO}$  = fuel used in drying of alternative fuels outside the project site (t/yr)

$HV_{FDAFO}$  = heating value of fuel used for drying alternative fuels outside the project site (TJ /tonne)

$EF_{FDAFO}$  = emission factor for the fuel used for drying of alternative fuels outside the project site (tCO<sub>2</sub>/TJ)

$PD_{AFO}$  = power consumption in drying the alternative fuels (MWh/yr) outside the project site

$EF_{pO}$  = CO<sub>2</sub> emission factor due to power generation outside the project where the drying of alternative fuels takes place, determined according to the methodology presented in AM0002 (tCO<sub>2</sub>/MWh).

**Emission Reductions**

Total emission reductions are given by the following formula:

$$AF_{ER} = FF_{GHG} - AF_{GHG} - OT_{GHG} - LK_{trans} + OT\_GHG_{FF} + BB_{CH4} + LW_{CH4} - GHG_{PAFO} \quad (16)$$

where:

$FF_{GHG}$  = GHG emissions from fossil fuels displaced by the alternatives (tCO<sub>2</sub>/yr)

$AF_{GHG}$  = GHG emissions from alternative fuels (tCO<sub>2e</sub>/yr)

$OT_{GHG}$  = GHG emissions from on-site transport and drying of alternative fuels (tCO<sub>2e</sub>/yr)

$LK_{trans}$  = leakage from transport of alternative fuel less leakage due to reduced transport of fossil fuels (tCO<sub>2</sub>/yr)

$OT-GHG_{FF}$  = emissions from reduction of on-site transport of fossil fuels (tCO<sub>2e</sub>)

$BB_{CH4}$  = GHG emissions due to burning of biomass that is used as alternative fuel (tCO<sub>2e</sub>/yr)

$LW_{CH4}$  = baseline GHG emissions due to anaerobic decomposition of biomass wastes in landfills (tCO<sub>2e</sub>/yr)

$GHG_{PAFO}$  = GHG emissions that could be generated during the preparation of alternative fuels outside the project site (tCO<sub>2</sub>/yr)



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#### Applicability

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- Fossil fuel(s) used in cement manufacture are partially replaced by alternative fuels, including renewable biomass<sup>7</sup>, where renewable biomass residues are in surplus and leakages in other uses of the renewable biomass will not occur;
- CO<sub>2</sub> emission reduction relates to CO<sub>2</sub> emissions generated from fuel burning requirements only and is unrelated to the CO<sub>2</sub> emission from decarbonisation of raw materials (i.e. CaCO<sub>3</sub> and MgCO<sub>3</sub> bearing minerals);
- The methodology is applicable only for installed capacity (expressed in tonnes clinker/year) that exists by the time of validation of the project activity;
- The amount of alternative fuels available for the project is at least 1.5 times the amount required to meet the consumption of all users consuming the same alternative fuels, i.e. the project and other alternative fuel users.

This monitoring methodology shall be used in conjunction with the approved baseline methodology ACM0003 (“Baseline methodology for emissions reduction through partial substitution of fossil fuels with alternative fuels in cement manufacture”).

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<sup>7</sup> Renewable biomass residues are such that they do not contribute to global warming. The Executive Board may further define renewable biomass based on recommendations from the Meth Panel and the AR WG.

**Monitoring methodology***Baseline and project emissions*

| ID number  | Data Type  | Data Variable      | Symbol    | Data Unit               | Measured (m), calculated (c) or estimated (e) | Recording Frequency   | Proportion of Data to be Monitored | How will the Data be Archived (electronic/paper) | For How Long is the Archived Data Kept?       | Comment | Instrument used to record |
|--|------------|--------------------|-----------|-------------------------|---|---|------------------------------------|--|---|---------|---------------------------|
| <b>Monitoring of parameters related to clinker production</b>  |            |                    |           |                         |   |   |                                    |  |   |         |                           |
| 1.   | mass       | Clinker production | C         | Ton                     | measured, calculated                          | recorded/calculated and reported monthly  | 100%                               | electronic, paper                                | 2 years after the end of the crediting period |         | Weighing feeders          |
| <b>Monitoring of emissions related to the use of alternative fuels in kilns during the crediting period (for each type of fuels - and each kiln independently)</b> |            |                    |           |                         |   |   |                                    |  |   |         |                           |
| 2.   | quantity   | Fuel type          | $Q_{AF}$  | Units of mass or volume | measured                                      | recorded continuously and reported monthly and adjusted according to stock change | 100%                               | electronic, paper                                | 2 years after the end of the crediting period |         | Scale                     |
| 3.   | heat value | Fuel Heating value | $HV_{AF}$ | TJ/tonne                | measured, calculated                          | monthly   | 100%                               | electronic, paper                                | 2 years after the end of the crediting period |         | Calorimeter               |



| ID number | Data Type       | Data Variable                              | Symbol           | Data Unit                    | Measured (m), calculated (c) or estimated (e) | Recording Frequency             | Proportion of Data to be Monitored | How will the Data be Archived (electronic/paper) | For How Long is the Archived Data Kept?       | Comment       | Instrument used to record |
|-----------|-----------------|--|------------------|------------------------------|---|---------------------------------|------------------------------------|--|---|---------------|---------------------------|
| 4.        | heat            | Alternative fuel heat input                | HI <sub>AF</sub> | TJ                           | calculated                                    | calculated and reported monthly | 100%                               | electronic, paper                                | 2 years after the end of the crediting period | For each kiln |                           |
| 5.        | emission factor | Emission Factor                            | EF <sub>AF</sub> | tCO <sub>2</sub> /TJ         | IPCC default                                  | fixed                           | 100%                               | electronic, paper                                | The entire crediting period                   |               |                           |
| 6.        | fraction        | Share of heat input from alternative fuels | S <sub>AF</sub>  | %                            | calculated                                    | calculated monthly              | 100%                               | electronic, paper                                | 2 years after the end of the crediting period |               |                           |
| 7.        | ratio           | Moisture penalty                           | mp               | MJ/tonne/ 10% alt fuel share | calculated                                    | at start of crediting period    | 100%                               | electronic, paper                                | 2 years after the end of the crediting period |               |                           |

*Monitoring of emissions related to the baseline GHG emissions from the fossil fuel(s) displaced by the alternative fuel(s)*



| ID number | Data Type | Data Variable | Symbol          | Data Unit               | Measured (m), calculated (c) or estimated (e) | Recording Frequency   | Proportion of Data to be Monitored | How will the Data be Archived (electronic/paper) | For How Long is the Archived Data Kept?       | Comment  | Instrument used to record |
|-----------|-----------|---------------|-----------------|-------------------------|---|---|------------------------------------|--|---|--|---------------------------|
| 8.        | quantity  | Fuel type     | Q <sub>FF</sub> | Units of mass or volume | measured                                      | recorded continuously and reported monthly and adjusted according to stock change | 100%                               | electronic, paper                                | 2 years after the end of the crediting period | For each of the fossil fuels consumed: (i) in the year prior to the validation, (ii) during the project activity, (iii) in the baseline scenario | Scale                     |



| ID number | Data Type  | Data Variable      | Symbol           | Data Unit | Measured (m), calculated (c) or estimated (e) | Recording Frequency | Proportion of Data to be Monitored | How will the Data be Archived (electronic/paper) | For How Long is the Archived Data Kept?       | Comment   | Instrument used to record |
|-----------|------------|--------------------|------------------|-----------|---|---------------------|------------------------------------|--|---|---|---------------------------|
| 9.        | heat value | Fuel Heating value | HV <sub>FF</sub> | TJ/tonne  | measured, calculated                          | monthly             | 100%                               | electronic, paper                                | 2 years after the end of the crediting period | For each of the fossil fuels consumed:<br>(i) in the year prior to the validation,<br>(ii) during the project activity,<br>(iii) in the baseline scenario | Calorimeter               |



| ID number  | Data Type       | Data Variable                       | Symbol                        | Data Unit             | Measured (m), calculated (c) or estimated (e) | Recording Frequency           | Proportion of Data to be Monitored | How will the Data be Archived (electronic/paper) | For How Long is the Archived Data Kept?       | Comment  | Instrument used to record |
|--|-----------------|-------------------------------------|-------------------------------|-----------------------|---|-------------------------------|------------------------------------|--|---|--|---------------------------|
| 10.  | emission factor | Emission Factor                     | EF <sub>FF</sub>              | tCO <sub>2</sub> /TJ  | IPCC default                                  | fixed                         | 100%                               | electronic, paper                                | 2 years after the end of the crediting period | For each of the fossil fuels consumed: (i) in the year prior to the validation, (ii) during the project activity, (iii) in the baseline scenario |                           |
| <i>Monitoring of emissions related to on-site transportation and drying of alternative fuels</i> |                 |                                     |                               |                       |   |                               |                                    |  |   |  |                           |
| 11.  | quantity        | Transportation of fuel used on-site | OF <sub>v</sub>               | Kg                    | measured                                      | recorded and reported monthly | 100%                               | electronic, paper                                | 2 years after the end of the crediting period |  | Fuel record               |
| 12.  | emission factor | Emission Factor                     | VEF <sub>CO<sub>2</sub></sub> | g CO <sub>2</sub> /kg | IPCC default                                  | fixed                         | 100%                               | electronic, paper                                | The whole crediting period                    | Ref. notes below   |                           |
| 13.  | emission factor | Emission Factor                     | VEF <sub>CH<sub>4</sub></sub> | g CH <sub>4</sub> /kg | IPCC default                                  | fixed                         | 100%                               | electronic, paper                                | The whole crediting period                    | Ref. notes below   |                           |



| ID number  | Data Type       | Data Variable  | Symbol             | Data Unit | Measured (m), calculated (c) or estimated (e) | Recording Frequency                   | Proportion of Data to be Monitored | How will the Data be Archived (electronic/paper) | For How Long is the Archived Data Kept?       | Comment          | Instrument used to record |
|--|-----------------|--|--------------------|-----------|---|---------------------------------------|------------------------------------|--|---|------------------|---------------------------|
| 14.  | emission factor | Emission Factor  | VEF <sub>N2O</sub> | g N2O/kg  | IPCC default                                  | fixed                                 | 100%                               | electronic, paper                                | The whole crediting period                    | Ref. notes below |                           |
| 15.  | quantity        | Fuel used for any drying of alternative fuels          | FD                 | Kg        | measured                                      | recorded and reported monthly         | 100%                               | electronic, paper                                | 2 years after the end of the crediting period |                  | Flowmeter, weigher        |
| 16.  | heat            | Heating Value for fuel for drying alt. Fuels           | FD_HV              | TJ/tonne  | measured, C                                   | monthly                               | 100%                               | electronic, paper                                | 2 years after the end of the crediting period |                  | Calorimeter               |
| 17.  | emission factor | Emission factor for the fuel used for drying           | VEF <sub>D</sub>   | tCO2/TJ   | IPCC default                                  | fixed                                 | 100%                               | electronic, paper                                | The whole crediting period                    | Ref. notes below |                           |
| <b><i>Monitoring of emissions reduction from reduction of on-site transport of fossil fuel</i></b> |                 |  |                    |           |   |                                       |                                    |  |   |                  |                           |
| 18.  | quantity        | Fuel saving from on-site transportation of fossil fuel | OF <sub>FF</sub>   | kg        | measured                                      | measured monthly and reported monthly | 100%                               | electronic, paper                                | 2 years after the end of the crediting period |                  | Fuel consumption records  |



| ID number | Data Type       | Data Variable        | Symbol                              | Data Unit                      | Measured (m), calculated (c) or estimated (e) | Recording Frequency | Proportion of Data to be Monitored | How will the Data be Archived (electronic/paper) | For How Long is the Archived Data Kept?       | Comment | Instrument used to record |
|-----------|-----------------|----------------------|-------------------------------------|--------------------------------|---|---------------------|------------------------------------|--|---|---------|---------------------------|
| 19.       | emission factor | Fuel emission factor | EF <sub>T</sub><br>CO <sub>2e</sub> | kgCO <sub>2e</sub><br>/kg fuel | default value                                 |                     | 100%                               | electronic, paper                                | 2 years after the end of the crediting period |         | NA                        |

*Leakage*

| ID number  | Data Type | Data Variable  | Symbol            | Data Unit                   | Measured (m), calculated (c) or estimated (e) | Recording Frequency | Proportion of Data to be Monitored | How Will the Data be Archived (electronic/paper) | For How Long is the Archived Data Kept?       | Comment | Instrument used to record |
|--|-----------|--|-------------------|-----------------------------|---|---------------------|------------------------------------|--|---|---------|---------------------------|
| <i>Monitoring of emissions due to burning of biomass in the field in the baseline scenario</i> |           |  |                   |                             |   |                     |                                    |  |   |         |                           |
| 20.  | quantity  | Biomass fuel which would have been burnt in the absence of the project | $Q_{AF-D/B}$      | Tonnes                      | estimated                                     |                     | 100%                               | electronic, paper                                | 2 years after the end of the crediting period |         |                           |
| 21.  | fraction  | Carbon fraction of the biomass   | BCF               | Tonnes C per tonnes biomass | IPCC default                                  |                     |                                    |  |   |         |                           |
| 22.  | fraction  | Carbon released as CH <sub>4</sub> in open air burning                 | CH <sub>4</sub> F |                             | IPCC default                                  |                     |                                    |  |   |         |                           |
| <i>Monitoring of emissions due to landfilling of biomass in the baseline scenario</i>          |           |  |                   |                             |   |                     |                                    |  |   |         |                           |
| 23.  | quantity  | Biomass fuel that would have been                                      | $Q_{AF-L}$        | Tonnes                      | estimated                                     |                     | 100%                               | electronic, paper                                | 2 years after the end of the crediting period |         |                           |



| ID number | Data Type | Data Variable                                    | Symbol           | Data Unit             | Measured (m), calculated (c) or estimated (e) | Recording Frequency | Proportion of Data to be Monitored | How Will the Data be Archived (electronic/paper) | For How Long is the Archived Data Kept?       | Comment   | Instrument used to record |
|-----------|-----------|--|------------------|-----------------------|---|---------------------|------------------------------------|--|---|---|---------------------------|
|           |           | landfilled without project                       |                  |                       |   |                     |                                    |  |   |   |                           |
| 24.       | fraction  | Methane conversion factor                        | MCF              |                       | IPCC default                                  |                     |                                    |  | 2 years after the end of the crediting period | Default = 0.4 for un-managed shallow waste sites under 5 m. |                           |
| 25.       | fraction  | Degradable organic carbon content of the biomass | DOC              | tC/tonnes of biomass. | IPCC default                                  |                     |                                    |  | 2 years after the end of the crediting period | Default value is 0.3.                                       |                           |
| 26.       | fraction  | Portion of DOC that is converted to landfill gas | DOC <sub>F</sub> |                       | IPCC default                                  |                     |                                    |  | 2 years after the end of the crediting period | Default value is 0.77.                                      |                           |



| ID number  | Data Type         | Data Variable                       | Symbol           | Data Unit        | Measured (m), calculated (c) or estimated (e) | Recording Frequency   | Proportion of Data to be Monitored | How Will the Data be Archived (electronic/paper) | For How Long is the Archived Data Kept?       | Comment   | Instrument used to record |
|--|-------------------|-------------------------------------|------------------|------------------|---|---|------------------------------------|--|---|---|---------------------------|
| 27.  | fraction          | CH <sub>4</sub> in landfill gas     | F                |                  | IPCC default                                  |   |                                    |  | 2 years after the end of the crediting period | Default value is 0.5.   |                           |
| 28.  | fraction          | CH <sub>4</sub> that is oxidized    | OX               |                  | IPCC default                                  |   |                                    |  | 2 years after the end of the crediting period | Default value is 0.   |                           |
| 29.  | fraction          | Landfill gas portion that is flared | NFL              |                  | estimated                                     |   |                                    |  | 2 years after the end of the crediting period | Obtained from host country  |                           |
| <b><i>Monitoring of emissions due to off-site transport of fuels</i></b> |                   |                                     |                  |                  |   |   |                                    |  |   |   |                           |
| 30.  | quantity          | Alternative Fuels                   | Q <sub>AF</sub>  | Ton              | measured                                      | recorded continuously and reported monthly based on actual silo stock level changes | 100%                               | electronic, paper                                | 2 years after the end of the crediting period |   | Weighing feeders          |
| 31.  | specific quantity | Average truck capacity for          | CT <sub>AF</sub> | Tonnes per truck | calculated                                    | monthly   | 100%                               | electronic, paper                                | 2 years after the end of the crediting period | The quantity can be estimated based on additive material hauling distance and |                           |



| ID number | Data Type        | Data Variable   | Symbol             | Data Unit                         | Measured (m), calculated (c) or estimated (e) | Recording Frequency | Proportion of Data to be Monitored | How Will the Data be Archived (electronic/paper) | For How Long is the Archived Data Kept?       | Comment  | Instrument used to record               |
|-----------|------------------|---|--------------------|-----------------------------------|---|---------------------|------------------------------------|--|---|--|---|
|           |                  | transport of alternative fuels  |                    |                                   |   |                     |                                    |  |   |  | estimated fuel consumption per shipment |
| 32.       | distance         | Average distance for transport of alternative fuels                   | D <sub>AF</sub>    | Km/truck                          | calculated                                    | monthly             | 100%                               | electronic, paper                                | 2 years after the end of the crediting period | In certain cases other means of transportation which require that other formulas be used |   |
| 33.       | emission Factors | Emission factors  | EF <sub>CO2e</sub> | Kg CO2eq per km or per kg of fuel | calculated                                    | monthly             | 100%                               | electronic, paper                                | 2 years after the end of the crediting period | Ref. notes below   |   |
| 34.       | quantity         | Fossil fuels which is reduced due to consumption of alternative fuels | RQ <sub>FF</sub>   | Ton                               | calculated                                    | calculated monthly  | 100%                               | electronic, paper                                | 2 years after the end of the crediting period |  |   |



| ID number  | Data Type | Data Variable                                    | Symbol    | Data Unit        | Measured (m), calculated (c) or estimated (e) | Recording Frequency | Proportion of Data to be Monitored | How Will the Data be Archived (electronic/paper) | For How Long is the Archived Data Kept?       | Comment   | Instrument used to record                  |
|--|-----------|--|-----------|------------------|---|---------------------|------------------------------------|--|---|---|--|
| 35.  | quantity  | Average truck capacity for transport of $Q_{FF}$ | $CT_{FF}$ | Tonnes per truck | calculated                                    | monthly             | 100%                               | electronic, paper                                | 2 years after the end of the crediting period |   |  |
| 36.  | distance  | Average distance for transport of $Q_{FF}$       | $D_{FF}$  | Km/truck         | calculated                                    | monthly             | 100%                               | electronic, paper                                | 2 years after the end of the crediting period | In certain cases other means of transportation which require other formulas be used |  |
| <b><i>Monitoring of alternative fuel reserves that may be used by other users (data to be completed for each type of fuel independently)</i></b> |           |  |           |                  |   |                     |                                    |  |   |   |  |
| 37.  | quantity  | Alternative fuel used by other users             |           | Ton              | estimated                                     | yearly              | 100%                               | electronic, paper                                | 2 years after the end of the crediting period | Track whether project activity reduces  | Based on data from local, national, and/or |



| ID number   | Data Type | Data Variable   | Symbol            | Data Unit        | Measured (m), calculated (c) or estimated (e) | Recording Frequency | Proportion of Data to be Monitored | How Will the Data be Archived (electronic/paper) | For How Long is the Archived Data Kept?       | Comment   | Instrument used to record   |
|---|-----------|---|-------------------|------------------|---|---------------------|------------------------------------|--|---|---|---|
| 38.   | quantity  | Alternative fuel reserve available in the region                  |                   | Ton              | estimated                                     | yearly              | 100%                               | electronic, paper                                | 2 years after the end of the crediting period | alternative fuel available to other users groups so that their GHG emissions will increase. | international government institutions; industry associations; and other reliable sources of information |
| <b><i>Monitoring of preparation of alternative fuel outside the project site/outside the cement plant sites</i></b> |           |   |                   |                  |   |                     |                                    |  |   |   |   |
| 39.   | quantity  | Fuel used in drying of alternative fuels outside the project site | FD <sub>AFO</sub> | Ton, kg or litre | measured                                      | monthly             | 100%                               | electronic, paper                                | 2 years after the end of the crediting period | To be estimated for each type of fuel independently   |   |



| ID number | Data Type       | Data Variable  | Symbol                  | Data Unit                | Measured (m), calculated (c) or estimated (e) | Recording Frequency | Proportion of Data to be Monitored | How Will the Data be Archived (electronic/paper) | For How Long is the Archived Data Kept?       | Comment   | Instrument used to record |
|-----------|-----------------|--|-------------------------|--------------------------|---|---------------------|------------------------------------|--|---|---|---------------------------|
| 40.       | heat            | Heating Value of fuel used for drying alternative fuels outside the project site           | HV <sub>FDA</sub><br>DO | TJ or Tcal/unit of fuel  | estimated                                     | monthly             | 100%                               | electronic, paper                                | 2 years after the end of the crediting period | To be estimated for each type of fuel independently |                           |
| 41.       | emission factor | Emission factor for the fuel used for drying of alternative fuels outside the project site | EF <sub>ADO</sub>       | T of CO <sub>2</sub> /TJ | calculated based on default value             | monthly             | 100%                               | electronic, paper                                | 2 years after the end of the crediting period | To be estimated for each type of fuel independently |                           |
| 42.       | quantity        | Power consumption of drying the alternative fuels outside the project site                 | PD <sub>ADO</sub>       | Kwh                      | measured                                      | monthly             | 100%                               | electronic, paper                                | 2 years after the end of the crediting period |   |                           |



| ID number | Data Type       | Data Variable   | Symbol | Data Unit                   | Measured (m), calculated (c) or estimated (e) | Recording Frequency            | Proportion of Data to be Monitored | How Will the Data be Archived (electronic/paper) | For How Long is the Archived Data Kept?       | Comment                                 | Instrument used to record |
|-----------|-----------------|---|--------|-----------------------------|---|--------------------------------|------------------------------------|--|---|---|---------------------------|
| 43.       | emission factor | Emission factor for power generation outside the project site where drying of alternative fuels takes place | EFpO   | Ton CO <sub>2</sub> per MWh | calculated                                    | calculated and reported yearly | 100%                               | electronic, paper                                | 2 years after the end of the crediting period | To be calculated from each type of fuel |                           |



Notes:

1. In order to estimate biomass fuel that would have been landfilled without project and biomass fuel which would have been burnt in the absence of the project, project participants should carry out a survey before and after the project activity implementation.

2. Emission factors to be used to calculate leakage from transportation emissions:

|                                       |   |                           |
|---------------------------------------|---|---------------------------|
| Transportation emissions from trucks* | Truck capacity                                | To be measured            |
|                                       | Return trip distance                          | To be measured            |
|                                       | CO <sub>2</sub> emission factor <sup>a</sup>  | 1097 g/km<br>3172.31 g/kg |
|                                       | CH <sub>4</sub> emission factor <sup>a</sup>  | 0.06 g/km<br>0.18 g/kg    |
|                                       | N <sub>2</sub> O emission factor <sup>a</sup> | 0.031 g/km<br>0.09 g/kg   |

\* These values are illustrative examples and should be replaced by corresponding specific project data, as necessary.

<sup>a</sup> IPCC default values for US heavy diesel vehicles, uncontrolled.

Due to fuel sourcing from various locations even within a single fuel type (e.g. coal from 2 regions), distances for each source should be measured, and any changes due to contract renewal also reflected.

3. If ships are used to deliver fuels, then assume that ship fuel is HFO380 with a heat content of 41.868 GJ/tonne and emission factor of 77.4 kgCO<sub>2</sub>/GJ, as per IPCC default values. Ships are collecting another material close by and so fuel is for one-way trip.

4. ID.37-38. This monitoring task tracks whether the project activity may reduce the amount of biomass available to other users groups so that they might shift their productive or other activities in ways that would lead to increased GHG emissions. To demonstrate that there is an abundance of surplus biomass a proposed project activity should demonstrate that: The amount of biomass for which there are no users/off-takers should be 1.5 times the amount required to meet the consumption of all users consuming the same biomass.

5. Power system data and information: If available, data and information on generation, fuel types, fuel consumption, energy content and carbon emission factors from government ministries and agencies should be used. If unavailable, information from neighbouring countries may be used. If the latter is unavailable, international best practice data may be used together with IPCC default calorific values and carbon emission factors.

*Quality Control (QC) and Quality Assurance (QA) Procedures*

| <b>Data</b>                        | <b>Uncertainty level of data (High/Medium/Low)</b> | <b>Are QA/QC procedures planned for these data?</b>    | <b>Outline explanation why QA/QC procedures are or are not being planned.</b>                          |
|------------------------------------|--|--|--|
| 1-3, 11, 15-16, 18                 | Low  | Yes – According to ISO 9000 or similar quality systems |  |
| 20-23, 29                          | Medium   | No   | Fraction of biomass that would have been decayed/burnt and/or landfilled will be estimated             |
| 5, 10, 12-14, 17, 19, 21-22, 24-28 | Low  | No   | While IPCC fractions are reliable defaults, the project proponent should validate these default values |
| Other leakage data                 | Medium   | No   | An independent expert should validate the data quality.  |