Climate MRV for Africa – Phase 2
Development of National GHG Inventory
Cement production (IPPU)

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Project of the European Commission DG Clima Action

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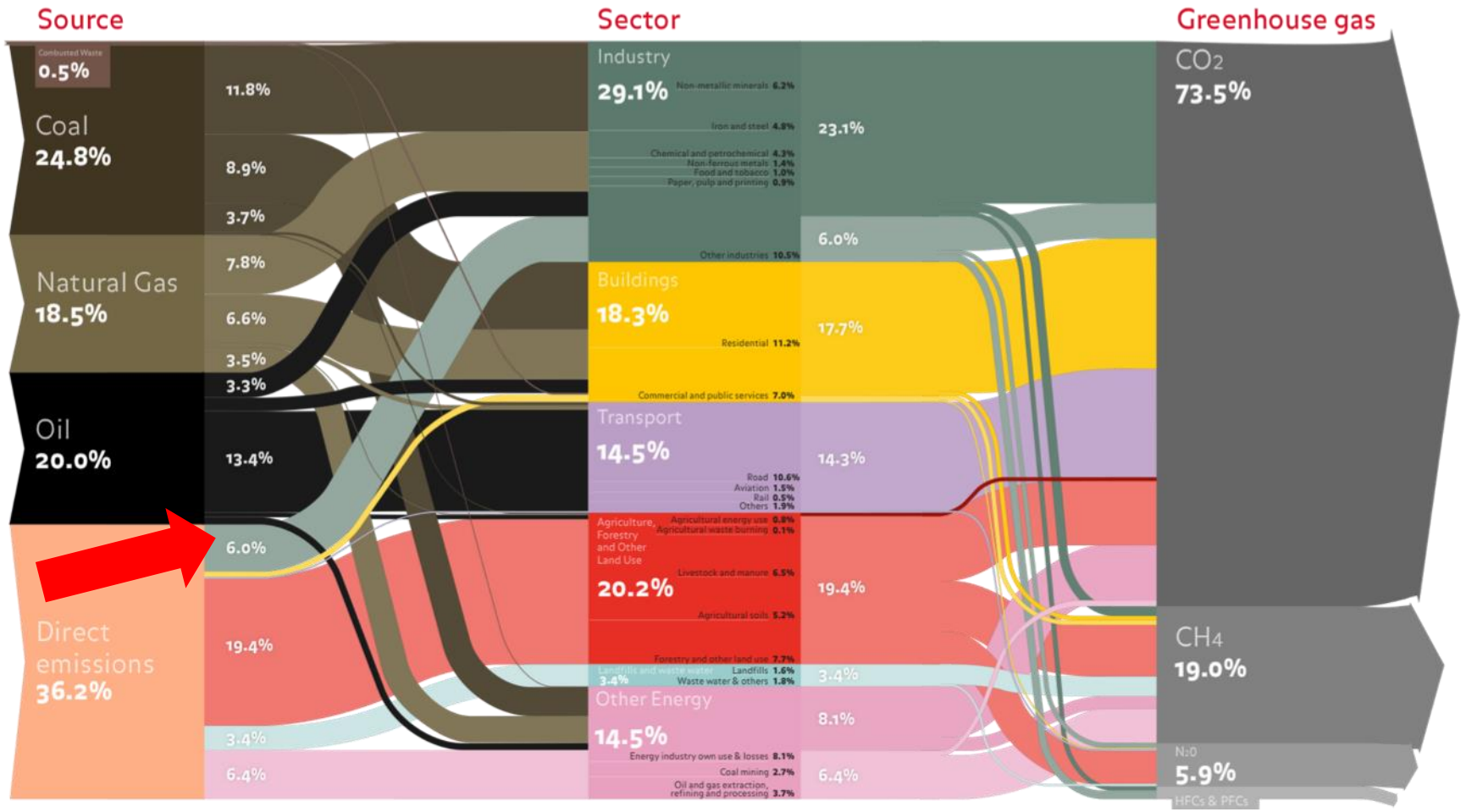
Cement Production and Global GHG Emissions



Source: ASN Bank and Ecofys (2016), update to the WRI 2000 figure, using 2012 data

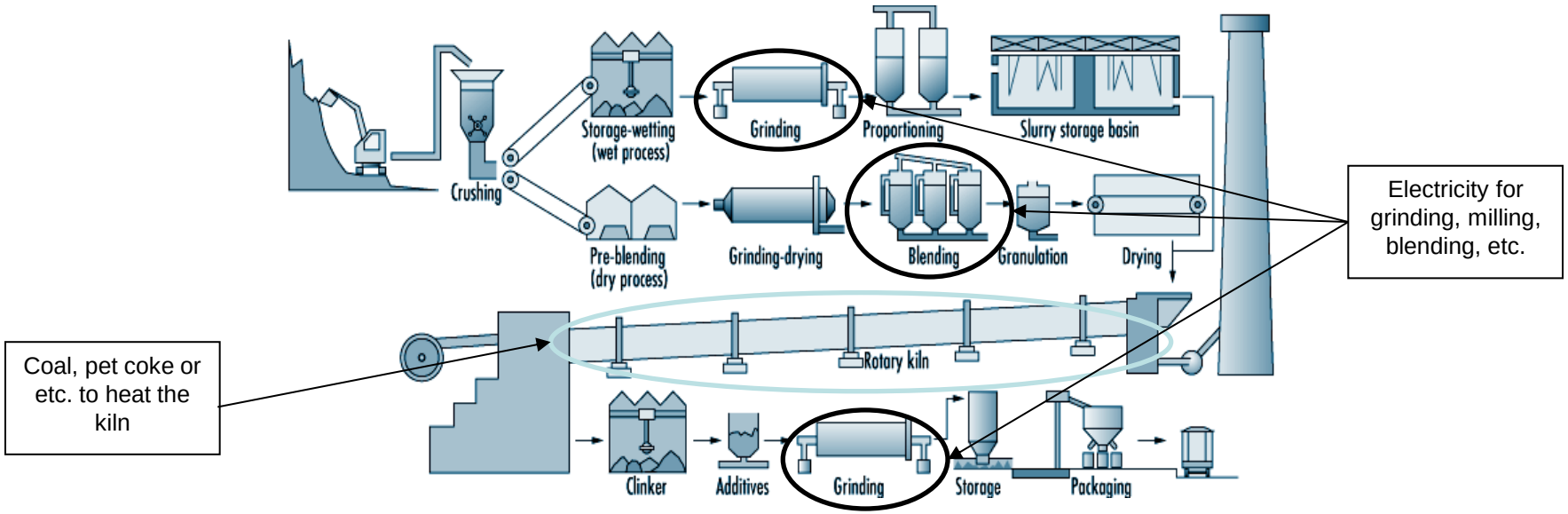
Total emissions worldwide (2012)

51,840

MtCO2 eq

Emissions Sources from Cement Production

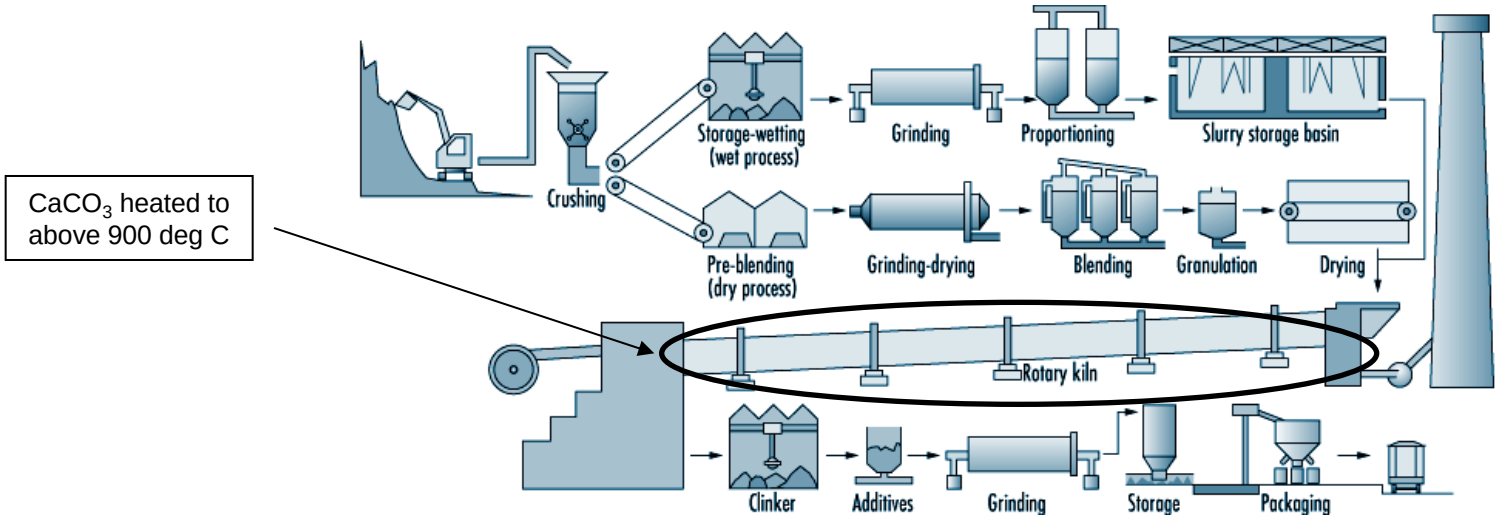
- Energy use (Energy, Sector 1)



Source: Encyclopaedia of Occupational Health and Safety Ed. 3, Articles “Cement” by L. Prodan

Emissions Sources from Cement Production

- CO_2 emissions from the thermal decomposition of limestone (IPPU, Sector 2)



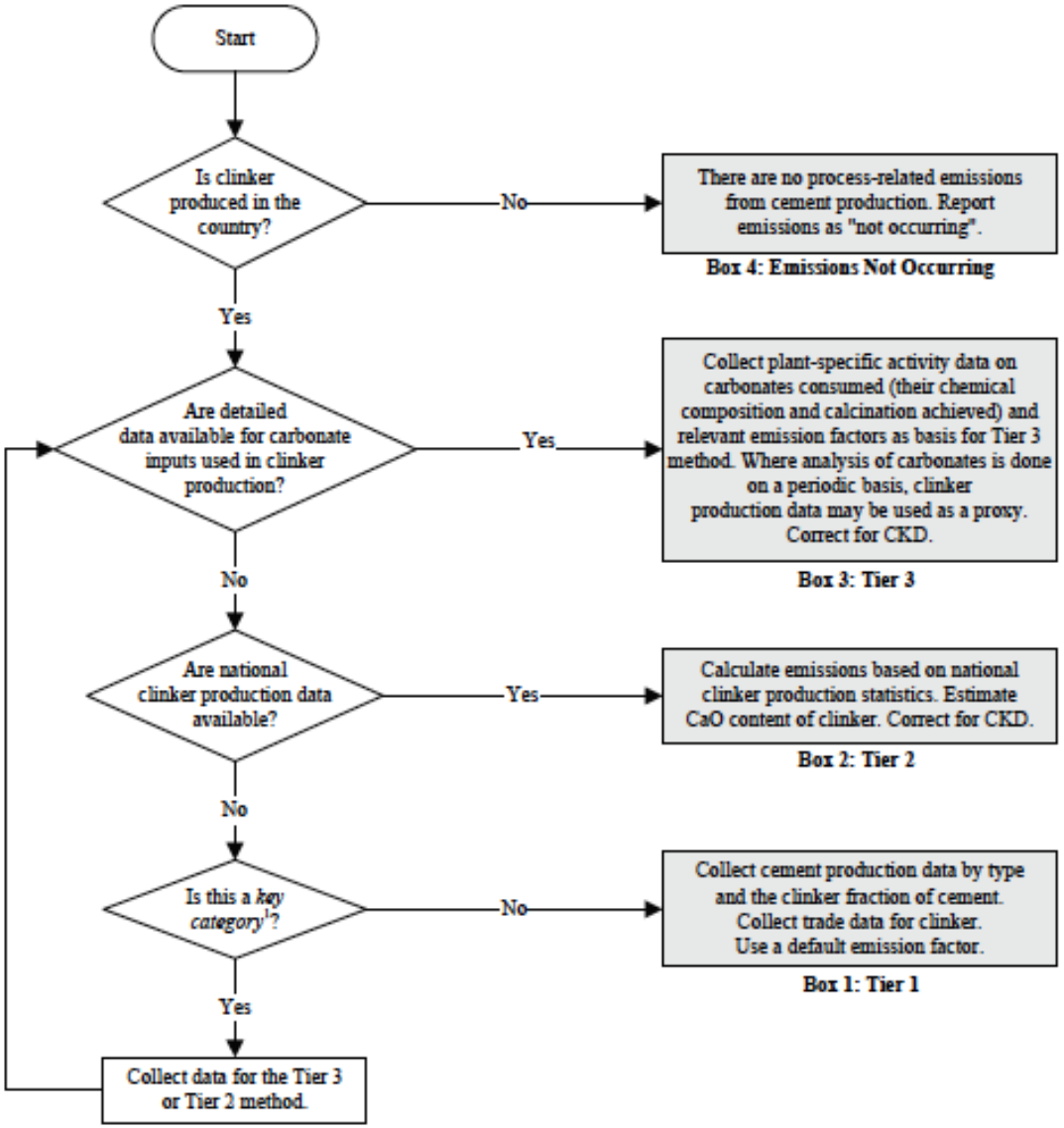
$CaCO_3$ + (*heat*) → CaO + CO_2

Source: Encyclopaedia of Occupational Health and Safety Ed. 3, Articles “Cement” by L. Prodan

Emissions Potential for the Category

- Default emission factor of 0.52 tonnes of CO_2 per tonne of clinker
- 1 million tonnes of clinker leads to 520,000 tCO_2 of direct emissions

Decision Tree for Cement Production Emissions



Source: IPCC 2006 Vol. 3, Ch. 2, Fig. 2.1

Tier 1 Method

IPCC 2006: Tier 1 Method

EQUATION 2.1
TIER 1: EMISSIONS BASED ON CEMENT PRODUCTION

$$CO_2\ Emissions = \left[\sum_i (M_{ci} \bullet C_{cl\,i}) - Im + Ex\right] \bullet EF_{clc}$$

Where:

CO_2 Emissions = emissions of CO_2 from cement production, tonnes

M_{ci} = weight (mass) of cement produced[3] of type *i*, tonnes

C_{cli} = clinker fraction of cement of type *i*, fraction

Im = imports for consumption of clinker, tonnes

Ex = exports of clinker, tonnes

EF_{clc} = emission factor for clinker in the particular cement, tonnes CO_2/tonne clinker
The default clinker emission factor (EF_{clc}) is corrected for CKD.

Source: IPCC 2006 Vol. 3, Ch. 2, Eq. 2.1

$$EF_{clc} = \frac{0.65\ t\ CaO}{1\ t\ Clinker} \div 56.03\% \frac{CaO}{CaCO_3} \times 43.97\% \frac{CO_2}{CaCO_3} \times 1.02\ (CKD\ corection) = 0.52 \frac{tCO_2}{tClinker}$$

(new to IPCC 2006)

Tier 1 Activity Data

- M_{ci}: Cement production (tonnes), by type, e.g.
  - Ordinary Portland Cement,
  - Masonry Cement,
  - Other special or blended cements
- *Im*, *Ex*: Clinker imports and exports (tonnes)
- C_{cli}: Clinker fraction of each type of cement
  - *Alternative: use default values*: 95% clinker if essentially all Portland Cement, 75% clinker if significant amounts of Masonry and/or Blended Cements are being produced

Tier 1 Activity Data Sources

- M_{ci}: Cement production (tonnes)
  - National level - statistics agency, Ministry of Industry, Sector association, etc.
  - Plant-level, if available
- *Im*, *Ex*: Clinker imports and exports (tonnes)
  - Customs agency, the UN, sector association, department of commerce, etc.
- C_{cli}: Clinker fraction of each type of cement
  - National level
  - Plant-level
  - Defaults

Tier 1 Uncertainty

Source of uncertainty	Range of uncertainty	How to mitigate
Clinker fraction of the cement (applying assumption that all cement is Portland)	Up to 35%	Collect production data on types of cement and clinker fraction of each type
Unreliable clinker import & export data	50%	Obtain data from customs office or similar
Default CKD correction factor of 2% (includes assumptions about proportion of recycling of CKD, extent of calcination)	25-35%	Although uncertainty is high, impact on the estimations is low

Tier 2 Method

IPCC 2006: Tier 2 Method

EQUATION 2.2
TIER 2: EMISSIONS BASED ON CLINKER PRODUCTION DATA

$$CO_2\ Emissions = M_{cl} \bullet EF_{cl} \bullet CF_{ckd}$$

Where:

CO_2 Emissions = emissions of CO_2 from cement production, tonnes

M_{cl} = weight (mass) of clinker produced, tonnes

EF_{cl} = emission factor for clinker, tonnes CO_2/tonne clinker (See discussion under Section 2.2.1.2, Choice of Emission Factors, for Tiers 1 and 2 below.) This clinker emission factor (EF_{cl}) is not corrected for CKD.

CF_{ckd} = emissions correction factor for CKD, dimensionless (see Equation 2.5)

Important assumptions, *inter alia*:

- (Nearly) 100% calcination is achieved
- CaO mainly is obtained from limestone
- (Nearly) all CKD is captured

Source: IPCC 2006 Vol. 3, Ch. 2, Eq. 2.2

Tier 2 Method Emission Factor

- If country-specific data on CaO content of clinker and CaO sources (e.g. limestone or other) are available, then **it is *good practice* to estimate a country-specific emission factor**:
  - Average CaO content in clinker (in units of mass)
  - Percent of CaO derived from $CaCO_3$, versus other sources such as blast furnace slag or fly ash (mineral impurities from burning pulverised coal in a power plant, captured from the exhaust gases)

$$EF_{cl} = \frac{0.65\ t\ CaO - t\ CaO\ from\ slag\ or\ fly\ ash}{1\ t\ Clinker} \div 56.03\% \frac{CaO}{CaCO_3} \times 43.97\% \frac{CO_2}{CaCO_3} = 0.5101 \frac{tCO_2}{tClinker}$$

Tier 2 Method for Cement Kiln Dust

- CF_{ckd} correction factor addresses what happens to **particulates from the raw materials** along the kiln line apparatus, and to what extent these particulates are ***calcined***
- Since the Tier 2 emission estimate is based on the ***output*** of the clinker process, the CKD correction adds back emissions from CKD that was lost before it could become clinker

Tier 2 Method for Cement Kiln Dust

EQUATION 2.5
CORRECTION FACTOR FOR CKD NOT RECYCLED TO THE KILN

$$CF_{ckd} = 1 + (M_d / M_{cl}) \bullet C_d \bullet F_d \bullet (EF_c / EF_{cl})$$

Where:

CF_{ckd} = emissions correction factor for CKD, dimensionless

M_d = weight of CKD not recycled to the kiln, tonnes[a]

M_{cl} = weight of clinker produced, tonnes

C_d = fraction of original carbonate in the CKD (i.e., before calcination), fraction[b]

F_d = fraction calcination of the original carbonate in the CKD, fraction[b]

EF_c = emission factor for the carbonate (Table 2.1), tonnes CO_2/tonne carbonate

EF_{cl} = emission factor for clinker uncorrected for CKD (i.e., 0.51 tonnes CO_2/tonne clinker), tonnes CO_2/tonne clinker

Example:

$$CF_{ckd} = 1 + \left(\frac{1t}{10t}\right) \times 0.85 \times 0.5 \times \left(\frac{0.4397}{0.51}\right) = 1.037$$

Source: IPCC 2006 Vol. 3, Ch. 2, Eq. 2.5

Tier 2 Activity Data & Sources

- M_{cl}: Clinker production (tonnes)
  - Preferable to collect data from ***individual plants***, although data from national statistics are acceptable
- For calculation of the EF_{cl} and the CKD correction factor (CF_{ckd}), it is also advisable to collect data on:
  - CaO content of the clinker
  - Fraction of the CaO from calcium carbonate (vs. slag, fly ash)
  - CKD collection and recycling practices
  - Calcination fraction of CKD

Tier 2 Uncertainty

Source of uncertainty	Range of uncertainty	How to mitigate
CaO content of clinker	3 - 8%	Collect data on CaO content of clinker from individual plants
Source of CaO	1 - 3%	Collect data on sources of CaO from individual plants; most important if there is reason to suspect that slag or fly ash are utilized
CKD correction factor (includes assumptions about proportion of recycling of CKD, extent of calcination)	Up to 80%	Obtain data on weight and extent of calcination of CKD, per plant

Tier 3 Method

IPCC 2006: Tier 3 Method

- ***New method in 2006 Guidelines***
- The Tier 3 emission estimate is based on the ***input*** to the clinker process, mainly:
  - amount of raw material input (e.g. limestone),
  - emission factor of the raw material given its specific chemical characteristics, and
  - fraction of calcination achieved
- Additionally, CO_2 emissions from non-carbonate carbon in the raw materials are considered, basically carbon in kerogen or fly ash that is combusted in the kiln, contributing to heating (unintentionally)

Source: IPCC 2006 Vol. 3, Ch. 2, Eq. 2.3

EQUATION 2.3

TIER 3: EMISSIONS BASED ON CARBONATE RAW MATERIAL INPUTS TO THE KILN

$$CO_2\ Emissions = \sum_i (EF_i \bullet M_i \bullet F_i) - M_d \bullet C_d \bullet (1 - F_d) \bullet EF_d + \sum_k (M_k \bullet X_k \bullet EF_k)$$

Emissions from carbonates

Emissions from uncalcined CKD not recycled to the kiln

Emissions from carbon-bearing non-fuel materials

Where:

CO_2 Emissions = emissions of CO_2 from cement production, tonnes

EF_i = emission factor for the particular carbonate *i*, tonnes CO_2/tonne carbonate (see Table 2.1)

M_i = weight or mass of carbonate *i* consumed in the kiln, tonnes

F_i = fraction calcination achieved for carbonate *i*, fraction[a]

M_d = weight or mass of CKD not recycled to the kiln (= 'lost' CKD), tonnes

C_d = weight fraction of original carbonate in the CKD not recycled to the kiln, fraction[b]

F_d = fraction calcination achieved for CKD not recycled to kiln, fraction[a]

EF_d = emission factor for the uncalcined carbonate in CKD not recycled to the kiln, tonnes CO_2/tonne carbonate[b]

M_k = weight or mass of organic or other carbon-bearing nonfuel raw material *k*, tonnes[c]

X_k = fraction of total organic or other carbon in specific nonfuel raw material *k*, fraction[c]

EF_k = emission factor for kerogen (or other carbon)-bearing nonfuel raw material *k*, tonnes CO_2/tonne carbonate[c]

Tier 3 Method Emission Factor

- EF_i must be determined for each carbonate input *i*, with full accounting of CO_2 content of the carbonate used as raw material
- Effectively, data to determine the emission factors must be obtained on a plant-by-plant basis
- The factor can be determined rigorously, per plant, when the method is implemented, and then a proxy per unit clinker can be put in place
  - However, the emission factor should be periodically checked and re-calibrated, especially if there is any change to the process or source of the raw materials.

Tier 3 Method for Cement Kiln Dust

- Calculation of CKD related emissions is similar to the Tier 2 case, but uses measured data of CKD not recycled to the kiln
- Since Tier 3 estimations are based on ***inputs*** to the process, the CKD correction subtracts emissions from CKD that was lost before it could become clinker (before calcined)

Tier 3 Activity Data & Sources

- All data and emission factors are obtained from information from **individual plants**; highly unlikely the data will be available from national sources
- When applying Tier 3, it is important that all plants in the country are surveyed- this method is complete only when all carbonates consumed are included
- If some plants are capable of reporting the data needed for Tier 3, and others not, then a combination of Tier 3 and Tier 2 can be applied
- If plant-level data is considered to be unreliable or highly uncertain, then it is ***good practice*** to use Tier 2

Tier 3 Uncertainty

Source of uncertainty	Range of uncertainty	How to mitigate
CKD emissions (in absence of measurements of CKD recycled to the kiln, or when applying assumptions about fraction of calcination)	Up to 80%	Obtain data on weight and extent of calcination of CKD, per plant
All other sources minor	1 - 3%	

QA/QC for Cement Emissions

- **Recommendation 1**: When bottom-up data are applied (Tiers 2 & 3), make a comparison with the results of the top-down, Tier 1 approach.
- **Recommendation 2**: Compare national emission factors to IPCC default factors and explain the differences
- **Recommendation 3**: Compare Activity Data between sites to identify inconsistencies
  - For example, content of CaO in clinker, and content of clinker in cement

Considerations for Reporting

- **It is *good practice* to document & archive all data needed to generate the emissions estimates**
- **Tier 1:** Report cement production data, clinker imports and exports, any data or assumptions on CaO content of clinker
- **Tier 2**: Report how clinker production data was derived, level of data collection, data or assumptions on CaO content of clinker, plant-specific data on other sources of CaO, details on fraction of calcination, any assumptions for the CKD correction factor
- **Tier 3:** Report all the procedures undertaken and methodologies used to determine carbonates used, weight fractions and EFs

Thank you!

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