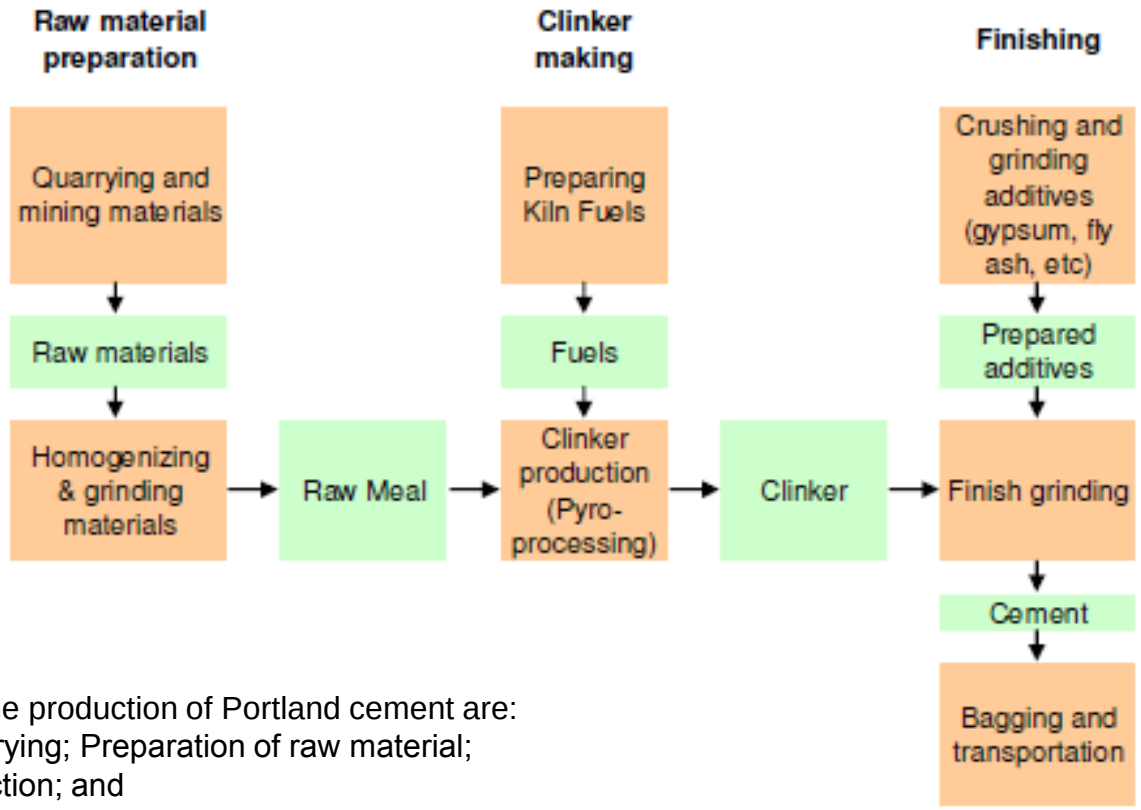
Part 3 – Direct GHG from Cement Manufacturing

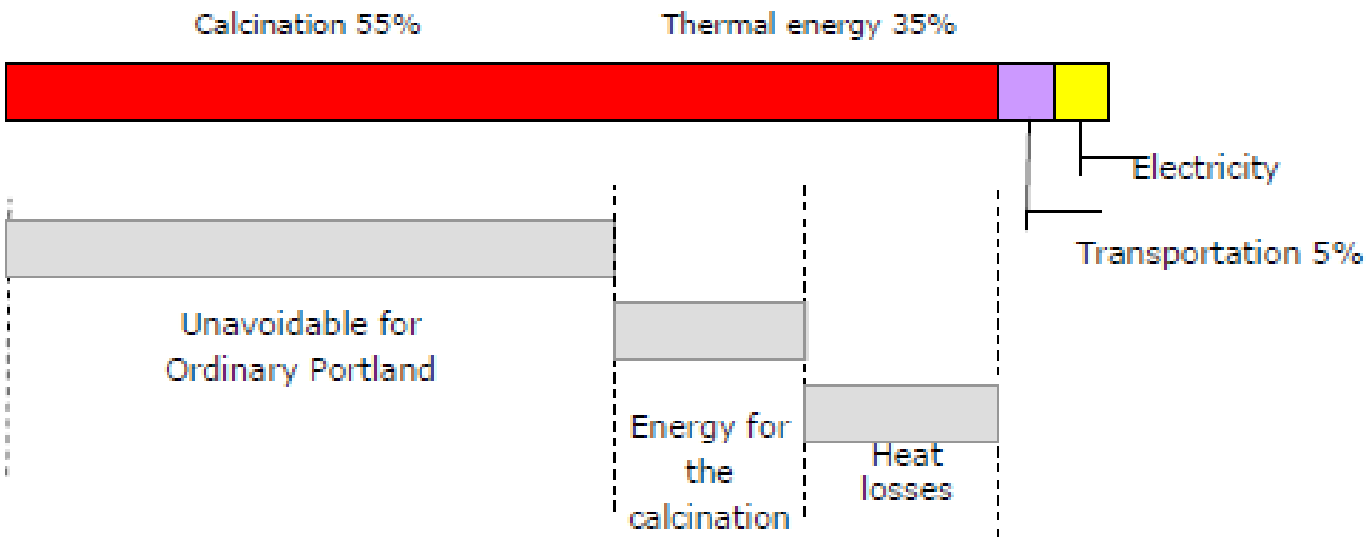
Calculation of Greenhouse Gas (GHG) Inventory for Indonesia Cement Industries

Schematic Representation of Cement Production Process



Main steps of the production of Portland cement are:
- Mining & quarrying; Preparation of raw material;
- Clinker production; and
- Finish grinding to produce cement.

CO2 Sources in the Production of Cement Clinker



Sources of CO_2 emissions - Direct and *Indirect

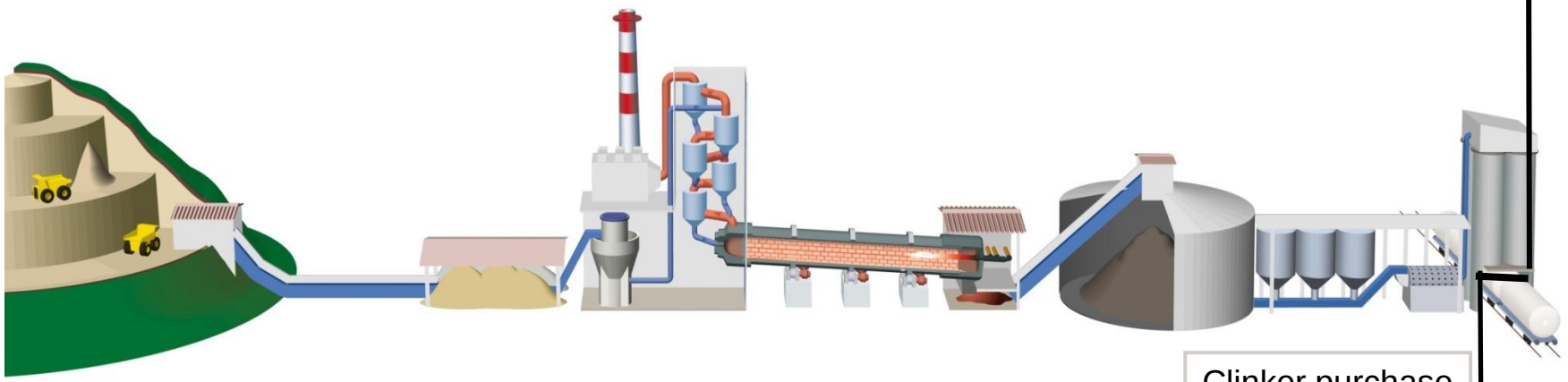
On-site transportation; Non-kiln fuels; own electric power production

Quarry

Non-kiln fuels: raw materials drying

Calcination

Kiln fuels



Clinker purchase

Electric power purchase*

Boundary of CO2 reporting

Direct Emission

Emissions from sources that are owned or controlled by the reporting entity. In cement plants, direct CO2 emissions result from the following sources:

1. Calcination of carbonates, and combustion of organic carbon contained in raw materials;
2. Combustion of kiln fuels related to clinker production :
   - a. Combustion of conventional fossil kiln fuels;
   - b. Combustion of alternative fossil kiln fuels (also called fossil AF or fossil wastes) and mixed fuels with biogenic carbon content;
   - c. Combustion of biomass fuels and biofuels (including biomass wastes);

Direct Emission (Continued)

3. Combustion of non kiln fuels:
   - a. Combustion of conventional fossil fuels
   - b. Combustion of alternative fossil fuels (also called fossil AF or fossil wastes) and mixed fuels with biogenic carbon content;
   - c. Combustion of biomass fuels and biofuels (including biomass wastes);
4. Combustion of fuels for on-site power generation;
5. Combustion of the carbon contained in wastewater.

Table 1: Parameters and proposed data sources for calculation of direct CO2 emissions

Emission components	Parameters	Units	Proposed source of parameters
CO_2 from raw materials: Methods based on raw material input (A1, A2)			
> Calcination of raw material consumed for clinker production	Raw meal consumed Kiln feed Dust return correction CO_2 content in raw meal or loss on ignition (LOI)	t t mass fraction mass fraction	Calculated Measured at plant level Determined at plant level Measured at plant level
> Calcination of dust	Dust leaving kiln system excluding bypass dust CO_2 content in dust or loss on ignition (LOI)	t mass fraction	Measured at plant level Measured at plant level
Furthermore for detailed input method (A2)			
> Partial calcination of bypass dust	Bypass dust leaving kiln system and Bypass dust CO_2 content	t mass fraction	Measured at plant level Measured at plant level
> Additional raw materials not included in kiln feed	Additional raw materials Additional raw materials CO_2 content	t mass fraction	Measured at plant level Measured at plant level

Table 1: Parameters and proposed data sources for calculation of direct CO2 emissions

CO_2 from raw materials: Methods based on clinker output (B1, B2)			
> Calcination of raw material consumed for clinker production	Clinker produced Emission factor clinker	t kg CO_2/ t cli	Measured at plant level Default = 525; or as calculated in detailed output method (B2)
> Calcination of dust	Dust leaving kiln system Emission factor clinker Dust calcination degree	t kg CO_2/ t cli calcined	Measured at plant level Default = 525; or as calculated in detailed output method (B2)
> Organic carbon in raw materials	Clinker produced Raw meal : clinker ratio TOC content of raw meal	fraction t cli t / t cli mass fraction	Measured at plant level Measured at plant level Default = 1.55; can be adjusted Default = 0.2%; can be adjusted
Furthermore for detailed output method (B2)			
> Calcination of raw material consumed for clinker production	CaO + MgO in clinker	mass fractions	Measured at plant level

Table 1: Parameters and proposed data sources for calculation of direct CO2 emissions

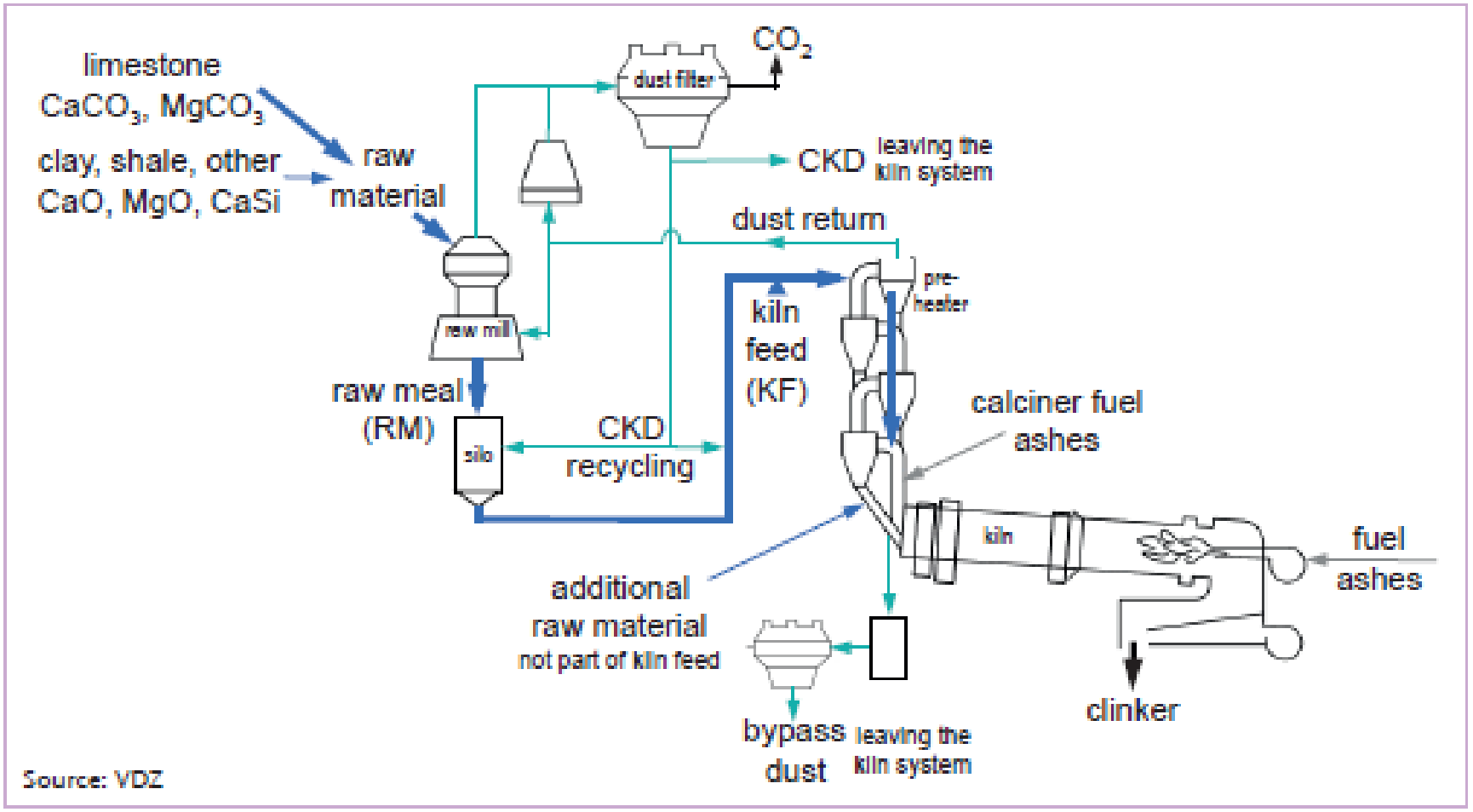
Emission components	Parameters	Units	Proposed source of parameters
> Corrections of emission factor clinker	CaO + MgO from non-carbonate sources in raw materials	mass fractions t	Measured at plant level Measured at plant level
	Ca + Mg silicate sources in raw materials (e.g. as part of clay minerals)	mass fractions t	Measured at plant level (e.g. with QXRD with Rietveld refinement) Measured at plant level
CO_2 from kiln and non-kiln fuel combustion:			
> Conventional fuels	Fuel consumption Lower heating value Emission factor	t GJ /t fuel t CO_2 /GJ fuel	Measured at plant level Measured at plant level IPCC / CSI defaults, or measured
> Alternative fossil fuels (fossil AF) and mixed fuels	Fuel consumption Lower heating value Emission factor Biogenic carbon content	t GJ /t fuel t CO_2 /GJ fuel mass fraction	Measured at plant level Measured at plant level CSI defaults, or measured CSI defaults, or measured at plant level
> Biomass fuels (biomass AF)	Fuel consumption Lower heating value Emission factor	t GJ /t fuel t CO_2 /GJ fuel	Measured at plant level Measured at plant level IPCC / CSI defaults, or measured
> Wastewater combusted	–	–	Quantification of CO_2 not required

t = metric tonne, AF = Alternative fuels, cli = clinker, TOC = Total organic carbon, QXRD = Quantitative X-Ray Diffractometry

CO2 from Raw Material Calcination

- Calcination CO2 is directly linked with clinker production.
- Calcination of CKD and bypass dust can be a relevant source of CO2 where such dust leaves the kiln system for direct sale, addition to cement or other products, or for discarding as a waste.
- On plant level, calcination CO2 can basically be calculated in two ways, based on :
  - ✓ volume and carbonate content of the raw meal consumed (**input method**),
  - ✓ volume and composition of clinker produced (**output method**) plus dust leaving the kiln system.

Figure 1: Example of mass flows in the clinker production process in a plant for the production of clinker with cyclone pre-heater and rotary kiln.



Source: VDZ

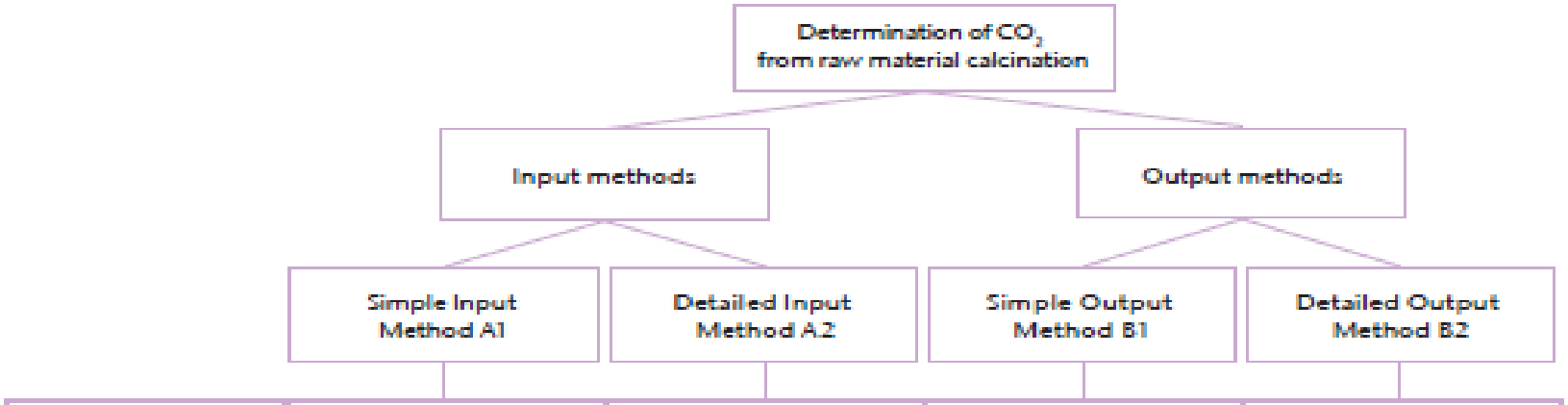
Input and Output - based Method

- Both input and output based methods are included in the 2006 IPCC Guidelines for National Greenhouse Gas Inventories and the Guidelines for Monitoring and Reporting of Greenhouse Gas Emissions (MRG) in the European Emission Trading System (EU ETS).
- Input and output methods are, in theory, equivalent. The WBCSD/CSI decided to include both types of methods in the Protocol Version 3 spreadsheet.
- Companies may choose to apply the raw meal-based input method or the clinker based output method.
- The choice should be made according to the availability of adequate data and measurements of the mass flows.

Simple and a Detailed Method

- The choice between two method depends on both the intended use of reporting and the availability of data.
- The detailed reporting methods shall be preferred, if the data required for the more detailed methods can be made available with sufficient accuracy and within the limits of practicability.
- The simple methods are also intended for companies that just started CO2 reporting. After a few years such companies should start using the detailed methods after gaining experience with CO2 reporting, appropriate measurements and the quality control of measurements.

Figure 2: Overview of methods for the determination of CO_2 emissions from raw material calcination



Principle parameter and analysis method	raw meal consumed LOI (weight loss on ignition)	raw meal consumed CO_2 content (e.g. by IR-analysis of gases)	clinker produced default value	clinker produced CaO, MgO analysis (e.g. by XRF)
CO_2 from organic carbon (TOC)	partially included separate analysis for raw materials with high TOC content	included as part of CO_2 content no separate accounting required	default value	TOC analysis (if relevant) or default value
CO_2 from bypass dust	included complete calcination assumed, no analysis	residual CO_2 content	default value of clinker complete calcination assumed	CaO, MgO analysis or default value of clinker
CO_2 from CKD	LOI	CO_2 content	default value or analysis	analysis or default value
Additional raw materials fed to calciner or kiln inlet	not covered	CO_2 content accounted separately	included no separate accounting required	included no separate accounting required

Output Methods (B1) and (B2)

Companies shall use their plant-specific data, as follows:

(1) Clinker:

- Calcination CO2 shall be calculated based on the volume of clinker produced and an emission factor per tonne of clinker.
- The emission factor shall be determined based on the measured CaO and MgO contents of the clinker, and corrected if relevant quantities of CaO and MgO in the clinker from non-carbonate sources.
- In the absense of a better data, a default of 525 kg CO2/t clinker shall be used (Simple Output Method)

(2) Dust:

- CO2 from bypass dust or cement kiln dust (CKD) leaving the kiln system shall be calculated based on the relevant volumes of dust and an emission factor.
- The calculation shall account for the complete volumes of dust leaving the kiln system, irrespective of whether the dust is sold directly, added to cement, or discarded as a waste.
- Bypass dust is usually fully calcined. Therefore, emission related to bypass dust shall be calculated using emission factor for clinker.

- In the absence of plant-specific data on dust volumes, the IPCC default for CO2 from discarded dust (2% of clinker CO2, shall be used.
- Using plant- or company-specific data is clearly preferable.

(3) CO2 from Organic Carbon in Raw Materials:

The raw materials used for clinker production usually contain a small fraction of organic carbon which is mostly converted to CO2 during pyroprocessing of the raw meal.

The total organic carbon (TOC) contents of raw materials can vary substantially between locations, and between the types of materials used.

Data compiled by the CSI Task Force indicate that a typical value for TOC in the raw meal is about 0.1 – 0.3% (dry weight).

CO2 emissions from organic carbon in raw materials shall be quantified and reported to ensure completeness of the inventory.

However, since their contribution to overall emissions is small, a simplified self-calculating mechanism has been implemented in the spreadsheet which multiplies clinker production with the following default values:

- Default raw meal to clinker ratio: 1.55
- Default TOC content of raw meal: 2 kg /t raw meal (dry weight, corresponding to 0.2%)

Equation for the output methods B1 and B2 as implemented in plant sheet:

Equation 6 : CO_2 Raw Material = Clinker x EF_{cli}/1000
+ Bypass D leaving kiln system x EF_{cli}/1000
+ CKD leaving kiln system x EF_{CKD}
+ Raw Meal Consumed x $fTOC_{RM}$ x 3,664

The Raw Meal Consumed is here calculated by Equation 7:
Raw Meal Consumed = Clinker x RM/Cli-ratio

CO2 Raw Material = total CO2 from raw material (t CO2/y)

Clinker = clinker production measured at plant level (t/y)

EF_{cli} = CO2 emission factor of clinker (kg CO2/t clinker); simple output method (B1) default value

= 525 kg CO2/t clinker, detailed output method (B2), determined in auxiliary sheet CalcB2

Bypass D leaving kiln system = amount bypass D leaving kiln system (t/y)

CKD leaving kiln system = amount of cement kiln D leaving the kiln system (t/y)

EF_{CKD}= CO2 emission factor of partially calcined CKD determined according to Eq. 5 (t CO2/t CKD)

Raw Meal Consumed = amount of raw meal consumed for clinker production and bypass dust (t/y)

$fTOC_{RM}$ = weight fraction of TOC in the raw meal (); default value = 0.2%

RM/Cli ratio = raw meal clinker mass ratio (raw meal consumed per clinker production); default value = 1.55

CO2 from Conventional Fuels

- Conventional fuels are fossil fuels including e.g. coal, petcoke, fuel oil and natural gas.
- To calculate CO2 from conventional fuels and also alternative and non kiln fuels based on fuel consumption, Lower Heating Values, and the CO2 emission factors.

Fuel consumption and lower heating values (LHV or net calorific value NCV) of fuels are routinely measured at plant level.

- CO2 emission factors default values from fuel shall be used. The default value for petcoke is based on analyses compiled by the CSI Task Force.
- Companies are encouraged to use plant- or country-specific emission factors if reliable data are available. The emission factor of fuels shall be based on the total carbon content.

CO2 from AF, Mixed Fuels and Biomass Fuels

CO2 from biomass fuels

is considered climate neutral, because emissions can be compensated by re-growth of biomass in the short term.

CO2 from biomass fuels is reported as a ”memo item“, but excluded from the national emissions totals.

- **CO2 from fossil fuel-derived wastes** (also called **alternative fossil fuels** or **fossil AF**)
- **GHG savings** achieved through the utilization of AF shall be accounted as **net emissions** in the Protocol.

CO2 from mixed fuels with biomass and fossil fractions:

- In the case that biofuels are combusted jointly with fossil fuels (e.g. pretreated industrial and/or domestic wastes), a split between the fossil and non-fossil fraction of the fuel should be established and the emission factors applied to the appropriate fractions.

Reporting Required in this Protocol

- Direct CO2 from combustion of **biomass** (including biomass fuels, biomass wastes and the biomass fraction of mixed fuels) shall be reported as a memo item, but excluded from emissions totals.
- The IPCC default emission factor of 110 kg CO2/ GJ for solid biomass shall be used, except where other, reliable emission factors are available.

Reporting Required in this Protocol (cont'd)

- Direct CO2 from combustion of **fossil** AF and the fossil fraction of mixed fuels shall be calculated and included in the direct CO2 emissions **(gross emissions** and **gross emission including CO2 from on-site power generation,** i.e. **total direct CO2 emissions).**
- CO2 emission factors depend on the type of AF or mixed fuel used and, therefore, shall be specified at plant level where practical.
- In the absence of plant- or company-specific data, companies shall use the default emission factors.

CO2 from Kiln Fuels

- Kiln fuels in this protocol are all fuels fed to the kiln system plus fuels that are used for drying and processing the raw materials or other kiln fuels.
- Included are fuels inserted through a main firing system of the kiln as well as fuels added to a calciner or directly to the kiln inlet.
- Also fuels used for fuel heating (e.g. for heavy fuel oil used for clinker production) shall be reported under kiln fuels.

CO2 from Non Kiln Fuel

All fuel which are not included in the definitions of kiln fuel :

- For plant and quarry vehicle—tobe discussed
- Room heating or cooling
- Thermal process equipment (e.g dryer)
- In a separate installation for on-site production of electrical power

Note that fuels consumed for drying of raw materials for the production of clinker and kiln fuels are included in the kiln fuel section.

These emissions are accounted for in the spreadsheet as non-kiln fuels combusted on site :

- CO2 from non-kiln fuels is reported separately, by application type, to provide flexibility in the aggregation of emissions. The spreadsheet distinguishes the following applications:
  - equipment and on-site vehicles
  - room heating/cooling
  - drying of MIC such as slag or pozzolana
  - on-site power generation in separately fired boilers
- CO2 from off-site transports by company-owned fleets is currently excluded from the boundary

- Measured plant-specific lower heating values shall be used, if available. Alternatively CSI default values can be applied.
- If the same type of fuel is used as non-kiln fuel and kiln fuel, then the CO2 emission factors used for reporting shall correspond.
- Otherwise, measured plant specific emission factors shall be used, if available.
- Alternatively CSI defaults values can be applied.

CO2 from Transports

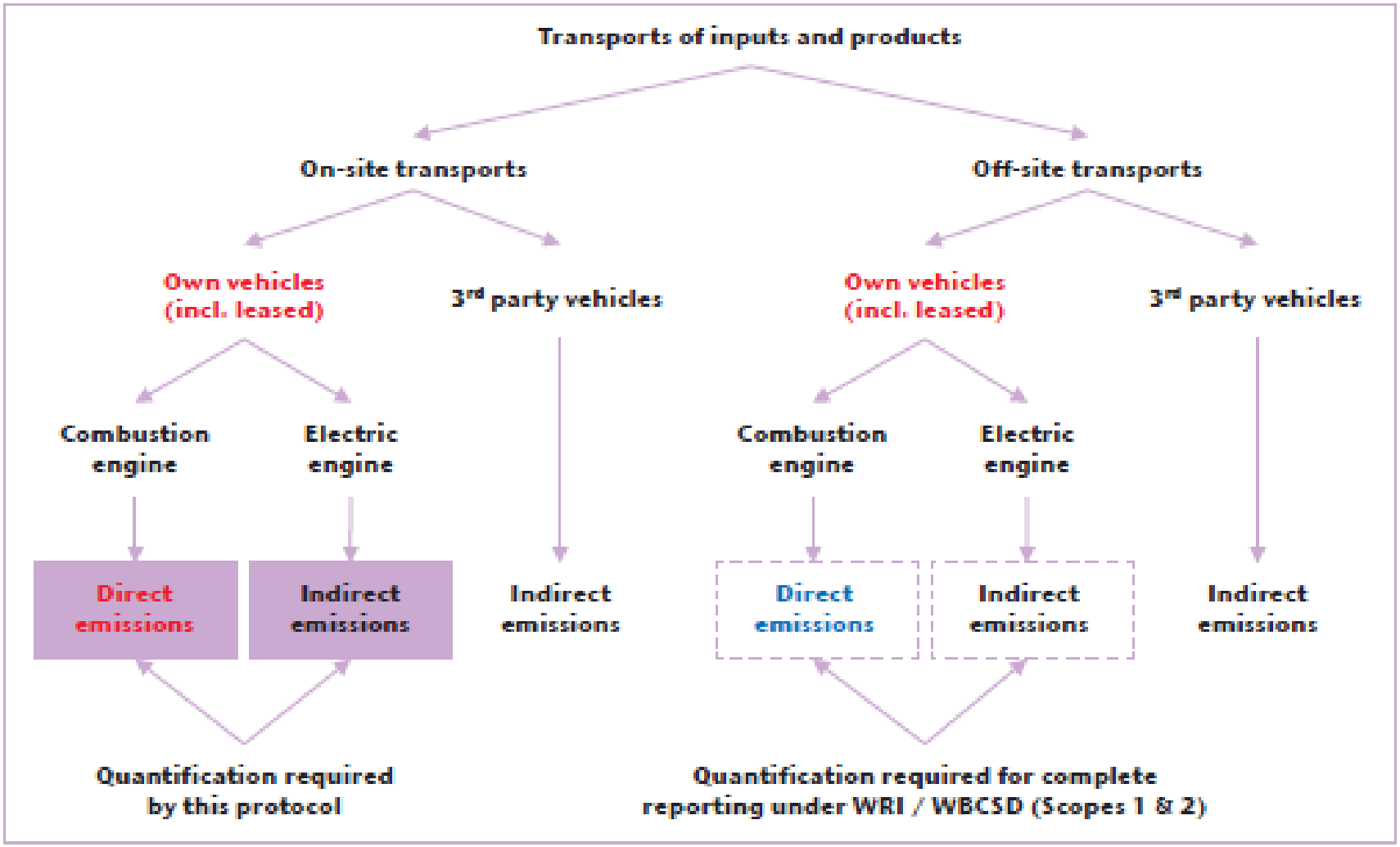
- Cement production requires transports for the provision of raw materials and fuels as well as for the distribution of products (clinker, cement, concrete).
- In some cases, clinker is transferred to another site for grinding. Transport modes include conveyer belts, rail, water, and road.
- If transports are carried out by independent third parties, the associated emissions qualify as indirect.

- This protocol requires that companies account for energy consumption and associated emissions of on-site transports carried out with own vehicles (including leased vehicles).
- Examples include the fuel consumption of quarry vehicles and the electricity consumption of conveyor belts. Note that emissions related to consumed electricity qualify as indirect, except if the electricity is produced by the company itself (on-site power production).

In contrast, this protocol does not require companies to quantify emissions related to the following types of transport:

- On-site transports carried out by third parties (i.e. vehicles not owned or controlled by the reporting entity); to be discussed
- All off-site transports, (e.g. of fuels, intermediates and finished products), irrespective of whether the transports are carried out by third parties or by company-owned fleets.

Figure 3: Breakdown of transports by type, and coverage of this protocol



CO2 from Wastewater

Some cement plants inject wastewater in their kilns, for example as a flame coolant for control of nitrogen oxides (NOx).

The carbon contained in the wastewater is emitted as CO2.

This protocol does not require cement companies to quantify their CO2 emissions related to wastewater consumption, because these emissions are usually small and, in addition, difficult to quantify.

Non-CO2 Greenhouse Gases

Emissions of methane (CH4) from cement kilns are very small due to the high combustion temperatures in the kilns.

- CH4 emissions are typically about 0.01% of kiln CO2 emissions on a CO2-equivalent basis.
- Emissions of N2O from cement kilns are typically small
- The other GHG covered by the Kyoto Protocol (PFC, HFC, SF6) are found not to be relevant in the cement context.

- This protocol does not require cement companies to quantify their non-CO2 GHG emissions from kilns.
- Besides the relative insignificance of these gases in the context of cement production, the main underlying reason is that most voluntary and mandatory reporting schemes are currently restricted to CO2 for the reporting of the cement sector.
- Relevant emissions of CH4 and N2O may, however, result from the stationary combustion of non-kiln fuels (e.g., dryers, on-site power generation).
- If required, these emissions should be reported using the WRI / WBCSD calculation tool for stationary fuel combustion (see www.ghgprotocol.org).