Fact Sheet 18

Embodied CO_2e of UK cement, additions and cementitious material

1 Introduction

The information in this fact sheet is aimed at providing lifecycle[1] data to inform 'carbon footprinting' in the concrete supply chain. This fact sheet replaces a previous version which provided CO_2 information for UK cement, additions and cementitious materials. This new version reflects greenhouse gas reductions achieved by the sector but also has a broader scope and now includes all greenhouse gases converted to a CO_2 equivalent basis (CO_2e).

The indicative CO_2e for the main cementitious constituents of concrete are shown in Table 1 and have been derived from calendar year 2010 data. Data are 'cradle to factory gate', so transport from the place of manufacture of the cementitious material to the concrete plant is not included.

Table 1: CO_2e of UK cement, additions and cementitious material

Cement, additions and cementitious material [Descriptions of the materials are shown below]	**CO_2e**	
Portland Cement CEM I: cradle to factory gate	**913**	**kg CO_2e/tonne CEM I**
	(From cradle to leaving the factory gate of the addition manufacturer)	
Ground granulated blastfurnace slag (ggbs)	**67**	**kg CO_2e/tonne GGBS**
Fly Ash (from coal burning power generation)	**4**	**kg CO_2e/tonne Fly Ash**
Limestone Fines (see Note 1)	**75**	**kg CO_2e/tonne Limestone**
Weighted Average Cement (see Note 2). This is the weighted average of all CEM I, II, III and IV factory-made cements supplied by MPA Cement Member Companies in the UK.	**849**	**kg CO_2e/tonne cement**
Weighted Average Cementitious: cradle to factory gate (see Note 3). Includes all CEM I, II, III, IV cements, ggbs and fly ash supplied in the UK.	**787**	**kg CO_2e/tonne cementitious**

Note 1: Data supplied by a single UK supplier
Note 2: MPA Cement members are Hanson Cement, CEMEX UK, Lafarge Cement UK and Tarmac Buxton Lime and Cement. It is assumed that the material supplied to Northern Ireland is in the same proportion to that supplied in the UK. Materials imported and sold by companies not manufacturing in the UK are not included.
Note 3: The Weighted Average Cementitious CO_2e is the CO_2e of the individual cementitious materials i.e. CEM I, CEM II, CEM III, CEM IV and additions, weighted by the relative tonnages of each supplied in the UK. It is a representative number to use to address the CO_2e of concrete elements at the design stage where it is not possible to identify or specify a particular cement or equivalent combination as shown in Tables 3 and 4 below.

[1] This Fact Sheet has been designed to be compatible with the principles of draft standard ISO 14067 to provide a cradle to gate 'partial carbon footprint' as defined in that standard.

Cementitious materials available for use in the UK are:

Cement	Cement to BS EN 197-1, Cement — Part 1: *Composition, specifications and conformity criteria for common cements*
Ggbs	Ground granulated blastfurnace slag to BS EN 15167-1 Ground granulated blastfurnace slag for use in concrete mortar and grout — Part 1 Definition, specifications and conformity criteria
Fly ash	Fly ash to BS EN 450-1 Fly ash for concrete — Part 1: *Definition, specifications and conformity criteria*
Limestone	Limestone fines to BS 7979 *Specification for limestone fines for use with Portland cement*

Ggbs, fly ash and limestone are additions which are used in combination with CEM I at the concrete works in accordance with the British Standard for Concrete, BS 8500-2. These combinations are equivalent to the respective factory-made composite cements listed below:

CEM II/A or B-S, V, -L or -LL	Portland-slag, siliceous fly ash and limestone cements
CEM III/ A, B or C	Blastfurnace cement
CEM IV/B-V	Pozzolanic cement, siliceous fly ash

Note: CEM IV/BV may only be available to special order but its equivalent combination is available from a concrete plant.

2 Embodied CO_2 of factory-made cements and combinations

The CO_2e for factory made cements and combinations that are commonly available in the UK are shown in Tables 2 and 3 respectively. The data in this fact sheet does not include the transport of materials to the concrete plant and this should be added by the concrete manufacturer in order to determine the CO_2e for material delivered to a specific concrete plant.

Table 2: CO_2e of factory made cements

Cement[a] (Factory made cement)	**Secondary Main Constituent (smc)**[2] **Low – High Content (%)**	**CO_2e**[b] **Includes transport of all constituent materials to the cement works but not transport to concrete plant (this should be added as shown in section 3.1 below)** **smc content Low – High, (kg CO_2e/tonne)**
CEM I Portland Cement		**913**
CEM II/A-LL or L Portland Limestone Cement	**6 – 20 (limestone)**	**859 – 745**
CEM II/A-V Portland fly-ash cement	**6 – 20 (fly ash)**	**859 – 746**
CEM II/B-V Portland fly-ash cement	**21 – 35 (fly ash)**	**728 – 615**
CEM II/B-S Portland slag cement	**21 – 35 (ggbs)**	**743 – 639**
CEM III/A Blastfurnace cement	**36 – 65 (ggbs)**	**622 – 398**
CEM III/B Blastfurnace cement	**66 – 80 (ggbs)**	**381 – 277**
CEM IV/B-V Pozzolanic (siliceous fly ash) cement	**36 – 55 (fly ash)**	**598 – 441**

a For CEM I, 1% mac and 5% gypsum is assumed. For CEM II, CEM III and CEM IV at the highest proportion of the smc it is assumed that no mac is incorporated and at the lowest proportion of smc it is assumed that mac is added at 1% with the appropriate proportions of limestone, fly ash and ggbs

b CO_2e figures for CEM II, CEM III and CEM IV are based on the range of smc proportion, where the range is from the minimum to maximum proportion of smc. CO_2e can be interpolated for proportions of smc between the minimum and maximum, noting that the minimum CO_2e is associated with the highest proportion of smc

[2] Secondary Main Constituents or SMC are cementitious materials that are added to clinker or CEM I to produce CEM II, CEM III and CEM IV type cements.

Table 3: CO_2e of combinations produced at the concrete works.

Combination[a] (CEM I and addition combined at concrete plant)	**Addition**	**CO_2e**[b] **Includes transport of all constituent materials to the additions works but not transport to concrete plant (this should be added as shown in section 3.1 below)**
	Low – High Content (%)	**Addition content Low – High, (kg CO_2e/tonne)**
CIIA-LL or L	**6 – 20 (limestone)**	**863 – 745**
CIIA-V	**6 - 20 (fly ash)**	**858 - 731**
CIIB-V	**21 - 35 (fly ash)**	**722 – 595**
CIIB-S	**21 - 35 (ggbs)**	**735 – 617**
CIIIA	**36 - 65 (ggbs)**	**608 - 363**
CIIIB	**66 - 80 (ggbs)**	**354 – 236**
CIVB-V	**36 - 55 (fly ash)**	**586 – 413**

a For *combinations* the CO_2e figure for CEM I is used together with the figures for limestone, fly ash and ggbs in the appropriate proportions

b CO_2e figures for CII, CIII and CIV are based on the range of addition proportion, where the range is from the minimum to maximum proportion of the addition. CO_2e can be interpolated for proportions of addition between the minimum and maximum, noting that the minimum CO_2e is associated with the highest proportion of addition

3 Transport

3.1 Equations to Include Transport to the Concrete Works in CO_2e

The data in this fact sheet does not include any transport of materials to the concrete plant and this should be added by the concrete manufacturer in order to determine the CO_2e for material consumed at the concrete plant. The following calculations allow the concrete producer to calculate the CO_2e for material transported to and consumed at the concrete plant.

CO_2e = Cement type CO_2e as given in Table 3 + (% CEM I in combination x CEM I transport $kgCO_2e/t$) + (% of addition x transport $kgCO_2e/t$ of the addition)

e.g. CO_2e of a CIIB-V combination with 35% fly ash including transport to the concrete works (CEM I transport is 11kg CO_2e/t cement and fly ash transport is assumed to be 7 $kgCO_2e/t$ fly ash):

CO_2e of CII/B-V = 595 + (0.65 x 11) + (0.35 x 7)
CO_2e of CII/B-V = 605 $kgCO_2e/t$ cement

3.2 Representative Values of CO_2e Associated with Portland Cement Transport

If the consumer does not have information about the source and transport distances of the Portland Cement that is being consumed then the following representative values can be used as an estimate.

The $kgCO_2e/t$ Portland Cement transport are:

By Road: 10 $kgCO_2e/t$ Portland Cement
By Rail: 17 $kgCO_2e/t$ Portland Cement
By Water: 31 $kgCO_2e/t$ Portland Cement
Average: 11 $kgCO_2e/t$ Portland Cement

Note: that these figures are based on average industry data of transport of all factory-made cements and therefore includes packed as well as bulk products transported over varying distances.

4 Interpolation of CO_2e in Tables 2 and 3

As stated in the footnotes to Tables 2 and 3, values may be interpolated. For example:

CEM II/A-LL declared by the manufacturer at 15% limestone is: 786 kg CO_2/tonne

NOTE. That is the difference between the high and low CO_2e figures for CEM II/A-LL (859 - 745 = 114) is divided by the high and low difference in proportions (20 – 6 = 14) giving 114 ÷ 14 = 8.1 per 1%. 15% limestone is 5% lower than 20% so the CO_2e value is higher: 745 + (5 x 8.1) = 785.5, or 786 kg CO_2/tonne to the nearest tonne.

Similarly:
CEM II/B-V declared by the cement manufacturer at 30% fly ash is: 655 kg CO_2/tonne.

CEM III/A declared by the cement manufacturer at 40% ggbs is: 591 kg CO_2/tonne
CEM III/A declared by the cement manufacturer at 50% ggbs is: 514 kg CO_2/tonne
CEM III/B at 70% ggbs is: 351 kg CO_2/tonne

The same interpolations can be applied for combinations (Table 3) produced at the concrete works.

5 Scope and Boundaries

Table 4 demonstrates that the majority of data used in the Fact Sheet has been collected from operators and has been verified by external auditors. Where data collection did not take place under a regulated scheme, then Defra standard factors have largely been applied to data collected by trade associations. Where there are minor gaps in data, estimates have been used.

Table 4: Cradle to gate inventory of CO_2e, with source of data

Manufacturing Process	**Ground Clinker**	**Cement**	**Ggbs**	**Fly ash**	**Lime-stone**	**MAC**	**Gypsum**
Fuel for transporting materials to processing plant (extraction, processing, delivery and use)	-	-	CSMA	UKQAA	Omya UK	MPAC	BG*
Fuel for Transport to cement works (extraction, processing, delivery and use)	MPAC transport data converted using Defra guidelines[3]	-	MPAC transport data converted using Defra guidelines[3]	MPAC transport data converted using Defra guidelines[3]	MPAC transport data converted using Defra guidelines[3]	MPAC transport data converted using Defra guidelines[3]	MPAC transport data converted using Defra guidelines[3]
Alternative Raw Materials (transport to cement works)	MPAC	-	MPAC	MPAC	MPAC	MPAC	MPAC
Natural Raw Materials (extraction and transport)	MPAC	-	-	-	Omya UK	MPAC	BG*
Alternative Waste-derived Fuels (transport)	MPAC	-	-	-	-	-	-
Kiln Fuel (extraction, processing and delivery)	MPAC data on quantity converted using Defra guidelines[3]	-	-	-	-	-	-
Primary Electricity for clinker or granulation (includes raw materials processing)	CCA MPAC	-	CSMA	-	-	-	-
Calcination	EU ETS MPAC	-	-	-	-	-	-

[3] *"2011 Guidelines to Defra/DECC's GHG Conversion Factors for Company Reporting"*, 2011, Defra, Using 'All Scopes' factors, http://archive.defra.gov.uk/environment/business/reporting/pdf/110707-guidelines-ghg-conversion-factors.pdf

Combustion	EU ETS MPAC	-	-	-	-	-	-
Direct emissions of methane	MPAC	-	-	-	-	-	-
Direct emissions of nitrous oxide	MPAC	-	-	-	-	-	-
Fuel for drying	-	-	CCA CSMA	UKQAA*	Omya UK	MPAC*	-
Fuel for mobile plant	-	-	CSMA	UKQAA*	Omya UK	MPAC*	-
Primary Electricity to grind classify/separate.	CCA MPAC	CCA MPAC	CCA CSMA	-	Omya UK	MPAC*	-
Imported Clinker or Granulate	MPAC	-	CSMA	-	-	-	-
Waste	MPAC	-	-	-	-	-	-
Key:							
BG	Data supplied by British Gypsum. Note that this is 2007 calendar year data.						
CCA	Data as audited and verified under the UK Climate Change Agreement						
CSMA	Cementitious Slag Makers Association						
*	Estimate						
EU ETS	Regulated, audited and verified under the European Union Emissions Trading Scheme and its monitoring, reporting and verification guidelines						
MPAC	Mineral Products Association- Cement						
UKQAA	United Kingdom Quality Ash Association						

6 Carbon emission factors and allocation

6.1 General

Emissions of CO_2e in the generation and transmission of electricity were based on the 2009 grid rolling average factor in the 2011 Defra Guidelines[3].

Data on transport of raw materials and kiln fuel was collected by MPA and other contributing associations and converted using the 2011 Defra Guidelines[3]. The factors used included emissions associated with extraction and processing of the fuels.

6.2 Cement

Higher accuracy industry specific carbon emissions factors and calorific values in accordance with the EU ETS Monitoring and Reporting Guidelines, *'Guidance on Annual Verification'* v5, December 2008[4] have been used. Where used, biomass for combustion is considered 'carbon neutral' under the EU ETS and therefore is not considered to contribute CO_2e to the overall CO_2e value.

6.3 By-products

No CO_2e from the primary processes has been allocated to either blast furnace slag from iron manufacture or fly ash from coal fired power stations. This is on the basis that these materials will arise, irrespective of whether they are used or not. EN 15804[5] has been used as guidance and under

[4] EU ETS Monitoring and Reporting Guidelines, Guidance on Annual Verification v5, December 2008, http://www.decc.gov.uk/en/content/cms/emissions/eu_ets/euets_phase_ii/monitoring/monitoring.aspx

[5] EN 15804 "*Sustainability of construction works- Environmental product declarations- Core rules for the product category of construction products*".

this standard, processes contributing of the order of 1% or less to the overall revenue are allowed to be neglected for the purposes of allocation. An estimate based on UK data concluded that the revenue from blastfurnace slag relative to the total revenue (iron + slag) was only of this order and that allocation was therefore not necessary.

6.4 Imported materials

CO_2e attributable to materials transport to the UK is calculated using distance data collected by MPA Cement and *'2011 Guidelines to Defra/DECC's GHG Conversion Factors for Company Reporting'*[3]. Data concerning imported materials by non-manufacturers (independent importers) is not included in this fact sheet.

7 Which cementitious associations have contributed data to this Fact Sheet?

This information has been supplied by the following associations and their members:

MPA Mineral Products Association, http://cement.mineralproducts.org/

CSMA Cementitious Slag Makers Association, www.ukcsma.co.uk

UKQAA UK Quality Ash Association, www.ukqaa.org.uk

NOTE: More information on sustainability is available at www.sustainableconcrete.org.uk

8 Where can I find out more?

For information on the methodology used in this fact sheet please contact Dr R. Leese (Richard.Leese@mineralproducts.org) or Dr D. Casey (Diana.Casey@mineralproducts.org) at MPA.

MPA Cement has also published an Environmental product Declaration for the UK average cement. This is available to download here: http://cement.mineralproducts.org/sustainability/sustainable_production/environmental_product_declaration.php

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