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8																		0.5190	WBCSD GNR suggests 60 percent process emissions of global average of 866 kg CO2 per tonne of clinker
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11																		0.5203	IPCC tier 1 approach, IPCC 2006
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13 14																		0.5190	truing up to CDIAC process emission factor
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16	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Million tonnes CO2	Cement process emissions
17	57.1%	57.5%	57.8%	58.2%	58.6%	58.9%	59.3%	59.7%	60.1%	60.5%	60.9%	61 30	62.70	64 501	CE 90'	67.00	CC 404		Drocess emissions on persons of Carro CO2
18 19	57.1%	37.3%	57.8%	38.2%	38.8%	38.9%	59.5%	39.7%	60.1%	60.5%	60.9%	61.3%	63.7%	64.5%	65.8%	67.0%	66.4%		Process emissions as percent of Gross CO2
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23 24	210	237	245	255	267	286	298	330	362	430	484	533	617	679	692	806	890	9,150	China, PRC
25	28	28	27	27	26	25	25	24	22	24	26	26	29	34	35	30	31	587	HeidelbergCement
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34 35		13	14	13	12	11		11	11	10	10	10	11					402	Taiheiyo
34 35 36	13 376						11 470							10 914	930	1,017	1,106		Taiheiyo
34 35 36 37	376	13	14	13	12	11 457	470	504	537	10 613	10 678	735	838	914	930	1,017	1,106	13,205	Taiheiyo Emissions from identified cement prod'n (MtCO2)
34 35 36 37 38		13	14	13	12	11		11	11	10	10	10	11					402	Taiheiyo Emissions from identified cement prod'n (MtCO2)
34 35 36 37 38 39	376	13 405	14 415	13 426	12 438 120	11 457	470	11 504	537	10 613	10 678	735 201	838 229	914 249	930 254	1,017 278	1,106 y	13,205	Taiheiyo Emissions from identified cement prod'n (MtCO2) Carbon in identified cement prod'n (MtC)
34 35 36 37 38 39 40	376	13	14	13	12	11 457	470	504	537	10 613	10 678	735	838	914	930	1,017	1,106	13,205	Taiheiyo Emissions from identified cement prod'n (MtCO2) Carbon in identified cement prod'n (MtC)
34 35 36 37 38 39 40 41	376	13 405	14 415	13 426	12 438 120	11 457	470	11 504	537	10 613	10 678	735 201	838 229	914 249	930 254	1,017 278	1,106 y	13,205	Taihelyo Emissions from identified cement prod'n (MtCO2) Carbon in identified cement prod'n (MtC) CDIAC cement emissions (Million tonnes of CO2) 1929-2010
34 35 36 37 38 39 40	376 103 682	13 405	14 415 113 744	13 426 116 766	12 438 120 766	11 457 125 795	470 128 828	11 504 138 868	537 147 923	10 613 167 1,011	10 678 185 1,092	735 201 1,173	838 229 1,301	914 249 1,400	930 254 1,414	1,017 278 1,509	1,106 y	13,205 3,604 32,519	Taihelyo Emissions from identified cement prod'n (MtCO2) Carbon in identified cement prod'n (MtC) CDIAC cement emissions (Million tonnes of CO2) 1929-2010
34 35 36 37 38 39 40 41 42 43 44	376 103 682	13 405	14 415 113 744	13 426 116 766	438 120 766	11 457 125 795	470 128 828	11 504 138 868	537 147 923	10 613 167 1,011	10 678 185 1,092	735 201 1,173	838 229 1,301	914 249 1,400	930 254 1,414	1,017 278 1,509	1,106 y	13,205 3,604 32,519	Taiheiyo Emissions from Identified cement prod'n (MtCO2) Carbon in identified cement prod'n (MtC) CDIAC cement emissions (Million tonnes of CO2) 1929-2010 CDIAC cement emissions (Million tonnes of carbon)
34 35 36 37 38 39 40 41 42 43	376 103 682 186	13 405 111 722 197	14 415 113 744 203	13 426 116 766 209	12 438 120 766 209	11 457 125 795 217	128 828 226 56.8%	11 504 138 868 237 58.0%	537 147 923 252 58.2%	10 613 167 1,011 276 60.6%	10 678 185 1,092 298 62.1%	735 201 1,173 320 62.7%	838 229 1,301 355 64.4%	914 249 1,400 382 65.3%	930 254 1,414 386 65.7%	1,017 278 1,509 412 67.4%	1,106 3 302 3 1,638 3 447 3 67.5% 3	13,205 3,604 2,32,515 8,875 40.66	Taiheiyo Emissions from identified cement prod'n (MtCO2) Carbon in identified cement prod'n (MtC) CDIAC cement emissions (Million tonnes of CO2) 1929-2010 CDIAC cement emissions (Million tonnes of carbon) Percent of cumulative CDIAC cement emissions
34 35 36 37 38 39 40 41 42 43 44 45	376 103 682 186	13 405 111 722 197	14 415 113 744 203	13 426 116 766 209	12 438 120 766 209	11 457 125 795 217	128 828 226 56.8%	11 504 138 868 237 58.0%	11 537 147 923 252	10 613 167 1,011 276 60.6%	10 678 185 1,092 298 62.1%	735 201 1,173 320 62.7%	838 229 1,301 355 64.4%	914 249 1,400 382 65.3%	930 254 1,414 386 65.7%	1,017 278 1,509 412 67.4%	1,106 3 302 3 1,638 3 447 3 67.5% 3	13,205 3,604 32,519 8,875	Taiheiyo Emissions from identified cement prod'n (MtCO2) Carbon in identified cement prod'n (MtC) CDIAC cement emissions (Million tonnes of CO2) 1929-2010 CDIAC cement emissions (Million tonnes of carbon) Percent of cumulative CDIAC cement emissions
34 35 36 37 38 39 40 41 42 43 44 45 46	376 103 682 186	13 405 111 722 197	14 415 113 744 203	13 426 116 766 209	12 438 120 766 209	11 457 125 795 217	128 828 226 56.8%	11 504 138 868 237 58.0%	537 147 923 252 58.2%	10 613 167 1,011 276 60.6%	10 678 185 1,092 298 62.1%	735 201 1,173 320 62.7%	838 229 1,301 355 64.4%	914 249 1,400 382 65.3%	930 254 1,414 386 65.7%	1,017 278 1,509 412 67.4%	1,106 3 302 3 1,638 3 447 3 67.5% 3	13,205 13,604 32,519 8,875 40.69	Taihelyo Emissions from identified cement prod'n (MtCO2) Carbon in identified cement prod'n (MtC) CDIAC cement emissions (Million tonnes of CO2) 1929-2010 CDIAC cement emissions (Million tonnes of carbon) Percent of cumulative CDIAC cement emissions
34 35 36 37 38 39 40 41 42 43 44 45 46	376 103 682 186	13 405 111 722 197	14 415 113 744 203	13 426 116 766 209	12 438 120 766 209	11 457 125 795 217	128 828 226 56.8%	11 504 138 868 237 58.0%	537 147 923 252 58.2%	10 613 167 1,011 276 60.6%	10 678 185 1,092 298 62.1%	735 201 1,173 320 62.7%	838 229 1,301 355 64.4%	914 249 1,400 382 65.3%	930 254 1,414 386 65.7%	1,017 278 1,509 412 67.4%	1,106 3 302 3 1,638 3 447 3 67.5% 3	13,205 3,604 2,32,515 8,875 40.66	Taihelyo Emissions from identified cement prod'n (MtCO2) Carbon in identified cement prod'n (MtC) CDIAC cement emissions (Million tonnes of CO2) 1929-2010 CDIAC cement emissions (Million tonnes of carbon) Percent of cumulative CDIAC cement emissions
34 35 36 37 38 39 40 41 42 43 44 45	376 103 682 186	13 405 111 722 197	14 415 113 744 203	13 426 116 766 209	12 438 120 766 209	11 457 125 795 217	128 828 226 56.8%	11 504 138 868 237 58.0%	537 147 923 252 58.2%	10 613 167 1,011 276 60.6%	10 678 185 1,092 298 62.1%	735 201 1,173 320 62.7%	838 229 1,301 355 64.4%	914 249 1,400 382 65.3%	930 254 1,414 386 65.7%	1,017 278 1,509 412 67.4%	1,106 3 302 3 1,638 3 447 3 67.5% 3	13,205 13,604 32,519 8,875 40.69	Taihelyo Emissions from identified cement prod'n (MtCO2) Carbon in identified cement prod'n (MtC) CDIAC cement emissions (Million tonnes of CO2) 1929-2010 CDIAC cement emissions (Million tonnes of carbon) Percent of cumulative CDIAC cement emissions
34 35 36 37 38 39 40 41 42 43 44 45	376 103 682 186 55.2%	13 405 111 722 197 56.1%	14 415 113 744 203 55.8%	13 426 116 766 209 55.6%	12 438 120 766 209 57.2%	11 457 125 795 217 57.5%	470 128 828 226 56.8% Total e	11 504 138 868 237 58.0%	11 537 147 923 252 58.2%	10 613 167 1,011 276 60.6%	10 678 185 1,092 298 62.1%	735 201 1,173 320 62.7% product	838 229 1,301 355 64.4%	914 249 1,400 382 65.3% ough 20	930 254 1,414 386 65.7%	1,017 278 1,509 412 67.4% on tonno	1,106) 302) 1,638) 447) 67.5%)	13,205 13,604 32,519 8,875 40.69	Taiheiyo Emissions from identified cement prod'n (MtCO2) Carbon in identified cement prod'n (MtC) CDIAC cement emissions (Million tonnes of CO2) 1929-2010 CDIAC cement emissions (Million tonnes of carbon) Percent of cumulative CDIAC cement emissions (Cement process emissions, excluding China
34 35 36 37 38 39 40 41 42 43 44 45	376 103 682 186 55.2%	13 405 111 722 197 56.1%	14 415 113 744 203 55.8%	13 426 116 766 209 55.6%	12 438 120 766 209 57.2%	11 457 125 795 217 57.5%	470 128 828 226 56.8% Total e	11 504 138 868 237 58.0% missions	11 537 147 923 252 58.2% s from ide	10 613 167 1,011 276 60.6% entified	10 678 185 1,092 298 62.1% cement	10 735 201 1,173 320 62.7% product	838 229 1,301 355 64.4% cion thro	914 249 1,400 382 65.3% ough 20	930 254 1,414 386 65.7% 10 (milli)	1,017 278 1,509 412 67.4% + electric in ent of gross	1,106 3 302 3 1,638 3 447 3 67.5% 3	13,205 3,604 32,519 8,875 40.69 13,205 4,059 ("Gross cement emissions" s for 1990, 2000, 2005, ar	Taiheiyo Emissions from identified cement prod'n (MtCO2) Carbon in identified cement prod'n (MtC) CDIAC cement emissions (Million tonnes of CO2) 1929-2010 CDIAC cement emissions (Million tonnes of carbon) Percent of cumulative CDIAC cement emissions (Cement process emissions, excluding China worksheet.) 1 2006.
34 35 36 37 38 39 40 41 42 43 44 45	376 103 682 186 55.2%	13 405 111 722 197 56.1%	14 415 113 744 203 55.8%	13 426 116 766 209 55.6%	12 438 120 766 209 57.2%	11 457 125 795 217 57.5%	470 128 828 226 56.8% Total e	11 504 138 868 237 58.0% missions	11 537 147 923 252 58.2% s from ide	10 613 167 1,011 276 60.6% entified	10 678 185 1,092 298 62.1% cement	10 735 201 1,173 320 62.7% product	838 229 1,301 355 64.4% cion thro	914 249 1,400 382 65.3% ough 20	930 254 1,414 386 65.7% 10 (milli)	1,017 278 1,509 412 67.4% + electric in ent of gross	1,106 3 302 3 1,638 3 447 3 67.5% 3	13,205 13,604 32,519 40.61 13,205 4,05: ("Gross cement emissions"	Taiheiyo Emissions from identified cement prod'n (MtCO2) Carbon in identified cement prod'n (MtC) CDIAC cement emissions (Million tonnes of CO2) 1929-2010 CDIAC cement emissions (Million tonnes of carbon) Percent of cumulative CDIAC cement emissions (Cement process emissions, excluding China worksheet.) 1 2006.

Cell: CN2

Comment: Rick Heede

CMS lists the IPCC 1996 Guideline factor of EF clinker = 0.646 * 0.785 = 0.5071 tCO2 per tonne of clinker produced. (Average clinker lime percentage of 64.6 percent; molecular weight ratio of CO2/CaO = 78.5 percent.)

Cell: CN4

Comment: Rick Heede

To quote from Boden et al (1995): "This conversion factor was obtained by dividing the molar mass of carbon by the molar mass of calcium oxide and multiplying this quotient by the average fraction of calcium oxide contained in cement: (12.01 g C/mole CaCO3 + 56.08 g Ca) //mole Ca(CO3)** 0.635 g CaO / g cement * 0.136 g C / g cement.*

"The consensus that 63.5% of the typical cement in the world is composed of calcium oxide is based on the opinions of experts consulted in the field, as well as inspection of composition data by type and country (Griffn 1987).*

(CMS: The formula: (12.01/56.08)*0.635*3.667 = 0.4987, rounded up to 0.500.

CDIAC (1995) Estimates of Global, Regional, and National Annual CO2 Emissions from Fossil-Fuel Burning, Hydraulic Cement Production, and Gas Flaring: 1950-1992, by T. A.. Boden, G. Marland, & R. J. Andres. cdiac.oml.gov/epubs/ndp/ndp030/ndp0301.htm#co2man

Cell: CN6

Comment: Rick Heede (Mar10):

WBCSD's Cement Sustainability Initiative reports average global gross emissions per tonne of clinker produced at 866 kg CO2 per tonne (declining from 914 kg CO2/tonne in 1990. See rpt for geographic, process (wet vs dry), or temporal variables, and entity reporting by region. Process emissions from calcining limestone into clinker is typically 540 kg CO2 per tonne of clinker.

WBCSD, Cement Sustainability Initiative (2009) Cement Industry Energy and CO2 Performance "Getting the Numbers Right", World Business Council for Sustainable Development, 44 pp., www.wbcsdcement.org

Cell: CN8

Comment: Rick Heede

WBCSD Cement Sustainability Initiative (2009) Cement Industry Energy and CO2 Performance "Getting the Numbers Right", World Business Council for Sustainable Development, 44 pp., wbcsdcement.org.

Page 30:

10) about 60% of gross CO2 emissions originate fom limestone decomposition
(2) 40% are fuel emissions where, apart from energy efficiency, the fuel composition plays a role.
In Figure 6.4: Gross CO2 emissions per tonne of clinker, 2006: GNR global average 866 kg CO2 per tonne of clinker.

CMS: Thus 60 percent of 866 kgCO2/t = 519.6 kg CO2/tonne.

Cell: CN11

Comment: Rick Heede

PIECC (2006) Guidelines, Vol. 3, Chapter 2, Section 2.2.1.2 Choice of Emission Factors, Tier 1 Method, page 2.11.

"For the default CaO composition, 1 tonne of clinker contains 0.65 tonnes CaO from CaCO3. This carbonate is 56.03 percent CaO and 43.97 percent CO2 by weight (Table 2.1). The amount (X) of CaCO3 needed to yield 0.65 tonnes CaO is: X = 0.65/0.5603 = 1.1601 tonnes CaCO3 (unrounded). The amount of CO2 released by calcining this CaCO3 = 1.1601 • 0.4397 = 0.5101 tonnes CO2 (unrounded). Assuming a correction addition of 2 percent to account for CKD, the rounded default emission factor (EFclc) for clinker is 0.52 tCO2/tonne of clinker.'

Intergovernmental Panel on Climate Change (2006) 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Volume 3: Industrial Processes and Product Use, Chapter 2: Mineral Industry Emissions, www.ipcc-nggip.iges.or.jp/public/2006glvol3.html

Cell: CN13

Comment: Rick Heede

Note: CMS compared carbon emissions from world cement production using USGS production data 1926-2010 results in estimates ~3.8 percent higher than cement emission estimates by CDIAC (based on both totals 1950-2010).

Correcting the Carbon Majors calculations to that of CDIAC suggests a process emission factor of 519.6 - (519.6 0.00377) = 499.86 kg CO2/tonne.

CDIAC (1995) Estimates of Global, Regional, and Naitonal Annual CO2 Emissions from Fossil-Fuel Burning, Hydraulic Cement Production, and Gas Flaring: 1950-1992, by T. A.. Boden, G. Marland, & R. J. Andres. cdiac.ornl.gov/epubs/ndp/ndp030/ndp0301.htm#co2man

Cell: CN18

Comment: Rick Heede

* CMS has collected data from company CSR reports on gross CO2 emissions on each entity's emissions from both process emissions (calcining limestone) and thermal + electric input emissions. ("Gross cement emissions" worksheet.)

In order to estimate process emissions only (to exclude each entity's fossil fuel emissions), CMS uses WBCSD's CSI data on average industry process emissions as a percent of gross CO2 emissions for 1990, 2000, and 2005-2009.

This percentage (in row 12) is applied to each entity's gross CO2 emissions from cement manufacturing (previous worksheet).

This percentage data series is derived in the Cement.xls workbook / "Cement industry data", Table 3, row "AB"

Cell: CN23

Comment: Rick Heede:

CMS uses CDIAC emissions from cement production in China 1929-2010.

Cell: CN40

CDIAC data in million tonnes of carbon converted to CO2, which is 3.664191 times Carbon if carbon and oxygen isotopes are accounted for, per Kevin Baumert May05, then at World Resources Institute: CO2 conversion is, precisely: C=12.0107 + O=15.9994 x 2 = 44.0095/12.0107 = 3.664191.

Comment: Rick Heede

From the associated "Methods" paper: CDIAC's emissions methodology is not described.

Boden, T.A., G. Marland, and R.J. Andres. 2009. Global, Regional, and National Fossil-Fuel CO2 Emissions. Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, U.S. Department of Energy, Oak Ridge, Tenn., U.S.A. doi 10.3334/CDIAC/00001.

Dec11: CMS added CDIAC extrapolations for gas emissions from their dataset "Preliminary 2009-2010 Global & National Estimates by Extrapolation" (undated) to the main file cited above

Cell: CN52 Comment: Rick Heede:

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Cell: CN53 Comment: Rick Heede: Process emissions

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