

Table S1: Ecoinvent 3.6 database documentation of clinker production: South Africa (ZA)

Reference product	Amount
Clinker	1 kg
Inputs from Technosphere	Amount
Ammonia, liquid	0.000918 kg
Bauxite	0.04 kg
Cement factory	6.2e-12 unit
Diesel, burned in building machine	0.0132 MJ
Diesel, low-sulphur	0.000427 kg
Electricity, medium voltage	0.14 kWh
Hard coal	0.145 kg
Industrial machine, heavy, unspecified	3.76e-05 kg
Iron ore, crude ore, 46% Fe	0.000143 kg
Light fuel oil	0.000367 kg
Lime, hydrated, loose weight	0.00388 kg
Limestone, crushed, for mill	0.9 kg
Lubricating oil	4.71e-05 kg
Magnetite	0.01 kg
Refractory, basic, packed	0.00019 kg
Refractory, fireclay, packed	8.21e-05 kg
Refractory, high aluminum oxide, packed	0.000137 kg
Sand	0.05 kg
Steel, chromium steel 18/8, hot rolled	5.86e-05 kg
Inputs from Technosphere	Amount
Tap water	0.336 kg
Urea, as N	1.5e-06 kg
Inputs from environment	Amount
Water, cooling, unspecified natural origin	9.57e-06 m3
Water, unspecified natural origin	0.0016 m3
Emissions to air	Amount
Ammonia	2.25e-05 kg
Antimony	2.24e-09 kg
Arsenic	1.22e-08 kg
Beryllium	2.97e-09 kg
Cadmium	6.87e-09 kg
Carbon dioxide, fossil	0.838 kg
Carbon dioxide, non-fossil	0.0155 kg
Carbon monoxide, fossil	0.000489 kg

Chromium	2.1e-09 kg
Chromium VI	5.44e-10 kg
Cobalt	3.98e-09 kg
Copper	1.42e-08 kg
Dioxins, measured as 2,3,7,8-tetrachlorodibenzo-p-dioxin	9.43e-13 kg
Lead	8.39e-08 kg
Manganese	5.74e-10 kg
Mercury	3.25e-08 kg
Methane, fossil	8.79e-06 kg
NM VOC, non-methane volatile organic compounds	5.59e-05 kg
Nickel	6.71e-09 kg
Nitrogen oxides	0.000977 kg
Particulates, < 2.5 um	2.37e-05 kg
Particulates, > 10 um	6.5e-06 kg
Particulates, > 2.5 um, and < 10um	0.000123 kg
Selenium	1.98e-09 kg
Sulphur dioxide	5.92e-05 kg
Thallium	1.3e-08 kg
Tin	9.05e-09 kg
Vanadium	4.97e-09 kg
Water	0.000294 m3
Zinc	6.34e-08 kg
Emissions to air	Amount
Ammonia	2.25e-05 kg
Antimony	2.24e-09 kg
Arsenic	1.22e-08 kg
Beryllium	2.97e-09 kg
Cadmium	6.87e-09 kg
Carbon dioxide, fossil	0.838 kg
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Lead	8.39e-08 kg
Manganese	5.74e-10 kg
Mercury	3.25e-08 kg
Methane, fossil	8.79e-06 kg
NM VOC, non-methane volatile organic compounds, unspecified origin	5.59e-05 kg

Table S2: Ecoinvent 3.6 dataset documentation for Portland cement production: South Africa

Reference product	Amount
Cement, Portland	1 kg
Inputs from Technosphere	
Cement factory	5.36e-11 unit
Clinker	0.902 kg
Electricity, medium voltage	0.0376 kWh
Ethylene glycol	0.00019 kg
Gypsum, mineral	0.0475 kg
Limestone, crushed, for mill	0.05 kg
Steel, low-alloyed	5.25e-05 kg
Emissions to air	
Heat, waste	0.135 MJ

Table S3: Uncertainty results for mid-point analysis

Impact category	Unit	Mean	Median	SD	CV	2.50%	97.50%	SEM
Fine particulate matter formation	kg PM2.5 eq	0.000803	0.000737	0.000325	40.5%	0.000355	0.001615	1.03E-05
Fossil resource scarcity	kg oil eq	0.141404	0.12733	0.062775	44.34%	0.05776	0.300724	0.001985
Freshwater ecotoxicity	kg 1,4-DCB	0.016241	0.013214	0.011798	72.6%	0.005574	0.04833	0.000373
Freshwater eutrophication	kg P eq	0.000329	0.000243	0.0003	91.2%	6.02E-05	0.001051	9.48E-06
Global warming	kg CO2 eq	1.00863	0.913186	0.459852	45.6%	0.388636	2.158094	0.014542
Human carcinogenic toxicity	kg 1,4-DCB	0.026046	0.012594	0.06141	235.8%	0.003659	0.12182	0.001942
Human non-carcinogenic toxicity	kg 1,4-DCB	0.494297	0.358147	0.439479	88.9%	0.120207	1.767484	0.013898
Ionizing radiation	kBq Co-60 eq	0.0104	0.005285	0.024081	231.6	0.001014	0.050712	0.000762
Land use	m2a crop eq	0.00797	0.007082	0.003759	47.2%	0.003102	0.01781	0.000119
Marine ecotoxicity	kg 1,4-DCB	0.022008	0.017491	0.016481	74.9%	0.007482	0.067542	0.000521
Marine eutrophication	kg N eq	1.95E-05	1.75E-05	9.64E-06	49.4%	7.25E-06	4.38E-05	3.05E-07

Mineral resource scarcity	kg Cu eq	0.002204	0.002005	0.00093	42.2%	0.000926	0.004503	2.94E-05
Ozone formation, Human health	kg NOx eq	0.002116	0.001942	0.000937	44.3%	0.000851	0.004525	2.96E-05
Ozone formation, Terrestrial ecosystems	kg NOx eq	0.002132	0.001959	0.000945	44.3%	0.000857	0.00456	2.99E-05
Stratospheric ozone depletion	kg CFC11 eq	1.97E-07	1.70E-07	1.08E-07	54.9%	6.95E-08	4.73E-07	3.43E-09
Terrestrial acidification	kg SO2 eq	0.00247	0.002266	0.001	40.5%	0.001096	0.005009	3.16E-05
Terrestrial ecotoxicity	kg 1,4-DCB	1.050833	0.939033	0.498372	47.4%	0.412359	2.398997	0.01576
Water consumption	m ³	0.001112	0.002269	0.016392	1473.9%	0.03951	0.033396	0.000518

Table S4: Uncertainty results for end-point impacts of analysis

Impact category	Unit	Mean	Median	SD	CV	2.50%	97.50%	SEM
Fine particulate matter formation	DALY	5.06E-07	4.62E-07	2.06E-07	40.7%	2.40E-07	1.03E-06	6.51E-09
Fossil resource scarcity	USD2013	0.016632	0.014993	0.007489	45.03%	0.007227	0.036052	0.000237
Freshwater ecotoxicity	Species.yr	1.10E-11	9.05E-12	8.41E-12	76.3%	3.61E-12	3.06E-11	2.66E-13
Freshwater eutrophication	Species.yr	2.13E-10	1.54E-10	1.94E-10	90.8%	3.72E-11	7.49E-10	6.12E-12
Global warming, Freshwater ecosystems	Species.yr	7.73E-14	6.91E-14	3.55E-14	45.8%	3.17E-14	1.71E-13	1.12E-15
Global warming, Human health	DALY	9.38E-07	8.38E-07	4.30E-07	45.9%	3.84E-07	2.07E-06	1.36E-08
Global warming, Terrestrial ecosystems	Species.yr	2.83E-09	2.53E-09	1.30E-09	45.9%	1.16E-09	6.26E-09	4.10E-11
Human carcinogenic toxicity	DALY	8.28E-08	4.14E-08	1.81E-07	218.9%	1.30E-08	3.91E-07	5.73E-09
Human non-carcinogenic toxicity	DALY	1.14E-07	8.32E-08	1.16E-07	102.3%	2.67E-08	3.78E-07	3.67E-09

Ionizing radiation	DALY	8.95E-11	4.74E-11	1.46E-10	162.5%	9.41E-12	3.91E-10	4.60E-12
Land use	Species.yr	7.05E-11	6.27E-11	3.24E-11	45.9%	2.84E-11	1.54E-10	1.02E-12
Marine ecotoxicity	Species.yr	2.26E-12	1.85E-12	1.78E-12	78.8%	7.24E-13	6.48E-12	5.64E-14
Marine eutrophication	Species.yr	3.37E-14	2.99E-14	1.67E-14	49.5%	1.23E-14	7.59E-14	5.28E-16
Mineral resource scarcity	USD2013	0.000513	0.000461	0.000222	43.3%	0.000225	0.001092	7.01E-06
Ozone formation, Human health	DALY	1.94E-09	1.75E-09	8.74E-10	44.9%	8.17E-10	4.34E-09	2.76E-11
Ozone formation, Terrestrial ecosystems	Species.yr	2.78E-10	2.50E-10	1.25E-10	44.9%	1.17E-10	6.20E-10	3.95E-12
Stratospheric ozone depletion	DALY	1.05E-10	9.28E-11	5.30E-11	50.7%	3.88E-11	2.45E-10	1.68E-12
Terrestrial acidification	Species.yr	5.25E-10	4.82E-10	2.13E-10	40.6%	2.51E-10	1.08E-09	6.75E-12
Terrestrial ecotoxicity	Species.yr	1.21E-11	1.08E-11	6.48E-12	53.4%	4.70E-12	2.76E-11	2.05E-13
Water consumption, Aquatic ecosystems	Species.yr	1.97E-15	1.94E-15	1.51E-14	766.7%	-2.86E-14	3.51E-14	4.78E-16
Water consumption, Human health	DALY	2.33E-09	3.96E-09	3.29E-08	1414.0%	-6.99E-08	6.41E-08	1.04E-09
Water consumption, Terrestrial ecosystem	Species.yr	2.52E-11	3.72E-11	2.00E-10	791.7%	-4.18E-10	4.17E-10	6.32E-12

Table S5: Uncertainty results for end-point impacts analysis: Damage assessment

Damage category	Unit	Mean	Median	SD	CV	2.50%	97.50%	SEM
Ecosystems	Species.yr	3.97E-09	3.54E-09	1.79E-09	45.2%	1.68E-09	8.58E-09	5.67E-11
Human health	DALY	1.64E-06	1.46E-06	7.50E-07	45.6%	7.07E-07	3.64E-06	2.37E-08
Resources	USD2013	0.017145	0.015467	0.007701	44.9%	0.007478	0.037304	0.000244