Proposed GHG reduction measures: Improve energy efficiency, switch to natural gas, and make limestone blended cement

Baseline Assumptions *(Constants, Emission Factors and References can be found at the bottom of the page)*

Parameter	Value	Units	Source	Assumptions
2020 CO2 equivalents production from cement	14.75813747	MMT/yr	Sum of emissions due to fuel combustion, production process & electricity use	
2020 Estimate CO2 equivalents due to fuel combustion	5.364846535	MMT/yr	2% annual increase over 2004 CARB GHG Draft Inventory	
2020 Estimate CO2 equivalents due to production process	8.295	MMT/yr	2% annual increase over 2004 CARB GHG Draft Inventory	
2020 Estimate CO2 equivalents due to electricity use	1.098228564	MMT/yr	2% annual increase over 2004 CARB Staff Analysis for EAMs	
2020 CA clinker production	17,538,419.27	short tons clinker/yr	2% annual increase over 2004 CARB GHG Draft Inventory Documentation	
2020 Cement production	16,374,587.89	metric tons/yr	2% annual increase over USGS 2004 Minerals Yearbook: Cement	
2020 Fuel Combustion= Coal	1737946.703	tons	2% annual increase over 2004 CARB GHG Draft Inventory	
2020 Fuel Combustion= Pet Coke	383556.326	tons	2% annual increase over 2004 CARB GHG Draft Inventory	
2020 electricity use	1976.811415	GWh	2% annual increase over 2004 CARB Staff Analysis for EAMs	
2020 CO2 equivalents from Coal Combustion	3.931908353	MMT/yr	2% annual increase over 2004 CARB GHG Draft Inventory	
2020 CO2 equivalents Pet Coke Combustion	1.182362642	MMT/yr	2% annual increase over 2004 CARB GHG Draft Inventory	
2020 Total CO2 eq from High Carbon fuels	5.114270995	MMT/yr	(sum of coal and pet coke emissions)	
2020 Energy from Coal	41345752.06	Mbtu	(coal combustion X heat content of coal)	
2020 Energy from Pet Coke	11552716.54	Mbtu	(pet coke combustion X heat content of pet coke)	
2020 Total Energy from High Carbon fuels	52898468.6	Mbtu	(sum of coal and pet coke)	
2020 Costs due to coal use	$87,279,683	dollars/yr	(coal combustion X price of coal)	
2020 Costs due to pet coke use	$13,978,787	dollars/yr	(energy from pet coke X price of pet coke)	
2020 GHG intensity	0.90	MT CO2 eq/metric ton clinker		

Scenario I: All CA cement plants met LBL best practice energy intensity

International Best practice energy intensity	2.62	MBtu/short ton clinker	Coito et al. 2005.	Assumes that this applies to Clinker Production Assumes that Raw Materials Preparation & Finish Grinding
International Best practice energy intensity-electricity	109	kWh/short ton clinker	Coito et al. 2005.	
Total energy from onsite fuel combustion	45950658.48	Mbtu/yr	(energy intensity X clinker production)	
Total electricity use	1911687700	kWh/yr	(energy intensity-electricity X clinker production)	
Energy use = to coal	32624967.52	Mbtu/yr		Assumes that the fuel mix remains the same after implementation of energy efficiency measures
Energy use = to PET coke	5514079.018	Mbtu/yr		
Energy use = to liquid/solid waste fuels	4135559.263	Mbtu/yr		
Energy use = to natural gas	1838026.339	Mbtu/yr	(fraction of total energy consumption X energy from fuel combustion)	
CO2 from coal use	3083059.431	MTCO2/yr	(emission factor X energy use)	
Total CO2 equivalents from coal use	3104109.965	MTCO2 eq/yr	(CO2 emissions / fraction of CO2 eq due to CO2)	
CO2 from PET coke use	562436.0598	MTCO2/yr	(emission factor X energy use)	
Total CO2 equivalents from pet coke use	563693.6062	MTCO2 eq/yr	(CO2 emissions / fraction of CO2 eq due to CO2)	
CO2 from liquid/soild waste use	351522.5374	MTCO2/yr	(emission factor X energy use)	
CO2 from natural gas use	97507.2973	MTCO2/yr	(emission factor X energy use)	
Total CO2 equivalents from natural gas use	97744.41699	MTCO2 eq/yr	(CO2 emissions / fraction of CO2 eq due to CO2)	
Total CO2 equivalents from fuel combustion	4.12	MMT/yr	(Sum of each fuel type)	
Reduction from 2004 level due to reductions in fuel combustion	1.25	MMT/yr	(Baseline-emissions under scenario)	
Reduction from 2004 level due to electricity use	0.04	MMT/yr	(Percent reduction X baseline)	
Percent reduction in electricity use	3.29%		(Baseline-electricity use under scenario)	
Total reduction in CO2 eq emissions	8.70%		(Sum of reductions / baseline)	
Percent reduction in coal use	21.09%		(Baseline-coal use under scenario)	
GHG intensity	0.82	MT CO2 eq/metric ton ce	(Total emissions per metric ton cement produced under scenario)	
Copollutants				
Mercury: Reduction due to reduced coal combustion	27.82	lbs	(Emissions factor X reduction in coal use)	
NOx	Reduced proportional to reduced fuel combustion (e.g. 21% reduction in coal combusted)			
PM	Reduced due to reduced fuel, in particular coal, combustion			
Costs				
Technical improvements to improve efficiency in clinker production	$90,000,000	dollars	CARB Staff Analysis for EAMs	
Cost Effectiveness	72.13	dollars/MT CO2 eq	(cost / CO2 eq reduction due to fuel combustion)	
Tons of coal used	1371373.16188		(energy use due to coal / heat content)	
Cost of coal used	$68,870,360		(quantity of coal X cost of coal)	
Cost savings due to reduced coal	$18,409,323		(baseline coal costs - cost of coal under scenario)	

Scenario II: All CA cement plants met LBL best practice energy intensity and switch to natural gas

International Best practice energy intensity	2.62	MBtu/short ton clinker	Coito et al. 2005.	Assumes that this applies to Clinker Production Assumes that Raw Materials Preparation & Finish Grinding
International Best practice energy intensity-electricity	109	kWh/short ton clinker	Coito et al. 2005.	
Total energy use from onsite fuel combustion	45950658.48	Mbtu/yr	(energy intensity X clinker production)	
Total electricity use	1911687700	kWh/yr	(energy intensity-electricity X clinker production)	
Energy use = to coal	0	Mbtu/yr		Assumes that the fuel mix remains the same after implementation of energy efficiency measures
Energy use = to PET coke	0.00	Mbtu/yr		
Energy use = to liquid/solid waste fuels	4135559.263	Mbtu/yr		
Energy use = to natural gas	39977072.88	Mbtu/yr	(fraction of total energy consumption X energy from fuel combustion)	
CO2 from coal use	0	MTCO2/yr	(emission factor X energy use)	
Total CO2 equivalents from coal use	0	MTCO2 eq/yr	(CO2 emissions / fraction of CO2 eq due to CO2)	
CO2 from PET coke use	0	MTCO2/yr	(emission factor X energy use)	
Total CO2 equivalents from pet coke use	0	MTCO2 eq/yr	(CO2 emissions / fraction of CO2 eq due to CO2)	
CO2 from liquid/soild waste use	351522.5374	MTCO2/yr	(emission factor X energy use)	
CO2 from natural gas use	2120783.716	MTCO2/yr	(emission factor X energy use)	
Total CO2 equivalents from natural gas use	2125941.069	MTCO2 eq/yr	(CO2 emissions / fraction of CO2 eq due to CO2)	
Total CO2 equivalents from fuel combustion	2.48	MMT/yr	(Sum of each fuel type)	
Reduction from 2004 level due to reductions in fuel combustion	2.89	MMT/yr	(Baseline-emissions under scenario)	
Reduction from 2004 level due to electricity use	0.04	MMT/yr	(Percent reduction X baseline)	
Percent Reduction in electricity use	3.29%		(Baseline-electricity use under scenario)	
Total reduction in CO2 eq emissions	19.81%		(Sum of reductions / baseline)	
GHG intensity	0.72	MT CO2 eq/metric ton ce	(Total emissions per metric ton cement produced under scenario)	

Scenario III: All CA cement plants met LBL best practice energy intensity, switch to natural gas, and produce 5% limestone blended cement

International Best practice energy intensity	2.62	MBtu/short ton clinker	Coito et al. 2005.	Assumes that this applies to Clinker Production Assumes that Raw Materials Preparation & Finish Grinding
International Best practice energy intensity-electricity	109	kWh/short ton clinker	Coito et al. 2005.	
Reduced clinker production	16661498.3	short tons clinker	(baseline production - 5% reduction)	
Total energy use from onsite fuel combustion	43653125.56	Mbtu/yr	(energy intensity X reduced clinker production)	
Total electricity use	1816103315	kWh/yr	(energy intensity-electricity X reduced clinker production)	

Energy use = to coal	0	Mbtu/yr		Assumes that the fuel mix remains the same after implementation of energy efficiency measures
Energy use = to PET coke	0.00	Mbtu/yr		
Energy use = to liquid/solid waste fuels	3928781.3	Mbtu/yr		
Energy use = to natural gas	37978219.23	Mbtu/yr	(fraction of total energy consumption X energy from fuel combustion)	
CO2 from coal use	0	MTCO2/yr	(emission factor X energy use)	
Total CO2 equivalents from coal use	0	MTCO2 eq/yr	(CO2 emissions / fraction of CO2 eq due to CO2)	
CO2 from PET coke use	0	MTCO2/yr	(emission factor X energy use)	
Total CO2 equivalents from pet coke use	0	MTCO2 eq/yr	(CO2 emissions / fraction of CO2 eq due to CO2)	
CO2 from liquid/soild waste use	333946.4105	MTCO2/yr	(emission factor X energy use)	
CO2 from natural gas use	2014744.53	MTCO2/yr	(emission factor X energy use)	
Total CO2 equivalents from natural gas use	2019644.016	MTCO2 eq/yr	(CO2 emissions / fraction of CO2 eq due to CO2)	
Total CO2 equivalents from fuel combustion	2.35	MMT/yr	(Sum of each fuel type)	
Reduction from 2004 level due to reductions in fuel combustion	3.01	MMT/yr	(Baseline-emissions under scenario)	
Reduction from 2004 level due to electricity use	0.09	MMT/yr	(Percent reduction X baseline)	
Reduction from 2004 level due to production process	0.41	MMT/yr	(5% reduction in baseline emissions due to production process)	
GHG intensity	0.69	MT CO2 eq/metric ton ce	(Total emissions per metric ton cement produced under scenario)	
Percent reduction in electricity use	8.13%		(Baseline-electricity use under scenario)	
Percent reduction in emissions due to production process	5.00%		(limestone blending results in proportional decrease in pyroprocessing)	
Total reduction in CO2 eq emissions	23.82%		(Sum of reductions / baseline)	
Copollutants				
Mercury: Reduction due to eliminating coal combustion	145.40	lbs	(Emissions factor X reduction in coal use)	
Mercury: Reduction due to reduced limestone pyrolisis	46.29	lbs	(avg concentration of mercury in limestone X reduction in limestone processed)	
Total Mercury Reduction	191.69	lbs	Sum of reductions	
NOx: Percent Reduction due to reduced coal combustion	Additional stack control needed to controls for NOx emissions associated with natural gas combustion			
PM: Percent Reduction due to reduced coal combustion	Reduction due to reduced fuel, in particular coal, combustion and limestone pyrolisis			
Costs				
Cost from natural gas replacing coal & pet coke	$278,624,804		(Price of natural gas X natural gas used)	
Increased cost replacing coal & pet coke	$177,366,334		(Energy costs - baseline costs for coal and pet coke)	
Technical improvements to improve efficiency in clinker production	$90,000,000.00			
Cost Effectiveness	78.04	dollars/MT CO2 eq	(Cost of technical improvements + increased fuel costs) / tons of CO2eq reductions)	

Scenario IV: All CA cement plants replace high carbon (coal and pet coke) fuels with low carbon (natural gas) fuel

CO2 from natural gas replacing high carbon fuels	2806263.759	metric tons	(emissions factor X natural gas used)
Total CO2 equivalents from natural gas replacing coal	2813088.073	metric tons	(CO2 emissions / fraction of CO2 eq due to CO2)
Total CO2 equivalents from fuel combustion	3.147034483	MMT	(sum of emissions due to natural gas and to alternative fuels)
Reduction from 2004 level due to reductions in fuel combustion	2.217812052	MMT	(baseline - emissions under scenario)
Percent CO2eq reduction	15.03%		(emission reduction / baseline)
GHG intensity	0.77	MT CO2 eq/metric ton ce	(Total emissions per metric ton cement produced under scenario)
Copollutants			
Mercury: Reduction due to eliminating coal combustion	131.91	lbs	(Emissions factor X reduction in coal use)
NOx	Additional stack control needed to controls for NOx emissions associated with natural gas combustion		
PM	Reduced due to elimination of coal combustion		
Costs			
Cost from natural gas replacing coal & pet coke	$406,789,223		(Price of natural gas X natural gas used)
Increased cost	$305,530,753		(Energy costs - baseline costs for coal and pet coke)
Cost efficiency	$137.76	$/metric ton	(costs / CO2 eq reduction)

Scenario V: All CA cement pants produce 5% Limestone Blended Cement

Reduction from 2004 level due to reductions in fuel combustion	0.27	MMT/yr	
Reduction from 2004 level due to electricity use	0.41	MMT/yr	(limestone blending results in proportional (5%) decrease in emissions due
Reduction from 2004 level due to production process	0.05	MMT/yr	to reduced clinker production)
Total CO2 eq reduction	0.74	MMT/yr	(Sum of reductions)
Percent CO2eq reduction	5.00%		
GHG intensity	0.86	MT CO2 eq/metric ton ce	(Total emissions per metric ton cement produced under scenario)
Copollutants			
Mercury: Reduction due to reduced coal combustion	6.60	lbs	(Emissions factor X reduction in coal use)
Mercury: Reduction due to reduced limestone pyrolisis	46.29	lbs	(avg concentration of mercury in limestone X reduction in limestone processed)
Total Mercury Reduction	52.88	lbs	(Sum of reductions)
NOx	Reduced proportional to reduced fuel combustion (e.g. 5% reduction in coal combusted)		
PM	Reduced due to reduced fuel, in particular coal, combustion and limestone pyrolisis		

Constants

Parameter	**Value**	**Units**	**Source**
Cost of coal	50.22	$/ton coal	EIA 2005 avg price of industrial coal in CA
Cost of natural gas	7.69	$/Mbtu	2020 Energy Price Forcecast (in 2006 dollars) Draft Macroeconomic analysis CAT Report
Cost of petroleum coke	1.21	$/Mbtu	EIA 2005 avg price of industrial pet coke
CO2 Emission Factor for coal	0.0945	MTCO2/MBTU	CARB GHG Draft Inventory draft documentation
CO2 Emission Factor for pet coke	0.102	MTCO2/MBTU	CARB GHG Draft Inventory draft documentation
CO2 Emission Factor for liquid/solid waste	0.085	MTCO2/MBTU	CARB EF for "Alternative Fuels"
CO2 Emission Factor for natural gas	0.05305	MTCO2/MBTU	CARB GHG Draft Inventory draft documentation
coal-Fraction of CO2 equivalent emissions from CO2 emissions	0.993218496		calculated from CARB GHG Draft Inventory
petcoke-Fraction of CO2 equivalent emissions from CO2 emissions	0.997769096		calculated from CARB GHG Draft Inventory
natural gas-Fraction of CO2 equivalent emissions from CO2 emissior	0.997574085		calculated from CARB GHG Draft Inventory
heat content of coal	23.79	Mbtu/metric ton	CARB GHG Draft Inventory draft documentation
heat content of pet coke	30.12	Mbtu/metric ton	CARB GHG Draft Inventory draft documentation
Fraction of total energy consumption -coal	0.71		Hanle et al. 2004
Fraction of total energy consumption - pet coke	0.12		Hanle et al. 2004
Fraction of total energy consumption -liquid and solid waste fuels	0.09		Hanle et al. 2004
Fraction of total energy consumption -natural gas	0.04		Hanle et al. 2004
conversion short ton to metric ton	0.90718474	metric ton	
Mercury emissions from coal combustion in cement plant	0.000075900	lbs Hg/ton coal	Mean California Air Toxics Emission Factor
Average limestone input per ton clinker	1.32	ton/short ton clinker	USEPA memo June 28, 2004 Use of "low mercury" feed and fuel to reduce
Average mercury concentration per ton limestone input	0.02	ug/g	mercury emissions from portland cement manufacturing.

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