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Gigaton Analysis of the Cement Industry

The Case for Rapid Adoption of Proven Technologies

Cement

Primer Report

The Carbon War Room

The Gigaton Throwndown Initiative

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Executive Summary

Potential for Gigaton Scale Reduction of CO_2 in Cement Industry

The cement industry is one of the most carbon-intensive industries due in large part to the thermal energy required to produce clinker; the key component of cement. The world produced 3 billion metric tons of cement in 2009, emitting more than 2.4 gigatons (Gt) of CO_2 into the atmosphere. The industry predicts global cement production is projected to grow to 5.9 billion tons by 2020 amounting to annual CO_2e emissions from the production of cement to more than 4.8 Gt. China alone is expected to produce an extra 4 billion metric tons of cement annually by 2020. At a price of roughly $100 per metric ton,[1] the profit margin for the industry is around 33 percent.[2] The total size of the global cement market is more than $250 billion.[3]

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Emerging technologies have the potential to further reduce emissions significantly. Since calcination is the primary source of emissions in the cement industry, the most promising technologies going forward are binders that are adequate alternatives to clinker.

Aggressive pursuit of proven carbon intensity reduction measures has the potential to reduce emissions by 0.9 Gt to 3.4 Gt annually before 2020. Upgrades to existing cement plants and the construction of new buildings using efficient technologies translates to at least a 0.9 Gt emissions savings.

The largest potential source of reductions with proven technology is the accelerated use of alternative fuel (370 Mt), followed by clinker substitution with alternative materials (300 Mt), thermal energy efficiency improvements (140 Mt), and electricity efficiency improvements (90 Mt).

Emerging technologies have the potential to further reduce emissions significantly. Since calcination is the primary source of emission in the cement industry, the most promising technologies going forward are binders that are adequate alternatives to clinker. These include alkali-activated, magnesia, and sulfo-aluminate cements. Another promising class of technologies – those with the potential to sequester CO_2 from flue gas and process it to produce building materials – is fast emerging, but is unlikely to scale within the time frame of interest. The potential for scaling traditional methods of carbon capture and storage (CCS) is remote, owing to high estimated capital costs for using such technology – $592.9 billion according to the IEA BLUE scenario, with little expected return without a price on carbon.[4]

Investment Opportunity

Reaching a gigaton-scale reduction in CO_2 emissions from the production of cement will require a capital investment of $175 billion, of which increasing thermal efficiency is the most capital intensive ($149 billion) and also the least cost effective. With an investment of $10 billion for alternative fuels, $17 billion for clinker reduction, and $.6 billion for electricity efficiency ($27.6 billion), there is an opportunity to reduce emissions by 760 Gt of CO_2 annually while also generating significant returns with short payback periods.

Switching from coal to biomass for firing cement kilns requires an initial investment of $6.5 million for a 1 million metric ton capacity plant, and would yield savings of $3.8 million per year.

Lowering the clinker content of cement requires additional capital expenditures of $13 million for a 1 million metric ton capacity plant for storage and handling, Using blast shag and fly ash to create a 50% blend would yield $11.8 million in savings annually, just from the reduced cost of clinker alone. The savings derived from a reduced thermal energy requirement (producing blended cement requires less heat and thus less fuel) would significantly add to the savings. A 25% blend would yield $5.7 in annual savings.

Upgrading to state-of-the-art equipment with an energy efficiency of 89 kWh/t production requires an initial investment of 660,000 per 1 million metric ton capacity plant, and would yield annual savings of $1.19 million per annum.

[1] Snap 2010

[2] IBISWorld 2010

[3] Hoffman & Byrne 2009

[4] WBCSD 2009

Market Barriers

Due to high capital expenditure requirements, most cement plants are highly leveraged. As a result, cement manufacturers encounter difficulties accessing capital for investment in efficiency improvements to reduce emissions. A million metric ton capacity plant has an average lifespan of 50 years and costs about $250 million to construct, equivalent to approximately three years of production. Efficiency improvement efforts usually entail large capital costs. For instance, upgrading to pre-heaters and pre-calciners costs about $90 million for a million metric ton capacity plant, and waste heat cogeneration usually accounts for 15 percent of the total investment of cement enterprises.

Globally, 18 major cement producers, including the top five cement producing companies – Lafarge (France), Holcim (Switzerland), Heidelberg (Germany), CEMEX (Mexico), and Italcementi (Italy) – together account for a mere 30 percent of the total cement production on the planet. In China, the top 10 producers account for only 23 percent of total cement production in the country. The situation is similar in India, with the top five producers accounting for approximately 46 percent of their market. Thus, it is difficult for any one actor to have unilateral impact by altering production habits. Cement producers are in a competitive market dominated by price and cannot compromise on quality. As a result, the industry is risk averse and reluctant to invest in unproven technology.

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Calcination of limestone to produce clinker contributes to about 50 percent of CO_2 emissions from cement manufacturing. Thus, two important levers for decreasing emissions are reducing the clinker content of cement and finding alternative ways of producing clinker. However, each measure has an impact on one or more of the desired characteristics of cement such as strength, durability, malleability, and price. Alternative cements therefore end up being used in most cases for niche applications, though certain types of blended cements are being used as direct replacements for OPC.

Because cement is used for the construction of structures that we trust with our lives, the industry faces stringent regulations to uphold the highest standards for safety. In addition to such regulations on cement manufacturers, large purchasers of cement (such as Departments of Transportation) impose their own restrictions in the form of procurement standards, which are often even more stringent. Such restrictions often become embedded in the system and create barriers against positive change, particularly those that are prescriptive rather than performance-based.

Emissions from Cement Productions

The production of one metric ton of cement creates an average of 820 kg of CO_2 emissions. Collectively, the production of 3 billion metric tons of cement in 2009 accounted for 5 percent of total global anthropogenic CO_2 emissions.

Carbon Emissions from Cement Manufacture

Production Phase	kg CO_2/tclinker	kg CO_2/tcement
Calcination	510	403
Fuel	353	318
Electricity	–	100
Total	–	820

Clinker, the main ingredient in cement, is made by heating limestone along with clay, sand, and small amounts of bauxite and iron ore at temperatures as high as 1,450°C in a kiln. Current processes require an average of 3.9 gigajoules per metric ton of clinker (GJ/$t_{clinker}$). Coal and petcoke are the most common fuels used for cement production, accounting for about 90 percent of the derived thermal energy.

Thermal Energy & Carbon Intensity of Fuel Sources

Fuel Source	201°0 Derived Energy	kg CO_2/tclinker
Coal	90%	374.4
Petcoke	90%	393.9
Natural Gas	5%	211.38
Fossil Based Alternatives	3%	273
Carbon-neutral Fuels	2%	–

Electrical energy is used in the rotary kiln and for grinding and mixing raw materials as well as finished cement. The average amount of electricity used at a cement plant is 111 kWh/t_{cement}[5] and the average concentration of emissions from the power sector is 0.9 kg/kWh. Thus, the average CO_2 emissions from electricity consumption are 100 kg of CO_2/t_{cement}.

At the current average clinker-cement ratio of 79 percent, the total CO_2 emissions resulting from cement manufacturing are 820 kg of CO_2/t_{cement}.

Industry Growth

Global cement production grew by 6.5 percent between 2004 and 2009, with growth rates in China and India higher than 11 and 8 percent respectively. The Chinese cement industry grew at an annual rate of 12.2 percent between 1970 and 1995 and higher than 9.5 percent per year consistently for all but one of the last ten years.[6] The Chinese growth rate used in this report is based on the seemingly realistic projections made by 8.4 percent per year between 2010 and 2015, and 7.8 percent per year between 2015 and 2020.[7] Similarly, the Indian cement industry has been growing at

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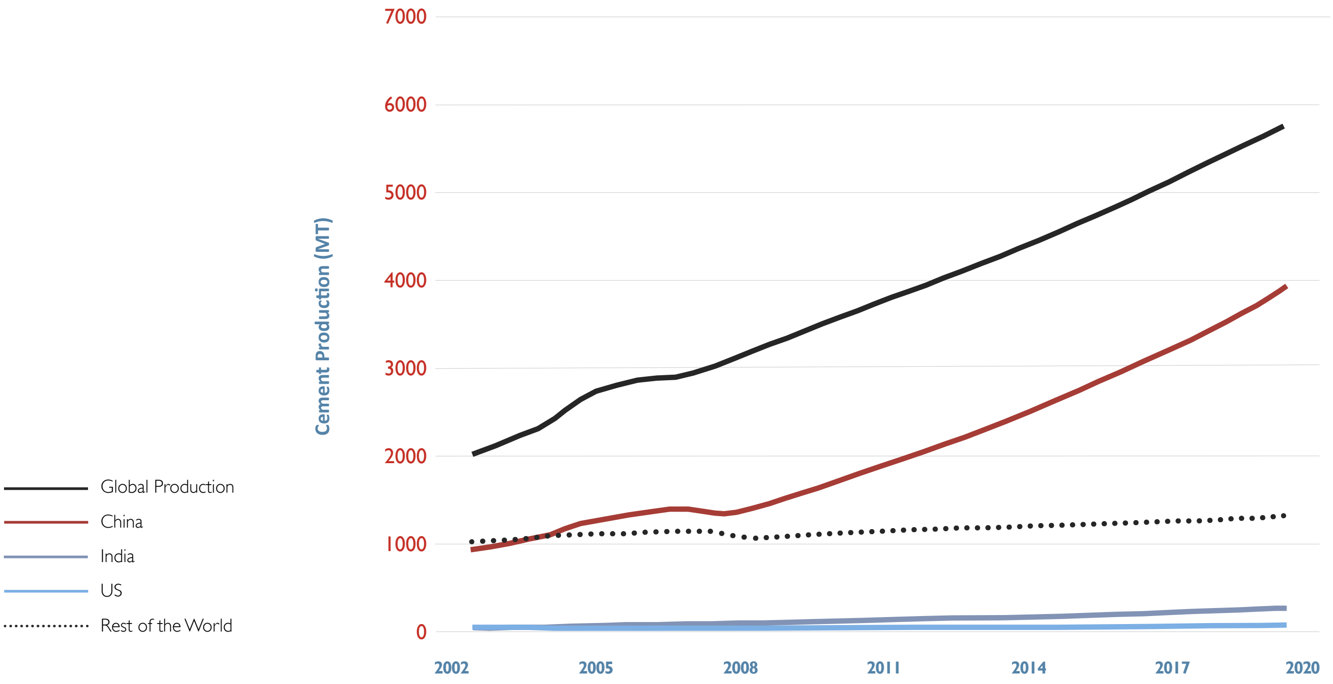
[5] WBCSD 2009

[6] Hendriks 2004; Tsinghua University of China 2008

[7] Tsinghua University of China 2008

higher than 8 pecent per year and is expected to grow at 8 percent per year for the next decade.[8] The third largest cement producing country in the world, the US, shrunk at -6.2 percent per year between 2004 and 2009, but is projected to recover and grow at more than 4 percent per year till 2020.[9] The cement industry in the rest of the world grew at an average 2.1 percent per year between 2004 and 2009, and is projected to grow at the same rate going forward to 2020.

2003-2020 World Cement Production



Source USGS 2009; CEMBUREAU 2009; CEMBUREAU 2008; Tongbo 2010; Confederation of Indian Industry 2010

Under these assumptions, cement production is expected to almost double from the 2009 level to 5.9 billion metric tons in 2020 – an average annual growth rate of 6.24 percent. China, with the highest production share (currently 54 percent) and one of the highest growth rates alone will account for 80 percent of this growth with production reaching 3.96 Gt in 2020.

Notably, this industry growth projection is largely different from growth projections made by the WBCSD (1.25 percent per year between 2000 and 2050 to 4.4 Gt in the high growth scenario and merely 0.84 percent to 3.69 Gt in the low growth scenario), McKinsey (3.20 percent between 2005 and 2030 to 5.2 Gt), and WWF/Lafarge (1.49 percent per year to 5.5 Gt by 2050). Our projections seem most realistic given the explosive historic and expected growth rates in China and India, and the high and accelerating global rate of growth since 1970.

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[8] Confederation of Indian Industry 2010

[9] IBISWorld 2010

Confronting Global GHG Emissions in the Cement Industry

By aggressively pursuing implementation of proven technologies, the cement industry can reduce emissions by an estimated 900 Mt annually by 2020. The largest potential source of reductions with proven technology is the accelerated use of alternative fuel (370 Mt), followed by clinker substitution with alternative materials (300 Mt), thermal energy efficiency improvements (140 Mt), and electricity efficiency improvements (90 Mt).

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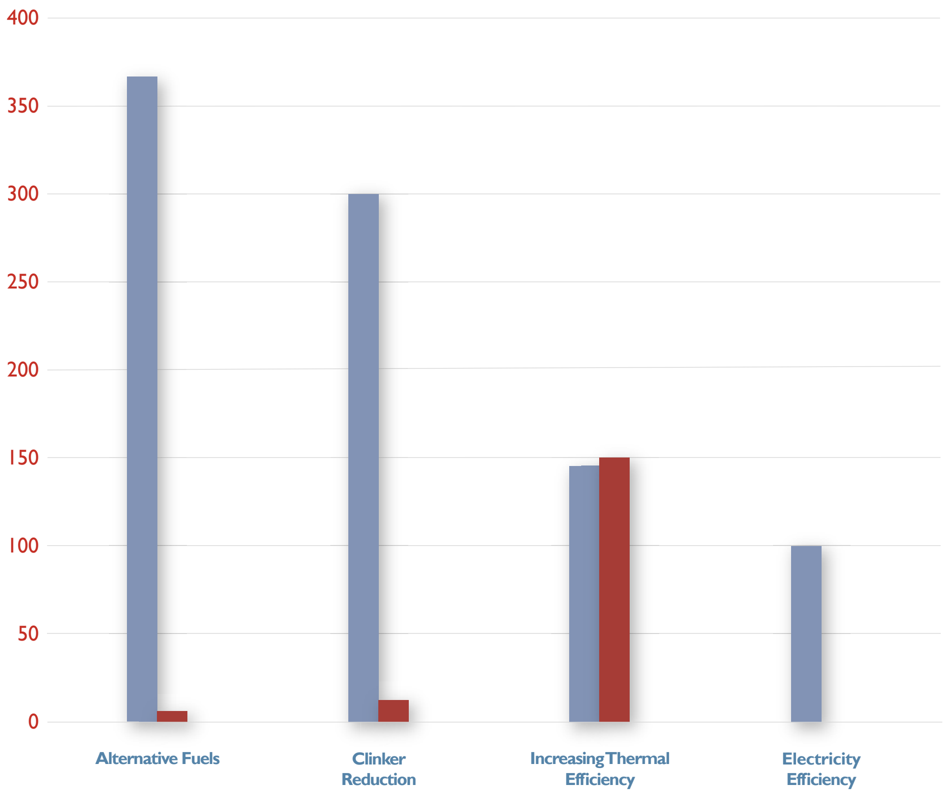
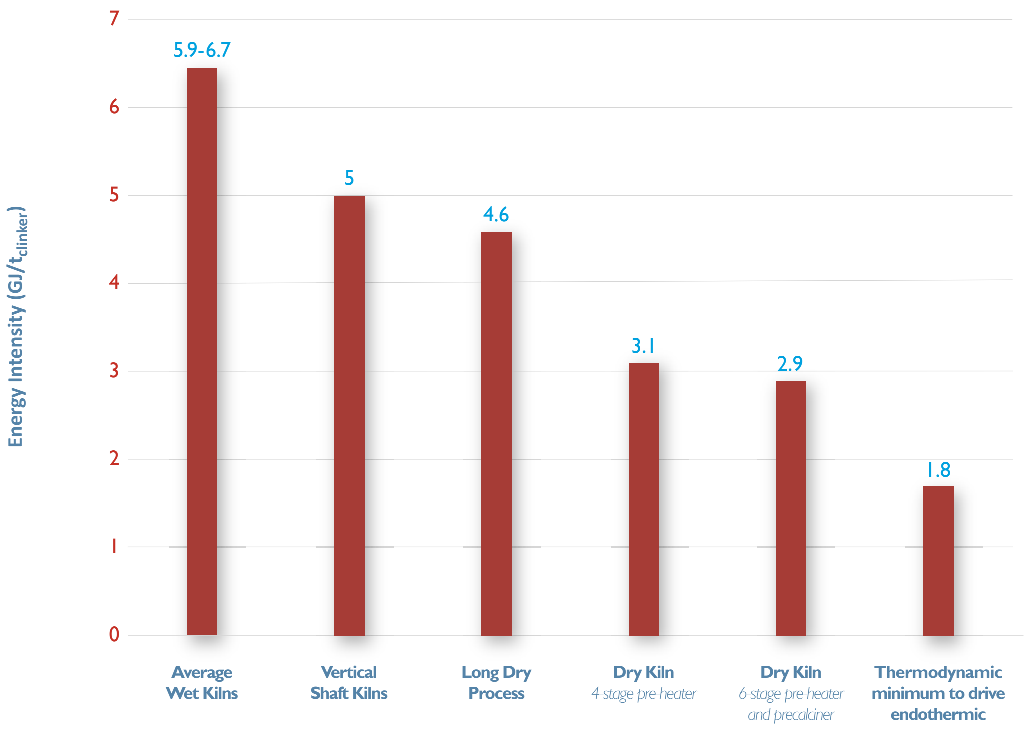
The Path to Gigaton Scale Reduction



High Efficiency Kilns

Switching from wet kilns to state-of-the-art dry kilns could result in savings as high as 3.8 GJ/$t_{clinker}$. If coal or petcoke is the fuel of choice at the plant, these energy savings translate to 380 kg of CO_2 emissions reduction per metric ton.

Scaling Up • *Energy Intensity*



Source IEA 2007

The efficiency of the average cement plant today is roughly 3.9 GJ/$t_{clinker}$.[10] Thermal efficiency will likely improve at an annual rate similar to that achieved between 1994 and 2003 to 3.62 GJ/tclinker in 2020, meaning that 51 percent of all new plants are predicted to have an efficiency of 2.9 GJ/$t_{clinker}$.[11] To reach gigaton-scale CO_2 reductions, all new plants built between 2011 and 2020 (3321 Mt of capacity) must be state-of-the-art, resulting in an average thermal efficiency of 3.3 GJ/$t_{clinker}$ by 2020.

In comparison, the top five percent of cement plants today operate at a thermal energy intensity of 2.9 GJ/t_{cement}. The target for the 2020 efficiency scenario is achievable, especially with China's mandate to demolish all vertical shaft kilns by 2020 and replace them with state of the art technology.[12] China has already replaced 260 Mt of vertical shaft kilns since 2006 and is on course to replace the entire remaining stock (approximately 30 percent) with state-of-the-art technology by 2020.[13]

[10] WBCSD 2009

[11] IEA 2007

[12] McKinsey 2009

[13] Tongbo 2010

Clinker Replacements

Blended cements consist of a mixture of Ordinary Portland Cement (OPC) and replacement material, which can be naturally derived or the product of silica-rich waste material that reacts with calcium hydroxide to form calcium silicate hydrate. Popular pozzolans used today include fly ash, slag, and silica fume. Ground limestone and recycled concrete can also be blended in small quantities as filler material with clinker. "The economic benefits of using natural pozzolans could save contractors up to 25% per bag of cement."[14]

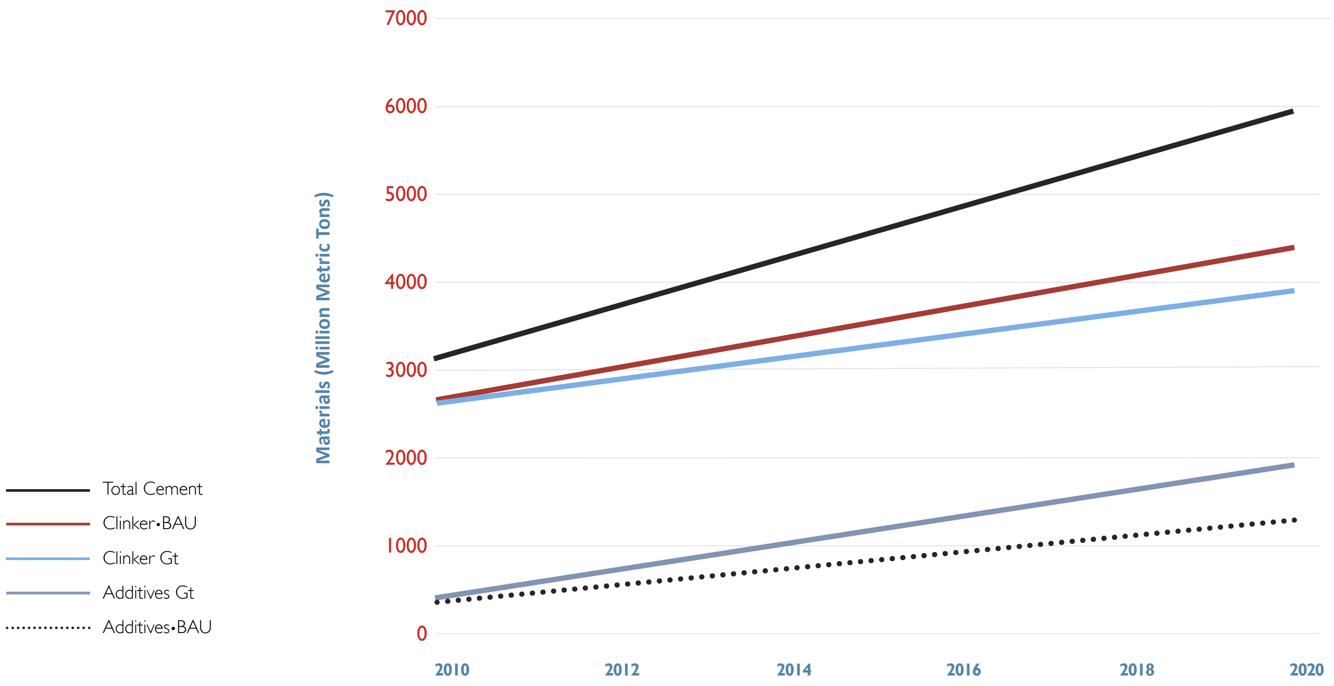
Blended cements have a lower heat of hydration, improved workability and higher resistance to chemical effects associated with alkali-aggregate reactions. Portland cement can be replaced with pozzolans today, for example using standard ASTM C 1157 in the US or EN 197 in Europe. Blended cements already have a 68 percent market share in India, 52 percent in Europe, and 40 percent in China, but only 4 percent in the United States. Though blended cements are allowed in most jurisdictions to contain up to 35 percent fly ash or up to 70 percent blast furnace slag, much smaller percentages are actually mixed in with OPC.[15] The addition of replacement materials entails no process emissions and greatly reduces the thermal energy required for production.

China and India have already set aggressive targets for decreasing the clinker content of cement produced domestically from 65 percent down to 49 percent by 2020 in China, and from 75 percent down to 52 percent by 2030 in India.

Also noteworthy, adding 5 percent limestone and 5 percent recycled concrete as filler material will yield an ambitious but viable blend of cement (50 percent clinker, 45 percent supplementary cementing materials, and 5 percent gypsum). China and India have already set aggressive targets for decreasing the clinker content of cement produced domestically from 65 percent down to 49 percent by 2020 in China, and from 75 percent down to 52 percent by 2030 in India.

Emissions from calcinations will account for more than 2.2 Gt of emissions annually by 2020 in the business as usual (BAU) scenario. By reducing the clinker-cement ratio from 74 percent to 64 percent by 2020 in the BAU scenario, the industry can save 298 Mt of CO_2 emissions per year from the reduction of calcination alone.

Scaling Up • *Blended Cement Production 2010–2020*



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[14] Harris *et al.* 2005

[15] Bhushan 2010

In order to reach gigaton scale, the industry would have to utilize 85 percent of available fly ash, slag, and natural pozzolanic material in the manufacturing process by 2020, along-with substitution of 5 percent clinker each by limestone and recycled concrete filler.

Scaling Up • *Blended Cements*

Material	2020 BAU (Mt/%)	2020 Gt (Mt/%)	Availability (Mt/%)
Clinker	4364 (74%)	3780 (64%)	–
Gypsum	295 (5%)	295 (5%)	–
Alternatives • *Total*	1238 (21%)	1822 (31%)	–
Fly Ash	619	765	900
Slag	124	213	250
Pozzolan	186	255	300
Limestone	186	295	Plenty
Recycled	124	295	3500

Source Availability Statistics - WCSB 2009; Holcim 2009

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Moving toward a cleaner fuel mix has the greatest potential to reduce CO_2 emissions in the industry. The predominant fuels used in the cement industry today are also the most polluting.

Since the replacement of 1 metric ton of clinker results in the reduction of 0.51 metric tons of CO_2 emissions, the total abatement potential from the reduction of calcination is 298 Mt CO_2.

Electrical Energy

Processing blended cements requires an additional 8.9 kWh/t_{cement}, mainly due to an increased grinding requirement.[16] Since the total additional quantity of blended cement produced in the gigaton scenario is 1.3 billion metric tons and the carbon intensity of electricity is 0.9 kg/kWh, the total additional emissions amount to 10.4 Mt CO_2.

The reduction potential is substantial: a study of European cement plants found that the 90th percentile kilns consume roughly 130 kWh/tcement while the 10 percent best in class kilns consume just 89 kWh/t_{cement}.[17] The global average is close to 111 kWh/t_{cement}.

The 2020 efficiency scenario envisages reduction of the electricity intensity of cement plants from 106 kWh/t_{cement} in the BAU scenario to the current state of the art 89 kWh/tcement on average.[18] This would yield an emissions reduction of 92 Mt of CO_2 at a total additional capital cost of $0.61 billion.

Alternative Fuels

Moving toward a cleaner fuel mix has the greatest potential to reduce CO_2 emissions in the industry. The predominant fuels used in the cement industry today are also the most polluting. The two biggest cement manufacturers – China and India – each depend almost entirely on coal. It is possible to derive 100 percent of thermal energy from alternative fuels sources, including various types of waste.

Waste materials such as used tires can also be used to fire kilns and can result in significant emission reductions. The use of waste materials has lower carbon intensity than coal or petcoke, and cement kilns are more efficient than incinerators that would otherwise be used to dispose of these wastes. Another advantage is that the process does not generate residues because the ashes are incorporated into the clinker mixture.

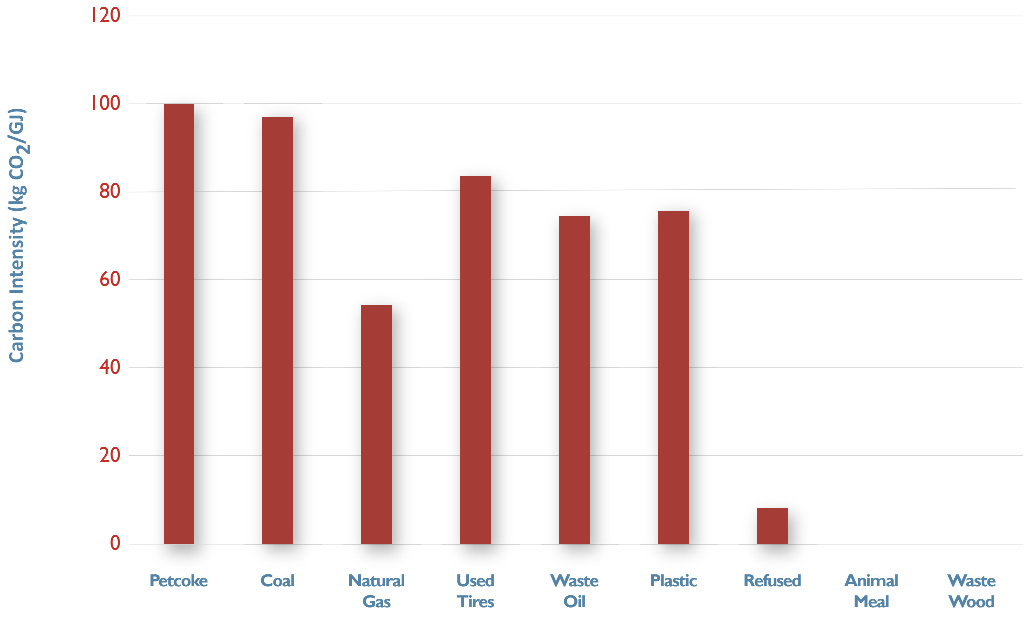
[16] Hasanbeigi *et al.* 2010

[17] WBCSD 2006

[18] WBCSD 2009

Other alternative fuels include agricultural and forestry biomass as well as waste materials including biodegradable municipal waste, animal waste, paper waste, animal meat, and bone meal.

Intensity of Emissions for Various Fuels



Source Habert 2010

In order to reach a gigaton-scale reduction in CO_2 emissions, cement manufacturers worldwide would have to use a mix of fuels to fire their kilns that consist of 40 percent less coal and petcoke, which will reduce the amount of CO_2 emitted per GJ of thermal energy produced from the current average of 92.3 to 67.6.

Scaling Up • *Alternative Fuels Split*

Fuel Source	2010	2020 BAU	2020 Efficiency
Coal/Petcoke	90%	75%	50%
Gas	5%	15%	15%
Fossil-Waste	2%	5%	15%
Non-fossil	3%	5%	20%
kg CO_2/GJ	92.3	85.1	67.6

At 2.55 GJ/t_{cement}, the estimated thermal energy requirement given the use of high efficiency kilns and an aggressive blend, the total heating value requirement from non-fossil alternative fuels to reach gigaton scale by 2020 is 3 billion GJ. At an average energy content of 10 GJ/t, the total requirement of non-fossil alternative fuels in the global cement industry in 2020 amounts to 301 Mt. Meeting this feedstock requirement does not present a challenge: The total energy value of unused forest biomass residues in ten provinces in 2006 in China alone was 1.6 billion GJ.[19] At 10 GJ/t, the 500 Mt of collected municipal solid waste globally accounts for another 15 billion GJ of thermal energy.[20]

Scaling Up • *Alternative Fuels Requirements*

Fuel	Energy Content (GJ/t)	Unit	2010 Usage	2020 BAU	2020 Efficiency
Coal	30[21]	MT	332	449	251
Natural Gas	53[22]	BCM	14	71	59
Fossil-Waste	40[23]	MT	6	22	56
Non-fossil	10[24]	MT	33	90	301

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[19] Murray & Price 2008

[20] Holcim 2009

[21] EIA 2010

[22] Ibid

[23] Average taken from Murray & Price 2008

[24] Tsinghua University of China 2008

Investment Requirements

In order to achieve an annual reduction of 900 Mt of CO_2 representing a 19 percent reduction in emissions, $176 billion in capital expenditures is required over 10 years.

Thermal Efficiency and Fuel Substitution

Upgrading to pre-heaters and pre-calciners saves between 0.9 and 2.8 $GJ/t_{clinker}$ and costs around $91 million for a one million metric ton capacity plant. Switching from coal and petcoke to natural gas and alternative fuel plants costs $6.5 million per million metric ton capacity.

To achieve the business as usual (BAU) target of 3.62 $GJ/t_{clinker}$, 51 percent of new plants (1680 Mt) need to incorporate the highest thermal efficiency technology. To meet the fuel substitution targets, cement plants representing 884 Mt of production capacity will need to burn natural gas and plants representing 295 Mt each need to burn fossil waste and carbon-neutral fuels.

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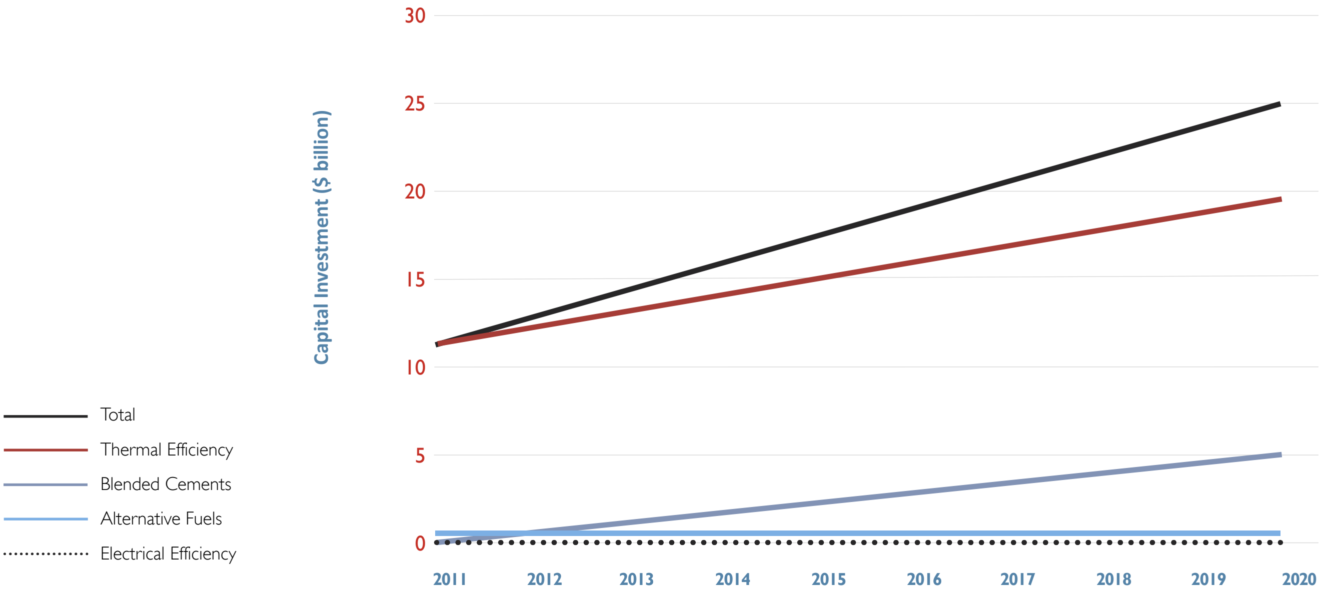
Given the rising price of coal ($141.90 per metric ton in Jan. 2011), switching to non-fossil alternative fuels to fire cement plant kilns, particularly biomass, is increasingly attractive.

In order to reach gigaton scale, 100 percent of the new plants (3552 million metric tons of capacity) must utilize the highest thermal efficiency technology, resulting in an overall thermal intensity of 3.34 $GJ/t_{clinker}$.[25] To meet the fuel substitution targets, plants producing a combined annual total of 884 Mt of cement, need to burn natural gas and fossil-waste, and plants producing a combined total of 1179 Mt need to burn carbon-neutral fuels.

Scaling Up • *Total Additional Capital Investment 2010-2020*



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[25] Assuming none of the existing plants are retrofitted to process alternative fuels.

The additional capital investment required is $159 billion by 2020, as outlined in the table below.

Capital Investment for Thermal Efficiency and Fuel Substitution

Investment 2010

$ Billion	BAU	Gt	Additional
Subtotal • *Efficiency Improvement*	153	302	149.3
Gas	4.7	4.7	0.0
Fossil-Waste	1.5	5.3	3.8
Carbon-Neutral Fuels	1.3	7.0	5.7
Subtotal • *Fuel Substitution*	7.5	17.1	9.6
Total	160	319	159

Rate of Return

The capital cost to upgrade the pre-heaters and pre-calciners in a 1 million ton cement plant is $91 million dollars. These upgrades yield energy savings of .9-2.8 GJ/$t_{clinker}$. At an average cost of $141.90 per ton of coal, the savings derived from such an upgrade would be $2,128,500 - $6,622,000 annually for a million ton capacity plant producing cement with a 50% clinker content, and $4,044,150 - $12,581,800 annually for a plant producing OPC. As a result, the internal rate of return varies widely, and is only positive within a 10-year timeframe (6%) in the highest possible efficiency scenario (2.6 GJ savings) for plants producing OPC.

The average price per metric ton of biomass alternative fuels is $32.50.[26] Given the rising price of coal ($141.90 per metric ton in Jan. 2011),[27] switching to non-fossil alternative fuels to fire cement plant kilns, particularly biomass, is increasingly attractive. With an average energy content of 10 GJ/t, savings from using biomass as a replacement for coal in a 1 million metric ton capacity plant, at an average energy requirement target of 2.55 GJ/t_{cement} would be approximately $3.8 million per annum.

Switching from coal to alternative fuel requires an additional investment of $6.5 million per million metric ton capacity plant, therefore switching from coal to biomass will begin yielding savings after a year and a half. For a plant with a 50-year life span, the total savings could amount to $184 million.

As the price of coal is variable, as is the price of biomass each plant must conduct an individual analysis of the potential savings from switching fuel sources. Other factors such as transportation may add additional costs as well.

Blended Cement

Storage and handling of alternative materials requires between $10 and $16 million per million metric ton of cement production capacity.[28] A weighted average of $13 million has been used for this analysis.

Based on the regular composition of Ordinary Portland Cement (OPC) (approximately 95 percent clinker and 5 percent gypsum) and the aggressive blend (50 percent clinker), 53 percent of cement will remain as OPC by 2020 in the BAU scenario. In the efficiency scenario, this number changes to 31 percent in order to achieve an average clinker-cement ratio of 64 percent.

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25 IEA 2007

26 IMF, Australian Export Price, January 2011

27 ECRA 2009

Thus, the production capacity of blended cement in the gigaton scenario grows by 3130 Mt, and that of OPC cement by 190 Mt, between 2010 and 2020. In the BAU scenario, the corresponding numbers are 1840 Mt and 1480 Mt. The total additional capital investment required for the gigaton scenario calculates to $17 billion. Operational cost savings will depend on price of clinker substitutes and reductions in fuel use.

Capital Investment for Cement Capacity

Investment 2010-2020

$ Billion	BAU	Gt	Additional
OPC	371	47	-324
Blended	483	824	341
Total	854	871	17

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OPC has proven to be a reliable and high-performing material and its raw materials are cheap and easy to produce in large quantities.

Rate of Return

Lowering the clinker content of cement has the potential to generate large cost savings for cement plant operators with very short payback periods for initial capital expenditure for new handling and storage equipment.

The average price of clinker in China is $55.00 per metric ton, including shipping costs.[29] Substitutes for clinker, cost substantially less: $30 per metric ton for fly ash and $5 per metric ton for blast furnace slag.[30]

Processing blended cements requires an additional 8.9 Kwh/t_{cement}, raising the costs for operating a 1 million metric ton plant by $623,000 per year.[31] Even with this additional cost, switching to a mix of these clinker alternatives can save $11.8 million for a 50 percent blend and $5.6 million for a 25 percent blend annually for a 1 million metric ton plant.

Factoring in the high capital cost for new handling and storage facilities that cost on average $13 million for a 1 million ton capacity plant, the internal rate of return would be 90 percent for the 50 percent blend and 41 percent for the 25 percent blend, and that doesn't even include the savings generated from the reduced cost of fuel derived from the reduced thermal energy requirement achieved by reducing clinker content.

Electrical Energy

The capital investment required for these efficiency measures ranges between $0.20 metric ton of CO_2 emissions reduction (efficient motors) and almost $12 per metric ton of CO_2 emissions reduction (raw meal blending systems).[32] The weighted average of these electricity efficiency improvement measures amounts to $6.60 per metric ton of CO_2 emissions reduction. Thus, the total additional capital investment required to reduce 92 Mt of emissions between the BAU and the Gt scenarios is $0.61 billion.

Rate of Return

By reducing the amount of electricity necessary to produce cements from 106 kWh/t in the BAU scenario to the current state-of-the-art 89 kWh/t_{cement} production equipment, cement manufacturers can save $1.19 million per annum.

The capital expenditure required for upgrading to state-of-the-art equipment with an efficiency of 89 kWh/t is $660,000 per 1 Mt capacity plant, yielding an internal rate of return of 198%. The payback period will vary for individual plants based on the kWh cost in a given location.

[29] Average taken from: Fiji Times 2010

[30] Averages taken from: ACAA 2010; Climate Tech Wiki 2010

[31] Based on average cost of $.07/kWh for industrial consumers in the United States, EIA 2010

[32] Tsinghua University of China 2008

Barriers to Implementation

Key Barriers for Blended Cement

The potential for future applications of blended cements depend upon the industry's attitude, availability of blending materials, regulatory standards, and legislative requirements. In addition, there remain technical issues that need to be addressed.

OPC has proven to be a reliable and high-performing material and its raw materials are cheap and easy to produce in large quantities. This has led to a lack of innovative drive in the cement industry and limits the uptake of alternative materials. Leadership by large procurement agencies and enhanced visibility of structures such as the Freedom Tower in New York (50 percent fly ash) and the De Young Museum in San Francisco (50 percent fly ash) using high percentages of alternative materials have helped to raise awareness about the potential for these materials, however much more must be done to increase its adoption.

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The greatest barriers to the adoption of energy efficient kilns are the large investment requirements, and the large costs of production disruption.

The composition of OPC and blended cements is very different, resulting in several variations in performance. For instance, OPC generally has higher 7-day strength than blended cements, even though the ultimate strength of blended cements is often higher than OPC. The lower initial strength can reduce the speed of construction and thus negatively affect the economics of a project.[33] There are also concerns about using waste materials in cement since industrial wastes can contain high and variable levels of toxic metals.

Development of innovative blends that closely mimic the properties of OPC would greatlt accelerate adoption. A leading player for blended cements is Taiheyo Cement Corporation in Japan, which manufactures Eco-cements by using traditional pozzolans and pozzolans created by treating the ash from incinerating a wide variety of industrial and municipal waste sources.

There is both a limitation and large uncertainty surrounding the availability and cost of alternative materials such as fly ash and granulated blast furnace slag. The estimated global quantities of fly ash, slag, and natural pozzolans were around 500, 200, and 300 million metric tons respectively in 2006,[34] compared to global cement production in excess of 2 billion metric tons. In addition to limits on gross volumes, regional and local availability of such materials varies. This is a critical challenge, since transportation costs often make the use of blending materials prohibitively expensive.

Regulations and procurement standards have historically been prescriptive, specifying floors and ceilings for various cement constituents, rather than setting standards based off of performance. While some countries have introduced performance-based standards, the main actors in the cement industry are reluctant to prescribe or adopt them owing to lack of information and incentives. For instance, of all the State Departments of Transportation in the United States, only two allow for the use of performance-based standards. These departments argue that there was a lack on incentive for the cement industry to shift away from the tried and tested prescriptions.[35]

Other types of regulation can also limit the use of alternative materials. For instance, the U.S. Environmental Protection Agency is considering a new policy of treating coal combustion products (such as fly ash) as hazardous wastes under Subtitle C of the Resource Conservation and Recovery Act. Industry experts believe that this 'hazardous' designation would create a stigma resulting in rejection of fly ash by the market place.'' [36]

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[33] Xuequan et al. 1999

[34] WBCSD 2009

[35] Missouri and Oklahoma Departments of Transportation

[36] Adams 2010

Challenges Reaching Thermal Energy Efficiency and Fuel Replacement Goals

The greatest barriers to the adoption of energy efficient kilns are the large investment requirements, and the large costs of production disruption. Reducing the GJ/t_{cement} usage on a level necessary to reach gigaton scale would require an investment of $150 billion. In addition, even if this investment is attainable, the implementation of energy efficient kilns will require alternative fuels, which poses a problem in production schedules. Acquiring alternative fuels and preparing them for use can be a logistically difficult task given the varying legislative and environmental barriers in different countries.

Some countries make heavy use of alternative fuels to meet a majority of their needs. For instance, the Netherlands cement industry derives approximately 83 percent of its thermal energy needs from alternative fuels. However, various barriers prevent alternative fuels from being the fuel of choice globally.

Pre-treatment is often required to ensure uniform composition and optimal combustion, which may increase thermal energy consumption. There are other technical issues, such as the control of chlorine and heavy metals that require special handling, transportation equipment, and storage facilities.

Reusable biomass is more readily available in an agricultural belt and municipal waste is found near urban centers. Moreover, consistency of quality is a major challenge. Co-location of industries may help relieve this problem.

There is varying legislative support and enforcement related to co-processing, land filling, and incineration within and across countries. Classification and control at the source point of the waste favors the use of municipal solid waste in the cement production system, but the waste streams in critical countries such as China and India are mixed and lack classification and control. Moreover, the waste collection networks in these countries are inadequate.

There is also a poor public understanding and acceptance of the incineration of municipal solid waste and other waste materials that are thought to be toxic but in fact do not release any pollutants.

Alternative fuel costs are likely to increase as competition with alternative end-use producers (biogas, biofuels, energy generation in other industries) continues to increase their demand for feedstock.

Future Solutions

While it is clear that the use of high efficiency kilns, the use of alternative fuels, and clinker substitutions can reduce CO_2 emissions from the cement industry on a gigaton scale, there are other solutions that should receive consideration and funding for further development.

Solar Power for Thermal Energy

The use of solar thermal energy in the cement industry should be strongly encouraged in countries with good solar radiation. Heat generated by solar concentrators can be used for preheating the air supply for the plant, preheating the raw mill, or generating additional heat to increase the electricity output of waste heat recovery units during daytime. As the uptake of cements based on alternative chemistry increases, solar thermal technology will become even more important due to the lower kiln temperatures (700°C - 800°C) required.

…

The use of solar thermal energy in the cement industry should be strongly encouraged in countries with good solar radiation.

As highlighted in the gigaton scenario, the biggest opportunity for emissions reduction in the cement industry is from the use of carbon-neutral fuels. In order to fully capture this potential, the cement industry needs to be assured of a consistent supply of biomass and the biomass industry of a consistent source of revenue.

The concepts of co-location of industries and collection and characterization of wastes have a heavy dependence on urban planning.

Carbon Capture and Storage

Though carbon capture and storage (CCS) is a potentially game changing technology, only 10 percent of current plants can be linked to CCS. Other researchers have also dismissed the prospects of any traditional CCS technology (oxyfuel, chemical/physical absorption, membrane processes, sorbent processes, etc.) taking off in the cement industry, citing cost as the largest barrier. [37]

The argument against CCS in the cement industry rests on both the concentration of emissions in electricity generation from coal and on the guaranteed rate of return based on expenses in the power industry. Current estimates for the cost of CCS in cement plants are around $50 to $100 per metric ton of CO_2, which would double the price of cement.

However, alternative approaches to CCS could be commercialized in the cement sector by 2020 given adequate support. At least four such approaches are gaining attention and investment.

One of the most promising processes is Calera, which has received a $20 million investment from the U.S. Department of Energy as well as investments from Khosla Ventures and Peabody Coal. Though initially producing only aggregate substitutes, Calera proposes to eventually produce alternatives to clinker. The process involves bringing seawater, brackish water, or brine into contact with the waste heat in power station flue gas where CO_2 is absorbed, resulting in bicarbonate minerals. After turning CO_2 into bicarbonate, the process involves a second step of electrochemistry to turn bicarbonate into carbonate, which is the substitute building material. Calera reports that a 20 to 50 percent replacement of Portland cement has been tested against ASTM C 1157 concrete specifications.[38]

Calera states that it has achieved greater than 90 percent CO_2 capture at its pilot plant and makes a conservative estimate of 70 percent capture for commercial scale plants. It projects that for a 2 Mt cement plant, it will capture 1.1 million metric tons of CO_2 per annum and increase building material production to 2.4 Mt. The total capital expenditure will be between $180 and $220 million ($90–$110 million/Mt capacity). The cost of CO_2 capture will be between $50 and $60 per metric ton of CO_2. The company is confident that it can make money if it can sell the building materials that it produces for a price of $25 per metric ton.[39]

The technology is still in development and several more pilot plants have to be built to assess various parts of the process and suitability to a number of conditions, including those where a natural source of electrolytes is not available. Issues relating to the disposal of hydrochloric acid, a byproduct of the electrochemical process, also need to be addressed.

[37] VDZ & PENTA 2008

[38] Constantz 2009;
Damtoft *et al.* 2008

[39] Calera 2010

Appendix I. Industry Experts and Key Players

Organization	Website
Alliance for Energy and Economic Growth	http://www.yourenergyfuture.org/
America Portland Cement Alliance	http://www.cement.org/
American Coal Ash Association	http://www.acaa-usa.org/
American Concrete Institute ACI	http://www.concrete.org/general/home.asp
American Iron and Steel Institute	http://www.steel.org/
Battelle	http://www.battelle.org/
CalStar Cement	http://calstarproducts.com/
CCAP	http://www.ccap.org/
Cement Kiln Recycling Coalition	http://www.ckrc.org/
Cemex	http://www.cemex.com/
China Building Materials Academy (CBMA)	http://www.cbma.com.cn/english/index.htm
Editor, World Cement Magazine	http://www.worldcement.com/
EERE - Industrial Technologies Program (ITP)	http://www1.eere.energy.gov/industry/
FL Smidth	http://www.flsmidth.com/
Heidelberg Cement	http://www.heidelbergcement.com/global/en/company/home.htm
IBIS World	http://www.ibisworld.com/
IEA	http://www.iea.org/
IFC	http://www.ifc.org/
IPCC	http://www.ipcc.ch/
ITIBMIC	http://china.lbl.gov/collaborators/institute-technical-information-building-materials-industry-china-itibmic
Kauffman Foundation	http://www.kauffman.org/
KDH Humbolt Wedag	http://www.khd.com/
Khosla Ventures	http://www.khoslaventures.com/khosla/default.html
Lafarge	http://www.lafarge.com/
LBNL	http://www.lbl.gov/
MIT Concrete Sustainability Hub	http://web.mit.edu/cshub/
National Ready-Mix concrete association	http://www.nrmca.org/
Peabody Energy	http://www.peabodyenergy.com/
PEG India Cement Consulting Engineers	http://www.pegindia.in/_eng/_OurExp_Cement.html
Polysius	http://www.polysius.com/en/
Portland Cement Association	http://www.cement.org/
Re-Use People of America	http://thereusepeople.org/
Regenerative Ventures	http://www.regenerativeventures.com/
RMC Research & Education Foundation	http://www.rmc-foundation.org/
Schenk Process	http://www.schenckprocess.com/en/
Shree Cement	http://www.shreecement.in/
Slag Cement Association	http://www.slagcement.org/
The Athena Institute	http://www.athenasmi.org/about/index.html
UNDP/UNEP	http://www.undp.org/; http://www.unep.org/
US EERE	http://www.eere.energy.gov/
US EIA	http://www.eia.doe.gov/
US EPA	http://www.epa.gov/
US Geological Society	http://www.usgs.gov/
USGS Minerals Yearbook: Cement	http://minerals.usgs.gov/minerals/pubs/commodity/cement/
World Business Council for Sustainable Development	http://www.wbcsd.org/templates/TemplateWBCSD5/layout.asp?MenuID=1
World Resources Institute	http://www.wri.org/
World Statistical Data Review from CEMBUREAU	http://www.cembureau.be/newsroom/article/world-statistical-review-1996-2008-now-available
WWF	http://www.worldwildlife.org/home-full2.html

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About The Carbon War Room

Carbon War Room works on breaking down market barriers for capital to flow to entrepreneurial solutions to climate change, by employing a sector-based approach focusing on the solutions that make economic sense right now. We target the movement of institutional capital into a working marketplace and the elimination of market inefficiencies (in the form of insufficient information and high transaction costs, among others). Policy and technology are necessary conditions to the solution; however, they are neither sufficient, nor the bottleneck to progress.

Our vision is to see markets functioning properly, and clean technology successfully scaling to promote climate wealth, business and economic growth. In the role of a climate wealth catalyst, Carbon War Room focuses on areas where a sector-by-sector approach to climate change can be applied to generate gigaton-scale carbon savings. We seek to complement existing efforts and organizations, leveraging our convening power, our market-driven, solutions-oriented focus, and our powerful global network to develop and implement catalytic change.

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