

New Regulations Can Stimulate Improvements In Efficiency And Sustainability For The U.S Cement Industry

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New environmental regulations on toxic and greenhouse gas emissions by cement manufacturers present the U.S. cement industry with significant challenges. This paper describes the current regulatory climate and describes a number of opportunities in which manufacturers can become more efficient in both energy and materials use. Ultimately, the new regulatory climate is seen as an opportunity for the industry to undertake long overdue modernization.

Keywords: cement, environment, efficiency, sustainability, regulations

Introduction

2010 has seen significant changes to environmental regulations related to the emission of air pollutants, including toxic substances and greenhouse gases. These updated regulations impact a number of industrial sectors, but the U.S. cement industry is specifically targeted primarily due to emissions of mercury, which has been linked to a range of harmful effects on human health and the environment. Typically, new regulations are heralded as threats to the competitiveness and profitability of industry. However, an alternative view presents the current regulatory environment as ripe with opportunity for outdated facilities to adopt new energy efficient technology with relatively short payback periods that can, in turn, help fund more modern emissions control systems. The resulting profile is one of a modernized, efficient and cleaner industry that has the capacity to respond to demand, is competitive with foreign imports, and earns a healthy profit due in large part to energy savings and less wasteful practices.

Background

The manufacture of portland cement is a three-step process consisting of crushing and combining the raw materials, heating the mixture, and grinding the resulting material into the finished product. Lime and silica are the primary constituents, making up about 85% by weight. Common sources of lime are quarried limestone, shells and chalk. The lime source is combined with silica sand, as well as other raw materials such as shale, clay, blast furnace slag, and iron ore, and ground to a fine powder. The powder is heated in large kilns to a temperature of approximately 2700° F in a process referred to as calcination. The resulting product, called clinker, is discharged from the kiln and later ground with approximately five percent gypsum to produce the powder recognized as portland cement. There are many excellent sources of detailed information about cement production, including Worrel (2008b) and van Oss (2005), and of course the website for the Portland Cement Association (PCA) which were all referenced for this review.

A total of 2.8 billion tons of cement was produced globally in 2009 (USGS 2010). The U.S. is the world's third largest producer of cement, producing approximately 4 percent of the world's total (IEA 2007). China is by far the world's largest cement producer, supplying almost half of the total global production. India comes in second at just under 6 percent. In the U.S. cement production is primarily a regional business with customers traditionally purchasing cement from local sources. Nearly 98% of U.S. cement is shipped to its customers by truck (PCA 2010). In 2009, there were 100 clinker-producing plants in the U.S. and 157 operating cement kilns within those plants (O'Hare & Sullivan 2010).

Portland cement manufacturing is energy intensive and also produces substantial emissions in the form of particulates, carbon dioxide, acid gases, organic compounds, and various metals. Of greatest concern to human health and the environment is the release of mercury into the atmosphere. The U.S. Environmental Protection

Agency (EPA) lists cement manufacturing as the third-largest source of mercury air emissions in the U.S. (USEPA 2010d). Mercury from cement kiln emissions is deposited in water and on land where it undergoes microbial transformation into methylmercury. This highly toxic compound accumulates in fish and shellfish, which are the main sources of mercury exposure to humans. There can be considerable variability in the amount of pollutants emitted from cement kilns, either due to varying levels of mercury and organic compounds in the raw materials and fuels fed to the kiln, or due to performance of the air pollution control technology.

Cement manufacturing also emits carbon dioxide (CO₂) from combustion of fossil fuel and from calcination of limestone (van Oss 2005). The CO₂ that is released from the limestone as it is heated during calcination accounts for 50 percent of all cement industry CO₂ emissions. CO₂ is considered to be a greenhouse gas (GHG) and a contributor to global climate change.

Recent regulatory action by the EPA has addressed both air toxics and GHG releases and is expected to have a major impact on the U.S. cement industry. As a result, cement manufacturing plants must adopt modern air pollution control technology and also become more energy efficient in order to meet the new standards. If planned correctly, the savings realized from energy efficiency improvements can help fund a significant portion of the plant upgrades required to meet the new emission limits, and also have the potential to ultimately boost profitability and global competitiveness. In addition, the cement that is produced can be used more efficiently through a combination of measures including more efficient design of structures, greater durability, and the use of alternative materials in blended cements. The following sections provide more detail on recent regulatory actions and describe trends and opportunities for greater sustainability in cement manufacturing and use.

Regulations for Air Toxics

The Clean Air Act is the comprehensive federal law that regulates air emissions from stationary and mobile sources. On August 6, 2010, EPA issued an amendment to the National Emission Standards for Hazardous Air Pollutants (NESHAP) (a program under the Clean Air Act) that imposes stricter limits on the allowable emissions of mercury, total hydrocarbons (THC), hydrochloric acid (HCl) and particulate matter (PM) from both new and existing portland cement kilns across the U.S. The EPA also issued an amendment to the New Source Performance Standards (NSPS) that limits emissions of particulates and ozone-forming pollutants from new kilns. However it is the amendment to NESHAP that has prompted the most concern from the PCA concerning potential impacts to the U.S. cement industry.

Cement manufacturing has been regulated under NESHAP since 1999 when the industry was initially targeted based on emissions of various metals and polychlorinated biphenyls (PCBs). The 1999 NESHAP rule established emission limits for THC, using it as a surrogate indicator for PCB and other organics. However, limits on metals were not included in the 1999 rule or in the amendments that followed in 2006. To fulfill the requirements of the Clean Air Act, EPA has now set emissions standards for metals using PM as a surrogate indicator, and has added specific limits for mercury emissions and HCl.

The NESHAP emissions standards are based on the maximum achievable control technology (MACT) for portland cement manufacturing kilns. The EPA undertook a detailed study of all existing cement kilns for which they had emissions data for mercury, THC, HCl, and PM (USEPA 2010d). They identified the lowest emitting (considered best performing) 12 percent, and used a statistical analysis to account for variability among the different plants. The MACT limits for each of the specific pollutants or surrogates were then calculated based on the best performers.

How difficult will it be for plants to meet the new standards? Based on actual plant emissions, the EPA found that all kilns in the pool of best performers, as well as several additional kilns not included in that pool, met the promulgated standards for mercury, THC and PM. Virtually all kilns in the pool also met the HCl standard (USEPA 2010d). In other words, not only all the best performers, but a number of additional plants as well are already meeting the promulgated standards, indicating that it is possible to reduce emissions and still produce a competitively priced product.

To achieve further reductions in mercury beyond the MACT limit, as was requested by some environmental groups, the available options become quite complicated and costly. Those measures include relocating the kiln to a quarry having lower mercury concentrations in the limestone, transporting low-mercury limestone, switching fuels, or

installing additional control devices. The EPA considered these measures to be technically infeasible or not cost-effective and therefore declined to include more stringent standards. The EPA conducted an economic impact analysis for the year 2013, which will be the year that all existing kilns will have to be in compliance (expected to be 158 kilns at 100 plants). The economic impact model was designed to simulate potential decisions made in the cement industry to meet an environmental policy under a regulatory scenario.

The final rule was made after considering 3,229 comments received from the portland cement industry, environmental groups, State environmental agencies and others during the comment period, and has the characteristics of a well-documented and technically-defensible analysis.

Of course there are some unique cases. There are two plants that are co-located by quarries where the limestone contains exceptionally high levels of naturally occurring mercury – on the order of five to 10 times higher than all the other limestone sources in the country. It is unlikely that these two plants will be able to achieve the new standard without extensive air pollution controls or switching to another source of limestone.

Regulations for Greenhouse Gases

On May 13, 2010, the EPA issued a final rule that addressed GHG emissions from stationary sources under the Clean Air Act. This final rule set thresholds for GHG emissions that define when permits under the New Source Review Prevention of Significant Deterioration (PSD) and Title V Operating Permit programs are required for new and existing industrial facilities. Facilities responsible for nearly 70 percent of the national GHG emissions from stationary sources will be subject to permitting requirements under this rule including the nation's largest GHG emitters—power plants, refineries, and cement production facilities (USEPA 2010e).

Currently, there are no emissions limits on GHG including CO₂. EPA's new rule establishes a gradual phase-in of GHG emission limits during 2011 to 2013 for newly constructed or modified sources that will emit a significant quantity of GHG over an established threshold. Existing plants will not be regulated for GHG unless they implement a significant modification that bumps their CO₂ emissions over the threshold (e.g. installing a new kiln).

The current atmospheric concentration of CO₂, which makes up 85 percent of greenhouse gases, is 390 parts per million (ppm), the highest in recorded history. The Intergovernmental Panel on Climate Change (IPCC) is recommending that the annual global CO₂ emission rate be reduced to maintain an atmospheric level of CO₂ at or below the 1990 level (approximately 350 ppm) in the next 20 years. As a result, governments and leaders of major CO₂-producing industries, such as power generation, transportation, oil refining, and manufacturing of steel and concrete, are contemplating decisive measures to achieve a drastic cut in the global CO₂ emission rate by 2030 (Mehta 2009).

One mechanism that has been suggested to achieve this goal is cap and trade. Cap and trade is a policy approach for controlling large amounts of emissions from a group of sources (USEPA 2010a). An overall cap on maximum emissions in a selected period is chosen to achieve the environmental goal. Then authorizations to emit are allocated to the sources in the group. The total number of allowances cannot exceed the cap. Sources may choose to lower their emissions and trade, sell, or bank their excess allowances, or they may continue emitting at higher levels and purchase allowances to cover the excess. Two existing cap and trade programs, the Acid Rain Program (covers annual sulfur dioxide emissions from most fossil fuel burning power plants) and the NO_x Budget program (covers summer nitrogen oxide emissions from selected sources in the eastern U.S.), have track records of effective emissions reduction.

More than a dozen bills were proposed or introduced in the 111th Congress that were designed to reduce GHG in the U.S. by putting a price on those emissions (RFF 2010). H.R. 2454, the American Clean Energy and Security Act of 2009, also known as the Waxman Markey cap and trade bill, was the most ambitious cap and trade bill so far and also the most successful, having passed in the House in June 2009. The bill is now stalled with the Senate deciding not to take action this year. A tri-partisan cap and trade bill was also started in the Senate by Democrat John Kerry, independent Joe Lieberman and Republican Lindsay Graham. After Graham dropped out, the bill continued as the Kerry-Lieberman bill, also known as The American Power Act. For a variety of political reasons, the bill died and never came to a vote in the Senate.

If the U.S. does implement cap and trade legislation in the future, it will certainly impact the U.S. cement industry. Until such time, there are a number of approaches that would proactively move the industry toward greater efficiency and sustainable practices, as well as greater profitability, in light of the current regulatory environment and in anticipation of future restrictions on CO₂ emissions. These are discussed in the following sections.

Improvements in Efficiency

Plant configuration greatly influences efficiency. There are two general methods of introducing the raw material feed into the cement kiln. One method uses a dry feed and the other adds water to the raw materials to produce a slurry. Dry kilns and kilns with preheaters located outside the calciner are far more energy efficient than wet kilns, which demand additional energy to burn off the water in the slurry. Wet kilns account for approximately 20 percent of clinker production in the U.S. (IEA 2007).

During the 1970s and 1980s many wet kilns were replaced by more modern equipment and the overall energy efficiency of the industry improved. This improvement was short-lived however, as falling energy prices over the next decade accompanied by an increased demand for cement caused some of the older units to be brought back online. As of 2000, the U.S. cement industry was among the least energy efficient in the world, using nearly 80 percent more energy in the production of clinker than was used in Japan, the world leader in energy efficiency – a consequence of the country's substantial investments in R&D. At the same time, U.S. manufacturers also used 10 percent more clinker in the production of cement than was used in Japan (NAS 2010). Other countries like Germany and Mexico have reduced the amount of energy to produce a ton of cement by more than 1% a year over the last decade (IEA 2007).

According to the PCA, the U.S. cement industry has adopted a year 2020 voluntary target of 20 percent improvement (from 1990 baseline) energy efficiency—as measured by total Btu-equivalent per unit of cementitious product. However, in their report, *Real Prospects for Energy Efficiency in the United States*, the National Academy of Sciences (NAS 2010) reports that energy use for U.S. cement production actually increased by 10 percent per ton in the 1990s, so the industry has some catching up to do over the next ten years to meet their goal.

Cement manufacturers could begin to make progress toward their goal of reducing their energy usage by taking advantage of programs such as DOE's Save Energy Now, which helps large industrial facilities improve their energy performance. Between 2006-2008, they identified \$14 million in energy-saving opportunities at 16 U.S. cement plants—with 71 percent of these opportunities having a payback period of less than 2 years. Only \$300,000 of those savings have been implemented, leaving \$13 million on the table (EDF 2010).

McKinsey (2009) suggests reasons why these opportunities are being missed. Even low-cost plant changes and upgrades may require technical analysis that on-site employees don't perform because of insufficient training, awareness, or management concern. There is often a lack of focus on energy efficiency by top management and a preference for short-term targets at the expense of projects with longer payback periods.

NAS speculates that the reason that U.S. firms have not upgraded their facilities is due to the age of most of the installed plants. Local permitting and other requirements such as emissions estimates and public comment periods can be time-consuming and the real or perceived costs may make the economics of maintaining the old, inefficient facility appear more attractive than investing in a modern, efficient plant. This was echoed by McKinsey, which identified regulatory requirements as a major barrier to U.S. industry's lack of new investment across all sectors.

Other Efficiency Upgrades

Additional options include process changes that can incur significant capital cost. Most are not feasible unless undertaken as part of a planned plant upgrade. These include switching to lower carbon fuels, such as from coal to natural gas; burning waste fuels; upgrading the raw materials handling systems; upgrading the kiln by installing more efficient burners and improved process control systems, and upgrading the finish grinding equipment (van Oss 2005, Worrell 2008a and b).

Improving Sustainability

A different approach to reducing the environmental impact of cement manufacture is simply to consume less cement. Mehta (2009) suggests three tools to reduce the demand for cement: 1) consume less concrete; 2) consume less cement in concrete mixtures; and 3) consume less clinker in cement.

Consume Less Concrete

Green building standards such as the U.S. Green Building Council's Leadership in Energy and Environmental Design (LEED) encourage and give credit for reuse of existing structures, use of recycled content materials, and reduction of construction waste (USGBC 2010). Specific design strategies such as the use of thin wall foundations, simplified building geometry, and use of steel instead of concrete, can reduce the amount of concrete required for new buildings (Chini 2002). Unprocessed, crushed concrete can be reused as bulk fill, bank protection, base or fill for drainage structures, road construction, and noise barriers and embankments. With additional processing, crushed concrete can also be used in new concrete for pavements, shoulders, median barriers, sidewalks, curbs and gutters, and bridge foundations; structural grade concrete; soil-cement pavement bases; and other applications (PCA 2010).

Consume Less Cement in Concrete

Mehta (2009) reports that specifying a 56-day or later strength (rather than 28-day) for structural elements that will not be subjected to significant loads before 2 to 3 months of age can result in 15 to 20 percent cement savings. Other strategies for consuming less cement include using plasticizing admixtures instead of more mixing water and cement to obtain the required consistency of concrete; and optimizing the size and grading of aggregates to reduce the total volume of cement paste in the concrete mixture (Buffenbarger 2009).

Consume Less Clinker in Cement

The amount of clinker used in the cement can be reduced either before or after calcination (van Oss, Worrell 2008a and b). Both methods reduce CO₂ emissions and both produce what is referred to as a blended cement. Prior to calcination, a portion of the limestone can be replaced with a material that does not require calcination such as slag (from steel production), and fly ash or bottom ash (from coal combustion); this has the dual benefit of reducing CO₂ emissions from the calcining reaction as well as from the energy used for the process. Alternatively, a portion of the limestone clinker in the cement mix can be replaced with other cementitious materials including fly ash or other pozzolans (materials that exhibit cementitious properties in the presence of calcined lime and water). Both methods allow increased production of finished cement without increasing clinker production. Worrell et al. (2008b) identify potential energy savings of up to 20 percent, CO₂ emissions reductions ranging from 10 to 35 percent, and a payback period of less than one year from the deployment of blended cement technologies.

The addition of alternate cementitious materials is highly dependent on cost and availability of the materials and also on what is allowable by the relevant building codes. On the horizon, additional regulatory restrictions may hinder approval for the use of fly ash blends in particular. On May 4, 2010, EPA announced that a proposal to regulate for the first time coal ash to address the risks from the disposal of the wastes generated by the electric power industry. EPA is considering two possible options for the management of coal ash. Both options fall under the Resource Conservation and Recovery Act (RCRA). Under the first proposal, EPA would list these residuals as special wastes (i.e. hazardous) subject to regulation under Subtitle C of RCRA, when destined for disposal in landfills or surface impoundments. Under the second proposal, EPA would regulate coal ash under Subtitle D of RCRA, the section for non-hazardous wastes. Under either option, the continued use of fly ash as a cement additive is considered to be a beneficial use of a waste product. Even under the first proposal, once the material is encapsulated, it would no longer carry the special waste designation.

Vaughan and Merryman (2010) foresee two potential impacts of these EPA options on fly ash use in concrete: economic incentive and public perception. If disposal costs for coal combustion residuals (CCRs) increase, there could be a corresponding increase in the supply of fly ash on the market for beneficial use. However, if the EPA chooses to designate CCRs as special waste, the permitting requirements and potential litigation costs associated

with handling and transporting could be prohibitive. There may also be reluctance on the part of the consumer to utilize a product that once carried a special waste designation, even after encapsulation. The cement industry fears that a special waste designation would make fly ash “the new asbestos” and “stigmatize its use as an ingredient in concrete” (Post 2010). The final rule on this issue is still pending at the time of this paper.

The Threat of Imports

Will new regulations on the cement industry cause a shift to imported product? Economists for the cement industry are making grim predictions that the current regulatory environment will spell the end of domestic cement production and make U.S. builders reliant on imported product (O’Hare & Sullivan 2010, Weinstein 2010). However, these predictions are based on a few worst-case assumptions:

The U.S. economic recovery will be immediate and rapid resulting in heavy demand for cement. The U.S. cement industry will not be able to afford to comply in time to respond to this demand. PCA predicts that after the precipitous drop in U.S. cement consumption from a high of 128 million metric tons in 2005 to a low (so far) of 68.5 million metric tons in 2010, the economy is poised to bounce back beginning in 2011 with demand increasing rapidly and exceeding the 2005 levels within 5 years. In reality, with a three-year compliance period for the new NESHAP rule, available assistance programs such as DOE’s Save Energy Now, and considering that a good number of plants are already meeting the new standards, there is reason to believe that the U.S. cement industry will be able to continue to respond to growing demand as the economy recovers.

How quickly the industry can respond will depend on the capacity and efficiency of the existing facilities. In the 2010 Mineral Commodity Summary for cement (USGS 2010), the U.S. Geologic Survey (USGS) reports that by the end of 2009, 14 plants had closed, and only 3 new plants had opened - attributed to the ongoing severe decline in construction spending and associated cement sales. A number of planned expansion projects at existing plants were put on hold, as were plans for at least two new plants, and several plants were idled temporarily, due to full cement silos. Up until 2008, lower sales had been accommodated by reductions in imported cement. If the industry does anticipate a sharp upturn in demand for its product, now would be the time to examine options for upgrading the retired plants and bringing them back online.

We can expect to see a shift to imported product beginning in 2013 when all U.S. plants must comply with the 2010 NESHAP rule. Use of imported cement peaked in 2005-2006 corresponding to high demand, a shortfall in domestic production capacity, and an ease in shipping costs, none of which had to do with emissions limits (USGS 2010). A more serious concern than environmental regulation is that the U.S. cement industry will cease to be competitive with imports due to lack of investment and outdated technology including improvements in plant energy efficiency as well as capacity to control air emissions. The import percentage of U.S. cement consumption has dropped from 27 percent in 2006 to 8 percent in 2009. Now is the time to strategize for future production to forestall resorting to imports when demand rises again.

Other factors independent of environmental regulation that may contribute to the use of imported cement are company ownership and trade policies. Over the past 20 years, foreign firms have become major shareholders in more than 80 percent of U.S. domestic cement plants (NAS 2010). This change in ownership has eroded political support in the U.S. for antidumping tariffs, which until recently, protected domestic producers from low-priced imports. Without the penalty of tariffs, foreign firms can choose to increase imports rather than invest in new or upgraded plants in the U.S.

Developing countries have no comparable environmental regulations and therefore have a cost advantage over the U.S. According to the USGS (2010), the majority of imported cement and clinker imported from 2005 to 2008 came from four countries: China (22 percent), Canada (19 percent), Republic of Korea (9 percent), and Thailand (7 percent). The remaining 43 percent of imported cement came from a host of other countries including Mexico, Colombia, and various European sources. Obviously, manufacturers in Canada and Europe are not taking advantage of lax environmental regulations in developing nations. In the case of China, the country is making great strides toward establishing their own environmental regulatory framework and has, in fact, been working with the U.S. EPA to develop standards similar to our Clean Air Act. (USEPA 2010b). In 2008, the Chinese government imposed regulatory guidance of eliminating old capacity before expanding capacity, and mandated the elimination of 250 million tons of annual production capacity by outdated plants by 2010 (Zhang 2008). Upon further examination

therefore, it seems clear that the assumption about developing countries being free of environmental restrictions is unfounded.

Conclusion

The US cement industry today is facing challenges as a result of increasingly strict regulations, as well as pressure to become more energy efficient and reduce greenhouse gas emissions. How the industry responds to these challenges will determine whether it assumes a leadership position in sustainable technology, or whether it will lag behind the rest of the world. The current regulatory and economic climate can however, be viewed as an opportunity for positive change that can result in a more efficient, sustainable, and profitable domestic cement industry in the future.

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