Building a Sustainable Future: Minimizing the Environmental Impact of Cement Manufacturing and Maximizing the Environmental Benefits of Cement Products

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ABSTRACT *The global cement industry has taken dramatic steps to enhance sustainable development by improving how cement is made and how cement and concrete are used. By minimizing energy use, emissions, and virgin material use in manufacturing, the industry can minimize any negative environmental impacts. At the same time, the industry is advancing the use of concrete and other cement products to create energy efficient buildings and pavements. The positive effects of reducing energy use in the general population can dramatically outweigh the impact of the cement manufacturing process.*

KEYWORDS: Sustainability, cement, environmental, energy efficiency

1. OVERVIEW

Cement manufacturing is a large industrial process that requires significant inputs of raw materials and energy. Cement plants have historically emitted large quantities of particulate matter, nitrogen oxides, and other gaseous and solid wastes. Some plants have also produced discharges of process water and stormwater. In the past few decades, however, cement manufacturing companies around the world have worked hard to reduce the environmental impact of this process.

While some of the improvements have been driven by legal requirements, many industry programs look beyond simply regulatory compliance or even the broader issue of environmental performance. The new focus is on sustainability, a holistic perspective that encompasses environmental impact, raw material use, community involvement, worker and customer health and safety, energy use, and economic performance.

The goal of sustainability is to leave the world a better place for future generations. Companies are learning that they are more profitable and more sustainable if they think in terms of a triple bottom line: economic, social, and environmental. This approach enables business development to meet the needs of the present without compromising the ability of future generations to meet their own needs. Two major examples of sustainability programs are the Cement Sustainability Initiative, a global effort under the auspices of the World Business Council for Sustainable Development, and the Portland Cement Association's Cement Manufacturing Sustainability Program, which involves facilities in the United States and Canada.

Sustainability also examines the impacts of a product throughout its lifetime. Life-cycle analysis assesses not just the environmental impact of manufacturing a product, but of its use and disposal. Cement and concrete perform well under life-cycle analysis. While their manufacturing impacts might be greater than those of competing materials, cement and concrete have a long lifespan and can enhance the energy efficiency of buildings and pavements. This paper will provide a contrast between historical approaches to environmental regulation and the emerging principles of sustainability.

2. ENVIRONMENTAL SUSTAINABILITY

Sustainability starts with environmental performance. While it is only one of three foundations, environmental concern is the key to sustainability.

In fact, the concepts of sustainable development and sustainability were borne of environmentalism. In 1987, the United Nations World Commission on Environment and Development presented a document,

commonly called the *Brundtland Report*, to the U.N. General Assembly. The report addressed concerns that historical development paths tended to deplete natural resources, including clean air and water. It called for future economic development that could be sustained without depleting natural resources or harming the environment. The report famously defined sustainable development as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs."

The Brundtland Report was primarily concerned with global equity and the sustainable economic growth of developing nations. This concept spread through the 1990s and was expanded to the broader concept of sustainability, which can guide the philosophies and actions of individual countries, communities, industries, companies, facilities, and people.

The worldwide cement industry has adopted sustainability as a guiding principle. This commitment is evident in the industry's significant steps to reduce levels of air emissions, solid waste, and water discharges.

2.1 Historical command-and-control regulation

Before Brundtland, environmentalism relied on an adversarial system in which government entities required industrial facilities, automobiles, and communities to utilize process or technological controls to limit air emissions, solid waste, and water discharges. This command-and-control approach sought to filter or capture pollution rather than limiting its creation.

In many countries, including most in North America and Europe, this approach was effective in removing most pollution from the most significant sources. For example, requiring U.S. cement plants to install particulate matter controls reduced those emissions by more than 99 percent.

Most observers agree that the command-and-control approach was appropriate in the first stage of the environmental movement. From the industrial revolution of the nineteenth century until the advent of environmental awareness in the mid-twentieth century, most industries and individuals envisioned natural resources, fresh air, and clean water as limitless. By the time that humankind realized that this was not case, dramatic steps were necessary. In the early 1970s many governments established environmental ministries, agencies, and laws. In the last three and a half decades, industrialized countries achieved strong gains. . The initial challenge of sustainable development was to ensure that developing countries learned the lessons of the past and developed in a smarter and more environmentally aware manner.

Now that old facilities generally include emissions controls—at least in developed countries—the challenge is to ensure that new facilities are designed to reduce the need for such controls. Sustainability looks beyond command-and-control measures to ensure that future development and industrialization are conducted wisely.

2.2 Beyond compliance

One element of sustainability is that environmental policy—whether at the government or corporate level—shouldn't be based on the rigid structure of legal requirements. Rather, these decisions should consider the long-term welfare of the people with a stake in a company or a country. As this broader approach has gathered momentum, industry and government are increasingly turning to voluntary measures to minimize environmental impacts. Often these measures are accompanied by market-based mechanisms for ensuring that overall emissions of a given pollutant are kept to a sustainable level.

The global cement industry has been a shining case study for the effectiveness of voluntary measures. One example is the Greenhouse Gas (GHG) Protocol developed in a cooperative effort by the World Resources Institute and the World Business Council for Sustainable Development (WBCSD), with active participation from the Portland Cement Association (PCA) and cement companies around world. The Protocol provides a consistent means of measuring carbon dioxide (CO_2) and other greenhouse gas emissions from cement plants.

With a globally recognized and utilized measurement tool, the cement industry established voluntary CO_2-reduction goals. For example, PCA member companies committed to reduce their total CO_2 intensity by 10 percent between 1990 and 2020. Inspired by this pledge many individual companies have set even more ambitious targets whether unilaterally or through programs such as World Wildlife Fund's Climate Savers or the U.S. Environmental Protection Agency's Climate Leaders.

2.2.1 PCA Cement Manufacturing Sustainability Program

The Portland Cement Association's Cement Manufacturing Sustainability (CMS) Program incorporates environmental improvements with health and safety concerns. The mission of the CMS Program is:

> To meet the rising demand for portland cement through environmentally and socially responsible business practices that use state-of-the-art technologies to continuously minimize emissions, promote a safe workplace, improve energy efficiency and conserve natural resources, and cost effectively produce a high-quality product.

The program seeks to accomplish this mission by making sustainability an integral part of the industry's approach to business. It balances society's need for cement products with stewardship of the air, land, and water; conservation of energy and natural resources; and maintenance of safe work places and communities. The major components of the CMS program are environment and energy issues and health and safety issues. The three primary elements of the environment and energy branch are a voluntary code of conduct, a program to establish continuous improvement goals, and an environment and energy awards program.

The centerpiece of the CMS program is a voluntary code of conduct--a set of principles, performance measures, and a reporting protocol, designed to guide decision making, business practices, and operating performance in a sustainable fashion. These principles, adopted by the PCA Board of Directors, are:

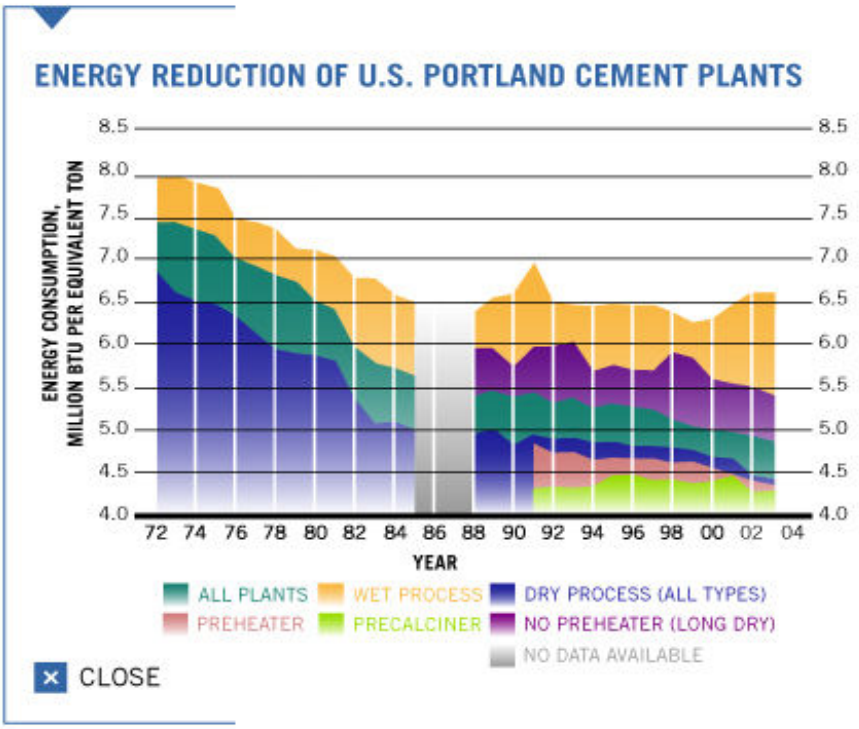
I. The safety and health of our employees, our neighbors, and our customers is our first consideration in the production and distribution of a quality product.
II. We will continue to implement effective controls, which reduce or eliminate the release of pollutants to the air, to the land, and/or to the water.
III. We will actively seek ways to manage wastes in a responsible and environmentally sound manner.
IV. We will pursue effective improvements in energy efficiency and promote the conservation of resources.
V. We will seek ways to beneficially and safely utilize recyclable wastes as raw materials, fuels, and product components as part of our overall commitment to waste minimization and recycling.
VI. We will continue to conduct mining operations in a responsible and environmentally sound manner.
VII. We will participate with lawmakers, regulators, and other interested parties in the development of rational and effective health, safety, and environmental laws and regulations.

PCA has established environmental performance measures that translate the CMS Program Principles into action. A long-term reduction target is identified for each key performance measure and then progress toward that target is measured against a baseline. So far these goals address carbon dioxide emissions, cement kiln dust disposal, environmental management systems, and energy efficiency. Each goal applies to the entire cement industry in the United States. For example, the Table 1 illustrates the trend in energy efficiency in the U.S. cement industry.

After the goal for adoption of environmental management systems (EMSs) was finalized, the percentage of U.S. plants using written EMSs increased from 29 to 47 percent in one year. The first two goals established—for carbon dioxide and cement kiln dust—are well on track for full attainment. Reductions of cement kiln dust in the United States are illustrated in Table 2.

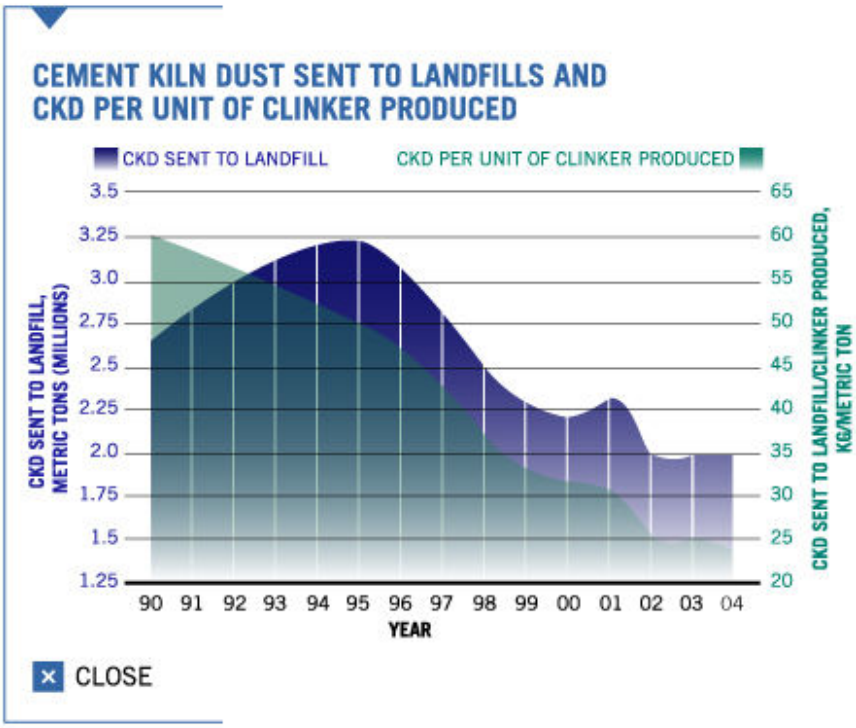
While emissions of particulate matter and sulfur dioxide are not addressed by continuous improvement goals, the U.S. cement industry has achieved significant reductions in these areas as well, as illustrated in Tables 3 and 4.

Table 1



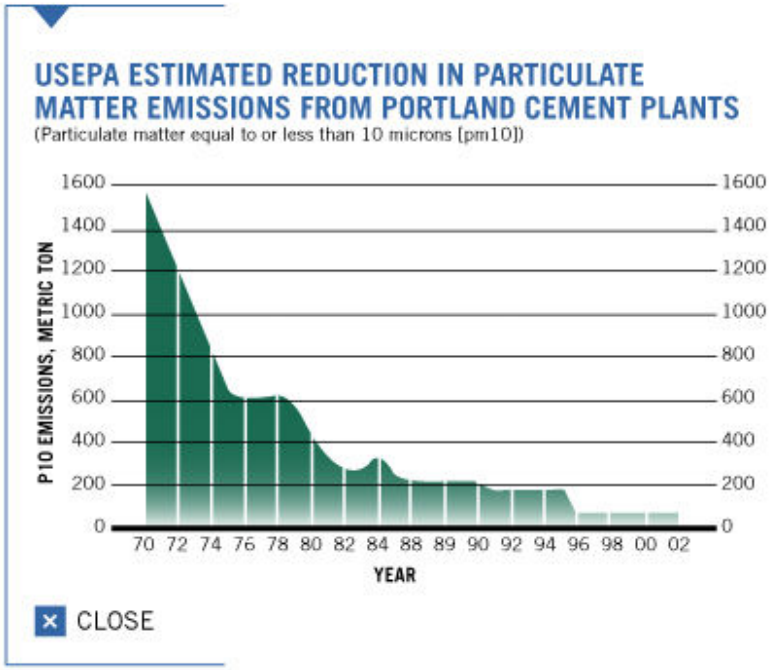
Source: PCA Report on Sustainable Manufacturing, 2006

Table 2



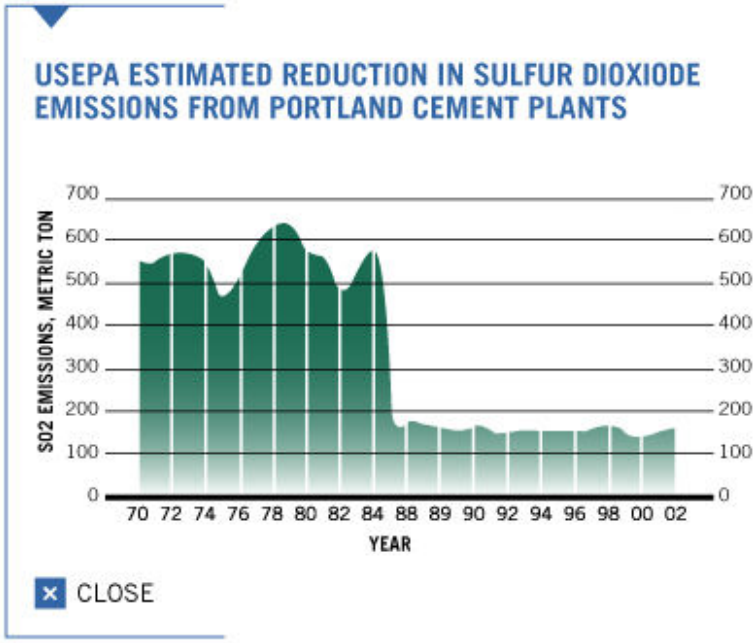
Source: PCA Report on Sustainable Manufacturing, 2006

Table 3



Source: PCA Report on Sustainable Manufacturing, 2006

Table 4



Source: PCA Report on Sustainable Manufacturing, 2006

Another important aspect of PCA's sustainability effort is an annual awards program. Each year this program recognizes manufacturers throughout North America that achieve superior environmental performance. The awards—judged by an independent group of individuals from within other environmental organizations, federal agencies, media, and other industry sectors—address the following categories:

- Environmental Performance
- Land Stewardship
- Outreach
- Innovation
- Energy Efficiency
- Overall Environmental Excellence

The CMS has encouraged U.S. cement manufacturers to give environmental and societal interests the same weight as economic interests. The health, safety, and welfare of employees and the communities in which they live and work are increasingly recognized as essential components of cost-effective manufacturing, distribution, and use, and are integral to all business decisions.

2.2.2 WBCSD Cement Sustainability Initiative

The Cement Sustainability Initiative (CSI) was created by most of the world's major cement manufacturers under the auspices of the World Business Council for Sustainable Development. According to the CSI website, the objectives of the program are to:

- Explore what sustainable development means for the cement industry
- Identify and facilitate actions that companies can take as a group and individually to accelerate the move towards sustainable development
- Provide a framework through which other cement companies can participate and
- Provide a framework for working with external stakeholders.

After a three-year period of data gathering, stakeholder involvement, and analysis, CSI released an Agenda for Action in 2002. The plan for the following five years includes task forces and projects addressing:

1. Climate protection and CO2 management
2. Responsible use of fuel and materials
3. Employee health and safety
4. Emission monitoring and reporting
5. Local impacts on land and communities
6. Reporting and communication.

A progress report on these activities will be released in 2007. The Web site also includes case studies and the results of a series of stakeholder dialogues in developed and developing countries.

2.3 Life-cycle impact: creating a sustainable product

A sustainable industry should be marked not only by a minimal environmental impact during the manufacturing process, but during the entire life cycle of the product. Cement and concrete products fare very well in life-cycle analyses. Concrete is highly durable, and concrete buildings and pavements are more energy efficient than those made with competing products.
Durability is a key attribute. A longer lasting product needs to be manufactured and applied fewer times. Concrete will not rust, rot, or burn, requiring less energy and resources over time to repair or replace. Concrete builds durable, long-lasting structures including sidewalks, building foundations and envelopes, as well as roadways and bridges. As the most widely used building material in the world, concrete structures have withstood the test of time for more than 2,000 years. Because of its longevity, it can be a viable solution for environmentally responsible design.

Concrete also creates more energy-efficient structures than other building materials. Homes and buildings constructed from insulated concrete walls are not subject to large daily temperature fluctuations. This means home or building owners can lower heating and cooling bills up to 25 percent–and occupants within these structures are more comfortable. Also heating, ventilating, and air-conditioning can be designed with smaller-capacity equipment.

Additionally, concrete minimizes the effects that produce urban heat islands. Studies have shown that urban environments have higher temperatures in areas where there are few trees, and a multitude of paved surfaces and buildings. This additional heat causes air conditioning systems to work harder, which uses more energy (up to 18 percent more) and promotes the formation of smog. Light-colored concrete absorbs less heat and reflects more light than dark-colored materials—thereby reducing heat gain. Light colored pavements also require less site lighting to provide safe night-time illumination levels, whether on parking lots, driveways, or sidewalks.

Finally, studies have shown that vehicles get better gas mileage riding on concrete pavements than on other materials. Concrete's rigid surface creates less drag, particularly in hot weather when asphalt becomes even softer.

These end-use energy savings are a crucial portion of PCA's greenhouse gas reduction program. Although the energy savings experienced by users of concrete do not count toward the industry's goal of reducing carbon dioxide from the manufacturing process, they could offset greenhouse gas emissions from the manufacture of the product. In other words, if concrete is utilized in a way to enhance its energy efficiency, the industry could become a net sink of carbon dioxide as opposed to a source.

Recycling also factors into cement's life-cycle analysis, both during the cement manufacturing process and in the production, use, and disposal of concrete. Many materials such as steel slag, foundry sand, and fly ash can be used to replace the essential raw materials of cement: calcium, silica, alumina, and iron. Many other by-products and wastes can be used as alternatives to virgin fuels as well. Examples of these are petroleum coke, waste tires, solvents, and any off-spec combustible materials. In some cases there are regulatory or other barriers to acquiring permits for the use of these materials in the United States, but PCA is working with the U.S. Environmental Protection Agency and other industries to educate regulators and the public on the environmental benefits of utilizing wastes in cement manufacturing.

Opportunities for utilizing by products do not end at the cement manufacturing stage. Many wastes and industrial byproducts such as fly ash that would otherwise clog landfills can be added to concrete mixes. These byproducts also reduce reliance on raw materials. For example, in 2001, the concrete industry used 11,400,000 metric tons of fly ash—a byproduct of coal combustion at electric power utility plants. This saves natural resources and utilizes a by product that would otherwise be wasted.

Finally, when a concrete structure has served its purpose, it can be recycled as aggregate in new concrete paving, backfill, or as road base. Even the reinforcing steel in concrete (which often is made from recycled steel) can be recycled and reused. Concrete is easy to use and can be readily recycled. Delivered and prepared for each specific project, concrete typically produces very little waste.

3. SOCIAL SUSTAINABILITY

Gaining less attention than environmental concerns but equally important are the social impacts of sustainability. Sustainable industries must strive to maximize positive effects on society through education, employment, economic welfare, stakeholder empowerment, and other factors. Negative social impacts should be minimized. Social sustainability can be seen as a series of concentric circles expanding around a company of other entity.

3.1 Occupational health and safety

At the center of sustainable industries and companies are individual employees. The health, safety, and welfare of employees and the communities in which they live and work are essential components of economic, environmental, and societal factors by which sustainability decisions are weighed.

The U.S. cement industry places a high value on health and safety. PCA's code of conduct described above includes a commitment to health and safety. PCA's occupational health and safety (OHS)

program sets high standards for health and safety and recognizes companies with strong safety records, as well as those that install innovative technologies to create a safer workplace.
The first of two PCA awards programs recognizes specific innovations and actions that enhance a facility's safety culture and infrastructure. The other highlights outstanding safety records in the following categories:

- One year without a lost time accident
- Five or more years without a lost time accident
- One million hours without a lost time accident

In addition, PCA has prepared a series of safety information advisories (SIAs) addressing health and safety topic areas of importance to cement manufacturers. The intent of the SIAs is to provide both corporate and plant level health and safety professionals with tools to enhance existing programs.
Cement-industry associations in other parts of the world also stress occupational health and safety. But health and safety concerns extend beyond the industry's own employees to the community and beyond.

3.2 Community health and safety

Controlling emissions, waste, and discharges is essentially a community health and safety program—and in the case of greenhouse gases or other pollutants with broader consequences, a global health and safety program. Therefore, the environmental sustainability steps discussed above are directly relevant to community concerns.
Other community health and safety issues include safe quarry operations and safe driving and rail operation guidelines. Less direct but equally important contributions include sponsorship of local youth athletic programs and health-care benefits for employees and their families. Finally, the very act of employing community members contributes to their ability to obtain good nutrition and medical care and to their general physical and mental health. All of these are factors by which the cement industry creates sustainable communities.

3.3 Customer health and safety

The next ring of social sustainability includes the customers and users of cement. One form of outreach to this group is sharing of information on the contents of the product. For example, in the United States manufacturers provide their customers with a material safety data sheet (MSDS) with detailed information on any health or safety concerns associated with ingredients in cement. PCA's Occupational Health and Safety Committee recently provided updated guidance to member companies in the form of a model MSDS, a copy of which is attached.
Another type of guidance can be provided to users of concrete. PCA has issued a pocket brochure titled "Working Safely with Concrete" to ensure that concrete workers use proper personal protective equipment and take other steps to safeguard their well being.

3.4 Community involvement

A mark of social sustainability that extends beyond health and safety is stakeholder involvement. Many cement companies have established community involvement committees to give their neighbors a voice in major decisions that might affect the community. An informed and participatory community can make the right decisions to become a sustainable community.

4. ECONOMIC SUSTAINABILITY

The final leg is economic sustainability. For a company to remain a valuable member of the community in which it operates and to contribute to environmental and social sustainability, it must remain in business. This requires operating at a long-term profit.

4.1 Cost savings

Many of the measures taken to achieve environmental and social sustainability directly benefit the financial bottom line and therefore contribute to economic sustainability. Air emissions, solid waste, and water discharges are the results of inefficiencies in an industrial system. An ideal system would produce no waste or byproducts. While generally unattainable, this is still the ultimate goal of a sustainability program.

Greater energy efficiency, for example, improves both profits and the environment. Minimizing the wasting of cement kiln dust is another example of converting what used to be wasted into a raw material.

A third example is the use of alternative fuels and raw materials. Using byproducts of other industries saves the cost and environmental impact of mining or otherwise obtaining virgin raw materials. In many cases, cement plants are paid to utilize these materials. The most commonly used alternative raw materials include blast furnace and iron slag, fly ash, bottom ash, copper slag, foundry sand, mill scale, sandblast grit, synthetic gypsum, and waste glass. Commonly used alternative fuels include scrap tires, non-recyclable plastics, waste oil, solvents, and other used and waste materials. In many cases cement plants are paid to utilize these materials. In virtually all cases, they are less expensive to acquire than virgin raw materials. In this way conserving natural resources also conserves financial resources.

4.2 Stakeholder satisfaction

Another means by which a company can ensure financial sustainability is to maximize the satisfaction of their employees, customers, communities, shareholders, and other stakeholders. Taking care of employees and being a good community member are two ways to achieve stakeholder satisfaction. Having a strong record of striving towards environmental and social sustainability are increasingly important in attracting and pleasing customers, communities, shareholders, and other stakeholders.

5. THE PATH FORWARD

Cement manufacturers around the world have taken great strides toward achieving well-balanced sustainability. While many industrialized countries strive to improve their environmental and social performance, there are other countries in which this is still not the case. India is an example of a country still grappling with significant development challenges, yet one in which the cement industry is highly efficient and is marked by many sustainable characteristics. Other developing countries should learn the lessons of the industrialized world and look to India as a model.

Even in the United State, Europe, and other countries with decades of government involvement in environmental improvement, the old command-and-control systems still dominate many facets of regulation. Further shifts in policy are necessary to support the holistic approach to controls that characterized an enlightened sustainability approach.

In addition, more research could further improve the sustainability of the cement industry. These efforts should include research into how to improve the manufacturing process and how to develop building and pavements that enhance user energy efficiency.

Finally, more the world needs to learn more about the effective use of cement and concrete to make stronger, more durable, more energy efficient structures. While such education can come from research into new techniques, simply spreading readily available knowledge could create great energy savings and therefore emission reductions. Greater and smarter use of concrete can offset the impact of cement manufacturing and help create a cleaner, safer, healthier planet--the ultimate objective of sustainability.

6. CONCLUSIONS

In many countries the cement industry has embraced the environmental, social, and economic facets of sustainability through formal mechanisms such as the World Business Council for Sustainable Development's Cement Sustainability Initiative and the Portland Cement Association's Cement Manufacturing Sustainability program. At the association, corporate, and facility level, cement

companies have taken less formal measures simply as good environmental stewards and community members. Motivations aside, the industry has dramatically improved its environmental performance, safety record, stakeholder involvement, and other metrics that comprise the broad measure of sustainability. As this approach spreads further and as cement and concrete are more widely used, the industry will continue to make the world a better place.

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