CLIMATE POLICY INITIATIVE

Cap and Trade in Practice: Barriers and Opportunities for Industrial Emissions Reductions in California

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About CPI

Climate Policy Initiative is a team of analysts and advisors that works to improve the most important energy and land use policies around the world, with a particular focus on finance. An independent organization supported in part by a grant from the Open Society Foundations, CPI works in places that provide the most potential for policy impact including Brazil, China, Europe, India, Indonesia, and the United States.

Our work helps nations grow while addressing increasingly scarce resources and climate risk. This is a complex challenge in which policy plays a crucial role.

Executive Summary

California is both one of the largest economies and one of the largest emitters globally, making its climate change policies some of the most important in the world. They are also some of the most ambitious. In particular, California's Global Warming Solutions Act of 2006 (AB32) set a series of policies and programs across all major business sectors to return California emissions to 1990 levels by 2020. A key component of this set of policies is the Cap and Trade Program, which caps greenhouse gas (GHG) emissions from key business sectors in California. The Cap and Trade Program both acts as a backstop to ensure that AB32's GHG reduction targets are met and drives the lowest-cost emissions abatement solutions across economic sectors through its trading and offset mechanisms.

With the Cap and Trade Program in its second year of full operation, we have the opportunity to see how firms make business decisions in the presence of a carbon price — whether abatement options that have been identified as technically feasible prove to be attractive in practice, or whether barriers prevent firms from pursuing otherwise cost-effective abatement options.

This working paper examines how abatement decisions under the Cap and Trade Program work in practice in one industry. Through financial modeling and stakeholder interviews, we look at how the carbon price affects business decisions to invest in energy savings and emissions abatement in the cement industry — a major emitter covered under the Cap and Trade Program. In particular, our work aims to:

1. Provide policymakers in California, other U.S. states, and other jurisdictions a window into how U.S. industrial firms make compliance decisions under a carbon pricing system in the context of broader business practices
2. Identify barriers to cost-effective abatement by industrial firms under carbon pricing policies, and policy levers that could address those barriers

We explore these questions by modeling a set of representative abatement options under a range of carbon prices. Based on interviews with industry experts, we also consider additional decision factors not included in the model, such as customer priorities and risk perception.

We find that the carbon price signal is making a difference in how firms approach abatement decisions. Our modeling indicates that introducing a carbon price brings some abatement options within firms' investment criteria, and a high carbon price makes more abatement options financially attractive (see Figure ES1). Industry stakeholders confirm that firms are currently factoring an expected carbon price into their investment decisions, and the introduction of the Cap and Trade Program has driven more interest in abatement strategies. However, the impact of the carbon price on a decision to abate emissions also depends on a range of other factors specific to each abatement option. In most cases, the carbon price is not the most important factor in making an abatement decision financially attractive.

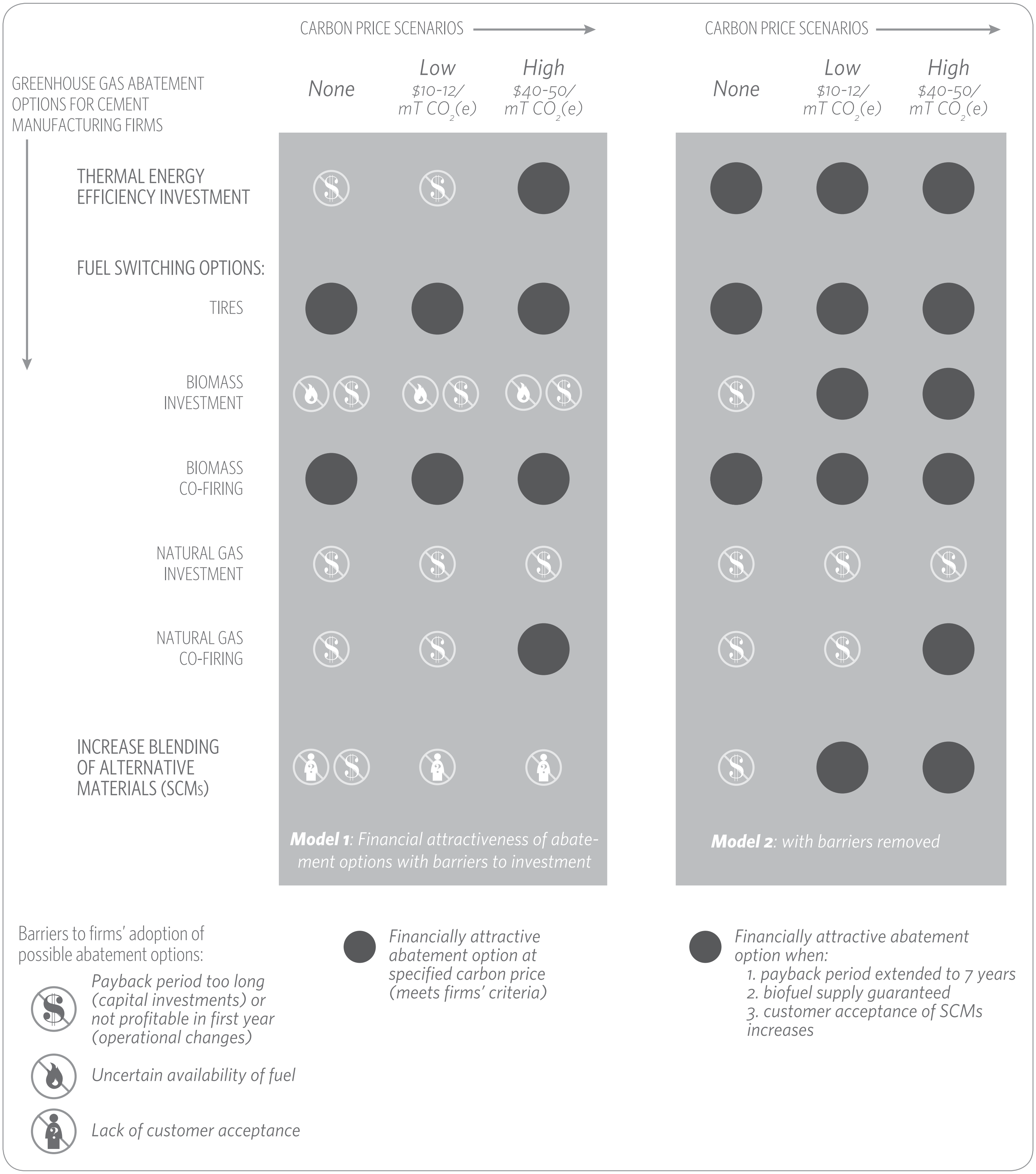
Three barriers to otherwise cost-effective abatement options stand out for the cement industry and may also prove important for other industries:

Firms have short payback period criteria and capital constraints for investments. Internal constraints on and criteria for capital investment emerged as a key barrier to cost-effective abatement investments. Typically, firms only invest in projects with very short payback periods (1.5-3 years, according to CPI interviews). This conservative cutoff for investment means that firms are unlikely to invest in projects that take longer to pay back, even if projects are very profitable over the lifetime of the investment. The impact of the recession has further exacerbated conservative payback period criteria, because abatement projects face tight competition from other capital projects considered by a cement firm. Our modeling suggests that if firms' maximum payback periods were longer, more investments would appear financially attractive under both low and high carbon prices.

Firms require more predictability and availability of alternative fuels. Some promising abatement options involve switching to lower-carbon fuels that are not yet widely used in California; firms require more certainty about future fuel availability and prices before making major investments.

Customer purchasing practices and practices of other actors along the value chain make it difficult for firms to engage in abatement activities. Prescriptive standards and entrenched customer purchasing practices make it difficult for firms to blend more alternative materials (supplementary cementitious materials, or "SCMs") into

Figure ES1: Financial Attractiveness of Abatement Options Based on Firms' Investment Criteria



cement — an otherwise attractive option for emissions abatement at the cement plant. A firm's ability to change blending rates also depends on its control over the concrete manufacturing facilities where blending of SCMs often occurs.

The impact of these three barriers on firms' abatement decisions is illustrated across a range of carbon prices in Figure ES1. The scenarios on the left show the abatement options (shaded in dark gray) that appear to meet firms' stated criteria for pursuing investments or operational changes. For the abatement options that do not meet those criteria (unshaded), the table lists the key barriers that stand in the way.

The right-side scenarios in Figure ES1 show how investment decisions would likely change if the barriers identified earlier were removed. Specifically, the figure illustrates which abatement options would meet firms' criteria if:

- Firms lengthen their payback period cutoff to seven years from the initial investment.
- Firms are confident that biofuel supplies are reliable and predictable.
- Customer purchasing practices become flexible enough to enable firms to determine SCM rates that meet customer performance needs (corresponding to cement containing 15% SCMs).

Policy uncertainty has also played a role in industry decisions during the first year of the California Cap and Trade Program. Regulators continued to clarify and modify aspects of the program throughout its first year, and the industry has focused attention on ensuring favorable treatment under the program — in particular, securing freely allocated allowances to cover its compliance obligations.

Policy Implications

The U.S. cement industry and its decision-making processes were created in a non-carbon-constrained world, and those processes are still in place today. California's carbon price is an important component of investment decisions by the cement industry, and it makes emissions-reducing investments more attractive to firms. However, the Cap and Trade Program alone — at least with the range of carbon prices likely to emerge in California — will not remove the remaining barriers to further lower the cost of abatement and ultimately, the cost of a transition to a low-carbon industry. Policy measures in addition to the carbon price and California's current suite of climate-focused policies can help address some of the internal and external barriers identified here and unlock low-cost emissions reductions in the cement industry, including:

- Financial support for capital investments that yield large emissions reductions and are cost-effective over the long term but take longer to pay back
- Policy supports to improve availability, reliability, and price certainty for alternative fuels, such as public investment or guarantees
- Government initiatives to increase blending of alternative materials where safe and appropriate, such as changes in purchasing practices by Caltrans and other large customers , customer education programs, initiatives to influence standard-setting processes, and collaborative research efforts between government and industry

California's Cap and Trade Program is expected to successfully reduce emissions to the level of the cap, and California firms are expected to comply with the program. But California — and other governments using or developing carbon-pricing policies — can achieve the cap at even lower costs if it harnesses additional policy tools that break down barriers to otherwise cost-effective emissions reductions.

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1. Introduction

What works in theory sometimes needs a little help to work in practice. Analysis based in economic theory typically points to carbon pricing policies as the most cost-effective way to achieve economy-wide greenhouse gas emissions reductions. Examining business decisions under a real-world carbon pricing system offers valuable insights into how to fine-tune the system for efficiency and where complementary policies may be necessary to overcome non-price market barriers and achieve emissions reduction goals at least cost.

Under California's Cap and Trade Program, barriers to abatement in one sector do not jeopardize the state's overall environmental goals. As long as the cap is enforced, the state will achieve its emissions reduction target. But the program can be most cost-effective if firms in each sector are able and willing to undertake low-cost and cost-saving emissions reductions. If cost-effective emissions reductions in one sector prove to be unattainable, emissions reductions in other sectors must make up the difference, raising the overall cost of abatement.

California has long been a leader in environmental policy innovation for the United States. Its new Cap and Trade Program provides other states and federal policymakers a window into how industrial firms make decisions under a carbon pricing system — both how carbon prices affect investment decisions and where other factors prove stronger decision drivers. We focus here on the cement industry under California's Cap and Trade Program, using financial modeling as an anchor to ask the following questions:

- Do the abatement options commonly discussed as options for the cement industry meet firms' internal criteria for making investments under carbon pricing?
- How large a role does the carbon price play in driving abatement decisions, relative to other factors such as energy prices and non-price barriers?
- How do a firm's organizational structure and customer practices influence the impact of carbon prices on abatement decisions?

We present this working paper to begin to identify the factors that impact efficient abatement decisions under a carbon price. Our intention is to stimulate discussion of how additional policy levers outside the realm of carbon pricing policy can be brought to bear to achieve economy-wide emissions reductions at lower cost.

Section 2 of the paper provides background on the Cap and Trade Program and on the California cement industry. Section 3 describes our approach to analysis, and Section 4 presents our findings. In Section 5, we discuss some of the key barriers to low-cost abatement and the implications for policy beyond carbon pricing.

Why cement?

The cement industry is the largest greenhouse gas emitter in the industrial sector, both in California and nationally (California Air Resources Board 2013a; U.S. Environmental Protection Agency 2013). California's cement industry represents 2% of emissions covered under the Cap and Trade Program (California Air Resources Board 2013a).

Although the cement industry is a small emitter in comparison to the power sector and the oil and gas industry, the industry provides a valuable window into business decisions under a cap-and-trade system. Power and oil and gas are subject to several concurrent layers of significant and new climate-mitigating policies, including the Renewable Energy Standard and Low Carbon Fuel Standard. By contrast, the Cap and Trade Program is the primary climate-mitigating policy that affects cement manufacturers and other industrial firms in California.

In addition, cement is a commodity with a fairly uniform production process. Products and manufacturing processes differ somewhat less from plant to plant, relatively speaking, than they do in other California industries, allowing us to look beyond product difference in detecting factors that affect firm-level compliance decisions.

2. Background

Cap and Trade Program

California's Cap and Trade Program — the United States' first economy-wide cap-and-trade system — is now in its second year of full implementation. The first years of the Cap and Trade Program provide an opportunity for policymakers to get a clearer picture of how covered firms are engaging with the program. Empirical evidence and analysis of firms' experience can help California policy-makers identify where compliance decisions differ from pre-implementation expectations, identify barriers to cost-effective compliance, and then adapt future program design to reduce costs and improve the performance of the program.

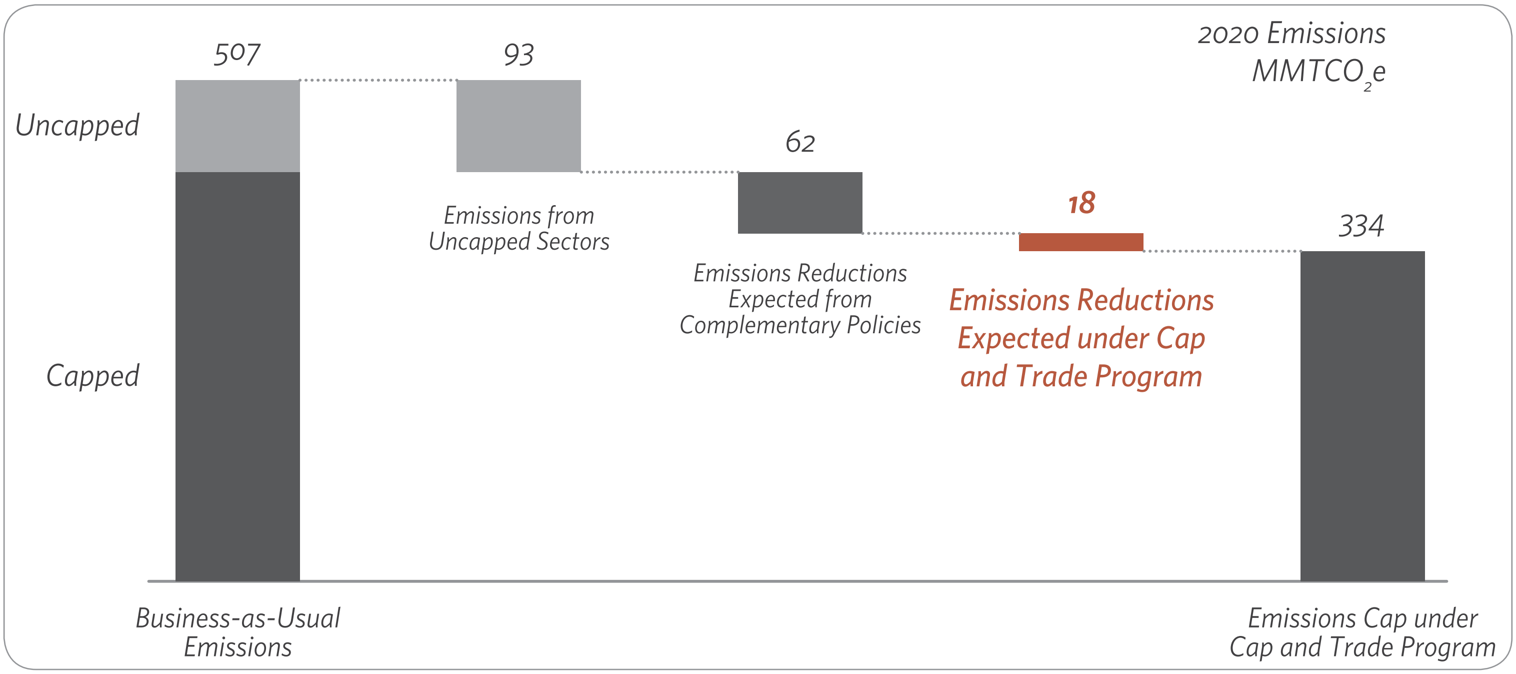
California's Global Warming Solutions Act of 2006 (hereafter, "AB32") established the California Cap and Trade Program as a key component of a broad suite of programs to achieve statewide greenhouse gas (GHG) emissions reductions to 1990 levels by 2020. Once the program is in full effect, the covered sectors will represent roughly 85% of California's GHG emissions. The Cap and Trade Program acts as a backstop to the suite of other sector-specific "complementary policies" under AB32, ensuring that California achieves its emissions-reduction targets through the most cost-effective means possible (California Air Resources Board 2006: 1; Climate Policy Initiative 2013). The resulting carbon prices are expected to drive approximately 20% of the reductions required in covered sectors to achieve AB32's statewide 2020 goals (California Air Resources Board 2010a: 54).

Figure 1 shows the expected contributions from the Cap and Trade Program and complementary policies toward meeting the state's overall emissions reduction target. Table 2 lists key dates in the development and implementation of the program.

The Cap and Trade Program is divided into three compliance periods between 2013 and 2020, with allowances from all covered entities due at the end of each compliance period. The first compliance period covers the power and industrial sectors, including cement production, starting in 2013. The second compliance period begins in 2015 and expands the list of regulated entities to include natural gas and transportation fuel suppliers.

Covered firms must submit one allowance for each metric ton of carbon dioxide equivalent ($MTCO_2e$) emitted. Firms have two basic compliance options when their emissions are greater than the number of allowances they have: they can abate (reduce) emissions, or they can buy

Figure 1: Meeting the 2020 Emissions Cap (Sources: California Air Resources Board 2011a; California Air Resources Board 2013b; Environmental Defense Fund 2014)



allowances or offsets to cover their emissions. The California Air Resources Board (CARB) allocates free allowances industry-by-industry according to leakage risk and transition assistance needs as the program gets underway (California Air Resources Board 2011b: 1, 8, 16–17). Firms can acquire allowances at quarterly auctions administered by CARB, or purchase them via commodities exchanges. CARB will decrease the total volume of allowances in the system by approximately 2% each year during the first compliance period and approximately 3% each year thereafter to tighten the cap and ensure emissions statewide continue to decline (Title 17, California Code of Regulations, §95841).

CARB set the price floor (minimum price) for Vintage 2013 allowances at $10 per $MTCO_2e$ emissions at the first auction in November 2012. To help protect businesses against potential market volatility, CARB also holds a fraction of all allowances in three equal-sized reserve tiers at fixed prices, and these reserve allowances cannot be resold. Each year, both the price floor and the reserve tier prices for carbon allowances rise by 5% plus inflation (Title 17, California Code of Regulations, §95911(c)(3)(A) and §95913(e)(4)).

Between the first allowance auction and the end of 2013, prices for Vintage 2013 allowance futures fluctuated between $11.55 and $16.40 (data available from Climate Policy Initiative 2013). As of early April 2014, Vintage 2014 allowance futures were trading at approximately $12 — roughly 6% above the price floor. Both supply and demand for allowances will expand significantly in 2015 when transportation fuels come under the cap.

A team of economists under contract to CARB has projected that the carbon price is likely to remain very close to the price floor between now and 2020 (Bailey et al. 2013). Based on modeling across a range of assumptions, the economists estimate that there is an 80% chance that the carbon price will be at or near the price floor in 2020, a 1% chance it will be in between the price floor and the reserve price tiers, and a 19% chance it will be at or above the reserve price tiers. CARB has adopted a resolution to keep the carbon price at or under the highest reserve price tier, and it is currently developing a cost containment mechanism to accomplish that goal (California Air Resources Board 2013c).

Table 1: Key Dates in Cap and Trade Program Implementation

DATE	EVENT
September 27, 2006	Assembly Bill 32 (AB32), California Global Warming Solutions Act, signed into law
June 30, 2007	CARB adopts discrete early action greenhouse gas reduction measures — precursors to the "complementary policies"
December 6, 2007	CARB sets 2020 target at 427 $MMTCO_2e$ (subsequently updated to 431 $MMTCO_2e$ due to a technical adjustment) CARB adopts regulation mandating reporting of GHG emissions from large emitters
December 11, 2008	CARB approves AB32 Scoping Plan, which lays out the state's primary strategies to achieve its emissions reduction target, including the Cap and Trade Program
October 20, 2011	CARB adopts Cap and Trade regulation as a key provision within AB32
November 14, 2012	First auction of Cap and Trade allowances
January 1, 2013 – December 31, 2014	First compliance period: Electricity generating facilities and importers and large industrial facilities covered by Cap and Trade Program
January 1, 2014	Linkage with Quebec begins
January 1, 2015 – December 31, 2017	Second compliance period: Upstream fuel distributors covered by Cap and Trade Program
January 1, 2018 – December 31, 2020	Third compliance period
December 31, 2020	Deadline for achieving 2020 GHG emissions cap

(Sources: California Air Resources Board 2014a; Environmental Defense Fund 2014; California Air Resources Board 2014b: 28)

See the California Carbon Dashboard (www.calcarbondash.org) for further details on the California Cap and Trade Program as well as up-to-date CARB documents and information.

California Cement Industry

Overview

The California cement industry emitted 6.9 million metric tons of CO_2e ($MMTCO_2e$) in 2012 — representing 2% of all covered emissions, and 6.4% of covered emissions excluding fuel suppliers (see Figure 2). It is the largest GHG emitter by industry after the power sector and the petroleum and natural gas industry.

The Cap and Trade Program covers nine cement manufacturing facilities owned by six companies, including all of the cement plants currently operating in California (California Air Resources Board 2013a). The cement plants currently operating in California, with information on their parent companies, are listed in Table 2.

The cement manufacturing process is relatively straightforward: (1) Limestone is mined from a quarry and is then (2) crushed and ground-up along with other raw materials, such as clay and shale. (3) This mixture then passes through a preheater system and a long, horizontal rotary kiln where it is super-heated to form clinker. During this process, limestone ($CaCO_3$) decomposes (a process known as "calcination"), releasing carbon dioxide (CO_2). (4) The clinker is then rapidly cooled and put into a (5) finish grinder with other additives to form cement powder, before (6) being moved to a silo for storage until shipment (U.S. Environmental Protection Agency 1995; KEMA Inc. and Lawrence Berkeley National Laboratory 2005). Most cement is shipped to ready-mix concrete plants, where it is combined with aggregates and other materials to form concrete, or to producers of other materials such as cement blocks and pavers.

Cement manufacturing has three primary emissions sources, illustrated in Figure 3: limestone calcination (~55% of emissions), fuel combustion (~40% of emissions), and electricity use (~5% of emissions) (Global Network for Climate Solutions: 1; Worrell and Galitsky 2008: 14; European Cement Research Academy and Cement Sustainability Initiative 2009). Typically, cement plants meet the majority of their electricity needs with electricity from the grid. Under the Cap and Trade Program, cement firms are only responsible for emissions due to electricity generation if the electricity is generated on-site. Emissions from off-site electricity generation are the responsibility of the respective generator.

Primary Abatement Options

Analysis of abatement potential in the cement industry generally points to three main categories of abatement options for the cement industry (see e.g., KEMA Inc. and Lawrence Berkeley National Laboratory 2005; Worrell and Galitsky 2008; International Energy Agency and World Business Council for Sustainable Development 2009; Olsen et al. 2010; Sathaye et al. 2010).

- *Energy efficiency improvements* to reduce the amount of fuel combustion and/or electricity required to manufacture cement
- *Fuel switching* to decrease the combustion of high-carbon fuels such as coal and petroleum coke

Table 2: California Cement Companies and Manufacturing Plants Covered Under AB32

COMPANY (LOCATION OF HEADQUARTERS)	PARENT COMPANY (LOCATION OF HEADQUARTERS)	PARENT COMPANY [EXCHANGE]: [TICKER]	FACILITY LOCATION	AB32 COVERED EMISSIONS IN 2012 ($MTCO_2E$)
CalPortland (California)	Taiheiyo Cement Corp. (Japan)	TYO: 5233	Colton, CA	137
			Mojave, CA	1,108,248
Cemex (Mexico)	Cemex (Mexico)	NYSE: CX BMV: CEMEX	Apple Valley, CA	1,557,437
Lehigh Hanson (Texas)	HeidelbergCement Group (Germany)	FWB: HEI	Cupertino, CA	914,330
			Redding, CA	229,339
			Tehachapi, CA	543,614
Mitsubishi Cement (Nevada)	Mitsubishi Materials Corp. (Japan)	TYO: 5711	Lucerne Valley, CA	1,066,652
National Cement (California)	Vicat SA (France)	Euronext: VCT	Lebec, CA	463,345
TXI (Texas)	TXI (Texas)	NYSE: TXI	Oro Grande, CA	1,032,735

(Source for emissions data: California Air Resources Board 2013a)

Figure 2: Industry's Share of Statewide Emissions in 2011 (Source: California Air Resources Board 2013d)

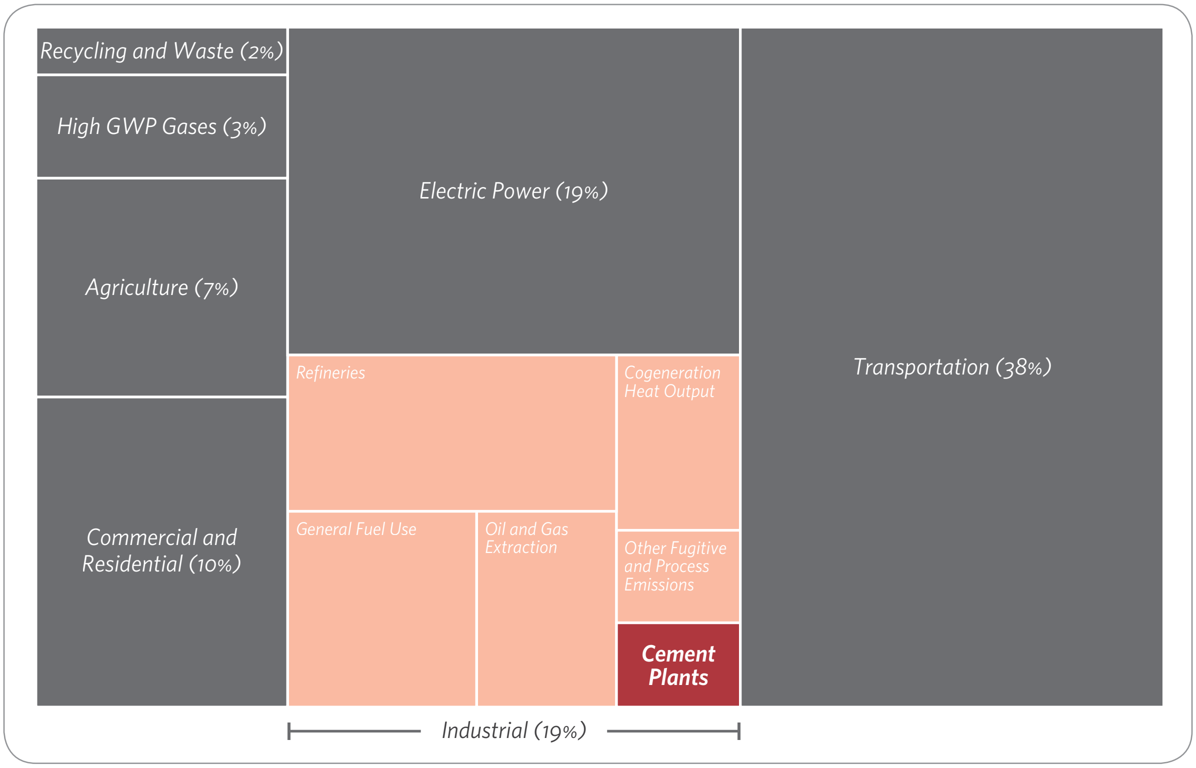
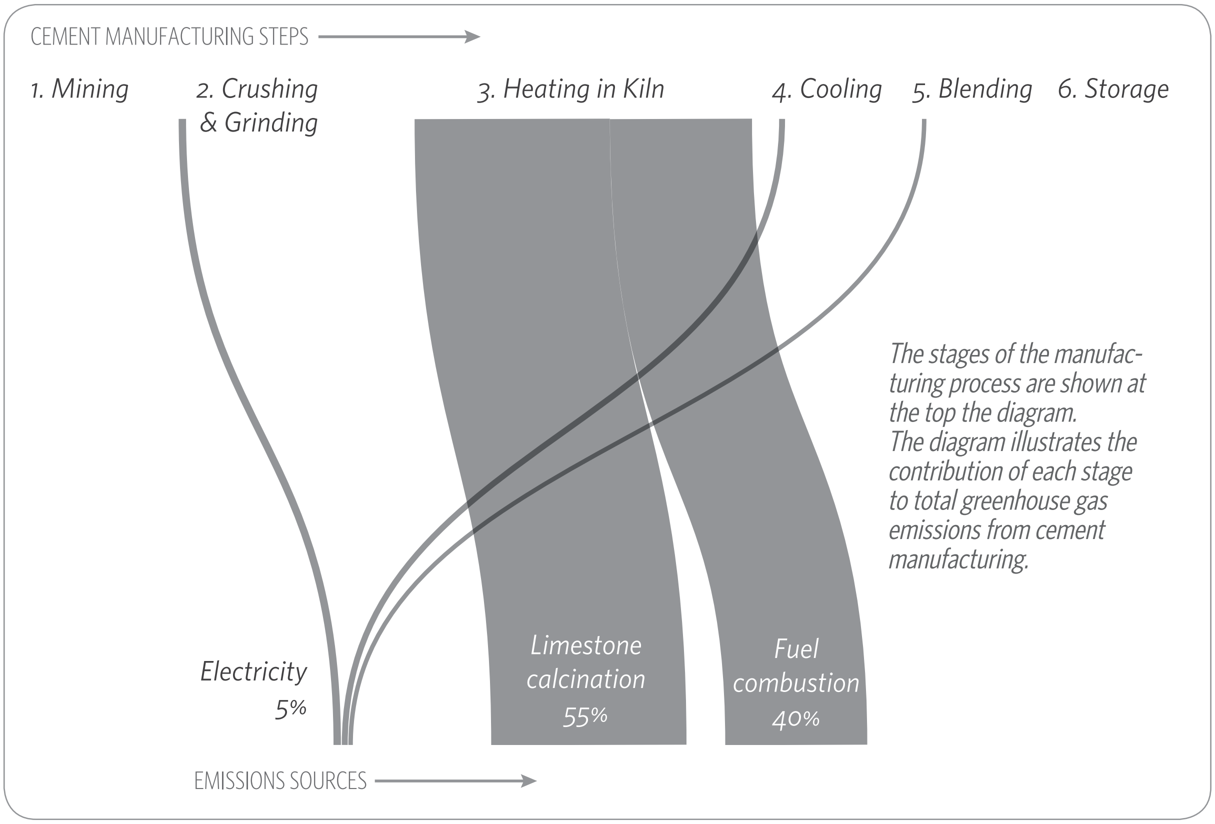


Figure 3: Cement Manufacturing Process and Emissions Sources



(Data sources: Global Network for Climate Solutions: 1; Worrell and Galitsky 2008: 14; European Cement Research Academy and Cement Sustainability Initiative 2009)

- *SCM blending:* Increased blending of supplementary cementitious materials (SCMs) to reduce the proportion of clinker in the finished product (clinker production in the kiln accounts for the majority of both process and combustion emissions)

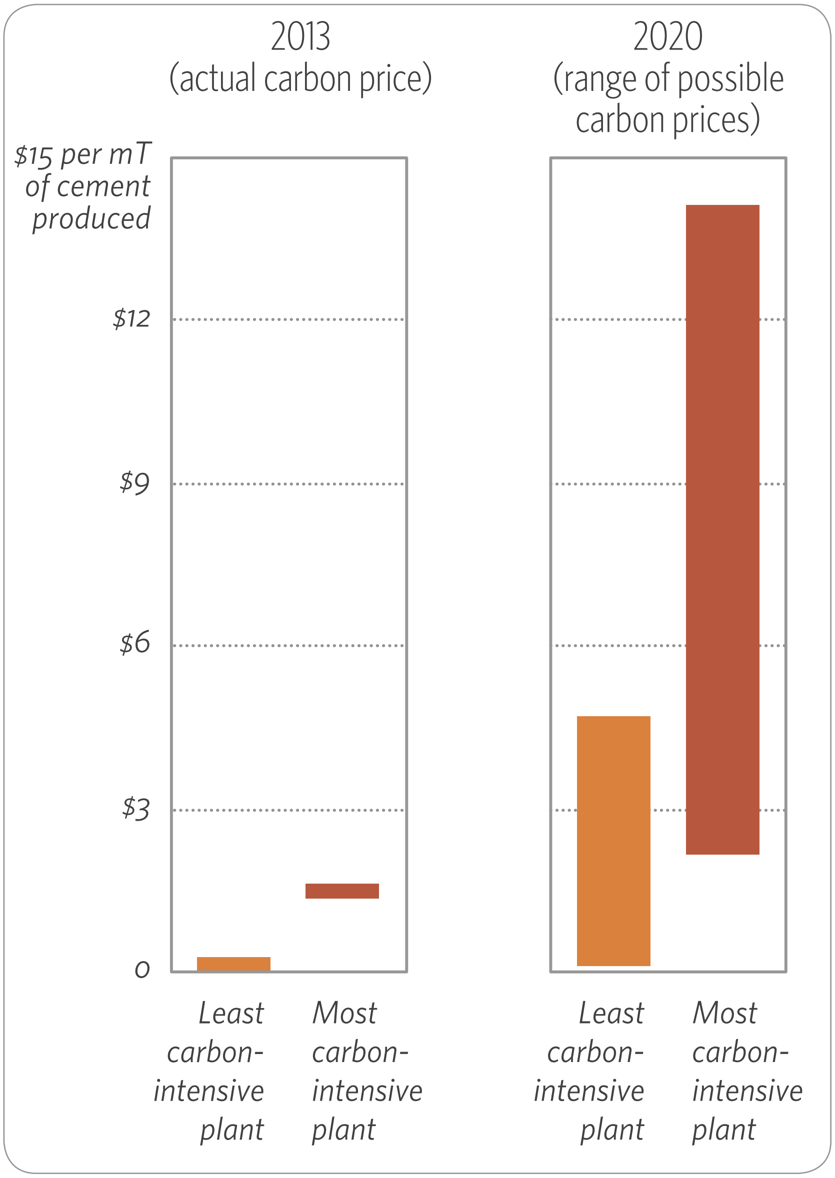
Industry stakeholders said in interviews that they are already considering some of these options. As the cement industry's proportion of freely allocated allowances decreases over time and the price of allowances rises, emissions abatement may become an increasingly important component of cement facility compliance strategies.

Allowance Allocation

The cement industry will initially receive freely allocated allowances that will nearly cover its emissions, due to the risk of emissions leakage. Emissions leakage — i.e., production moving out of state, where emissions are not regulated by Cap and Trade — has figured prominently in the cement industry's engagement with the Cap and Trade Program. CARB considers the cement industry to be at high risk of emissions leakage under the Cap and Trade Program, due to its high energy intensity and the presence of competition from imported cement (California Air Resources Board 2010b). Although free allocations will decrease over time as the cap declines, cement firms will continue to receive freely allocated allowances to cover a majority of their emissions through 2020 (Title 17, California Code of Regulations, §95891, Table 9-2).

Under the Cap and Trade Program, cement firms receive freely allocated allowances in proportion to their production. The allocation is benchmarked to the least carbon-intensive plant; for 2013, each plant receives 0.786 allowances for each metric ton of cement produced. Plants that are more carbon-intensive must reduce emissions or purchase allowances to make up the difference. In addition, the overall allocation of allowances declines each year as the overall emissions cap declines. CARB has released data on carbon intensity across California's cement plants, although the plants are not identified individually (California Air Resources Board 2011b).

Figure 4: Compliance costs will vary based on carbon intensity and carbon prices



This figure compares the estimated compliance costs between the least carbon-intensive and most carbon-intensive cement plants, if all plants' emissions remained at 2012 levels. Dollar figures are per metric ton of cement produced. Actual production at California's cement plants ranges between approximately 200,000 and 1.5 million metric tons of cement (estimated based on emissions data).

(Sources: California Air Resources Board 2011b; California Air Resources Board 2013a; Title 17, California Code of Regulations, §95891, Table 9-2)

Even though the cement industry is receiving freely allocated allowances to cover most of its emissions, cement firms will still have to reduce emissions or purchase allowances to cover the remainder. This remaining compliance cost will grow year by year as the cap tightens. We can estimate the range of compliance costs for cement plants covered by Cap and Trade by multiplying the portion of a plant's emissions that are not covered by freely allocated allowances by the carbon price. Figure 4 shows the range of estimated compliance costs that the most and least carbon-intensive plants would face in 2013 and in 2020, based on 2012 emissions levels.

Industry Engagement in Cap and Trade Development

The California cement industry has been an active participant throughout CARB's development and deployment of AB32's Cap and Trade Program. In public commentary and feedback to CARB via the Coalition for Sustainable Cement Manufacturing and Environment (CSCME), California cement manufacturers have expressed significant concerns related to emissions leakage. Manufactures have reiterated throughout both written CARB commentary and in stakeholder interviews that they already face higher environmental compliance costs, labor costs, and fuel costs in California than their out-of-state competitors (Coalition for Sustainable Cement Manufacturing & Environment 2009a: 2). They have also stated that, as an extremely energy-intensive industry, they had already made significant efforts to make their manufacturing process as energy-efficient as possible prior to AB32 (Coalition for Sustainable Cement Manufacturing & Environment 2010: 2). CSCME expressed concern that without significant action to address leakage, the Cap and Trade Program would make California's firms less competitive and could prompt an increase in cement imports from China, leading to a net increase in GHG emissions as a result of increased transportation emissions (Coalition for Sustainable Cement Manufacturing & Environment 2009b: 3).

To address leakage concerns, the cement industry advocated for several remediative approaches throughout the development of the Cap and Trade Program. CARB took into account expected leakage risk for trade-exposed and/or highly energy-intensive industries in its free allocation of allowances to industry. The cement industry continues to advocate for a "border adjustment" that would apply an equal carbon price to cement imported from outside California, and CARB recently proposed adding such an adjustment (California Air Resources Board 2014c).

Cement Industry Experience under the European Union Emissions Trading System

The European cement industry has been covered by the European Union Emissions Trading System (EU ETS) since 2005. While the European industry structure and market do differ somewhat from the U.S. cement industry, the experience of cement firms and other industrial firms under the EU ETS offers some useful insights for California.

Industry's experience under the EU ETS indicates that the free allocation of allowances has an impact on the approach some firms take to the allowance market. In theory, business decisions about abatement under a cap-and-trade system should not depend on the method for allocating allowances — the impact of the carbon price should be the same whether firms are reducing emissions in order to avoid buying allowances or in order to sell excess allowances. However, some research suggests that refineries and other industrial firms in the EU tended to engage with the market for the purpose of achieving compliance, rather than maximizing profit (Lacombe 2008; Hervé-Mignucci 2011). When firms received freely allocated allowances to cover most of their emissions, some focused their efforts on covering the remaining emissions, rather than looking at their emissions and compliance obligations as a whole. It is possible that similar dynamics could emerge in California.

A recent study of cement firms under the EU ETS found that cement firms initially turned management attention to emissions reduction opportunities, but that attention waned as the carbon price declined and as policymakers continued to revise the system (Climate Strategies 2014). The study concluded that the carbon price alone is unlikely to drive further mitigation in the EU cement industry, and other policy levers — such as lowering regulatory barriers to burning alternative fuels at cement plants, or adapting building codes and standards to allow more blended cement — would have a greater impact.

3. Approach

We modeled abatement options across a range of carbon prices to explore decisions we would expect from a typical California cement manufacturing facility. Our model and findings are based on literature review and stakeholder interviews.

We present a simplified but realistic vision of the investment choices that cement companies make as they consider their primary GHG abatement options. Our goal is to understand how the introduction of a carbon price affects the attractiveness of particular abatement investments, particularly in conjunction with changing energy prices and other variables.

We used these preliminary findings in order to identify areas where modeling says that abatement investments make financial sense for cement manufacturers under the Cap and Trade Program. Through interviews with industry stakeholders, we gathered additional information on non-financial factors that influence cement companies' abatement decisions, such as regulatory considerations and internal firm priorities.

To examine the relevance of a carbon price to the attractiveness of particular abatement investments, we modeled each investment across four carbon price scenarios to reflect a range of possible future prices (See Figure 5 for carbon price scenarios and Table 3 for key model parameters). Our model plant is an average California cement plant — i.e., the assumed fuel mixtures used, useful lives of investments, upfront costs of investments, thermal efficiency improvements, typical SCM blending rates, and anticipated GHG reductions associated with abatement actions are based on statewide averages rather than the characteristics of any one particular facility or company. We also assumed standard rates of corporate taxation, cost of capital, and accelerated depreciation schedules based on IRS guidance. Our analysis assumes that the Cap and Trade Program will be extended beyond 2020, as there appears to be consensus among key stakeholders that this is likely to occur.

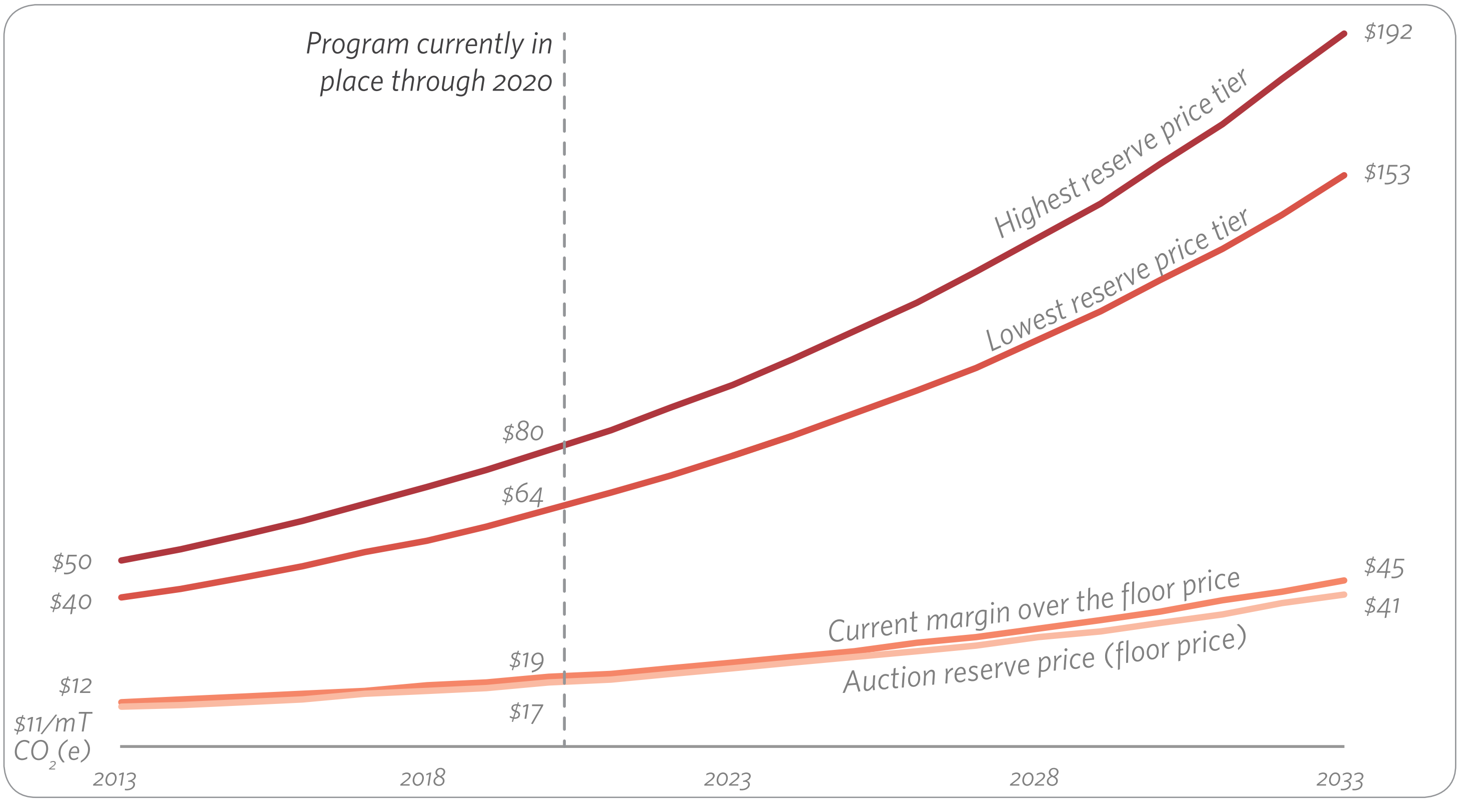
Table 3: Key model parameters

PARAMETER	USED IN MODEL
Annual production	923,000 metric tons cement
Baseline carbon intensity	1 ton CO_2e/ton cement
Baseline fuel mix	70% coal 30% petroleum coke
Year abatement decision is implemented	2013
Useful lifetime of investments	20 years
Accelerated depreciation	15 years
Cost of capital	15%
Income tax rate	30%
Energy prices	Energy Information Administration projections (Annual Energy Outlook 2013)
Carbon prices	See Figure 5

Cement companies have indicated that they only consider projects with a maximum payback period of less than three years, with some examples citing a target payback period as short as one year (Coito et al. 2005; KEMA Inc. 2012: 69). There are arguments both for and against this approach to project selection. The useful life of a capital investment is typically much longer than three years, and a project with a payback period longer than three years may have a greater net present value than a shorter-payback project. However, looking over a longer time horizon requires the firm to make more projections of future market conditions and commodity prices; a firm may decide that the additional upfront cost of this analysis is not worth it, or that it is not willing to take on the risk associated with future price uncertainty. In our modeling, we looked at the investment's net present value over its full estimated 20-year lifetime, but we assumed firms would only choose to pursue projects with a payback period of less than three years, given current practices.

The model described in this section can be downloaded at www.climatepolicyinitiative.org.

Figure 5: Modeled Carbon Price Scenarios



These four scenarios cover the range of carbon prices consistent with the Cap and Trade Program regulations. In our model, the lowest scenario is the auction reserve price (price floor), which started at $10 in 2012 and increases by 5% plus inflation each year. The "current margin over the floor price" is set for 2013 at the market price for Vintage 2013 futures observed at the end of 2013, and grows at the same rate as the floor price. The two high price scenarios represent the lowest and highest of the three reserve price tiers, which begin at $40 and $50 in 2013 and grow by 5% plus inflation.

4. Findings

Our modeling and stakeholder interviews indicate that there are some technically feasible abatement options with positive economic impact available to cement firms, especially if carbon prices are high. However, other factors may prevent firms from pursuing these strategies, even if they appear cost-effective over the lifetime of the investment. In addition, the importance of the carbon price in the investment's profitability varies across the different abatement options.

- *Energy Efficiency:* By introducing a carbon price, the Cap and Trade Program makes already-profitable investments in energy efficiency more financially attractive. However, firms' internal priorities and short required payback periods for investment will continue to limit investment in efficiency if carbon prices remain low. Higher carbon prices might be able to overcome some of these barriers.
- *Fuel Switching:* Incorporating more lower-carbon fuels such as tires and biomass into plants' existing processes appears to be an attractive abatement option to firms. However, the feasibility of fuel switching depends on the location and technical requirements of the plant. An investment in switching to biomass appears highly profitable over the long term, but firms' short investment horizon and their uncertainty about future supply of alternative fuels pose barriers to investment in the short term.
- *SCM Blending:* The Cap and Trade Program makes blending of supplementary cementitious materials financially attractive, especially if carbon prices are high. However, blending more SCMs may not be feasible for a particular plant, depending on the end use for its products. The primary barrier to increasing SCM blending is technical specifications used by state agencies and other customers, which the carbon price alone will not address.

These abatement options are compared against firms' investment criteria in Figure 6. The figure summarizes the abatement options that appear to meet firms' stated investment criteria with no carbon price, with a low carbon price (near the price floor), or with a high carbon price (at an allowance reserve price). It then illustrates which abatement options meet firms' criteria given the absence of barriers that are currently relevant in firms' decisions about these options. We describe each abatement option in more detail in the following sections.

Investment in Energy Efficiency

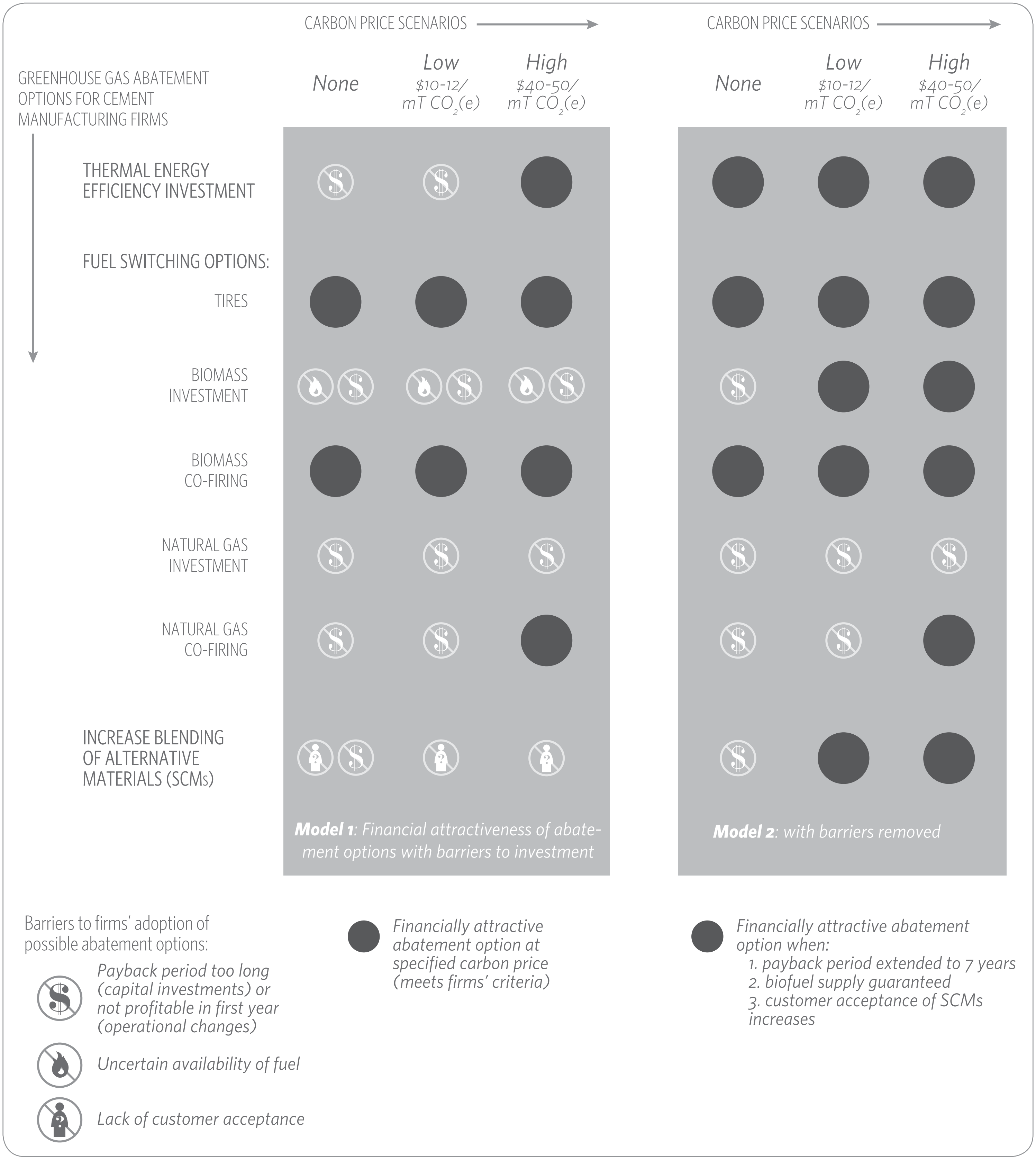
By introducing a carbon price, the Cap and Trade Program makes already-profitable investments in energy efficiency more financially attractive. However, firms' internal priorities and short required payback periods for investment will continue to limit investment in efficiency if carbon prices remain low. Higher carbon prices might be able to overcome some of these barriers.

Background

Energy efficiency improvements at cement plants target fuel combustion in the kiln (thermal efficiency improvements) or the electricity that powers other components of the cement manufacturing process (electric efficiency improvements). Our analysis focuses on thermal efficiency improvements, because improving thermal efficiency directly lowers plant obligations under the Cap and Trade Program by reducing fuel use and associated GHG emissions.

We do not model here the impact of the carbon price on electric energy efficiency improvements. Cement plants are large electricity consumers, and many plants may be able to identify cost-effective electric efficiency improvements that will reduce greenhouse gas emissions from electricity generation (Olsen et al. 2010; KEMA Inc. 2012). However, cement plants are not directly responsible for off-site electricity emissions under the Cap and Trade Program; this analysis focuses on a cement plant's direct obligations under the program. We do note that some California cement plants are developing on-site renewable energy generation capacity, which would reduce emissions from the power sector under the Cap and Trade Program. Other policy mechanisms, such as ratepayer-funded energy efficiency programs, also help drive investments in electric efficiency. California cement plants have undertaken electric efficiency improvements in the past with the help of utility rebates, and utilities will

Figure 6: Financial Attractiveness of Abatement Options



likely continue to pursue such improvements under the Cap and Trade Program.

Not all efficiency improvements involve investing in new equipment; firms can also improve both thermal and electric efficiency through changes to operations and maintenance, such as careful motor management and more frequent preventative maintenance of the kiln (Sathaye et al. 2010). These decisions still require an investment of time and internal resources to implement, but they do not incur capital costs. Global estimates suggest better maintenance and optimization of plant operations could reduce fuel use by 3-5% (Ba-Shammakh et al. 2008), although as California's plants are already more efficient than the global average, their potential savings may be smaller. California's cement plants have already been working to optimize their production processes during the last several years, in an effort to cut costs during the economic downturn; they have indicated that they will continue to pursue these types of efficiency improvements over the next few years (KEMA Inc. 2012).

All of California's cement plants have implemented thermal efficiency projects over the past 5-10 years, ranging from projects well under $1 million to a full-scale plant modernization costing $400 million (California Air Resources Board 2013e). Some firms have actively pursued efficiency investments in order to curtail spending on energy by implementing company-wide energy plans (Coppinger 2008).

CARB required all cement plants with 2009 emissions over 250,000 $MTCO_2e$ to undertake an assessment of energy efficiency opportunities at their plants. These assessments turned up relatively few current opportunities for investments that met CARB's cost-effectiveness criteria (a maximum cost of $10/$MTCO_2e$ for the purposes of the assessment) and that firms considered feasible but were not yet implementing. Cement firms reiterate in their public communications that they have implemented most of the feasible energy efficiency opportunities (Coalition for Sustainable Cement Manufacturing & Environment 2010).

CARB's analysis and our modeling are based on current technology availability and costs; however, more energy efficiency opportunities are likely to arise over time as technologies improve. Past analysis demonstrates that technology costs have declined and more options have become available over time in the cement sector, as in many others (Sathaye et al. 2010).

Pre-Implementation Expectations

California's cement firms are already considering and actively pursuing opportunities to save energy; cement firms and CARB are in agreement that there is little "low-hanging fruit" currently available without major facility changes. Even so, CARB's analyses indicate that it expects the cement industry to invest in some energy efficiency improvements under the Cap and Trade Program, including installing better-insulating refractory brick in the kiln, improving the efficiency of the clinker cooler, and improving combustion in the kiln (California Air Resources Board 2010c; California Air Resources Board 2013e).

Modeling Approach

To determine the impact of the carbon price on efficiency investment decisions, we modeled an investment of $1 million that yields a 5% (0.15 MMBtu per metric ton of cement) reduction in annual kiln fuel usage, with a 20-year useful lifetime. Our modeled project is based on data from a subset of energy efficiency projects undertaken by California cement plants over the last 5-10 years, as reported by cement firms to CARB (California Air Resources Board 2013e). We excluded data reported on full-scale plant modernizations, because it was not possible to separate out the energy efficiency improvement from other components of the project.

Findings

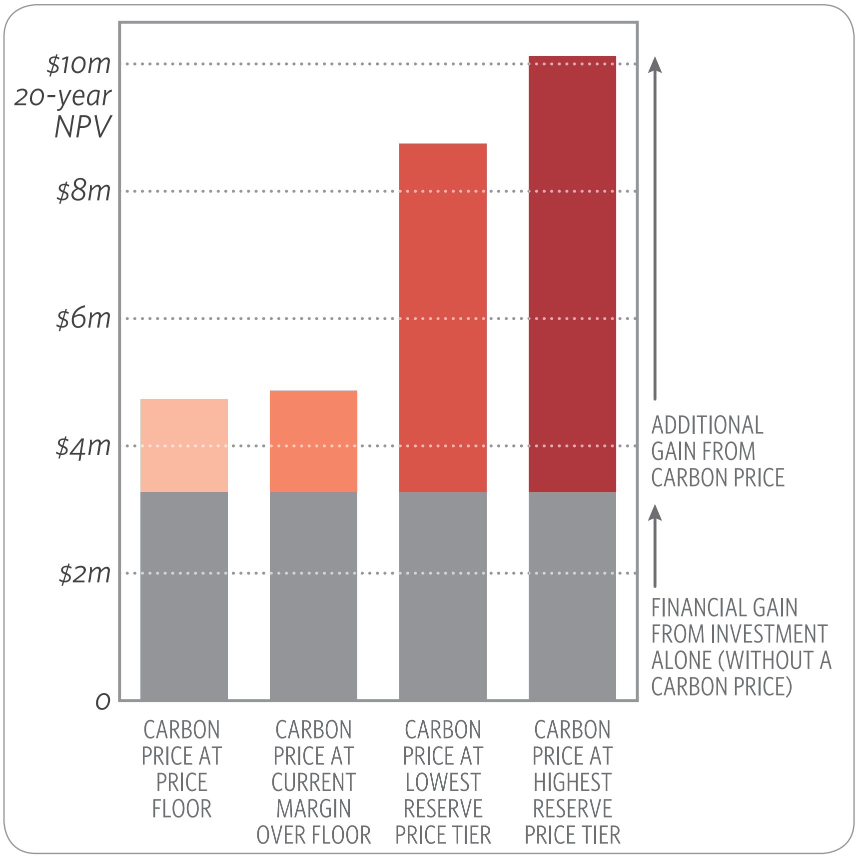
The modeled thermal efficiency improvement would be profitable at any carbon price at or above the floor, but only meets firms' internal criteria for investment at high carbon prices.

In interviews, cement industry stakeholders said their firms do consider the carbon price when making decisions about investments in efficiency: They incorporate a forecasted carbon price into their internal financial modeling. However, the carbon price is only one factor in firms' investment decisions.

Without a price on carbon, the modeled project investment is profitable with a simple payback period of five years. Cement companies have indicated that they only pursue projects with a payback period of three years or less, which implies that they would likely not pursue the modeled project without a carbon price (Coito et al. 2005; California Air Resources Board 2010c). However, cement firms did invest in the efficiency projects on which we based our model project, as well as other large facility investments reported to CARB that do not pay for themselves through energy savings — indicating that business factors other than energy cost savings may motivate firms to invest in similar efficiency projects (California Air Resources Board 2013e).

A carbon price makes the efficiency investment more attractive, but the payback period remains too long to meet cement firms' stated investment criteria if the carbon price is low. With a carbon price at the price floor ($10.71/ $MTCO_2e$ in 2013), the investment yields over $100,000 in annual carbon allowance cost savings in the first year (with greater savings in following years), in addition to approximately $400,000 in first-year fuel cost savings. To put these savings in context, the modeled plant spends approximately $8 million on kiln fuel annually before the efficiency investment is made. However, even though the carbon price improves the payback for this investment, the payback period with a carbon price at or near the price floor is four years — still longer than the payback period typically sought by cement companies. If the carbon price is instead closer to the allowance reserve price tiers ($40-50 per ton in 2013), the payback period for the thermal efficiency investment shrinks to two years, making it appear an attractive investment for cement firms.

Figure 7: Lifetime Value of Energy Efficiency Investment



This graph shows the 20-year net present value of the modeled energy efficiency investment. Gray bars show the financial gain from energy cost savings. Orange and red bars show the financial gain from the plant's ability to purchase fewer allowances, or profit from selling excess allowances, under the Cap and Trade Program. See "Approach" section for model parameters.

We would expect a firm's decisions to invest in the modeled energy efficiency project to depend more on energy cost savings at lower carbon prices and depend more on carbon cost savings at higher carbon prices. In isolation from competing business interests and other factors, we would only expect the Cap and Trade Program to change a firm's decision on an energy efficiency investment if carbon prices markedly change the financial benefits of the investment. Investments in energy efficiency yield a financial benefit without carbon prices by reducing energy costs. Figure 7 illustrates energy and carbon cost savings over the lifetime of the modeled efficiency investment. If carbon prices remain near the price floor, the total net present value of carbon cost savings would be approximately one-half the value of fuel cost savings over the lifetime of the investment. If carbon prices are high, carbon cost savings would exceed energy cost savings — implying that they might more substantially impact a decision to improve efficiency.

Other factors play a part in affecting a firm's energy efficiency decisions in the context of broader business-wide decision-making. Within each firm, efficiency projects must compete with other projects for limited capital investment funds. Cement firms are sensitive to other high-priority concerns, including capital constraints, mandatory investments to comply with other environmental regulations, and maintaining production volume. For example, firms curtailed investment in facility improvements during the economic recession, which hit the cement industry particularly hard due to its strong ties to the construction industry (KEMA Inc. 2012). In a 2005 survey, California's cement firms ranked "cost savings" last on a list of overall firm priorities; at the top, they ranked meeting production schedules and maintaining their market position (Coito et al. 2005). In addition, a large-scale overhaul of a cement plant can trigger a new environmental review, substantially increasing the cost and time required for the investment.

Policy Implications

The carbon price improves the financial picture for efficiency investments, but other policies are necessary to address other decision factors and to lower non-financial barriers to these otherwise cost-effective investments.

Pre-implementation analysis of abatement costs does not reflect other competing investment needs and the degree to which competing needs impact the viability of energy efficiency improvements that, in isolation, look attractive at some carbon prices. In the next few years of California Cap and Trade implementation, cement industry decisions will shed light on any factors preventing expected low-cost compliance decisions favoring energy efficiency. In particular, if carbon prices increase and do not prompt increased energy efficiency improvements, CARB should pay attention to the other internal business factors that might prevent the improvements. If the barrier is capital constraints for covered firms, policy levers in addition to the Cap and Trade Program — for example, supporting abatement projects through a green bank or other public financing mechanism — could potentially help lower this barrier and enable cost-effective efficiency investments.

Fuel Switching

Incorporating more lower-carbon fuels such as tires and biomass into plants' existing processes appears to be an attractive abatement option to firms. However, the feasibility of fuel switching depends on the location and technical requirements of the plant. An investment in switching to biomass appears highly profitable over the long term, but firms' short investment horizon and their uncertainty about future supply of alternative fuels pose barriers to investment in the short term.

Background

Coal is by far the dominant kiln fuel in cement plants in California and worldwide. Coal made up 70% of the fuel mix at California's cement plants in 2009, making cement plants the largest coal consumers in California (California Air Resources Board 2013e). Table 4 gives the current fuel mix used in California's cement plants. Switching from coal and petroleum coke to less carbon-intensive fuels is an important emissions reduction option for California cement firms.

California cement plants currently employ a limited amount of alternative fuels, including natural gas, waste rubber tires, and biomass (which can include wood waste, municipal solid waste, or other material). Most of the plants burn some natural gas or fuel oil on site (U.S. Environmental Protection Agency 2013). Four plants burn tires as fuel, with tires making up between 8% and 33% of the total fuel mix in 2010 (California Air Resources Board 2012).

Some alternative fuels can be burned ("co-fired") in limited quantities along with coal and petroleum coke, without requiring different equipment or a permanent change in operations. In order to fully transition the plant to a different fuel, however, the firm must typically install a new burner system. Additional costs are also associated with transporting alternative fuels to, and within, the cement plant — for example, installing a new

Table 4: Kiln Fuel in California's Cement Plants

FUEL	SHARE (BY MMBTU)
Coal	70%
Petroleum coke	16%
Tires	8%
Natural gas	5%
Biomass, diesel, and other waste	1%

(Source: California Air Resources Board 2013e)

natural gas supply line, or installing equipment to feed tires into the kiln. The required capital investment depends on the fuel and on the equipment already in place at the cement plant. Fuel switching can also affect the plant's capacity: If the replacement fuel has a lower BTU value (heat content) than coal, then replacing coal with the same volume of the new fuel will not generate the same amount of heat.

Switching fuels can carry an additional benefit of reducing local air pollution: mercury emissions from coal combustion make cement plants some of the biggest mercury emitters in California (Harrison 2012; Weiss 2012). However, burning tires and other waste can also generate local air pollution, and plants must receive permits from their local air districts in order to start burning tires. Most of California's cement plants are permitted to burn tires, although not all currently do (California Air Resources Board 2012).

Modeling Approach

To determine the potential impact of the Cap and Trade Program on fuel switching at cement plants, we modeled three different fuel switching investments, as well as two incremental shifts in the fuel mix. In all cases, we assume that the starting fuel mix is 70% coal and 30% petroleum coke — a simplified version of the current statewide fuel mix. We assume the new fuel replaces coal first, since it is more expensive than petroleum coke. The modeled fuel switching decisions are listed in Table 5.

Pre-Implementation Expectations

CARB included two fuel switching options in its technical review of cement industry abatement options: a capital investment in tire-feeding equipment, and a capital investment in natural gas infrastructure. The global Cement Sustainability Initiative highlights the potential for switching to alternative fuels and notes the range of alternative fuels already used by cement plants globally, including food processing waste, plastics, paper and wood waste, waste oil, and other solid and liquid fuels (Cement Sustainability Initiative 2005: 20). The Cement Sustainability Initiative notes that the selection of fuel depends on the particular geography and needs of the cement plant.

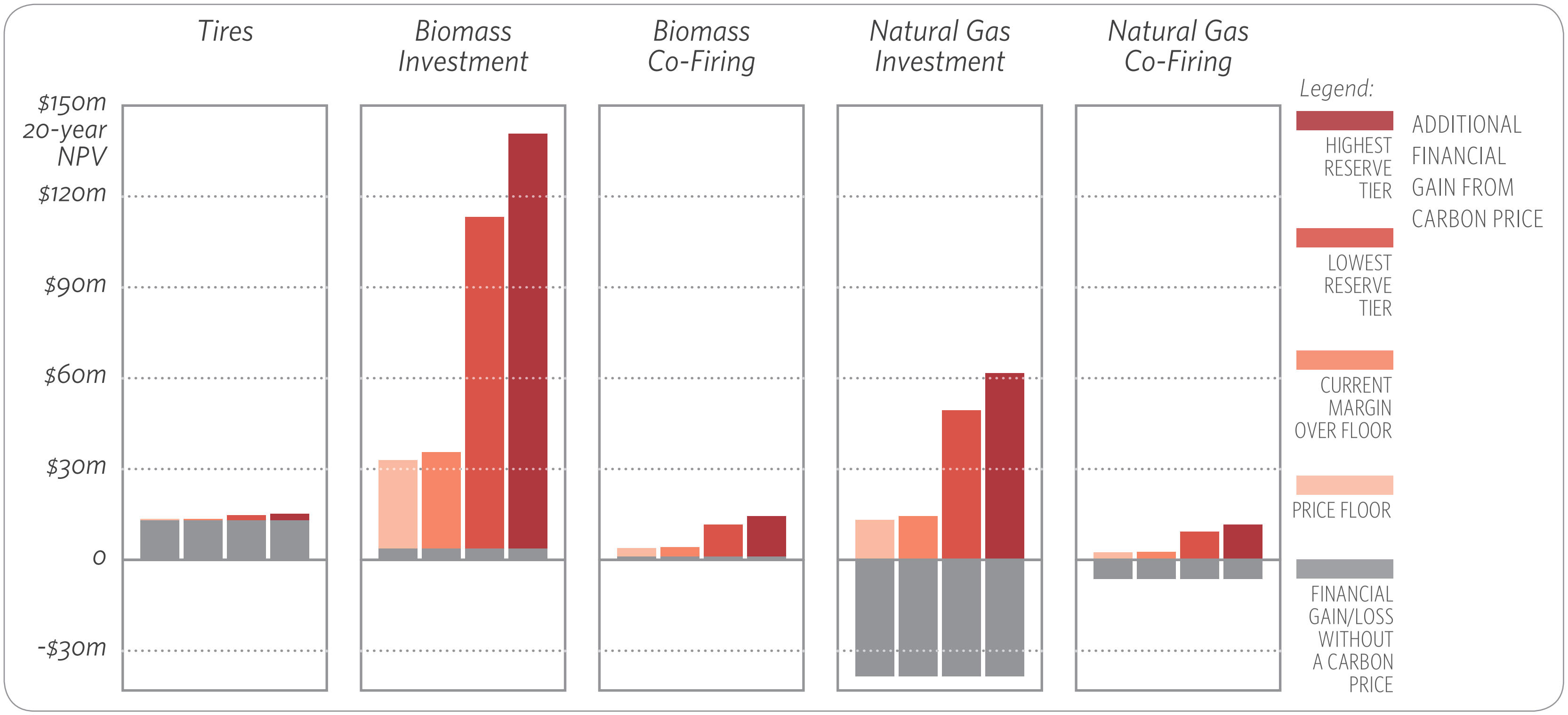
Emissions from biogenic sources — including emissions from combustion of biomass as a fuel — are not covered under the Cap and Trade Program. Substituting biomass for coal or petroleum coke therefore has a particular advantage under the program, since that substitution dramatically reduces the plant's compliance obligations.

Table 5: Modeled Fuel Switching Decisions

FUEL	DESCRIPTION	NEW FUEL MIX	DATA SOURCES
Tires	$2.5 million capital investment in tire feeding equipment	50% coal 30% petroleum coke 20% tires	CARB (2010c), stakeholder interviews
Biomass	$9.5 million capital investment to switch to a biomass burner system for the kiln	100% biomass	International Renewable Energy Agency (2012) and other sources (see model for more details)
Biomass	Co-firing a limited amount of biomass with existing equipment	60% coal 30% petroleum coke 10% biomass	International Renewable Energy Agency (2012) and other sources (see model for more details)
Natural gas	$12 million capital investment to switch to a gas burner system for the kiln	100% natural gas	CARB (2010c)
Natural gas	Co-firing a limited amount of natural gas with existing equipment	50% coal 30% petroleum coke 20% natural gas	Stakeholder interviews

Figure 8: Value of Fuel Switching Options over 20 Years

This graph shows the 20-year net present value of the modeled fuel switching options. Orange bars include the financial gain or loss from differences in fuel prices, as well as changes in operations and maintenance costs. Orange and red bars show the financial gain from the plant's ability to purchase fewer allowances, or profit from selling excess allowances, under the Cap and Trade Program. See "Approach" section for model parameters.



Findings

We find that some fuel switching options appear financially attractive even without a carbon price, and others are very financially attractive with a carbon price. However, non-price barriers are significant — in particular, concerns about the future availability and prices of alternative fuels.

Figure 8 compares lifetime energy and carbon cost savings for the modeled fuel switching options.

Looking across the five fuel switching options modeled, our modeling suggests the following:

Tires: Because of the low cost of waste tires, incorporating tires into the fuel mix appears financially attractive even without a carbon price: The modeled investment pays back within three years under all price scenarios. The carbon price itself has only a small impact on the value of this fuel switching investment, relative to the impact of fuel prices. This suggests it is unlikely that carbon prices would be the primary driving force behind such an investment. However, industry stakeholders indicated there has been an uptick in interest in tire-feeding equipment since the introduction of AB32.

Biomass: The modeled investment in switching to biomass is profitable under any carbon price scenario, in large part because of the carbon price. If carbon prices are low, the investment is very profitable in later years but the payback period is too long to meet industry's stated investment criteria. If carbon prices are high, the modeled investment in switching to biomass would be highly profitable, paying back the investment within two years. The majority of the financial returns are associated with the carbon price. Because emissions from biomass combustion do not incur compliance obligations under the Cap and Trade Program, a plant that switched to largely biomass combustion could profit from selling its allocated allowances to other covered emitters.

Co-firing a small amount of biomass does not require a capital investment, so payback period is not a concern. Co-firing biomass is profitable under any price scenario, and potential carbon cost savings are larger than energy cost savings under any price scenario.

Natural Gas: The value of the modeled investment in switching to natural gas depends on future energy prices as well as carbon prices — in particular, on the future movement of natural gas prices relative to coal. However, the investment is not profitable under most price scenarios, and the payback period for the investment does not fall under seven years in any modeled price scenario. An incremental increase in natural gas as a share of the fuel mix is profitable under high carbon prices but not under low carbon prices.

In interviews, cement industry stakeholders highlighted biomass and waste as promising options under the Cap and Trade Program, but they cited reliable pricing and supply as a notable risk, especially when considering significant reliance on alternative fuels for combustion. Before making the modeled investment in switching to biomass, a firm would need assurance that the new fuel would continue to be available at a predictable price for the lifetime of the investment — or at least as long as the investment takes to pay back.

In general, co-firing of lower-carbon fuels that do not require a capital investment — for example, increasing tire volumes at a plant already equipped and permitted for tire burning, or co-firing a limited amount of biomass in existing coal burners — appears to be an attractive option in our model. The feasibility of this option depends in part on where the plants are located in relation to fuel sources, since transportation costs can add significantly to the cost of alternative fuels.

Policy Implications

Policy levers that address the supply and price of alternatives to coal will likely provide California more leverage in facilitating lower-carbon fuels substitution at cement plants. For example, on paper, incorporating biomass into the fuel mix appears to be attractive options for cement firms; however, uncertainty about the availability and price stability of biomass could be a barrier to this otherwise profitable abatement decision. Policy mechanisms could help create a more reliable source of fuel derived from solid waste and other forms of biomass. Given enough time and a high enough carbon price, cement firms may take action to create and secure these supply streams themselves, but policy intervention could facilitate this transition.

Increasing Blending of Alternative Materials (SCMs)

The Cap and Trade Program makes blending of supplementary cementitious materials financially attractive, especially if carbon prices are high. However, blending more SCMs may not be feasible for a particular plant, depending on the end use for its products. The primary barrier to increasing SCM blending is technical specifications used by state agencies and other customers, which the carbon price alone will not address.

Background

Supplementary cementitious materials (SCMs) are alternative materials that have similar physical properties to cement — they react chemically when combined with water and harden when dried. Blending additional SCMs into cement after the kiln stage reduces both fuel usage and process emissions of CO_2, because the finished product contains a smaller proportion of clinker that passes through the kiln. SCMs can be blended either at the cement plant or at the concrete plant, or both. California cement plants blend, on average, 8% SCMs into their end product (California Air Resources Board 2010c).

Different cement end uses can tolerate different SCMs and blend proportions, since SCMs can alter the strength, speed of setting, and other properties of the final product. The level of SCM blending also depends on the availability of SCMs and their price. Two materials commonly used as SCMs — fly ash from coal-fired power plants, and slag from iron and steel manufacturing — are not produced in California. Limestone, also used as an SCM, is readily available at cement plants.

Many U.S. customers for concrete and other cement products specify a particular blend of cement, rather than a set of performance specifications the cement product must meet. Government agencies that procure cement (e.g., for highway construction), or that set requirements for cement usage (e.g., in state or local building codes) often use similar prescriptive procurement practices. These prescriptive standards reduce the flexibility cement firms have in substituting equally performing SCMs for clinker — a significant barrier to greater penetration of blended cement (Arbuckle, Lepech, and Keoleian 2013).

At the request of the cement industry, the U.S. standard for portland cement — American Society for Testing and Materials (ASTM) Standard C-150 — was revised in 2005 to accommodate up to 5% ground limestone

SCM Blending under the European Union Emissions Trading System

SCM blending in the U.S. occurs more frequently at concrete plants, whereas in the EU it occurs more frequently at cement plants (International Energy Agency and World Business Council for Sustainable Development 2009). Accordingly, rates of SCM blending at cement plants are significantly higher in the EU than in the U.S. Among cement plants reporting data to the World Business Council on Sustainable Development, total SCM blending rates in 2011 were 25.2% in the EU and 7.9% in the U.S. (Cement Sustainability Initiative 2011). An additional reason for the higher blending rates in the EU is that EU cement users typically rely on performance-based standards, rather than prescriptive standards.

EU cement plants increased SCM blending rates during the early years of the EU Emissions Trading System (EU ETS). We might expect similar decisions in California under the Cap and Trade Program, but the U.S. construction industry's use of prescriptive standards rather than performance standards in engineering specifications likely limits the degree to which the California cement industry can flexibly follow suit. Among EU cement plants reporting data to the World Business Council on Sustainable Development, SCM blending rates had increased from 21.5% in 2000 to 22.6% by the year the EU ETS came into effect (2005), and reached approximately 25% by 2007 (Cement Sustainability Initiative 2011).

(Benn, Baweja, and Mills 2012; KEMA Inc. 2012: 61). This change was incorporated into California Department of Transportation (Caltrans) standards in 2009. More recently, the ASTM standard for blended cement has been revised to accommodate up to 15% ground limestone (Cement Americas 2012); however, large purchasers still prescribe the blend of cement, so additional efforts would be required to increase adoption of higher blends of ground limestone. The new standard is not yet in wide use in California, and industry interviewees indicated that more technical work is needed to ensure that cement with a higher limestone percentage can be safely and reliably used in California applications (National Precast Concrete Association 2012).

Pre-Implementation Expectations

In designing the Cap and Trade Program and determining the cement industry's free allowance allocation, CARB assumed that the industry could increase SCM blending rates from 8% to 15% by 2020 and make money from this change (California Air Resources Board 2010c). Based on these analyses, CARB and other observers might expect to see SCMs as a good abatement opportunity for the cement industry in its compliance strategy.

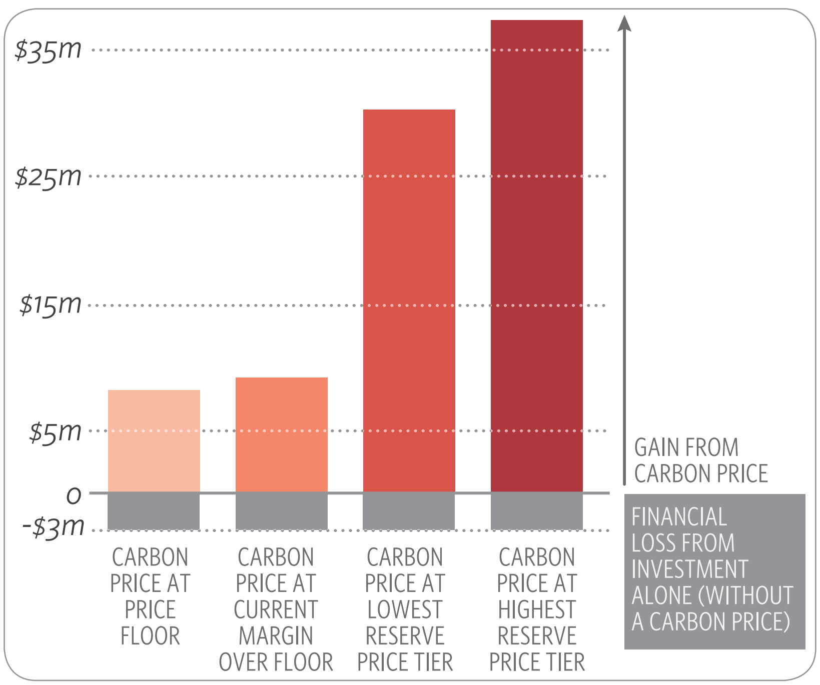
Modeling Approach

To explore the impact of the carbon price on the financial attractiveness of SCM blending, we modeled the financial impact when a cement plant increases SCM blending from 8% to 15%, the option considered by CARB in its abatement cost curve. We assume that this switch does not require a capital investment and that SCMs are blended at the end of the production process, reducing the volume of material processed in the kiln. We assume that the additional SCM being blended is fly ash, since current Caltrans standards allow for a higher percentage of fly ash than currently blended.

Findings

Of the three abatement strategies in this study, SCM blending is the most sensitive to a carbon price, but its feasibility at an individual cement plant depends on whether the plant's customers (largely ready-mix concrete plants and other product manufacturers, as well as the end-use customers for concrete) are able and willing to use a different blend of cement in their finished products.

Figure 9: Value of SCM Blending over 20 Years



This graph shows the 20-year net present value of increasing SCM blending to 15%. Gray bars include energy cost savings (a financial gain) that are offset by the additional cost of purchasing SCMs. Orange and red bars show the financial gain from the plant's ability to purchase fewer allowances, or profit from selling excess allowances, under the Cap and Trade Program. See "Approach" section for model parameters.

For our modeled plant, increasing blending of fly ash does not pay off without a carbon price, since the cost to purchase and transport fly ash to California is slightly greater than the avoided fuel costs. A price on carbon shifts the balance: Increasing SCM blending is profitable with a carbon price at the price floor and very profitable with a high carbon price. If ground limestone can be used as an SCM instead of fly ash, increasing blending is a cost-saving measure, and industry would likely make this shift regardless of the carbon price.

In contrast to the other two abatement strategies, SCM blending has a greater impact on carbon cost savings than on energy cost savings, illustrated in Figure 9. As a result, we would expect the carbon price to be more salient in firms' decisions about SCM blending than in decisions about efficiency or fuel switching. Under all carbon and energy price scenarios we modeled, carbon cost savings are 2-10 times as large as energy cost savings over a 20-year period.

We also note that those cement companies that do not own ready-mix concrete plants (but instead supply external ready-mix plants) do not have as much control over SCM blending as those companies that also control concrete mixing operations, because concrete plants are among the primary customers of cement plants. In such cases, control of at least a portion of the abatement option is separated from the obligated party — the cement company — under the Cap and Trade Program. Additional analysis is required to determine the extent to which this acts as a barrier.

Policy Implications

The Cap and Trade Program makes blending of supplementary cementitious materials financially attractive, but customer preference and procurement practice favoring prescriptive standards for concrete blends raises a barrier to efficient compliance. Policy tools to change customer preference and procurement practices would not only lower the cost of Cap and Trade compliance for the cement industry (and thus all sectors covered), but it would also boost the cement industry's flexibility in meeting customer performance needs at least cost.

One such tool might be a dedicated customer education and outreach effort to change specification practices in more applications where using blended cement is technologically feasible. Large cement customers such as Caltrans could also make an impact by following best practices in their own procurement — for example, using performance-based rather than prescriptive specifications. Caltrans and other agencies could also participate in standard-setting processes to promote increased SCM blending where safe and appropriate, and could partner with industry to explore technical and regulatory solutions that would allow the use of blended cements with higher limestone content.

Lastly, if customer preference does shift to accommodate more SCM blending, the shift may happen at ready-mix concrete plants rather than at cement plants. The resulting emissions reduction would be the same, but the incentives for abatement may be weaker if ready-mix plants are under separate ownership from the obligated cement plants. CARB and other observers should keep this in mind when reviewing SCM blending in coming years.

Impact of Removing Barriers

Our modeling shows that the carbon price has the potential to make a difference in the finances of abatement options. But lowering other barriers has the potential to make even more abatement opportunities feasible and financially attractive, in conjunction with the carbon price. Figure 6 illustrates which abatement options would meet firms' criteria if the following barriers were removed:

- Public financial support allows firms to lengthen their required payback period to seven years.
- Firms are assured of a reliable supply of biofuels.
- Initiatives to increase blending of alternative materials where safe and appropriate are launched and are successful; customer purchasing practices become flexible enough to allow firms to switch their product entirely to cement containing 15% SCMs.

5. Opportunities to Identify Cost-Reducing Policy Tools

Under the Cap and Trade Program, California will meet its emissions reduction target as long as the cap is enforced. Barriers to abatement in one industry do not jeopardize the overall ability of the program to meet its environmental goals. However, those barriers can impact the overall cost-effectiveness of the program.

If California is to meet its emissions target most cost-effectively, policy and business solutions must be implemented to open pathways for firms to pursue low-cost and cost-saving emissions reductions. Our work shows that in these cases, California (and other governments developing carbon pricing systems) may need to look for other policy tools to lower barriers to cost-effective abatement — barriers that will not be detected before conducting on-the-ground firm-level assessment.

As an energy-intensive and emissions-intensive industry dominated by large firms, the cement industry actively engages in and strategizes on its participation in the Cap and Trade Program. California's cement firms factor the carbon price into their investment models and are aware of the abatement options available to them. Whether they pursue these options over the coming years depends on a number of factors both internal and external to the firms.

Policy solutions to the following three key barriers to cost-effective abatement in the cement industry may also have broader application to other industries under the Cap and Trade Program:

Payback Period Criteria and Capital Constraints: Our modeling and stakeholder interviews point to firms' short required payback period as a significant barrier to otherwise cost-effective investments in efficiency and fuel switching.

Although cement firms determine their own internal investment criteria, there may be ways for policy to support longer-term investments that would produce cost-effective emissions reductions — particularly if capital constraints also prove to be a similar barrier to cost-effective abatement actions in other industries covered under the Cap and Trade Program. Through an institution such as a green bank, the state could provide supplemental financing to encourage firms to invest in projects that produce substantial emissions reductions but take longer to pay back. Non-governmental initiatives are also underway to encourage longer-term planning and investments by industrial and commercial firms — pointing out that a strict short-term approach to capital investments can block investments in energy efficiency measures that could be highly profitable to the firms over a 5-10 year time period (Environmental Defense Fund 2011).

Predictability and Availability of Alternative Fuels: To help drive a transition to lower-carbon fuels in California's largest coal-consuming industry, California could invest in creating a reliable supply stream for fuels derived from solid waste and other biomass, or could provide guarantees to firms seeking price certainty before committing to major investments.

Customer Purchasing Practices: Increasing blending of limestone and other SCMs has the potential to reduce emissions while generating cost savings for the industry. Caltrans and other agencies could work with cement firms and standard-setting bodies to increase the use of blended cement with higher ground limestone content, and could provide education and outreach to large cement customers to encourage the use of performance-based rather than prescriptive specifications.

Further efforts to understand abatement decisions at the business level, to identify barriers to investment in the most cost-effective abatement options, and to develop policy solutions would benefit both CARB and covered firms — providing a pathway to further lower the costs of a successful Cap and Trade Program.

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