November 30, 2022

NRDC and RMI Joint Comments on SB 596 Cement Sector Net-zero Emissions Strategy

The Natural Resources Defense Council (NRDC) and RMI sincerely appreciate the opportunity to submit comments to the California Air Resources Board (CARB) on implementation of SB 596. Our comments run through different decarbonization levers that hold promise in reducing greenhouse gas (GHG) emissions from the cement industry in California and reduce the embodied carbon of cement used in the state.

Our comments are structured in the following sections:

Introduction

There are seven cement plants located in California that in 2019 made up 11.5% (approximately 11.2 million tons) of the U.S. cement industry's clinker capacity, according to the Portland Cement Association.[1] In 2019, California's cement industry consumed 34.3 petajoules of fuel and emitted 2.8 Mt CO_2.[2] Lehigh Hanson owned three plants located in Cupertino, Redding, and Tehachapi. Lehigh Hanson's Cupertino plant, located in the San Francisco Bay Area Air Quality Management District (AQMD), was built in 1939 and last retrofitted in 1979. Lehigh Hanson's Cupertino plant in 2019 had the largest clinker capacity of all three of Lehigh Hanson's California plants that year at 1,351,000 mt/year.[3] However, the Cupertino plant's cement kiln ceased operation in April 2020 and in November 2022 the company announced that cement production has permanently ceased.[4]

Lehigh Hanson's Redding plant, located in the Shasta County AQMD, was built in 1981.[5] In 2019, the Redding plant's clinker capacity was 509,000 mt/year with total facility emissions of 293,213 mt CO_2e in 2019.[6] The Redding facility's emissions slightly decreased in 2020 to 283,688 mt CO_2e but rose back up to 336,591 mt CO_2e in 2021.[7] Lehigh Hanson's Tehachapi is one of the three cement plants located within the Eastern Kern Air Pollution Control District (APCD). Its Tehachapi plant was built in 1906 but more recently renovated in 1992. In 2019, the Tehachapi plant's clinker capacity was 970,000 mt/year with total facility emissions of 553,980 mt CO_2e.[8]

Both Lehigh Hanson's Redding plant and Tehachapi plant were acquired by Martin Marietta in a $2.3 billion deal to acquire Lehigh Hanson, Inc.'s West Region business that was completed October 1, 2021.[9] The Redding plant changed ownership again in March 2022 in a deal between Martin Marietta and

CalPortland. In August 2022, Martin Marietta also announced its plan to sell the Tehachapi cement plant to CalPortland.[10] With the completion of these acquisitions, the number of cement manufacturers in California will decrease to four companies: CalPortland, Mitsubishi, CEMEX, and National Cement Company of California.

In 1987, the National Cement Company of California (NCC) acquired the General Portland cement plant in Lebec. The plant located in the Eastern Kern APCD was built in 1966 and was most recently retrofitted in 1999.[11] In 2019, the NCC plant's clinker capacity was 1,033,000 mt/year and total facility emissions of 795,657 mt CO_2e.[12] The NCC Lebec plant is the only plant in California and one of only eight plants nationwide to use alternative fuels as a primary fuel.[13] Alternative fuels used include petroleum coke, natural gas, tire derived fuel, and pistachio shells.

The third plant in the Eastern Kern APCD is CalPortland's Mojave facility. The plant produces approximately 1.3 million tons of cement annually. CalPortland's Mojave plant had a clinker capacity of 1,384,000 mt/year in 2019.[14] Its 2019 total facility emissions were 1,124,098 mt CO_2e. Total facility emissions marginally decreased the following years. In April 2022, CalPortland announced that its Mojave plant would switch from production of Ordinary Portland Cement to a Type IL blended Portland-Limestone cement. The new blend of Type II/V Portland-Limestone cement is titled Advancement HS (high sulfate) and is expected to reduce manufacturing CO_2 emissions by approximately 10%.[15]

CalPortland's Oro Grande plant is in the Mojave Desert AQMD and was built in 1907.[16] This facility was retrofitted in 2008 making it the most recently renovated cement plant in California. The Oro Grande facility 's clinker capacity in 2019 was 1,728,000 mt/ year with total facility emissions of 1,250,996 mt CO_2e.[17] The CEMEX Victorville cement plant is also located in the Mojave Desert AQMD. The Victorville plant was built in 1916 and last renovated in 2001. This CEMEX plant had the largest clinker capacity in 2019 of 2,701,000 mt/year.[18] Its total facility emissions for 2019, 2020, and 2021 were also the highest of all California cement facilities. A summary of this information can be found in Table 1.

Table 1. California Cement Plants and Key Background Data (PCA, 2019. Plant Information Summary; EPA, 2022. Facility Level Information on Greenhouse Gases Tool.)

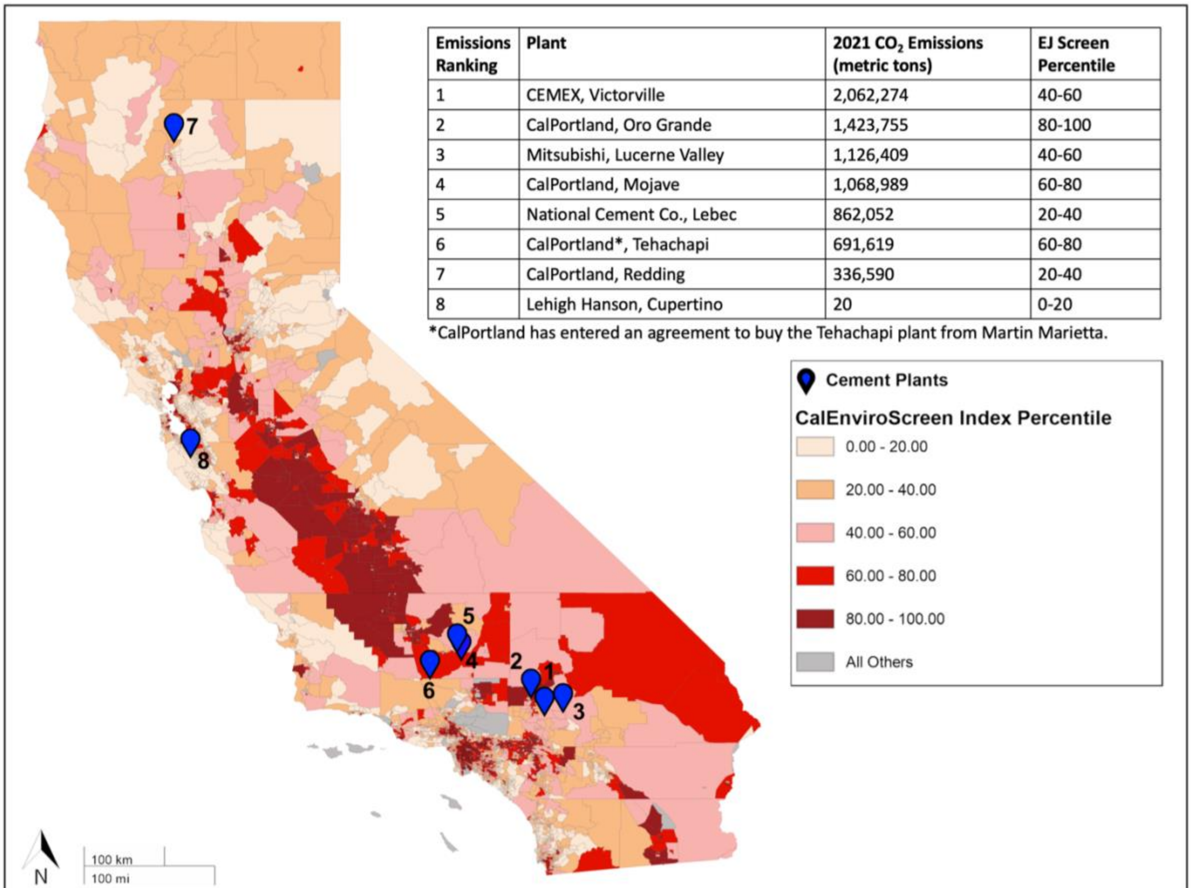
Company	Air Districts	Clinker capacity (1000 mt/year in 2019)	2019 Total Facility Emissions (mt CO_2e)[a]	2020 Total Facility Emissions (mt CO_2e)[a]	2021 Total Facility Emissions (mt CO_2e)[a]	Year built	Last Retrofit
Lehigh Hanson, Cupertino[b]	San Francisco Bay Area AQMD	1,351	771,203	185,626	20	1939	1979
CalPortland, Redding	Shasta County AQMD	509	293,213	283,688	336,591	1981	NA

[a] Excluding biogenic emissions.
[b] Lehigh Hanson announced on November 14, 2022, that the kiln will be permanently shut down.

National Cement Company of California Inc, Lebec	Eastern Kern APCD	1,033	795,657	836,390	862,052	1966	1999
CalPortland, Tehachapi[c]	Eastern Kern APCD	970	553,980	527,208	691,619	1906	1992
Mitsubishi, Lucerne Valley	South Coast AQMD	1,544	1,063,584	1,164,761	1,126,409	1957	1982
CalPortland, Mojave	Eastern Kern APCD	1,384	1,124,098	1,116,573	1,068,989	1956	1981
CalPortland, Oro Grande	Mojave Desert AQMD	1,728	1,250,996	1,375,061	1,423,756	1907	2008
CEMEX, Victorville	Mojave Desert AQMD	2,701	1,907,920	2,047,862	2,062,274	1916	2001

California's cement plants are co-located with limestone deposits. Some of these plants are remote and some are located near communities. To assess the areas around the plants, we applied CARB's CalEnviroScreen which characterizes the environmental, health, and socioeconomic conditions of communities based on 2010 census districts. The map below (Figure 1) shows the CalEnviroScreen output, with higher percentiles indicating a greater pollution burden relative to other parts of the state. The Mojave, Tehachapi, and Oro Grande plants are in areas that rank poorly (60th to 100th percentiles) in the CalEnviroScreen and produce 36% of the state's clinker (Figure 2). The map also shows that facilities in Southern California are particularly clustered. The top three emitting plants (Victorville, Oro Grande, and Lucerne Valley) are proximate to each other. The Mojave, Lebec, and Tehachapi plants are also closely located to one another.

[c] CalPortland has entered an agreement to buy the Tehachapi plant from Martin Marietta. The deal is pending regulatory review.



Emissions Ranking	Plant	2021 CO_2 Emissions (metric tons)	EJ Screen Percentile
1	CEMEX, Victorville	2,062,274	40-60
2	CalPortland, Oro Grande	1,423,755	80-100
3	Mitsubishi, Lucerne Valley	1,126,409	40-60
4	CalPortland, Mojave	1,068,989	60-80
5	National Cement Co., Lebec	862,052	20-40
6	CalPortland*, Tehachapi	691,619	60-80
7	CalPortland, Redding	336,590	20-40
8	Lehigh Hanson, Cupertino	20	0-20

*CalPortland has entered an agreement to buy the Tehachapi plant from Martin Marietta.

November 28, 2022

Figure 1. Map of California cement facilities color coded based on the CalEnviroScreen index.

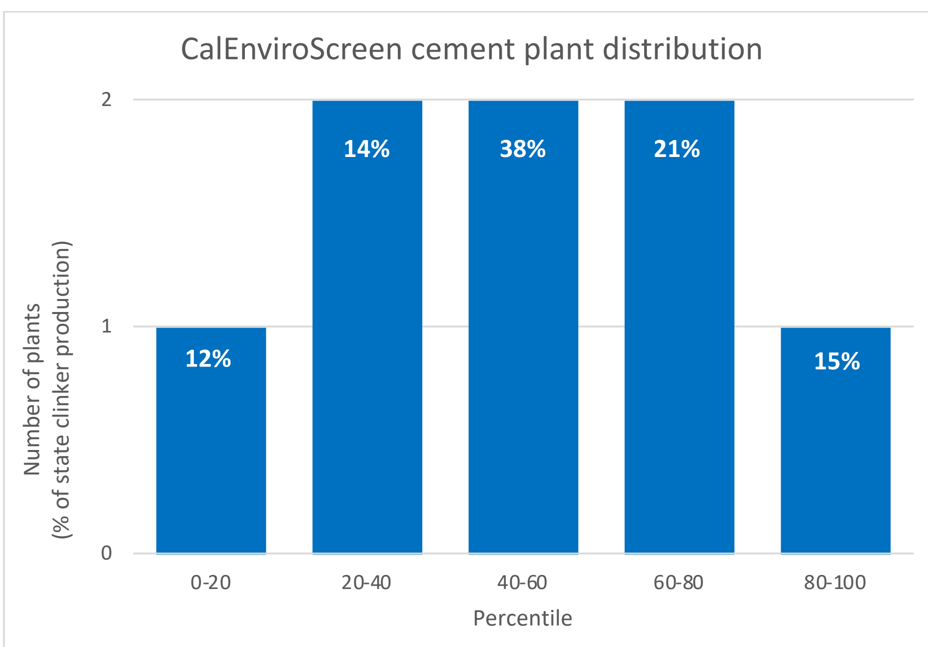


Figure 2. Number of California cement plants and fraction of total clinker production by CalEnviroScreen index percentile.

Emission Reduction Technologies

Clinker substitution

Top-line: Clinker substitution, and in particular blended cements, are the most impactful near-term solution to reduce emissions of traditional clinker. CARB should support production of blended cement through 1) work with DGS and Caltrans to establish demonstration projects with high replacement ratios of new blended cements, 2) work with Caltrans on efficient approval timelines for lower-GWP blends, 3) explore a low-carbon procurement policy to create stable markets for the lower-carbon products, and 4) study the impact of cap-and-trade allowances based on cement output.

By far, the most accessible near-term solution to mitigate the sector's health, climate, and environmental impact is to reduce the ratio of clinker in cement and of cement in concrete. Blended cements should be a central focus of CARB's decarbonization strategy. A mix of policies, including rapid approval of lower global warming potential (GWP) blends, public procurement, and demonstration projects will be needed to fully realize the potential of this decarbonization lever.

Historically, clinker-to-cement ratio reductions have been driven by cost considerations since several supplementary cementitious materials (SCMs) are less expensive than traditional clinker. Deployment of SCMs varies significantly by region depending on the availability of local material supply. Future supply of commonly used SCMs like fly ash and blast furnace slag, which are by-products of coal burning and steel manufacturing respectively, will diminish as the market moves away from coal and as steel production relies more heavily on electric arc furnaces.[19] California already faces scarce slag availability and relies exclusively on overseas imports.[20] Other SCMs, such as calcined clays, natural pozzolans, and limestone perform well, are available in California and hold promise in substituting up to 60% of OPC clinker in cement.[21] Caltrans has also initiated a study, expected to conclude in June 2024, to evaluate the availability of SCMs beyond the traditionally used fly ash and slag.[22] RMI's Concrete Solutions Guide includes several considerations regarding the availability of different SCMs in the United States.[23] The primary barriers to increasing SCM use are prescriptive specifications, unfamiliarity from industry, and supply-side restrictions.

An easily accessible decarbonization lever in the near term is the use of Portland limestone cement (PLC, Type IL) produced by replacing 5-15% of clinker with limestone. PLC has similar performance characteristics and 10% fewer emissions compared to OPC due to the limestone's nearly zero associated emissions. [24] PLC has been used in large quantities in Europe since the 1960s for both ready-mix and precast products.[25] Adoption in the United States has been slower partly because some state Departments of Transportation have yet to adopt provisions that allow the use of PLC.[26] Caltrans only recently approved the use of PLC.[27] Caltrans's authorized materials list for use in concrete already includes three pozzolan blended cements (Type IP, produced in neighboring states), as well as a ternary blend (Type IT) produced by Calportland's Mojave plant. This opens up the door for approval of additional blended cements like LC3 (also a Type IT) as well as natural pozzolans.[28] We encourage CARB to work closely with Caltrans to identify an efficient process for prompt evaluation and approval of lower-GWP cement blends, aligned with SB596's emissions targets, to increase usage of blended cements.

The United States, including California, is unique compared to other major countries in that SCMs are often mixed in during *concrete* making, rather than the cement mixing stage. CARB should not only encourage increased use of SCMs during concrete making, but also support greater production of blended cements. Some of California's cement plants are already investing in blended cements, including PLC.[29] There are many benefits to blended cements including that cement producers have the technical capability to balance cement chemistry, optimize key parameters like sulfate content, material blending, setting times, and mix in appropriate admixtures. CARB should support greater production of blended cements at the cement mixing stage to ensure high product quality and accountability.

The challenge is gaining broad buy-in on the use of blended cements in California, especially for high replacement ratios. Stakeholders across the value chain need to familiarize themselves with the use of blended cements and build an evidence base of project successes. We encourage CARB to work with Caltrans and the Department of General Services (DGS), the two agencies that procure and use large volumes of cement and concrete, to pilot blended cements with high clinker replacement ratios in the range of 30-50%, starting with non-structural applications like sidewalks. The benefit of demonstration projects stems from exposing a wide range of stakeholders, including ready mix companies, construction companies, finishers, engineers, and owners to blended cements.

Public Procurement. While education and demonstrations will help accelerate market adoption of blended cements, California should leverage the state's purchasing power to rapidly expand the market for lower embodied carbon concrete – and, by extension, lower carbon cement. An example of such a low-carbon procurement policy is SB778, a bill introduced in the state legislature in 2021, which would have required the submission of an Environmental Product Declaration (EPD) to qualify for bidding for publicly-funded construction projects and directed DGS, in consultation with CARB, to establish a GWP benchmark for bidders starting in 2025.[30] We encourage CARB to liaise with DGS, Caltrans, and relevant stakeholders to explore the most efficient and effective pathway toward a cement and concrete procurement policy akin to SB778, as well as ways to promptly stand up blended cement demonstration projects. NRDC published a Design Guide to State and Local Low-Carbon Concrete Procurement offering an array of policy design approaches and will continue to work with partners, the legislature, and relevant agencies to identify and execute the best way forward toward such a policy.[31]

Cap-and-trade. California's cement plants are also already regulated under the state's cap-and-trade program, which requires state emissions to drop 40% below 1990 levels by 2030. The industrial sector includes many energy intensive, trade exposed industries (EITE, including cement), which receive free allowances to cover the majority of their GHG emissions based on clinker output and efficiency.[32] Cement manufacturing is classified as having high emissions intensity and medium trade exposure and thus overall included as a high leakage risk sector.[33] Based on the emissions reporting thresholds, California's cement plants report their annual emissions and verify them with an independent third party. Cement producers also report the amount of clinker produced, as well as the amounts of limestone and gypsum consumed.[34] As a result, CARB should already have an existing GHG emissions reporting structure for cement produced in-state. However, reporting doesn't cover cement imported from other states or from abroad. CARB needs to consider an additional emissions reporting tool, such as Environmental Product Declarations (EPDs) or other robust third-party verified lifecycle analyses (LCA) that would allow for standardized reporting of the emissions embodied in any type of cement that is consumed in the California market, irrespective of its origin.

Cap-and-trade allocates allowances to the cement industry based on clinker and mineral additives produced.[35] If CARB were to instead allocate allowances under cap-and-trade based on cement output, it could further encourage the use of blended cements, as such blends would serve to reduce the compliance obligation on covered cement plants. We encourage CARB to study the impacts and plausibility of such a modification to the cap-and-trade program, alongside any other measures it takes to implement SB596.

Unlike cap-and-trade, which regulates cement manufacturing, SB596's emission targets apply to all cement used in the state, and not just cement produced in the state. As a result, the law requires CARB to consider how to deal with embodied CO_2 emissions in imported cement, with the goal of ensuring a level playing field for in-state manufacturing and reducing the risk of leakage. We urge CARB to consider establishing a border carbon adjustment, akin to the one currently being considered in Europe to protect against emissions leakage. A border carbon adjustment mechanism would also enable reconsideration of the free allowances allocated to cement manufacturing under the state's cap-and-trade program.[36]

Traditional Portland Cement Alternatives. Other companies and laboratories are exploring various cement types with lower associated emissions. Fiscal and regulatory stimulation of further research and development into alternatives to OPC such alkali-activated, calcium silicates (Brimstone) and reactivated $CaCO_3$ (Fortera) is needed.

Fuel switching

In 2019, California had eight cement plants that produced 11.2 million tons of clinker and emitted 7.8 million tons of CO_2e (excluding biogenic emissions). Most of the fuel-related CO_2 emissions resulted from combustion of coal (68%) and petroleum coke (17%) to heat cement kilns. Natural gas is responsible for 9% of total fuel-related CO_2 emissions from California's cement industry, whereas alternative fuels, such as scrap tires and municipal solid wastes (MSW), contributed to only about 5% of fuel-related CO_2 emissions from the cement industry in California in 2019.

Table 2. Cement plants and types of fuel combusted (EPA FLIGHT, 2022)

Company	Fuels
Lehigh Hanson, Cupertino	Petroleum Coke (primary), Natural Gas, other solids
CalPortland, Redding	Coal (primary), Natural Gas, pet coke, flexicoke, tires, MDF, rice hulls
National Cement Corporation of California Inc, Lebec	Petroleum Coke, Natural Gas, tire derived fuel/Pistachio Shells (as secondary)
CalPortland (formerly Lehigh Hanson), Tehachapi	Coal/Gas/Coke/engineered municipal solid waste/Biomass
Mitsubishi, Lucerne Valley	Coal, tires, wood and wood residuals, biomass fuels (solid), and natural gas
CalPortland, Mojave	Coal, Natural Gas, Pet Coke, Fuel Oil #2
CalPortland, Oro Grande	Natural Gas and Coal
CEMEX, Victorville	Coal, Pet Coke, tires, tires fluff, wood chips, agriculture, refuse derived fuel, and natural gas

Near-term fuel switching options

Top-line: Co-processing of alternative fuels is unlikely to meaningfully contribute to GHG emissions targets for the cement sector and, in some cases, may lead to adverse air pollution impacts. Some categories of biomass hold potential for near-term emissions reductions; however, these are necessarily limited in supply and thus do not offer a scalable solution. Cement plants considering additional alternative fuel co-processing must accurately demonstrate safety and genuine emissions reductions using EPDs or an equally robust LCA framework. In order to ensure alternative fuels deliver genuine GHG emissions reductions and avoid exacerbating non-CO_2 pollution, CARB staff would also need to ensure the agency has the necessary capacity to monitor LCAs and administer any additional safeguards.

Alternative fuels. Near term fuel switching options that can provide meaningful GHG emissions reductions in the cement sector are limited. The industry is increasingly turning to alternative fuels as an intermediary alternative to burning fossil fuels to heat cement kilns.[37, 38] However, preliminary research on the emissions impact of alternative fuel combustion, commissioned by NRDC and conducted by the Global Efficiency Intelligence, indicates that co-processing of alternative fuels is unlikely to result in a meaningful reduction in the overall CO_2 emissions of the cement industry. The preliminary research, which will be published in Q1 2023, indicates that scrap tires and waste plastic have the lowest CO_2 abatement potential for co-processing in kilns (less than 1%). Some sources of biomass such as agricultural waste have the highest abatement potential. Other sources of biomass such as forest-derived biomass lead to higher GHG emissions than fossil fuels. The emissions reductions of biomass types vary considerably depending on the source, among other factors

Biomass. Currently, at least two of California's cement plants are burning residual biomass leftover from processing of edible crops (e.g., rice husks, nut shells, fruit pits). California produces over 800,000 tonnes of nut shells and fruit pits which, by one estimate, can replace approximately 20% of the cement industry's coal consumption in California without facility retrofits.[39] However, biomass cannot be assumed to be a carbon neutral fuel. The GHG emissions profile depends heavily on the biomass source, its counterfactual use or fate, pre-processing requirements, and transportation requirements.[40] For example, burning forest-derived biomass[d] for electricity emits more CO_2 than fossil fuels, which remains in the atmosphere for many decades. While burning forest biomass for electricity in some very limited cases can provide benefits when compared to fossil fuels, the total net lifecycle emissions from logging, transporting, drying, processing, and combustion typically persist in the atmosphere over the long term, even accounting for mitigating factors like forest regrowth. [41]

CARB should not assume categorical "carbon neutrality" for biomass. Instead, CARB should require any cement facility switching from burning fossil fuels to biomass as a means of complying with SB596 to demonstrate, using an EPD or comparably robust LCA method, that the alternative fuel in question is reducing emissions compared to the displaced fuel, and ensure it has sufficient agency capacity to assess such a claim. In addition, SB596 directs CARB to identify actions to reduce adverse air quality impacts. CARB should carefully and rigorously consider both the GHG and air pollution impact of combustion of different alternative fuels. For example, combustion of non-biogenic materials in municipal waste, if not properly controlled, can create harmful air pollutants, such as benzene, PFAs, dioxins, particulate matter, and heavy metals, which, if released, can lead to adverse environmental and health impacts on communities near plants.[42]

[d] Not including industrial waste generated in wood and pulp processing facilities.

Strategic use of biogas – methane produced from organic sources like food waste in landfills and wastewater treatment plants – could potentially partially reduce emissions from the cement industry. Biogas use in cement plants has been demonstrated and a cement plant in Tulsa, Oklahoma uses biogas from a nearby landfill to cover 20% of the kiln fuel needs, as well as for raw material drying.[43, 44] However, biogas is limited in availability and may not always reduce climate and other sources of pollution.[45]

Oxyfuel combustion. Oxyfuel combustion refers to enriching the kiln environment with oxygen to promote more efficient combustion, reducing air pollutants (especially NOx) and fuel demand by 3–5%.[46] Reduced contaminants and higher concentration of CO_2 in the flue gas could also potentially reduce the cost of carbon capture and storage (CCS) on cement plants. A demonstration project combining oxyfuel combustion with CCS has been commissioned in Germany.[47]

Long-term fuel switching options

Top-line: Green hydrogen and kiln electrification could prove transformational in deeply decarbonizing cement production. Both technologies, however, are still in early development stages and each face a set of challenges. CARB can pursue measures to help leverage federal and state funding and incentivize pilot and demonstration projects in California to reduce project risk and gain early learnings. Close collaboration with CEC, CPUC, and CAISO will be necessary to evaluate cement process electrification and its potential impact on the grid and renewable energy infrastructure buildout.

Hydrogen. Green hydrogen for cement production is at early stages of development. Hydrogen has different heat dispersion properties in the kiln relative to fuels used today and creates a temperature profile not yet suitable for the calcination and sintering of materials. New burner technologies and fuel feeding will be necessary to fully replace fossil fuels with hydrogen. Several companies are testing partial replacement of carbon-based fuels with hydrogen.[48] HeidelbergCement has successfully demonstrated a mix of hydrogen, meat and bone meal, and glycerin in one of its kilns in the United Kingdom. The trial was part of a broader research project on industrial fuel switching which has received over $4 million (£3.2 million) from the UK government.[49] CEMEX recently announced that it has installed hydrogen injection equipment on all its plants in Europe but it is unclear whether they are being used.[50, 51] The trial used ”grey” hydrogen produced from fossil gas as a proof of concept. As CARB explores a potentially expanded role for hydrogen in the industrial sector, it is critical to prioritize only the development and deployment of green hydrogen produced from the electrolysis of water with renewable electricity. The latter has primacy over other types of hydrogen from a climate, public health, and economic standpoint. Furthermore, blending green hydrogen with fossil fuels is characterized by important limitations. Some studies are concluding that hydrogen blending is an inefficient and cost-prohibitive solution relative to alternative emissions abatement solutions, primarily due to hydrogen's much lower energy content relative to natural gas that drives up the volume of the blend needed and waters down emissions abatement.[52, 53] To the extent that hydrogen is blended in existing gas infrastructure to deliver to cement plants, further assessments of safety implications of blending will be key. A recent study commissioned by the CPUC concluded that blending hydrogen at shares any higher than 5% in existing natural gas pipelines begins posing safety risks.[54] The public health implications of burning hydrogen, or hydrogen blends, also require caution and further assessments. When burned, hydrogen may produce even more air pollution than natural gas, if not properly managed.[55, 56] We encourage CARB to diligently consider these challenges as it explores the role of green hydrogen in decarbonizing cement production.

Electrification. Electrification of the kiln and pre-calciner may represent a longer-term option to deeply decarbonize cement manufacturing. Currently only a small fraction of a plant's energy needs are covered by electricity, limited to auxiliary processes like raw material preparation, grinding, packing, and loading.[57] However, the barriers to cement process electrification are understood to be mostly economic rather than physical. Kiln electrification eliminates on-site combustion by-products, which in addition to reducing harmful air pollution, can render capture of the cement plant's process emissions easier and cost-effective. One challenge however is that kilns run around the clock and therefore face challenges with intermittency of renewable electricity. Heat storage like the technology offered by Rondo Energy could help address this issue.

There are several early cement process electrification efforts underway globally, including two in California. Cement electrification technologies, however, are at various stages of pre-commercial development with varying degrees of published results and have yet to be proven at scale. Here we highlight a few that hold promise in partially or entirely electrifying the cement making process.

- Oakland based Rondo Energy has developed a commercially available drop-in replacement for fossil-fired boilers that in theory can be used in cement applications.[58] The technology uses electrical resistance to turn excess electricity into high-temperature heat stored in thousands of tons of brick, like the ones used in steel blast furnaces, which can charge within a few hours and store energy for days. The process can absorb excess power from the grid or from variable sources, such as solar and wind.[59] Rondo Energy has partnered with TITAN Cement, Breakthrough Energy Ventures, and Energy Impact Partners to raise funding for the first manufacturing line and for industrial demonstrations of its technology.[60]
- Pasadena-based Heliogen seeks to leverage concentrated solar and thermal storage to decarbonize limestone calcination. In October 2022, the company received a $4,100,000 award from the U.S. Department of Energy Solar Energy Technologies Office (SETO) to accelerate the demonstration of a solar-driven calciner, heating limestone to 950°C to drive the chemical breakdown of limestone into lime.[61] While Heliogen has commercial contracts, none yet are for cement.
- Synhelion has a pilot-stage project with CEMEX to apply its proprietary solar technology to the cement industry. In 2021, Synhelion successfully demonstrated not only calcination, but also clinkerization, using concentrated solar.[62]
- Finland based Coolbrook claims to have developed the only electric process heating technology able to reach 1700°C without burning fossil fuels but little is known about the specific technology.[63] The company has entered agreements with CEMEX and UltraTech Cement and is planning commercial scale demonstrations in 2024.[64]
- Two other Finish companies, VTT and Finnsementti, as part of the Decarbonate project, have successfully tested a pilot-scale (9 meter long) mobile electrically-heated rotary kiln.[65] HeidelbergCement's subsidiary in Sweden, Cementa, and electricity producer Vattenfall conducted a pilot study which showed that it is technically feasible to electrify the cement process.[66] More recent updates were not readily available.

Beyond traditional clinker, some companies are also looking to electrify clay calciners that can be used for products like LC3 and other calcined clay based cements. FLSmidth, in collaboration with the Danish Technological Institute, Rondo Energy, VICAT, Cementos Argos, and the Technical University of Denmark are planning to build a pilot plant. According to the project plan, the ECoClay partners expect to be able to start construction on their first full-scale electric clay calcination installation by the end of 2025.[67]

We strongly encourage CARB to explore ways to leverage existing federal and state funding to demonstrate emerging technologies, such as kiln electrification. Federally, the Inflation Reduction Act establishes a new "Advanced Industrial Facilities Deployment Program" in the Office of Clean Energy Demonstrations within the Department of Energy with a budget of $5.8 billion available through 2026 for direct financial assistance, on a competitive basis, with 50% cost-share for projects that reduce GHG emissions from industrial facilities. Cement kiln electrification would be a perfect fit for this new funding and should be leveraged to advance commercial projects in California.[68] Alongside these federal incentives, the CEC has set aside $100 million for industrial decarbonization that can provide financial incentives for the implementation of direct electrification of cement plants. The program generally provides eligible industrial facilities with direct funding to purchase and deploy technology that electrifies processes that currently use gas or other fossil fuels.[69]

Kiln electrification will only reduce emissions if it relies on an efficient, reliable, and clean grid. We encourage CARB to engage closely with the California Public Utilities Commission (CPUC), the CEC, and the California Independent System Operator (CAISO) to evaluate whether and how California's grid can support electrification as the technology approaches commercialization. Current industrial electricity rates compared to fossil gas rates in California do not support electrification and projects may face reliability issues.[70] Non-grid connected renewable energy sources for on-site electrification could potentially alleviate grid reliability concerns.

To make electrification economically viable for cement plants the current electricity and fossil gas rate structure should be revisited. Second, there will likely need to be upgrades to the grid to support significant new loads from electric kilns, including new distribution and transmission. Finally, on top of both of these challenges, new electricity generation for kiln electrification will need to come from additional renewable energy resources. All of California's energy agencies must be intimately involved in evaluating the grid transformation necessary to meet this potential new demand and carefully consider possible competition for land and resources with the already immense renewable energy buildout necessary to reach California's clean energy goals.[71]

Carbon Capture Utilization & Storage

Top-line: Abating process emissions from cement production will require capturing and permanently storing them underground. Alternatively, captured CO_2 from cement process emissions could be injected into, and therefore sequestered in, concrete. SB905, passed in the 2022 legislative session, places important environmental, social, and labor conditions that must at a minimum guide the responsible deployment of cement CCS projects in California. For CCS to become available at scale and within a relevant timeframe, investments in pilots and larger-scale demonstrations must start now to bring down their costs and risks.

Carbon Capture & Storage. 60% of GHG emissions from cement manufacturing are process emissions, released due to the decomposition of limestone into lime in the kiln. The selective use of CCS has potential to play an important role as a solution to that significant share of emissions from cement production that cannot be abated through other measures. Even stacked together the decarbonization solutions outlined in the previous sections cannot fully decarbonize a cement plant. The remaining emissions associated with the chemical decomposition of limestone will remain unaffected; these heat-trapping emissions are either captured or continue to be emitted to the atmosphere.

CCS emerges as the only currently available tool to reach net zero in the cement sector because 60% of the CO_2 released in cement production is from process emissions released during the chemical breakdown of limestone.[72] Consequently, even if cement kilns are retrofitted in the future to accommodate low-carbon fuels, such as green hydrogen, most CO_2 emissions produced in the cement making process will remain. Beyond 2030, as the need for deeper decarbonization increases, CCS is one of a suite of advanced technologies that could prove transformational in meeting this challenge.

For CCS to meaningfully benefit the climate and avoid harm to communities, several necessary safeguards need to be applied. The recently enacted SB905 places important environmental, social, and labor conditions to guide the responsible deployment of cement CCS projects in California.[73] Cement CCS projects must at a minimum follow the guidelines and safeguards established by SB905. The law includes, among others, the following provisions:

- Requires the use of best available control technologies to minimize non-GHG emissions associated with CCS projects.
- Requires a project operator to submit an air monitoring and mitigation plan to CARB.
- Requires monitoring and reporting of geologic sequestration and seismicity for at least 100 years after the last date of injection, and clarifies that an operator is financially responsible for at least 100 years.
- Empowers CARB to require changes in operations (incl. pausing operations) if the monitoring detects irregular activity around a sequestration site.
- Explicitly states that in carrying out this program, CARB must prioritize reduction of fossil fuel production.
- Requires CARB to regularly evaluate and report potential local environmental and long-term leakage impacts and propose mitigation measures.
- Prohibits the use of pipelines until PHMSA has finalized its minimum federal safety standards for transportation of carbon dioxide, and operators must show compliance with those standards.

The law also prohibits the use of captured CO_2 for enhanced oil recovery (EOR); directs CARB to establish a Carbon Capture, Removal, Utilization, and Storage Program; and directs the California Geological Survey to establish the Geologic Carbon Sequestration Group to provide independent expertise and regulatory guidance to identify high-quality, suitable storage locations.

For CCS to become available at scale and within a relevant timeframe, investments in pilots and larger-scale demonstrations must start now to bring down their costs and risks and can leverage existing federal incentives like the 45Q tax credit for permanent sequestration. Cost-sharing for first-of-a-kind projects will help build the know-how, lower barriers to wider adoption of this advanced technology, reduce future project risk, and evaluate the efficacy, safety, and viability of this technology. An earlier version of SB905 sought to do just that, directing CARB, the State Energy Resources Conservation and Development Commission, and the State Water Resources Control Board to award funding for 1-5 cement CCS pilots to evaluate the safety, efficacy, and benefits of geologic carbon sequestration for cement production as part of a public-private partnership.[74] We encourage CARB to identify and support the types of state incentives that, when coupled with federal incentives, could enable first-of-a-kind cement CCS projects.

From an infrastructure deployment standpoint, CCS retrofits will make financial sense for cement plants not approaching retirement age within the next 10 years. Several studies have identified the potential for CCS in southern California where 5 cement plants are in relative proximity to potentially viable sequestration sites. Should those plants pursue CCS they could leverage economies of scale for CO_2 transportation and sequestration and require limited infrastructure buildout.

In addition to CO_2 infrastructure, CARB should carefully consider options for powering carbon capture. CCS incurs an additional energy load to the plant, as well as for compression of the CO_2 for transport. This parasitic load is likely to vary depending on the type of capture technology used (e.g., amine solution, solid sorbent). One pilot capture project in Brevik, Norway, consumed an additional 2.4GJ per ton of captured CO_2.[75] CCS will only meaningfully reduce CO_2 emissions if powered with clean energy. In evaluating the potential for CCS to abate cement plant emissions, CARB should assess the impact CCS may have on the grid and renewable power generation in collaboration with the state's energy agencies.

Carbon Utilization. Concrete has the remarkable property of absorbing and storing CO_2 directly from the air over time through a gradual process known as recarbonation.[76] Current estimates assume that over its lifecycle concrete may gradually sequester up to 40% of calcination-related CO_2 emissions during production (which does not include emissions from combustion).[77] However, carbon uptake in concrete is limited and highly dependent on end-of-life practices, and a comprehensive lifecycle assessment is necessary to understand the net CO_2 benefit.[78]

Concrete's unique natural function as a carbon sink can be augmented with new technologies that increase the rate of CO_2 absorption. The most common category of carbon utilization involves curing concrete using CO_2 instead of water. The CO_2 used in the process can, in some cases, increase concrete strength while storing CO_2 in concrete. Current low-carbon cement and concrete technologies can store up to 5% of CO_2, with an upward potential of 30%.[79] The considerable uncertainty around the amount of CO_2 that could be reabsorbed by cement and concrete has hindered its inclusion emissions inventories, such as the UNFCCC.[80] The total amount of carbon sequestered is dependent on the material use: climate, whether the concrete is exposed to indoor or outdoor environments, the form factor of the concrete (e.g., thin walls vs thick foundational slabs), the permeability of the concrete (which is dependent on the water-to-cement ratio and any SCMs used), whether it is painted or coated, etc.[81] None of these use-phase variables would be known to the cement producer. Recarbonation also occurs to concrete (not cement), over a long period of time, and the extent and timeframe is highly uncertain.

CARB should carefully consider whether to account for concrete recarbonation in the agency's definition of net-zero cement. Considering the uncertainty regarding the extent of CO_2 uptake in concrete, the limited availability of information, and the considerable uptake variability based on parameters like application (e.g., indoor vs. outdoor), material thickness, and treatment of demolition waste, we caution against CARB incorporating concrete recarbonation in its definition of net-zero cement.

An emerging technology being pioneered at the Redding cement plant in California foregoes concrete recarbonation, and instead seeks to feed the captured CO_2 back into the kiln. The technology developed by Fortera, a materials technology company in Silicon Valley captures CO_2 and feeds it back into the kiln, to produce reactive calcium carbonate which can then be used as a SCM.[82] The result, according to the company, is a product that's 60% less emissions intensive and can be blended with OPC at a ratio of roughly 20%. Cement product category rules (PCR), which are used in creating EPDs, should be modified to reflect interventions that demonstrate stack emissions reductions. PCRs are developed by the program operator, NSF, for the Portland Cement Association. Current cement PCRs produce EPDs that would not reflect emissions reductions for technologies like the one tested by Fortera.

Conclusions

There are several levers available to the cement industry to reduce emissions and reach the climate targets set out in SB596. For near-term policy interventions to produce long-term and deep emissions reductions, CARB needs to work with other agencies, the legislature, and relevant stakeholders to promote two parallel and complementary goals:

1. to promptly and widely deploy existing decarbonization measures and practices, and,
2. to evaluate the efficacy and cost-effectiveness of innovative interventions at commercial scale, like the selective use of CCS, kiln electrification, and green hydrogen, through pilot and demonstration projects.

In the near term, clinker substitution is the most impactful and readily available lever to reduce emissions of traditional clinker. To support clinker substitution, CARB should work with DGS, Caltrans, and the legislature on demonstration projects, efficient approval timelines for lower-GWP blends, and a low-carbon procurement policy. Near term fuel switching options are limited to co-processing of alternative fuels many of which are unlikely to meaningfully contribute to GHG emissions targets for the cement sector.

In the future, green hydrogen and kiln electrification could prove transformational in eliminating combustion emissions from cement manufacturing. CCUS is also going to be necessary to prevent process emissions from reaching the atmosphere. All of these technologies are at early development stages and CARB should pursue measures to help leverage federal and state funding and incentivize pilot and demonstration projects in California to reduce project risk and gain early learnings. Assessing the full impact of emerging technology deployment will also require close collaboration with other state agencies and offices.

NRDC and RMI appreciate the opportunity to provide comment and we look forward to working with CARB and other stakeholders in developing a cement decarbonization strategy for the state.

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