Adoption of Limestone Calcined Clay Cement and Concrete in the US Market in the Drive to Net Zero

Pavitra Srinivasan, American Council for an Energy-Efficient Economy
Ali Hasanbeigi, Global Efficiency Intelligence
Nora Esram, American Council for an Energy-Efficient Economy

ABSTRACT

The addition of supplementary cementitious materials (SCM) to cement and concrete, which has been gaining acceptance over the past 15 years, is key to reducing the embodied carbon emissions of these ubiquitous materials through the material efficiency pathway. Limestone calcined clay in particular offers distinct advantages (broad availability, non-fossil sourced, low heat and energy requirements for production) over other SCMs from industrial waste (such as fly ash and blast furnace slag) when added to cement or concrete and is widely used internationally. While clay use has been limited in the United States, market interest may be increasing, based on initial results from pilot projects over the past 1–2 years.

This paper analyzes how we can increase the adoption of limestone calcined clay cement and concrete in the U.S. market by considering (1) potential applications and testing requirements for limestone calcined clay concrete to develop market confidence around its use; (2) technical, economic, and policy barriers to its use and solutions to overcome these barriers; (3) lessons learned internationally that may be applied in the U.S. context; and (4) the potential energy efficiency improvements and greenhouse gas reductions available from the use of limestone calcined clay cement and concrete on the path to decarbonizing the cement industry.

Introduction

Cement production is among the most carbon- and energy-intensive industrial sectors, accounting for roughly 7% of the world's total carbon dioxide (CO_2) emissions (Hasanbeigi et al., 2021). In 2020, the United States was ranked fourth in global cement production, with 89 million metric tons (Mt), while global cement production as a whole was about 4,300 Mt (USGS 2022). Cement production has been steadily increasing over the past few decades and is projected to continue growing, according to the International Energy Agency (IEA/WBCSD 2018). As a result, decarbonizing the cement industry will be crucial to meeting goals of the Paris Climate Agreement.

Cement manufacturing typically consists of three main steps:

(1) Raw materials and solid fuels are pre-processed using techniques like grinding, crushing, and drying.

(2) Clinker is produced either through the wet or dry process in a kiln, where raw materials are heated to temperatures of 1500°C, leading to the decomposition of calcium carbonate into calcium oxide and CO_2.

(3) Clinker is then ground with gypsum and other additives in a mill to produce cement. Cement is the key ingredient in concrete, a widely used building material.

Producing cement is a carbon-intensive process and is responsible for the bulk of the CO_2 emissions associated with concrete. Accordingly, reducing emissions from cement is key to overall reductions across the cement and concrete industries.

This paper explores the potential for using supplementary cementitious materials (SCM) and focuses on limestone calcined clay cement as an alternative to traditional Portland cement in reducing CO_2 emissions from cement and concrete production. We provide insights on the current status and adoption of limestone calcined clay cement globally, along with barriers to adoption and policy recommendations to promote use of limestone calcined clay cement in the United States.

The paper begins by introducing the current state of the cement industry in the United States, including production, consumption, and CO_2 emissions. Then it delves into the potential for using SCMs and the favorable properties of limestone calcined clay cement. Subsequent sections discuss international case studies on limestone calcined clay cement, providing evidence for its effectiveness in reducing CO_2 emissions while maintaining quality and durability. We also assess the current status of limestone calcined clay cement adoption in the United States and barriers to its acceptance and implementation, such as lack of awareness, regulations, and market incentives. Our analysis shows the CO_2 emissions reductions possible from the adoption of limestone calcined clay cement in the United States, and the paper concludes with policy recommendations and an action plan to promote the adoption of limestone calcined clay cement in the United States.

Cement Production and Consumption in the United States

The United States produced 89.3 Mt of Portland cement and masonry cement in 2020 and is the fourth-largest producer and consumer of cement in the world. Cement was produced at 96 plants in 34 states in 2020. Of those, 87 plants employed the dry kiln process, and 9 used the wet kiln process. Sales of cement in 2018 were around $12.7 billion. Texas, Missouri, California, and Florida have the highest cement production, in that order (USGS 2022). Total cement shipments to final customers in the United States was 102 Mt in 2020 (USGS 2022). Of this, around 47 Mt was used in public construction projects, which is 46% (PCA 2016) of total U.S. cement use. It should be noted that in the majority of cases, the government and its contractors do not purchase cement, but instead purchase concrete (mainly ready-mix concrete), which is the final product used in construction projects. The values shown in this paper include the cement used in concrete that is used in construction projects.

Figure 1 shows the total cement consumption for public and private construction in the United States and selected states. Among these states, Texas accounts for the highest cement consumption followed by California and Florida. Most of the selected states are among the top cement-consuming states in the United States. We used the share of cement used in public construction compared to the total cement used in the United States (46%) as a proxy for estimating the cement used for public construction in each state. Around 25% of total cement and concrete procured by governments in the United States is by means of federal funds, with the remaining by means of state and local government funds (Hasanbeigi and Khutal 2021). We used this 25:75 ratio to estimate government procurement of cement using federal funds, and state and local government funds in each state.

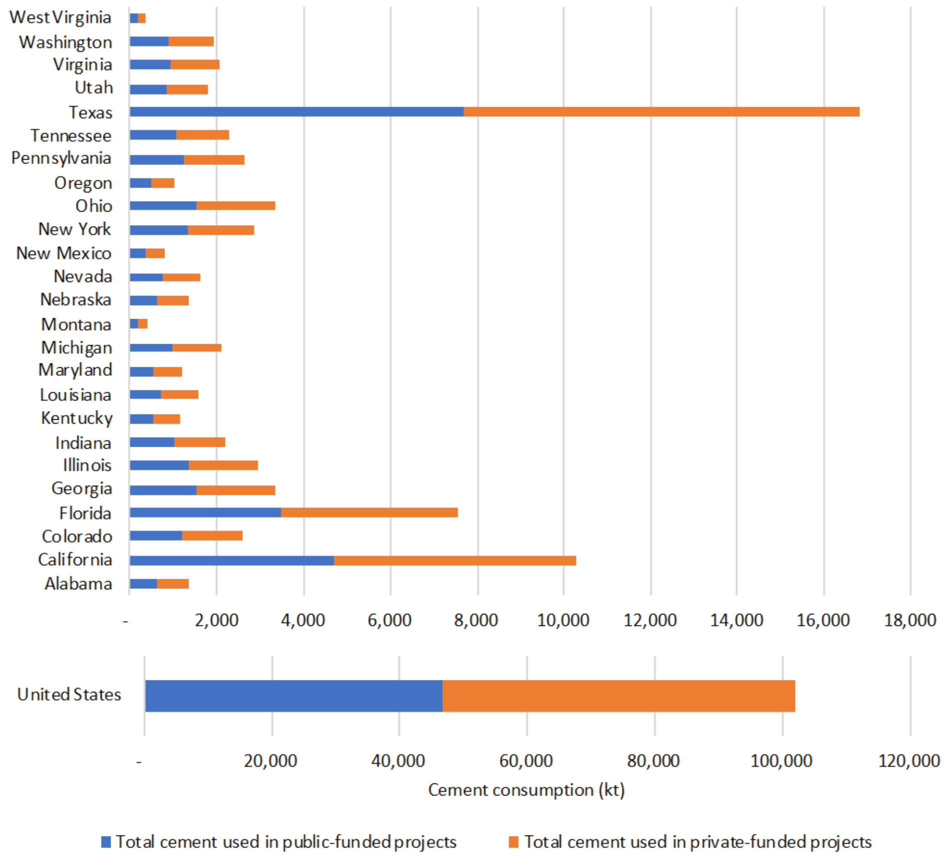

Figure 1. Total cement consumption for public and private construction in the United States and selected states in 2020 (Source: this study based on USGS 2022 and PCA 2016 data)

CO_2 Emissions from the U.S. Cement Industry

The U.S. cement industry emitted around 72 Mt of CO_2 in 2020 (calculated based on data from USGS 2022 and EPA 2022). Because CO_2 emissions result from calcium carbonate decomposition, 57% of CO_2 emissions from cement manufacturing are associated with the chemical reaction in the process and not the energy use. The other 43% of emissions can be attributed to energy-related CO_2 emissions (figure 2).

The CO_2 emissions from the cement industry can be reduced through energy efficiency improvements, clinker substitution with SCMs, use of alternative binding materials, switching from traditional fuels to alternative fuels, and carbon capture and storage (IEA 2018).

The limestone calcined clay cement that is the focus of this report is a type of SCM that can be used to substantially reduce CO_2 emissions from the cement industry. Below we discuss SCMs, in particular limestone calcined clay cement and different aspects of its application and potential for CO_2 emissions reduction, in more detail.

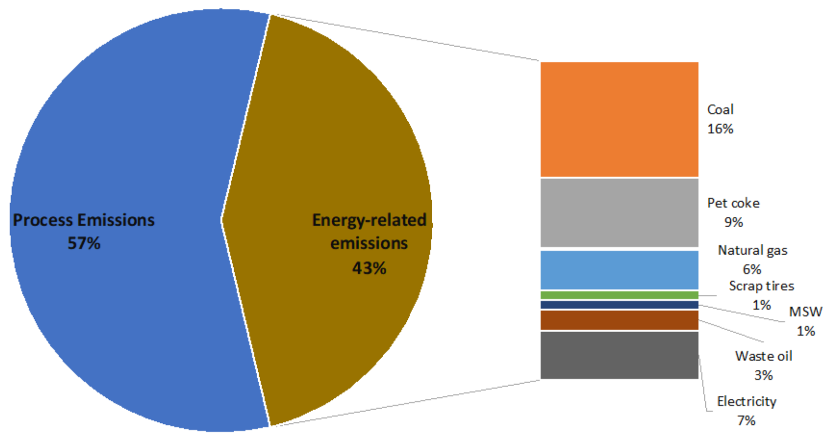

Figure 2. Shares of CO_2 emissions from the U.S. cement industry in 2020 (USGS 2022; EPA 2022)

Limestone Calcined Clay Cement

What Is Limestone Calcined Clay Cement?

Limestone calcined clay cement is a low-carbon alternative to the standard Portland cement that can reduce CO_2 emissions related to cement manufacturing by up to 40% by replacing some of the clinker with limestone and calcined clays (EPFL 2023). Limestone calcined clay cement is a blended cement where the synergy between calcined clay and limestone allows for the reduction in clinker factor by 0.5. This reduction in the clinker factor in cement has emerged as a promising solution for CO_2 emissions reduction from cement and concrete production in the near term. Limestone calcined clay cement has been extensively tested and is proven to reach ordinary Portland cement performance, making it a highly efficient and reliable option for construction projects (Krishnan et al. 2019; EPFL 2023).

Limestone calcined clay cement is globally scalable as the raw materials—limestone and calcined clay—are abundantly available worldwide, unlike other commonly used SCMs such as fly ash or slag. Additionally, limestone calcined clay cement is cost effective, with production costs up to 25% lower than ordinary Portland cement due to savings in energy and materials. Limestone calcined clay cement is already being produced in several plants worldwide, making it a highly attractive option for the cement industry to reduce its carbon footprint. Limestone calcined clay cement provides the required concrete strength and durability and also improves the workability of concrete. It can be used in a wide range of applications, such as residential buildings, commercial buildings, roads, and pavements. (Scrivener et al. 2018; Duan et al. 2020).

It should be noted that energy is needed to calcine the raw clay before using it in limestone calcined clay cement production. However, the energy needed to calcine a tonne of raw clay is lower than the fuel needed for production of the clinker that calcined clay replaces because of the lower temperature needed to calcine clay (lower than 800°C) compared to traditional clinker production (around 1500°C) (EPFL 2023).

Limestone calcined clay cement has favorable mechanical properties, including strength similar to Portland cement, and more durability than other cement mixtures. Limestone calcined clay cement is suitable for a range of structural applications, including parking lots, roads, bridges, and buildings, with case studies showing that it meets strength requirements and emits less CO_2 over its lifecycle than Portland cement. Limestone calcined clay cement may exhibit slightly lower compressive strength in the earlier timelines but can exceed the strengths of Portland cement past 90 days because of main chemical reactions that occur during hydration. Limestone calcined clay cement also exhibits better durability than Portland cement and some blended cements with other SCMs like fly ash, particularly in terms of chloride resistance, alkali silica reaction resistance, and resistance to marine environments. Recycled aggregate concrete could also be combined with limestone calcined clay cement to achieve higher sustainability while maintaining sufficient mechanical properties (Guo et al 2022; Dhandapani et al. 2018; Pillai et al. 2019; Scrivener 2019). The compressive strength of limestone calcined clay cements has also been shown to be similar to that of ordinary Portland cement.

Research to further advance the development and commercialization of limestone calcined clay cements is ongoing (Sánchez et al., 2019).

Status and Adoption of Limestone Calcined Clay Cement/Concrete in the United States

Limestone calcined clay cement is already covered in the ASTM Standard C595 and C595m for Blended Hydraulic Cement, and certain formulations are covered under ASTM C618, so it enjoys acceptance in the standards community.

In the1930s, calcined shale was used in the Golden Gate Bridge and Bay Bridge construction projects. The Golden Gate Bridge is still standing, and while a new Bay Bridge was constructed to better accommodate seismologic activity, the eastern span of the unused old bridge stood until it was dismantled in 2014.

In 1997, one company patented a cementitious product, by inter-grinding a calcined high-quality kaolin with clinker and optimized gypsum content. In the 2000s, Class F fly ash was abundant in the market at a low cost, achieving similar product performances, and this same cementitious product switched to using fly ash. As high-quality fly ash has become less available and more costly, calcined clay use was resurrected at the company in 2017. Currently, the company manufactures its product as a blended cement with calcined clay. This natural pozzolan falls under the Class N designation for natural pozzolan in ASTM C618 (Ash Grove 2023). Most recently, the Ashgrove Cement Company conducted a pilot project in which it converted one of its rotary kilns at its Midlothian, Texas, plant to produce calcined clay cement exclusively.

Minnesota (MN) Department of Transportation (DOT) is in the process of conducting a pilot of several concrete products as part of its MN Road Initiative in partnership with the National Road Research Alliance (NRRA), which operates in 11 states and is designed to test new technologies in a real-world environment. The MN Road demonstration project is a critical step in a transition to new materials for road and infrastructure construction and is strongly supported by FHWA, MNDOT, and industry. One of the products tested in the Minnesota pilot was a non-traditional blended hydraulic cement, which was expected to be limestone calcined clay concrete (consisting of 50% Portland cement clinker, 15% ground limestone, and 30% calcined clay known as LC3), supplied by Ash Grove Cement, but ended up being a slightly different mix (not LC3).

General project requirements involved ensuring Portland limestone mixtures used an American Society for Testing and Materials ASTM C595 Type IL (20) blended cement, mixtures met performance requirements based on American Association of State Highway and Transportation Officials (AASHTO) R 101 Developing Performance Engineered Concrete Pavement Mixture (required 500psi flex at 28 days, 5-8% air), and the product was batched and mixed at a central plant and paved using slip form paving equipment. The pilot consists of a section of pavement 250 ft long by 27 ft wide (2 lanes and shoulders) paved with the clay concrete product and being evaluated for performance over a 2-year period and development of a lifecycle assessment (LCA). The pilot included identifying material providers, establishing mixture requirements, managing trial batching, and structuring a testing program. Initial results appear to indicate good compressive strength and other early performance characteristics (Sutter et. al., 2023).

Environmental product declarations (EPD) are not available for LC3 because of the requirement that a production facility be in continuous operation for at least 1 year before generating an EPD for inclusion in the Building Transparency-operated EC3 EPD database and repository. The Federal Highway Administration (FHWA) is working with the National Renewable Energy Laboratory's (NREL) LCA Commons database to provide the necessary lifecycle inventory (LCI) data for EPD development (Sutter et. al., 2023).

Although there has been limited experience with limestone calcined clays in the United States, there is growing interest evidenced by the increase in conference presentations, workshops, and discussion of pilots and demonstration projects. Additionally, there is increasing cement and concrete company interest in identifying sources of and using clays in products.

International Case Studies for Limestone Calcined Clay Cement

The use of limestone calcined clay cement has been studied in several countries around the world, including India, Brazil, Colombia, and Cameroon. We explore international case studies on the use of limestone calcined clay cement in different countries and discuss the findings and implications of these studies.

India. One of the earliest and most extensive case studies on the use of limestone calcined clay cement was conducted in India. The study was funded by The Swiss Agency for Development and Cooperation, and it involved the construction of a building using limestone calcined clay cement as the primary binder, shown in figure 5. The concrete produced from limestone calcined clay cement had a compressive strength of 40 MPa, which is comparable to concrete from traditional ordinary Portland cement (Bishnoi et al., 2014).

China. In China, researchers conducted a case study on the use of limestone calcined clay cement in concrete production and found that it had compressive strength comparable to concrete produced from ordinary Portland cement. The researchers found that limestone calcined clay cement could be used in high-stress applications and could help reduce the carbon footprint of infrastructure projects in China (Huang et al., 2020).

Brazil. In Brazil, a case study compared the performance of limestone calcined clay cement and concrete to traditional ordinary Portland cement and concrete in the construction of a residential building. The concrete produced from limestone calcined clay cement had a compressive strength of 47 MPa, slightly higher than the concrete produced from ordinary Portland cement. The concrete produced from limestone calcined clay cement also had a carbon footprint up to 38% lower than the concrete produced using traditional ordinary Portland cement (Euler et al., 2023).

Colombia. In Colombia, Argos has developed commercial production of limestone calcined clay cement since 2020. It is reported that the technology cuts energy consumption by 30% and reduces carbon output by almost half (EPFL, 2020). The plant can produce 0.45Mt/yr of calcinated clay and is the first major cement plant to install such a line following smaller trials in Switzerland, India, and Cuba (Global Cement, 2023).

Cuba. The case study of limestone calcined clay cement in Cuba aimed to assess its economic and environmental potential in the Cuban context. The study was conducted collaboratively by CIDEM and the Laboratory of Construction Materials at EPFL. The Cuban cement industry has been using limestone calcined clay cement since 2011 and has found it to be a promising solution to meet the growing demand for cement while reducing GHG emissions. The study compared limestone calcined clay cement with traditional Portland cement and commercial blended cement with zeolite sold in Cuba. Results showed that limestone calcined clay cement reduced production costs 15-25% compared to conventional solutions and reduced GHG emissions up to 20-23% compared to business-as-usual practice (Diaz et al. 2017; Sanchez Berriel et al. 2016).

Cameroon. Germany-based ThyssenKrupp Industrial Solutions is building a 720t/day calcined clay and a 2400t/day cement production capacity for Oyak Çimento at Kribi in Cameroon. It will use the supplier's "polysius activated clay" technology. This plant was expected to be commissioned in late 2021 (Perilli, 2022).

Ghana. CBI Ghana's plant near Accra is developing a new clay calciner system expected to substitute 30–40% of the clinker in the final product, resulting in a reduction of up to 40% CO_2/t of blended cement compared to ordinary Portland cement. Overall, the grinding plant will reduce its CO_2 emissions by 20% compared to its current output. CBI Ghana expects energy and fuel savings, as well as lower overheads from clinker imports (Perilli, 2022).

These international case studies provide further evidence for the potential of limestone calcined clay cement as a sustainable alternative to traditional ordinary Portland cement. While further research is needed to fully evaluate the performance and long-term durability of limestone calcined clay Cement, these studies suggest that it could play an important role in reducing the carbon footprint of the construction industry around the world.

CO_2 Emissions Reduction Potential of Limestone Calcined Clay Cement in the United States

Figure 3 shows annual CO_2 emissions associated with cement used in the United States and selected states in 2020. We used the weighted average CO_2 intensity of cement produced in the United States and net imported cement to calculate annual CO_2 emissions associated with cement consumption. Around half of the annual CO_2 emissions linked with cement consumption are associated with public construction, which was around 37 Mt CO_2 in 2020. Therefore, government procurement has significant leverage in incentivizing decarbonization of cement production through various decarbonization measures including the use of limestone calcined clay cement.

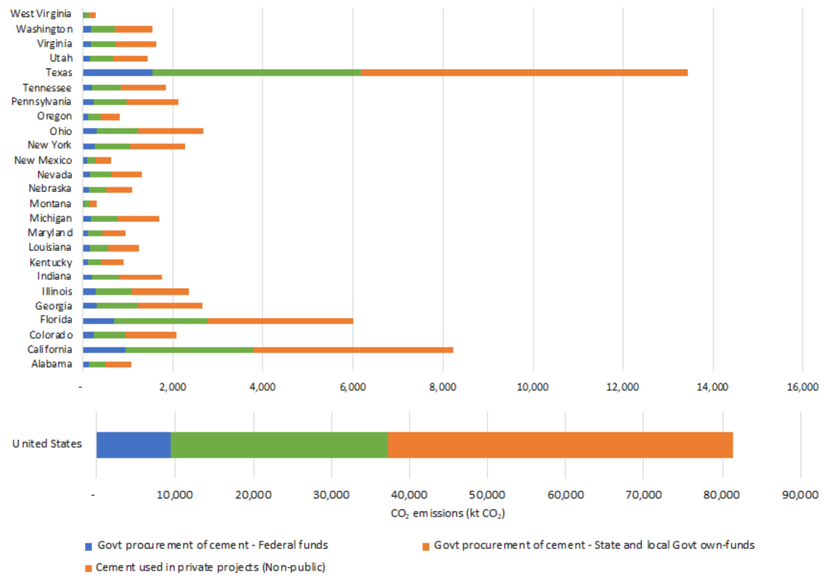

Figure 3. Annual CO_2 emissions associated with cement used in the United States and selected states as of 2020 (source: this analysis)

To estimate the potential impact of the use of limestone calcined clay cement on CO_2 emissions associated with cement used in the United States, we developed several scenarios with various rates of adoption for limestone calcined clay cement as a share of total cement demand nationally and in selected states (table 1). Based on how much limestone calcined clay cement replaces ordinary Portland cement in each scenario, we calculated a weighted average cement CO_2 intensity for the cement used. We assumed the CO_2 intensity of limestone calcined clay cement is 30% lower than the CO_2 intensity of Portland cement. It should be noted that the literature reports a CO_2 intensity reduction of up to 40% is reported for limestone calcined clay cement (Krishnan et al. 2019; EPFL 2023).

Table 1. Limestone calcined clay cement adoption scenarios for the cement industry in the United States

Scenario	Share of total cement demand replaced with limestone calcined clay cement (%)	Weighted average cement CO_2 intensity ($kgCO_2$/t cement)
Baseline	-	799
Low	10%	775
Medium	20%	751
High	30%	727
Transformative	50%	679

Using the annual CO_2 emissions associated with cement use in the United States presented above and the scenarios defined in table 1, we estimated the annual CO_2 emissions reduction potential resulting from limestone calcined clay cement adoption nationally and in selected states under different scenarios based on 2020 emissions data (figures 4-8).

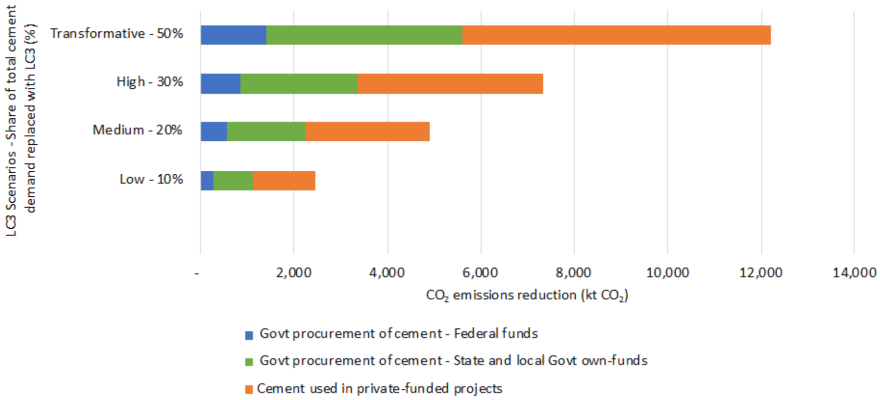

Figure 4. Annual CO_2 emissions reduction potential resulted from limestone calcined clay cement adoption under different scenarios in the United States in 2020

Under the Low scenario of limestone calcined clay cement adoption, annual emissions reduction of 1.1 Mt CO_2 can be achieved directly from government procurement of cement for construction. This annual CO_2 emissions reduction potential from government procurement of cement would increases to 3.4 Mt CO_2 and 5.6 Mt CO_2 under the High and Transformative scenarios, respectively. The potential CO_2 emissions reduction impacts from the adoption of limestone calcined clay cement in the U.S. market would more than double if we consider the potential impact from the limestone calcined clay cement used in non-public construction projects. The potential impacts of limestone calcined clay cement adoption in select states are shown in figures 4-8.

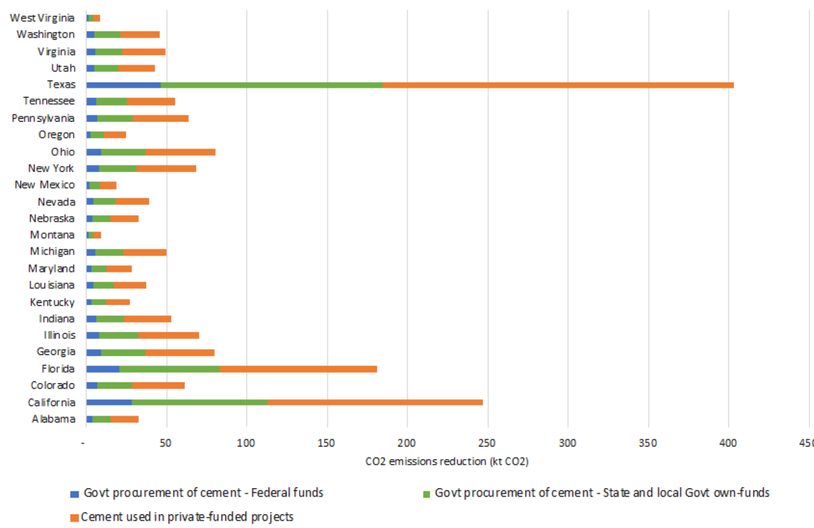

Figure 5. Annual CO_2 emissions reduction potential compared to 2020 resulting from limestone calcined clay cement adoption in select states – Low scenario (10% of cement consumption replaced with limestone calcined clay cement)

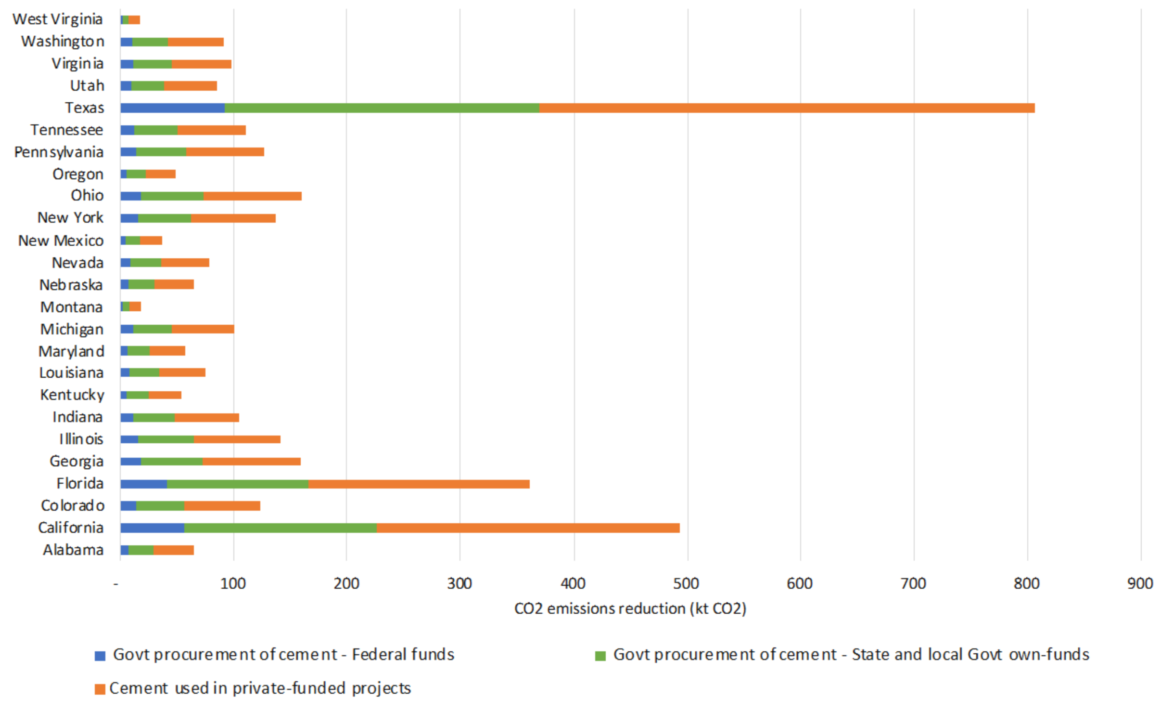

Figure 6. Annual CO_2 emissions reduction potential resulted from limestone calcined clay cement adoption in the selected states in 2020 – Medium scenario (20% of cement consumption replaced with limestone calcined clay cement)

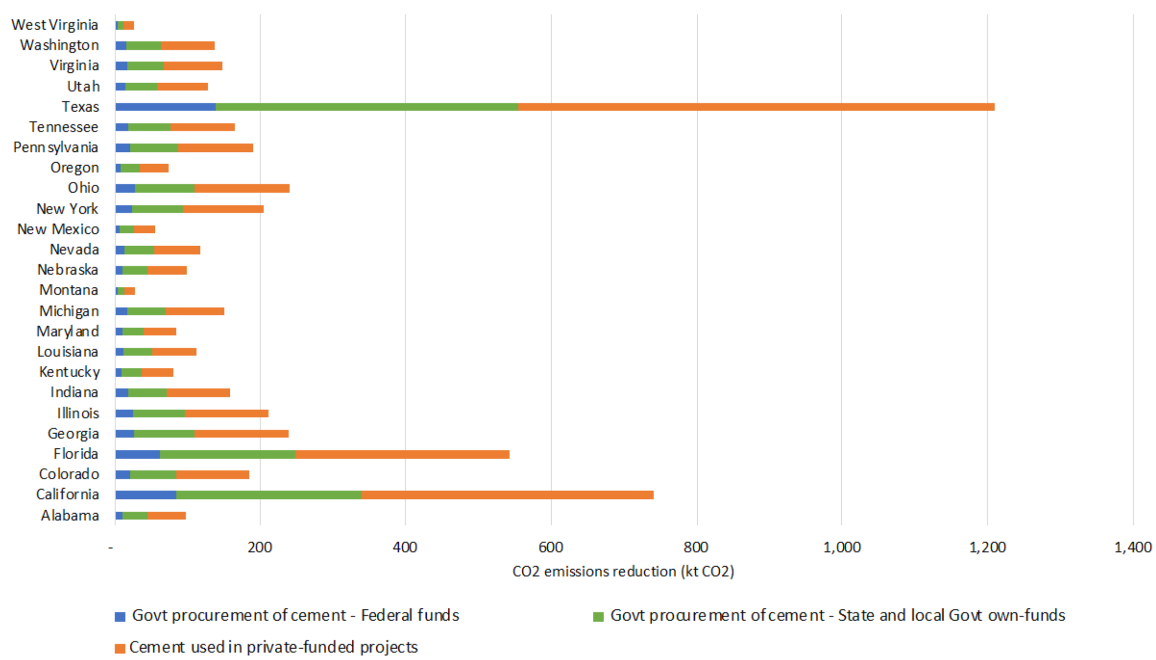

Figure 7. Annual CO_2 emissions reduction potential resulted from limestone calcined clay cement adoption in the select states in 2020 – High scenario (30% of cement consumption replaced with limestone calcined clay cement)

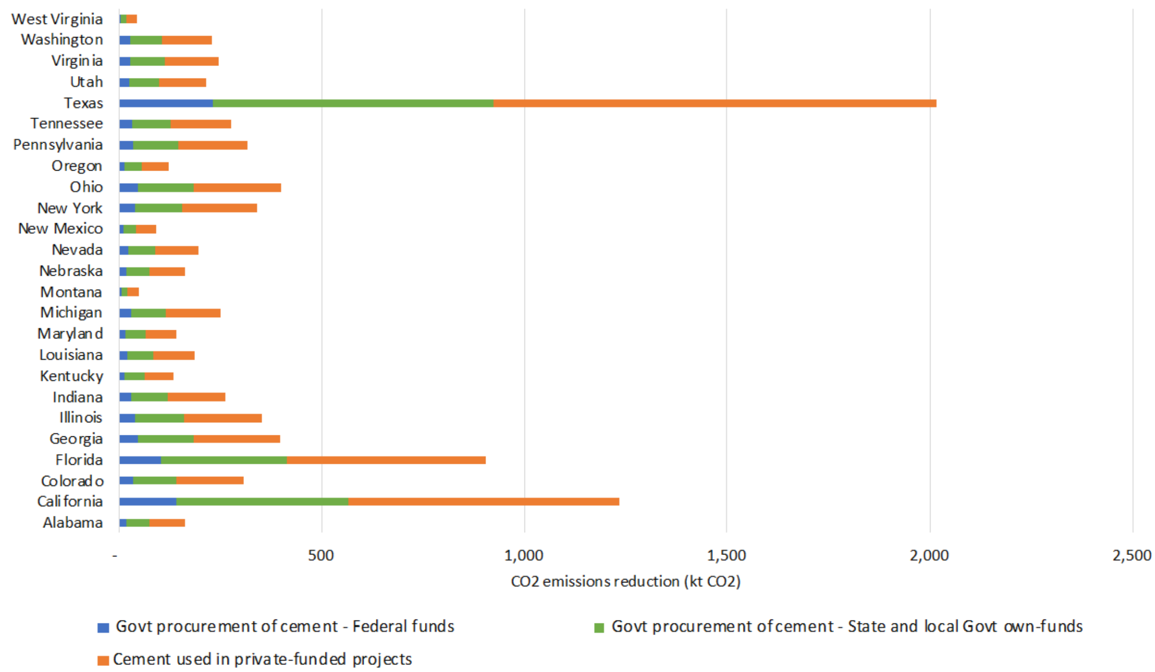

Figure 8. Annual CO_2 emissions reduction potential resulted from limestone calcined clay cement adoption in the selected states in 2020 – Transformative scenario (50% of cement consumption replaced with limestone calcined clay cement)

Barriers to Adoption of Limestone Calcined Clay Cement in the United States

The use of calcined clay in concrete has faced several barriers in the U.S. market. Technical barriers include the fact that clay activated in a rotary kiln system is less reactive and typically allows for only 15–25% substitution in concrete (FLSmidth, 2020). Additionally, the use of calcined clay affects the workability of concrete, which can be somewhat mitigated with the use of superplasticizers (Specify Concrete, 2021). Substituting ordinary Portland cement with limestone calcined clay cement requires higher mixing energy due to the extended dry-to-paste transition phases with an increase in limestone calcined clay cement content, and 50% substitution of ordinary Portland cement by limestone calcined clay cement has led to a considerable reduction in compressive strength and lower flexural strength values. The lack of infrastructure for producing and distributing limestone calcined clay cement is another barrier (Wang et al., 2021, (Ez-zaki et al., 2021).

Current industry standards and codes for cement production may not accommodate the use of alternative materials like calcined clay. This can make it challenging for limestone calcined clay cement producers to meet the specifications, which can limit adoption in the market. However, limestone calcined clay cement fulfills requirements through the standard ASTM C 595/C595M – 16 “Standard Specification for Blended Hydraulic Cements”, 21 which allows as little as 45% clinker, plus the combination of up to 15% limestone and up to 40% pozzolan (Fernando and Scrivener, 2019).

Policy barriers include the lack of regulation and incentives for using low-carbon cement alternatives like limestone calcined clay cement (Kavya Sree et al., 2021). The current regulatory framework for cement production in the United States does not provide incentives for the adoption of low-carbon cement alternatives like limestone calcined clay cement. The absence of a carbon tax or other carbon pricing mechanism disincentivizes companies from investing in low-carbon cement production processes. Also, current procurement policies of the U.S. government and other major consumers of cement do not prioritize low-carbon alternatives. This makes it difficult for companies that produce limestone calcined clay cement to compete in the market and for customers to choose low-carbon options. This is slowly changing with the introduction of a Buy Clean policy at the federal level and in a few states such as California, Washington, and Oregon (Hasanbeigi et al. 2021).

Also, there may be a lack of awareness and understanding of limestone calcined clay cement among policymakers, industry stakeholders, and the public. Education and outreach efforts are necessary to increase awareness of the benefits of limestone calcined clay cement and encourage its adoption in the industry.

Policy Recommendations and Action Plan

Below we list actions that governments, and cement and concrete companies can take to help with the adoption of limestone calcined clay cement in the United States.

Actions by U.S. Cement and Concrete Producers

Invest in limestone calcined clay cement production technology. Producers of cement and concrete can do this by upgrading or constructing manufacturing facilities that use limestone calcined clay cement technology. This could raise the manufacturing capacity in the United States.

Conduct research and development. To enhance the performance of limestone calcined clay cement and its compatibility with various concrete mix designs, cement and concrete makers can engage in research and development. Work on enhancing the workability, setting time, strength, and durability of concrete based on limestone calcined clay cement will fall under this activity.

Create collaborations with suppliers and contractors. To expand the accessibility and availability of limestone calcined clay cement in the market, cement and concrete makers can create partnerships with suppliers and contractors. This may entail collaborating with vendors to provide a dependable supply chain, ensuring the availability of limestone calcined clay cement at the right cost, and working with contractors to promote the use of limestone calcined clay cement in their projects.

Collaborate with governmental organizations. Cement and concrete producers can work with governmental organizations to create policies and guidelines that encourage the use of limestone calcined clay cement in construction. This can involve offering suggestions and criticism on proposed regulations and collaborating with government organizations such as the U.S. Department of Energy (DOE) and its national labs to provide technical resources and experience.

Participate in limestone calcined clay cement standardization initiatives. To guarantee the quality and uniformity of the product, cement and concrete companies can take part in limestone calcined clay cement standardization initiatives. This may entail establishing limestone calcined clay cement standards and certification procedures in collaboration with regulatory authorities and standards organizations and ensuring adherence to these standards.

Educate customers and stakeholders. Cement and concrete manufacturers can help educate customers and stakeholders about the advantages of limestone calcined clay cement and how to use it in projects. This can involve offering technical assistance, education, and resources, as well as launching marketing and public relations initiatives to advance the usage of limestone calcined clay cement.

Conduct limestone calcined clay cement trials. To examine the performance of the product and pinpoint areas for development, cement and concrete makers can carry out small-scale limestone calcined clay cement studies. This could stimulate further industrial adoption of limestone calcined clay cement and help boost its reputation and market confidence.

Actions by Federal and State Governments

Create procurement policies. The General Services Administration (GSA) which is responsible for all federal procurement, and state-level procurement agencies can create procurement guidelines that encourage the use of limestone calcined clay cement along with other sustainable building materials. This may involve establishing limestone calcined clay cement certification criteria, setting goals for the usage of limestone calcined clay cement in government construction projects, and offering incentives to contractors to do so. Federal and state Buy Clean policies can help promote the use of limestone calcined clay cement to enable and meet greater long-term reductions in emissions.

Finance research and development. The government can finance limestone calcined clay cement research and development, including studies on its functionality and performance. Universities and some DOE national labs have the capacity to conduct the needed research for limestone calcined clay cement.

Provide tax incentives. The government can offer tax breaks for the manufacture and use of limestone calcined clay cement technology, including accelerated depreciation for limestone calcined clay cement manufacturing equipment and tax credits for limestone calcined clay cement production.

Develop standards for limestone calcined clay cement. Standard-setting and certification agencies can develop standards for limestone calcined clay cement to ensure its quality and consistency. These standards can cover various aspects of limestone calcined clay cement production, such as raw material selection, calcination temperature, and grinding procedures, as well as performance requirements for limestone calcined clay-based cement and concrete.

Include limestone calcined clay cement in existing standards. Standard and certification agencies can include limestone calcined clay cement in their existing standards for cement and concrete. This can help promote the use of limestone calcined clay cement by providing a recognized framework for its use.

Promote the use of limestone calcined clay cement in building codes and material specification lists. The federal government can encourage the use of limestone calcined clay cement in building codes and state governments can add limestone calcined clay cement and concrete to state DOT material specification lists, for example, by including limestone calcined clay cement as a permitted material or by developing distinct codes for sustainable materials.

Provide technical assistance and education. The government can provide technical assistance and education on limestone calcined clay cement, including providing training and resources to industry professionals on the use of limestone calcined clay cement in construction projects.

Cooperate with industry stakeholders. To encourage the use of limestone calcined clay cement in the construction sector, standard-setting and certification organizations can work together with industry stakeholders. This may entail working in collaboration with trade associations and academic institutions to create limestone calcined clay cement standards and certification programs, as well as promoting limestone calcined clay cement at trade shows and other events.

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