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CONCRETE SOLUTIONS GUIDE

Use Green Heat

Decarbonize Kiln Technology

Cement kilns are the site of 90% of the emissions associated with concrete production. Although 50% of these emissions are produced directly from the calcination of limestone,[1] and can therefore only be eliminated through the use of SCMs or carbon capture and storage, the remaining 50% of emissions can be mitigated through interventions at the kiln itself.

Key Takeaways

Cement kilns are responsible for 90% of emissions in concrete produced with portland cement.

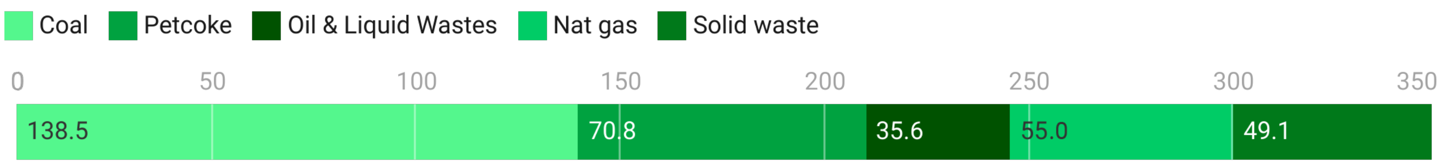
Despite the long life of kilns and challenges of deep retrofits, reducing the emissions from process heat can be accomplished with fuel switching and efficiency upgrades.

These low-risk, high-yield opportunities have the potential to deliver 18% emissions reductions without requiring deep retrofits.[2]

Opportunity

More than 90% of the readily mitigable emissions at kilns come from burning fossil fuels to reach the high temperatures required to drive the clinker sintering reactions. In the past several decades, US kilns have already made terrific gains in energy efficiency, logging a 53% reduction in the energy intensity of kilns between 1970 and 2017, due in part to the shift away from wet kilns. However, these emissions remain high, and there are ample opportunities for further reducing these emissions through efficiency improvements (as demonstrated by the EPA's ENERGY STAR program[3]) and switching to biomass or other low-carbon fuels. Many of these improvements will also deliver cost savings for cement producers.

Exhibit 6: Energy consumption in US cement kilns by fuel type (PJ/y)



Fuel usage in cement kilns is dominated by fossil sources. There are opportunities to utilize sustainably produced biomass-based fuels to reduce emissions.

Considerations

Data from the US Geological Survey on the fuel mix used by cement kilns indicates that approximately 60% of heat comes from coal-based fuels, with the remainder from natural gas and wastes.[4] Although waste fuels can be cost effective and provide certain environmental benefits (e.g., avoiding the landfill), these fuels can also cause localized issues, such as airborne particulate matter.

One near-term opportunity for cement kilns to reduce the emissions associated with heat generation is to switch to sustainably produced biomass-based fuels. Life-cycle emissions impacts of different types of biomass should be taken into account and factored into the decision-making process. Widespread adoption would require some expansion in biomass fuel availability, but the additional demand associated with switching all US cement production to biomass fuels (~350 PJ) is

equivalent to just 7% of the total biomass energy produced in the United States in 2019 (~5,300 PJ). There are further barriers to biomass uptake besides supply and distribution, including lack of clarity from regulators on permitted fuels, lengthy permitting timeframes for new fuels, and preference for certain fuels among local communities.

The switch to biomass would likely increase fuel costs compared with the current mix. Energy efficiency improvements could help to limit this impact by reducing the required amount of biomass fuel required. Based on biomass price ranges from IRENA,[5] wood wastes, agricultural residues, and landfill gas could be cheaper than coal in some instances and would be less expensive than natural gas in almost all cases. For example, coal costs to produce a ton of cement are US$5.85, whereas the lowest-cost wood waste (US$0.50/GJ) would only cost about US$2.00 per ton of cement. However, the supply of these alternative fuel sources is limited. Costs also vary significantly based on the proximity of the cement producer to a suitable biomass feed source. While these issues add a degree of friction to fuel transition at kilns, they are well-defined problems with straightforward solutions.

Oxygen enrichment can also reduce fuel demand by 3%–5% by limiting the amount of nitrogen that is heated in the kiln. This effectively allows for some electrification of the kiln energy requirement, as direct fuel consumption is replaced with electrical energy for oxygen production. The total amount of abatement from this strategy is dependent on the emissions intensity of the electricity source. Oxygen enrichment may also assist in positioning a kiln for carbon capture and storage (CCS) in the future, as it will increase the carbon dioxide concentration in the off-gas.

Additional fuel options may be available in the future, depending on the success of ongoing research and development. These include the possibility of using green hydrogen or direct electrification of high-temperature processes (e.g., using a plasma torch).

Lastly, electricity consumption at cement kilns (primarily associated with grinding of clinker) can be further reduced to achieve improved efficiency. For example, replacing ball mills with vertical roller mills can reduce grinding energy by 25 kWh/ton while providing operating cost savings of 30%–40%. Recovery of waste heat for cogeneration (or on-site renewable generation) of electricity would also assist in reducing the external electricity demand and associated emissions. In some markets, the existing regulatory regime presents a barrier to implementing this strategy, as concrete producers are subject to fixed charges from utilities.

Related Solutions

2. Mix It Up: Supplementary cementitious materials (SCMs)

State of the Market

The ENERGY STAR program has an industry benchmarking system for both cement and concrete production facilities. These systems offer a detailed guide for energy efficiency improvements and cost-saving opportunities in cement making, which can be found in our additional resources at the end of this guide. The benchmarking program allows facilities that receive a rating of at least 75 out of 100 to carry the ENERGY STAR label, which developers and concrete producers can look for when procuring cement.

Despite the resources available and the cost-effectiveness of efficiency upgrades, there is still substantial room for improvement. A 2013 ENERGY STAR guide for the cement industry reported that the highest-efficiency kilns use 2.9 GJ/ton, which is 27% less than the current average. These reductions are primarily achieved by the recycling of heat through the incorporation of multistage pre-heaters and pre-calciners. Exhibit 6 indicates the cost and carbon savings still left on the table.

Endnotes

1. Madeleine Rubenstein, "Emissions from the Cement Industry," *Columbia Climate News*, May 9, 2012, **https://news.climate.columbia.edu/2012/05/09/emissions-from-the-cement-industry/.**

2. Hasanbeigi and Springer, *Deep Decarbonization Roadmap for the Cement and Concrete Industries in California,* 2019.

3. "ENERGY STAR Focus on Energy Efficiency in Cement Manufacturing," ENERGY STAR, accessed May 11, 2021, **https://www.energystar.gov/industrial_plants/measure-track-and-benchmark/energy-star-energy-1.**

4. Kenneth C. Curry and Hendrik G. van Oss, "Cement," in 2017 *Minerals Yearbook*, USGS, August 2020, **https://prd-wret.s3.us-west-2.amazonaws.com/assets/palladium/production/atoms/files/myb1-2017-cemen.pdf.**

5. *Biomass for Power Generation*, IRENA, June 2012, **https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2012/RE_Technologies_Cost_Analysis-BIOMASS.pdf.**

Charles Cannon, Valentina Guido, and Lachlan Wright, ***Concrete Solutions Guide: Six Actions to Lower the Embodied Carbon of Concrete,*** **RMI, 2021, http://www.rmi.org/concrete-solutions-guide/.**

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