EXECUTIVE SUMMARY

ASSESSMENT OF LOW-CARBON FUEL PATHWAYS FOR THE CEMENT AND GLASS INDUSTRIES

The cement and glass manufacturing industries are energy intensive. Together, the two industries consume around 450 trillion Btu (475 trillion kJ) of energy,[1] of which the cement industry contributes more than one-half of the total final energy. These industries also produce significant emissions. In 2020, the combined carbon dioxide (CO_2) emissions from these two sectors were about 75 million metric tons of CO_2 equivalent (CO_2e), comprising about 70% of total emissions from the minerals subsector.[2] Addressing these emissions is key to achieving economy-wide decarbonization goals.

This report describes incumbent fuels, process flows, and source emissions in the cement and glass manufacturing industries. It then specifies potential decarbonization pathways that rely on alternative (low-carbon) fuels and other technological innovations.

Key findings from the full report include:

- Measures to improve both electrical and thermal energy efficiency can lower carbon emissions in the cement and glass industries. Electrical energy efficiency can be improved by using modern machinery (including advanced grinding machinery), increasing automation, and using variable-speed drives. Thermal energy efficiency in the cement industry can be enhanced by replacing older wet-kiln technology with dry kilns and implementing waste heat recovery systems. The primary challenge to incorporating energy efficiency measures is the significant capital investment.
- Among alternative fuel options for both industries, waste-derived fuels—created from tires, sawdust, waste oils, sludge, and other types of waste—are most promising because they are less expensive, offer a lower carbon footprint, and are an effective method of waste management. In addition to replacing incumbent fossil fuels, using waste as fuel also reduces landfill-related emissions.
- Biomass fuels derived from hemp, sorghum, willow, switchgrass, and oat hulls are potential candidates for fuel substitution. However, biomass fuel is more expensive than both fossil fuel and waste-derived fuel.
- Hydrogen is gaining momentum as a potential fuel constituent in the cement and glass industries. Some manufacturers are investigating the use of hydrogen in combination with biomass-based fuels.
- Carbon capture and sequestration (CCS) is a promising means of decarbonization that can address CO_2 emissions from both fuel combustion and process emissions. However, capturing CO_2 and producing a concentrated CO_2 stream is challenging and costly.

1. U.S. Energy Information Administration, "Manufacturing Energy Consumption Survey (MECS), 2018 MECDS Survey Data, Table 1.1 First Use of Energy for All Purposes (Fuel and Nonfuel), 2018," February 2021, https://www.eia.gov/consumption/manufacturing/data/2018/pdf/Table1_1.pdf.
2. U.S. Environmental Protection Agency, "GHGRP Minerals Sector Profile," https://www.epa.gov/ghgreporting/ghgrp-minerals-sector-profile.

- Substituting carbonated raw materials (which contain carbon such as limestone or calcium carbonate that must be removed during processing) with decarbonated raw materials (in which carbon has been removed before processing) could reduce process emissions in the cement industry. Fly ash (a waste product of coal and biomass combustion) and blast furnace slag are examples of decarbonated raw materials. Cement created from fly ash and slag, known as geopolymer cement, is currently produced in small-scale demonstrations. In the glass industry, mineral slags, waste incineration ashes, and other secondary raw materials are currently being explored to replace carbonated raw materials.[3] Availability of decarbonized raw materials is a key challenge across these two sectors.
- Novel cements and clinker substitution present decarbonization options for the cement industry. An important element in the manufacturing process, clinker (the precursor to cement) is produced by grinding limestone and clay and mixing the result in high-temperature kilns. In clinker substitution, traditional clinker is blended with alternative materials such fly ash, slag, or silica fume to reduce carbon emissions. Cement formed through clinker substitution is known as supplementary cementitious material. Pozzolans (silica-based materials that can form cementitious material under specific conditions) such as clay and shale can also be used in clinker substitution, and new cement manufacturing processes that rely on plentiful basalt as a primary feedstock are under development. Advancing these new cement manufacturing approaches requires significant process changes and techno-economic analysis conducted at scale to impact overall emissions from the cement industry.
- In glass manufacturing, using recycled glass (also called cullet) can reduce energy consumption. Mixing recycled glass with raw materials is an efficient waste-management method that also helps conserve natural resources used to produce glass. Because recycling glass does not generate processing byproducts, overall glass processing requires less heat, which reduces fuel use and extends furnace life. In theory, glass can be recycled indefinitely without losing quality, contributing to a more sustainable manufacturing process.

This report describes potential decarbonization solutions for the cement and glass industries. The report includes an overview of each manufacturing process and its associated emissions. The report then presents key low-carbon alternatives under consideration to mitigate the industries' emissions, discusses adoption barriers, and identifies research needs.

3. Glass Worldwide, "Glass Experts Seek Carbon-free Glassmaking Materials," undated, https://www.glassworldwide.co.uk/Articles/glass-experts-seek-carbon-free-glassmaking-materials.

The Low-Carbon Resources Initiative

This report was published under the Low-Carbon Resources Initiative (LCRI), a joint effort of the EPRI and GTI Energy addressing the need to accelerate development and deployment of low- and zero-carbon energy technologies. The LCRI is targeting advances in the production, distribution, and application of low-carbon energy carriers and the cross-cutting technologies that enable their integration at scale. These energy carriers, which include hydrogen, ammonia, synthetic fuels, and biofuels, are needed to enable affordable pathways to economy-wide decarbonization by mid-century. For more information, visit www.LowCarbonLCRI.com.

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