To The Point
Carbon Capture in the Cement Industry

Globally, cement production accounts for about 7% of total greenhouse gas (GHG) emissions, one of the largest sectoral carbon footprints on the planet.[1] In 2021, the US cement industry produced approximately 93 million metric tons of Portland and Masonry cement. This cement production produced about 69 million tons of carbon dioxide (CO_2) emissions, representing nearly 5% of the US industrial sector GHG emissions and just over 1% of US total GHG emissions.[2]

Emissions Contributors

Over 85% of the CO_2 emissions associated with the production of cement are largely from two primary contributors:

- Clinker production, which involves the calcination of limestone and releases CO_2 as a byproduct.
- CO_2 generated from the combustion of carbon-based fuels to heat the cement kiln to high temperatures needed for the reaction during the manufacturing process.

The remaining CO_2 emissions are primarily attributed to electricity used to run machinery, such as crushers and fans, and the fuels combusted on-site, such as diesel for loaders, compressors, and trucks.[3]

Carbon Capture Technology

Carbon capture, also known as carbon capture utilization and storage (CCUS), offers an effective solution for the cement industry to reduce CO_2 emissions. CCUS refers to capturing CO_2 emissions from various industrial sources before it is released into the atmosphere. The primary sources of emissions from the cement production process can include combined emissions from kiln flue gas (calcination and kiln fuel combustion emissions) and boiler flue gas emissions. The captured CO_2 is then transported and stored, or it is utilized to prevent GHG emissions and mitigate climate change.

Carbon capture with 95% capture efficiency can reduce cement production's CO_2 emissions by nearly 70%, which accounts for the additional energy required to operate the carbon capture equipment.[4]

This capture phase includes three forms of carbon capture processes.

- **Pre-combustion Capture** separates CO_2 from fuel by combining the fuel with air and/or steam to produce hydrogen or synthetic gas for combustion and a separate CO_2 stream that could be stored or utilized for productive purposes.
- **Post-combustion capture** involves extracting CO_2 from the flue gas following the combustion of fossil fuels or biomass. Absorption using chemical solvents such as an amine is a commercially available technology that can capture large quantities of CO_2 from both kiln and boiler flue gases*, typically 85% to 90% of the CO_2.[5] Other novel CO_2 capture technologies, such as membrane-based or cryogenic CO_2 capture systems, could be evaluated in place of the amine-based post-combustion CO_2 capture system based on specific plant needs.
- **Oxygen Combustion** involves burning fuel with a mixture of oxygen and recirculated CO_2, generating a concentrated stream of CO_2.[6]

After capture, the CO_2 is purified and compressed, typically into a supercritical** state, to produce a concentrated CO_2 stream for transport to its destination, where it will either be stored or used for productive purposes. The supercritical CO_2 can be stored in depleted oil and gas formations or deep geological formations of porous rock designed to protect underground drinking water sources from long-term sequestration. When sequestered, the CO_2 typically bonds/reacts with other minerals/particles to form carbonate minerals, leading it to become trapped underground.[7] Another use of CO_2 is for productive industrial use such as oil and gas production, chemical manufacturing, medical use, food and beverage production, etc.

Carbon Capture Considerations

Selecting the right process: There are several choices for CO_2 capture for the cement industry and selecting a suitable capture process is highly dependent on the state of the kiln gas, including its composition, temperature, flow rate, and CO_2 concentration.

An amine-based, post-combustion process can be an effective form of CCUS as it is designed to recover high-purity CO_2 from low-purity streams and remove other pollutants often found in kiln gases. The amine process also offers the most flexibility during installation for space considerations.

The oxyfuel process burns fuel with oxygen instead of air to generate a nearly pure stream of CO_2 in the flue gas. The oxyfuel process however, will require significant modifications of cement production equipment, particularly in the clinker cooler, rotary kiln, calciner, and preheater.[8]

Compression and transport: a compressor is needed to transition the purified CO_2 from its normally gaseous state to a supercritical state for more efficient transport. Compressors can be purchased or leased with the leasing company's maintenance and repair services.

The CCUS system must be able to transport the purified CO_2 to its final destination, whether that be a sequestration site or commercial/industrial facility. In some locations, commercial pipeline operators may be able to offtake the CO_2 for a fee. If these pipeline services are unavailable, the plant operator will need to install and operate their pipeline or seek out other commercial transportation services such as trucking or rail.

Site space: Post-combustion systems can have a large footprint, and pre-combustion capture systems require space to connect to the kiln. Careful planning will be required to ensure that there is enough space to accommodate its footprint and that the space is properly located for the installation of the retrofit CO_2 capture system.

Balance of plant capacity: The available space must be evaluated to determine whether it is sufficient to meet the needs of the carbon capture and compression system or if it can be expanded to accommodate these demands. Key items to consider are:

- The existing plant's instrument air system capacity.
- The fuel gas system is needed to support the additional capacity requirements of the industrial boiler to meet the needs of the solvent regeneration process.
- An increased electrical demand will be needed to support the carbon capture system.

Safety Considerations: Amines and their degradation products can be poisonous to people and dangerous to the environment. The oxyfuel technologies require oxygen, increasing the risk of fires and explosions. Nevertheless, using oxygen or amine chemicals is normal in many industries, and proven safety procedures can be implemented to utilize these processes in the workplace safely.

Importance of Carbon Capture

While implementing CCUS in the cement industry comes with challenges, CCUS has the potential to play a crucial role in minimizing CO_2 emissions in the cement industry. Ongoing research and advancements in carbon capture technology, combined with supportive policies and incentives, will further support the scaling and use of CCUS.

Other business considerations can support the use of CCUS in the cement industry. Increasingly, organizations are setting GHG emissions reduction targets that include their supply chain emissions, thereby linking the success of their suppliers' GHG reductions to their ability to meet ambitious GHG reduction targets.

The cement industry represents an impactful opportunity for industrial decarbonization and carbon capture, and storage has the potential to play a crucial role in minimizing CO_2 emissions from the cement industry. By adopting and integrating appropriate carbon capture technologies, cement manufacturers can contribute significantly towards sustainable development goals, reducing their carbon footprint, and mitigating the adverse impacts of climate change.

Learn More & Connect

For more information on protecting your business, contact your local risk engineer, visit the Chubb Risk Consulting Library, or check out www.chubb.com/riskconsulting.

* Flue gas refers to the exhaust gas released from a cement kiln, primarily composed of carbon dioxide (CO_2) along with other pollutants like sulfur dioxide (SO2) and nitrogen oxides (NOx) from fuel combustion

** A fluid state of carbon dioxide that occurs when it's at or above its critical temperature and pressure where it can adopt properties midway between a gas and a liquid

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