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POLICY BRIEF

Quantifying Environmental Impacts from Concrete Production, While Accounting for Data Variability and Uncertainty

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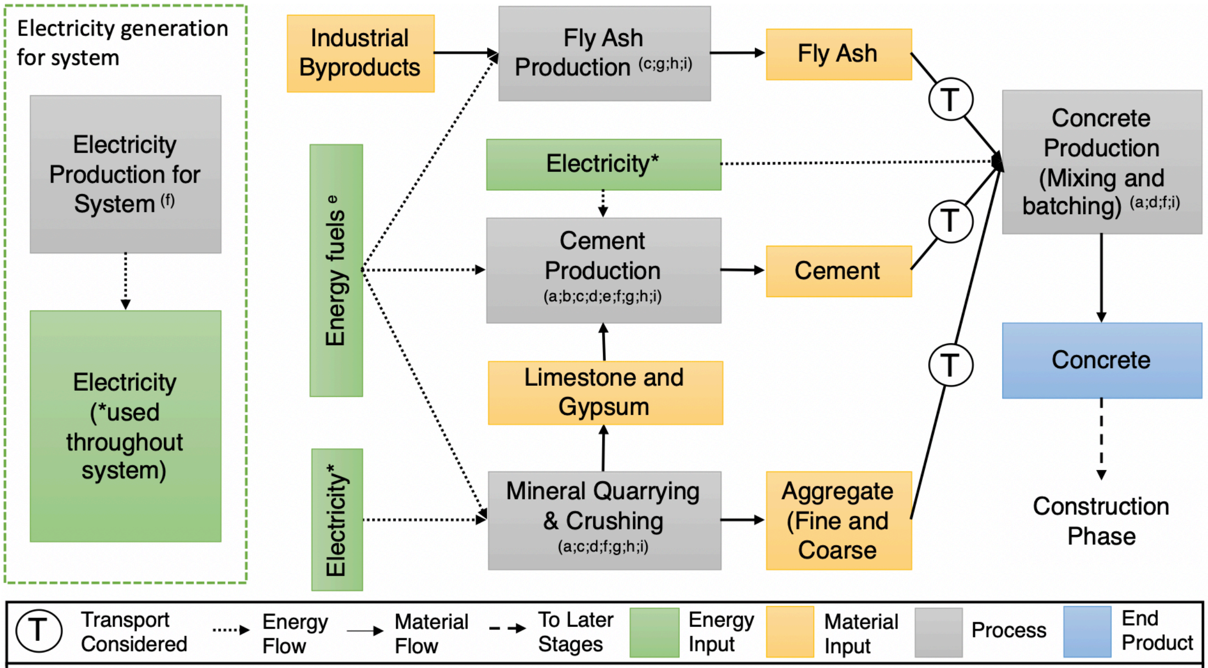
Issue

Concrete is the second most-used material on earth, surpassed only by water. Composed of cement (made by heating lime and clays at extremely high temperatures), crushed stone (aggregates), water, and other admixtures as needed, concrete is used in construction of roads, bridges, ports, and buildings. Concrete is also responsible for over 8% of annual anthropogenic greenhouse gas (GHG) emissions globally. As population and urbanization increase and existing infrastructure deteriorates, demand for production of concrete will increase, and with it, the environmental burdens from its production.

The models used to determine environmental impacts of producing concrete have considerable uncertainty and variability. This makes it challenging to identify the most effective means of mitigating these burdens. While environmental impacts are typically reported as a single, determinant value for a given product, the actual modeled impacts can vary based on many factors such as technological variation (e.g., different equipment efficiency), spatial inputs (e.g., resources available in a region), and temporal inputs (e.g., the electricity grid at a certain point in time). These challenges are exacerbated by the fact that the key drivers for air pollutant emissions and GHG emissions vary. While many are linked to the energy resources used in the production of cement, there are also notable air pollutant emissions from quarrying practices. Improved understanding of the environmental impacts from producing concrete and the probability of mitigating such impacts will allow decision makers to



Uncertainty considered: a) electricity demand; b) kiln efficiency; c) material mass; d) emission from raw-materials); e) emissions from kiln fuel; f) emissions from electricity; g) transportation distance; h) emissions from transport; i) uncertainty by emissions type

Figure 1. Parameters considered in assessing environmental impacts from concrete production

examine drivers with the greatest likelihood of yielding meaningful emissions reductions.

Researchers at the University of California, Davis used an environmental impact assessment methodology to evaluate impacts throughout each stage of concrete production, while accounting for data uncertainty and variability (Figure 1). This methodology permits assessment of the probability of reducing GHG emissions through commonly discussed mitigation methods, as well as the probability of potential co-beneficial reductions or unintended increases in air pollutant emissions.

Key Findings

Mechanisms that drive down cement content in concrete have a high probability of substantially lowering GHG emissions. This is due to a strong correlation between Portland cement (the conventional cement used) content in a concrete and GHG emissions from producing a concrete mixture. Although the methods for reducing cement content in concrete do not necessarily lead to high probabilities of reducing all air pollutant emissions, they will reduce air pollutants that are typically tied to the fuels or raw materials used in cement production (e.g., SO_x emissions).

Carbon capture, utilization, and storage (CCUS) can reduce GHG emissions, but may increase air pollutant emissions. CCUS requires additional energy and other requisite compounds to uptake GHGs. If the energy resources come from fossil fuels, there can be increases in emissions of air pollutants. These potential unintended environmental consequences should be considered when implementing CCUS.

Improved data quality will reduce uncertainty regarding a mitigation measure's likelihood of lowering GHG and air pollutant emissions. There are greater sources of uncertainty for air pollutant emissions due to poorer data quality than for GHG emissions. Improvements to data collection and reporting would better illuminate methods—beyond appropriate use of fuel resources—that would drive down both types of emissions.

Policy Implications

The environmental impact assessment methodology described here can help policymakers prioritize mitigation measures to reduce the environmental impacts of concrete production. For instance, use of more efficient kilns will reduce emissions, but further improvements in kiln technologies may produce more limited benefits than using cleaner-burning kiln fuels and cleaner electricity grids. The two most prevalent resources used to meet high thermal energy demands in cement kilns are coal and petroleum coke, both of which produce high GHG and air pollutant emissions. Using lower-emitting fuel resources will lead to reduced emissions.

Increasing the proportion of mineral admixtures can also lower the high-GHG-emitting Portland cement content in concrete. These commonly include materials like fly ash, ground granulated blast furnace slag, and limestone. Most, but not all, state departments of transportation have verified up to 15% replacement with limestone is viable for performance requirements, so accelerating and supporting the use of this compound will reduce emissions. For the use of other common mineral admixtures, optimizing mixtures to achieve desired performance with appropriate levels of mineral admixture can also reduce emissions. However, such optimization may not always be cost-effective and could lead to more moderate gains.

More Information

This policy brief is drawn from "Benchmarking GHG Emissions from California Concrete and Readily Implementable Mitigation Measures," a report from the National Center for Sustainable Transportation, authored by Patrick R. Cunningham and Sabbie A. Miller of the University of California, Davis. The full report can be found on the NCST website at https://ncst.ucdavis.edu/project/benchmarking-greenhouse-gas-emissions-california-concrete-production-and-readily.

For more information about the findings presented in this brief, contact Sabbie A. Miller at sabmil@ucdavis.edu.

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