BRIEF # 12

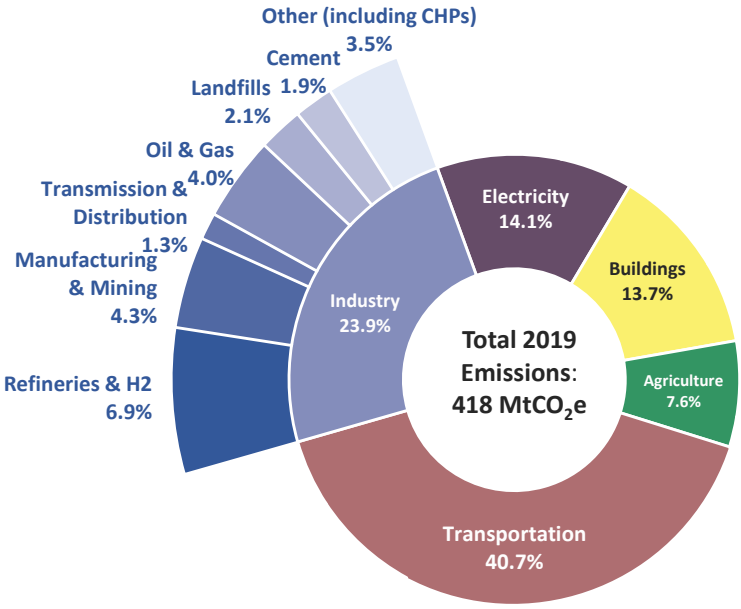
PATHWAYS TO CARBON NEUTRALITY IN CALIFORNIA

Decarbonizing the Industrial Sector

Stanford
Center for Carbon Storage
Carbon Removal Initiative

This brief discusses key findings from the following report: In Jae Cho, Michael L. Machala, Alexander Evers, Sarah D. Saltzer and Adam Brandt, "Pathways to Carbon Neutrality in California: Decarbonizing the Industrial Sector", Stanford Center for Carbon Storage and Stanford Carbon Removal Initiative, May 2022.

In 2019, the Industrial sector emitted 100 Mt of CO_2e or 24% of California's total. Industrial sector emissions are some of the most difficult to abate due to the sector's diversity, capital intensive operations, and the need for process heat which is typically provided from the combustion of fossil fuels. This study contains a bottom-up accounting of over 400 emitting facilities in the industrial sector in California. While electrification and fuel switching are technically feasible methods for decarbonizing many of these facilities, currently carbon capture and storage (CCS) is the most cost-effective emissions abatement technology.



KEY FINDINGS

1. The Industrial sector is responsible for nearly 25% of California's CO2e emissions primarily due to the combustion of fossil fuels for process heat. This emissions level has not changed significantly over the past 20 years.

2. Steamflood operations are the primary source of emissions in the **Oil & Gas** subsector. These emissions occur from steam generation units, of which there are estimated ~750 (+/- 20%) in the state, as well as much larger CHP units. Technoeconomic modeling of CCS retrofits on both types of facilities, depending on fuel and electricity prices, can show positive cash flow, while other decarbonization options (e.g., concentrated solar power) would require additional incentives.

3. Fluidized catalytic crackers, hydrogen SMRs, and CHPs are responsible for the majority of the emissions in the **Refining & Hydrogen** subsector. Technoeconomic modeling of CCS-retrofits on all of these types of facilities show positive cash flow.

4. Fuel combustion for process heat and the chemical reaction that occurs when making clinker are the primary sources of CO2e emissions in the **Cement** subsector. Technoeconomic modeling of CCS retrofits, electrification, and a fuel switch to hydrogen are all cash-flow negative, with CCS both costing the least and abating the highest volume of CO2.

5. The **Manufacturing & Mining** subsectors use process heat at different temperatures to produce thousands of different products fabricated by hundreds of facilities in California. CCS-retrofits at the largest 5 mining and petrochemical products facilities and largest 3 food products facilities can reduce emissions by 60% and 29%, respectively. Notably, the high concentration of food manufacturers located over suitable geologic CO2 storage sites may reduce barriers to CO2 transport for sequestration.

6. The **Transmission & Distribution** subsector has fuel combustion emissions at over 100 compressor stations located across the state but CO2e emissions are dominated by fugitive methane emissions (78% of total CO2e) associated with natural gas conveyance through over 200,000+ miles of pipeline. The most expensive abatement options when adjusted for inflation to 2025 yield an LCOC of $53/t CO2e, and many options can acutally make money.

7. Biogenic emissions are not included in California's emission reduction targets, yet these emissions (e.g., wood and furniture products which utilize heat generated from the combustion of wood-based residue left over from the wood manufacturing process) can be significant and may be more cost-effective to abate than other sources of industrial emissions.

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