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Emerging technology snapshot

Reducing Emissions in the Cement, Chemical and Steel Industries

This study provides an analysis of research and development (R&D) trends directed toward emissions reductions in three hard-to-abate industrial sectors – steel, concrete and chemicals. An examination of scientific publications, grants and patents provides a long-, medium- and near-term view on emissions-reducing innovations being considered for these sectors.

Enabling Science and Technology

"Hot" R&D Topics

Carbon Capture Utilization and Storage (CCUS) technologies have dominated emissions reduction R&D in the past few years. Other topics attracting increasing research interest include nanomaterials, green cement, solar energy and power-to-X technologies. The fastest growing subject is "green" hydrogen, which refers to hydrogen produced using electricity generated from renewable energy sources such as solar or wind.

Emerging R&D Topics

Emerging topics include technologies such as methane pyrolysis, geopolymers, direct air capture and metal-organic frameworks (MOFs). MOFs have the third-highest acceleration among all topics in the literature, mainly due to their accessible porosities, low energy demand, high surface areas and the fact they can be engineered to specifically target carbon dioxide (CO_2).

Alternative Materials, Processes and Fuels

The use of lower carbon fuels (e.g. biomass, hydrogen) for process heat should be maximized. Waste products like fly ash, blast furnace slag or rice husks can replace or supplement clinker in cement. In the steel sector, emissions can be reduced by transitioning to cleaner technologies like electric arc furnaces and hydrogen direct reduction.

Retrofit and Interim Solutions

Many of the promising abatement technologies are in the early stage of development and will not be commercially viable for years or decades. Interim emission reduction measures include implementing energy management systems, upgrading to more energy-efficient equipment, and employing advanced data analytics and artificial intelligence to optimize existing processes.

Reuse and Recycling

Reuse and recycling processes such as waste heat utilization can increase the efficiency of industrial plants and reduce energy consumption. Other technologies like mineralization can sequester captured carbon in rocks, which can then be reused in activities like construction. In the chemical sector, plastic waste can be turned into valuable secondary raw materials through the use of innovative recycling techniques.

Signals

Academic

Canada's Ontario Tech University is the global leader in publications related to green hydrogen generation. In terms of Canadian research grants, the University of Toronto has received the highest number of awards for research projects examining nanomaterials and supercritical CO_2 extraction technologies.

Government

Since 2016, Natural Sciences and Engineering Research Council of Canada (NSERC) has provided 100 grants for emissions reduction research projects. The majority of funding has been for development of CCUS technologies, but other areas of research include MOFs, nanomaterials, green cement and geopolymers.

Collaboration

China is the world leader in emissions reduction R&D and a frequent collaborator of Canadian researchers; other collaborations within Canada are generally bilateral efforts. In the US, the Department of Energy is the main hub of research activity and the most prolific collaborator.

Corporate

ArcelorMittal, Tata Steel and Heidelberg Cement are the top commercial organizations in terms of volume of scientific publications. In the patents, China's Sinopec and South Korea's POSCO are the leading assignees. Patenting activity is primarily in the areas of energy efficiency, waste heat recovery and recycling.

Impact

Social

Air pollution is known to contribute to lung cancer, heart disease and other physical ailments, but recent research indicates it also affects mental health and may lead to cognitive disorders such as dementia and ADHD.

Technological

Carbon capture provides the most significant emission reduction potential before 2030. However, once built, such facilities cannot be retrofitted with hydrogen-based or electrification technologies once they become commercially available after 2030.

Economic

The timing of investments and capital stock renewals in these three sectors will be critical to optimize the implementation of shorter-term measures, while allowing space for future innovative technologies to be deployed by 2050.

Environmental

The cement, steel and chemical industries account for approximately 70% of global industrial carbon emissions (representing 25% of CO_2 emissions overall), and consume 40% of the world's energy.

Policy

The key policy challenge for these sectors will be to both support projects that advance innovation and achieve net-zero targets, while at the same time implementing shorter-term measures that achieve 2030 emissions-reduction goals.

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