INDUSTRY DECARBONIZATION FACT SHEET

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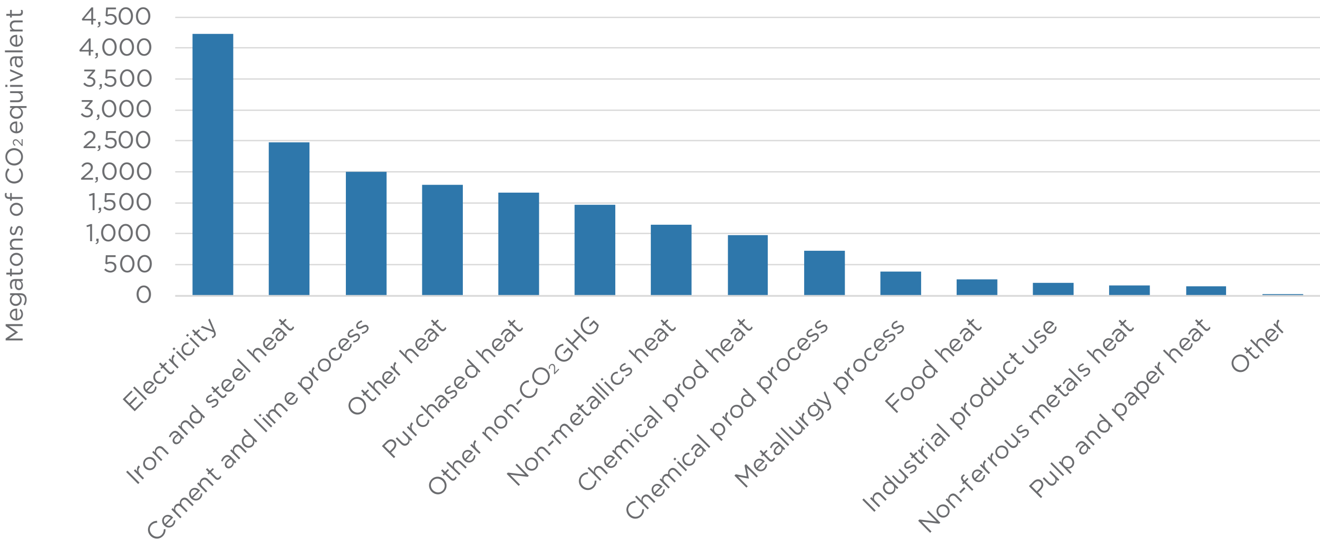
Greenhouse gas (GHG) emissions from industrial operations are a big and growing problem that has historically seen little attention. Electricity use, heat needs (varying from 50–1,600°C [122–2,912°F]), and chemical process carbon dioxide (CO_2) (e.g., from cement, lime, hydrogen, and other chemical production) create the largest amount of such emissions, as shown in Figure 1.

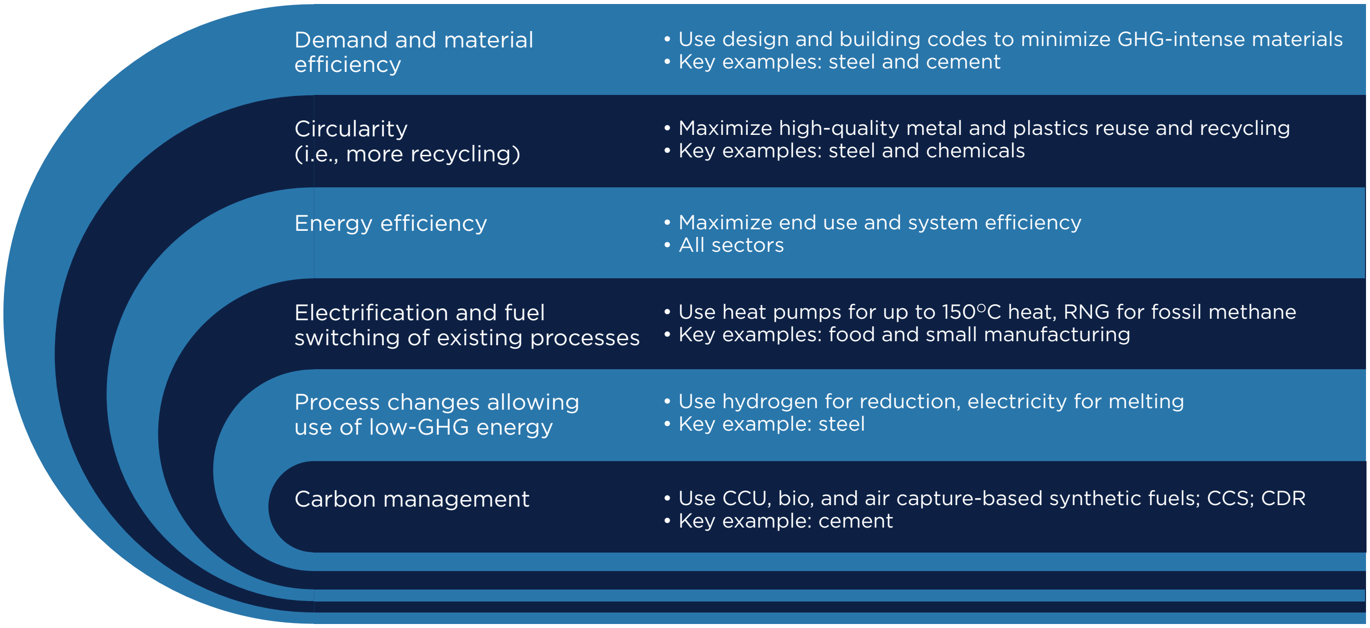
Figure 1: Global industrial greenhouse gas sources by sector, 2019



Source: IPCC, Climate Change 2022: Mitigation of Climate Change*, April 4, 2022, ch. 11,* https://www.ipcc.ch/report/ar6/wg3/.

Until the Paris Agreement was adopted in 2015, industrial GHG mitigation was focused on energy efficiency, coal-to-gas or electricity fuel switching, and carbon capture and storage (CCS). Mitigation generally stopped at the reduction of GHG emissions by roughly 50 percent by 2050. The Paris Agreement changed everything: its emphasis on keeping the global temperature increase “well below 2°C and toward 1.5°C” shifted the global CO_2 and GHG targets to net zero by 2050 and 2070, respectively. In a world meeting the Paris targets, any industrial facility still emitting CO_2 in 2050 will likely have to pay for additive, permanent, and verifiable atmospheric carbon dioxide removal (CDR) offsets at the prevailing price. The latest Intergovernmental Panel on Climate Change (IPCC) report has shown industrial deep decarbonization is possible but would require a set of interlocking strategies, described in Figure 2 and expanded below.

Figure 2: Strategies for decarbonizing industry



Source: Author configuration based on IPCC, Climate Change 2022: Mitigation of Climate Change, *April 4, 2022, ch. 11, fig. 11.9, https://www.ipcc.ch/report/ar6/wg3/.*

- **Material efficiency through better design and building code revisions.** Using best global practices incorporating GHG intensity along with other design goals for vehicles, machinery, buildings, and infrastructure could reduce cement use up to 26 percent and steel by 40 percent.
- **More material circularity, initially through much more and higher quality recycling.** Such efforts will be central to reducing emissions from most metals and plastics, and eventually a wider set of chemicals and concrete aggregates, among other materials.
- **Energy efficiency at the point of end use and as integrated process systems.** This strategy can range from using industrial heat pumps for low grade heat (up to 150°C) to better integration of processes to reduce overall heat requirements—for example, with continuous casting of iron and steel products.
- **Fuel switching for existing processes.** Where technically and economically feasible, most coal-to-gas switching has already occurred. A significant GHG benefit could be derived from reducing upstream fugitive methane emissions to less than 0.5 percent from current levels, which vary widely by region—for example, from 0.2 percent in British Columbia to 7–9 percent in the Permian Basin of the Southwest United States. Another key area for fuel switching is clean electrification for heat, with some interim replacement of fossil methane gas with low GHG bio or synthetic methane, also known as "renewable natural gas." Many forms of electrification for industry are possible today, directly through electrothermal or induction heating or indirectly through industrial heat pumps, which can reach up to 150°C, with efficiencies up to 400 percent at lower temperatures. Heat pumps are generally more expensive than using natural gas or coal directly for low heat levels, however, and electrification at higher temperatures can impose challenging time-specific capacity needs on the electricity grid.
- **Process changes to allow use of zero-emissions fuels and feedstocks.** Fundamental changes to steel, chemical, and other material production are being commercially piloted that will allow use of clean electricity, hydrogen, low GHG carbon, and combinations thereof to be used as replacements for methane and coal for delivering heat and for chemical reactions.
- **Carbon management** (e.g., flue gas CO_2 capture, utilization of waste CO_2, sourcing of lower GHG carbon sources like biomass and direct air capture, and permanent geological storage). This will be necessary for several sectors and legacy assets, especially cement process CO_2 emissions. "Drop-in" synthetic net-zero

GHG liquid and gaseous fuels and feedstocks made with low-GHG carbon, hydrogen, and oxygen can replace current fossil fuels and are commercially feasible but are considerably more expensive.

Carbon capture and utilization and permanent geological storage, hydrogen made from methane and CCS ("blue") or electrolysis ("green"), electrification, and waste heat cascading and reuse with heat pumps will all be easier to supply economically if facilities are located closer together. Such proximity could possibly occur in preplanned and approved net-zero industrial clusters, such as at seaports with existing refineries and their hydrogen needs.

If accomplished, decarbonization of industry will lead to several benefits beyond slower climate change. Along with electrifying personal transport and buildings, industrial decarbonization will help dramatically improve air quality, reducing some of the 5.9–7.5 million early deaths globally each year due to poor local air quality.[2]

Policy Considerations

Policy makers seeking pathways toward industrial decarbonization could consider the following options:

- Enact policies to ensure a large, growing, reliable, and relatively inexpensive supply of very low GHG electricity.
- Speed up the process of innovation and early-to-late commercialization for near-zero-emissions technologies to reduce production investment risk, with a focus on establishing lead markets (e.g., through government and private green procurement or targeted and dynamic subsidies, such as with contracts that provide a minimum price for a limited number of tons for a limited time).
- Establish physical industrial clusters to reduce the cost of blue and green hydrogen and CCS, and to allow waste heat reuse with industrial heat pumps.
- Implement policies to drive broad market uptake of near-zero industrial options, including: loans and tax credits to alleviate CAPEX-heavy investments, like for heat pumps; GHG standards for heat and steam; carbon pricing; and performance regulations.
- Establish international coordination regarding green procurement, GHG accounting, trade policies (e.g., border carbon adjustments and standards to make sure imports face similar climate policy stringency as domestic production does), and technology transfer and finance for developing countries, where most new demand and investment will be.

Notes

1. IPCC, *Climate Change 2022: Mitigation of Climate Change*, April 4, 2022, ch. 11, https://www.ipcc.ch/report ar6/wg3/.
2. R. Fuller et al., "Pollution and health: a progress update," *The Lancet Planetary Health* 6, no. 6 (June 2022): E535–E547, https://www.thelancet.com/journals/lanplh/article/PIIS2542-5196(22)00090-0/fulltext; IEA, *Energy and Air Pollution: World Energy Outlook Special Report*, June 2016, https://www.iea.org/reports/energy-and-air-pollution.

About the Author

Dr. Chris Bataille has been involved in energy and climate policy analysis for 26 years as a researcher, energy systems and economic modeler, analyst, writer, project manager, managing consultant, and founding partner. His career has been focused on the transition to a globally sustainable energy system, more recently technology and policy pathways to net-zero GHG emissions by all sectors by 2050-70 to meet the Paris Agreement goals. He is an Associate Researcher at the Institute for Sustainable Development and International Relations (IDDRI.org) in Paris working on the Deep Decarbonization Pathways project (DDPinitiative.org), and an Adjunct Professor at Simon Fraser University. Chris was a Lead Author for the Industry Chapter of the 6th cycle of the IPCC Assessment Report 2019-2022, as well as the Summary for Policy Makers and Technical Summary. He manages an ongoing global project to review technology and policy options for net-zero decarbonization of heavy industrial sectors, including the global Net Zero Steel project (netzerosteel.org), which has produced facility level, geospatial net zero pathways for the global steel industry. Chris is continuing his focus on industrial decarbonization at CGEP.