

EXECUTIVE SUMMARY

LOW-CARBON FUEL PATHWAYS FOR THE PRIMARY METALS INDUSTRIES

Primary metals manufacturing encompasses industries that take raw materials from mined ores or scrap metals and use heat, electricity, or other processes to produce refined metals, including alloys. These products are used across the economy for purposes such as manufacturing vehicles, machinery, construction materials, and consumer products.

Primary metals processing is a major contributor to greenhouse gas (GHG) emissions on a global scale. Steel, aluminum, and copper together represent the majority of production—and greenhouse gas emissions—within the industry. This report focuses on the prospects for decarbonization in this subset of the primary metals industry, because reducing the carbon footprint for these processes could strongly ameliorate the industry's global climate impacts. Meeting the objectives implicit in national, international, and industry GHG reduction goals requires a large-scale transition to new technologies over the next few decades.

Key insights from the [full report](#) include:

- Improved efficiency in materials use and increased recycling, which decrease the need for mining and primary metals processing should provide substantial near-term GHG reductions.
- Direct electrification technologies can be a significant contributor to near-term emissions reduction, provided electricity generation is decarbonized. A variety of electric technologies are currently available and under development to replace fossil-fuel-combustion-based process heat inputs, including electric resistance, inductive, and radiative heating.
- Measures to improve efficiency—such as advanced heat recovery and reuse technologies, including thermal energy storage—can deliver near-term GHG reductions. In applications for which heating processes are too technically challenging or costly to electrify, conversion to low-carbon fuel sources may be a more viable alternative.
 - Direct substitution with drop-in fuels, such as renewable natural gas (RNG) or synthetic natural gas (SNG), presents few technical barriers to significant near-term emissions reduction, but may be limited by capacity constraints.
 - Hydrogen, often blended with other fuels, is under active study as a fuel substitute for process heating applications across the industrial sector. Active research and development (R&D) work is in progress for hydrogen-capable and fuel-flexible burners for industrial furnaces, including those used in primary metals processing.
- Direct reduction of iron using low-carbon hydrogen rather than fossil fuels is a promising approach to lowering total carbon dioxide emissions from steel processing.
- Carbon capture, utilization, and storage (CCUS) can be applied to address emissions for remaining fossil-fuel consumption in the sector. Carbon capture technologies present solutions for obtaining emissions reductions where process-related CO₂ emissions are significant and also concentrated in the effluent stream, such as in steel and aluminum smelting.



This report reviews the current global R&D efforts to develop a picture of the decarbonization in this industry. Background discussion addresses the magnitude of carbon emissions attributable to primary metals processing, leading to a survey of the available technical approaches to reduce these emissions over the next 30 years. While the report gives particular attention to fuel- and feedstock-based solutions, such as substituting green hydrogen for fossil fuels, it also addresses nonfuel approaches, such as electrification and heat recovery. The report identifies research gaps to provide guidance on R&D efforts for which the Low-Carbon Resources Initiative's (LCRI's) ongoing work and shared expertise may synergize with parallel efforts around the globe.

The Low-Carbon Resources Initiative

This executive summary was published under the Low-Carbon Resources Initiative (LCRI), a joint effort of EPRI and GTI Energy addressing the need to accelerate development and deployment of low- and zero-carbon energy technologies. The LCRI is targeting advances in the production, distribution, and application of low-carbon energy carriers and the cross-cutting technologies that enable their integration at scale. These energy carriers, which include hydrogen, ammonia, synthetic fuels, and biofuels, are needed to enable affordable pathways to economy-wide decarbonization by mid-century. For more information, visit www.LowCarbonLCRI.com.

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