# Forging a Greener Future: The Imperative of Decarbonizing Steel Production

By Anna Littlefield and Edikan Udofia

**A**s evening approaches in Pueblo, Colorado, the vast steel mill begins to transform under the setting sun. The EVRAZ Rocky Mountain Steel mill, a longstanding institution in this industrial area for more than a century, is evolving as part of the push to decarbonize the global steel industry. Collaborating with Lightsource bp, the mill is shifting to solar energy, positioning itself as the first steel mill in North America to operate predominantly on solar power. The solar conversion is set to abate almost half a million tons of greenhouse gas emissions.

This change in Pueblo is a microcosm of the broader transformation happening across the global steel sector. If considered as a nation, the worldwide steel sector would rank as the third-largest $CO_2$ emitter globally, trailing only China and the United States. This stark reality underlines the need for change in one of the planet's most indispensable yet carbon-intensive industries. Earlier this year, the U.S. Department of Energy announced its intention to allocate up to $6 billion for technology aimed at reducing emissions in the production of steel, cement, chemicals, and aluminum. Among the twenty awards already declared, is one for an aluminum plant located in Fort Lupton, Colorado. These investments reflect the scale of the challenge at hand and the importance of these industries often referred to as 'difficult-to-decarbonize.'

Steel is foundational in contemporary infrastructure and is responsible for about 7-9% of global $CO_2$ emissions, per reports from the International Energy Agency (IEA). Within the United States, annual steel production has reached 88 million tons. The ubiquitous nature of steel in our society creates a multifaceted issue, explored in depth in "Decarbonizing the iron and steel industry: A systematic review of sociotechnical systems, technological innovations, and policy options," published in 2022. This publication emphasizes that plans to decarbonize steel must account for environmental, economic, and social dimensions, recognizing that the steel sector supports millions of jobs globally.

The journey towards green steel involves a variety of technologies, each bringing its own potential and obstacles. The predominant steel production method, known as the Blast Furnace-Basic Oxygen Furnace (BF-BOF), is responsible for roughly 70% of the world's steel output and is notably carbon-intensive. This technique emits about 1.8 to 2 metric tonnes of $CO_2$ per metric tonne of steel produced, mainly due to coal being used as both an energy source and a reducing agent. Conversely, the Electric Arc Furnace (EAF) process, which mainly relies on recycled steel, results in approximately 0.3-0.4 tonnes of $CO_2$ per tonne of steel. Nonetheless, the $CO_2$ emissions from EAF can fluctuate considerably based on the electricity source employed during production.

Emissions vary not only because of manufacturing methods but also as a result of changing societal and economic conditions that impact industry. These changes can be observed across the world through remote sensing. The Earth Observation Group of the Payne Institute has developed a novel technique for tracking steel emissions using the same satellite data they have long used to track methane emissions and gas flaring. The resolution is high enough to track individual emitters and showed the fluctuation of the steel industry during the Covid-19 pandemic, and the shuttering of Ukraine's steel plants during Russia's invasion. Innovative monitoring techniques such as this will enable global accountability as the competition in green steel intensifies.

The pursuit of sustainable steel has ignited an international rivalry some have compared to the 1960s space race. Nations and corporations around the globe are striving to innovate and market eco-friendly steel production technologies, acknowledging the significant economic advantages of being a leader in this domain. Boston Metal, a startup located in Massachusetts, is pioneering a technique known as molten oxide electrolysis, which can generate steel with zero direct $CO_2$ emissions when utilizing renewable energy. In Sweden, the HYBRIT project, a collaborative effort by SSAB, LKAB, and Vattenfall, has successfully created the first fossil-free steel in the world using green-hydrogen fueled direct reduction. Meanwhile, in Germany, H2 Green Steel has plans to establish a large-scale facility that will utilize hydrogen-based methods to produce 5 million tonnes of eco-friendly steel each year by 2030. China, as the leading steel producer globally, is also making strides. Baowu Steel Group, the top steel manufacturer in the country, is spearheading a green steel coalition involving 62 companies and institutions, anticipating peak carbon emissions as of 2023 with plans to cut them by 30% by 2035.

These efforts are not solely focused on environmental responsibility; they also aim to gain a strategic advantage in a swiftly evolving global market. End-users are recognizing the urgency as well. Kerstin Enochsson, Volvo's head of procurement stated "the race to secure supplies of fossil-fuel free steel is already underway," and in reference to the SteelZero Initiative said "There's not really an alternative material to steel for us when making cars, but at the same time, we see that we can't continue using steel that has been made the traditional way."

Although technological advancements dominate the news, the human narrative of this industrial shift is just as important to understand. In western Pennsylvania's Mon Valley, an area known for its long history of steel production, workers are facing an unpredictable future. Third-generation steelworkers, from communities entrenched in the industry, are concerned about its future. They recognize that the same career options may not exist for their children as did for their parents and grandparents. The shift to green steel brings both opportunities and challenges to these communities. It has the potential to generate new, specialized jobs in fields such as hydrogen technology and advanced manufacturing, but also poses risks to jobs specific to traditional manufacturing processes. It is crucial for policymakers and industry leaders to work for a fair and inclusive transition, offering training, assistance, and community specific benefits.

Government policies are essential in speeding up the shift to green steel. Mechanisms for carbon pricing, like the EU's Emissions Trading System, can provide economic motivation for reducing emissions. Similarly, the EU's suggested Carbon Border Adjustment Mechanism, aims to ensure fair competition and stop "carbon leakage" to areas with laxer environmental standards. In the United States, the recent passge of the Inflation Reduction Act offers substantial motivations for clean energy and decarbonizing industries. Nevertheless, more specific policies may be necessary to encourage investment in green steel technologies.

Reducing carbon emissions in steel manufacturing is not merely a mandate for the environment; it represents both a technical challenge and an economic prospect that could shape the 21st century. Achieving this goal requires unified efforts from all involved parties:

- Policymakers need to offer definite, long-term guidelines through carbon pricing, regulatory measures, and incentives for research and development as well as infrastructure growth.
- Business leaders must adopt innovative approaches, making investments in emerging technologies while refining current processes.
- Individuals and businesses, including those in construction and automotive sectors, should insist on and be prepared to invest in environmentally friendly or 'green' steel.
- Scientists and developers should persist in exploring new frontiers, creating innovative technologies, and creatively problem solve in these foundational industries.
- Communities and laborers need to advocate for themselves by requesting the appropriate training opportunities and education as industrial transitions occur.

The situation is critical and the task of reducing carbon emissions in steel production is formidable, yet it presents a unique chance to overhaul one of the planet's most essential industries for a sustainable future. As steel mills begin operations each day across the globe from Pueblo to Shanghai, the true challenge lies not in our capabilities but rather in our collective determination. Innovative technologies are being developed, the economic arguments are growing more compelling, and the urgency for environmental action couldn't be more evident. The task before us is to redefine the steel industry and, through it, shape a more sustainable future.

## ABOUT THE AUTHORS

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Anna Littlefield is the Program Manager for Carbon Capture Utilization and Sequestration for the Payne Institute at the Colorado School of Mines. As a current PhD student in the Mines geology department, her research focuses on the geochemical impacts of injecting CO2 into the subsurface as well as the overlap of geotechnical considerations with policymaking. Anna joins the Payne Institute with 8 years' experience in the oil and gas industry, where she worked development, appraisal, exploration, new ventures, and carbon sequestration projects. Her academic background is in hydrogeology with an M.S. in geology from Texas A&M University, and a B.S. in geology from Appalachian State University. Anna is passionate about addressing both the societal and technical challenges of the energy transition and applying her experience to advance this effort.

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Edikan Udofia is a Ph.D. candidate in Operations Research with Engineering at the Colorado School of Mines. He also holds a Master's degree in Mineral and Energy Economics from the same institution, which complements his extensive academic and practical experience in the field. Prior to his academic pursuits, Edikan spent over a decade in industries including oil and gas, mining, agribusiness, and logistics. In these roles, he honed his expertise in strategy and implementation, business development, project management, and new venture planning.

With a research focus on industrial-scale data analysis, Edikan combines principles from statistics and operations research. He is particularly interested in applying these concepts to enhance efficiency in complex systems. His unique perspective is grounded in both industry experience and academic rigor, which bolsters his approach to data-driven problem-solving.

Beyond his research, Edikan is dedicated to fostering collaboration. He firmly believes in the importance of academia and industry working in tandem to tackle complex challenges. This belief not only informs his work but also shapes his broader approach to his field of study.

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