Falling Further Behind

How a **Failure to Transition to Green Steel** Could Cost US Steelmakers, Western Pennsylvania Communities, and the Environment

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GLOSSARY

Blast Furnace (BF): A towering cylinder lined with heat-resistant (refractory) bricks, used by integrated steel mills to smelt iron from iron ore. Its name comes from the "blast" of hot air and gasses forced up through the iron ore, coke, and limestone that load the furnace.

Basic Oxygen Furnace (BOF): A pear-shaped furnace, lined with refractory bricks, that refines molten iron from the blast furnace and scrap into steel. Up to 30% of the charge into the BOF can be scrap. Hot metal accounts for the rest.

Blast Furnace-Basic Oxygen Furnace (BF-BOF): The most common production pathway for primary steel production. A major source of greenhouse gas emissions, water pollution, and soil contamination.

Creating Helpful Incentives to Produce Semiconductors (CHIPS) and Science Act of 2022: Legislation signed into law by President Biden on Aug. 9, 2022, investing nearly $250 billion in a combination of semiconductor and other scientific research and development (R&D).

Coke: A coal-based fuel with high carbon content and few impurities, made by heating coal or oil in the absence of air. It is an important industrial product used mainly in iron ore smelting.

Coking coal, or metallurgical (met) coal: A specific grade of hard coal with elevated carbon content.

Crude steel: The first solid steel product upon solidification of liquid steel. It also includes liquid steel, which goes into production of steel castings. Crude steel is normally processed into finished steel either by rolling or by forging processes.

Direct Reduction of Iron, or Direct Reduced Iron (DRI): A solid state process that reduces iron ore into iron using a reducing gas in a shaft reduction (or non-coking coal in a rotary kiln). It also refers to the solid product produced from the DRI process (see sponge iron).

Electric Arc Furnace (EAF): A high-temperature furnace that uses high-voltage electric currents as the primary heating element.

Electrolyzer: A system that uses electricity to break water into hydrogen and oxygen in a process called electrolysis:

- **Alkaline electrolyzers** use liquid electrolyte solution, such as potassium hydroxide (KOH) or sodium hydroxide (NaOH), and electric current to break water molecules into hydrogen and oxygen.

- **Proton Exchange Membrane (PEM) electrolyzers** use a solid polymer electrolyte and electric current to break water into hydrogen and oxygen.

Fossil fuel-free steel: Steel manufactured without the use of fossil fuels. This means no natural gas, coal, or oil is used in its production and any electricity used comes from renewable resources.

Green hydrogen: Hydrogen produced via electrolysis using renewable electricity coupled with renewably-sourced electrical energy.

"Green steel": A general class of steelmaking technologies that provide a carbon footprint reduction. Does not imply any quantification of the actual level of greenhouse gas produced or the method of production.

Hot Briquetted Iron (HBI): Direct reduced iron (DRI) that has been processed into briquettes. Because DRI may spontaneously combust during transportation, HBI is preferred when the metallic material must be stored or moved.

Hot-rolled coil (HRC): A tightly rolled form of steel. HRC prices are used as the leading indicator of the steel industry's overall health.

Infrastructure Investment and Jobs Act (IIJA) of 2021: Also known as the Bipartisan Infrastructure Law (BIL) and signed by President Biden on November 15, 2021, authorizing $1.2 trillion for transportation and infrastructure spending to bolster the transportation, energy, water, and utility sectors, as well as state and local governments.

Inflation Reduction Act (IRA) of 2022: Federal legislation enacted in August 2022 to reduce the national deficit, lower inflation while investing in domestic energy production, create good jobs, and transform US efforts to address the climate crisis.

Minimill: A relatively small-scale steel mill that uses scrap metal as starting material.

Million tons per annum (mtpa): A unit of measurement that quantifies the mass of a material produced or processed in millions of tonnes over the course of one year.

One Big Beautiful Bill Act (OBBBA) of 2025: Enacted in July 2025, the 870-page bill reshapes federal policy across nearly every major sector of the economy through significant policy shifts, funding reallocations and regulatory changes.

Pig iron: Melted iron produced in a blast furnace that has been solidified or cast.

Primary, or virgin, steel: Steel that uses iron ore as its main source of metallic input. Scrap typically accounts for 15-25% of the metallic input in primary production.

Secondary production: Steel production based on scrap. However, iron or direct reduced iron (DRI) is also commonly added to electric furnaces, which are the typical unit for secondary production.

Synthesis gas (syngas): A mixture of carbon monoxide, carbon dioxide, and hydrogen. Syngas is produced by gasification of a carbon-containing fuel to a gaseous product that has some heating value. Examples of syngas production include gasification of coal emissions, waste emissions to energy gasification, and steam reforming of coke.

Sponge iron (SI): Direct Reduced Iron (DRI) is also known as sponge iron because of its spongy micro structure.

Tariff: A tax imposed by the government on the value of goods imported into the country. Tariffs are paid at the port of entry by the company of record that is importing the shipment and are assessed against the value of the imported goods. Whether or not (and to what degree) domestic companies pass on these tariff costs to consumers is a subject of intense economic research.

“Zero-emission steel,” or “near zero-emission steel”: While not officially defined, it is a term used to distinguish those technologies that have the potential to deliver full decarbonization.

EXECUTIVE SUMMARY

The economic and political landscape around industrial decarbonization has changed dramatically in the United States since our first report on green steel in 2023. In that report, we estimated that a conversion from traditional coal-based processes to one based on green hydrogen could not only benefit the environment by eliminating emissions from primary steel production in Pennsylvania but could also retain steel jobs, create new renewable energy jobs, and give the state a first-mover advantage in global markets.

But without large-scale investment and political willpower, the opportunity for a US renaissance in steelmaking, driven in part by decarbonization investments, may be slipping away. As this report will highlight, China has come to dominate traditional steel markets since 2000, while US steel jobs are in decline. Now, driven in part by its own climate commitments and global trade pressure for decarbonized steel, China is signalling it may begin its pivot toward industrial decarbonization at scale. Other regions are following suit, and **the US risks not only losing the opportunity to lead the 21st-century steel market, but falling even further behind.**

Key Findings:

- Recent legislation that seeks to undo much of the federal government's investment in industrial decarbonization **risks implicitly doubling down on traditional steelmaking,** where the US has already lost considerable ground to China and other Asian producers.

    - China currently produces over 50% of the world's crude steel as of 2024, up from 36.6% in 2005. The rest of Asia collectively produces approximately 20% of crude steel, while the US produces only 4.2%, down from nearly 8% in 2005.

    - China's rapid rise in the global steel market over the past two decades has occurred nearly simultaneously with a large decline in US steel and iron employment. While not the sole factor, China's increasing dominance in the steel industry has played a role in the loss of American steel jobs. **American steel employment has declined by over 50,000 jobs over the last several decades** and, as our 2023 report found, many of these job losses occurred in primary steel communities like Western Pennsylvania and Gary, Indiana.

    - **Steel prices and demand have taken a downturn in recent years** as China's real estate and construction boom has chilled. A global glut of cheap Chinese steel has made profitable operations more difficult for American steelmakers, even though the US imports little steel directly from China. Tariffs, which have a long history in the US steel industry, have created additional uncertainty that may help steelmakers in the short term but could also hamper demand by creating headwinds for the broader economy.

- **Emerging global demand for low-carbon green steel can create new market opportunities for steelmakers.** Many regions of the world have pressed ahead with investments in both decarbonizing industries like steelmaking and investing in green hydrogen technology. Additionally, governments in the European Union seeking to meet their climate emissions reduction targets have implemented import fees that account for the emissions intensity of products. This carbon border adjustment mechanism (CBAM) will hurt the competitiveness of high-emissions-intensity, traditionally made steel in European markets, where the US already ranks outside of the top 10 importing nations.

- **The recent approval of US Steel's sale to Japanese steelmaker Nippon offers a potential opportunity to reverse course and invest in modernizing the US steel industry.** As part of its agreement to acquire US Steel, Nippon has committed to invest $5.5 billion between the Mon Valley Works in Pennsylvania and the Gary Works in Gary, Indiana, over the next three years. It has also committed to spending an additional $1 billion to construct a new mill in a location "to be determined." This could provide the capital spark needed to convert facilities to modern processes that would make the US competitive in emerging markets rather than relining old blast furnaces and continuing to lose ground in the competition with China. Investments in lower-emissions steelmaking now could position US steelmaking operations for more long-term market success.

This report represents one of the most extensive current overviews of the state of the global steel industry and the potential economic opportunities to continue the pursuit of green steel, in particular. Our aim is to provide the reader with a deeper understanding of both historical trends and a slew of recent, rapid developments that have generated immense uncertainty for American steelmakers, workers, and the communities reliant on these companies.

INTRODUCTION

Much has changed since our 2023 report (1), which analyzed the potential economic opportunities presented by the decarbonization of crude steel production in Pennsylvania's Mon Valley. The political and economic landscape in 2025 is so radically different from just two years ago that many analysts are struggling to catch up, creating near-term uncertainty for the steel industry (2). A contentious American election cycle (3) and subsequent change in administration in Washington, D.C., the threat and partial enactment of a new tariff regime upending global trade (4), the reversal of a Presidential blockade on the sale of US Steel to a Japanese steelmaker (5), the large slowdown of Chinese real estate markets and the associated construction boom (6), Europe's implementation of emissions taxes on imports (7), and the passage of legislation through the US Congress dismantling and reversing key decarbonization incentives from the Inflation Reduction Act (IRA) (8) are just a few of the landmark events from the prior 24 months. Major impacts of all of these events on the steel industry are still unraveling.

This report does not attempt to predict exactly what the future will hold as these global shifts unfold. Any such forecasts would rely on far too many assumptions to be either credible or useful, and we believe that any such steel-industry fortune tellers should be regarded with a heavy dose of skepticism. What this report does do, however, is lay out the current facts surrounding steel decarbonization from a global perspective. It is increasingly clear that one-step-forward, three-steps-back is an untenable decarbonization policy if the United States wants to lead the future of steel production. Europe and Asia will not wait for the United States to pave the way when it comes to emissions reductions from industrial sectors such as steel. In fact, delays in the US may only serve to further increase Chinese market share [See Figures 1 and 2]. Indeed, in 2024, for the first time ever, the Chinese government did not issue any new construction permits for coal-based blast furnace basic oxygen furnace (BF-BOF) steel facilities (9). This major change provides at least some signal that the Chinese government is eyeing a future in which low-emission green steel is not just an environmental luxury, but a valuable global commodity in its own right. To be competitive long-term, the US must begin to view green steel in the same way and make sound investments for the future.

To support this conclusion, this report proceeds by first providing a snapshot of the global steel industry, including supply and demand trends across regions and countries, as well as historical patterns. We pay special attention to the continuing rise of Chinese steel production. We then proceed to examine the impact of President Trump's 2025 tariffs as they pertain to the steel industry, which includes context on prior rounds of steel tariffs, both in the early 2000s and during the first Trump administration. These geopolitical and trade policy changes are critical to understand before we then discuss the status of global efforts to decarbonize steel production. Our discussion here surveys trends in green steel, green hydrogen, and green iron investments being made in other parts of the world. Finally, we briefly explore how, despite legislative changes in the US, the recent acquisition of US Steel by the Japanese firm Nippon Steel Corporation could provide an opportunity to make capital investments that would set the stage for green steel production down the road.

Considering the impact of decarbonizing steel production on Western Pennsylvania's economy is essential. In 2023, we found that shifting to green steel production could reduce greenhouse gas

emissions, boost jobs, and grow the region's economy. Our modeling suggested back then that continuing "business as usual" in the Mon Valley with traditional BF-BOF steelmaking could result in a further 30% decline in total regional steel jobs by 2031, due in part to the continuation of economic forces such as outsourcing, automation, and ever-intensifying global competition.

We found that shifting to low-emission DRI-EAF steelmaking, powered by green hydrogen and renewable electricity infrastructure, could disrupt those trends and instead potentially increase total regional jobs supported by steelmaking by between 27% and 43% (as compared to the above job loss scenario) over the same time frame. Jobs supported by the shift to green steelmaking would be more likely to stay in the Ohio River Valley due to the region's infrastructure ties and would be less susceptible to international outsourcing or poaching by other states. As we noted in our 2023 report, Pennsylvania could see a "first-mover advantage," helping to attract other decarbonizing firms in search of renewable power sources. But such an advantage likely dwindles day-by-day, as other regions and countries rush to win the race for decarbonization dominance and the US falls further and further behind.

What is 'green steel'?

'Green steel', sometimes called 'carbon-free' or 'fossil-free' steel, is a steelmaking process that uses "green" hydrogen in the chemical reaction that converts iron ore into usable inputs for steelmaking. This process is often referred to as "DRI," or direct reduction of iron, and replaces the emissions-heavy blast furnace step that traditionally uses coal to reduce iron. Electric arc furnaces (EAFs) are used to produce steel following DRI, whereas basic oxygen furnaces (BOFs) are used following traditional blast furnaces.

Green steel describes an emerging and virtually emissions-free way to produce primary steel (that is, using mined iron ore rather than recycled scrap steel) (21). Many US companies already use EAF technology to produce recycled steel products from scrap steel. The steel and iron industry is estimated to produce roughly 7% of global greenhouse gas (GHG) emissions and 11% of carbon dioxide (CO_2) emissions, with most of the emissions coming from primary steel production (22,23).

In order to produce green steel, traditional blast furnace and basic oxygen furnace facilities that produce primary steel will need to invest in the DRI and EAF equipment, as well as procure a source of green hydrogen. Green hydrogen is produced, at a basic level, by running renewable-generated electric current through water (H_2O) and separating hydrogen and oxygen, generating zero or near-zero carbon emissions. This process is called electrolysis and occurs inside electrolyzers.

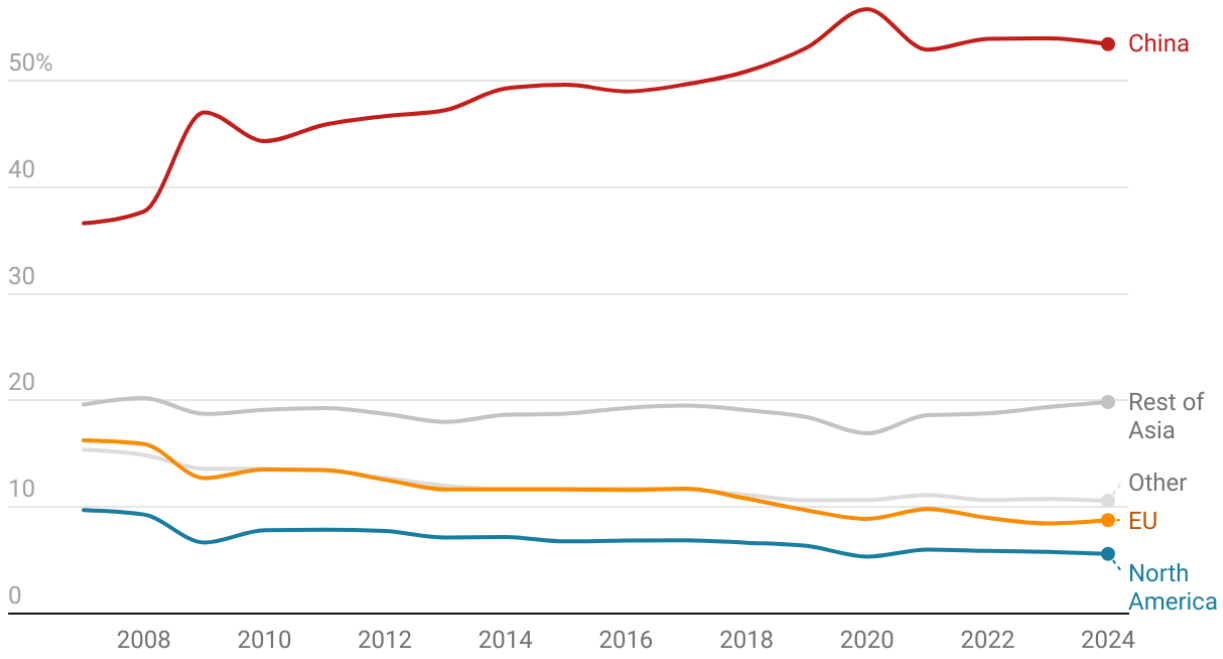
For a full technical discussion, see our previous 2023 report (1).

WHERE IS CRUDE STEEL MADE TODAY? WHAT DOES DEMAND LOOK LIKE?

Today, over one-half of the crude steel produced on Earth is made in China. In 2020, according to World Steel Association data, China became the first country to produce over 1 billion metric tons of steel in a year, and its percentage of global production increased rapidly between 2007 and 2021, before stabilizing over the past four years. In 2024, Chinese crude steel production accounted for 53.4% of the global crude steel output. By contrast, European Union (EU) members produced around 8.7% of global crude steel, and the United States produced approximately 4.2% [See Figure 1].[1]

Over half of the world's crude steel is produced in China.

Figure 1: Annual share of global crude steel production by region, 2007-2024



"Other" includes countries in South America, Africa, Australia, the Middle East, and non-EU Europe that produce at least 2 million metric tons of steel annually.

Chart: Ohio River Valley Institute • Source: World Steel Association • Created with Datawrapper

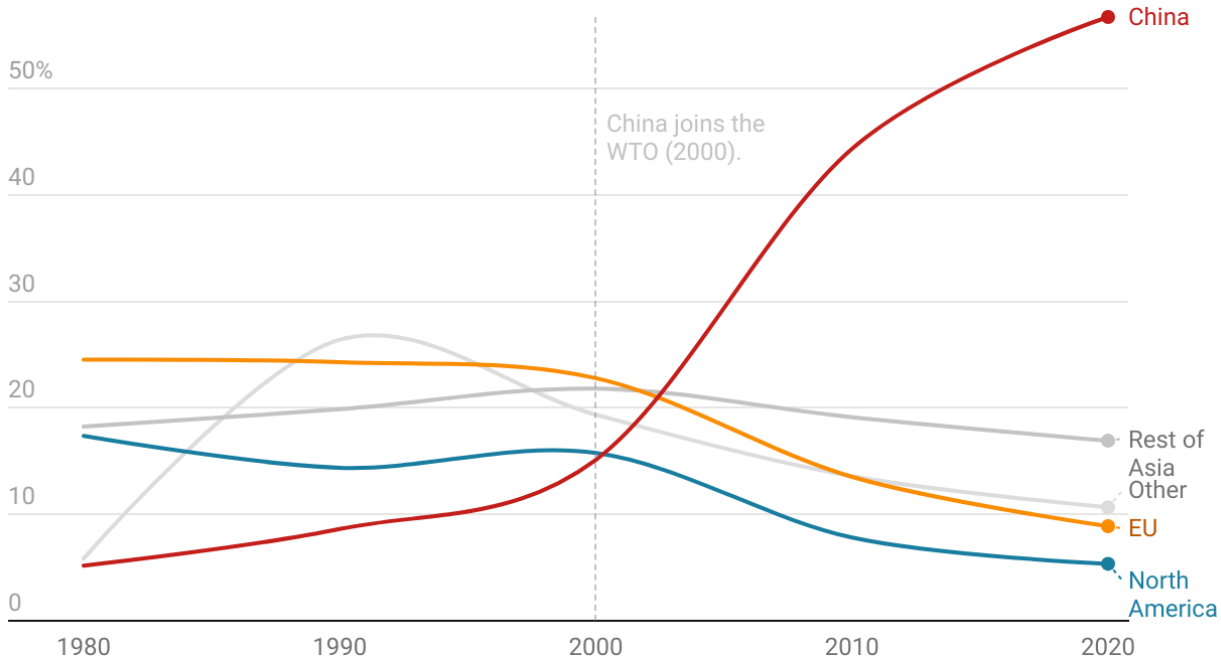
In 2007, Chinese steel accounted for only 36.6% of global production, while the EU and the US produced approximately 16.3% and 7.3%, respectively. That means that between 2007 and 2024, Chinese investment in steelmaking capacity grew its global production share by 45.9% while the EU's share declined by 46.6% and the US production share declined by 42.5% from 2007 global shares.

[1] Data includes only countries who produce at least 2 million metric tons of steel annually.

The rise in global share of Chinese crude steel production is even more stark when you zoom out and examine data between 1980 and 2020 [Figure 2]. The increase becomes particularly evident following liberalization of trade when China joined the World Trade Organization in 2000.

The steel landscape has changed dramatically since 1980.

Figure 2: Share of global crude steel production by region, 1980-2024



"Other" includes countries in South America, Africa, Australia, the Middle East, and non-EU Europe that produce at least 2 million metric tons of steel annually.

Chart: Ohio River Valley Institute • Source: World Steel Association • Created with Datawrapper

The dramatic change in the steel landscape between 1980 and 2024, captured in Figures 1 and 2, also corresponds to a sharp decline in US steel and iron employment over the same time period [Figure 3]. It further correlates with the sharp decline in Pennsylvania's steel employment that was shown in our 2023 report (1).

There have also been domestic forces working against traditional US primary steel production. Amid China's ascension to becoming the largest steel producer in the world, the rise of US minimill steel production (71), which uses scrap steel as its primary input and is less labor-intensive, has largely located in the South and in so-called "right-to-work" states. This has led to downward pressure on employment and wages at US blast furnace basic oxygen furnace (BF-BOF) operations in northern states such as Pennsylvania and Indiana.

A major domestic inflection point came in 1989 when Nucor built the world's first flat-rolled electric arc furnace (EAF) mill, allowing secondary steel producers to move beyond lower-quality and construction steels to capture market share on product lines that had been long dominated by BOFs, such as power generation, oil and gas, and the automotive steel (72). As a result, the share of US steel production

made via EAF jumped from 38% to 61% in the period from 1991 to 2010 (73). While scrap-based minimills are not yet capable of producing all grades of steel that can be made via BF-BOF, today EAFs account for about 70% of all US steel production (74). Some argue that instead of innovating, updating technology and building more efficient mills in order to compete with these minimills, legacy steel producers have instead spent their time and money to fight foreign steel, ultimately becoming even less competitive in the process (71).

Steel employment in the US is on the decline.

Figure 3: US iron and steel mill & ferroalloy employment, 1987-2024

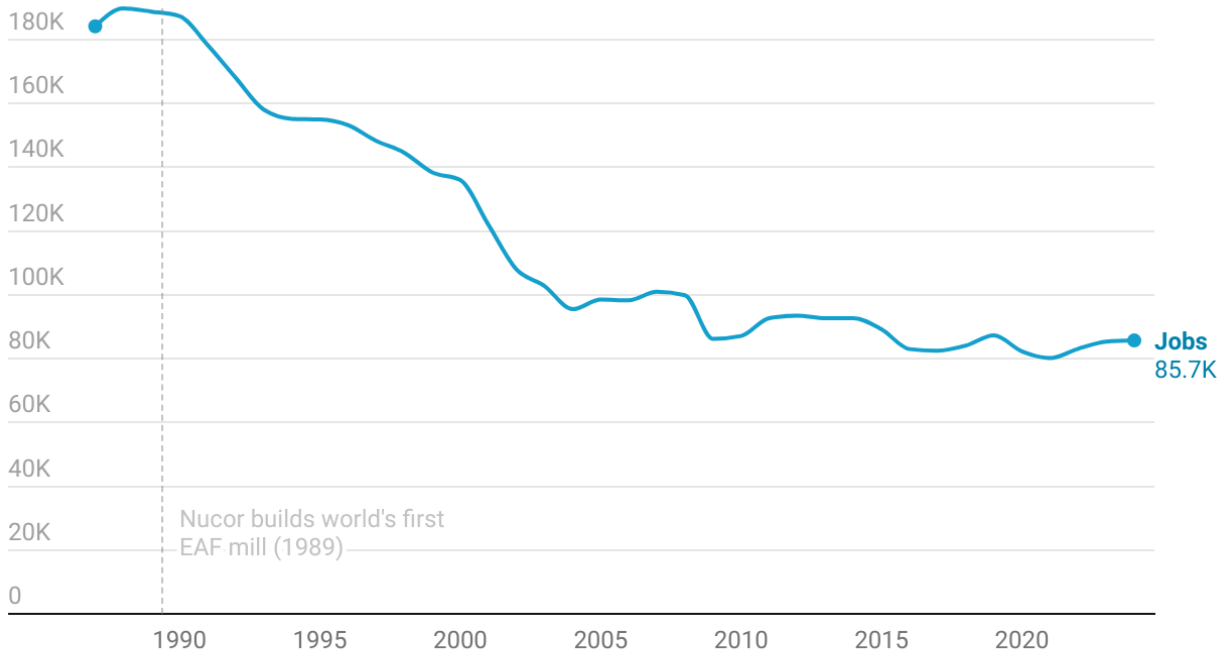


Chart: Ohio River Valley Institute • Source: US Bureau of Labor Statistics • Created with Datawrapper

It is clear that over the past two decades, China has become the dominant producer in the global steel market, fueled in part by its own domestic construction boom in the last decade. During this period Chinese demand for crude steel increased by 50% (10). Both Chinese supply and Chinese demand matter significantly for the outlook on decarbonizing the steel industry, largely because of their impact on steel prices. Simply put, an oversupply of high-emission steel drives prices down and makes it more difficult for companies to make capital investments necessary to transition to cleaner technologies. There is some evidence, however, that consumer preferences for low-emission steel products, content requirements for tax incentives, and government emissions adjustments to import taxes may help to develop a so-called 'green premium'. This is, effectively, a willingness-to-pay specifically for steel with a low-emissions profile. The development of a green premium could influence steel production trends and investment decisions over the next several decades, but only if companies are able to anticipate it correctly. To explore this idea further, we first examine global steel demand and price trends.

Trends in Global Demand for Steel

Understanding the global demand picture for all types of steel is anything but straightforward. Global steel demand varies significantly by region and fluctuates with economic conditions; demand tends to rise in times of economic growth and slow during recessions. The current US administration has added uncertainty to the picture, launching various trade wars, with many tariffs or potential tariffs targeting steel and related imports in particular. This added uncertainty makes assessing the true US demand for steel difficult.

Broader trends, however, suggest that the global glut in steel production will continue, at least in the short term. Global demand for steel is forecast to see tepid growth of just 1% in 2025, following a slight decline in 2024. China, which has generally been a large driver of growing steel demand, has seen a slowdown in its construction boom. In the US, persistently high interest rates may continue to tamp down demand as manufacturing construction waits for a better investment climate. Uncertainty surrounding the inflationary impact of tariffs, however, has resulted in the US Federal Reserve becoming more uncertain about how quickly to lower interest rates (11). The recent passage of the One Big Beautiful Bill Act will also likely have an impact on steel demand by reducing incentives or delaying infrastructure spending authorized by the Biden Administration's Infrastructure Investment and Jobs Act ($1.2 trillion) and Inflation Reduction Act ($750 billion). By some estimates, new infrastructure spending accounts for roughly 40% of projected steel demand in the US and, accordingly, any chilling effect on previously planned clean infrastructure construction will ostensibly reduce steel demand. (2).

Slowing demand is a particular problem given the overproduction the global steel market has already experienced since 2021 and the looming additional production capacity that is already under construction.

Trends in US Demand for Steel

Since President Trump's re-election, the US steel industry has experienced several significant developments in the first half of 2025. Forecasts for domestic steel demand before the Trump administration's sweeping global tariffs had suggested a modest increase for 2025, following a lackluster 2024 (12).

This anticipated domestic growth for the steel industry was primarily attributed to federal initiatives, such as the Infrastructure Investment and Jobs Act (2021), the CHIPS Act (2022), and the Inflation Reduction Act (2022). These bills, passed during the Biden administration, were widely expected to bolster infrastructure projects and, consequently, increase American steel consumption. In an October 2023 earnings call, US Steel's CEO said that "Enabled by legislation like the Bipartisan Infrastructure Law, the CHIPS Act and the Inflation Reduction Act — what we like to call the Manufacturing Renaissance Act — the United States is experiencing a once-in-a-generation onshoring boom" (15). Now, that so-called boom may be in jeopardy as the new administration seeks to undo many of the signature Biden-era initiatives and radically shift US trade policy (16).

Underlying demand from the two largest end users of domestic steel, the automotive and construction industries, has remained relatively robust in 2025, despite uncertainty about economic conditions and tax credits (141).

Analyzing the underlying demand scenario is highly complex, with various indicators of demand open to multiple interpretations. A statistic called "capacity utilization" can be an interesting proxy for demand, given that it measures how much output an industry is estimated to generate, divided by the federal government's estimate of "sustainable maximum production" – i.e., how much could be produced by an industry, factoring in normal downtime (14). That is, how much of their current production capacity are companies actually using? Presumably, companies adjust their production capacity utilization in response to market trends and whether or not their products are selling.

Capacity utilization trends dating back to 2019 for the iron and steel industry, compiled by the US Federal Reserve, show August 2025 capacity utilization around 74% (Figure 4). However, there are industry reports more specific to steel that indicate a capacity utilization of roughly 78% (75). Even if we view 100% capacity as an unachievable or unrealistic production goal, US iron and steel product capacity utilization in the US was still down significantly from its highs prior to the Great Recession.[2]

The market signals for the domestic steel industry, illustrated by stock prices for Nucor and Cleveland Cliffs, suggest optimism. Share prices have rebounded sharply since Trump's so-called Liberation Day tariff announcements in April. Even legal challenges to the tariffs have not caused the stock prices to decline significantly.

Domestic steel prices, particularly since early April, have risen sharply since then, continuing to increase after tariffs on imported steel were increased to 50%in June. (See next section: Steel Tariffs and Trade Uncertainty.) As of August, domestic steel prices are more than double China's and nearly double the World Export price (76).

Taking a longer term view paints a less rosy picture. The industry's job numbers are a fraction of what they were in the 1980s (refer again to Figure 3), and capacity utilization seems unlikely to return to the heady days of 85%-95% since the 1980s, including the early 2000s. Ever since the Great Recession in 2008, capacity utilization has rarely topped 80%. (Figure 4).

[2] We note that according to data from the Board of Governors of the Federal Reserve, the US Capacity Index for Iron and Steel Products reached highs of 97.8% and 99.3% during the economic booms of the 1990s and early 2000s, respectively. The Capacity Index has not returned above its pre-2008 level (92.5%) since the Great Recession.

US capacity utilization has plateaued below 80%

Figure 4: Capacity utilization for US iron and steel production, 2019 through August 2025

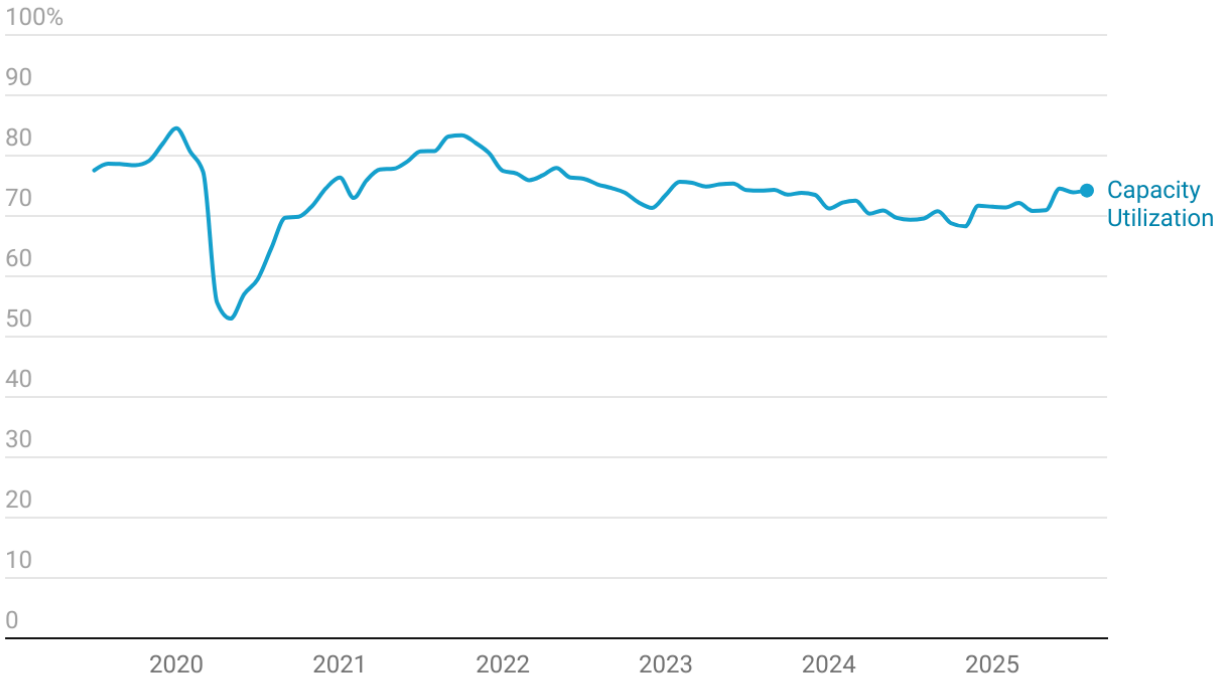


Chart: Ohio River Valley Institute • Source: Board of Governors of the Federal Reserve System • Created with Datawrapper

STEEL TARIFFS AND TRADE UNCERTAINTY

The US steel industry is no stranger to tariffs. In 2017, during his first term, President Trump ordered the Commerce Department to investigate whether steel and aluminum imports were a risk to US national security. To do this, the first Trump administration used Section 232 of the Trade Expansion Act of 1962, a little-used trade enforcement tool that had not been put to use in any industry in more than a decade (77).

But even before the Trump era, the US previously tried a different form of steel tariffs, which were implemented by President George W. Bush in March 2002 under Section 201 (78). These emergency steel safeguards included tariffs of up to 30% on select steel products and were to remain in effect until 2005. However, the tariffs were removed in December 2003 after a ruling by the World Trade Organization (WTO) concluding that such tariffs violated the US' commitments to the trade body. At the time, the US also faced threats of retaliatory tariffs from the EU.

By 2017, however, the US steel industry had been feeling the effects of global overcapacity and made allegations of unfair trade practices by other nations. This time, when the Section 232 investigation was launched, Commerce had 152 antidumping and countervailing duty orders in place from 32 different countries and 25 additional investigations underway on steel products, making steel one of the most active areas for trade cases (17). However, the steel industry argued that the existing trade measures at the time were not enough to address the threat posed by global excess steel capacity. The picture the industry paints regarding overcapacity has been compared to a never-ending game of "whack-a-mole" (79).

When Commerce publicly released its steel report in February 2018, it found that "present quantities and circumstance of steel imports are 'weakening our internal economy' and threaten to impair the national security" (18). Specifically, Commerce noted the reduction in US BOF facilities since 2001 and the potential impact of further plant closures on the capacity needed in a national emergency. "The only effective means of removing the threat of impairment is to reduce imports to a level that should, in combination with good management, enable US steel mills to operate at 80% or more of their rated production capacity," Commerce said.

This led to President Trump enacting a 25% tariff on nearly all US steel imports, which took effect in March 2018 (19). Most notably, Canada and Mexico, the US' largest steel trading partners, were exempt from the tariffs when first implemented, as the three countries were negotiating an updated North American trade agreement.

And while Commerce did put the 80% capacity utilization threshold in its report, there is no timeline or trigger for the tariffs to be removed under the law, and they were not removed by the Biden administration when the estimated Iron and Steel Product Capacity Index rose above 80% in 2021. Since 2018, both Trump's prior administration and the Biden administration negotiated country-specific deals for alternative arrangements to the steel tariffs. This led to a total exemption for Australia,

tariff-rate quotas for Japan, the EU, and the UK—allowing these countries to export a certain amount of steel before being subject to the 25% tariff—and quotas for Argentina, Brazil, and South Korea. In 2018, Commerce also introduced a process to allow US parties to request exclusions for items that are not "produced in the United States in a sufficient and reasonably available amount or of a satisfactory quality." According to the industry, the impact of the tariffs was dramatically weakened by these exemptions (82).

Shortly after taking office for a second term, Trump issued a Presidential Proclamation in March 2025 expanding the existing Section 232 tariffs on steel and aluminum to remove all country- and product-specific exclusions, thus making all imports of steel into the US subject to the 25% tariff. This was done as "imports of steel articles from certain countries exempted from the tariff or subject to alternative agreements have increased significantly, while excess capacity in the global steel industry has begun to increase again in recent years," according to the proclamation. The alternative agreements also have not resulted in sufficient action by trading partners to address non-market excess capacity "caused primarily by China," according to the White House. Further expanding the tariff program, for the first time, the Section 232 tariffs were extended to nearly $150 billion worth of derivative products made from the metals, ranging from nuts and bolts to tractor parts, metal furniture, construction materials, and machinery parts (83).

Less than three months later, Trump announced a doubling of the steel and aluminum tariffs, (84) increasing the Section 232 tariff rate on steel imports[3] and associated derivative products to 50% on June 4. Once tariffs are in place under Section 232, it is up to the discretion of the president to adjust the tariff levels or remove them as they see fit. However, Cleveland-Cliffs CEO Lourenco Goncalves in October seemingly took credit for the higher tariff rate, telling Politico that "without giving any details, I have my fingerprints on the 50%" (142). The higher 50% tariffs also apply to the value of steel and aluminum content in imported derivative products. The Commerce Department expanded the derivatives list to include household appliances in June, marking the first time consumer goods were specifically targeted by Trump's tariffs (88). In August, the Trump administration quietly expanded the 50% steel and aluminum tariffs to include more than 400 additional product categories (89). This expanded the tariff list to include products such as fire extinguishers, machinery, construction materials, and specialty chemicals that either contain or are contained in aluminum or steel.

And while some form of steel tariffs have been in place since 2018, so far tariffs have not led to significant investment in modernizing the US' challenged primary steelmaking operations. Despite much of the reasoning for the application of original steel tariffs being centered on the country's shrinking production of primary steel produced via BF-BOF, most of the increased capital spending by US steelmakers in the wake of the 2018 steel tariffs went to scrap-based EAF production (90). In fact, all of the new flat-rolled steel capacity built in the US following the original steel tariffs was EAF,

[3] One exception was made for the UK, which was kept at a 25% tariff level on steel and aluminum due to ongoing trade negotiations related to the "US-UK Economic Prosperity Deal" (86). The two countries in May previewed a general terms document that would see the Section 232 tariffs on UK steel imports replaced by a quota arrangement (87). However, whatever agreement on steel the US reaches with the UK will have very little consequence, as US steel imports from the UK totaled only 240,397 metric tons in 2024, representing less than 1% of the more than 26 million metric tons of steel imported into the US that year.

scrap-based production. That is to say, the US primary steel industry is due for major capital investment in the coming decade. This investment will take the form of either relining antiquated and demonstrably uncompetitive BF-BOF facilities or investments in newer, cleaner, modern DRI technologies.

Steel Prices: The Ultimate Market Signal

The steel industry has largely hailed the new tariffs as positive, with one American steel CEO claiming that the tariffs will 'level the playing field' for US companies (91). This thinking seems to center on the belief that tariffs on steel from Canada and Mexico—countries from whom the US imports a large quantity of steel—will reduce foreign competition, making domestic steel more competitive. Industry groups, including the American Iron and Steel Institute (AISI), Steel Manufacturers Association (SMA), Committee on Pipe and Tube Imports (CPTI), Specialty Steel Industry of North America (SSINA), and American Institute of Steel Construction (AISC), have also welcomed and supported the expanded steel tariffs (92).

However, as much as industry may wish for a sunny price forecast, the reality is much more cloudy and complex, as US economic conditions remain uncertain long-term. Companies that produce finished steel products are taking a "wait-and-see" approach to consumer spending. Capital expenditures and consumer confidence measures have been volatile throughout the year. Construction and automotive industries, which represent the largest end-use markets for domestic primary steel, are seeing varied results and public comments made by steel executives indicate the market has been a mixed bag for domestic steelmakers in the wake of the tariffs (76, 93). During Cleveland-Cliffs' second-quarter earnings call on July 21, CEO Lourenco Goncalves said the tariffs "played a significant role in supporting the domestic steel industry" (98). However, that same day, Mark Millett, CEO of Steel Dynamics Inc., said "the uncertainty regarding trade policy continues to cause hesitancy in customer order patterns across [SDI's] businesses, despite healthy underlying demand factors" (94).

In the wake of the tariffs, US steelmakers have issued a series of price increases, raising costs for domestic manufacturers that make everything from cars to military tanks (93). The higher tariffs have disproportionately affected steel distributors, processors, and original equipment manufacturers. As of August, market participants were reporting that steel prices in the US would be weaker if not "artificially propped up" by tariffs (95). The tariffs have created a widening margin between US domestic and imported steel prices, with offshore prices for hot-rolled coil continuing to rise in the US spot market as domestic hot-rolled coil prices have held firm at higher levels (96).

One gauge of domestic price levels is the producer price index (PPI). The US Federal Reserve maintains data on the PPI for hot-rolled and cold-rolled steel products, shown in Figure 6.[4] It is important to note that the index is measured from a base year (1982 = 100) and so this data does not reflect the market

[4] The Producer Price Index (PPI) measures the average change over time in the prices received by domestic producers within the industry. Unlike the consumer price index (CPI) which is used to track inflation, the PPI tracks prices at the wholesale or production stage, making it an indicator of intermediate cost pressures within the economy. The overall index is constructed using a fixed-basket methodology, weighted by industry output value. PPIs can then be disaggregated by industry, commodity, and stage of processing, allowing researchers to trace price dynamics through production chains. An upward trend in the indices means that producers are receiving higher wholesale prices, which may be passed through to consumers by the final manufacturer. For this reason, researchers often use PPI as a leading indicator for consumer price inflation.

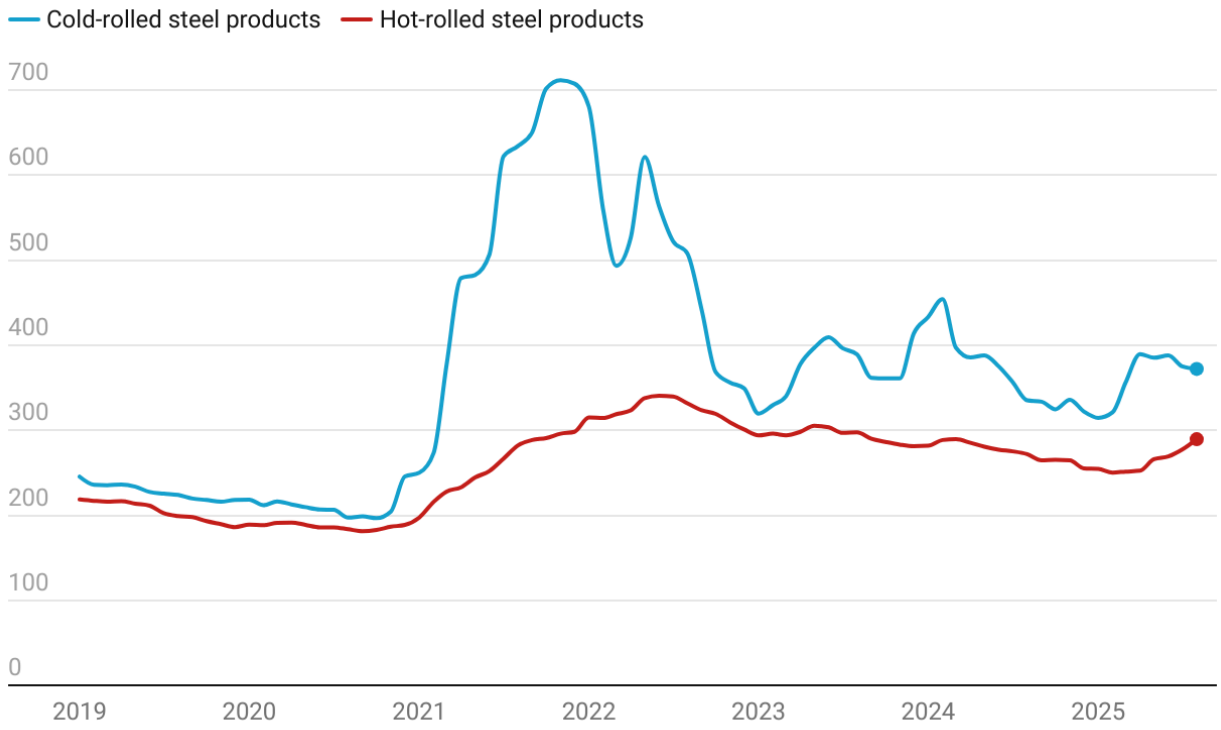
price in dollars, but rather the change in prices over time. As the data indicate, both hot-rolled and cold-rolled products experienced an upward spike during the pandemic, when Chinese supply chains were hugely constrained and consumer demand for steel-intensive goods like automobiles and appliances rose sharply. Prices have been relatively stable since 2023 but showed early signs of increasing in early 2025, following the tariff announcements.

Only more time will tell whether this upward price trend will continue or whether slowing demand or increased foreign production will mute the impact of the tariffs and keep US primary steel (relatively) uncompetitive. If the latter comes to pass, US producers may be forced to choose between large capital investments that price levels cannot support or discontinuing primary steel production in places like the Mon Valley and Gary, Indiana, where steel has long been a bedrock of the local economy and culture.

We argue that there is a third option, which is to become a leader in low-emission steelmaking, which stands to benefit from both its unique value to consumers in the market (i.e., the developing green premium) and from favorable treatment by governments in terms of border adjustments, tax incentives, and content requirement regulations.

Steel prices have been relatively stable since 2023.

Figure 5: Producer Price Index (PPI) for primary steel products, 2019-2025



The Producer Price Index (PPI) measures the average change over time in the prices received by domestic producers within the industry. The index is measured from a base year (1982 = 100).

Chart: Ohio River Valley Institute • Source: US Federal Reserve Bank of St. Louis • Created with Datawrapper

What happens if the US doesn't compete in primary steel anymore?

Replacing domestic steel production with imports can lead to job losses, diminished domestic manufacturing capabilities, and increased supply chain vulnerabilities. But considering how trade-exposed the industry is, it is not unimaginable for a country to lose its ability to make steel from scratch. Once a blast furnace is decommissioned, it cannot then be turned back on quickly or inexpensively (97). This is something that policymakers in the United Kingdom (UK) have learned the hard way. This past spring, lawmakers in Parliament were recalled from a recess in April to pass emergency legislation to take control of British Steel amid reports that the company's owners, China's Jingye Group, were trying to shut down steelmaking operations by starving the plant of the raw materials needed to keep the blast furnace operating (99). This left UK lawmakers scrambling at the last minute to secure the coke and iron ore pellets needed to power the furnace (100). They did this because the government viewed losing primary steel production as a risk to its economic security. Were the plant to stop producing virgin steel, the UK, once a world leader in steel, would be the only member of the G7 group of leading economies without the ability to make it. (101). And while the government has had to act fast, the crisis at British Steel didn't happen overnight. Like the decline in US primary steelmaking, it has been decades in the making. Ahead of the UK government taking control, in March

2025, owner Jingye said the plant was losing £700,000 a day, prompting a consultation on its closure as it said the blast furnaces were “no longer financially sustainable.”

The US government also sees the need to maintain primary steel production, as the public explanation for the implementation of steel tariffs in the US has largely centered on the government’s view that it is a national security risk to lose the ability to make primary steel. The US Commerce Department has said that a domestic steel industry is needed for national defense requirements and for critical infrastructure sectors, including transportation systems, the electric power grid, water systems, and emergency power generation systems. But as current direct demand from the Department of Defense only requires about 3% of total US steel production, defense and critical infrastructure requirements alone are not sufficient to support a robust steel industry. This then requires US steel producers to be financially viable and competitive in the commercial market in order to be available to produce the needed steel output in a timely and cost-efficient manner in times of national emergency, including war.

Secondary steel can be used to fulfill some of these requirements; however, specific steel grades for applications that demand the absolute highest quality and purity remain more difficult to produce in EAFs. Most commonly, it has been said that the automotive sector requires steel produced from coal-based blast furnaces to meet its quality standards. However, international green steel group SteelWatch has called this way of thinking “outdated,” as today’s EAFs use varying quantities of virgin iron to dilute impurities present in scrap. For example, the group notes that the Big River Steel EAF steel plant in Osceola, Arkansas, is developing processes to simplify the production in EAFs of advanced high-strength steel grades (AHSS), as used in the automotive industry. Big River, a non-union EAF steelmaker that has been owned by US Steel since 2021, has already started to produce electrical steel for electric vehicle engines in Arkansas, products that historically have only been produced via BF-BOF.

GREEN STEEL IN THE NEW ECONOMIC LANDSCAPE

This report began with a lengthy update on the global steel market and international trade landscape because these massive changes have occurred very rapidly and pose major consequences for the timeline along which the steel industry could be decarbonized. This potential delay is of particular concern, as policymakers around the planet attempt to limit rising global temperature averages to 1.5°C in hopes of mitigating the increasing frequency and intensity of extreme weather events, such as floods, droughts, and wildfires, which could upend human populations with tragic health and economic costs (20).

The economic reality that industrial decarbonization has faced since its onset is that there are not always obvious financial incentives for producers to make the large capital investments upfront that are needed to both construct and install new technologies (such as EAFs and hydrogen electrolysis facilities) or to generate the renewable electricity to power them. How, then, does our society provide such an incentive? Generally speaking, two broad categories of action might be taken that could spur the industry to shift its investment strategies: government intervention or changes in consumer behavior, which are often complex and slow to materialize.

"Intervention" simply means that a government policy impacts private business and economic decisions in some way to correct for externalities that might inadvertently harm the public or produce dramatic inequities in opportunity for Americans. One of the largest sources of "government intervention" is the US tax code. Tax rates, exemption rules, credit programs, and filing procedures all distort markets in some way, whether intentionally or unintentionally. Interestingly, few politicians from either major political party in the United States decry the nearly $20 billion per year in subsidies and preferential tax treatment for fossil fuel companies as "welfare" or "socialism," although the terms may be apt (25).

Government intervention and investment during the middle of the 20th century shaped massive pillars of the US economy, including the agricultural and automotive sectors. From production subsidies, to government-backed insurance programs, to safety regulations, to procurement contracts, to tax credits, the federal government has shaped the modern American economy the way that a gardener might coax a vine along a trellis. And in a democracy, as public priorities change in the face of new data and scientific discoveries, it is reasonable that the government can change its policies to help meet the moment, as it did by providing a variety of tax incentives, grants, and subsidies under Biden-era legislation such as the IRA (26). These interventions were not adversarial, and federal dollars were not to punish but to help US companies not only become more environmentally sustainable but also more competitive. As this report has already shown for traditional steelmaking in particular, the US industry was largely outcompeted by China and other nations before the passage of these laws.

The US government can play a large role in shaping what the future of industry looks like. The Biden Administration made efforts to advance green steel production through a federal initiative to cut carbon emissions from steel mills through the Department of Energy's Office of Clean Energy Demonstrations

(OCED) (102). Through OCED's Industrial Demonstrations Program, steelmakers Cleveland-Cliffs and SSAB were awarded up to $500 million each for projects to produce iron using hydrogen. However, the plans were ultimately dropped by the companies amid shifting priorities under the Trump administration (1`03).

Instead, Trump's administration, which has canceled over $7.5 billion in awards for clean energy projects that were to be funded by OCED, has put its support behind the coal industry (104). As part of this effort, the Trump administration has moved to designate metallurgical (met) coal, or steelmaking coal, as a critical material (105). Environmental groups, however, have argued that the effort to designate metallurgical coal a "critical material" in the department's 2026 Critical Materials Assessment relies on a flawed and insufficient process, as met coal fails to meet the legal definition of a 'non-fuel' material (106). Not only that, according to data from the US Energy Information Administration, of the estimated 67 million short tons of met coal produced in the US in 2023, 76%, or 51 million short tons, was exported to coke producers and steelmakers around the world, showing no evidence of a supply chain risk or US reliance on imports (107).

In the long run, over the coming half-century, there will be opportunities for US policymaking to help industrial producers decarbonize and modernize. Unfortunately, in the short run, we assess that most of the incentive to decarbonize the industrial sector will come from foreign competition and consumer-driven changes. Consumers may value the climate more as time goes on and be willing to pay a so-called "green premium" in order to ensure that the products they buy have a low-intensity emissions footprint. Additionally, foreign governments may implement new fees and taxes on products with high emissions intensity, as we are beginning to see in the European Union with the carbon border adjustment mechanism (CBAM).

Green Steel Premiums Are Still Emerging

Green steel costs more to produce than traditional steel because it requires increased electricity demand for hydrogen production (i.e., electrolyzers), electric arc furnaces, direct reduction-grade (DR-grade) pellets, green hydrogen, and significant infrastructure upgrades (143).

These increased costs can be passed on to buyers; however, the overall emergence of a "green steel premium," or the additional cost buyers are willing to pay for low-carbon steel, has been uneven and regional, with disparities across Europe, Asia, and the Americas. While Europe has emerged as a first mover in mills trying to enforce higher prices for cleaner production, a green premium for steel has been slow to emerge in the US market.

Cleveland-Cliffs was the first in the US to introduce a "green premium" for steel it makes using Hot-Briquetted Iron (HBI), a low-carbon iron feedstock, produced at its facility in Toledo, Ohio. (29). Announcing the $40 per short ton "Cliffs H" surcharge in July 2023, Cliffs' CEO Lourenco Goncalves said the company "deserve[s] to be paid for a characteristic of our steel that truly differentiates us" from other global suppliers to the automotive industry (30). Goncalves said he sees this increased cost being passed on to consumers, estimating it would increase the window sticker price of a car by less than 0.1%.

Offtake agreements with major buyers done on an index plus premium basis, like those used to fund Scandinavian green steel projects (27), can provide early demand, reduce investor risk and help secure financing for facility investment. In 2023, the clean energy think tank Rocky Mountain Institute (RMI) launched the Sustainable Steel Buyers Platform in an effort to advance the purchase of inaugural volumes of near-zero emissions steel in North America (31). Companies that have signed on to the effort include Amazon, Microsoft, and Meta. RMI estimates US annual demand for near-zero emissions steel will reach 6.7 million tons by 2030 (32). To put this into perspective, the US produced 79.5 million tons of steel in 2024, with a typical steel plant producing about 2 million tons annually (33,34).

Along with increased demand from the private sector, the public sector can also play a role in advancing green steel through procurement policies that can lead to stable demand for clean steel production. Production and investment tax credits can be tools to de-risk investment and narrow the gap on the cost of production. Other routes include imposing a price on carbon-intensive production, which can make conventional steel more expensive when accounting for its high emissions. Mechanisms like a carbon border tax can shift market dynamics, reflecting the true cost of CO2 emissions and thus making green steel more attractive.

European Carbon Border Adjustment Mechanism (CBAM)

The EU's Carbon Border Adjustment Mechanism (CBAM) is a policy tool designed to place a fair price on the carbon emissions embedded in carbon-intensive goods like iron and steel imported into the EU while promoting cleaner industrial production in non-EU countries (35). By ensuring that imported goods bear a carbon price equivalent to that of domestic production, CBAM prevents carbon leakage and upholds the EU's climate objectives without disadvantaging local industries.[5] The mechanism aligns with World Trade Organization (WTO) rules and is being implemented in phases, with a transitional period from 2023 to 2025, before its full application in 2026 (36).

The greenhouse gases that need to be monitored have been defined according to the activities and emissions of the greenhouse gases listed in a special EU Directive that established a scheme for greenhouse gas emission allowance trading (37). The iron and steel sector needs to monitor carbon dioxide, as it is the primary greenhouse gas emitted during the traditional coal-based primary steel production process.

[5] Carbon leakage refers to the situation that may occur if, for reasons of costs related to climate policies, businesses were to transfer production to other countries with laxer emission constraints. This could lead to an increase in their total emissions. The risk of carbon leakage may be higher in certain energy-intensive industries, like iron and steel production.

The formula for calculating specific embedded emissions in the iron and steel sector is presented below (38).

$$Specific\ embedded\ emissions\ =\ \frac{Total\ CO2\ emissions\ from\ iron\ and\ steel\ production}{Total\ iron\ and\ steel\ production}$$

- The numerator, "Total CO2 emissions from iron and steel production," represents the sum of CO2 emissions released during the entire iron and steel production process in metric tons. It encompasses both direct and indirect emissions.[6]

- The denominator, "Total iron and steel production," refers to the overall amount of iron and steel produced within a specific timeframe. It is usually measured in cubic meters and represents the total quantity of iron and steel manufactured during that period (38).

The recent EU Commission's draft proposal suggests modifying the CBAM rules by introducing a 50-metric-ton annual mass-based threshold, which would exempt most small and medium-sized importers while still covering over 99% of emissions under the scheme. Additionally, the proposal aims to simplify compliance rules to make it easier for companies to claim CBAM cost reductions for goods imported from a country where manufacturers already pay a CO2 price (35).

Russia, India, South Korea, China, and Turkey were the EU's top import sources of iron and steel in 2024 (Figure 5). Indeed, the US did not crack the top 10. Imposing CBAM CO2 emissions tariffs on iron and steel produced via traditional carbon-intensive methods potentially affects the importer's competitiveness in the European market. Many countries recognize the potential impact of CBAM. Countries like India, China, and Turkey have encouraged steel manufacturers to adopt decarbonization strategies, including investing in low-carbon technologies and improving energy efficiency, to maintain their market position within the EU.

[6] Emissions to report include the indirect emissions linked to the electricity used in the production process, as well as the direct and indirect emissions to produce precursors, and finally the direct emissions to produce iron and steel products.

Who are the largest exporters of steel to the EU?

Figure 6: Iron and steel imports, 2024 (euros)

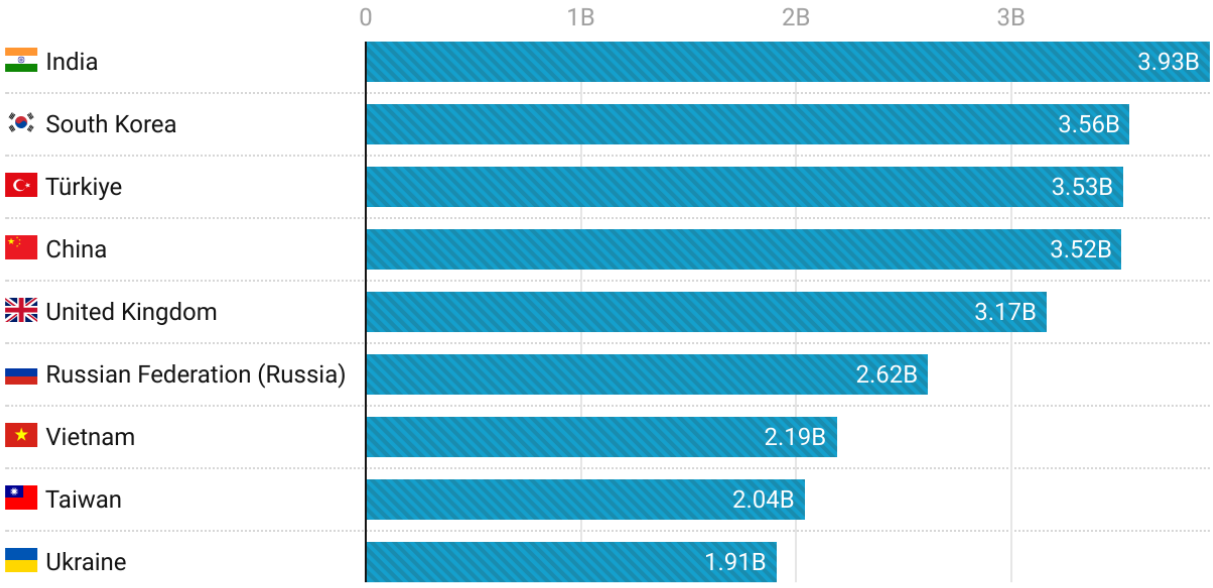


Chart: Ohio River Valley Institute • Source: Eurostat • Created with Datawrapper

DECARBONIZATION EFFORTS ARE UNDERWAY GLOBALLY

The twin pressures of European intervention, as well as consumer demand and emerging green premiums, have been enough to initiate at least some decarbonization efforts in other countries. According to a July 2025 BCC market study, global green steel markets are projected to grow from $7.4 billion in 2024 to $19.4 billion by 2029, a compound annual growth rate of 21.4% (39). Still, this would represent just 1.2% of global steel market size in 2024, suggesting that there is plenty of room for continued growth into the middle of the century (108).

Whether these efforts stall or continue remains to be seen. Regions and countries are investing in low-carbon technologies like hydrogen-based direct reduction of iron (DRI), electric arc furnaces (EAF), and carbon capture. While progress varies due to factors like energy availability and economic conditions, the green steel transition is gaining momentum across continents. This transformation is not only crucial for reducing emissions from one of the most carbon-intensive industries but also for supporting clean energy and sustainable infrastructure development worldwide. The following subsections provide a brief, high-level overview of major developments in green steel by region, although these highlights are not comprehensive.

Green Hydrogen: The 'Secret Ingredient' for Green Steel

Transitioning to green, or fossil-free, steel is impossible without the implementation of green hydrogen-based DRI-EAF technology. Green hydrogen is produced, at a basic level, by running renewable-generated electric current through water (H2O) to separate hydrogen (H2) and oxygen (O), generating zero or near-zero carbon emissions. This process is called electrolysis and occurs inside electrolyzers.

Green hydrogen is essential for decarbonizing hard-to-electrify sectors like heavy industry, transport, and synthetic fuels. Still, today, green hydrogen remains in the early stages of deployment amid complex challenges.

In 2025, the total global active and upcoming capacity for low-carbon hydrogen reached 132 Mtpa, with an impressive 88% attributed to green hydrogen plants (109).

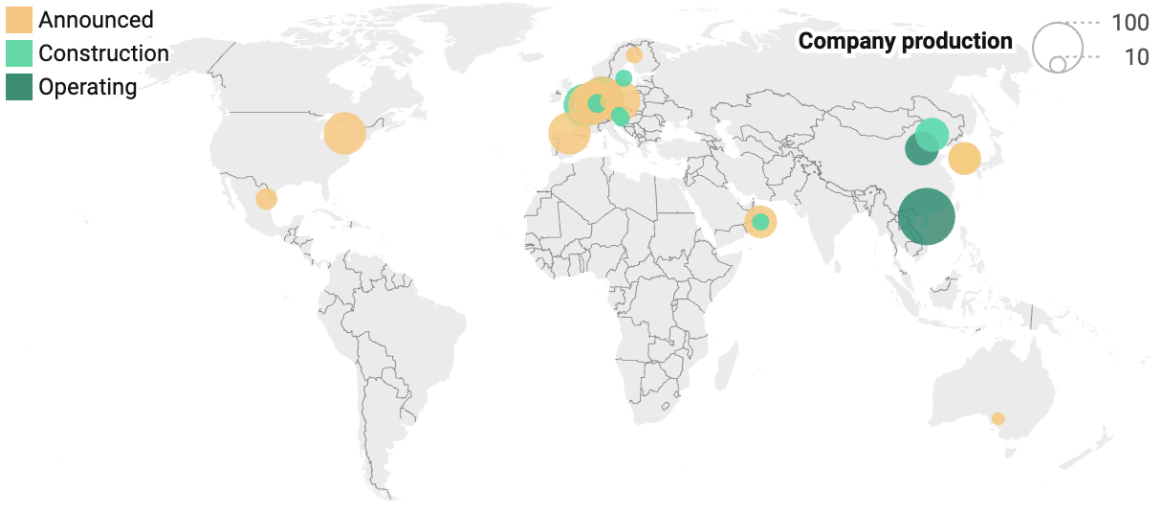
Despite these positives, green hydrogen initiatives are facing setbacks. High production costs (ranging from $1–3 per kg for fossil-based sources to $3.4–7.5 per kg for electrolysis using low-emission electricity), insufficient demand, and infrastructure barriers have led to project cancellations and scaling-down decisions, jeopardizing climate targets such as the EU's 2030 goal of 40 GW capacity, of which only ~12 GW is expected to come online (110, 111, 112).

North America is losing ground in the global low-carbon hydrogen race, with its projected share of global capacity expected to drop from 46% in 2025 to just 28% by 2030 (113). The region faces growing headwinds from policy shifts, most notably due to the current administration's curbing of green hydrogen momentum through halted funding and high tariffs on imports.

The One Big Beautiful Bill Act, signed into law on July 4, 2025, includes updates to the Section 45V Clean Hydrogen Production Tax Credit, shortening the timeline for projects. New rules require facilities to begin construction before January 1, 2028, to be eligible for the tax credit. Previously, under the Inflation Reduction Act (IRA), the construction start date had to be before January 1, 2033, to qualify for the credit (114). Many developers fear they won't meet the new requirements, potentially derailing up to 75% of announced green hydrogen capacity in the US. This accelerates a pivot toward natural gas-derived "blue" hydrogen projects that use steam methane reformation coupled with carbon capture, utilisation, and storage (CCUS) and reinforces regional disparities, as federal rollback contrasts with continued state and provincial support.

Decarbonization efforts are underway globally.

Figure 7: Map of full-scale low-carbon steel projects by company production (million USD)



Map: Ohio River Valley Institute • Source: Industry Transition • Get the data • Created with Datawrapper

Asia

In Asia, China remains a leader in emission reduction efforts, upgrading over 600 million metric tons of steel capacity to ultra-low-emission technologies between 2019 and the middle of 2024. In February

2025, China's Ministry of Industry and Information Technology (MIIT) released the Normative Conditions for the Steel Industry 2025 guide, emphasizing this transition to low-carbon production and promoting green technologies, low-carbon ironmaking, and EAF steelmaking, while phasing out high-emission equipment (40,41).

Despite progress, challenges remain. The hydrogen used in many DRI-EAF plants currently comes from coke ovens[7] or natural gas,[8] raising concerns about its long-term sustainability. However, growing demand from the automotive sector could accelerate the shift toward truly green steel production. Leading Chinese steel manufacturers Baowu and HBIS have been forming strategic partnerships with automakers to meet growing demand for low-carbon steel (42).

In 2022, the Hydrogen Steelmaking Consortium, formed by major Japanese steel firms Nippon, JFE, and Kobe Steel, in collaboration with NEDO's Green Innovation Fund, launched Super COURSE50, aiming to halve CO2 emissions using the injection of heated external hydrogen, achieving a world-leading 33% reduction in trials. NEDO's Green Innovation Fund also supports alternative methods, including direct hydrogen reduction and electric arc furnace technology, recognizing that steelmaking processes vary globally based on resource availability (43). According to Global Energy Monitor, around 80% of Japanese steel is still made using coal-based BF-BOF technology (115). Against this background, Nippon Steel investors backed three climate-related proposals at the June 2024 Annual General Meeting (AGM). Supported by major global asset managers, these measures—covering climate-related lobbying disclosure, linking executive pay to emissions reduction targets, and Paris Agreement-aligned climate goals—show investors leveraging their influence to demand transparency and stronger climate action (116).

Despite decarbonization challenges like the high cost of green hydrogen and limited scrap availability hindering EAF adoption, India's steel sector is transitioning toward low-carbon direct reduced iron (DRI) production methods. By 2025, several pilot initiatives and early commercial-scale projects are expected to employ hydrogen blends in conventional gas-based DRI processes, while forging the groundwork for full-hydrogen DRI routes. Simultaneously, expansions in green hydrogen production, storage, and transport infrastructure will reduce dependence on fossil-based reductants (i.e., natural gas or coal), aligning the Indian steel industry with emerging global decarbonization standards. Tata Steel, the oldest steel company in India, intends to use nuclear energy to power electrolyzers for green hydrogen production. Tata aims to cut its CO2 emissions by 40% by 2030 and become 100% CO2-neutral by 2045 (45–47).

South Korea is advancing hydrogen technologies through steelmakers like POSCO, which plans to shift to a low-carbon production model through innovative technologies like HyREX (Hydrogen Reduction), and Hyundai Steel with its Hy-Cube system—a proprietary hydrogen-based steel production process (48,49). However, a 2024 survey indicated that major South Korean steelmakers, including POSCO and

[7] Coke-oven hydrogen refers to hydrogen gas that is produced as a by-product in the coking process during steelmaking or other metallurgical operations. Typically, 50–60% of the coking by-product gas is hydrogen, which can be separated and purified for use as coke-oven hydrogen in various applications, including direct reduction of iron (DRI).
[8] Steam methane reforming (SMR) makes hydrogen by reacting natural gas (methane) with high-temperature steam to produce a mixture of hydrogen and carbon monoxide, called syngas. The carbon monoxide is then reacted with more steam to make additional hydrogen and carbon dioxide, after which the hydrogen is separated and purified.

Hyundai Steel, have minimal reliance on renewable energy, with fossil fuels still accounting for nearly all their energy consumption (50).

Turkey, the largest exporter of steel to the EU by volume, benefits from a high share of scrap-based EAF steel production (70% of total steel-making capacity in 2024), but still operates some carbon-intensive blast furnaces (`117). Turkey relies heavily on imported scrap metal, primarily sourced from the EU, the United Kingdom, and the United States. This supply has already dwindled, however, due to the Trump administration's imposing tariffs on semi-finished and finished steel, and no tariffs on scrap. In Q1 2025, Turkey's scrap imports fell 11.7% driven by sharp declines from the US and the UK, as US steel tariffs redirected scrap to domestic smelters. Meanwhile, Turkey increased imports from the Netherlands, signaling a shift in sourcing toward alternative suppliers (118).

Europe

With China rapidly catching up, Europe is still a frontrunner in green steel innovation. The year 2025 is pivotal as the EU advances industrial transition with the Clean Industrial Deal (51) and the Steel and Metals Action Plan (52) – both set to impact the steel sector directly (53). The European steel industry has support from the European government financial institutions as well. The European Investment Bank (EIB) has been financing flagship green steel projects like H2 Green Steel, supporting R&D and innovation (e.g. voestalpine), and using its leverage (finance + policy advice) to push decarbonization of hard-to-abate sectors such as steel through hydrogen, DRI, and electric arc furnace technologies (1`19, 120).

Major firms like ArcelorMittal and SSAB are setting a trend for innovation. ArcelorMittal, the world's second-largest steelmaker, headquartered in Luxembourg, cancelled green steel projects in Germany, citing high electricity prices and regulatory hurdles. Instead, the company is shifting production to countries with reliable, low-cost electricity, starting with new electric arc furnaces in Dunkirk, France, powered by the Gravelines nuclear plant (121). Additionally, the company's Belgium, France, Luxembourg, and Spain entities just joined the Low Emission Steel Standard (LESS), reaffirming its commitment to hydrogen-based steelmaking (122).

Sweden is leading with SSAB's fossil-free HYBRIT steel, while H2 Green Steel is building a large-scale green steel plant in Boden, aiming for 5 million tonnes of green steel annually by 2030 (55,56).

France's startup GravitHy raised €60 million to launch production in 2029, powered by nuclear-generated low-carbon hydrogen. The facility aims to produce 2 million tons of direct reduced iron (DRI) and hot briquetted iron (HBI) annually, creating up to 500 direct jobs (57).

Spain's Hydnum Steel is building a zero-carbon steel plant integrating hydrogen, recycled scrap, and renewables. The facility will have an initial annual capacity of 1.5 million Mt, which could expand to 2.6 million Mt per year. Hydnum Steel has been awarded €60 million in funding by the Spanish Government under the PERTE for Industrial Decarbonisation, part of the EU's Next Generation EU programme. The project was declared a Priority Project by the Government of Castilla-La Mancha and recognised by the

World Economic Forum as one of the five leading global projects in industrial decarbonisation. The project is expected to generate over 1,000 direct jobs (123).

Austria's primary crude steel producer, voestalpine, is leading the country's green steel transition through its "greentec steel" program, which includes a broad portfolio of hydrogen and electric arc furnace (EAF) innovations (124). In partnership with VERBUND, Austria's leading energy provider, voestalpine is expanding one of the world's longest-operating PEM electrolysis plants at its Linz site to support the industrial-scale production of green hydrogen. Meanwhile, at the hydrogen-based fine-ore reduction (HYFOR) pilot plant in Donawitz, voestalpine has produced hydrogen-based steel using a mix of recycled scrap and hydrogen-reduced iron ore fines, with hydrogen supplied by an external gas partner. A tangible milestone was reached when Austria's national railway company, ÖBB, laid the world's first hydrogen-based steel track at Linz Central Station, using this material from voestalpine (125).

Looking ahead, voestalpine plans to replace two blast furnaces with EAFs starting in 2027, and beginning in 2030, intends to replace two additional blast furnaces in Linz and Donawitz, along with the construction of a third EAF at Linz as part of its decarbonization roadmap (126).

Africa

At the end of 2023, Namibia initiated the development of Africa's first fully decarbonized ironmaking facility. The HyIron-Oshivela project in western Namibia is backed by the German federal government, which has injected €13 million and will use renewable energy to generate direct reduced iron, aiming to scale to 1 million Mt of green iron annually (58). On March 12, 2025, HyIron-Oshivela began producing sub-Saharan Africa's first green hydrogen-powered iron. The facility features a 12 MW electrolyser, the largest of its kind in the southern hemisphere, positioning Namibia as a regional leader in renewable-powered industrial production (59). Water produced by the DRI process when hydrogen reacts with oxygen in the iron ore will be reused in the electrolyzer (60). The direct reduced iron produced at the plant can be used in Germany to manufacture green steel for the production of wind turbines or vehicles. (60).

Mexico

In Mexico, Ternium S.A., a steel products manufacturer headquartered in Luxembourg, is building a high-efficiency DRI-EAF steel plant in Pesquería featuring Zero-reformer ENERGIRON technology. The plant will deliver hot DRI at 600°C via the Hytemp pneumatic system and is compatible with either natural gas or hydrogen. It can also incorporate CO_2 capture, further lowering emissions and creating an additional revenue stream, and is expected to begin production in 2026. The plant will comply with the US, Mexico, and Canada Agreement (USMCA) "melted and poured" rule of origin regulations and has a projected annual production capacity of 2.6 million tons (61, 62).

South America

Brazil's Vale S.A. is exploring the development of a green hydrogen plant to supply a planned "mega-hub" for producing iron ore agglomerates, such as pellets or briquettes, using renewable hydrogen as a reducing agent. This initiative is part of Vale's strategy to achieve net-zero carbon (63).

Middle East and North Africa (MENA)

According to an IEEFA briefing, MENA is the world's leading hub for gas-based direct reduced iron (DRI) production. In 2023, the region produced 61 million Mt of DRI, equal to 45% of global production. Capacity continues to rise, with DRI-electric arc furnace (EAF) technology being the dominant route. Iran leads as the largest producer of both DRI and steel in MENA, followed by Saudi Arabia and Egypt (64).

Additionally, Israel's Helios Project Ltd is developing the Helios Cycle, a breakthrough zero-emission method using sodium to reduce iron at lower temperatures and cost. This process eliminates carbon emissions entirely and is compatible with low-grade ores, potentially transforming green steel economics. Its pilot with BlueScopeX in Australia, planned to begin in 2026, could set the stage for broader adoption (65).

THE RECENT ACQUISITION OF US STEEL PROVIDES AN INVESTMENT OPPORTUNITY

Despite a reduction in federal subsidies for decarbonization work, there are still domestic opportunities for a conversion to DRI and EAF technologies that would lay the groundwork for the US to be competitive in the low-emission steel market. There are currently 12 blast furnaces operated by two companies in the United States (66). One of these companies – US Steel – was just acquired by Japanese steelmaker Nippon, which has committed to invest $10.8 billion into US Steel's facilities through 2028, including $2.4 billion of planned capital investment in the facilities that make up the Mon Valley Works (127).

Combining Nippon Steel's financial resources, US Steel's iron ore assets, and renewable energy potential in the US could open up new possibilities for producing low-emission steel — especially as demand grows in industries like automotive manufacturing (128). However, Nippon has instead so far signaled a doubling down on coal-based steel production by promising to reline or repair six US Steel blast furnaces by 2030, contradicting its stated goal of going carbon-neutral by 2050 (129). Speaking at an industry event in August, US Steel CEO David Burritt said Nippon is moving forward with plans to reline its largest blast furnace at the Gary Works in Indiana in 2026 (130). Despite nearly $11 billion in planned investment between 2025 and 2028, based on the current outlay of capital disclosed in filings with the US Securities and Exchange Commission, it does not indicate that the company has plans for any major investment into DRI-EAF or another transition to clean primary steel production in the Mon Valley at this time.

Nippon's US Steel investments provide an opportunity for producing low-emission steel

Figure 8: Nippon's planned capital investments in US Steel facilities, 2025-2028

State	Facility	2025	2026	2027	2028	Total 2025-2028
Arkansas	Big River Steel	$0.1	$0.9	$0.9	$1.3	$3.0
Indiana	Gary Works	$0.4	$0.9	$0.8	$1.1	$3.1
Pennsylvania	Mon Valley	$0.1	$0.7	$0.7	$0.9	$2.4
Minnesota	Keetac/Minntac	$0.2	$0.2	$0.3	$0.3	$0.8
Alabama	Fairfield Works	$0.2	$0.2	$0.1	$0.1	$0.5
TBD	New Mini Mill	--	--	--	$1.0	$1.0
Total	--	$0.9	$2.7	$2.6	$4.6	$10.8

$ in billions

Table: Ohio River Valley Institute • Source: U.S. Steel 8-K filed 6/18/25 with SEC • Created with Datawrapper

Providing more details on its investment plans, Nippon in November announced it will build a new hot strip mill at the Mon Valley's Edgar Thomson Works in Braddock (131, 144). This would replace the current hot strip mill located at the Irvin Works in West Mifflin, which was installed in 1938. The company also plans to spend $100 million to construct a slag recycler at Edgar Thomson (145).

An investment of this magnitude in a new rolling mill can be seen as a sign that steelmaking has a future in the Mon Valley. However, it would require more capital than the company has outlined to dramatically update and modernize US Steel's upstream iron- and steel-making operations, currently served by the Clairton Coke Plant and Edgar Thomson Plant. While a transition to green steel production is capital-intensive, so is continuing the status quo, as blast furnace relining costs run anywhere from an estimated $300 million to $1 billion per unit on a 15- to 25-year cycle, according to some sources (132).

Relining a blast furnace rather than transitioning to green production, whether it happens at a US Steel facility in Pennsylvania or Indiana, would have a direct impact on the Mon Valley, as the coke to feed the furnaces at the Gary Works is produced at the Clairton Coke Plant. Pursuing a reline rather than modernizing facilities places heightened pressure on steelworkers and local workforces downstream of the steel supply chain, whose jobs, families, and livelihoods rely on maintaining the historic competitiveness of the US primary steel industry (133). Additionally, with such long lifespans, relines pose a risk that these facilities will become stranded assets amid tightening climate regulations (134). Even more concerning for historic steel communities, continuing business as usual operations without adequate investment in maintaining and modernizing facilities leaves these plants vulnerable to breakdowns and incidents that can impact the health of workers and the community. An August 11

explosion at the Mon Valley's Clairton Coke Plant that killed two workers and injured 10 more has drawn heightened attention to the dangers associated with coal-based operations for workers and communities, particularly in light of the plant's history of maintenance issues, explosions, and environmental violations, Past incidents include a massive fire on December 24, 2018 that knocked out the facility's pollution controls and led to 102 consecutive days of illegal emissions of sulfur dioxide and hydrogen sulfide (134, 135). US Steel has said preliminary findings for the August 2025 incident indicate that the explosion was the result of a gas valve failure that allowed coke oven gas to fill the area, "ultimately exploding when finding an ignition source" (136). A US Steel executive in November said that capital will be directed to the Clairton Coke Plant, however, details on planned investment have not been made public (144).

Policy support at a federal, state, or local level can encourage needed investment in modernization. While still largely focused on coal-based production, with the backing of Japan's government, Nippon recently announced it will convert a portion of its steelmaking processes in the country from blast furnaces to hydrogen DRI-EAFs, signaling that it could be moved to invest in the technology in the US, should the right support or incentives be put into place (137). And as this report noted, Nippon already is trialing the use of heated hydrogen injection to replace the traditional coke-based reduction processes in Japan.

Currently, the US government is in a unique position in its oversight of US Steel, with Nippon agreeing to include a "golden share" as part of a national security agreement with the Trump administration to close the deal. The national security agreement gives the White House veto power over plant closures, offshore production shifts, and other strategic decisions (146). Additionally, Nippon has agreed that it will not close, idle or sell the Mon Valley or Gary Works prior to June 18, 2035.

When it comes to federal policy, the US already has an example of legislation supported by the industry, United Steelworkers, and environmental groups alike that exists and could spur the kind of next-generation investment needed in US primary steelmaking. The Modern Steel Act, introduced in August 2024 by Rep. Ro Khanna (CA-17) and co-lead Rep. Summer Lee (PA-12), would partner with the steel industry and workers to build new, modern facilities producing near-zero emissions iron and steel, with a priority to existing legacy steel, iron, coke, and coal communities (139).

At a state level, Pennsylvania lawmakers recently introduced the Fueling Opportunities for the Revitalization, Growth, and Efficiency of Steel Act, or FORGES Act, which includes a tax credit program for steel facility improvements, which are defined as: "A retrofit, upgrade or operational improvement…including the installation or use of advanced manufacturing technology" (138). It includes an additional tax credit for "advanced manufacturing technology investments," which are defined as capital investments in facility improvements involving advanced manufacturing technology that: enable lower-carbon steel production; increase electricity or hydrogen generation capacity; or use recycled steel as a material input. Additionally, PA House Bill 1556, a clean manufacturing tax credit, would offer a 30% tax credit for qualified production costs for an advanced clean manufacturing project, including clean steel (147).

Recent research has found that policies targeted directly at supporting new technologies – such as subsidies, public procurement, and supply-side clean steel mandates – are likely to be needed to enable the deployment of near-zero emission primary steel production technologies such as hydrogen DRI (140). In contrast, policies that put pressure on existing high-emitting steel plants, such as blast furnace capacity caps and carbon pricing, are more likely to encourage a shift to steel recycling and some intermediate-emissions technologies.

CONCLUSION

Despite recent political and policy upheaval in the United States, the majority of the world continues to move toward decarbonization of the steel industry, albeit perhaps not as fast as advocates had hoped several years ago. What is clear is that the outlook for traditional, high-emissions primary steel production in the US remains economically dubious and is reliant on both what may turn out to be transient tariffs and Chinese government policy, more than variables that the domestic industry can directly control.

If the domestic primary steel industry struggles, workers in places like the Mon Valley, PA and Gary, IN will continue to pay the price, through continued job loss, wage stagnation and, potentially, deteriorating safety as key infrastructure ages, as was the case in Clairton. And, if the domestic primary steel industry continues on its current path, damage to the environment may compound with the economic struggle.

Despite the tumultuous policy changes and supply and demand factors detailed in this report, there is a bright spot. The recent acquisition of US Steel by Nippon occurred alongside commitments by Nippon to the US government to make sizable capital investments. These capital investments could provide the starting point to begin to transition US primary steel production away from old BF-BOF technology and toward hydrogen-based DRI-EAF processes. The business case for this investment, we believe, is quite clear. Investing in the current processes, which have seen declining employment and given up market share to Chinese steel, is not a winning strategy long-term. Green steelmaking, however, provides an opportunity to lead in developing markets for lower-emissions steel by gaining advantages in trade with Asia and Europe through border adjustment mechanisms and through emerging green premiums.

We do not pretend that these investments will be cheap or easy. In fact, as has been the case with most pillar US industries from automobiles to agriculture, making this transition will, in the long run, require significant government backing in addition to sound strategic decision making. **However, making the green steel transition may also provide the single best opportunity for US steel companies and steel communities to reverse several decades of eroding steel jobs, wages, and market share.**

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