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Domestic Steel Manufacturing: Overview and Prospects

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SUMMARY

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May 17, 2022

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Based on 2020 volumes, the United States ranked as the world's fourth-largest steel producing country, second-largest steel importer, and twentieth-largest steel exporter. According to U.S. Census Bureau data, steel producers recorded $29.6 billion in profits in 2021, compared with $2.7 billion in 2020, as capacity utilization reached the highest level since 2007. Direct employment in steel manufacturing has declined by 49%, from 257,200 workers in 1990 to 131,400 workers in 2021. Steel is a major component in many consumer and industrial products, including motor vehicles, farm equipment, appliances in many types of buildings and highway construction, as well as in commercial and multifamily home construction.

Over the past decade, the share of U.S. steel consumption supplied by domestic mills has varied from 70% to 90%. A growing share of domestic production comes from "mini-mills" that melt steel scrap or direct reduced iron in electric arc furnaces, continuing the long-standing shift away from large, integrated mills that use ovens to heat coal into coke, combine the coke with iron ore in a blast furnace to produce pig iron, and then melt the pig iron in a basic oxygen furnace to produce liquid steel. The mini-mill sector maintains lower capital and energy costs per ton produced than the integrated mill sector. In addition, it has a largely nonunion workforce compared with highly unionized integrated mills. Many mini-mills are located in the South, with some in the Midwest and West, whereas most integrated mills are in Indiana, Michigan, Ohio, and Pennsylvania.

Since the 1970s, the U.S. government repeatedly has imposed duties on steel imports to protect U.S. steel production and employment. As of January 2022, 311 orders were in force imposing punitive duties on imported iron and steel mill products that were found to have been subsidized or sold below cost in the U.S. market and threaten the U.S. industry. In 2018, the Trump Administration imposed a separate set of tariffs on steel imports from almost all countries on national security grounds; during the Biden Administration the United States subsequently reached agreements with the European Union, Japan, and the United Kingdom to suspend those tariffs on specified quantities of their exports. The United States also has made increased use of domestic preference laws to require that iron and steel used in many federal projects and projects funded by federal grants be produced in the United States.

These measures and an expanding economy helped the domestic steel industry operate at 81.1% of rated capacity in 2021, the highest level since 2007. Domestic steel prices registered record highs throughout 2021 and remain high relative to prices abroad. High prices and the likelihood of greater demand due to the recently enacted Infrastructure Investment and Jobs Act (P.L. 117-58) have encouraged investments that are expected to add 8% to industry steelmaking capacity. However, they have not led to improved productivity; steel mill tonnage per employee has been generally flat for nearly two decades.

Excess steelmaking capacity has been a long-standing concern for domestic producers. The Organisation of Economic Co-operation and Development estimated excess capacity globally to be approximately 625 million metric tons in 2020. The large majority of capacity is in China, which accounted for over half of global steel output in 2020, while the United States accounted for approximately 4%. The Biden Administration has sought to address excess capacity in negotiations with trading partners over U.S. import restrictions.

Federal and state regulations have required steelmakers to control various air emissions, water discharges, and waste generation. No such federal standards exist for greenhouse gas emissions at present, but the possibility of future regulations represents a potential risk for steelmakers investing in long-lived production facilities. Reducing greenhouse gas emissions from steelmaking is likely to require new technologies in an industry that traditionally has spent little on research and development domestically. Several new approaches to reducing iron ore to elemental iron are in developmental phases, and implementing them is likely to require significant capital investments. The House-passed version of the America COMPETES Act of 2022 (H.R. 4521) seeks to establish a Department of Energy-led led research and development program specific to low-emissions steel manufacturing, working in collaboration with partners that span academia, industry, and government.

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Introduction

The condition of the domestic steel industry has been a long-standing concern of Congress because of steel's use in a wide range of consumer and industrial products—including motor vehicles, farm equipment, and appliances in many types of buildings and highway construction—and because of the economic activity and manufacturing jobs steel mills generate.

This report provides an overview of the domestic steel industry and its operating environment. It discusses industry capacity and output, steel prices, steel trade and regulatory measures, and employment and productivity. The report also examines efforts to reduce the industry's greenhouse gas emissions by developing "green steel." The report concludes with a discussion of select issues that may be of potential interest to Congress.

The Iron and Steel Manufacturing Process

Steel mills operate in two distinct ways. The traditional production method occurs at large, vertically integrated mills, which use ovens to heat coal into coke;[1] combine the coke with iron ore in a blast furnace to produce pig iron; and then melt the pig iron in a basic oxygen furnace to produce liquid steel. This production process is commonly known as the Blast-Furnace/Basic Oxygen Furnace (BF-BOF) method.

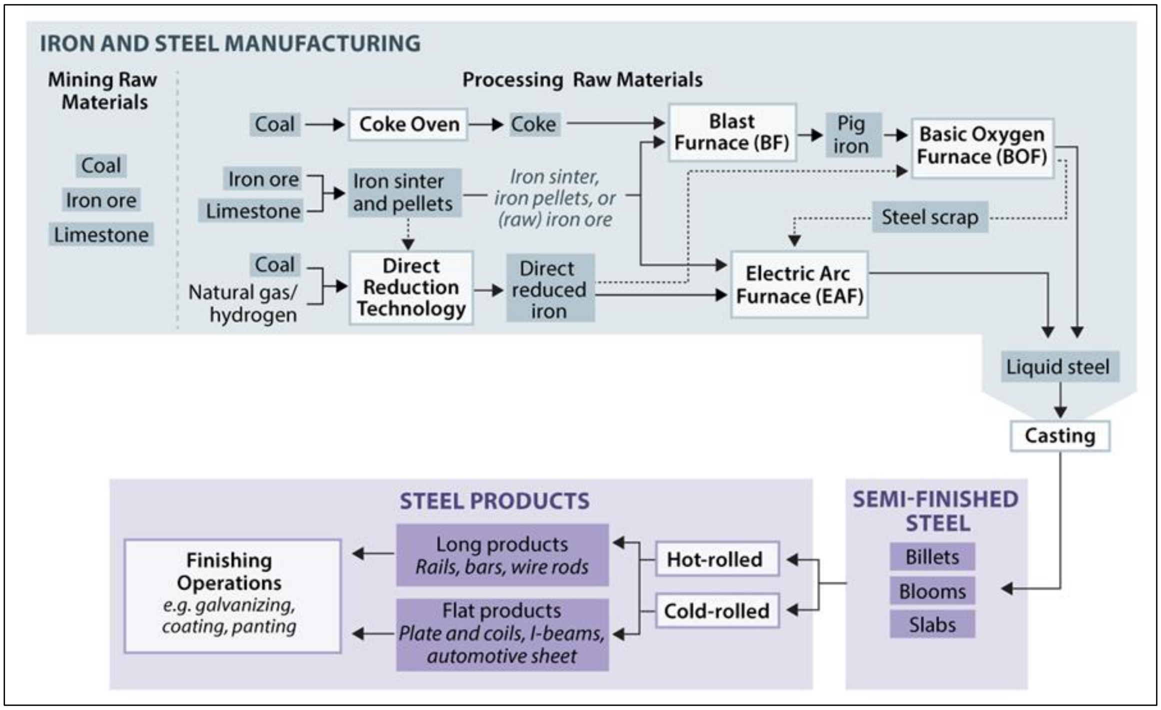
The alternate method occurs through "mini-mills," which use electric arc furnaces (EAFs) to melt steel scrap and, in some instances, use iron pellets to produce liquid steel. Unlike integrated mills, mini-mills do not require coke ovens or blast furnaces. However, some mini-mills use a process called direct reduction to remove oxygen from iron ore with heat from burning natural gas; the resulting product, direct reduced iron (DRI) or sponge iron, is turned into a lump, pellet, or briquetted form that can be transformed into liquid steel in EAFs.[2]

Once steel is produced in its liquid state, it is cast into rectangular slabs (long billets a few inches on a side) or other shapes and left to cool. Rolling mills then shape the semifinished steel into a variety of products, generally classified as either "flat" products (plate and coils of steel sheet) or "long" products (bars, rails, wire rods). The rolled steel products often undergo additional finishing operations, such as coating, painting, and galvanizing, to produce finished steel. **Figure 1** shows the process for manufacturing iron, steel, and finished steel products.

[1] Coke or coking coal—a solid mostly consisting of carbon—is the result of coal being heated at high temperatures in a coking oven, which drives off volatile compounds. In integrated steelmaking, coking coal is a necessary input that is combined with iron ore in a blast furnace to produce pig iron.

[2] Three domestic producers operate direct reduction facilities. Nucor Corporation operates a direct reduced iron facility in Convent, LA. Cleveland-Cliffs and Voestalpine Texas operate hot-briquetted iron facilities, which use a more compacted form of direct reduction technology, in Toledo, OH, and Corpus Christi, TX, respectively.

Figure 1. The Iron and Steel Manufacturing Process



Source: Figure created by CRS, adapted from Hasan Muslemani et al., "Opportunities and challenges for decarbonizing steel production by creating markets for 'green steel' products," *Journal of Cleaner Production*, vol. 315 (September 15, 2021), p. 10.

In 2021, three companies operated integrated steel mills in 11 U.S. locations, accounting for approximately 29% of domestic steel output. The remaining 71% of domestic steel production came from 101 mini-mills operated by 50 companies.[3]

Since the first mini-mill opened in 1969, mills using EAFs have undercut integrated mills on price and have forced them out of nearly all product markets, except for flat-rolled plate and sheet. The mini-mill sector maintains lower capital and energy costs per ton produced and has a largely nonunion workforce compared with highly unionized integrated mills.[4] Integrated mills, in some instances, have competitive advantages over their EAF counterparts in producing higher-quality grades of steel, such as sheet for automotive manufacturing.

Many companies in the steel industry are not involved with the melting stages, including processors such as slab converters. These operations—in some cases located on sites formerly occupied by integrated steel mills—purchase steel slabs and roll them into a variety of products, such as sheet and pipe. Slabs used for this purpose typically are imported, as most domestic mills that produce slabs process them further in their own facilities rather than selling them to other parties. Since the early 1980s, federal law and regulation have required that steel used in federally funded highway projects be manufactured in the United States; while raw materials used in the manufacturing process, such as iron ore, limestone, and scrap may be imported, the steel must be

[3] U.S. Geological Survey (USGS), *Mineral Commodity Summaries*, "Iron and Steel Statistics and Information," January 2022.

[4] Matthew Miller and Fateh Yahaya, *Industry Surveys: Metals & Mining*, CFRA, January 2022, p. 22.

melted and poured in the United States.[5] Since 2021, federal law has extended the melted and poured requirement for iron and steel to more types of federally funded infrastructure projects.[6] Consequently, steel mill products made by slab converters using imported slabs do not qualify.

Raw Materials Sourcing

The raw materials used by both integrated mills and mini-mills in steel production are largely sourced in the United States. Integrated steel mills primarily use iron ore obtained from mines in Michigan and Minnesota, which account for more than 90% of domestic iron ore supply.[7] U.S.-mined iron ore takes the form of taconite, a relatively low-grade source of iron-bearing rock that must be ground and then rolled into pellets to be useful in steelmaking.[8] Nearly all steel scrap used by mini-mills is obtained from domestic sources.[9] However, the end products from which steel scrap is derived, such as motor vehicle bodies and beams used in construction, may have originally been imported.

Operating Environment of the Domestic Industry

Demand for steel is highly cyclical, coming overwhelmingly from interest rate-sensitive sectors, such as construction and automotive manufacturing. Domestic steel consumption was 98 million metric tons in 2021, up 18% from 2020—when the Coronavirus Disease 2019 (COVID-19) pandemic led to temporary shutdowns of auto assembly lines—but well below the peak of 117 million metric tons in 2014. The two largest end-markets for steel in 2021 were construction and automotive, accounting for 47% and 25% of demand, respectively.[10]

The industry's profitability depends heavily on its capacity utilization. Steelmakers often lose money when demand is weak and production capacity is underutilized, but a small increase in capacity utilization can bring dramatic increase in profits. In 2021, steel producers recorded $29.6 billion in profits, compared with $2.7 billion in 2020, according to U.S. Census Bureau data.[11]

Between 2010 and 2021, annual raw steel production fluctuated between roughly 70 and 90 million tons (**Figure 2**), with the low point coming amid COVID-19-related production curtailments in 2020. Capacity utilization in the steel industry has been on an increasing trend,

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[5] Surface Transportation Assistance Act of 1982 (P.L. 97-424, §165); and Federal Highway Administration, "Buy America Requirements, Final Rule," 48 *Federal Register* 53099-53103, November 25, 1983.

[6] The Infrastructure Investment and Jobs Act (IIJA; P.L. 117-58), §70912(6)(A), states: "produced in the United States means—in the case of iron or steel products, that all manufacturing processes, from the initial melting stage through the application of coatings, occurred in the United States." Also §70912(5) defines "infrastructure" to include the structures, facilities, and equipment of a minimum list of works, including drinking water and wastewater systems, electrical transmission facilities and systems, broadband, among others.

[7] USGS, *Mineral Commodity Summaries*, "Iron Ore Statistics and Information," January 2022.

[8] Pelletizing involves crushing iron ore, grinding it into powder, rolling the powder into balls, and finally firing the balls in a furnace to produce marble-sized pellets that contain 60% to 70% iron.

[9] USGS, *Mineral Commodity Summaries*, "Iron and Steel Scrap Statistics and Information," January 2022.

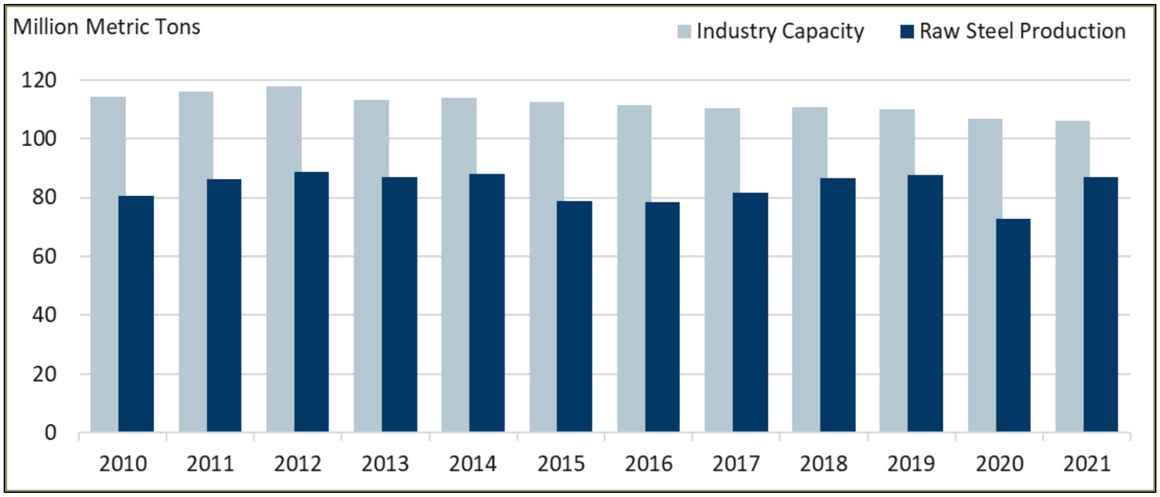
[10] USGS, *Mineral Commodity Summaries*, "Iron and Steel Statistics and Information," January 2022.

[11] Bureau of the Census, "Business and Industry Statistics," at https://www.census.gov/econ/currentdata/dbsearch?program=QFR&startYear=2000&endYear=2021&categories=371&dataType=104&geoLevel=US&notAdjusted=1&submit=GET+DATA&releaseScheduleId=.

save for a drop in 2020; in 2021, 81.1% of production capacity was utilized, the highest level since 2007.[12]

One long-standing concern for domestic producers is global excess steelmaking capacity, which the Organisation for Economic Co-operation and Development (OECD) estimated at approximately 625 million metric tons in 2020.[13] In short, excess capacity means that steelmaking facilities have the capacity to produce more steel than the market demands. The large majority of capacity is in China, which accounted for 57% of global steel output in 2020, with all other producing countries having shares of 6% or less.[14]

Figure 2. U.S. Steel Industry Capacity and Domestic Production



Source: American Iron and Steel Institute (AISI), *2020 Annual Statistical Report*, p. 3; and U.S. Geological Survey (USGS), "Iron and Steel Statistics and Information."

Based on 2020 volumes, the United States ranked as the world's fourth-largest steel producing country, second-largest steel importer, and twentieth-largest steel exporter. Over the past decade, the share of U.S. steel consumption supplied by domestic mills has varied from 70% to 90% (**Figure 3**).[15] During that same period, 8%-14% of U.S. steel production was exported each year. Canada was the largest source of imports in 2021, followed by Mexico and Brazil; Canada and Mexico accounted for the vast majority of total steel export volume, at 47% and 46%, respectively, in 2021.[16] The U.S.-Mexico-Canada Agreement affords duty-free movement of steel mill products among the three countries. Other sources of U.S. imports include South Korea, Russia, Japan, and Germany, which accounted for a combined 21% of all imports in 2021, and imports from China accounted for 2%. U.S. tariffs and/or quotas limit imports from all of these countries.

[12] The Federal Reserve Board publishes industrial production and capacity utilization data by industry. See Federal Reserve Board, "Industrial Production and Capacity Utilization - G.17," at https://www.federalreserve.gov/releases/G17/default.htm (January 14, 2022, releases).

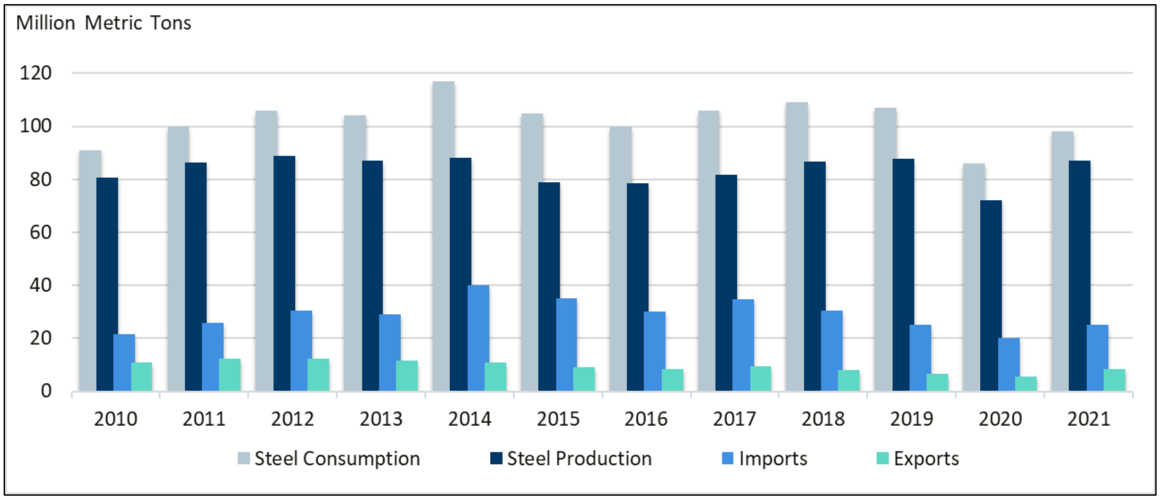
[13] Organisation for Economic Co-operation and Development (OECD) Steel Committee, *Latest Developments in Steelmaking Capacity*, September 2021, p. 11.

[14] World Steel Association, *2021 World Steel in Figures*, p. 9.

[15] USGS, *Mineral Commodity Summaries*, "Iron and Steel Statistics and Information," January 2022.

[16] U.S. Department of Commerce (DOC), "U.S. Steel Import Monitor," accessed February 28, 2022; and DOC, "Steel Mill Export Monitor," accessed February 28, 2022.

Figure 3. Domestic Steel Consumption, Exports, and Imports



Sources: AISI; USGS, "Iron and Steel Statistics and Information"; and U.S. Department of Commerce, "Global Steel Trade Monitor" (various reports).

Investments presently underway are expected to add roughly 8% to industry steelmaking capacity.[17] The large majority of these investments are in EAF mills, continuing the long-standing shift away from integrated production. For example, in 2021, the United States Steel Corporation (U.S. Steel), now the third-largest producer of raw steel in the United States, cancelled plans to modernize its integrated Mon Valley Works in western Pennsylvania and discontinued production of raw steel at its integrated Great Lakes Works near Detroit. U.S. Steel also acquired full control of an Arkansas mini-mill operator, Big River Steel, which is building a new mill with an EAF.[18] No new U.S. blast furnaces are being built, and several have been idled in recent years.

Domestic steel manufacturing operations have expanded geographically over the years. Traditionally, integrated mills operated primarily in Indiana, Michigan, Ohio, and Pennsylvania. The shift of manufacturing and construction to parts of the South and West, however, has led steel producers to open mini-mills in those areas to be closer to customers.

Steel Prices and Downstream Industries

Domestic steel prices in the United States are higher than those in other major markets. In December 2021, the price of hot-rolled band steel per metric ton was $646 in China and $1,031 in Europe, compared with $1,855 in the United States.[19] CFRA, an industry research firm, contends

[17] This CRS calculation is based on U.S. steel industry capacity of 106 million metric tons in 2021, based on USGS, *Mineral Commodity Summaries*, "Iron and Steel Statistics and Information," January 2022 and SteelOrbis, "US steel industry: A look back at 2021 and a look ahead to 2022," December 30, 2021, at https://www.steelorbis.com/steel-news/latest-news/us-steel-industry-a-look-back-at-2021-and-a-look-ahead-to-2022-1228244.htm.

[18] United States Steel Corporation (U.S. Steel), Form 10-K for the year ending December 31, 2021, pp. 4, 8; U.S. Steel, "First Quarter 2021 Earnings Call," April 30, 2021, p. 10, at https://s26.q4cdn.com/153509673/files/doc_financials/2021/q1/1Q-2021-Earnings-Call-Slides-20210430-vFINAL.pdf; U.S. Steel, "U. S. Steel Selects Osceola, Arkansas as Location for Most Advanced Steelmaking Facility in North America," January 11, 2022, at https://investors.ussteel.com/news/news-details/2022/U.-S.-Steel-Selects-Osceola-Arkansas-as-Location-for-Most-Advanced-Steelmaking-Facility-in-North-America/default.aspx; and Nucor Corporation, "Nucor to Build State-of-the-Art Sheet Mill," September 20, 2021, at https://www.nucor.com/news-release/#item=18306.

[19] World Steel Dynamics, *SteelBenchmarker: Price History, Tables and Charts*, December 27, 2021, at http://steelbenchmarker.com/history.pdf.

that U.S. steel prices were at unsustainable levels in 2021 and will ultimately correct as supply chains begin to rebalance and that the domestic industry's record earnings in 2021 will be the cyclical peak.[20] Domestic steel prices have dropped in 2022, averaging $1,481 per ton through March, yet remain high relative to prices abroad.[21]

A key reason domestic steel prices are higher than foreign prices is that the United States maintains significant restrictions on steel imports. These restrictions help shield domestic producers from foreign competition by limiting the volume of imports into the U.S. market. Import protection has been in effect, in various forms, since the late 1970s. Sources of import competition have shifted across different countries over the decades as trading partners have sought to support and expand their own domestic steel production.

Over the past 50 years, the United States has repeatedly imposed or negotiated restraints on imports of steel or steel products in response to complaints by U.S. steelmakers and unions that the U.S. industry was injured or threatened with injury by imports that were subsidized, sold below fair market value ("dumped"), or otherwise supported by unfair trade practices.[22] One example occurred in March 2018 when the Trump Administration imposed a 25% tariff on certain steel products from virtually all countries under Section 232 of the Trade Expansion Act of 1962 (19 U.S.C. §1862, as amended), which allows restrictions, such as tariffs or import quotas, on imports that have been found to harm national security.[23] The Trump Administration's stated objective was to reduce import volumes to a level that would enable the domestic industry to operate at 80% or more of rated production capacity.[24] In October 2021, the United States and the European Union (EU) reached an agreement under which the Section 232 tariffs were replaced with a tariff-rate quota allowing a specified quantity of steel imported from the EU to enter the United States duty-free each year.[25] The United States reached similar agreements with Japan in February 2022 and with the United Kingdom in March 2022.[26]

As of January 2022, 311 antidumping duty and countervailing duty orders were in force imposing punitive duties on iron and steel mill products from other countries, accounting for 47% of all

[20] Matthew Miller and Fateh Yahaya, *Industry Surveys: Metals & Mining*, CFRA, January 2022, p. 4.

[21] World Steel Dynamics, *SteelBenchmarker: Price History, Tables and Charts*, March 28, 2022, at http://steelbenchmarker.com/history.pdf.

[22] For more information on trade remedies, see CRS Report R46296, *Trade Remedies: Antidumping*, by Christopher A. Casey; and CRS Report R46882, *Trade Remedies: Countervailing Duties*, by Christopher A. Casey and Liana Wong.

[23] At the same time, Section 232 tariffs were applied to aluminum imports at a 10% rate. In May 2019, Canada and Mexico were exempted permanently from the Section 232 tariffs. Australia is not subject to any import restrictions; Argentina, Brazil, and South Korea are subject to annualized quotas in lieu of the tariffs.

[24] Bureau of Industry and Security, *The Effect of Imports of Steel on the National Security*, 2018, p. 5.

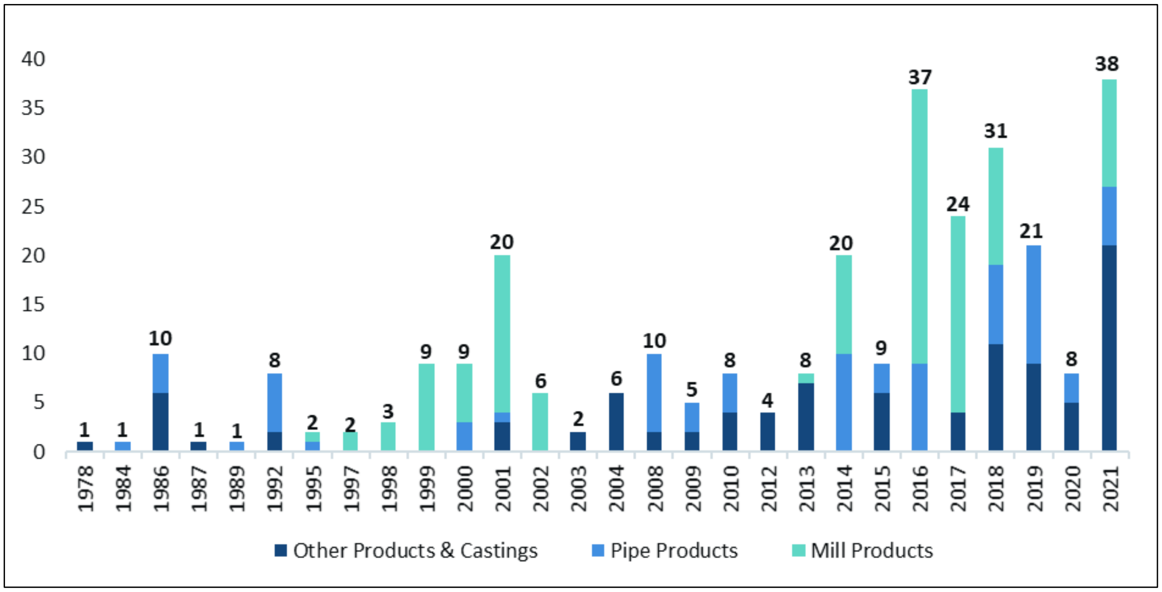
[25] Under the agreement, the United States will exempt up to 3.3 million metric tons of steel products imported from the European Union from Section 232 tariffs each year. If imports were to exceed this quantity, then the Section 232 duties would be reimposed for the remainder of the calendar year. Office of the United States Trade Representative (USTR), "Joint US-EU Statement on Trade in Steel and Aluminum," press release, October 31, 2021, at https://ustr.gov/about-us/policy-offices/press-office/press-releases/2021/october/joint-us-eu-statement-trade-steel-and-aluminum.

[26] The agreement with Japan allows 1.25 million metric tons of steel per year to enter the United States duty-free. It took effect on April 1, 2022. USTR, "Tai, Raimondo Statements on 232 Tariff Agreement with Japan," press release, February 7, 2022, at https://ustr.gov/about-us/policy-offices/press-office/press-releases/2022/february/tai-raimondo-statements-232-tariff-agreement-japan. The agreement with the United Kingdom allows 0.5 million tons of steel products in 54 categories to enter duty-free each year, effective June 1, 2022. USTR, "Announcement of Action on UK Imports Under Section 232," March 22, 2022, at https://www.commerce.gov/sites/default/files/2022-03/UK232-US-Statement.pdf.

such U.S. trade remedies.[27] **Figure 4** records the imposition of such orders specific to iron and steel products since 1978.[28]

Figure 4. U.S. Antidumping and Countervailing Duty Orders on Iron and Steel

Number of orders issued each year



Source: Figure created by CRS based on import injury investigations data from the U.S. International Trade Commission.

Many steel producers have transitioned to harder-to-make steel products, such as advanced high-strength steel or lightweight steel for automotive uses, to better compete in the domestic market and avoid the impact of cheaper steel imports. This is apparent in the gap between U.S. export and import prices—while U.S. exports of steel products were valued at an average of $1,570 per ton in 2021, imports were valued at an average of $1,171 per ton. The price gap between U.S. exports and imports reflects the fact that the United States exports mainly high-value steel products to Canada and Mexico, such as specially treated sheet that can be used in auto manufacturing, while less sophisticated products, such as semifinished ingots and construction reinforcing bar from Mexico, account for over half of such imports.[29]

The industry has increasingly globalized, with foreign producers establishing operating divisions within the United States even as domestic producers expand abroad.[30] For example, two major U.S. producers have foreign mill operations—U.S. Steel owns an integrated mill in Slovakia, and Nucor Corporation, the largest U.S. steel producer measured by tonnage, has several production facilities throughout North America and a direct reduced iron facility in Trinidad and Tobago. The

[27] U.S. International Trade Commission, import injury investigations, antidumping and countervailing duty orders, accessed January 21, 2022, at https://www.usitc.gov/sites/default/files/trade_remedy/documents/orders.xls.

[28] The U.S. Department of Commerce (Commerce) and the U.S. International Trade Commission are responsible for conducting antidumping and countervailing duty investigations pursuant to Title VII of the Tariff Act of 1930. Provided both agencies reach affirmative final determinations in their respective investigations, then Commerce will issue an antidumping duty order to offset the dumping margin or a countervailing duty order to offset the estimated subsidy rate.

[29] DOC, "U.S. Steel Import Monitor," accessed March 29, 2022; and DOC, "Steel Mill Export Monitor," accessed March 29, 2022.

[30] Terry Faber, *Iron & Steel Manufacturing in the US*, IBISWorld, February 2022, pp. 31-35.

Brazilian steelmaker Gerdau operates steel mills in the United States and Canada, while Welded Tube of Canada, a producer of oil country tubular goods—pipes and casings used in oil drilling—produces unfinished welded tubular products at its two mills in New York State, exports the unfinished goods to its Canadian parent for finishing operations, such as heat treatment and threading, and ships the final products back to the United States.

Domestic Content Regimes

In addition to trade measures, domestic preference statutes provide support to the U.S. steel industry. The Buy American Act of 1933 governs purchases by the federal government and requires that final products be mined, produced, or manufactured in the United States. If manufactured, either at least 55% of the cost of components (by value) must be manufactured in the United States or the end product must be a commercially available off-the-shelf item. In March 2022, the Biden Administration announced that the domestic content threshold specific to federal procurement would increase from 55% to 60% later that year, to 65% in 2024, and to 75% in 2029.[31]

Separately, several statutes and regulations, referred to collectively as "Buy America," require certain recipients of federal financial assistance for infrastructure-related projects to use domestic steel. Traditionally, Buy America covered highways, public transportation, airports, aviation, and intercity passenger rail, including Amtrak. The Infrastructure Investment and Jobs Act (IIJA; P.L. 117-58), enacted in November 2021, appropriates approximately $1.2 trillion through 2026 for a wide range of infrastructure investments, including electric transmission facilities, structures and equipment of electric utilities, broadband infrastructure, real property and buildings, wastewater facilities, and transportation facilities. The law extended Buy America to cover federally funded projects in all of these sectors.[32] In general, all iron and steel purchased for such projects must be melted and poured in the United States, and most components or equipment containing iron or steel must come from U.S. producers. Federal agencies administering these laws may grant waivers under certain circumstances.

Slab converters have sought waivers for products they manufacture in the United States from imported steel slabs, claiming there is insufficient domestic supply of semifinished steel slabs from U.S. mills.[33] To date, the Federal Highway Administration has not granted a waiver to slab converters. Provisions in the IIJA may make waivers more difficult to obtain.[34]

Steel Manufacturing Employment and Productivity

Steel mills directly employed 78,900 workers in 2021, representing less than 1% of the nation's 12.3 million manufacturing jobs. Steel mill employment declined 58% between 1990 and 2021 (**Figure 5**). The U.S. government projects employment in steel mills to rise approximately 1%

[31] Department of Defense, General Services Administration, National Aeronautics and Space Administration, "Federal Acquisition Regulation: Amendments to the FAR Buy American Act Requirements," 87 *Federal Register* 12780, March 7, 2022.

[32] For more information on Buy America and the IIJA, see CRS In Focus IF11989, *Congress Expands Buy America Requirements in the Infrastructure Investment and Jobs Act (P.L. 117-58)*, by Christopher D. Watson.

[33] Slab converters include firms such as California Steel Industries and NLMK USA that produce hot-rolled, cold-rolled, and galvanized sheet from slabs poured by steel mills, including foreign suppliers. California Steel Industries, *Comments on Section 232 National Security Investigation of Imports of Steel*, May 31, 2017, pp. 2-3; NLMK USA, *Comments on Section 232 National Security Investigation of Imports of Steel*, May 31, 2017, pp. 2-4.

[34] IIJA (P.L. 117-58) §70916(c), §70921(b-c), and §70923(b-c).

between 2020 and 2030.[35] A relatively large segment of the steel industry is comprised of firms involved in steel product manufacturing, which includes steel processors. In 2021, steel product manufacturing directly employed 52,500 workers, representing 40% of total steel industry employment.[36] Between 1990 and 2021, steel product manufacturing employment averaged approximately one-third of total steel industry employment. Total steel industry employment has declined 49%, from 257,200 workers in 1990 to 131,400 workers in 2021. Steel mill workers earned an average annual wage of $88,325 in 2020, higher than the annual average of $73,397 for all manufacturing.[37] The average annual wage in steel product manufacturing was $68,585.

The domestic content provisions in the IIJA could preserve or increase employment in the steel industry. The American Iron and Steel Institute (AISI) estimates that 2.1 labor hours were required to produce one ton of steel in 2020.[38] Based on AISI's estimate that $100 billion of infrastructure investment will create demand for five million tons of steel, an additional federal outlay of that amount would be expected to lead to 5,048 worker-years of employment in steel production, excluding activities such as administrative support, maintenance, and sales and marketing.[39] Other assumptions and data sources may yield other employment estimates.

Steel Mill Productivity

The increased use of electric arc furnaces to melt steel and their competitive impact on vertically integrated mills led to large increases in steel industry productivity between the late 1900s and 2004.[40] Mill productivity more than doubled, from 480 tons per employee in 1990 to 1,045 tons per employee in 2004 (**Figure 6**). Since then, industry productivity has remained generally flat, even as labor costs have fallen from more than 20% of total operating costs in the 1990s to an average of 11% in the 2010s.[41] The causes of this productivity stagnation are unclear. Research from the OECD indicates that steel industry productivity growth worldwide has been weak in recent years. OECD economists attribute this in part to government policies that keep older steel mills from closing (thereby keeping older technology in use), preventing reallocation of resources to the most productive firms and hindering the growth prospects of more innovative firms.[42]

[35] Bureau of Labor Statistics (BLS), *Employment and Output by Industry*, Table 2.11, accessed February 28, 2022, at https://www.bls.gov/emp/tables/industry-employment-and-output.htm.

[36] BLS, *Current Employment Statistics*, NAICS 3312—Steel Product Manufacturing, accessed February 28, 2022.

[37] BLS, *Quarterly Census of Employment and Wages*, accessed February 28, 2022.

[38] The American Iron and Steel Institute (AISI) attributes productivity gains to capital investments in particular facilities and a technically sound workforce with the ability to operate advanced steelmaking equipment and technology. AISI, *2020 Annual Statistical Report, Executive Summary*, p. 15.

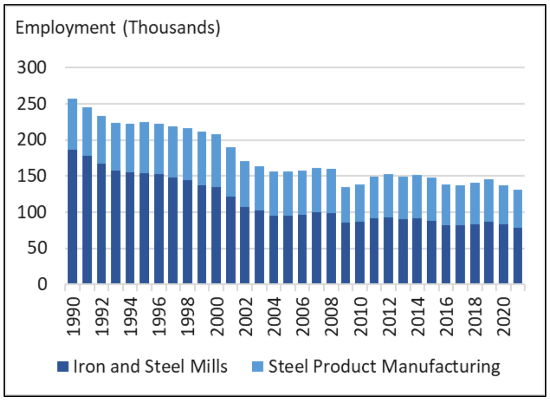
[39] This CRS calculation assumed a work year of 2,080 hours and a one-time expenditure; it does not assume expenditures beyond the initial $100 billion. AISI, "AISI Applauds House Passage of Bipartisan Infrastructure Bill," press release, November 6, 2021, at https://www.steel.org/2021/11/aisi-applauds-house-passage-of-bipartisan-infrastructure-bill/.

[40] Allan Collard-Wexler and Jan De Loecker, "Reallocation and Technology: Evidence from the US Steel Industry," *American Economic Review*, vol. 105, no. 1 (2015), pp. 131-135.

[41] BLS, *Industry Productivity Viewer*, NAICS 3311—Iron and Steel Mills, accessed April 4, 2022.

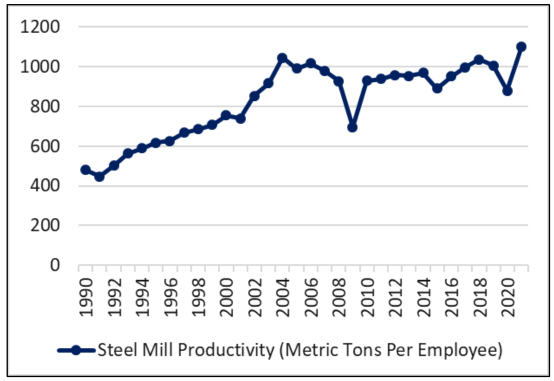
[42] Filipe Silva and Anthony de Carvalho, *Research and Development, Innovation, and Productivity Growth in the Steel Sector*, OECD, March 28, 2016, pp. 36-37. See also Filipe Silva, *Evaluating the Financial Health of the Steel Industry*, OECD, June 9, 2017, p. 9.

Figure 5. U.S. Steel Manufacturing Employment



Source: Bureau of Labor Statistics (BLS), Current Employment Statistics, North American Industry Classification System (NAICS) codes 3311—Iron and Steel Mills and 3312—Steel Product Manufacturing.

Figure 6. U.S. Steel Mill Productivity



Source: CRS, based on USGS, "Iron and Steel Statistics and Information"; and BLS, Current Employment Statistics, NAICS 3311—Iron and Steel Mills.

"Green Steel"

For decades, federal and state regulations have required steelmakers to control their air emissions, water discharges, and waste generation. No such federal standards exist for greenhouse gas (GHG) emissions at present, but the possibility of future regulations represents a consideration for steelmakers investing in long-lived production facilities. In addition, steelmakers, like firms in other industries, face increasing demands from customers and investors that they publicly disclose the GHG emissions throughout their supply chains and seek to reduce those emissions levels, potentially placing steelmakers with comparatively high emissions at a competitive disadvantage.[43]

The domestic steel industry's two chief trade groups—AISI and the Steel Manufactures Association—have stated that decarbonization of steel manufacturing is a top priority for domestic producers.[44] Four domestic producers—Cleveland-Cliffs, Steel Dynamics, Nucor, and U.S. Steel—have announced corporate objectives tied to decarbonized steel output by 2030, with planned GHG emission reductions ranging from 20% to 50%.[45] Some producers, including Steel

[43] This section provides a discussion on greenhouse gas emissions resulting from iron and steel production. The emission estimates in this section are specific to carbon dioxide emissions—the largest component of greenhouse gases—across modes of production (i.e., integrated steelmaking, electric arc furnace steelmaking). Nearly all of the emission estimates in this section concern the iron and steel production processes, which involves processing raw materials into liquid steel and does not take into account emissions from other sources, such as from mining, transportation of raw materials, rolling of steel mill products, and transportation of finished goods to the customer. This section does not discuss methane emissions—a smaller component of greenhouse gases—resulting from iron and steel production.

[44] S&P Global Platts, *Commodities 2022: US Steel Groups Focused on Trade Enforcement, Decarbonization*, January 7, 2022, at https://www.spglobal.com/platts/en/market-insights/latest-news/metals/010722-commodities-2022-us-steel-groups-focused-on-trade-enforcement-decarbonization.

[45] The scope, baselines, targets, gases, and boundaries of these climate objectives vary by company. See each company's sustainability reporting for more details.

Dynamics and U.S. Steel, have announced objectives of achieving net-zero carbon emissions by 2050.[46]

GHG emissions depend on the technologies and operations involved. On one end of the spectrum, mining iron ore and turning it into steel emit large volumes of greenhouse gases. One study estimates that integrated steelmaking emits approximately 2,200 kilograms of carbon dioxide per ton produced,[47] roughly half the amount produced annually by the average car.[48] Operation of the blast furnace that produces pig iron accounts for an estimated two-thirds of those emissions, on average. Another study estimates that blast furnace steelmaking emits roughly 1,900 kilograms of carbon dioxide per ton produced on average.[49]

At the other end of the spectrum are emissions from mini-mills, which generally use EAF technology to melt steel scrap and, in some instances, iron pellets. As described above, these mills do not use the same inputs or provide the same range of outputs as a fully integrated steel mill. In general, the mini-mills now used in more than two-thirds of U.S. steel production have lower carbon dioxide emissions per ton than integrated mills. Collecting and transporting steel scrap for use in an EAF is likely to involve lower emissions per ton of steel than mining, transporting, and processing iron ore for use in an integrated steel mill. However, carbon dioxide emissions arising from production in an EAF depend significantly on the source of electricity. A steel mill that receives power generated by burning coal is likely to have far higher emissions per ton than a mill drawing on gas-fired or renewable generation.

Some U.S. producers and industry trade groups contend that carbon dioxide emissions from mini-mills are 75% lower in comparison to integrated mills. However, an analysis of Europe's steel industry estimates that DRI used in EAF steelmaking emits roughly 35% lower emissions compared with blast furnace production, depending on energy mix and inputs:[50] EAF mills relying solely on scrap are estimated to emit approximately 840 kilograms of carbon dioxide per ton, while those using coal in a DRI process may emit as much as 1,950 kilograms per ton.[51]

Green steel, the popular term for steel produced with low or no net GHG emissions, is likely to require major changes in steelmaking technology. Integrated steelmaking is inherently more difficult to decarbonize than EAF steelmaking, largely due to the use of blast furnaces to reduce iron ore to elemental iron. Many of the technologies under development seek to create alternative methods of producing pig iron or sponge iron that do not rely on fossil fuels. Among these are:

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[46] LeadIT, Leadership Group for Industry Transition, "Green Steel Tracker," April 2021, at https://www.industrytransition.org/green-steel-tracker/.

[47] Zhiyuan Fan and Julio Friedmann, *Low-Carbon Production of Iron & Steel: Technology Options, Economic Assessment, and Policy*, Columbia University, School of International and Public Affairs, Center on Global Energy Policy, March 8, 2021 (hereinafter Fan and Friedmann, *Low-Carbon Production of Iron & Steel*).

[48] Environmental Protection Agency, "Greenhouse Gas Emissions from a Typical Passenger Vehicle," at https://www.epa.gov/greenvehicles/greenhouse-gas-emissions-typical-passenger-vehicle.

[49] Katharina Rechberger et al., "Green Hydrogen-Based Direct Reduction for Low-Carbon Steelmaking," *Steel Research International*, vol. 91, no. 11 (May 13, 2020).

[50] Monika Draxler et al., "The Steel Industry in the European Union on the Crossroad to Carbon Lean Production—Status, Initiatives and Challenges," *Berg Huettenmaenn Monatsh*, vol. 165, no. 5 (March 24, 2020), p. 222.

[51] Fan and Friedmann, *Low-Carbon Production of Iron & Steel*.

- **Select Biomass Fuels.** Fuels made from plant residues such as wood could be used as an alternative feedstock to reduce iron in blast furnaces. Biomass alternatives are sensitive to several factors, as the feedstock must be grown, harvested, processed, and transported with minimal life-cycle emissions for it to achieve high emission reductions through fossil fuel substitution.
- **Carbon Capture, Utilization, and Storage (CCUS).** CCUS units could be installed or retrofitted at both integrated mills and mini-mills to capture carbon dioxide from iron production in blast furnaces or DRI shaft furnaces. The carbon dioxide then may be stored underground or used to produce chemicals, such as methanol. At present, U.S. manufacturers' use of CCUS is discouraged by economic, technological, and other factors that have complicated wide-scale deployment.[52]
- **Green Hydrogen—Electrolysis.** Hydrogen created with electricity generated from renewable energy could replace coking coal and other fossil fuels used to remove oxygen from iron ore/pellets where the by-product is water rather than carbon dioxide. This could eliminate the need for coking coal used in blast furnaces and natural gas used in direct reduction of iron.[53]
- **Molten Oxide Electrolysis.** Iron ore is dissolved into a liquid electrolyte solution at high temperatures through a shaft furnace and then passed through an electrical current, yielding molten iron. This process could eliminate the need to use natural gas in direct reduction.

Research and Development Funding and Decarbonized Efforts

Reducing the steel industry's GHG emissions is likely to require expanded research and development (R&D) efforts. The U.S. primary metals subsector, of which iron and steel manufacturing is the largest component, spends a smaller proportion of its revenue on R&D than other manufacturing subsectors, such as computer and electronic products and motor vehicles. Between 2013 and 2020, R&D expenditures of the U.S. primary metals subsector averaged approximately 1.4% of the industry's operating revenue.[54] If R&D spending in iron and steel manufacturing were proportionate to that of other primary metals industries, it would have been in the range of $2 billion in 2020.[55]

Much current research aims at marginalizing the use of coking coal and blast furnaces, which are the primary sources of GHG emissions from steelmaking. Boston Metal, a U.S.-based metals technology firm, is attempting to use molten oxide electrolysis to dissolve iron ore in an

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[52] See CRS Report R44902, *Carbon Capture and Sequestration (CCS) in the United States*, by Angela C. Jones and Ashley J. Lawson.

[53] For more information on hydrogen, see CRS Report R46436, *Hydrogen in Electricity's Future*, by Richard J. Campbell.

[54] Bureau of Economic Analysis, National Income and Product Accounts, Table 3.7I, "Investment in Private Intellectual Property Products by Industry," at https://apps.bea.gov/iTable/iTable.cfm?ReqID=10&step=2.; and Bureau of the Census, *Business and Industry Statistics*, at https://www.census.gov/econ/currentdata/dbsearch?program=QFR&startYear=2000&endYear=2021&categories=371&dataType=101&geoLevel=US&notAdjusted=1&submit=GET+DATA&releaseScheduleId=.

[55] The primary metal manufacturing subsector (NAICS 331) includes iron and steel mills and ferroalloy manufacturing, steel product manufacturing, aluminum production and processing, nonferrous metals (except aluminum) production and processing, and foundries. The subsector's total revenue in 2020 was $196 billion, of which iron and steel mills accounted for 53%, according to U.S. Census Bureau data.

electrolyte solution at approximately 1,600ºC prior to an electric current being applied, which then produces molten iron.[56] The iron could then be fed into an EAF, avoiding the need for a coking oven and blast furnace. Boston Metal states that electrolysis shaft furnaces can be installed at iron ore facilities, as well as steel mills, and hopes to have a demonstration plant operational by 2025.[57]

Another initiative is flash ironmaking technology, which is intended to reduce iron ore fine powders into molten iron using a reducing agent of hydrogen or natural gas and leaving behind iron in its elemental state. This research, partially funded by the U.S. Department of Energy's Advanced Manufacturing Office, seeks to minimize the use of coke ovens and blast furnaces in steelmaking by providing an alternative method of producing a relatively pure iron that could be used in EAFs.[58] Researchers have claimed that flash ironmaking in combination with green hydrogen could offer up to 96% lower carbon dioxide emissions compared with steel production involving a blast furnace; although that figure does not consider emissions resulting from the electricity generation needed to power the EAFs.[59]

The transition to green steel is likely to require significant capital investments in alternative technologies and in discontinuing production methods associated with high emissions. Fastmarkets, a company that reports and forecasts commodity prices, estimates that the global steel industry would have to invest more than $1 trillion—an average of $35 billion annually—to reduce carbon dioxide emissions 61% by 2050, raising production costs by approximately $50 per ton.[60] Fastmarkets indicates that decarbonization of steelmaking would be most likely to occur through DRI-EAF production, in which coking coal ovens would be replaced with hydrogen and coal used to generate electricity replaced with renewable energy sources, such as geothermal or solar. Bloomberg New Energy Finance offers a lower estimate, forecasting the need for $278 billion of investments by global steelmakers through 2050, specifically through hydrogen and recycling.[61] U.S. steelmaker Cleveland-Cliffs states that is has spent $1.37 billion toward its goal of reducing emissions 25% from 2017 levels by 2030, with the majority of that amount allocated to a new direct reduction facility that uses carbon capture technology.[62]

Some steelmakers have suggested that they may be able to charge higher prices for steel produced with low-emissions technology, but the size of the potential market is unclear. The construction sector, the largest consumer of steel, has a decentralized and fragmented supply chain in which architects, fabricators, construction contractors, and local building officials all play roles. If green

[56] Andrzej Omietanski and Rebecca Campbell, "The green edge of steel: Cutting through carbon," White & Case, June 28, 2021, at https://www.whitecase.com/publications/insight/green-edge-steel-cutting-through-carbon.

[57] Boston Metal, "Transforming Metal Production", at https://www.bostonmetal.com/transforming-metal-production/.

[58] The Advanced Manufacturing Office serves as a technology development office with the objective of improving the energy and material efficiency, competiveness, and productivity of manufacturing in the industrial sector. U.S. Department of Energy, *Advanced Manufacturing Office: Steel Industry Roundtable, Summary Report*, November 2019, pp. 11-12.

[59] Mark Peplow, "Can industry decarbonize steelmaking?," *Chemical & Engineering News*, June 13, 2021.

[60] Fastmarkets, "The true price of green steel," November 2021, at https://insights.fastmarkets.com/the-true-price-of-green-steel/#lp-pom-text-74.

[61] Veronkia Henze, "Steel Industry Set to Pivot to Hyrdogen in $278 Billion Green Push," BloombergNEF, December 1, 2021, at https://about.bnef.com/blog/steel-industry-set-to-pivot-to-hydrogen-in-278-billion-green-push/.

[62] Alistair MacDonald, "Steelmakers Grapple With How to Cut Carbon Emissions," *Wall Street Journal*, August 21, 2021.

steel costs more than steel made with traditional methods, its use in a construction project at present would be at the option of the project owner or sponsor.[63]

Some automotive manufacturers, including BMW, Mercedes Benz, and Volvo Cars, have signaled interest in using green steel to reduce GHG emissions from their operations as early as 2025.[64] Moreover, automakers are moving away from solely focusing on tailpipe emissions and are seeking to reduce emissions of components and materials used in the production of vehicles, such as steel.[65] On average, 0.9 tons of steel is used to produce one vehicle. Based on this number, one analysis estimates that the cost of green steel produced via hydrogen (i.e., melting iron ore/pellets via blue or green hydrogen through DRI-EAF) for use in an electric vehicle would be approximately $400 per ton higher than non-hydrogen steel, resulting in a cost premium of $360 per vehicle.[66]

The large majority of mini-mill production comes through EAF steelmaking relying on scrap. In 2021, the U.S. steel market totaled 98.0 million tons, with domestic output of steel scrap totaling 59.2 million tons.[67] Consequently, EAF steelmaking relying solely on scrap does not have the capacity to supply domestic steel demand and may not be feasible in serving as the primary venue for the industry's green push. Producers seeking both to achieve decarbonization goals and to meet domestic steel demand may need to expand and diversify green steel investments into direct reduction facilities that could be utilized by both integrated mills and mini-mills.[68]

Issues for Congress

After reporting record earnings in 2021, domestic steel producers seem likely to face greater headwinds due to a slowing economy and continued global excess steelmaking capacity. The pressure to step up research into "green steel" and invest in decarbonization efforts is likely to impact the industry.

The United States has imposed restrictions on imports of steel and steel products since 1978, although the coverage of those restrictions has varied. While these import restrictions may have preserved employment in U.S. steel manufacturing, some of them may have adversely affected employment at steel-consuming industries by raising domestic steel prices. A study by the Peterson Institute for International Economics estimated that trade measures used to assist the domestic steel industry cost the U.S. economy approximately $120 billion between 1990-2019, a figure that exceeded the enterprise value of all publicly traded steel firms in 2020.[69] Congress

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[63] Hasan Muslemani et al., "Opportunities and challenges for decarbonizing steel production by creating markets for 'green steel' products," *Journal of Cleaner Production*, vol. 315 (September 15, 2021), pp. 9-10 (hereinafter Muslemani et al., "Opportunities and challenges for decarbonzing steel production").

[64] William Boston, "Green Steel Becomes a Hot Commodity for Big Auto Makers," *Wall Street Journal*, September 13, 2021.

[65] Muslemani et al., "Opportunities and challenges for decarbonzing steel production."

[66] Yingxia Yang, *Green Steel: Make Electric Vehicles Greener*, Boston University, Institute for Sustainable Energy, August 10, 2021, at https://www.bu.edu/ise/2021/08/10/green-steel-make-electric-vehicles-greener/.

[67] USGS, *Mineral Commodity Summaries*, "Iron and Steel Statistics and Information," January 2022, and USGS, *Mineral Commodity Summaries*, "Iron and Steel Scrap Information and Statistics," January 2022.

[68] U.S. producer Cleveland-Cliffs is an example of this as it has an active direct reduction plant that produces hot-briquetted iron (HBI), in part, to reduce ferrous scrap purchases. The HBI is then fed into either a basic oxygen furnace or an electric arc furnace to produce liquid steel.

[69] Gary Huffbauer and Eujin Jung, *Scoring 50 Years of US Industrial Policy, 1970-2020*, Peterson Institute of International Economics, PIIE Briefing 21-5, November 2021, p. 20.

may want to evaluate the impact of steel import restrictions on steel-using industries and consider whether the restrictions have achieved relevant goals, such as improving capacity utilization, productivity, and innovation in steelmaking.

The U.S.-EU agreement on Section 232 tariffs reached in October 2021 addresses additional subjects beyond the modification of tariffs on steel and aluminum. One such component pertains to global excess steelmaking capacity and the carbon intensity of steelmaking. The United States and EU agreed to establish a carbon-based sectoral arrangement specific to steel and aluminum trade.[70] In addition, the United States and EU would invite like-minded countries to participate in the arrangement and contribute to achieving goals related to global excess steelmaking capacity and supporting the reduction of carbon intensity of steel across modes of production.[71] In February and March 2022, the United States reached agreements with Japan and the United Kingdom, respectively, regarding Section 232 tariffs that contain similar objectives specific to global excess steelmaking capacity and the carbon intensity of the global steel sector. Congress may seek to explore the effectiveness of these agreements and their potential impact on domestic steelmakers.

The domestic steel industry has become increasingly globalized, and policies that support international cooperation regarding the industry's transition to green steel may be an important component of this. In particular, international standards to define and encourage the use of green steel may be important in accelerating the industry's transition. Congress may consider whether or not green steel criteria should have a role in federal procurement goals and domestic content requirements. This could involve establishing standard practices for reporting emissions intensity.

The Low-Emissions Steel Manufacturing Research Program section of the House-passed version of America COMPETES Act of 2022 (H.R. 4521, Section 10721) would require the federal government to establish an R&D program specific to low-emissions steel manufacturing. The program would be led by the Department of Energy and involve other federal agencies, academic institutions, nonprofit organizations, and private companies, including steel producers. The provision's stated purposes of the program include "significant net nonwater greenhouse emissions reductions" in the iron and steel production processes. The program would support research into carbon capture technologies, such as combustion and chemical looping processes, medium- and high-heat generation technologies, such as biomass and hydrogen, and renewable heat-generation technologies, such as solar and geothermal sources, among others. The Senate-passed version of H.R. 4521, United States Innovation and Competition Act of 2021, does not include a similar provision.

Decarbonization efforts tied to domestic steel production may unfold primarily through DRI-EAF steelmaking and as a result could impact integrated steel mill workers, as integrated mills have a highly unionized workforce compared with mini-mills. If decarbonization efforts lead to further market-share gains by mini-mills, this may adversely affect integrated mills and their workers.

[70] According to the agreement, the United States and EU are expected to form a technical working group to confer on methodologies for calculating steel and aluminum carbon-intensity for the purpose of market access.

[71] The White House, "FACT SHEET: The United States and European Union to Negotiate World's First Carbon-Based Sectoral Arrangement on Steel and Aluminum Trade," October 31, 2021.

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