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U.S. Aluminum Manufacturing: Industry Trends and Sustainability

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SUMMARY

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Christopher D. Watson
Analyst in Industrial Organization and Business

U.S. Aluminum Manufacturing: Industry Trends and Sustainability

Aluminum—a lightweight, ductile, malleable, and corrosion-resistant metal—is a major component used in a wide range of consumer, industrial, and technological goods, including aircraft, building materials, motor vehicles, and several types of defense and military equipment. The aluminum industry comprises three segments: upstream, secondary or recycled, and downstream. The upstream sector consists of mining bauxite, refining it to produce alumina, and smelting it to yield primary aluminum. Secondary aluminum is derived from recycled scrap metal. The downstream sector uses both primary and secondary aluminum to produce a variety of aluminum products.

Through 2000, the United States ranked as the world's largest producer of primary aluminum. In 2021, the United States accounted for less than 2% of global primary aluminum production and ranked as the ninth-largest primary aluminum producing country. Primary aluminum smelting is highly energy-intensive, with electricity estimated to account for up to 40% of production costs. Consequently, a major reason for the decline in U.S. primary aluminum production is that the United States is a relatively high-cost producer. The world's leading producers of primary aluminum are generally countries with comparatively low energy costs, including Canada, Russia, and the United Arab Emirates. By contrast, the United States is a major producer of secondary aluminum. In 2021, more than 75% of domestic supply came from secondary smelters. Secondary aluminum production is often more economically tenable than primary production, as it is approximately 95% less energy-intensive than primary smelting.

Secondary aluminum often has significant impurities, as it is derived from recycled products or scrap. Thus, manufacturers of components used in electronics and aerospace manufacturing often favor primary aluminum meeting specified purity standards. Many defense-related products must comply with particularly high purity standards. At present, the United States has one active smelter that produces aluminum of sufficient purity for use in military aircraft, as well as lightweight armor plating found in many defense ground and weapon systems. The greatest aluminum-related security concern regarding defense requirements appears to be the domestic availability of specific high-purity aluminum alloys, which can be derived from primary aluminum.

The U.S. and Canadian aluminum industries are highly integrated, as each market is a major trading partner of the other across the aluminum value chain. In 2021, more than 75% of Canadian production went to the United States, while roughly half of U.S. downstream products were exported to Canada. U.S. primary aluminum smelters operated at 55% of the industry's rated production capacity in 2021, compared with 95% in Canada and 88% globally. Over half of global primary aluminum smelting capacity is in China, which has become the world's leading producer in most segments of the aluminum value chain over the past two decades.

Excess capacity in the aluminum sector has been a growing concern for domestic producers. The Organisation for Economic Co-operation and Development found that the global aluminum industry received up to $70 billion in government support between 2013 and 2017, with the large majority of support concentrated in China and countries of the Gulf Cooperation Council.

In addition to being an energy-intensive process, aluminum manufacturing contributes approximately 2% to global greenhouse gases (GHG), equivalent to roughly 1.1 billion tons of carbon dioxide. More than half of GHG emissions related to aluminum manufacturing come from the generation of electricity used in primary aluminum smelting. A transition to carbon-neutral aluminum is likely to require significant capital investment in decarbonizing the electrical grid and in specific technologies used in primary smelting and recycling. P.L. 117-169 (commonly referred to as the Inflation Reduction Act of 2022), signed into law on August 16, 2022, established the Advanced Industrial Facilities Deployment Program in which the Department of Energy is expected to provide financial assistance to producers and production facilities of a variety of heavy manufacturing industries, including aluminum, that use advance technologies in manufacturing processes that effectively reduce GHG emissions. This could incentivize producers to invest further in decarbonizing specific production assets in aluminum manufacturing.

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Introduction

Congress has long been concerned with the health of the U.S. manufacturing base. One component of this base is aluminum—a lightweight, ductile, malleable, and corrosion-resistant metal. Aluminum is used in a wide range of consumer, industrial, and technological goods, including aircraft, building materials, motor vehicles, and many types of defense and military equipment.

This report provides an overview of factors affecting aluminum production in the United States, including energy costs, trade and regulatory issues, and demand. It also examines national security concerns tied to aluminum production and efforts to reduce the industry's greenhouse gas (GHG) emissions. The report concludes with a discussion of selected issues that may be of interest to Congress.

The Aluminum Manufacturing Process

The aluminum sector comprises three segments:

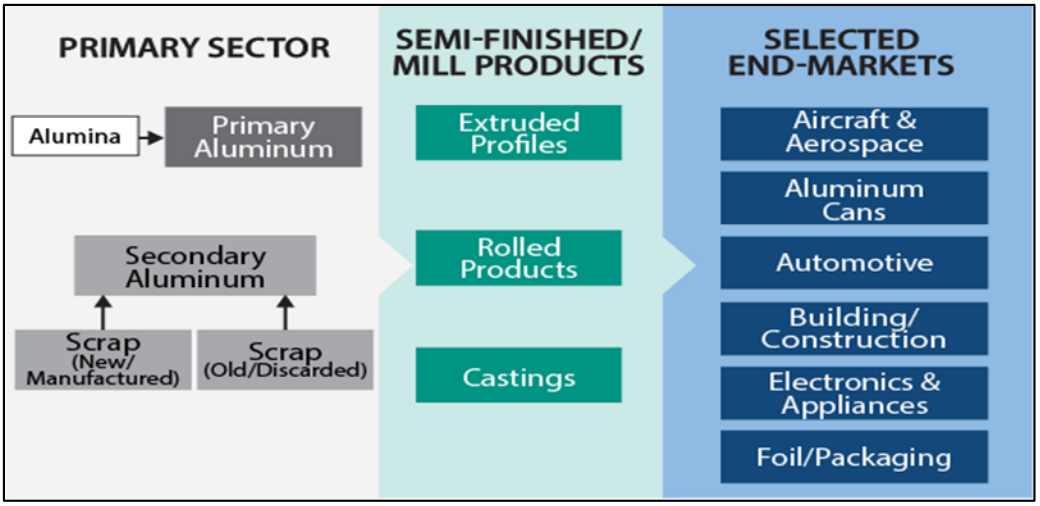
- The upstream sector, which includes the mining of bauxite, the refining of bauxite into alumina (aluminum oxide), and the smelting of alumina to yield primary aluminum. The molten aluminum is cast into ingots, billets, or slabs, collectively referred to as unwrought aluminum.
- Secondary aluminum is derived from recycled scrap metal. Secondary production involves smelting both old scrap recovered from finished products, such as cans and auto parts, and new scrap, material left over from processing aluminum into consumer or industrial products. Similar to primary aluminum, secondary aluminum typically is cast into unwrought shapes.
- The downstream sector uses primary or secondary aluminum to make aluminum products, which may then be used in the manufacture of motor vehicles, construction materials, consumer durables, and other products.

Wrought aluminum consists of downstream products that are worked in solid form by rolling, drawing, extruding, forging, or other mechanical processing. These are known commonly as semi-finished or mill products. Wrought aluminum can be resmelted and combined with alloying elements, such as copper, silicon, and zinc, to create metals with unique properties that may be necessary for specific applications. **Figure 1** depicts aluminum sources and their uses.

Generally, primary aluminum production is undertaken by vertically integrated holding companies that control bauxite mines, alumina refineries, smelting facilities, and in some instances, rolling and processing mills. This model affords producers insulation from price fluctuations and helps secure raw material supply. The secondary aluminum segment consists of smelting facilities and attached rolling mills that produce finished aluminum products from semi-finished aluminum. The downstream segment represents the largest component of the domestic aluminum industry, consisting of dozens of firms that produce flat-rolled and extruded products.[1]

[1] Jameson Ayers, *Aluminum Manufacturing in the US*, IBISWorld, October 2022, p. 25.

Figure 1. Aluminum Sources and Uses



Source: CRS, adapted from NERA Economic Consulting, *Impacts of Potential Aluminum Tariffs on the U.S. Economy*, June 2017, p. 1.

Domestic Production

Primary Aluminum

The U.S. and Canadian aluminum industries are highly integrated. The two markets are major trading partners with one another across the aluminum value chain. The large majority of Canadian unwrought aluminum goes to the United States. Roughly half of U.S. semi-finished aluminum products are exported to Canada. In the context of domestic production, the linkage between the two countries' industries is significant, specifically regarding the production of primary aluminum and downstream fabrication.

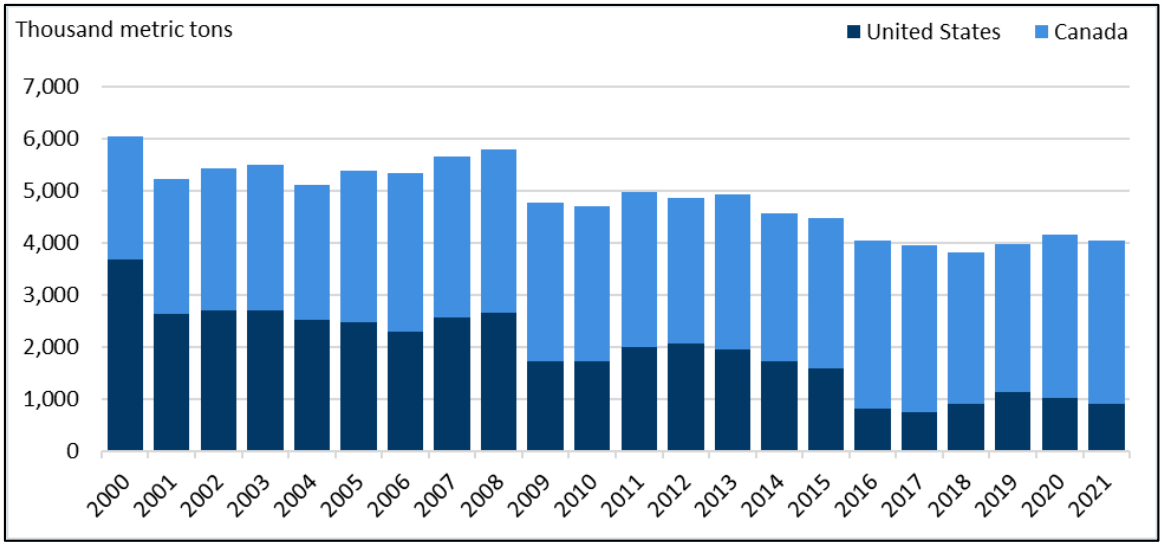
In 2021, the United States produced 908,000 metric tons of primary aluminum, significantly below peak domestic output of 5.1 million metric tons in 1980.[2] Through 2000, the United States ranked as the world's top producer of primary aluminum, but it had slipped to the ninth-largest by 2021, accounting for less than 2% of global primary aluminum production. Canada is the world's fourth-largest primary aluminum producing country, accounting for 5% of global output in 2021. Combined U.S.-Canadian primary aluminum production declined 33% between 2000 and 2016 but has been relatively stable since 2016 (**Figure 2**).

U.S. primary aluminum smelting capacity was 1.64 million metric tons in 2021. Domestic primary smelters operated at 55% of rated production capacity. Canadian smelters, by contrast, used nearly all of their 3.27 million metric tons of capacity in 2021. One domestic producer, Alcoa Corp., has three primary smelters in Canada and is estimated to account for almost one-third of that country's total primary smelting capacity.[3] Globally, primary aluminum smelters operated at 88% of rated capacity in 2021.

[2] The Aluminum Association, Industry Statistics, *North American Primary Aluminum Production*; and U.S. Bureau of Mines, *Mineral Yearbook: Metals and Minerals 1980* (Washington, DC: USGPO, 1981).

[3] Alcoa Corporation, Form 10-K for the year ending December 31, 2021, p. 6; and U.S. Geological Survey (USGS), *Mineral Commodity Summaries*, "Aluminum Statistics and Information," January 2022.

Figure 2. U.S. and Canadian Primary Aluminum Production



Sources: The Aluminum Association, Industry Statistics, *North American Primary Aluminum Production*; and U.S. Geological Survey (USGS), "Aluminum Statistics and Information."

Bauxite—the raw material used by primary smelters—is largely sourced overseas. Bauxite reserves are heavily concentrated in Australia, Guinea, and Vietnam. In 2021, the United States imported 3.6 million metric tons of bauxite; about 70% was refined into alumina used by primary smelters, while the remainder was used in products such as abrasives, cement, and chemicals.[4] Import sources for both mined bauxite and alumina include Australia, Brazil, and Jamaica.

A major reason for the decline in U.S. primary aluminum production capacity is that the United States is a relatively high-cost producer. Primary aluminum smelting is highly energy-intensive, with electricity estimated to account for up to 40% of the cost.[5] In 2021, Alcoa reported that electric power represented approximately 31% of the company's primary aluminum production costs.[6] Century Aluminum Company—chiefly a domestic producer—cites electricity as the company's single largest operating cost.[7] Generally, the world's leading producers are countries with lower energy costs, including Canada, Russia, and the United Arab Emirates (UAE). According to the World Bank, one kilowatt-hour of electricity cost, on average, $0.163 in the United States in 2019 compared with $0.123 in Canada, $0.081 in Russia, and $0.109 in the UAE.[8]

In 2000, 12 companies operated 23 primary smelting facilities in the United States; by the close of 2021, six primary smelters were operated by three firms—Alcoa, Century Aluminum, and Magnitude 7 Metals LLC (**Figure 3**).[9] In April 2020, Alcoa announced that it would curtail indefinitely its Intalco smelting facility in Ferndale, WA, reducing industry production capacity

[4] USGS, *Mineral Commodity Summaries*, "Bauxite and Alumina Statistics and Information," January 2022.

[5] The Aluminum Association, *Primary Production 101*, at https://www.aluminum.org/primary-production-101.

[6] Alcoa Corporation, Form 10-K for the year ending December 31, 2021, pp. 7, 14, and 67.

[7] Century Aluminum Company, Form 10-K for the year ending December 31, 2021, pp. 22, 51, and 58; and Century Aluminum Company, Form 10-K for the year ending December 31, 2019, p. 40.

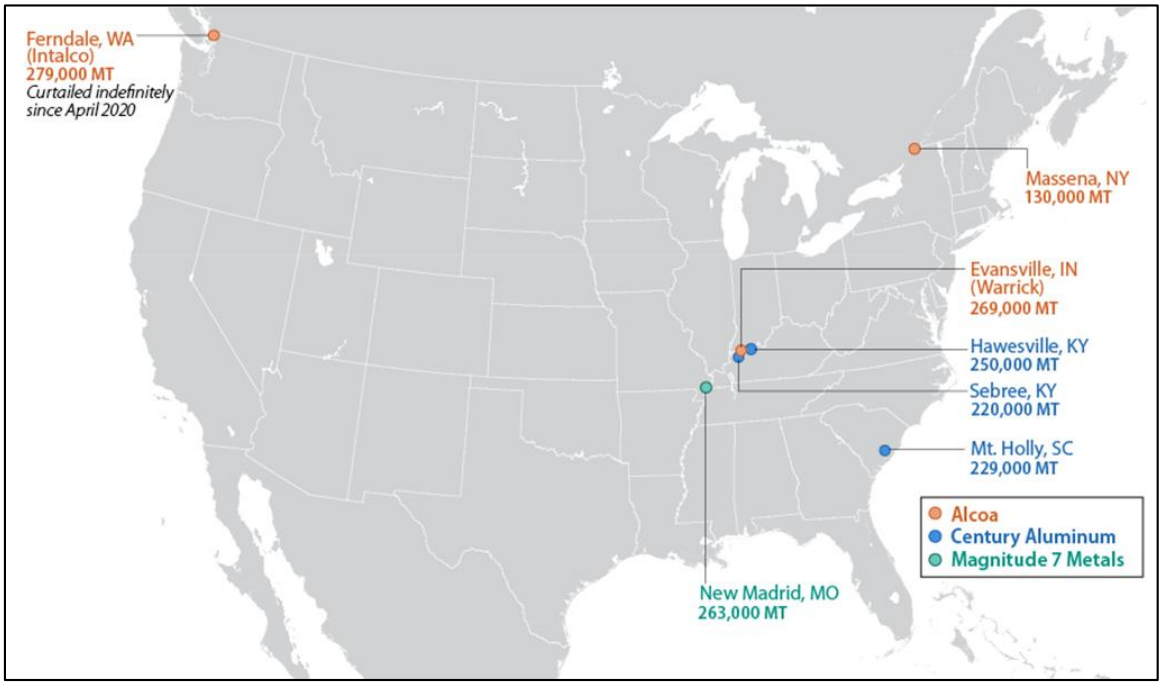
[8] World Bank, "GovData360, Getting electricity: Price of electricity," at https://govdata360.worldbank.org/indicators/h6779690b?country=BRA&indicator=42573&viz=line_chart&years=2014,2019.

[9] USGS, *Mineral Commodity Summaries*, "Aluminum Statistics and Information," January 2001 and January 2022.

by 230,000 metric tons.[10] In July 2022, Alcoa announced that it would partially curtail its Warrick smelter in Evansville, IN, by 54,000 metric tons citing operational challenges.[11] Alcoa had announced the permanent closure of the Warrick smelter in March 2016 citing similar reasons; it restarted three of the five smelting potlines[12] there in 2018, representing approximately 60% of the facility's production capacity.[13]

Figure 3. U.S. Primary Aluminum Smelters, 2021

Annual production capacity in metric tons (MT)



Sources: CRS using location of smelters obtained from Homeland Infrastructure Foundation-Level Data, Nonferrous Metal Processing Plants. Data for smelter production capacities are based on Alcoa Corporation, Form 10-K for the year ending December 31, 2021, pp. 6-7; Century Aluminum Company, Form 10-K for the year ending December 31, 2021, pp. 2-3; and USGS, "Aluminum Statistics and Information."

Note: Alaska and Hawaii are not shown on the map and no primary smelters are located in either state.

Much of the U.S. aluminum industry developed in areas where two federally owned utilities, the Bonneville Power Administration and the Tennessee Valley Authority, furnished electricity at low cost. As those entities have raised electricity prices over time, most of the aluminum smelters have closed, and imports now meet a large share of domestic demand. In addition to Alcoa's three primary smelters in Canada, it has one in Iceland and two in Norway, while Century Aluminum has one smelter in Iceland; in each case, the smelter has access to relatively inexpensive hydroelectric or geothermal power. Canadian imports meet a large share of U.S. demand for

[10] Alcoa Corporation, Form 10-K for the year ending December 31, 2021, p. 80.

[11] Alcoa Corporation, "Alcoa Announces Partial Curtailment at Warrick Smelter in Indiana," press release, July 1, 2022, at https://news.alcoa.com/press-releases/press-release-details/2022/Alcoa-Announces-Partial-Curtailment-at-Warrick-Smelter-in-Indiana/default.aspx.

[12] Smelting potlines are comprised of an interconnected row of electrolytic reduction pots used to smelt alumina into aluminum.

[13] Alcoa Corporation, Form 10-K for the year ending December 31, 2016, p. 17; and Alcoa Corporation Form 10-K for the year ending December 31, 2018, p. 13.

unwrought aluminum. By contrast, smelters in both Iceland and Norway almost exclusively sell to customers in Europe.[14]

U.S. primary smelters use older and less energy-efficient technologies than newer facilities abroad. The newest U.S. primary aluminum facility is Century Aluminum's Mt. Holly, SC, plant, which opened in 1980.[15] Primary smelting requires relatively large capital investments. A new smelter, for example, may represent at least a $1 billion investment while taking a minimum of three years to build and bring online.[16] Some domestic producers have chosen to invest in countries with lower energy costs: no new primary smelters are under construction in the United States. However, Alcoa is in negotiations to sell its closed Intalco primary smelter in Ferndale, WA, to Blue Wolf Equity Partners, which expects to spend roughly $175 million in modernizing the plant with new technology to produce 240,000 metric tons of aluminum annually.[17] The transaction may depend on Blue Wolf's ability to reach a power supply agreement with the Bonneville Power Administration.

Secondary and Downstream Aluminum

The United States is a major producer of secondary aluminum. Since the early 2000s, aluminum derived from scrap has represented an increasing share of total U.S. aluminum output. Secondary aluminum accounted for 78% of the 4.1 million metric tons of aluminum produced by U.S. smelters in 2021. Of that secondary production, 53% came from new scrap—material left over from primary smelting—and 47% from old scrap.

Secondary aluminum producers face a different cost structure from primary producers. Secondary production is roughly 95% less energy-intensive than primary production,[18] and the capital cost of a secondary smelter is comparatively low. Unlike primary production, secondary aluminum production in the United States has generally increased over time and is over twice the level of the early 1980s. In May 2022, Novelis Inc., the U.S. subsidiary of an India-based secondary and downstream producer, announced an investment of $2.5 billion in a new secondary smelter with an attached rolling mill in Bay Minette, AL, with the ability to produce 600,000 tons annually.[19] Over the past decade, the aluminum industry has invested more than $6.5 billion in new facilities and expansions, with the vast majority of such investments directed toward secondary smelting and the downstream segment.[20]

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[14] International Trade Centre, "Trade Map—Trade statistics for international business development," exports of unwrought aluminum (HS 7601) for Iceland and Norway. For the underlying data, see https://www.trademap.org/Index.aspx.

[15] Century Aluminum Company, "Mt. Holly, SC," at https://centuryaluminum.com/products-and-plants/mt-holly-sc/default.aspx; and Century Aluminum Company, Form 10-K for the year ending December 31, 2021, p. 3.

[16] Kirk Maltais, "US aluminium industry ponders case for building new smelter," *Fastmarkets MB*, April 3, 2018, at https://www.metalbulletin.com/Article/3798442/US-aluminium-industry-ponders-case-for-building-new-smelter.html.

[17] Joshua Partlow and Steven Mufson, "A factory wants to reopen making 'green' aluminum. Now it just needs clean energy," *Washington Post*, June 7, 2022, at https://www.washingtonpost.com/climate-environment/2022/06/07/aluminum-smelter-alcoa-intalco/.

[18] The Aluminum Association, *Secondary Production 101*, at https://www.aluminum.org/secondary-production-101.

[19] Novelis, Inc., "Novelis to Build $2.5 Billion Low-Carbon Aluminum Recycling and Rolling Plant," press release, May 11, 2022, at https://investors.novelis.com/2022-05-11-Novelis-to-Build-2-5-Billion-Low-Carbon-Aluminum-Recycling-and-Rolling-Plant.

[20] The Aluminum Association, "$2.5 Billion LowCarbon Recycling & Rolling Plant Investment Meets Growing U.S. Aluminum Demand," press release, May 11, 2022, at https://www.aluminum.org/25-billion-low-carbon-recycling-rolling-plant-investment-meets-growing-us-aluminum-demand.

The downstream sector is by far the largest segment of the U.S. aluminum industry. Downstream producers accounted for over 75% of the industry's $31.5 billion earnings in 2020.[21] There are dozens of downstream production facilities scattered across the United States, largely concentrated in the Midwest and Southeast. The largest downstream producers in the United States include Arconic Corp., Constellium SE, Kaiser Aluminum Corp., Novelis, and Sapa Extrusions.

Most major downstream producers rely on a combination of primary and secondary aluminum in their manufacturing operations. The amount of primary versus secondary aluminum used varies according to the performance requirements of the final product. Aluminum producers often must manage the properties of the aluminum alloy precisely to meet customer specifications, and this often favors the use of primary aluminum.

The Aluminum Market

Demand for aluminum is cyclical and largely depends on the health of the manufacturing sector, particularly pertaining to aviation products, motor vehicles, electrical equipment and machinery, packaging, and construction materials. In 2021, demand for aluminum in the United States totaled 4.3 million metric tons, up 8% from 2020—even as the Coronavirus Disease 2019 (COVID-19) pandemic contributed to curtailments and reduced production at facilities of aluminum-consuming industries. Domestic consumption remains below the recent peak of 5.7 million metric tons in 2017 (**Figure 4**). The three largest domestic end markets for aluminum in 2021 were transportation equipment, packaging, and building and construction. These end markets accounted for a combined 74% of U.S. aluminum consumption.[22]

Since the mid-2010s, U.S. aluminum demand has been generally flat. However, CRU International, a consulting company, forecasts that demand for aluminum in North America will expand by 5.1 million metric tons, or 45%, between 2020 and 2030. CRU estimates that roughly half of this growth will occur in the transportation sector as North America becomes a major electric vehicle production location.[23] Demand for packaging and construction combined is expected to increase by 27%. The Aluminum Association—the domestic industry's largest trade group—reported that North American (U.S. and Canadian) aluminum demand grew by 6.6% through the first half of 2022, driven by packaging among other segments.[24]

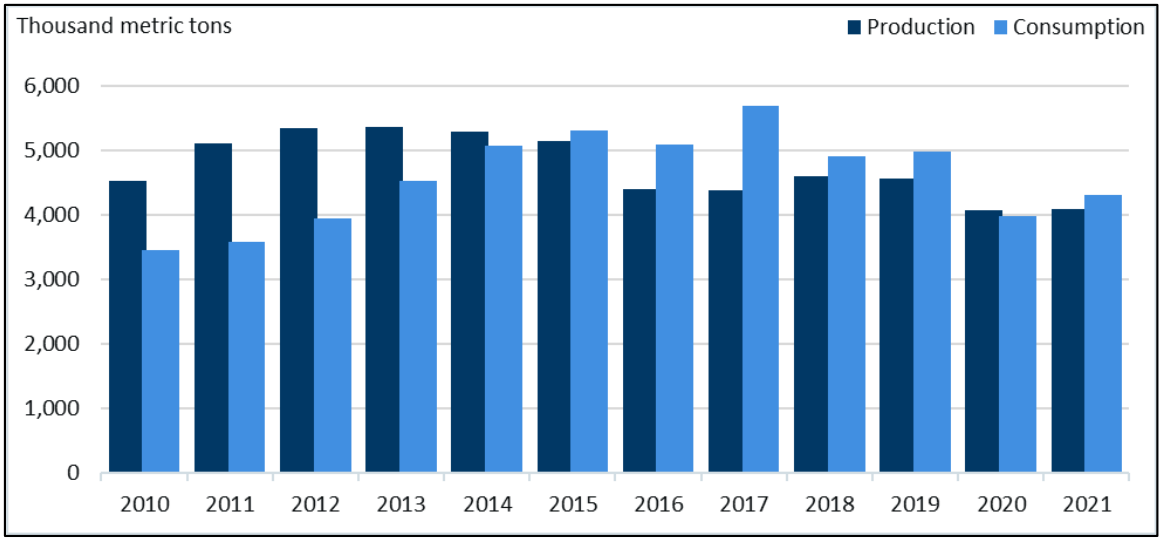
[21] Bureau of the Census, "Annual Survey of Manufacturers," at https://data.census.gov/cedsci/table?q=AM1831BASIC&n=3313%3A331313%3A331314%3A331315%3A331318.

[22] USGS, *Mineral Commodity Summaries*, "Aluminum Statistics and Information," January 2022.

[23] CRU International, *Opportunities for aluminum in a post-Covid economy*, January 28, 2022, p. 20, at https://international-aluminium.org/resource/opportunities-for-aluminium-in-a-post-covid-economy/.

[24] The Aluminum Association, "North American Aluminum Demand Up 6.6% Through First Half of 2022," press release, August 30, 2022, at https://www.aluminum.org/north-american-aluminum-demand-66-through-first-half-2022.

Figure 4. U.S. Aluminum Production and Consumption



Sources: The Aluminum Association, Industry Statistics, *U.S. Primary Aluminum Production*; and USGS, "Aluminum Statistics and Information."

Note: Production includes primary and secondary aluminum.

As discussed above, the U.S. and Canadian aluminum industries are heavily interconnected. In 2021, imports supplied 44% of the U.S. aluminum market, up from 39% in 2020.[25] More than half of U.S. aluminum imports in 2021 came from Canada. Canadian output of primary aluminum reached an estimated 3.13 million metric tons in 2021, more than three times that of the United States, with 81% of that production exported to the United States.[26] Mexico is not a major producer of aluminum but consumes large volumes of North American aluminum. Through the first half of 2022, the United States exported 219,000 metric tons of semi-finished aluminum products, with 59% going to Canada and 33% to Mexico. During the same period, U.S. imports of unwrought aluminum amounted to 2.14 million metric tons, with more than 60% coming from Canada.[27]

Over the past decade, 58%-69% of domestic supply of aluminum was exported each year. An important reason for the imbalance between production and consumption is that the United States is a major exporter of aluminum scrap, which represented 72% of total export volume in 2021. Mexico, Malaysia, and Canada were the three largest export markets, in that order, accounting for over half of total aluminum export volume from U.S. mills.[28] Canada and Mexico import the vast majority of U.S. non-scrap aluminum exports, including semi-finished products as well as small volumes of unwrought aluminum and alloys.

Global demand for semi-finished aluminum products is expected to increase up to 80% by 2050.[29] This could be significant for the prospects of U.S. producers, particularly for exports of aluminum

[25] USGS, *Mineral Commodity Summaries*, "Aluminum Statistics and Information," January 2022.

[26] The Aluminum Association, Industry Statistics, *North American Primary Aluminum Production*; and U.S. Department of Commerce, "U.S. Aluminum Import Monitor," accessed July 28, 2022.

[27] USGS, *Mineral Industry Surveys*, "Aluminum Statistics and Information," Table 8, June 2022.

[28] USGS, *Mineral Industry Surveys*, "Aluminum Statistics and Information," Table 9, December 2021.

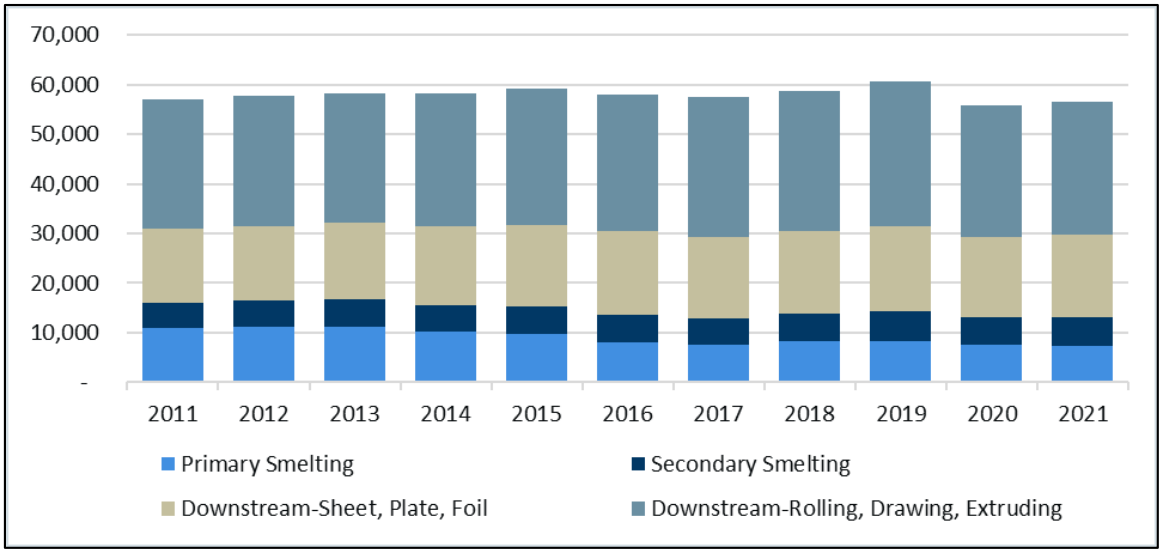
[29] "World aluminium industry must cut emissions by 77% by 2050 -IAI," *Reuters*, March 16, 2021, at https://www.reuters.com/world/china/world-aluminium-industry-must-cut-emissions-by-77-by-2050-iai-2021-03-16/

scrap and for semi-finished products. Moreover, the United States-Mexico-Canada Agreement (USMCA), in effect since July 2020, requires 70% North American aluminum content for automobiles and auto parts to qualify for duty-free trade. This could increase demand for U.S. and Canadian aluminum over time.[30]

Employment and Wages

Direct employment in U.S. aluminum manufacturing has declined 38%, from 91,388 workers in 2001 to 56,515 workers in 2021.[31] However, that decline occurred largely between 2001 and 2008; employment in the industry as a whole has been generally flat in recent years (**Figure 5**). In 2021, fewer than one in four workers in aluminum manufacturing were employed in primary or secondary aluminum smelting. The majority of jobs in aluminum manufacturing are at downstream sector facilities that make plate, sheet, extruded, and rolled products. The U.S. Bureau of Labor Statistics (BLS) projects employment in aluminum manufacturing to shrink approximately 6% between 2021 and 2031.[32]

Figure 5. U.S. Aluminum Manufacturing Employment



Source: Bureau of Labor Statistics, Quarterly Census of Employment and Wages, North American Industry Classification System (NAICS) codes 331313—Alumina Refining and Primary Aluminum Production; 331314—Secondary Smelting and Alloying of Aluminum; 331315—Aluminum Sheet, Plate, and Foil Manufacturing; and 331318—Other Aluminum Rolling, Drawing, and Extruding.

In 2021, workers in primary aluminum smelting and manufacturing of plate, sheet, and foil were among the aluminum sectors' highest earners, with annual average wages of $84,164 and

#:~:text=LONDON%2C%20March%2016%20(Reuters),Aluminium%20Institute%20said%20on%20Tuesday.

[30] Office of the U.S. Trade Representative (USTR), *The United States-Mexico-Canada Agreement Fact Sheet: Automobiles and Automotive Parts*, accessed June 21, 2022, at https://ustr.gov/sites/default/files/files/Press/fs/USMCA/USMCA-Autos_and_Auto_Parts.pdf.

[31] Bureau of Labor Statistics (BLS), *Quarterly Census of Employment and Wages*, North American Industry Classification System (NAICS) 3313—Alumina and Aluminum Production and Processing, at http://www.bls.gov/qcew.

[32] BLS, *Employment and Output by Industry*, Table 2.11, accessed September 8, 2022, at https://www.bls.gov/emp/tables/industry-employment-and-output.htm.

$88,136, respectively.[33] The secondary aluminum sector paid an annual average wage of $69,319, while workers involved in aluminum rolling and extruding were paid an average of $63,639 annually.[34] As a whole, the aluminum industry's annual average pay was $74,149, 3% lower than the annual average of $76,580 for all manufacturing.

Trade Measures, Regulatory Support, and Global Excess Capacity

Since the early 2010s, the United States has imposed or negotiated restraints on imports of a variety of downstream aluminum products in response to complaints by aluminum producers and industry associations that the U.S. industry was injured or threatened with injury by imports sold below fair market value ("dumped"), subsidized, or otherwise supported by unfair trade practices. In addition, the U.S. Department of Commerce has self-initiated some trade remedy proceedings involving aluminum.

The most recent round of trade actions began in March 2018 when the Trump Administration imposed a 10% tariff on certain aluminum products from virtually all countries under Section 232 of the Trade Expansion Act of 1962,[35] which allows restrictions, such as tariffs or import quotas, on imports that have been found to harm national security.[36] The Trump Administration's stated objective was to reduce import volumes to a level that would enable the domestic industry to operate at an average of 80% or more of production capacity.[37] An additional aim was to raise the price of imported aluminum to encourage domestic producers to restart idled capacity and expand employment.[38] In October 2021, the United States and the European Union (EU) reached an agreement under which the Section 232 tariffs on imports from EU countries were replaced with a tariff-rate quota allowing a specified quantity of aluminum imported from the EU to enter the United States duty-free each year.[39] The United States reached a similar agreement with the United Kingdom in March 2022.[40]

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[33] BLS, *Quarterly Census of Employment and Wages*, NAICS 331313—Alumina Refining and Primary Aluminum Production, and 331315—Aluminum Sheet, Plate, and Foil Manufacturing.

[34] BLS, *Quarterly Census of Employment and Wages*, NAICS 331314—Secondary Smelting and Alloying of Aluminum, and 331318—Other Aluminum Rolling, Drawing, and Extruding.

[35] 19 U.S.C. §1862, as amended.

[36] At the same time, Section 232 tariffs were applied to steel imports at a 25% rate. In May 2019, Canada and Mexico were exempted permanently from the Section 232 tariffs. Australia is not subject to any import restrictions; Argentina is subject to an annualized quota in lieu of the tariffs as are individual product imports that receive a product exclusion from the U.S. Department of Commerce.

[37] Bureau of Industry and Security, *The Effect of Imports of Aluminum on the National Security*, 2018, p. 107.

[38] Ibid., p. 104.

[39] Under the agreement, the United States will exempt up to 18,000 metric tons (MT) of unwrought aluminum under two product categories and 366,000 MT of semi-finished (wrought) aluminum under 14 product categories imported from the European Union from Section 232 tariffs each year. If imports exceed this quantity, then the Section 232 duties would be reimposed for the remainder of the calendar year. USTR, "Joint US-EU Statement on Trade in Steel and Aluminum," press release, October 31, 2021, at https://ustr.gov/sites/default/files/files/Statements/US%20232%20EU%20Statement.pdf.

[40] The agreement with the United Kingdom allows 900 MT of unwrought aluminum under two product categories and 11,400 MT of semi-finished (wrought) aluminum, other than foil (Harmonized System Heading 7607), under 12 product categories to enter the United States duty-free each year, effective June 1, 2022. For aluminum foil (7607), the agreement allows 9.3 TMT (thousand metric tons) under two product categories to enter duty-free each year. 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.

Separately, there are numerous antidumping (AD) and countervailing duty (CVD) orders imposing punitive duties on aluminum and aluminum products. Most of these orders were put into place after the Trump Administration's imposition of Section 232 duties. AD or CVD duties may be imposed when imports are found to have been sold below cost in the U.S. market or subsidized and threaten to injure a domestic industry.[41] As of September 2022, 34 AD or CVD orders concerning aluminum were in force, including many on semi-finished aluminum products imposed under the Biden Administration in 2021.[42] In June 2021, the International Trade Administration in the Department of Commerce implemented the aluminum import monitoring and analysis system to track imports of aluminum products and provide an early warning of import surges.[43]

The Section 232 restrictions are intended to raise domestic prices of the covered products, leaving downstream manufacturers that use those products to face higher input costs. Consequently, some U.S. manufacturers claimed to have difficulty competing with imported finished or derivative products and sought AD/CVD protection as well—a development some economists have referred to as "cascading protection."[44] A report from the Economic Policy Institute estimates that Section 232 measures have provided relief to domestic aluminum producers through improved output, employment, and capital investments while creating no adverse effects for aluminum-consuming industries, such as motor vehicle parts, construction goods, and canned beverages.[45] By contrast, research from HARBOR Aluminum on behalf of the Beer Institute estimates that between March 2018 and February 2022, Section 232 aluminum tariffs cost the U.S. beverage industry $1.4 billion, while amounting to $463 million in 2021.[46] Data from BLS show little change in employment at secondary smelters and at aluminum sheet, plate, and foil mills since 2018, while employment in primary aluminum production and at rolling, drawing, and extrusion plants has declined. On balance, the net effect on employment within the aluminum industry seems to be relatively minor.

The global aluminum sector has seen major changes over the last two decades with China's rise to be the leading producer in most segments of the aluminum value chain. Global output of primary aluminum has more than doubled, from 23.9 million metric tons in 2000 to 68 million metric tons in 2021. The majority of global smelting capacity is in China, which accounted for 57% of global primary aluminum output in 2021; combined, the United States and Canada represented 6% (**Figure 6**).

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[41] For more information on antidumping (AD) and countervailing duty (CVD) orders, 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.

[42] Of the 34 AD/CVD orders covering aluminum, 26 were introduced in 2021, affecting imports from Armenia, Bahrain, Brazil, China, Croatia, Egypt, Germany, India, Indonesia, Italy, Oman, Romania, Russia, Serbia, Slovenia, South Africa, Spain, Taiwan, and Turkey. U.S. Department of Commerce, "AD/CVD Proceedings," accessed September 6, 2022, at https://www.trade.gov/data-visualization/adcvd-proceedings.

[43] For information about the Aluminum Import Monitoring and Analysis (AIM) system, see International Trade Administration, "Industry Import Monitoring and Analysis," at https://www.trade.gov/aluminum.

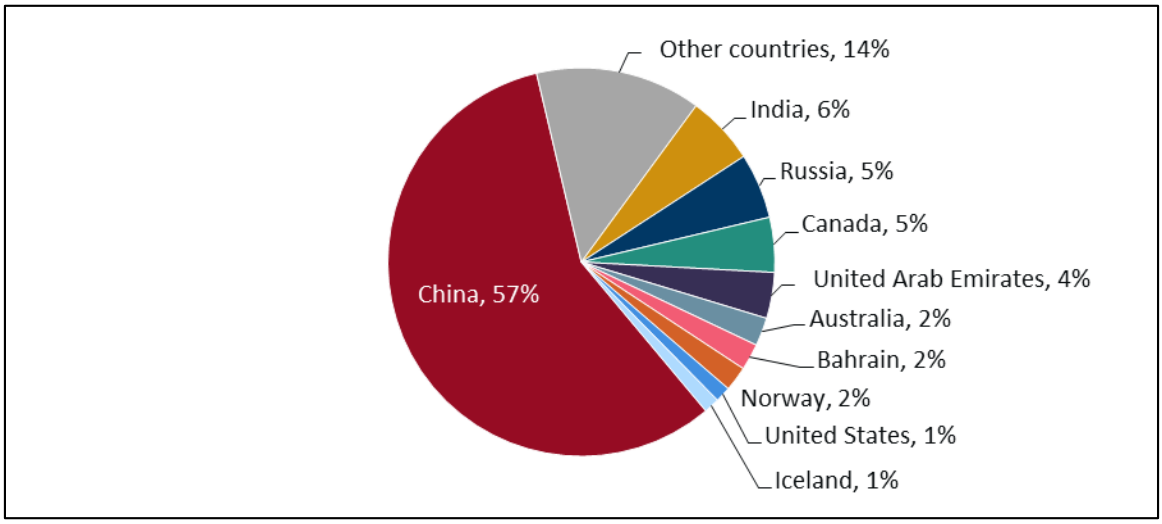
[44] Chad P. Bown, "Trump's steel and aluminum tariffs are cascading out of control," Peterson Institute for International Economics, February 4, 2020, at https://www.piie.com/blogs/trade-and-investment-policy-watch/trumps-steel-and-aluminum-tariffs-are-cascading-out-control.

[45] Adam S. Hersh and Robert E. Scott, "Aluminum producing and consuming industries have thrived under U.S. Section 232 import measures," Economic Policy Institute, May 25, 2021, at https://www.epi.org/publication/aluminum-producing-and-consuming-industries-have-thrived-under-u-s-section-232-import-measures/.

[46] Beer Institute, "New Research Shows the Tariffs on Aluminum Have Cost the U.S. Beverage Industry $1.4 Billion," press release, April 14, 2022, at https://www.beerinstitute.org/press-releases/new-research-shows-the-tariffs-on-aluminum-have-cost-the-u-s-beverage-industry-1-4-billion/.

Figure 6. Global Primary Aluminum Production, 2021

Top 10 producing countries



Source: USGS, "Aluminum Statistics and Information."

Note: USGS estimates that in 2021, global primary aluminum smelting capacity was 77 million metric tons.

The Organisation for Economic Co-operation and Development (OECD) estimates that primary smelting capacity in China amounted to roughly 48.7 million tons in 2018.[47] The OECD reports that excess capacity in the aluminum sector is hard to measure, as reliable capacity information may not be available for producers that are not publicly listed on stock exchanges. The Chinese government has acknowledged that its aluminum sector, which is in part state-owned, suffers from excess capacity and indicated as of 2019 that continued efforts to reduce inventory, cut overcapacity, and achieve a balance in supply and demand remain priorities.[48]

In addition, OECD economists found that subsidies and other market-distorting practices, particularly in China and the countries of the Gulf Cooperation Council (GCC), contribute to excess capacity and impact global competition in the aluminum sector.[49] The research looked at 17 of the industry's largest firms, representing more than half of global smelting capacity, which the OECD estimates received up to $70 billion in total government support between 2013 and 2017. Although all 17 firms received some form of support, five recipients, all Chinese, received 85% of all support. U.S.-based Alcoa was one of the 17 firms, having received approximately $1.5 billion in the form of nonfinancial support, chiefly through energy subsidies coming overwhelmingly from Canada and a GCC country (likely Saudi Arabia, where it has a joint venture).[50] A recent analysis by several international organizations, including the OECD, estimated that from 2014 to 2018, global aluminum firms benefited from subsidized intermediate

[47] Organisation for Economic Co-operation and Development (OECD), "Measuring distortions in international markets: the aluminium value chain," *OECD Trade Policy Papers*, no. 218, OECD Publishing, Paris, 2019, p. 53, at http://dx.doi.org/10.1787/c82911ab-en.

[48] Ibid., p. 51.

[49] The Gulf Cooperation Council includes Saudi Arabia, Kuwait, the United Arab Emirates, Qatar, Bahrain, and Oman. Ibid., pp. 6, 9.

[50] Ibid., pp. 13-14.

inputs, including energy, valued at $2.5 billion and from below-market borrowings of $8 billion per year.[51]

In April 2021, the Aluminum Association unveiled a policy document, *A Trade Policy Framework for the U.S. Aluminum Industry*. The framework expresses the association's view of global excess capacity as a significant challenge, urging the Biden Administration to engage in multilateral efforts to address market-distorting industrial policies with an emphasis on China.[52] Unlike the steel sector, no OECD or other multinational forum has been established exclusively to monitor global excess capacity in the aluminum sector.

Price Determination

Aluminum is a globally traded commodity, and its price is effectively determined by the price of futures contracts traded on the London Metal Exchange (LME). Regional and value-added premiums, such as the Midwest Premium, typically are added to LME prices to establish the base price of aluminum in the United States. This price is usually higher than the LME price, reflecting the cost of delivery to LME-approved warehouses in the United States, as well as U.S. demand conditions. Through the first half of 2022, for example, the average U.S. price for aluminum was $3,507 per metric ton, above the LME price, which averaged $2,789 per metric ton during the same period.[53] At that time, the LME price was at its highest level since 2008. According to S&P Global, aluminum prices were at record highs due to limited supply resulting from production curtailments, modification of Section 232 tariffs, demand growth in China, reduced Chinese exports of primary semi-finished aluminum, and economic sanctions on Russia.[54]

Reliance on LME price benchmarks has been blamed for unreasonably high U.S. aluminum prices. In 2014, the Senate Permanent Subcommittee on Investigations examined allegations that certain financial institutions, notably investment bank Goldman Sachs, had acquired LME-approved warehouses and used their control to delay delivery of metal to buyers, thereby creating artificial supply shortages that inflated aluminum prices.[55]

Between 2010 and 2014, the average queue time to receive aluminum from an LME-approved warehouse in the United States went from roughly 40 days to over 600 days; during the same period, the Midwest Premium rose from approximately $134 per metric ton of aluminum to slightly above $450 per metric ton.[56] The subcommittee's investigation found a broad consensus that the longer queue times had led to a wider gap between LME prices and U.S. prices, but there

[51] IMF et al., *Subsidies, Trade, and International Cooperation*, OECD Publishing, Paris, 2022, pp. 14-16, at https://doi.org/10.1787/a4f01ddb-en.

[52] The Aluminum Association, *A Trade Policy Framework for the U.S. Aluminum Industry*, at https://www.aluminum.org/sites/default/files/2021-10/TAA_Trade%20Framework-FINAL.pdf.

[53] USGS, *Mineral Industry Surveys*, "Aluminum Statistics and Information," Table 6, June 2022.

[54] S&P Global Commodity Insights, "Aluminum prices hit 13-year high on supply tightness, concerns," February 10, 2022, at https://www.spglobal.com/commodityinsights/en/market-insights/latest-news/metals/021022-feature-aluminum-prices-hit-13-year-high-on-supply-tightness-concerns.

[55] David Kocieniewski, "A Shuffle of Aluminum, but to Banks, Pure Gold," *New York Times*, July 20, 2013, at https://www.nytimes.com/2013/07/21/business/a-shuffle-of-aluminum-but-to-banks-pure-gold.html.

[56] U.S. Congress, Senate Committee on Homeland Security and Governmental Affairs, Permanent Subcommittee on Investigations, *Wall Street Bank Involvement with Physical Commodities*, 113th Cong., 2nd sess., November 21, 2014, pp. 173, 178-179.

was disagreement as to whether the longer queue times resulted in a higher absolute level of aluminum prices for U.S. buyers.[57]

Litigation over claims that financial firms violated antitrust laws by manipulating aluminum prices has persisted into this decade. In February 2021, a New York district court ruled in favor of defendants Goldman Sachs, JPMorgan Chase, and Glencore—stating that many aluminum purchasers bought aluminum overwhelmingly from smelters such as Alcoa and Rio Tinto rather than directly from the defendants; therefore the purchasers did not qualify as efficient enforcers of antitrust laws and lacked standing to sue.[58] Another case was decided in favor of Goldman Sachs and several others in June 2022 on similar grounds.[59]

National Security Concerns

As secondary aluminum is derived from recycled products or scrap, it often contains significant impurities. This makes it unsuitable for uses that require high and consistent quality. Manufacturers of components used in electronics and aerospace manufacturing often favor primary aluminum that meets specified purity standards. Many defense-related products must comply with particularly high purity standards. Specialty alloys and materials used in wrought aluminum products often have enhanced mechanical properties, such as heighted electrical conductivity and corrosion resistance, which are greatly preferred for aerospace and defense applications. However, military demand alone is insufficient to support domestic production of high-purity primary aluminum alloys. According to the Department of Defense (DOD), U.S. military requirements for aluminum represent approximately 3% of annual domestic production.[60]

The greatest aluminum-related security concern regarding defense requirements appears to be the availability of specific high-purity aluminum alloys, which can be derived from primary aluminum. The supply of high-purity aluminum is important to the production of high-performance aluminum alloys used in aerospace and defense products. In addition, aluminum alloys are one of several energetic materials used in missile and munition systems, according to DOD.[61]

One active U.S. smelter produces aluminum of sufficient purity for use in military aircraft, as well as in the lightweight armor plating found in many defense ground and weapon systems.[62] Century's Hawesville, KY (**Figure 3**), smelter produces primary aluminum with a purity of 99.9% compared with standard-purity aluminum of 99.7%. Standard ingots can undergo further

[57] Ibid., p. 180.

[58] In re Aluminum Warehousing Antitrust Litig., 520 F. Supp. 3d 455 (S.D.N.Y. 2021).

[59] Reynolds Consumer Prod. LLC v. Glencore AG, No. 16-cv-0595 (S.D.N.Y. June 3, 2022) (order granting joint stipulation of dismissal with prejudice).

[60] Letter from James N. Mattis, Secretary of Defense, to Wilbur L. Ross Jr., Secretary of Commerce, Memorandum for the Secretary of Commerce: Response to Steel and Aluminum Policy Recommendations, 2018, at https://www.commerce.gov/sites/default/files/department_of_defense_memo_response_to_steel_and_aluminum_policy_recommendations.pdf.

[61] Department of Defense, Assistant Secretary of Defense for Industrial Base Policy, *Industrial Capabilities Report to Congress, 2020 Annual Report*, January 2021, pp. 85-87, at https://media.defense.gov/2021/Jan/14/2002565311/-1/-1/0/FY20-INDUSTRIAL-CAPABILITIES-REPORT.PDF.

[62] Bureau of Industry and Security, *The Effect of Imports of Aluminum on the National Security*, 2018, p. 3; and Adam S. Hersh and Robert E. Scott, "Aluminum producing and consuming industries have thrived under U.S. Section 232 import measures," Economic Policy Institute, May 25, 2021, at https://www.epi.org/publication/aluminum-producing-and-consuming-industries-have-thrived-under-u-s-section-232-import-measures/.

electrolysis processing, known as the Hoopes process, to reach an "ultra" purity grade of up to 99.99%.[63] Century's Hawesville smelter produced 172,000 tons of primary aluminum in 2021,[64] with the large majority going to the commercial aerospace and electrical conductor markets. With respect to defense requirements, this smelter is a major supplier of high-purity aluminum to downstream producers, including Arconic, Constellium, and Kaiser. These firms use high-purity alloys and materials to produce aluminum products for an array of advanced aerospace and defense applications. In June 2022, Century announced that it would temporarily idle its high-purity smelter for up to a year due to rising energy prices.[65]

Downstream producer Arconic has the capability to produce high-purity aluminum from a standard ingot using a specific fractionalization crystallization process.[66] Canadian downstream producer Nature Alu manufactures aluminum ingots with an ultra-purity grade of 99.99% through a proprietary technology. The company states that it is the only North American manufacturer of high-purity aluminum that supplies the international market.[67] It is unclear whether the United States imports materials from this firm for use in military applications.

The Department of Homeland Security has designated 16 critical infrastructure sectors in the United States. One of these, "critical manufacturing," encompasses domestic production of primary metals, including aluminum, among other materials.[68] The Trump Administration's Section 232 aluminum report asserted that nearly all of the designated critical infrastructure sectors rely on aluminum products to accomplish their principal missions.[69] Separately, the aluminum industry's broadest trade group has pushed for the designation of the aluminum industry as an "essential industry" to allow continuation of operations in the event of a federal emergency, such as was declared during the COVID-19 pandemic.[70]

Decarbonizing Aluminum Manufacturing

The aluminum sector contributes approximately 2% to global GHGs, equivalent to roughly 1.1 billion tons of carbon dioxide.[71] As global demand for aluminum is expected to increase up to 80% by 2050, the aluminum industry is facing pressure to develop low-carbon or carbon-neutral manufacturing processes.[72] Aluminum producers, like firms in other industries, face increasing

[63] Danilo C. Curtolo et al., "High- and Ultra-High-Purity Aluminum, a Review on Technical Production Methodologies," *Metals*, vol. 11, no. 1407 (September 6, 2021), p. 4, at https://www.mdpi.com/2075-4701/11/9/1407/htm.

[64] Century Aluminum Company, Form 10-K for the year ending December 31, 2021, p. 3.

[65] Century Aluminum, "Century Aluminum to Temporarily Idle Its Hawesville Smelter Due to Soaring Energy Prices; Issues WARN Notice to Employees," press release, June 22, 2022, at https://centuryaluminum.com/investors/press-releases/press-release-details/2022/Century-Aluminum-to-Temporarily-Idle-Its-Hawesville-Smelter-Due-to-Soaring-Energy-Prices-Issues-WARN-Notice-to-Employees/default.aspx.

[66] Bureau of Industry and Security, *The Effect of Imports of Aluminum on the National Security*, 2018, p. 30.

[67] See Nature Alu website, at https://www.naturealu.com/index.

[68] Department of Homeland Security, Cybersecurity & Infrastructure Security Agency, "Critical Manufacturing Sector," at https://www.cisa.gov/critical-manufacturing-sector.

[69] Bureau of Industry and Security, *The Effect of Imports of Aluminum on the National Security*, 2018, p. 36.

[70] GlobalNewsWire, "American Aluminum an Essential Industry in a Moment of National Emergency," press release, March 19, 2020, at https://www.globenewswire.com/news-release/2020/03/19/2003425/0/en/American-Aluminum-an-Essential-Industry-in-a-Moment-of-National-Emergency.html.

[71] International Aluminium Institute, *Aluminium Sector Greenhouse Gas Pathways to 2050*, September 2021, at https://international-aluminium.org/resource/aluminium-sector-greenhouse-gas-pathways-to-2050-2021/.

[72] International Aluminium Institute, IAI releases aluminium sector's decarbonisation dataset in line with the

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 producers with comparatively high emissions—namely primary aluminum smelters—at a competitive disadvantage.[73]

Primary aluminum smelting generates direct emissions from the electrolysis of alumina using a carbon anode during smelting and from fuel combustion to produce heat and steam used in casting and fabrication. Direct emissions account for roughly 30% of total emissions from aluminum manufacturing.[74] More than 60% of indirect GHG emissions related to aluminum manufacturing come from the generation of electricity used to refine bauxite ore into alumina and to smelt the alumina into aluminum.[75] The emissions attributable to a particular producer may depend heavily on the power source.

About 90% of Canadian aluminum is produced from hydroelectric power in Quebec,[76] resulting in comparatively low GHG emissions per metric ton, whereas China, which relies predominantly on coal-fired electric generating plants, has much higher emissions per metric ton.[77] The United States stands in the middle in terms of sectoral GHG emissions per ton.[78] Secondary aluminum's rising share of total domestic supply is chiefly responsible for the U.S. decline in average emissions per ton. U.S. producers have also introduced process and technology improvements in aluminum smelting. The Aluminum Association asserts that the domestic industry reduced its GHG emissions by 59% between 2005 and 2018.[79] However, annual domestic production of primary aluminum fell sharply during this period, from 2.48 million metric tons in 2005 to 897,000 metric tons in 2018, a decline of 64%. Given that over 90% of emissions from aluminum manufacturing comes from primary smelting,[80] reduced primary smelting activity is likely to have been a major cause of decline in the sector's emissions. Secondary aluminum uses just 5% of the energy required for primary production,[81] so to the extent that greater availability of secondary aluminum reduces demand for primary aluminum, the industry's emissions per metric ton could be expected to fall, even in the absence of changes to production methods.

International Energy Agency's Beyond 2 Degrees findings, September 9, 2021, at https://international-aluminium.org/iai-releases-aluminium-sectors-decarbonisation-dataset-in-line-with-the-international-energy-agencys-beyond-2-degrees-findings/.

[73] Primary aluminum smelting is also a major source of global perfluorocarbon (PFC) emissions, a highly potent greenhouse gas.

[74] Mission Possible Partnership, *Closing the Gap for Aluminium Emissions: Technologies to Accelerate Deep Decarbonization of Direct Emissions*, December 2021, pp. 5-6, at https://missionpossiblepartnership.org/wp-content/uploads/2021/12/Closing-the-Gap-for-Aluminium-Emissions.pdf.

[75] International Aluminium Institute, *Aluminium Sector Greenhouse Gas Pathways to 2050*, September 2021, at https://international-aluminium.org/resource/aluminium-sector-greenhouse-gas-pathways-to-2050-2021/.

[76] Investissement Québec, *The Greenest Aluminum in the World*, accessed July 20, 2022, at https://www.investquebec.com/international/en/industries/aluminum/the-greenest-aluminum-in-the-world.html.

[77] Ali Hasanbeigi et al., *Aluminum Climate Impact: An International Benchmarking of Energy and CO2 Intensities*, Global Efficiency Intelligence, February 2022, pp. 3, 16, and 19 at https://static1.squarespace.com/static/5877e86f9de4bb8bce72105c/t/624d11ab5a37a4341fd85a6e/1649217981897/Aluminum+benchmarking+report-+Feb2022+rev2.pdf.

[78] Ibid., pp. 3, 15.

[79] The Aluminum Association, *Aluminum Sector Snapshot: Environmental Reporting*, April 2021, pp. 1, 5, at https://www.aluminum.org/sites/default/files/2021-10/Aluminum%20Association_Smart%20Sector%20Report.pdf.

[80] IEA, *Aluminium*, Paris, 2022, at https://www.iea.org/reports/aluminium.

[81] World Economic Forum, *The answer to the aluminium industry's emissions issue? Aluminium's infinite recyclability*, December 9, 2021, at https://www.weforum.org/agenda/2021/12/aluminium-emissions-recycling-circular-economy/.

Challenges of Decarbonizing

A transition to carbon-neutral aluminum is likely to require significant capital investment in decarbonizing the electrical grid and in specific technologies used in smelting and recycling. A recent study from Mission Possible Partnership, working in collaboration with the International Aluminium Institute,[82] estimates that approximately $1 trillion in investment is needed for the transition to a low-carbon upstream aluminum sector, with the majority of investment used to decarbonize electricity supplies.[83] This figure does not include the cost of decarbonizing other aspects of aluminum production. A study from the World Economic Forum estimates that low-emission aluminum is expected to be available as early as 2030 and may command a premium of up to 40%.[84]

Decarbonizing the domestic aluminum industry is likely to require changes in the U.S. energy grid.[85] At present, electricity is largely derived from nonrenewable energy sources. In 2021, 20.1% of electricity generated in the United States came from renewable sources,[86] and much of this generation is distant from smelting facilities.

In addition to decarbonizing the electricity sector, many technologies under development seek to address direct emissions in aluminum manufacturing, specifically targeting aluminum smelting and thermal energy and fuels used in casting and fabrication.

- **Inert Anodes.** This technology could be used as an alternative to carbon anodes, which are consumed in electrolysis during smelting—the most carbon-intensive process in aluminum manufacturing. Most research, at present, is focused on identifying the optimal anode material. Current materials being explored include ceramics, metal alloys, and sintered cermet, a ceramic-metal composite. Currently, the large majority of primary smelters use carbon anodes, which enable the process of electrolysis, with the combustion of these anodes emitting large quantities of carbon dioxide. In contrast, inert anodes have little to no direct GHG emissions.[87] ELYSIS, a joint venture between Alcoa, Rio Tinto, and Apple, seeks to create inert anodes that would eliminate GHG emissions from aluminum smelting, yielding carbon-free aluminum. The companies aim to demonstrate the viability of the technology in 2023, make it commercially available by 2024, and produce larger volumes of carbon-free aluminum approximately two years later.[88]

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[82] Aluminum is the preferred spelling in the United States; aluminium is the preferred spelling in the United Kingdom and many other English-speaking nations.

[83] Mission Possible Partnership, *Making Net-Zero Aluminium Possible*, September 2022, p. 52, at https://missionpossiblepartnership.org/wp-content/uploads/2022/10/Making-1.5-Aligned-Aluminium-possible.pdf.

[84] World Economic Forum, *The Net-Zero Industry Tracker: Aluminium Industry*, July 28, 2022, at https://www.weforum.org/reports/the-net-zero-industry-tracker/in-full/aluminium-industry/.

[85] William Alan Reinsch and Emily Benson, *Decarbonizing Aluminum: Rolling Out a More Sustainable Sector*, Center for Strategic and International Studies, February 25, 2022, at https://www.csis.org/analysis/decarbonizing-aluminum-rolling-out-more-sustainable-sector.

[86] U.S. Energy Information Administration, *What is U.S. electricity generation by energy source?*, March 4, 2022, at https://www.eia.gov/tools/faqs/faq.php?id=427&t=3.

[87] Mission Possible Partnership, *Closing the Gap for Aluminium Emissions: Technologies to Accelerate Deep Decarbonization of Direct Emissions*, December 2021, p. 6, at https://missionpossiblepartnership.org/wp-content/uploads/2021/12/Closing-the-Gap-for-Aluminium-Emissions.pdf.

[88] Alcoa, "Carbon free aluminium smelting a step closer: ELYSIS advances commercial demonstration and operates at industrial scale," press release, November 4, 2021, at https://www.alcoa.com/global/en/stories/releases?id=2021/11/carbon-free-aluminium-smelting-a-step-closer-elysis-advances-commercial-demonstration-and-operates-at-industrial-

- **Carbon Capture, Utilization, and Storage (CCUS).**[89] CCUS units could be installed or retrofitted at smelting facilities to capture direct emissions resulting from industrial processes. The gases then may be stored underground or used to produce chemicals, such as methanol. In the aluminum industry, CCUS could be the most viable midterm solution for smelting facilities that use fossil fuels.[90]
- **Hydrogen.** Hydrogen could be used to produce high-temperature heat to power secondary smelters but also could be used in alumina refining. There are three primary methods used to generate hydrogen: (1) *gray hydrogen*, produced using fossil fuels by splitting natural gas into hydrogen and carbon dioxide; (2) *blue hydrogen*, produced using the same process as gray hydrogen with the use of CCUS to capture roughly 90% of emissions;[91] and (3) *green hydrogen*, produced via electrolyzers from electricity generated from renewable energy sources.
- **Mechanical Vapor Recompression (MVR).** MVR—piloted by Alcoa with financial support from the Australian government—recovers waste heat from steam that would otherwise be discharged during alumina refining. The steam is captured and redirected to a compressor that raises its pressure and temperature so the steam may be reused. Alcoa is evaluating MVR powered by renewable energy and states that the technology could reduce carbon emissions from the alumina refining process by up to 70%.[92]

Another step in encouraging sustainability in the aluminum industry is to deploy better recycling technology to improve the quality of secondary aluminum. Sorting technologies, such as manual eddy current separators, make it possible to sort recycling inputs by material type. A more recent technological development in recycling involves X-ray transmission technology, which uses sensors that determine differences in quality and material density and sorts metal products, including aluminum, accordingly.[93] After scrap has been sorted, it is usually sent to secondary smelters where it is processed into molten aluminum. More precise sorting enables secondary smelters to produce higher quality aluminum and wrought alloys. As domestic aluminum capacity shifts from primary to secondary smelting, developing and refining methodologies to increase the usability of the declining supply of quality scrap become more important.

Considerations for Congress

U.S. primary smelters seem likely to face greater headwinds due to a slowing economy and rising energy costs, which have led to recent production curtailments and idling of capacity. The large

scale.

[89] For a discussion of the technology and policy considerations regarding carbon capture, utilization, and storage (CCUS), see CRS Report R44902, *Carbon Capture and Sequestration (CCS) in the United States*, by Angela C. Jones and Ashley J. Lawson.

[90] World Economic Forum and Accenture, *Aluminium for Climate: Exploring pathways to decarbonize the aluminium industry*, November 2020, p. 15, at https://www3.weforum.org/docs/WEF_Aluminium_for_Climate_2020.pdf.

[91] Michael Liebreich, *Liebreich: Separating Hype from Hydrogen – Part One: The Supply Side*, BloombergNEF, October 8, 2020, at https://about.bnef.com/blog/liebreich-separating-hype-from-hydrogen-part-one-the-supply-side/.

[92] Australian Renewable Energy Agency, *Mechanical Vapour Recompression for Low Carbon Alumina Refining*, October 26, 2021, at https://arena.gov.au/projects/mechanical-vapour-recompression-for-low-carbon-alumina-refining/.; and Alcoa, "Alcoa explores technology to reduce carbon emissions," press release, May 20, 2021, at https://www.alcoa.com/global/en/what-we-do/alumina/stories/releases?id=2021/05/alcoa-explores-technology-to-reduce-carbon-emissions.

[93] "Sorting technology can turn aluminum green," *recycling today*, September 14, 2021, at https://www.recyclingtoday.com/article/steinert-hoffmann-aluminum-sorting-technology-recycling/.

amount of unused capacity in the upstream sector has been and remains an issue for domestic smelters. The adverse impact of global excess capacity on the domestic industry also remains a challenge. Secondary and downstream aluminum producers, however, may experience improved commercial success over the next few years, as demand is expected to expand over the decade, domestic prices have registered record highs, and continued measures limiting imports remain in effect.

Decarbonizing the aluminum sector presents obstacles for domestic producers (see the "Challenges of Decarbonizing" section). The majority of the investment in decarbonization is likely to focus on improvements in the energy grid to decarbonize electricity supply; additional investment is likely to be made in reducing carbon emissions in aluminum production.

P.L. 117-169 (commonly referred to as the Inflation Reduction Act of 2022), signed into law on August 16, 2022, established the Advanced Industrial Facilities Deployment Program (§50161) at the Department of Energy. This program seeks to provide federal financial assistance to a variety of manufacturing industries, including aluminum, that introduce advanced technologies in production processes that effectively reduce GHG emissions. The Department of Energy is to administer this program and award approximately $5.8 billion in financial assistance through September 2026. Eligible production facilities would carry out projects for "(1) the purchase and installation, or implementation, of advanced industrial technology; (2) retrofits, upgrades to, or operational improvements at an eligible facility to install or implement advanced industrial technology; or (3) engineering studies and other work needed to prepare an eligible facility for activities."[94] The Secretary of Energy may provide financial assistance of up to 50% of the cost of a project carried out by an eligible production facility. In addition, the Secretary may give priority consideration of financial assistance to projects that demonstrate "(1) the expected GHG emission reductions to be achieved by carrying out the project; (2) the extent to which the project would provide the greatest benefit for the greatest number of people within the area in which the eligible facility is located; and (3) whether the eligible entity participates or would participate in a partnership with purchasers of the output of the eligible facility."[95]

The Trade Security Act of 2021 (S. 746), introduced by Senator Rob Portman, would amend Section 232 of the Trade Expansion Act of 1962 and require the Secretary of Defense to initiate investigations regarding whether certain U.S. imports present a national security threat. In addition, it would allow Congress to block a presidential import adjustment through a joint resolution. Under current law, the Department of Commerce is charged with conducting Section 232 investigations and is required to consult with DOD concerning imports under investigation.

Prior Congresses have considered legislation to address concerns that inadequate domestic production of primary aluminum could pose a risk in a national security crisis. Section 852 of the FY2021 National Defense Authorization Act (FY2021 NDAA; P.L. 116-283) required the Secretary of Defense to submit a report to Congress by March 1, 2022, on how the Defense Production Act (DPA; 50 U.S.C. §4501 et seq.) could be used to increase domestic aluminum refining, processing, and manufacturing. It is unclear whether this report was submitted to Congress and/or if it has been declassified for public viewing. Considering the deep integration of the U.S. and Canadian aluminum industries, if the DPA were to be used, it may treat primary aluminum produced by Canadian smelters as domestic content.[96]

[94] Inflation Reduction Act of 2022 (P.L. 117-169, §50161).

[95] Ibid.

[96] 50 U.S.C. §4552 (7).

Section 829 of the House-passed version of the FY2021 NDAA sought to add aluminum and aluminum alloys to DOD's specialty metals provision (10 U.S.C. §4863) and apply a domestic sourcing mandate to DOD and the Department of Transportation. Section 829 was not included in the FY2021 NDAA.

Author Information

Christopher D. Watson
Analyst in Industrial Organization and Business

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