Aluminum, Revitalized

Strengthening the Backbone of our Clean Economy

BLUEGREEN ALLIANCE

Contents

Lead Author

Ariel Pinchot

Supporting Authors

Ben Beachy and Charlie Martin

Contributors

Charlotte Brody (Appendix B), El'gin Avila (Appendix B), Joe Kendrick (analysis), and Roxanne Johnson (outline and research plan)

Acknowledgements

Special thanks to Jasmine Mossbarger, Eric Steen, and Mikayla Brunner at the BlueGreen Alliance for their assistance with editing and production, and to the BlueGreen Alliance's partners for their valuable guidance, review, and support.

BLUEGREEN ALLIANCE

Executive Summary

As one of the most important metals for modern life, aluminum is all around us. From our bridges and high-rise buildings to our smartphones and kitchen appliances, this highly durable, lightweight, and conductive material is essential. It's also a key ingredient for achieving our climate, jobs, and national security goals. As a primary component of solar panels, power lines, electric vehicles (EVs), and other clean technologies, aluminum is a building block of our clean energy solutions.[1] At the same time, producing aluminum requires a tremendous amount of energy, and globally, the sector is a significant contributor to greenhouse gas (GHG) emissions. As the world produces increasing amounts of this material for the clean energy economy, we must simultaneously decrease the emissions from its production in order to achieve global climate targets.

In the United States, our growing need for aluminum already far surpasses the dwindling output from our domestic primary production. As a result, much of the aluminum we use comes from abroad, including from countries where aluminum production is much more emissions-intensive. Increasing our aluminum procurements from highly-polluting overseas producers will only push our climate justice goals further out of reach. What we need to advance these goals is a secure, domestically produced supply of clean aluminum made with high-road labor standards.

Revitalizing clean aluminum manufacturing in the U.S. will not only cut a major source of climate pollution, reduce worker and fenceline community exposure to airborne pollutants, and secure a reliable supply of an essential material for clean energy—it will also create good jobs for hard-hit workers and communities, while supporting the current workforce and retaining existing jobs. This report lays out a set of targeted recommendations for getting there. After assessing the state of the domestic industry, we outline the employment, climate, and community benefits of revitalizing clean aluminum manufacturing and present a set of policy solutions that can help create and sustain a strong, clean aluminum industry.

State of the Industry

Up until the turn of the century, the U.S. was the world's leading aluminum producer. The industry had long provided the country with a stable supply of aluminum and good jobs. But decades of decline have left the industry in tatters. With the closure of nearly 20 smelters, production has dropped by over 80% since its peak in the 1980s.[2] As the industry languished, tens of thousands of aluminum workers have lost their jobs.[3] These losses have been particularly hard since aluminum manufacturing jobs tend to offer better wages, benefits, and access to unions than other available jobs,[4] especially for workers without a college degree.[5] As displaced aluminum workers lost their high wage jobs, their communities have had to grapple with the economic fallout of shuttered smelters. These forces, as seen within the broader manufacturing sector, have contributed to increased inequality, especially along racial lines.[6]

But job losses and increased inequality have not been the only consequence of the industry's decline. The U.S. aluminum industry's deterioration has also led to increased climate pollution. As companies closed U.S. smelters and domestic output diminished, the world's aluminum started to come from countries with lower environmental and labor standards and higher emissions. China and India, in particular, began to ramp up production.[7] Both countries produce aluminum with substantially higher emissions than the U.S. China's aluminum production is about 65% more emissions-intensive than ours and India's aluminum is made with double the emissions compared to U.S. aluminum.[8] As a result of these trends, about two-thirds of the world's aluminum is now made in countries with more emissions-intensive production than in the U.S.[9] Building up clean aluminum manufacturing in the U.S. will ensure that our growing use of aluminum in clean technology won't drive pollution overseas.

A Clean Aluminum Future

A revitalized U.S. aluminum sector has the potential to provide family-sustaining union jobs for tens of thousands of workers and hard-hit communities; support fenceline communities' fight for clean air and water; offer a reliable supply of a critical material for clean energy and national defense; and serve as a pivotal first mover in our efforts to slash industrial climate pollution.

Notable benefits of a revitalized aluminum sector may include the:

- Increase in the share of U.S. aluminum demand for critical clean energy and national defense purposes that's met via domestic supplies;
- Creation of new—and retention of existing—union jobs in the domestic aluminum industry;
- Increase in the average wage in the domestic aluminum industry;
- Economic benefits from increased aluminum production shared with impacted communities, including environmental justice, deindustrialized, and low-income communities and communities of color;
- Reductions in GHG emissions and toxic pollution from domestic aluminum facilities, relative to the current baseline; and
- Improved ranking of the U.S. versus other major aluminum producers in the carbon and pollution intensity of aluminum production.

Federal Policy Recommendations

The federal government has an array of tools to help advance a thriving U.S. aluminum industry. These include national security measures; federal procurement policies; programs for investing in industrial efficiency, emissions reductions, and clean manufacturing; authority over federally supported electricity generation; and trade policy. These policy recommendations lay out a set of three tools the federal government can deploy to help build and sustain clean aluminum manufacturing.

1. **Procurement—Buy America(n):** To revitalize U.S. aluminum manufacturing, part of the solution is to catalyze a large domestic market for clean U.S. aluminum. Buy America, Buy American, and related domestic content rules offer policy tools to do just that.

   For example, the Inflation Reduction Act, signed into law in 2022, includes domestic content provisions that could help compel private developers and manufacturers of solar, wind, transmission, and electric vehicle components to purchase U.S.-made aluminum. The law offers solar and wind developers a 10% bonus tax credit if a little over half of their parts and materials are U.S. made.[10] Given that aluminum is a primary ingredient in solar panels and other clean energy technologies, this policy creates a strong incentive for clean energy firms to buy domestic aluminum.

2. **Investment—Loan, grant, and tax credit programs and use of national defense policies:** The federal government should directly invest in clean aluminum production. It can do so by extending a mix of tax credits, loans, and grants to aluminum manufacturers to ramp up their capacity while cutting emissions.

   For example, The Inflation Reduction Act includes more than $50 billion for new grants, loans, and tax credits to support clean manufacturing. Some of this financing could help existing U.S. aluminum smelters become even cleaner and more globally competitive by boosting efficiency and slashing pollution. New investments also could help to reopen recently closed smelters by cutting production costs and offering an affordable supply of clean electricity.

   Specific Inflation Reduction Act investments that could help revitalize clean aluminum manufacturing include:

   - A new manufacturing production tax credit (45X) worth over $30 billion to support expanded manufacturing of solar and wind components, batteries, and critical materials like high-purity aluminum;
   - An expanded tax credit (48C), worth $10 billion, that is now available for manufacturers to install technology that achieves an at least 20% reduction in climate pollution; and
   - New grants and loans worth $5.8 billion for energy-intensive industrial facilities, including aluminum manufacturers, to adopt transformative, first-at-scale technologies with the potential for deep emissions cuts and sector-wide adoption.[11]

In addition to these Inflation Reduction Act investments, the Biden administration should also consider taking executive action under national defense policies such as the Defense Production Act and National Defense Stockpile to support clean aluminum manufacturing.[12]

3. **Trade—A trade mechanism on climate-polluting aluminum imports:** Smart trade policy can support growth in clean U.S. aluminum manufacturing by helping to reverse outsourcing to emissions-intensive countries and shift U.S. demand toward cleaner aluminum production. For example, a well-designed border fee on highly climate-polluting imports—frequently called a Carbon Border Adjustment Mechanism (CBAM)—could serve each of these ends while also supporting good aluminum manufacturing jobs and helping to curb aluminum emissions beyond our borders.

I. Introduction

In the 1990s, 23 primary aluminum smelters provided a stable supply of aluminum and good jobs in the United States. Today, just five of these smelters remain in operation, with a sixth in idle since June of 2022. As plant after plant closed, communities across the country have been devastated by the loss of jobs, while the production of an already emissions-intensive product is increasingly outsourced to countries with even lower environmental standards. As a result, the U.S. has become highly dependent on foreign supply chains for a material that is not only foundational to modern society, but a critical component for a myriad of national defense applications and a host of clean energy goods.

These trends mirror a broader decline in domestic manufacturing, which has had a profoundly negative impact on workers, communities, and the economy at large. Between 1998 and 2021, the U.S. lost over 5 million manufacturing jobs due to the growing trade deficit with China, Japan, Mexico, the European Union, and other countries.[13] Many workers were forced to turn to lower paying jobs in other sectors, exerting downward pressure on wages; while others were victims of the sharp rise in unemployment. The collective result has been growing inequality—between the late 1980s and 2000s, nearly a quarter of the employment inequality in the U.S. can be attributed to the loss of manufacturing jobs.[14] The impact has been particularly hard for Black workers and other workers of color, who have faced disproportionately high rates of job loss in manufacturing.[15] Existing racial injustices—such as limited access to better paying jobs due to discrimination and longstanding racial wealth and income gaps—has also meant these workers often face more difficulty weathering prolonged economic distress from the loss of income, further exacerbating inequities.[16]

At the same time, the outsourcing of manufacturing has also contributed to a global increase in industrial emissions. The U.S. is now the world's largest importer of embodied carbon emissions (the sum of all of the carbon emissions resulting from the manufacturing of a product or material), with levels twice as high as any other country.[17] As global emissions continue to push atmospheric temperatures upwards, climate change is becoming another driving force of inequality, with negative impacts disproportionately falling onto already vulnerable populations.

For many U.S. workers and families, basic needs like economic security and environmental stability are becoming increasingly out of reach. In the face of these urgent challenges, it is clear that the U.S. economy needs reimagining. We need a more equitable, climate resilient, and prosperous economy—one that values its workers, families, and communities.

A key to building this new economy will be the modernization and transformation of our industrial base. While U.S. manufacturing has declined in recent decades, it remains a key pillar of the U.S. economy. The sector has long been a source of high-wage jobs at various skill levels and a pathway into the middle class for millions of workers and families, including those without a college degree. The growth of the clean economy presents a tremendous opportunity to revitalize domestic manufacturing. Aluminum, steel, and other energy-intensive materials are major components of clean energy technologies, from solar panels to offshore wind turbines to EVs. Business-as-usual production of these energy-intensive materials would conflict with our climate and environmental justice goals. To seize the economic and environmental benefits of the growing clean economy, we must transform industrial production by both expanding clean technology manufacturing and cutting industrial emissions.

A modernized industrial base will help us address the climate emergency head on, while supporting cleaner air and spurring the creation of a new generation of good, safe jobs manufacturing clean technologies and products. The many benefits to workers, communities, and the economy include:

- ***Linking good, union jobs with climate action:*** Manufacturing jobs tend to have higher pay and stronger union density than other available jobs. Revitalizing the sector to meet the growing demands for clean energy goods and materials will support existing jobs and bring back good paying jobs to communities devastated by the decades-long decline in manufacturing. This will help workers and communities to reap the economic benefits of clean energy growth, expanding public support for climate action.

- ***Reducing economic and racial inequities:*** The decline in U.S. manufacturing has been a significant driver of growing economic inequality in recent decades.[18] The impact has been particularly hard for Black and other workers of color, who have experienced disproportionate job losses and pay cuts.[19] Reshoring manufacturing can help reverse these trends. It can bring dynamic industries back to communities that have been left behind by deindustrialization and under-investment and provide improved wages, benefits, workers' rights, and a step towards a more equitable economy.

- ***Advancing climate goals, reducing pollution:*** The United States has the capacity to produce energy-intensive materials like aluminum, steel, and cement more efficiently and with less pollution than many other countries. Despite this, the outsourcing of emissions-intensive manufacturing to countries with lower environmental and labor standards has exacerbated global industrial emissions while making the U.S. the world's largest importer of embodied carbon emissions.[20] Proactive investment, procurement, and trade policies can help to reshore U.S. manufacturing of essential materials while making domestic production processes even cleaner. This will help to cut industrial climate pollution at home and abroad, support cleaner air for fenceline communities, boost the competitiveness of domestic businesses, and retain and create good jobs in clean manufacturing.

- ***Facilitating economic and supply chain stability:*** As recent supply chain disruptions have revealed, our over-reliance on imports for essential products and materials has left the U.S. highly vulnerable to global demand shocks, supply shortages, and shipping bottlenecks. Shoring up domestic manufacturing for clean energy goods and essential materials would create stronger, more resilient supply chains. Doing so would support energy security, national security, and good-paying, union jobs. It would also help facilities keep prices in check. Reliance on a few foreign suppliers for clean energy goods brings the risk of monopoly pricing power. The growth of domestic manufacturing hubs for clean technologies and essential materials would foster competition and innovation that would help keep prices low over the long term.

Growth in clean aluminum manufacturing offers a win-win solution for our climate, jobs, and justice goals.

As the global demand for aluminum, and for low-carbon aluminum specifically, continues to climb, the U.S. has the opportunity to reverse the decline in domestic aluminum production and play a leading role in supplying clean aluminum. A revitalized U.S. aluminum sector has the potential to provide family-sustaining union jobs for tens of thousands of workers and hard-hit communities, support fenceline communities' fight for clean air and water, offer a reliable supply of a critical material for clean energy and national defense, and serve as a pivotal first mover in our efforts to slash industrial climate pollution. This report shows the potential employment, climate, and community benefits of a revitalized aluminum industry. Moreover, success in the aluminum industry can build support for similar action in other industries, spurring a race to the top.

Even with the benefits of revitalization, the aluminum industry faces steep hurdles. We need the right economic and policy incentives to succeed. The federal government has an array of tools to help advance a thriving U.S. aluminum industry. These include national security measures; federal procurement policies; programs for investing in industrial efficiency, emissions reductions, and clean manufacturing; authority over federally supported electricity generation; and trade policy. The policy recommendations presented in this report further outline how the federal government can use these tools to help create and sustain a stronger and cleaner aluminum industry.

Why Aluminum Matters

Aluminum, the second most used metal in the world, is a fundamental material for the U.S. economy.[21] Its unique combination of mechanical and physical properties gives the material tremendous versatility with applications spanning nearly all economic segments, from transportation, construction, and electrical transmission, to packaging and consumer durables. Its broad utility is further enhanced by its sustainability benefits. Not only is aluminum nearly infinitely recyclable, but it is an essential material for numerous goods for the clean energy economy.

Among its use in renewable energy components, it is particularly important for solar photovoltaic (PV) technologies, where it is used both for frames and panels. More than 85% of the mineral content in most solar PV components, for example, is aluminum.[22] And solar energy requires about 12.9 tons of aluminum per megawatt of installed capacity (which is about 25 times more aluminum than what's needed for coal-based energy).[23] Apart from solar, aluminum is also used in wind energy, hydroelectricity, and battery storage, meaning we will need a lot more of it to build out the clean energy supply.[24] But we'll also need more of it to distribute this energy. Despite its lower conductivity than copper, aluminum's lighter weight makes it ideal for main overhead power lines. It's now the most widely used material for electricity transmission and distribution.[25] Accommodating additional capacity from on-grid renewable electricity will require expanding and upgrading existing transmission lines, further adding to our aluminum demands.

Aluminum is also central to electrifying our ground transportation. Its low weight and high strength make it a favored material for EVs, where it's used for a range of parts from engine and battery housing to structural components.[26] A typical EV battery, for example, is between 19% to 32% aluminum by weight.[27] Across the entire vehicle, EVs use about 130-180 pounds more aluminum than vehicles with internal combustion engines (ICE).[28] With the growth of the EV market and tightening of restrictions on global emissions, aluminum use in the transportation sector will continue to grow.[29]

Distinguishing Primary and Secondary Production

Primary aluminum is virgin aluminum produced from raw materials whereas secondary aluminum is produced from recycled scrap.

In primary production, bauxite ore is chemically processed to produce aluminum oxide (alumina). The alumina is then transformed into pure aluminum through electrolytic smelting (electrolysis), known as the Hall–Héroult process. This process consumes enormous amounts of electricity and is the main driver of the high sectoral emissions.

In secondary production, scrap aluminum is cleaned, sorted, and melted in a furnace to create molten aluminum for further processing. Because aluminum recycling does not involve the highly electricity intensive process of electrolysis, energy consumption is a fraction (about 6%) of what is needed for primary production.

Given the lower energy needs of secondary production, expanding recycling can play an important role in reining in sectoral emissions. But given that the world's large and growing aluminum demand exceeds scrap availability, even if secondary production is maximized, primary production will continue to grow to meet global demand. Transforming primary production will therefore be critical to reducing aluminum emissions.

While this paper covers both primary and secondary production, the policy recommendations focus on primary aluminum production given the substantially higher emissions reduction potential of that segment.

For further description of the aluminum production process, energy use, and emissions, refer to Appendix A.

Sources: Aluminum Association; US Department of Energy (DOE)

In addition to its importance for the clean economy and the manufacturing base, the aluminum industry has long been a source of good paying, family supporting jobs. In 2021, workers in the aluminum sector earned an average annual wage of $55,790.[30] This is substantially higher than average wages in retail trades, $37,590, and accommodations and food services, $30,850.[31] The sector, like other manufacturing jobs, also provides an important pathway to the middle class as the jobs are accessible to workers without a college degree. For example, between 2017 and 2022, over 80% of aluminum sector workers did not have a bachelor's degree, compared to 62% of the broader workforce.[32] The sector also enjoys a strong union presence. In 2021, about 20% of the workforce was unionized, relative to 8.5% of workers across all durable goods manufacturing.[33]

Despite its many benefits, the domestic aluminum industry faces tremendous challenges. To begin, primary production has suffered a prolonged period of decline, falling by 74% from 1995 to 2021.[34] Like other manufacturing sectors, the industry has lost out to global competitors, like China. This has cost thousands of good-paying jobs in the industrial heartland.[35] The decline also endangers national security, as only one of the remaining domestic facilities produces high-purity aluminum necessary for defense applications used by the U.S. armed forces. With the temporary idling of this facility in June,[36] the U.S. is now entirely dependent on foreign suppliers for high purity aluminum (which includes China, Russia, and the United Arab Emirates).[37] While the curtailment is temporary, permanent closure is a serious risk without policy interventions or other improvements.

The other challenge is the high emissions intensity of aluminum production. Globally, the aluminum industry accounts for about 2% of total GHG emissions caused by human activity, the bulk of which are generated from primary production (discussed in greater detail in Appendix A).[38] It also generates other hazardous pollutants that carry health risks for workers and fenceline communities (further described in Appendix B). Achieving global climate goals will require significant cuts in these emissions. What's more, these emissions reductions must occur all while production is increasing to meet growing global demand. With business-as-usual production, supplying the global demand for aluminum would lead to a 45% increase in annual sectoral emissions by 2050, (reaching 1.6 Gt CO_2e from a 2018 baseline of 1.1 Gt CO_2e).[39] This greatly exceeds the sectoral carbon budget to meet the climate goals outlined in the Paris Agreement. Maintaining temperature increases to the midpoint of the range in the Paris Agreement goals would require total sectoral emissions to drop to 250 megatonnes (Mt) CO_2e by 2050.[40] That's a 77% reduction from the 2018 baseline, which needs to occur while production increases by up to 80%.[41] The emissions cuts would need to be even greater to reach net zero emissions by 2050 and maintain global temperature rises to 1.5 °C.

Ramping up secondary (recycled) production will help, as it emits a fraction of the emissions of primary production. Maximizing the collection, sorting, and recycling processes of wasted aluminum materials would help displace about 15% of the demand for primary aluminum, effectively reducing absolute CO_2e emissions by 250 Mt per year.[42] But under this scenario, post-consumer scrap would still only supply about 43% of the global aluminum demand in 2050, as there is simply not enough scrap to meet our needs for aluminum.[43] This means that regardless of recycling improvements, we will still need to increase primary production and mine additional bauxite (the primary raw input for aluminum; as described in Appendix A).

Production of primary aluminum in the U.S. is already much less emissions intensive than in top aluminum producing countries—including China and India. But we, like much of the world, continue to rely on imports of emissions-intensive aluminum from other countries.[44] Our dependency on imports of climate-polluting aluminum limits the potential climate gains of clean technologies like solar panels, power lines, and EVs that depend on aluminum.

The sector faces an important crossroads. We can continue to outsource aluminum production at the cost of good jobs, national security, and our climate goals. Or, with the right investment and policy decisions, a revitalized industry can provide a domestic supply of clean aluminum that improves national and economic security while creating good manufacturing jobs, cutting climate pollution, and supporting environmental justice.

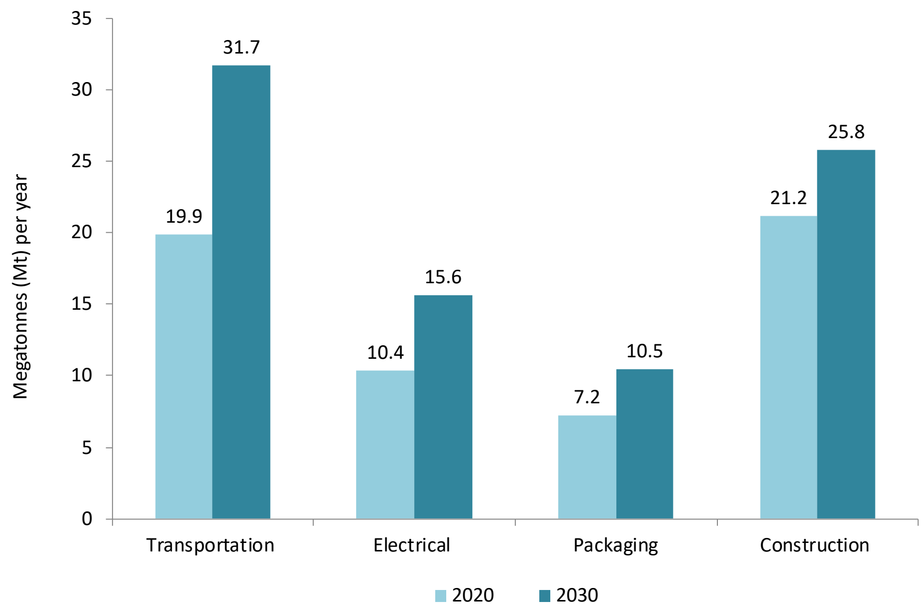
Global Outlook

As important as aluminum is for today's economy it will only be more integral for the future. The International Aluminum Institute (IAI) estimates that global demand will reach 170 Mt per year by 2050, marking an 80% increase from 2018 levels of 95 Mt.[45] Some estimates are even higher, with demand projected to reach 298 Mt per year by 2050.[46] In the near term, demand is expected to increase by 40% over the next decade (from 2020 to 2030).[47] The largest share of this demand growth will come from China (37%), followed by other Asian countries (26%), North America (15%), and Europe (14%).[48]

Numerous factors are driving the growth in global aluminum demand. Broad demographic trends like global population growth and rapid urbanization will increase the need from critical infrastructure sectors like construction, transportation, and expansion of the electrical grid (especially in the global south).[49] The transition to a more sustainable economy will further boost global demand from these (and other) sectors, given the importance of aluminum for a range of low carbon technologies.[50]

The highest growth, in terms of absolute demand, will come from the transportation sector (shown in Figure 1). The continued displacement of ICEs with EVs will be the biggest driver.[51] EVs use about 35% more aluminum content than ICEs, and by 2030, these vehicles are expected to represent 60% of global car sales (up from 5% in 2020).[52] This will help drive up the auto sector's consumption of aluminum to 31.7 Mt by 2030—about 11.8 Mt more than its 2020 use.[53] The bulk of this demand growth will come from China (30%), North America (22%) and Europe (19%).[54]

Figure 1 Projected Global Demand Growth by Sector



Data Source: CRU International Ltd, 2022. *Opportunities for Aluminium in a Post-Covid Economy.*

Demand will also increase from the electrical sector as countries transition to renewable energy sources, expand their electricity grids and deploy energy storage technologies. Under the International Energy Agency (IEA) net zero pathway, renewable energy will need to supply nearly 90% of total electricity by 2050.[55] Building the required renewable energy infrastructure—which is more aluminum intensive than traditional energy sources—will require significant quantities of aluminum. By 2030 the demand from the sector will reach 15.6 Mt, up from 10.4 Mt in 2020.[56] Solar PV will be the biggest driver of demand for the sector, accounting for over 87% of the energy sector's use of aluminum by 2050.[57] Between 2020 and 2050, it is estimated that solar PV technologies will require a total of more than 90 Mt of aluminum.[58] And because aluminum is used in a variety of energy technologies, demand will grow regardless of the mitigation pathway.[59]

We will see this play out intensely in the United States, where the massive build-out of utility-scale solar and wind projects, spurred by the renewable energy provisions of the Inflation Reduction Act, is expected to fuel enormous growth in aluminum demand. A new study on the impact of these provisions projects that by 2035 domestic solar and wind projects will use 7.8 Mt of aluminum per year, up from 0.2 Mt per year in 2022.[60] At this rate, the 2035 aluminum demand for these projects will be equivalent to about 130% of our current annual consumption levels, and over 150% of our current production levels.[61]

Demand for aluminum from the construction sector will be more modest, reaching 25.8 Mt by 2030 up from about 21 Mt in 2020.[62] This growth will be largely driven by economic and population growth, with the bulk (~65%) coming from Asia. Efforts to reduce climate emissions in the construction sector, such as green building codes and sustainability rating systems, may also have a positive impact on aluminum demand. For packaging, the annual demand for aluminum is expected to increase by about 3.3 Mt over the next decade.[63] This growth will largely be driven by the increased demand for canned beverages in North America, the shift away from PET plastic products in western countries, the transition from glass to aluminum in China's beer market, and the implementation of extended producer responsibility (EPR) and other recycling policies that favor aluminum products.

The Opportunity to Lead: The Case for Action

The precarious balance of the global aluminum supply is particularly concerning for the U.S. While the United States was once a leader in aluminum production, annual domestic primary production has declined significantly in the last few decades (falling by 74% since 1995).[69] The U.S. is now the world's top net importer of aluminum and is highly dependent on imports to meet domestic consumption.[70] Imports are expected to supply about 34% of total domestic aluminum demand in 2022.[71] This is considerably higher than import levels of other essential materials like cement (14%).[72] This weakened state of domestic production, against the backdrop of rising demand, carries serious economic, national security, and climate implications.

To begin, the dwindled production capacity and reliance on imports—including from Russia and China—pose a high risk of costly supply disruptions. Given that aluminum is an essential part of the supply chain for national defense-related industries any disruptions could impact national security. The vulnerability of the supply was heightened in June of 2022 when the single domestic facility with capacity to produce high purity aluminum necessary for military and aerospace applications announced it would temporarily idle its smelter.[73] Even before this curtailment, the U.S. Department of Defense (DoD) identified aluminum as a strategic material in short supply. It had also determined that in the face of a national emergency, the U.S. would likely have an inadequate supply of the material due to obstacles in accessing foreign sources.[74]

Supply Chain Constraints

On top of pressure to reduce sectoral emissions while increasing output, the sector also faces supply chain concerns, which are already manifesting at current demand levels. As the world emerges from the COVID-19 pandemic, global demand has bounced back, but supply is struggling to keep up. Mounting shipping costs and supply chain snags—such as limited supplies of rail cars and staff shortages—continue to cause delays in deliveries.[64]

Reduced global production due to the Russian invasion of Ukraine, the energy crisis in Europe, and power rationing in China are further constraining supply.[65] As a result, global aluminum prices, as with other commodities, have soared. In February, they reached their highest levels since the global financial crisis at $3,236 a tonne (this is up from a low of $1,444 per tonne in April 2020, driven by worker shortages from COVID-19 and a temporary decrease in demand for goods like cars).[66, 67]

The continued global supply chain constraints, paired with strong and growing demand, are putting the aluminum market in a precarious position. One industry analyst describes the market as heading towards inventory depletion by 2023.[68]

Given the large and growing use of aluminum in critical nondefense sectors—like transportation systems, power transmission, and construction—supply disruptions also would impact broader economic security.[75] The COVID-19 pandemic has underscored the perils of relying on foreign sources for critical materials. Over the last two years, shortages in commonly used goods highlight the importance of developing secure and reliable supply chains for products and materials, like aluminum, that are critical to a functioning economy.

Furthermore, some imports are coming from countries where primary aluminum production is more emissions intensive than domestically produced aluminum. For example, in China, where primary aluminum production is predominantly coal powered, the emissions intensity of production is about 65% higher than in the U.S. (see Appendix A).[76] With such high intensity production, China's primary aluminum sector generates more emissions than the entire country of Indonesia (as of 2020).[77] Addressing industrial emissions from aluminum production and other heavy industry, including embodied emissions from imports, is essential for meeting U.S. climate goals.

In some cases, our aluminum imports also come with embedded worker exploitation. As further discussed in Section II, labor rights and working conditions are extremely poor in several of the countries from which the U.S. sources aluminum—including Bahrain, China, Thailand, and Turkey.[78] In China's aluminum sector, this likely includes forced labor.[79]

Much of this imported aluminum could be made in the U.S. And it could be produced with lower emissions and better health and labor standards.

Fueled by global decarbonization efforts and the growing interest in sustainable and responsible manufacturing, the demand and price premiums for low-carbon aluminum are climbing.[80] This presents a tremendous opportunity for the United States to revitalize an industry it once dominated. With the right incentives and investments, the U.S. can restore and expand clean domestic aluminum production, making the industry more competitive in the global economy while mitigating supply risks, supporting climate action, and bringing back good-paying jobs to U.S. families. These efforts would also reduce air pollution and other toxic emissions, in support of fenceline communities calling for environmental justice.

With relatively stringent environmental standards, newly enacted public investments in clean manufacturing processes, and leadership in innovating clean technology, the U.S. has a competitive advantage in clean manufacturing. It is well positioned to play a leading role in transforming the aluminum industry and producing union-made, low-carbon aluminum to meet the needs of the clean economy.

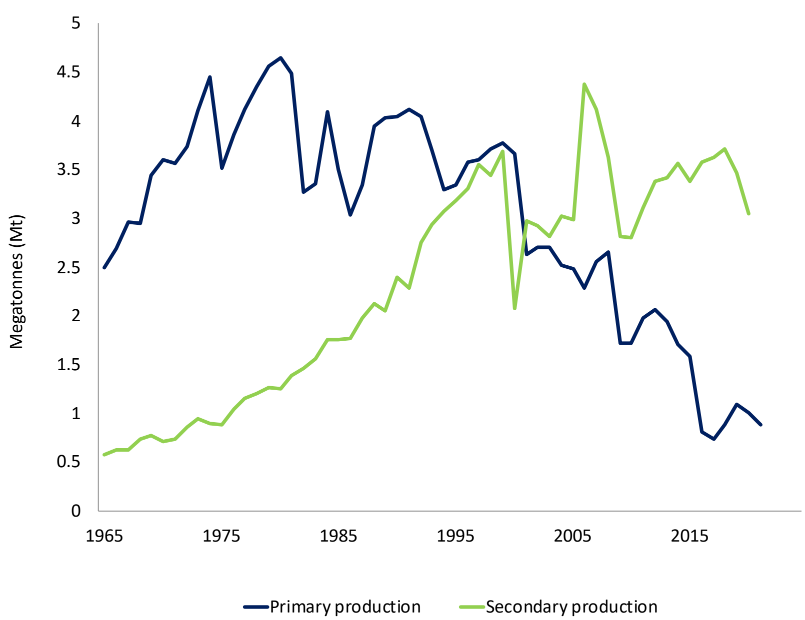
II: The Domestic Industry: Past and Present

The Decline of the Domestic Aluminum Industry

The United States was the leading global producer of primary aluminum throughout the twentieth century. At the end of World War II, the country was producing over 40% of the global supply of primary aluminum.[81] Production continued to rise until 1980, when it peaked at 4.65 Mt per year (shown in Figure 2).[82] That year, about 35,000 people were employed in primary aluminum production.[83] While production began falling after this point, the industry remained strong throughout the 1990s. In 1995, 23 primary smelters across 14 states produced over 3.3 Mt of primary aluminum.[84] Secondary production was on par, with an output of 3.19 Mt of recycled aluminum.[85] Collectively, the industry employed about 100,000 workers (shown in Figure 3).[86]

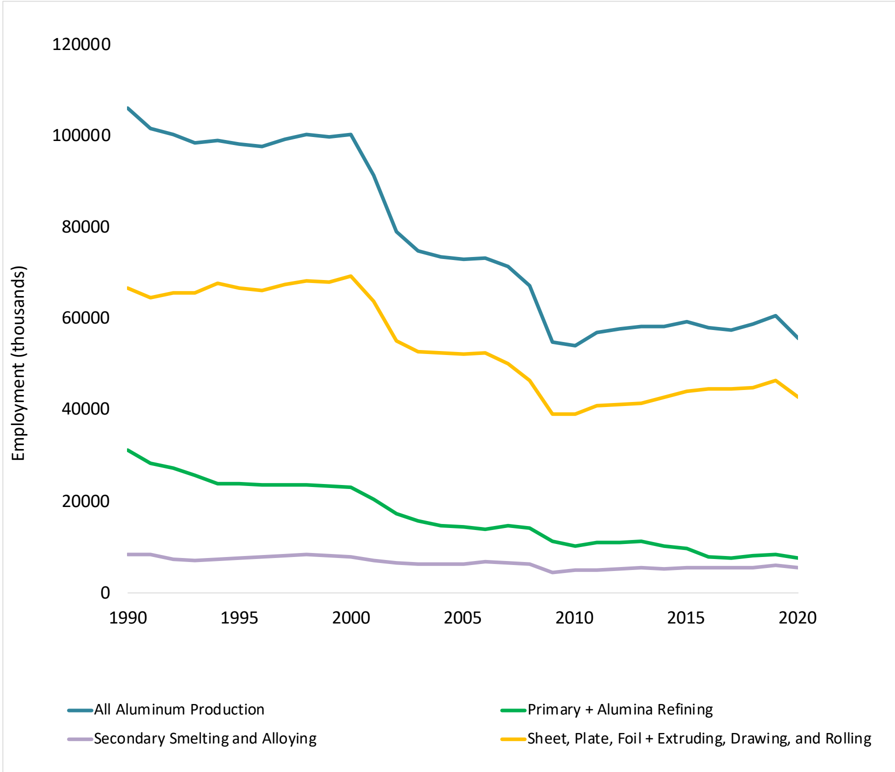
But by 2001, after production had dropped by 28% in a single year, the U.S. was no longer the world's leading producer of primary aluminum.[87] The industry has since continued on a long decline. Output reached a low of 741,000 metric tons (mt) per year in 2017, an 87% decrease from 2000 levels (shown in Figure 2).[88] By 2020, 15 primary facilities had shut down, two more remained idle, and nearly 45,000 jobs had disappeared (since 2000).[89] Jobs in primary production had dropped by about 27,000 from their peak in 1980.[90] A number of factors have contributed to this decline, including global overcapacity caused by foreign government subsidies—particularly by China—collapsing global prices, and high domestic costs of production (see Appendix D for further discussion).[91]

Figure 3 Average Employment Levels 1990-2020



Data source: *United States Geological Survey (USGS)*

Figure 2 Domestic Primary and Secondary Production, 1965-2020



Data source: *U.S. Bureau of Labor Statistics (BLS) Quarterly Census of Employment and Wages (QCEW)*

The area hit hardest from declines was the Pacific Northwest. Historically, the region had been the epicenter for domestic aluminum production due to significant public investment during the Depression and World War II eras. Namely, the federal construction of two large-scale hydropower projects on the Columbia River supplied an abundance of inexpensive electricity to smelters in Washington and Oregon. In the years following these public projects, the government encouraged the Aluminum Company of America (now ALCOA) and Reynolds Metals to build local smelters and utilize the new supply of hydropower and later deployed mechanisms like the federally funded Defense Plant Corporation (DPC) to build additional plants to help meet the growing need for aluminum for defense efforts.[92] By mid-century, the region accounted for 40% of domestic smelting capacity.[93] Today, all but one of the region's primary facilities—six in Washington and two in Oregon—have shuttered.[94] A single remaining facility in Washington has been curtailed since 2020. The other closed plants are scattered across eight states: Maryland, Montana, New York, North Carolina, Ohio, Tennessee, Texas, and West Virginia (shown in Appendix C). While only closed temporarily, the facility in Hawesville, Kentucky, is at risk of being added to this list.

Domestic secondary production did not experience the dramatic decline of primary production. Prior to 2000, primary production was consistently higher than secondary production. But beginning in 2001, levels of primary production dropped below secondary and the gap has continued to widen since (see Figure 2). While secondary production has experienced considerable fluctuation since the 1990s, 2021 production levels were near equal to 1995 levels (at around 3.2 Mt per year).

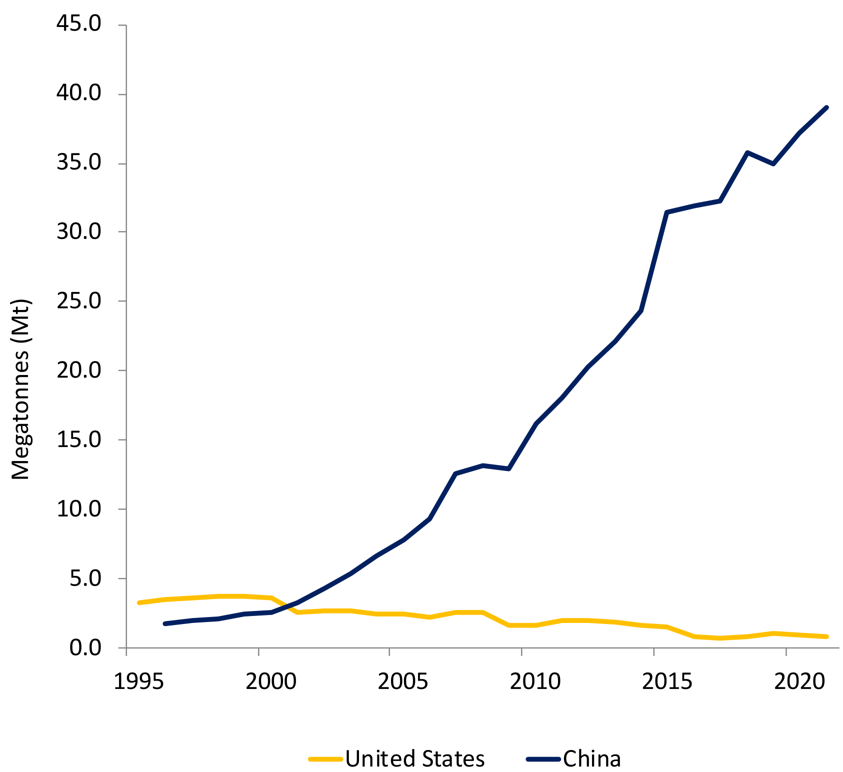
While general trends in production, capacity, and employment have largely been downward facing, overall employment in the industry did experience a period of modest growth from 2010 to 2019 (see Figure 3). During this period, the sector added over 6,500 jobs (reaching 60,500 jobs in 2019 up from 54,000 in 2010).[95] This growth was largely driven by additional jobs in secondary production and downstream manufacturing, while employment in primary production continued on a general decline. The upward trend was reversed by COVID-19 driven disruptions beginning in 2020 which caused a dip in employment. The biggest job losses since the start of the pandemic were in primary production (which fell by 9.6% from 2020 to 2022) and aluminum forging (which dropped by 10% over the same period).[96] The latter likely resulted in depressed demand for aluminum due to COVID-driven declines in sectors like transportation and aerospace, which forced many large manufacturers to reduce plant capacity in 2020.[97]

Aluminum Trade: Rising Global Emissions Intensity and Declining Labor Standards

The decline of primary aluminum production in the U.S. coincided with a meteoric rise in production in China, as shown in Figure 4. By 2003, China was producing more annually than the U.S. had produced in its peak production year of 1980.[98, 99] Over the last 25 years, China's production has grown by more than 2000%, reaching 39 Mt in 2021.[100] As a result, while China only produced 13% of the global share of primary aluminum in 2000, by 2021 this figure reached 57%.[101] China now produces 10 times more than the next biggest producer, India.

China and India are not only the top producing countries, but they are also the countries with the highest emissions intensity of production.[102] Emissions intensity in India is nearly double that of the U.S., while China's is about 65% higher than in the United States. Every ton of aluminum produced in China is associated with an additional ~5 t of CO2, relative to a ton produced in the U.S. on average (this does not include emissions associated with transport).[103] These two countries now produce 63% of the global supply of primary aluminum.[104] Given their high emissions profile, such market concentration is significantly driving up the emissions intensity of global production.[105] Indeed, if the U.S. had maintained the same share of global production as when its industry was at its peak (30.3% of global output in 1980) and production by the most intensive producers (India and China) fell proportionately, annual global sectoral emissions would be 15% lower than they are today.[106] That is an annual reduction of 102 Mt of CO2 emissions (558 Mt vs 660 Mt).

Figure 4 U.S. and China Primary Production 1995-2020



Data Source: *USGS*

While the United States has largely been a net importer of aluminum over the last six decades, imports have outstripped exports by a particularly large degree since the 1990s. In 2021, the country imported 5.6 Mt of aluminum.[107] That year, net imports (exports minus imports) were valued at $9.68 billion, making it the world's top net importer (see Appendix E). The country's imports are nearly twice as high as the next biggest importer (Japan). The largest source of imports to the U.S. is Canada, which provided about 57% of U.S. aluminum imports in 2021.[108] The next largest sources were UAE (6.4%), Mexico (5%), Russia (3.7%), Bahrain (3.2%), and China (2.9%).

In some cases, these imports come with social costs. Several of the countries from which the U.S. sources aluminum, for example, have very poor labor rights and working conditions. In fact, four—Bahrain, China, Thailand, and Turkey—are rated as among the worst countries in the world for worker rights by the 2021 Global Rights Index produced by the International Trade Union Confederation (IUTC).[109] The analysis indicates that with little access to de jure labor rights, workers in these countries are often exposed to authoritarian regimes and unfair labor practices. This means that workers' rights to organize, to take collective action, to strike, and to engage in collective bargaining are severely restricted and they have little protection from anti-union discrimination.

In Bahrain, for example, aluminum workers have been arbitrarily fired for participating in peaceful pro-democracy protests.[110] Meanwhile in Turkey government decree has been used to ban planned strikes across the metal industry.[111] In China, evidence indicates that some aluminum-sector workers may even be subject to forced labor. A recent study by a Washington D.C.-based consultancy identified numerous indicators of forced labor in the aluminum industry in Xinjiang, an autonomous territory in northwestern China that produces 17% of the country's aluminum.[112] Among other signals of forced labor, the Xinjiang aluminum industry was found to have ties to controversial labor transfer programs and to a state-owned economic and paramilitary organization that has been a target of U.S. government sanctions. These studies highlight the fact that some of our aluminum imports likely come with embedded worker exploitation.

The Domestic Industry Today

Facilities in Operation

Alumina refineries: There is currently one alumina refinery in the United States. Based in Louisiana, the refinery imports bauxite from its mining operation in Jamaica and uses a chemical process to produce smelter- and chemical-grade alumina.[113] With a production capacity of 1.2-million tons per year, the refinery produced 1 million tons of alumina in 2021, accounting for all of domestic production. This represented about 40% of alumina used for domestic consumption in 2021.[114] The remainder of alumina was imported, mainly from Brazil, Australia, Jamaica, and Canada.[115] Another refinery in Louisiana closed in 2020.

Primary facilities: There are currently five primary aluminum smelters operating in the U.S. (as of February 2023). The facilities, as shown in Appendix C, are located in Indiana, Kentucky, New York, Missouri, and South Carolina. A sixth facility, in Hawesville, Kentucky, temporarily idled its smelters in June 2022. The smelters are operated by three companies: Alcoa, Century Aluminum, and Magnitude 7 Metals.[116] In 2021, the six smelters produced 880,000 mt of primary aluminum, which was 13% less than 2020 levels.[117] By year end 2021, the smelters were operating at about 55% of collective capacity.[118] Collectively, these facilities employ over 3,000 people.[119]

There is an additional primary smelter in Washington State that has been curtailed since 2020. Ongoing efforts to restart the smelter hit a roadblock in late 2022 when the potential buyer was unable to secure a deal for affordable clean power to run the facility.[120] Another smelter in Washington State that had been idled since 2015 was permanently shut down in early 2021.

Secondary facilities: The U.S. secondary aluminum segment is significantly larger than the primary segment. According to the Bureau of Labor Statistics (BLS), there were 113 facilities engaged in secondary production as of 2020 (Table 1).[121] This figure includes facilities that recover aluminum and aluminum alloys from scrap to produce secondary aluminum, as well as those that manufacture alloys, powder, paste, or flake from purchased aluminum.[122] A 2022 inventory of secondary facilities indicate that about 90 process aluminum scrap to produce secondary aluminum or aluminum alloys.[123] Most of these 90 facilities (about 70) are found east of the Mississippi River close to industrial centers that provide a source of scrap and accessible markets.[124] The highest concentration is in Indiana, where there are 13 secondary facilities, and the surrounding corridor, with 11 in Kentucky, eight in Ohio, seven in Tennessee, six in Pennsylvania, five in New York, four in Missouri, and three in Illinois and Michigan each. The region is known as “Aluminum Alley” due to this clustering. Outside of this main grouping, states with the highest number of facilities include California (six), Alabama (five), and Texas (three).

In 2021, secondary (recycled) production amounted to about 3.2 Mt of aluminum, relative to 880,000 mt of primary.[125] About 53% of secondary aluminum was sourced from manufacturing scrap, while 47% came from discarded aluminum products (old scrap). Recycling rates vary across market segments. The highest rates are for manufacturing scrap, where nearly 100% of aluminum waste is captured and recycled.[126] In post-consumer scrap, the highest rates of recycling are found in industrial markets like automotive and buildings, where they often exceed 90%.[127] Rates are substantially lower for domestic containers and packaging recycling, which are about 35%.[128] Though within this segment, aluminum cans are recycled at a higher rate of about 50%.[129] At current rates of recycling, old scrap supplies about 30% of aluminum used domestically.[130]

Employment Snapshot

According to the BLS, U.S. aluminum manufacturing employed an annual average of 55,723 workers in 2020.[131] Of these jobs, alumina refining and primary production accounted for 7,555 and secondary smelting and alloying accounted for 5,456 (shown in Table 1). The remaining workers were employed at facilities that further process primary or secondary aluminum into rolled or extruded products.

Table 1. Aluminum Employment and Facilities, BLS 2020

Production Segment	Facilities	Employees
Alumina refining and primary aluminum production	110*	7,555
Secondary smelting and alloying of aluminum	113	5,456
Aluminum sheet, plate, and foil manufacturing	156	16,347
Other aluminum rolling, drawing, and extruding	308	26,365
Total	687	55,722

*Notes: The BLS uses the North American Industry Classification System (NAICS) to classify industry segments. The NAICs code for “alumina refining and primary aluminum production” includes facilities that refine alumina from bauxite, make aluminum from alumina, as well as some that also manufacture aluminum alloys and aluminum shapes (e.g., bar, ingot, rod, sheet). This explains the higher than expected figure for facilities in this category given the small number of alumina refineries and primary smelters.
Source: *BLS QCEW - QCEW NAICS-Based Data Files, 2020*

Other accountings of total employment for the industry are much higher and include a broader scope of workers. A 2022 economic impact study by economic research firm John Dunham & Associates, for example, estimates that the industry employed 164,402 people in 2022.[132] The boundaries for these production segments with the industry are slightly different than those used by BLS. As the breakdown in Table 2 shows, this figure includes employees in alumina refining, primary aluminum production, secondary aluminum production and alloying, manufacturing of aluminum sheet, plate, foil, extrusions, forgings, coatings, and powder, aluminum foundries, and metals service centers (MSC) and wholesalers.[133]

Table 2. Aluminum Industry Employment, John Dunham Associates, 2022

Production Segment	Employees
Alumina refining and primary production	4,367
Secondary aluminum production and alloying	9,329
Sheet + Extrusions	63,895
Foundry	49,706
Forging	9,362
Coating	2,828
MSC and wholesalers	24,915
Total	**164,402**

Data source: *John Dunham & Associates/Aluminum Association, 2022*

According to this study, the manufacturing sector of the industry (all segments except MSC and wholesalers) employs 139,487 people. About 4,370 of these jobs are in alumina refining and primary production. Most of these jobs in primary production (nearly 3,000) are in the five states where primary smelters are located (Kentucky, Indiana, Missouri, New York, South Carolina, see Table 3). Over 9,000 people are employed in secondary aluminum production and alloying. About 7,800 are concentrated within 10 states (shown in Table 4).

Table 3. Primary Production Jobs in States with Primary Smelters

State	Primary Production Jobs
Indiana	549
Kentucky	1,125
Missouri	500
New York	486
South Carolina	330
Total	**2,990**

Note: includes all jobs in primary production and alumina refining
Data source: *John Dunham & Associates, The Economic Impact of the Industry, 2022*

Table 4 Top Ten States for Jobs in Secondary Production/Alloying

State	Jobs	Facilities
New York	1,416	5
Ohio	1,261	8
Kentucky	1,018	11
North Carolina	1,000	2
Indiana	968	13
California	725	6
Tennessee	504	7
Pennsylvania	370	6
Alabama	286	5
Arkansas	240	1
Total	**7,788**	**64**

Note: Includes all jobs in secondary production and alloying
Data source: *John Dunham & Associates, The Economic Impact of the Industry, 2022*

In 2021, the national average annual pay for employees in the aluminum industry was $55,790.[134] This is higher than pay in retail trades ($37,590), accommodations and food service ($30,850), and other services ($48,290), but slightly lower than the figure for the entire manufacturing sector ($57,620).[135, 136] Production workers in the aluminum sector, however, tend to earn slightly more than production workers across all manufacturing sectors, with an annual average pay of $45,110 vs. $43,530.[137]

The value of these wages becomes even clearer when compared to the earning outlook in the states where these jobs are found. In a number of cases, aluminum workers are earning wages that are higher than the average for all occupations across the state. For example, the average annual pay for aluminum workers ($55,790) is higher than the average wage in South Carolina ($47,500), Kentucky ($48,200), Indiana ($50,400), Missouri ($51,400), North Carolina ($53,100), and Ohio ($53,200).[138]

Aluminum workers also enjoy relatively high rates of employee sponsored healthcare coverage. Between 2017 and 2022, about 66% of aluminum workers were included in employee healthcare, compared to a rate of about 33% for all manufacturing workers, and 50% for the entire labor force.[139] Access to pensions or retirement plan benefits in the aluminum workforce is similar to levels in the broader manufacturing sector (roughly 40%), but higher than the average for the entire workforce (about 33%).[140]

Unions maintain a significant presence in the aluminum industry. This is a benefit to the industry as unionized manufacturing workers earn significantly higher hourly wages than non-unionized workers with similar characteristics.[141] Union workers are also more likely than non-union workers to have employer-provided healthcare benefits.[142] As of 2021, about 20% of aluminum employees were unionized.[143] This is substantially higher than the level across durable goods manufacturing, which is only 8.5% across all industries.[144] The only three industries in durable goods manufacturing that have higher unionization rates than aluminum are foundries (29.5%), iron and steel manufacturing (25%), and railroad rolling stock manufacturing (23%). When looking just at production workers within the aluminum industry, unionization rates are even higher. From 2017 to April 2022, of the 30,985 production workers in the aluminum industry, 27% of them were represented by a labor union.[145]

In terms of workforce characteristics, data from the Current Population Survey (CPS) indicate that the sector is disproportionately male and white. From the period between 2017 and June 2022, about 75% of the aluminum workforce was male.[146] With women accounting for only 25% of employees, gender representation is lower than levels seen across the broader manufacturing sector (30% women), shown in Table 5.[147] As for racial and ethnic diversity, white workers make up about 68% of the workforce, while 32% are workers of color. This is also less diverse than broader manufacturing where about 36% of employees are people of color. After white workers, Hispanic workers make up the next largest group at about 16% of the aluminum workforce, followed by Black employees at 10%. All other races and ethnicities each account for 3% or less of total employees.

Table 5 Aluminum workforce by race/ethnicity and sex, 2017-2022

Sex	Aluminum	All Manufacturing
Male	74.6%	70.3%
Female	25.4%	29.7%
Race/Ethnicity		
AAPI	3.0%	7.1%
Black	10.0%	10.2%
Hispanic	15.8%	15.5%
Native American	0.9%	0.6%
Other/Mixed	2.2%	3.0%
White	68.1%	63.7%
All People of Color	31.9%	36.3%

Data source: *US Census, Current Population Survey, 2017-2022*

As for educational attainment, the CPS data show that aluminum workers tend to have lower education levels than the broader workforce. For example, over 80% of aluminum workers do not hold a bachelor's degree, compared to 62% for the entire workforce. While about a third of aluminum workers have completed some college or an associate's degree (which is comparable to the larger workforce), the bulk of aluminum workers (53%) only have a high school degree or less (compared to 35% for the whole workforce).[148] This suggests that the sector provides accessible jobs for workers without advanced education.

While the advantages of aluminum sector jobs are many, there are notable disparities within the workforce across racial, gender, and educational lines. These are especially apparent in median wages. Men, for example, earn about 28% more in median wages relative to women. The pay discrepancies between white workers and workers of color are nearly the same (27% higher for whites). Meanwhile, median wages for workers with a bachelor's degree are about 70% higher than workers with a high school degree or lower.[149]

Economic Impact

The aluminum industry—even in its declined state—has a sizable impact on the U.S. economy. A recent John Dunham & Associates/Aluminum Association study, referenced earlier in this section, uses econometric modeling to quantify the total economic contributions of the domestic industry.[150] The analysis estimates that the domestic aluminum industry contributes about $176 billion to the U.S. economy, accounting for 0.73% of the GDP in 2021.[151] While less than 1% of the GDP may seem low, it's important to remember that this is the industry's impact at substantially diminished capacity. The economic impact of thriving, revitalized industry would be considerably larger. For example, the output of iron and steel making, another key materials industry, is about 2.5% of the GDP (as of 2018).[152]

The analysis further estimates that the 164,402 Americans employed by aluminum manufacturers and wholesalers earn more than $13.55 billion in collective wages and benefits. This drives an estimated $73.2 billion in direct economic output. When supplier and induced impacts are factored in using an input/output model, the figures increase to 634,419 jobs and $47.1 billion in wages, with $14.97 billion in direct federal, state, and local taxes (excluding sales taxes on aluminum products).[153]

In the five states with primary smelters (Indiana, Kentucky, Missouri, New York, and South Carolina), the analysis estimates that the industry's total economic contribution is $39.78 billion.[154] This includes direct, supplier, and induced impacts. The direct economic impacts amount to $18.4 billion, with nearly 34,000 jobs in aluminum manufacturing and wholesale, and collective wages and benefits surpassing $3 billion.

Among these states, the greatest impact is found in Kentucky, the only state with two primary smelters. In addition to having the highest number of jobs in primary production (1,125 jobs) it has the third highest in secondary smelting and alloying (1,018). The entire industry (manufacturers and wholesalers) in Kentucky employs over 10,500 people and directly contributes $6.76 billion to the economy, with total economic contributions of over $13 billion (see Appendix X). This represents about 5.6% of the state's GDP in 2021.[155] This means that one of every 18 dollars of goods and services produced in the state comes from the aluminum sector.

The economic impact in Indiana is only slightly lower than in Kentucky. In addition to having one primary smelter with 549 jobs in primary production, Indiana has the fifth highest number of jobs in secondary production (968 jobs). The entire industry employs over 10,000 people, who collectively earn $909 million in wages and benefits. This creates a direct economic impact of $5.29 billion and total economic contributions of $11.09 billion, or about 2.7% of the state's GDP.

In Missouri, over 6,000 people work in the aluminum industry (including 500 in primary and 198 in secondary production). The industry provides $466 million in total wages and benefits and direct economic contributions of $2.45 billion. The total economic impact of the industry in the state is $5.42 billion, roughly 1.5% of Missouri's GDP.

New York's aluminum industry employs 4,717 people. This includes 1,416 jobs in secondary production, the most of any state, and 486 in primary production. While the total jobs in the industry are less than in Missouri, NY's direct impact of $2.72 billion and total economic impact of $7.42 billion (0.4% of its GDP) are both greater than in Missouri. This is largely driven by greater supplier and induced impact in New York.

In South Carolina, home to one primary and one secondary facility, the direct economic contributions of the industry amounts to $1.17 billion, with total economic contributions reaching $2.69 billion, about 1% of its GDP. The entire industry employs over 2,100 workers. Their collective wages and benefits are over $212 million.

In terms of states leading in employment in secondary production, the top five states overlap substantially with the states with primary smelters. Three states with primary smelters—New York, Kentucky, and Indiana—are among the top five for secondary production jobs. The other two in the top five are Ohio and North Carolina. In Ohio, over 16,000 people are employed in the aluminum industry. This includes 1,416 people, the second highest of any state, in eight secondary facilities. Total wages and benefits in the entire industry amount to $1.35 billion for a direct economic impact of $6.74 billion. The industry has a total economic contribution of $15.46 billion (2% of the state's GDP), including direct, supplier and induced impacts. This is higher than the impact in each of the states with primary smelters.

North Carolina has the fourth highest employment in secondary production (1,000 jobs). The industry collectively employs 3,520 people providing $263 million in wages and benefits. The direct economic impacts of the industry are $1.82 billion, with total contributions of $4.05 billion, or about 0.6% of the GDP.

III. Revitalizing the Industry: Federal Policy Recommendations

Vision of Success

A revitalized U.S. aluminum sector has the potential to provide family-sustaining union jobs for tens of thousands of workers and hard-hit communities, support fenceline communities' fight for clean air, offer a reliable supply of a critical material for clean energy and national defense, and serve as a pivotal first mover in our efforts to slash industrial climate pollution.

Notable benefits of a revitalized aluminum sector will include the:

- Creation of new-and retention of existing- union jobs supported and created in the domestic aluminum industry;
- Increase in the average wage in the domestic aluminum industry;
- Economic benefits from increased aluminum production shared among impacted communities—including environmental justice, deindustrialized, and low-income communities and communities of color;
- Reduction in greenhouse gas emissions and toxic pollution from domestic aluminum facilities, relative to the current baseline;
- Improved ranking of the U.S. versus other major aluminum producers in the carbon and pollution intensity of aluminum production; and
- Increase in the share of U.S. aluminum demand for critical clean energy and national defense purposes that can be met via domestic supplies.

The federal government has an array of tools to help achieve such benchmarks of a vibrant U.S. aluminum industry. These include national security measures, federal procurement policies, programs for investing in industrial efficiency, emissions reductions, and clean manufacturing, authority over federally supported electricity generation, and trade policy. Three types of tools deserve particular priority, as detailed below:

- Procurement: Buy America(n), domestic content requirements;
- Investment: Loan and grant programs and use of the Defense Production Act; and
- Trade: A border fee on climate-polluting aluminum imports.

While these recommendations are federally focused, there is also a continued role for states to play to complement federal action. In some cases, state leadership in fact paved the way for a federal-level policy. States can build on this leadership by spearheading new iterations of these policy mechanisms, or simply adopting similar policy measures as the federal government.

Federal Policy Recommendations: How to Get There

Procurement

To revitalize U.S. aluminum manufacturing, part of the solution could be to catalyze a large domestic market for clean U.S. aluminum. Buy America, Buy American, and related domestic content rules offer policy tools to do just that. For example, the Inflation Reduction Act, signed into law in 2022, includes domestic content provisions that could help compel private developers and manufacturers of solar, wind, transmission, and electric vehicle components to purchase U.S.-made aluminum. The law offers solar and wind developers a 10% bonus tax credit if a little over half of their parts and materials are U.S. made.[156] Given that aluminum is a primary ingredient in solar panels and other clean energy technologies, this policy creates a strong incentive for clean energy firms to buy domestically-produced aluminum.

As a material aluminum does not enjoy the same domestic content provisions as iron or steel and therefore is more exposed to market forces despite being a critical material for infrastructure, defense, and more.

The federal government may now use its vast buying power to support domestic, low-emissions aluminum producers that operate with high-road labor practices. Such a policy combined with actual compliance with existing domestic content requirements such as Buy American will serve as important tools for driving the industrial transformation necessary to confront climate change and toxic pollution while supporting and revitalizing domestic manufacturing and good jobs.

Aluminum Goods Procured

The federal government procures relatively little aluminum as an explicit component of the product being purchased—and not in high-enough volumes that would have a significant impact on domestic production or emissions levels. For instance, for FY2021, USASpending.gov shows several categories that mention aluminum content, but at relatively low dollar figures:[157]

1. $112.0 million – Ammunition/bombs (DOD)[158]
2. $37.6 million – Ground effect vehicles (GSA, DOD, DOS, others)[159]
3. $31.6 million – Small boats (DOD, DHS)[160]
4. $24.4 million – Prefabricated building components (VA, DOD)[161]

The federal government does purchase a wide range of high-volume products with aluminum components. However, aluminum content is not usually mentioned in the bidding or contract documents.

Top 10 Uses of Aluminum[162]

1. Power lines
2. High-rise buildings
3. Window frames
4. Consumer electronics
5. Household and industrial appliances
6. Aircraft components
7. Spacecraft components
8. Ships
9. Trains
10. Personal vehicles

For it to be an effective tool in supporting the domestic manufacturing of low-emission aluminum, federal funding either through direct procurement or federal assistance must go beyond the scope of simply raw aluminum and include finished goods that have significant domestically-produced aluminum content as well with transparent waiver systems that avoid the use of general applicability waivers.

Policy Tools

The Biden Administration has a number of different tools that it could use to prioritize the procurement of low-emissions aluminum.

Buy American

Executive Order (EO) 13858 (Jan. 31, 2019) encouraged the procurement, "to the greatest extent practicable," of aluminum (and other construction materials) produced in the United States. The effectiveness of this EO should be further assessed to determine and develop a more focused approach to a Buy American requirement for domestic aluminum.

Buy America and the "Build America, Buy America" Act (BABA)

Signed into law Nov 15, 2021, the Bipartisan Infrastructure Law (BIL), harmonizes Buy America rules and applies these domestic preferences more broadly, and went into effect on May 14, 2022. While existing Buy America requirements previously applied to iron, steel, and certain manufactured goods, BABA expands requirements to include all "manufactured products" and "construction materials" in construction contracts that include federal funding in the construction phase. These designations would cover aluminum to a degree, but not perfectly.

For "manufactured products" to qualify under BABA, the product must be manufactured within the U.S. and the "cost of the components of the manufactured product that are mined, produced, or manufactured in the United States is greater than 55 percent of the total cost of all components of the manufactured product, unless another standard for determining the minimum amount of domestic content of the manufactured product has been established under applicable law or regulation." For aluminum, this could allow for the sourcing of internationally produced aluminum in the final manufactured product if other components are both domestically produced and hit the 55 percent cost threshold.

Aluminum would be considered a "construction material" because it is a non-ferrous metal and can be incorporated into buildings, infrastructure, and/or public works. In the case of construction materials, all manufacturing processes for the construction material must have occurred in the United States. For aluminum, this would mean the smelting and fabrication processes would need to occur within the U.S., but not necessarily the mining and primary production.

Neither designation perfectly covers aluminum, so their effectiveness should be further assessed to determine if the domestic aluminum industry would benefit from similar designations to that of iron and steel, and if that would be feasible.

Forced Labor Concerns
The President could exercise executive authority to limit the procurement of aluminum determined to potentially have been produced overseas with forced labor, and therefore to have entered the United States illegally.

Investment

The federal government should invest in clean aluminum production. It can do so through a mix of tax credits, national security investments, and Department of Energy grant and loan programs.

The Inflation Reduction Act
Part of the solution lies in the climate and jobs investments of the Inflation Reduction Act, signed into law in 2022. This historic legislation offers more than $50 billion in investments to support clean manufacturing, which could help to spur growth in clean U.S. aluminum manufacturing.[163] For example, the law includes billions of dollars for new grants, loans, and tax credits that could help existing U.S. aluminum smelters become even cleaner and more globally competitive by boosting efficiency and slashing pollution. New investments could also help to reopen closed smelters by cutting production costs and offering an affordable supply of clean electricity. Meanwhile, the law will boost aluminum demand by driving growth in solar power, electric vehicles, and efficient buildings that use clean U.S. aluminum. Below are Inflation Reduction Act investments that could help revitalize U.S. aluminum manufacturing.

Supply-side Investments

- **A new manufacturing production tax credit**: The law establishes a new manufacturing production tax credit (45X) worth more than $30 billion to support expanded manufacturing of solar and wind components, batteries, and critical materials like high-purity aluminum. Manufacturers in these sectors have a "direct pay" option that will allow them to take advantage of the new tax credit for five years without relying on Wall Street financing that is typically unavailable for manufacturing investments. By offsetting production costs, the new tax credit could help certain idled U.S. aluminum smelters to restart operations.

- **An expanded tax credit for technology to reduce industrial emissions**: The law provides $10 billion for the 48C tax credit and makes the tax credit available—for the first time—for manufacturers to install equipment that achieves an at least 20% reduction in climate pollution. Aluminum smelters could use this tax credit to cover the cost of technology that reduces emissions, boosts efficiency, and increases competitiveness.

- **Grants for emissions-reducing upgrades:** The law creates a new, nearly $6 billion program at the Department of Energy to help manufacturers carry out emissions-reducing upgrades at aluminum, steel, cement, and other energy-intensive industrial facilities. The statute specifically names aluminum as a target sector for these investments, which will be distributed over the next five years. The financial support could include grants, loans, or rebates for commercial-scale capital improvements that reduce emissions and benefit local communities.[164] This program is paired with an additional $500 million from the Bipartisan Infrastructure Law (BIL) as part of the Industrial Demonstrations Program under the Office of Clean Energy Demonstrations. To the extent feasible, this money should fund demonstration projects that include the use of novel technologies at commercial industrial facilities, including aluminum facilities. Demonstrating commercial-scale use of new technologies is likely the most effective way of showing the potential of new technologies while helping to achieve economies of scale to reduce the price of deployment.

Demand-side Investments

- **Domestic content bonuses for clean energy tax credits:** The law includes four clean electricity tax credits worth more than $127 billion, each of which establishes—for the first time—a bonus 10% tax credit for projects that use domestically manufactured materials and parts. To qualify for the domestic content bonus, clean electricity developers must use domestically made iron and steel and manufactured components in which U.S. production accounts for roughly half of the value. The latter provision could help to boost demand for U.S. manufacturing of the aluminum used in solar panels, wind turbines, batteries, and other clean energy technologies. Non-profit and government entities also must meet these domestic content requirements to take full advantage of a "direct pay" option that makes the tax credits more accessible.

National Defense Investments

To support clean aluminum manufacturing, the federal government should consider using national defense policies such as the National Defense Stockpile and the Defense Production Act.[165]

- **National Defense Stockpile (NDS):** The president should restore primary aluminum to the NDS, with the requirement that it be produced in the U.S. with low-emissions practices (e.g., use of renewable energy; inert anode technology; and other processes that reduce emissions). The President has the discretion to designate strategic materials and the quality and quantity of such materials that are needed. Aluminum was previously part of the NDS. The NDS included between 250,000 tons of aluminum in 1949 to 2,500,000 tons in 1954. In 1965, the government began an effort to reduce its aluminum stockpile. Although aluminum is not currently stockpiled, it is still listed as a "material of interest" by the Defense Logistics Agency. Funding for acquisitions comes from a revolving fund known as the National Defense Stockpile Transaction Fund. The purpose of the National Defense Stockpile is to serve the interest of national defense only (Congress explicitly states that "[t]he National Defense Stockpile is not to be used for economic or budgetary purposes"). The ability of the president to drive demand for aluminum through adding it to the NDS would be limited to the extent to which it would be necessary for national defense. This can take into account military, industrial, and essential civilian needs of the United States for national defense.

- **Defense Production Act (DPA):** The Administration should use its authority under the DPA to help secure a robust supply chain for aluminum. Congress designed DPA—and reauthorized the law more than 50 times—specifically to address insufficient domestic production of strategic materials like aluminum. In fact, the Truman and Eisenhower administrations used DPA in the 1950s to help build the modern U.S. aluminum industry. By using DPA once again to bolster aluminum production, the Biden administration would be following both historical precedent and the letter of the law. Aluminum production falls well within DPA's broad definition of national defense.

  The administration could purchase clean electricity and resell it at a discount to aluminum smelters under Section 303a of the DPA. This section authorizes such government purchase and resale for "industrial resources" and "critical technology items," both of which are broadly defined enough to encompass electricity. The Biden administration just invoked Section 303 of DPA in June 2022 to boost manufacturing and deployment in five critical clean energy sectors.[166]

  Under sections 301 and 302 of the DPA, the Administration has the power to offer financial support in the form of loan guarantees and loans to support the production of industrial resources, critical technology items, or essential materials needed for national defense purposes. Loans and loan guarantees should be made available to establish and restore aluminum production facilities and ensure that facilities are efficient and have low emissions.

  Under section 303e of the DPA, the president has significant authority to reduce emissions from aluminum facilities. Under that section, "[i]f the President determines that such action will aid the national defense, the President is authorized…to procure and install equipment owned by the Federal Government in plants, factories, and other industrial facilities owned by private persons." To improve supply chain resiliency, reduce production costs, and limit emissions, the administration should buy and install technology to improve the efficiency of aluminum production. Additionally, recognizing that climate change is a national security threat, the Administration should use its authority under the DPA to buy and install technology to reduce emissions from aluminum production, including any retooling necessary for use of inert anodes in smelting.

Additional Department of Energy Tools
A wide range of existing Department of Energy and other agencies' programs also could be geared toward supporting clean aluminum production.

- **Additional Investment Tools**: Under Title XVII of the Energy Policy Act of 2005, the Department of Energy (DOE) is authorized to issue loan guarantees for projects that utilize a new or significantly improved technology to avoid, reduce, or sequester greenhouse gasses. DOE should prioritize projects that include the deployment of emission reduction technologies for aluminum smelting.

  Other investments included in the Inflation Reduction Act also could be used to expand clean aluminum production and/or reduce emissions at aluminum smelters. These include, for example, DOE's Energy Infrastructure Reinvestment program, which could offer loan guarantees to repurpose or replace energy infrastructure with manufacturing facilities. The Greenhouse Gas Reduction Fund, administered by the Environmental Protection Agency, also could potentially offer financial assistance to reduce emissions at aluminum smelters.

  Specific to the Intalco facility, the Bonneville Power Administration (BPA), a federal agency that markets power in Washington state, was appropriated $10 billion in the Bipartisan Infrastructure Law, which should be used to upgrade and expand its existing transmission network. Given the increasing efficiency and capacity for clean energy deployment that can result from this investment, BPA should direct more power to aluminum production to ensure a secure and clean supply chain.

- **Prioritizing power/PPAs from PMAs for aluminum production.** Through Power Marketing Administrations (PMAs), the Biden Administration can support aluminum production domestically through long term power purchase agreements (PPAs). Given that PMAs are federal agencies, the administration should ensure these agencies are operated in a way that maximizes public benefit, including by supporting clean aluminum production. One way PMAs can support domestic aluminum production is by agreeing to favorable PPAs, which will ensure aluminum producers are supplied with affordable clean energy.

  PMAs like BPA tend to have broad discretion in negotiating the terms and conditions related to a PPA. This discretion should be used to provide reliable, clean electricity at historic, competitive rates and terms. For example, directing excess power sales from BPA's 31 hydroelectric dams (which produce as much as 17,000 MW of clean energy) to aluminum production could support hundreds of good jobs while helping increase domestic production.

  Access to affordable, renewable energy is critical to transforming and revitalizing domestic aluminum production. To facilitate this, the Biden Administration and Congress should reform PMAs to better support clean manufacturing in sectors like aluminum. But beyond improving the allocation of existing electricity supplies, robust manufacturing revival will also require further industrial policy that expands renewable electricity production and transmission, and provides clean energy to industrial customers at affordable rates.

Trade

The U.S. currently imports more than 6.8 metric tons of aluminum and aluminum products per year.[167] Since the late 1980s, aluminum imports have more than quadrupled as U.S. aluminum production has fallen due to the outsourcing of metals manufacturing, including to countries with lower labor and environmental standards. As U.S. aluminum production has dropped, aluminum manufacturing in China has soared. Today, China produces 57% of the world's aluminum production—10 times as much as the world's second-largest producer and 88 times as much as the U.S.[168]

The offshoring of U.S. aluminum manufacturing has spelled not only the loss of U.S. jobs, but also an increase in global emissions from aluminum production. That's because aluminum production is significantly more emissions-intensive in several countries that have displaced U.S. aluminum manufacturing. The shift in production from the U.S. to China has particularly exacerbated industrial climate pollution, as aluminum manufacturing in China is about 65% more carbon-intensive than in the U.S. Aluminum production in India, the world's second largest producer, is nearly twice as carbon intensive as in the U.S.[169] Indeed, about two-thirds of the world's aluminum is made in countries where aluminum production is more carbon-intensive than in the U.S.

With smart trade policy, we have the opportunity to stem the outsourcing of aluminum production to emissions-intensive countries, shift U.S. demand toward cleaner aluminum production, and thereby support growth in clean U.S. aluminum manufacturing. The aluminum tariffs imposed under Section 232 of the Trade Expansion Act have already shown how beneficial targeted import measures can be for the sector. Improved market conditions under the policy encouraged significant investments in restarting and expanding U.S. smelters, which in turn, helped bring back 530,000 mt of primary aluminum capacity while bringing back 1,095 jobs.[170] Within two years of imposing the 10% tariff on imported aluminum in 2018, primary aluminum production had increased by 37.6% (relative to the preceding two year period, and prior to the economic shock from the COVID 19 pandemic).[171] A well-designed trade mechanism on highly climate-polluting imports—for example, a Carbon Border Adjustment Mechanism (CBAM)—could go further in supporting a revitalized clean aluminum industry.

A well-designed CBAM for aluminum could serve several of the goals outlined above for revitalization of aluminum manufacturing. It could support retention of U.S. aluminum production and jobs by making it costlier to import emissions-intensive aluminum produced overseas, thereby giving a competitive advantage to cleaner domestic producers. A trade mechanism on aluminum also could support growth in U.S. aluminum jobs by shifting U.S. demand toward relatively cleaner aluminum. Since U.S. aluminum manufacturing is among the cleanest in the world, this demand shift would support growth in domestic aluminum production.

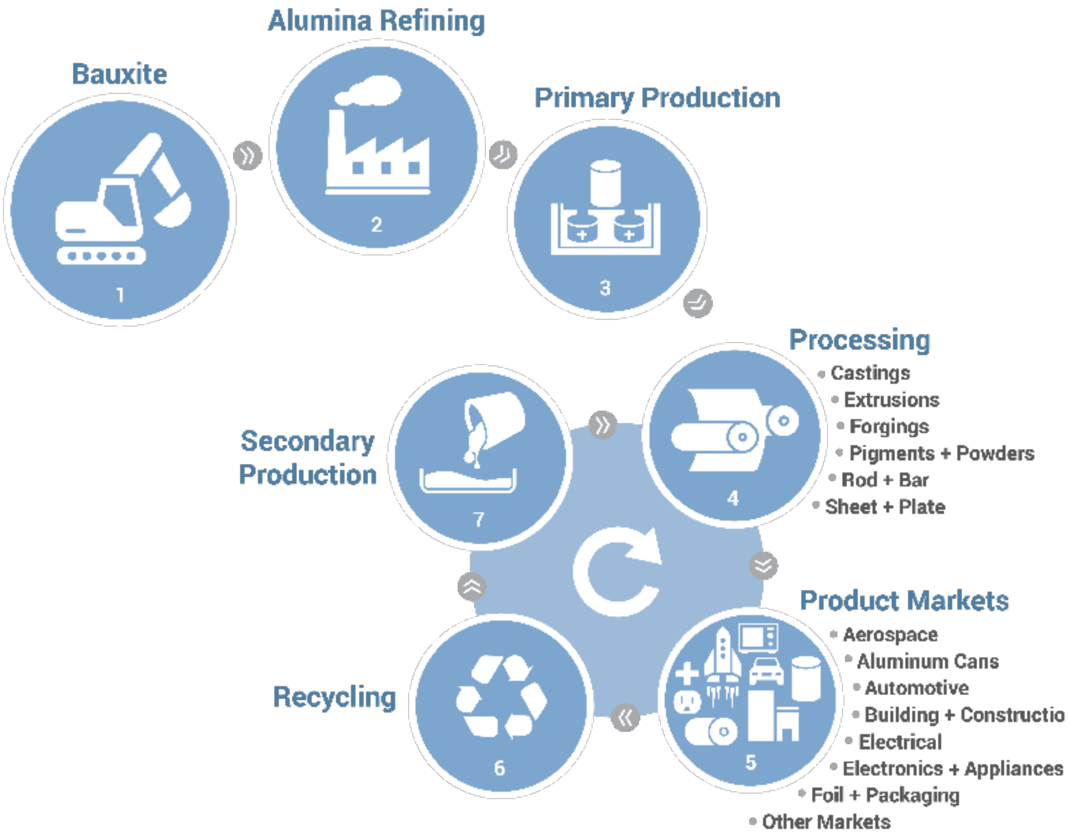
Bipartisan support for CBAM in the U.S. Congress suggests there may be a narrow path for congressional passage of a bill to establish a border fee on emissions-intensive imports, including aluminum. At the same time, Congress already has delegated authority to the Biden Administration to enact such a fee. Under Section 232 of the Trade Expansion Act of 1962, for example, the Biden Administration could establish a CBAM on climate-polluting aluminum imports as a matter of national security, on the basis that high carbon emissions abroad exacerbate the national security threats of climate change.[172] The Pentagon has already detailed the many national security threats from climate change, and courts have historically granted the executive branch broad discretion in determining what constitutes national security for the purposes of Section 232 tariffs.[173] As another example, the Biden Administration also could invoke Section 301 of the Trade Act of 1974 to enact a CBAM on aluminum, on the basis that it is "unjustifiable" for companies abroad to emit heavily and thereby impose additional climate costs on the world.[174]

We now have the opportunity to reverse the decline of U.S. aluminum manufacturing and play a leading role in supplying clean aluminum. If we get the details right, the policy choices we have outlined here could be a game-changer for producing clean aluminum to feed our growing clean economy. Doing so will deliver good jobs to displaced workers, revitalize industrial communities harmed by outsourcing and pollution, and strengthen our fight to secure a livable climate.

Appendix A.
Aluminum Production, Energy Use, and Emissions

Aluminum production involves three main segments: upstream production, downstream production, and secondary (recycled) aluminum.

Figure A.1. The Aluminum Life Cycle



Source: The Aluminum Association, 2021

Upstream Production
The upstream production segment involves sourcing raw material, refining, and smelting (steps one to three in Figure A.1).

Material sourcing: The primary material input for aluminum is mined bauxite, an ore that contains a high proportion of aluminum oxide, the chemical compound used to make aluminum metal. Most of the world's bauxite reserves are concentrated in tropical and subtropical regions, with large reserves in West Africa, Australia, and South America. As bauxite is generally found near the surface of the earth, extraction is done by open pit mining. After clearing forest, vegetation, and topsoil from the land, large bulldozers, or blasting and drilling methods, are used to break apart the rock and clay that covers the bauxite deposits. The loosened bauxite pieces are then transported to local plants for crushing and washing, and then shipped to alumina refineries for further processing.

Alumina refining: Because bauxite also contains a mixture of silica, iron oxides, and titanium dioxide, further refining is required to purify and obtain aluminum oxide (alumina). This involves a four stage chemical process, known as the Bayer process, in which the ore is ground, mixed in a caustic solution, heated in high-pressure containers, dissolved, precipitated out of the solution, and then finally washed and heated at temperatures of 2,000° F to release the water molecules that are bonded to the alumina.[175] The result is a pure alumina, taking the form of a white powder. Alumina refineries are generally sited close to bauxite mines or local ports for efficient transportation of materials. There is only one active refinery in the U.S., which is based in Louisiana and processes bauxite imported from Jamaica.

Smelting (primary production): The alumina is then transported to a smelting facility to be processed into aluminum through an electrolytic reduction process (electrolysis), known as Hall-Héroult process. In this process, alumina is dissolved in a molten bath of electrolyte, primarily consisting of cryolite, held in carbon-lined pots at temperatures of about 1760° F.[176] Then an electric current, which enters the pot through several carbon anodes, reduces the alumina into aluminum and oxygen. The oxygen is deposited into the carbon anode where it burns the carbon, forming carbon dioxide, and the aluminum sinks to the bottom of the pot. The resulting molten aluminum is then typically cast into oblong blocks called ingots, often alloyed with other metals. Generally speaking, producing one ton of aluminum requires two tons of alumina and four tons of bauxite.[177]

While this electrolytic smelting process has remained largely unchanged since the Hall-Héroult process was first developed in the 19th Century, there have been ongoing efforts to develop new technologies to reduce emissions from the process. These are described in greater detail later in this section.

Downstream Production
The ingots are transported to foundries or other processing facilities where they are further processed into semi-fabricated aluminum products, such as sheet, plate foil, extrusions, forgings, coatings, powder, and castings for use in various product markets.

Processing can occur either at vertically integrated facilities that produce primary or secondary aluminum or at facilities that manufacture purchased aluminum and specialize in specific value additions (See Table 4 in Section C for the distribution of U.S. facilities in each segment).

Secondary Production
The secondary production segment involves recycling aluminum scrap. Both new scrap—the residual materials from primary production processes, and old scrap—used materials discarded by consumers (e.g. beverage cans, vehicle components) can be recycled. There are two main stages in the production process: scrap treatment and smelting (shown in step 6 and 7 in Image 3). In the treatment stage, scrap is sorted, processed, and cleaned to separate the aluminum from other metals and contaminants. In the smelting stage, the scrap is melted into molten aluminum in a furnace at temperatures of 1300 to 1400° F.[178] This typically occurs in a reverberatory or rotary furnace, but crucible and electric furnaces are also used for this purpose.[179] At this point, alloyed elements can be added to the molten, and it can be cast into ingots or billets and rolled into sheets or extruded into final products. In 2019, about a third of the global aluminum production was produced from recycled scrap.[180]

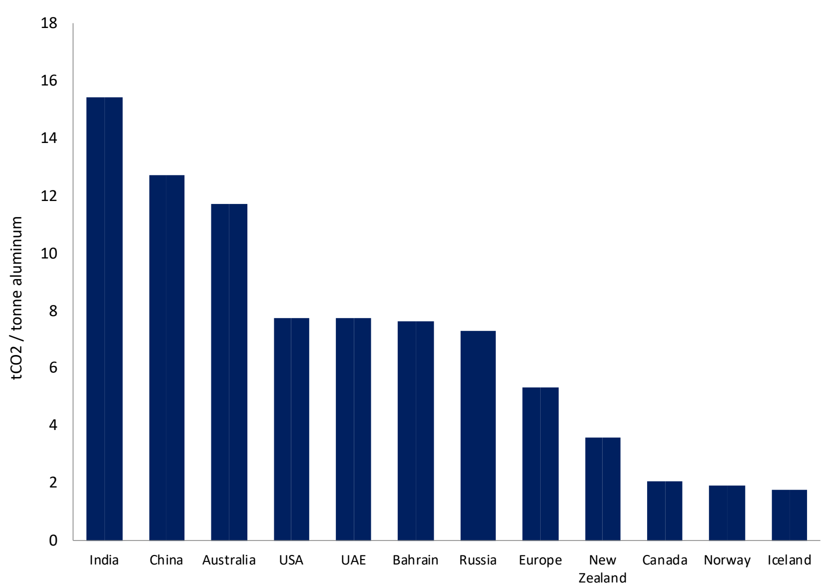
Because aluminum can be remelted over and over again while maintaining its quality, it is virtually impossible to distinguish aluminum products made with scrap from those made from virgin aluminum.[181] Recycling, however, does come with some loss. Each time aluminum is melted, some of the aluminum oxidizes as it is exposed to the air. This forms an aluminum oxide dross which must be skimmed off, representing a loss of material. Up to three percent of the scrap becomes dross in the secondary smelting process.[182] The losses, however, can be recovered if the dross is properly collected and treated.

Some primary producers are also exploring ways to integrate postconsumer scrap into the primary production process as a means to further enhance sustainability of their products.[183] As previously mentioned, increasing secondary production is an important component of reducing sectoral emissions since it is far less emissions-intensive than primary production. However, this must be paired with efforts to reduce climate emissions in primary production since there is insufficient scrap to meet growing demands through secondary production alone, even if recycling rates are maximized.

Energy and Emissions Intensity of Production
Primary aluminum production is a highly energy intensive process. It takes about 211 GJ of energy to produce a single tonne of aluminum, relative to 22.7 GJ per tonne of steel.[184] This high energy use is associated with high GHG emissions, which are generated both as a direct output of various processing activities ("direct" or "process emissions") as well as from producing the electricity consumed during production ("indirect emissions"). While carbon dioxide (CO_2) is the primary GHG emitted during aluminum production, other emitted GHGs include perfluorocarbons (PFCs) such as carbon tetrafluoride (CF_4) and hexafluoroethane (C_2F_6), as well as methane (CH_4) and nitrous oxide (N_2O).[185]

The emissions intensity of aluminum production varies widely across top producing countries (shown in Figure A.2). A recent benchmarking study by Global Efficiency Intelligence (GEI) found that the energy-related emissions intensity (from electricity and fuel use) ranges from about 1.5 to 15.5 t CO_2/t aluminum in 2019. Emissions intensity in the U.S. is slightly above the average for the sample, but significantly lower than the most intensive producers, which are also the world's largest producers. For example, emissions intensity in India, the most intensive producer, is nearly 100% higher than in the U.S. Meanwhile, China's aluminum production is 65% more emissions intensive than the U.S. This variation is largely driven by differences in the power sources for electricity. Emissions intensity is lowest in countries with low-emissions grid-based electricity or onsite (captive) hydropower, like Iceland, Norway, and Canada, and highest in regions that rely on captive coal power, like in India and China, or high emissions grid-based electricity.

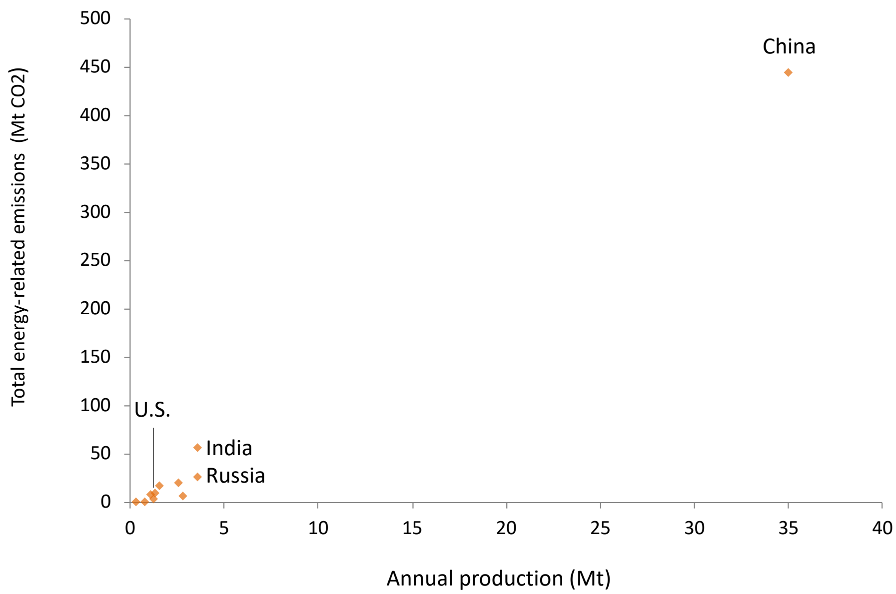
Figure A.2. Energy-related CO_2 intensity of aluminum production in 2019



Data Source: *Global Efficiency Intelligence (GEI), Aluminum Climate Impact An International Benchmarking of Energy and CO2 Intensities, 2022.*

In 2019, energy-related CO_2 emissions from global primary aluminum production generated 663 metric tons of emissions.[186] China's share, 445 metric tons, accounted for 67% of the total energy related CO_2 emissions for the sector. This is disproportionately high given that, in 2019, the country produced just under 60% of global aluminum output.[187] The U.S. produced 8 metric tons of CO_2 emissions from energy use in primary production, accounting for 1.3% of total energy related emissions, while accounting for 1.7% of global production.[188]

Figure A.3 Total annual emissions from primary aluminum production, by top producing countries (2019)



Data sources: *Global Efficiency Intelligence (GEI), Aluminum Climate Impact An International Benchmarking of Energy and CO2 Intensities, 2022 and USGS Aluminum Statistics and Information, Annual Publications, Mineral Yearbook, 2020.*

Reducing emissions from primary aluminum production requires addressing both the direct and indirect emissions. The greatest opportunity lies in indirect emissions given the significant share of emissions they represent. The indirect electricity emissions can be addressed by powering smelters with renewable energy sources. Addressing the direct emissions is more complex. While there are a number of available technologies that can help reduce emissions, challenges related to maturity of the technology and uncertainty about effectiveness, scalability, and financial viability persist.[189]

The most advanced technology with potential to deliver carbon neutrality in electrolytic aluminum production is inert anodes, which eliminate direct greenhouse gasses from traditional aluminum smelting, and have already been tested at commercial scale. Other technologies with potential to reduce emissions include the use of wetted cathodes, hydrogen fuels, mechanical vapor recompression, carbon-capture, utilization, and storage (CCUS).

Appendix B. Air Pollution and Health Impacts from Aluminum Production

Apart from the negative climate impact of GHG emissions, primary aluminum production creates health hazards for its workers, fenceline communities, and the people and animals who live where airborne pollutants eventually get deposited. Both the alumina refining and aluminum smelting process are associated with numerous chemical, physical, biological, psychosocial, and ergonomic hazards.[190]

The aluminum smelting process, for example, emits a number of criteria air pollutants (CAPs) and hazardous air pollutants (HAPs) that are known to cause serious health effects and harm to the environment. Among the pollutants emitted are the cancer causing chemicals asbestos, beryllium, and dioxin, as well as neurotoxic substances like lead and mercury. Other harmful pollutants include particulate matter, like metallic aluminum powder, aluminum oxide, and fluoride, which have been associated with increased incidence of cardiovascular disease and respiratory disorders among aluminum workers.[191] The particular exposures, and related health risks, vary across technology used and the specific step within the production process. For example, Soderberg smelters produce fumes containing high amounts of HAPs, which are released into the workplace when workers are tending the pots. Epidemiological evidence indicates a causal connection between exposures to specific agents used in these operations and certain cancer types. For example, a study of aluminum workers at a Soderberg smelter in British Columbia found significantly increased risk for stomach cancer and bladder cancer, and slightly increased risk for lung cancer, among a cohort of 6,423 men who worked at the smelter for at least three years.[192] These risks were linked to cumulative exposure to coal tar pitch volatiles (CTPV), measured as benzene soluble materials and/or benzo(a) pyrene (BaP).

Cancer is also documented among workers in pre-bake smelters. In one study of former aluminum workers in Badin, North Carolina, men who worked in pre-bake potrooms were found to have higher rates of both bladder and respiratory cancers, as well as mesothelioma.[193] An Australian study of 4,396 workers at two pre-bake smelters found an excess incidence of stomach cancer, mesothelioma, and kidney cancers.[194] There was no evidence, however, of excess risk for lung or bladder cancer or respiratory disease in the population, which the authors attribute to different types and levels of exposure between Soderberg and prebake smelters.

Bauxite mining is a hazardous process as well. The primary airborne hazards include aluminum/alumina and other inhalable dust from bauxite being extracted and broken apart. Chronic obstructive pulmonary disease (COPD) and other chronic respiratory diseases are common as a result of inhalable dust exposure.[195] Other physical hazards include noise, heat and humidity, ergonomics including whole-body vibration, naturally occurring radioactive materials, and UV radiation.

Abuses in Guinea Highlight the Need for Responsible Bauxite Mining

The adverse impacts of bauxite mining for fenceline communities are relatively obscured as little qualitative or quantitative feedback is collected from community members for most of these projects.[196] Like other extractive industries that deplete stock resources, bauxite mining can be an ecologically destructive practice with significant harm to local communities, wildlife, and the life support systems on which they depend. A responsible mining approach—built around the objective of safeguarding the human rights and livelihoods of affected communities; providing safe and healthy work opportunities; and minimizing environmental damage of bauxite extraction—is essential for mitigating the potential harm of this industry.[197]

The global bauxite mining industry is fraught with examples of widespread environmental and social harm. Negative impacts include, among others:

- biophysical impacts to the land like erosion and surface run-off from land clearing, increased vegetation loss, deforestation, and biodiversity loss, reduced soil nutrients and soil fertility;
- resource contamination impacts like air pollution from bauxite dust including airborne particulate matter; increased concentration of heavy metals in sediments;
- chemical leaching into water sources;
- socioeconomic impacts like forced displacement of local communities, land dispossession, loss of local livelihoods, poor working conditions for miners;
- and lack of transparency into the industry.

Bauxite mining in the Boké region of western Guinea, provides an illustrative example of the contemporary challenges within the industry. There, negative impacts of bauxite mining have permanently disrupted the social and cultural fabric of several communities. In the case of the Compagnie des Bauxites de Guinée's (CBG) mining operations in Boké, these activities are associated with documented human rights violations.[198] In 2016, CBG received $200 million from the International Finance Corporation and $150 million from the U.S. government's Overseas Private Investment Corporation, now known as the U.S. International Development Finance Corporation, to expand mining activities in the Boké.[199] This expansion has been associated with continued land dispossession of local communities, who have lost ancestral land, agricultural land, and residential land for mining activities, in many cases without consent.[200]

A 2018 social and environmental audit of the mine expansion found that while CBG committed to providing compensation for land it acquired in its resettlement policy framework, the company has not compensated landholders for loss of land in practice.[201] Indeed, at least seven communities have reported not receiving compensation for land that the company took from them.[202] Those who were offered compensation were routinely under compensated, and very few protections were proposed or implemented to reduce exposure to health risks including those from dynamite blasting and dust pollution.[203] The project has also caused irreversible damage to the soil, polluted water sources, and endangered wildlife.[204] Community leaders from 19 villages have reported that mining has reduced the flow and quality of local water sources that people depend on for cooking, drinking, and washing.[205]

While bauxite mining is highly profitable for companies like CBG, and an important source of tax revenue for the Guinean government, very few community members in the Boké region benefit from the mining operations. Community members are rarely trained to work in the mines, and community benefit agreements are not a common partnership practice.[206] The insufficient benefits paired with high social and environmental burdens from the mining activities are a source of widespread discontent among local populations. In 2017, for example, thousands of local residents engaged in large-scale demonstrations against the mining operations. Several young community members were killed by private security forces during the protests.[207, 208] Community discontent is also expressed more formally. In 2019, for example, community members from 13 local villages filed a complaint to the IFC's Compliance Advisor Ombudsman with claims that they have not been accorded their entitlements and protections under Guinean law and the IFC Performance Standards.[209] It wasn't until October 21, 2021 that representatives from these communities were able to come to an agreement with CBG on the use of explosives in the region.[210]

After minimal processing in Guinea, the crude bauxite from the CBG mine is exported to refineries around the world, including in China, North America, and Europe.[211, 212] In the United States, aluminum produced from CBG bauxite is used in a variety of familiar products. These brands include Mercedes-Benz, Volvo, Campbell's Soup, Coca Cola, and many other companies.

Camara's Story
Maciré Camara's (name changed to protect identity) story, as documented in a recent report by Human Rights Watch, is a prime example of the impacts on families when environmental justice and human rights practices are not established prior to the beginning of a project.[213] Prior to La Société Minière de Boké (SMB—Guinea's largest bauxite mining company) creating an industrial port in Diakhabia in 2016, Camara and her family were able to farm for food and income, planting rice and other crops on the fertile land near the Rio Nunez River. She could just make ends meet to feed her children three meals a day, earning up to 1.5 million Guinean francs (US$152) per week during a good harvest season and taking home around 10 million Guinean francs per year ($1,010).

The SMB began clearing hundreds of hectares of land, resulting in the disruption of the local ecological and environmental fabric of the community. The Camaras, as well as dozens of other households, lost their land. She was compensated only 4 million Guinean francs ($406) in 2016, a one-off payment that could not replace the land that her family depended on for their livelihood, or even provide enough food and resources to cover a year of lost wages. Four years later, she's been able to find a half hectare of land to farm on, and she and her family make ~3 million Guinean francs ($303) per year as of December 2020, a roughly 70% loss due to the seizure of land and displacement. Since construction ceased, SMB has been shipping millions of tons of bauxite to China Hongqiao's refineries, the world's largest aluminum producer, and little justice has been obtained for these communities.

The Role of Responsible Domestic Mining
The case in Guinea indicates the need for responsible domestic mining.

A number of the minerals needed for clean energy (including aluminum) are primarily extracted in countries that are not U.S. allies and often under shockingly poor environmental and labor conditions. Even as the United States joins other nations in rapidly deploying clean technology, our ability to manufacture these technologies is not keeping pace, or we are dependent on unfriendly nations for critical subcomponents or technology. It is not an understatement to say that the United States' dependence on metals and minerals from unfriendly countries compromises our national security and jeopardizes our ability to meet our climate goals.

The war in Ukraine is just the latest example of this risk. Russia controls a significant share of the world's aluminum, palladium, nickel, and cobalt, among other minerals. While economic sanctions do not target Russia's mining industry, many metal and mineral purchasers are voluntarily avoiding Russia, creating a squeeze in an already competitive market. This conflict is challenging an already strained supply chain and increasing mineral and metal prices. This directly jeopardizes our ability to build a cleaner and more secure energy future.

Responsible domestic mining is key to revitalizing U.S. manufacturing. Manufacturers need to see stable and long-term signals to locate clean energy technology manufacturing facilities in the United States. Securing a robust, vertical supply chain of minerals and materials domestically can serve as one such signal, and provide an inducement for companies to invest in domestic manufacturing. Conversely, if the current status quo continues, it creates an enormous supply chain risk for U.S. manufacturers, endangering their ability to meet the growing demand for clean technologies.

At present, the United States lacks a comprehensive strategy for responsibly mining these materials domestically, for developing secure and sustainable supply chains for their incorporation into the clean energy economy, and for leading by example—in cooperation with other nations that seek to mine and develop these resources in safe, environmentally, and socially responsible ways. As outlined in BGA's Manufacturing Agenda, responsible mining practices reflect three key principles: 1) strong corporate accountability 2) leaving a positive project legacy, and, 3) meaningful social and environmental obligation to the local community and region.[214] Responsible mining practices ensure that economic benefits are shared with workers and communities, prioritize community and worker safety, actively engage with stakeholders to obtain social license, and minimize environmental impact. Responsible domestic mining would help us build out clean technology supply chains here in North America, and serve as an anchor for reshoring and retaining domestic manufacturing.

Appendix C.
U.S. Aluminum Facilities

Table C.1 Primary Aluminum Smelters Closed (or idled) since 1995

Company	Facility	Capacity (thousand metric tons)
Alcoa	Alcoa, TN	215
Alcoa	Badin, NC	120
Alcoa	Ferndale, WA (Intalco)	279
Alcoa	Frederick, MD (Eastalco)	195
Alcoa	Massena East, NY (St. Lawrence)	130
Alcoa	Rockdale, TX	267
Alcoa	Wenatchee, WA	184
Century Aluminum	Ravenswood, WV	170
Columbia Falls Aluminum	Columbia Falls, MT	168
Goldendale Aluminum	Goldendale, WA	160
Kaiser Aluminum & Chemical Corp.	Mead, WA (Spokane)	200
Kaiser Aluminum & Chemical Corp.	Tacoma, WA	73
Northwest Aluminum Corp.	The Dalles, OR	82
Niagara Worldwide LLC	Hannibal, OH	271
Ravenswood Aluminum Corp.	Ravenswood, WV	170
Reynolds Metals Co.	Longview, WA	204
Reynolds Metals Co.	Troutdale, OR	121
Vanalco Inc.	Vancouver, WA	116

Source: *USGS*

Table C.2 Operating & Curtailed Primary Aluminum Facilities

Company	Facility	Established	Capacity (mt)	Employment	Electricity source	Notes
Alcoa	Evansville, IN (Warrick)	1960	269,000	550	An onsite coal fired power plant generates all of the power used by the Warrick smelting and rolling facilities.	
Alcoa	Ferndale, WA (Intalco) [Curtailed since 2020]	1966	279,000	(Skeleton crew)	Prior to curtailment the facility sourced from Bonneville Power Administration (BPA) under a long-term contract.	The facility has been fully curtailed since April 2020. Recent negotiations to restart the facility have failed over an inability to get affordable clean power.
Alcoa	Massena, NY	1902	130,000	450	The facility receives power from the New York Power Authority (NYPA) pursuant to a contract that expires in March 2026. Hydroelectricity accounts for 99 percent of purchased energy consumed (as of 2021).	Massena West is active (the Massena East Smelter permanently closed in 2014)
Century Aluminum	Hawesville, KY [Temporarily curtailed]	1970	252,000	~525	The facility has a power supply agreement with Kenergy Corporation. Kenergy and two other distribution cooperatives own the generation and transmission cooperative, Big Rivers Electric Corporation. The fuel mix for Big Rivers Electric, according to reported generating capacity, is: 40.1% natural gas (sourced from a recent coal-to-gas conversion of one of its generating plants), 37.4% coal, and 16% hydro.	On June 22, 2022, Century Aluminum announced that it would temporarily idle the smelter at this facility due to rising energy costs. The smelter began the idling process on June 27th. Four of the five potlines at this facility are specially configured and operated to produce high purity primary aluminum required for the defense, aerospace and electrical industries. It is the only domestic producer of high purity aluminum.

Century Aluminum	Mount Holly, SC	1980	231,000	~330	Electricity is supplied from Santee Cooper. In 2019, Santee Cooper's electricity by source was: 50% coal; 21% natural gas (boiler/ combined cycle); 15% nuclear; 10% natural gas/ oil from combustion turbines; 3% hydro	
Century Aluminum	Sebree, KY	1973	218,000	~625	The facility has a power supply agreement with Kenergy Corporation. Kenergy and two other distribution cooperatives own the generation and transmission cooperative, Big Rivers Electric Corporation. The fuel mix for Big Rivers Electric, according to reported generating capacity, is: 40.1% natural gas (sourced from a recent coal-to-gas conversion of one of its generating plants), 37.4% coal, and 16% hydro.	
Magnitude 7 Metals LLC	New Madrid, MO	Late 1960s	263,000	~515	Electricity is sourced through an agreement with Associated Electric Cooperative, Inc. (AECI). In 2021, power sources for the AECI were 47% coal, 28% gas, 13% wind, 5% hydro, 7% purchases.	

Sources: *Company Financial Statements*, *Company Press Releases*, *Company Websites*

Table C.3 Economic Contribution of the Aluminum Industry: States with Primary Smelters and Top 5 for Secondary Jobs

		Direct	Supplier	Induced	Total
Ohio +	Jobs	16,588	21,164	24,018	61,770
	Wages	$1.35 B	$1.63 B	$1.41 B	$4.39 B
	Impact	$6.74 B	$4.87 B	$3.86 B	$15.46 B
Kentucky *+	Jobs	10,527	14,264	14,717	39,508
	Wages	$1.02 B	$1.12 B	$0.93 B	$3.08 B
	Impact	$6.76 B	$3.66 B	$2.74 B	$13.17 B
Indiana *+	Jobs	10,098	12,855	14,141	37,094
	Wages	$0.91 B	$1.02 B	$0.89 B	$2.82 B
	Impact	$5.29 B	$3.28 B	$2.51 B	$11.09 B
Missouri *	Jobs	6,251	7,239	8,508	21,998
	Wages	$0.47 B	$0.54 B	$0.47 B	$1.48 B
	Impact	$2.45 B	$1.62 B	$1.35 B	$5.42 B
New York *+	Jobs	4,717	8,088	8,246	21,051
	Wages	$0.41 B	$0.88 B	$0.70 B	$1.99 B
	Impact	$2.72 B	$2.54 B	$2.17 B	$7.42 B
North Carolina +	Jobs	3,520	4,357	4,691	12,568
	Wages	$0.26 B	$0.32 B	$0.27 B	$0.86 B
	Impact	$1.82 B	$1.19 B	$1.04 B	$4.05 B
South Carolina *	Jobs	2,181	3,223	3,279	8,683
	Wages	$0.21 B	$0.25 B	$0.20 B	$0.67 B
	Impact	$1.17 B	$0.89 B	$0.63 B	$2.69 B

Notes: * indicates primary smelter; + indicates top state for secondary jobs
The "direct" figures account for all segments of the aluminum industry, as outlined in Table 5.
Data source: *Aluminum Association. U.S. Aluminum's Economic Impact. 2022*

Appendix D. Key Drivers Affecting U.S. Production

Global Market Prices: As an exchange-traded commodity, global aluminum prices are determined by global supply and demand trends for aluminum and its primary inputs, bauxite and alumina. The London Metal Exchange (LME), the world's largest exchange for metals, serves as a barometer of supply and demand for metals, including aluminum, and sets official prices. The metal industry uses the LME price of aluminum as a basis price, regardless of where aluminum is produced or sold. This means that the U.S. aluminum market is highly impacted by the LME prices and the volume of global production that they reflect.

This helps explain the decline in U.S. primary aluminum production and capacity in recent decades. As China and other leading producers expanded and maintained excess capacity beginning in the early 2000s, the world markets were flooded with surplus aluminum and the global prices crashed. Between 2007 and 2016, China's output of primary aluminum increased by 153% and the LME market price of aluminum fell 39%.[215] Given the high fixed costs of the industry, domestic producers struggled to weather this sustained price collapse, and over the same period, primary aluminum production in the U.S. dropped by 38%.[216]

Production Costs: Competitiveness in the global primary aluminum market is largely driven by production costs, particularly electricity which can account for up to 40% of the cost of primary production.[217] Electricity costs largely depend on the energy type (hydropower versus fossil-fuel) and the rates negotiated with electric power suppliers. The relatively high cost of grid-sourced electricity in the United States is a significant disadvantage for the domestic industry.[218] With a few exceptions, U.S. aluminum producers purchase electricity from the grid or from wholesale power markets, rather than relying on captive power sources; and, they tend to negotiate higher rates than global competitors.[219] U.S. smelters often cite high power rates as a barrier to competing globally and continuing operations.[220] This, for example, drove the temporary closure of the Hawesville, KY smelter in the summer of 2022. Similarly, securing a reliable and affordable energy supply is the main barrier to the ongoing efforts to reopen the Ferndale, WA smelter.

Several companies, including Alcoa and Century, have located newer smelting facilities close to low-cost electricity sources outside of the United States.[221] This gives countries with the ability to source low-cost energy or with significant energy reserves—like Canada, Iceland, Norway, Russia, Gulf States, and China—a major competitive advantage for production of primary aluminum.

Public Policy: Government policy and programs significantly shape the global aluminum industry. These interventions, designed to support domestic aluminum industries, mostly impact production costs for primary aluminum.[222] Common mechanisms used include: the provision of grants or low cost electricity to incentivize production; implementation of export tariffs to maintain a domestic supply and encourage production of value-added goods; and offering rebates on value-added taxes (VATs) to encourage exports, among others.

Historically, federal policy has played an active role in supporting the growth of the domestic aluminum industry in the U.S. For example, as previously mentioned, in the late 1930s the government encouraged private companies to invest in new smelters in Washington and Oregon with the promise of low-cost surplus electricity from large-scale federal hydropower projects under the Bonneville Power Administration (BPA). Access to low-cost electricity from BPA was a key driving factor in the expansion of the region's industry. As World War II waged on, the government sought out other opportunities to meet the growing need for aluminum for defense efforts. This included deploying the federally funded Defense Plant Corporation (DPC) to build additional facilities to boost production, which would be operated by private companies (and then sold when the war ended).[223] Government support for the industry continued into the early 1950s in the form of numerous financial incentives to aluminum manufacturers under the Defense Production Act (DPA). These and other federal policy initiatives have been critical in building the modern aluminum industry in the United States.

Like the United States once did, China has been implementing a number of policies to encourage development of its aluminum production since the early 2000s. Among its interventions, China has provided massive subsidization to the industry, delivered through concessional financing, tax, and environmental regulatory forbearance, and access to inputs like bauxite ore and electricity at below-market prices.[224, 225, 226] The country has also taken trade measures to restrict the export of primary aluminum while subsidizing semi-finished processed aluminum products with export tax rebates.[227, 228] Other countries—including India, Russia, Bahrain, Oman, Qatar, and Saudi Arabia—have used similar types of government support to dramatically expand capacity.[229]

Some industry and policy experts view these policies as unfair subsidies that undermine fair competition in market economies for aluminum, diminishing the ability of companies in the United States and other countries to compete in both domestic and export markets.[230] The United States has taken some steps to counter these policies. For example, in 2017, the Obama administration filed a complaint with the World Trade Organization maintaining that China's use of concessional financing and subsidized energy was undercutting global prices and artificially expanding the country's market share. The European Union, Japan, and Mexico also called on the body to address the measures that contribute to China's industrial overcapacity.[231] The United States took a step further in 2018 when it imposed a 10% tariff on aluminum imports, with exemptions for Canada and Mexico, under Section 232 of the Trade Expansion Act of 1962. The step was intended to protect the domestic industry in the name of national security. As a recent report by the EPI documents, this import measure had a significant impact in helping U.S. aluminum producers rebound.[232]

Availability of Scrap: Competitiveness in the secondary aluminum market is namely shaped by the availability of scrap, the primary input for production. Scrap availability is determined by a number of factors, including the age of the domestic aluminum industry, the scrap recycling infrastructure, and the relative development of a country's economy.[233] The United States fares well on all of these fronts. With a robust and mature end market and a strong culture of aluminum recycling, the United States is the world's leading generator of scrap.[234] This has helped the country maintain its status as the largest producer of secondary aluminum.

Continued Impacts of the COVID-19 Pandemic: In the United States, the ongoing COVID-19 pandemic has taken the lives of over 1.07 million people and left an additional 7% of the population suffering with symptoms of long-COVID.[235, 236] On top of this tragic toll on human life and wellness, the pandemic has had a substantial impact on the workforce. It is estimated that coronavirus illnesses have reduced the labor force by about 500,000 people, while leaving up to 4 million workers out of work due to long-COVID.[237, 238] Among the many negative effects of this continued crisis has been the exacerbation of long-standing disparities, as marginalized populations—particularly Black and Indigenous communities—continue to face disproportionate health risks, job losses, and ensuing economic insecurity.[239, 240, 241, 242]

The pandemic has also had a dynamic impact on the aluminum market. The pandemic-induced economic downturn impacted nearly every industrial sector, including those that rely heavily on aluminum (automotive, construction, and aerospace). Many production facilities that consume aluminum, including aerospace and automotive manufacturers, paused for several months and depressed demand. This led to a substantial downturn in the global consumption of aluminum, and a significant drop in prices.[243] While domestic primary smelters were exempted from lockdown orders, a number of secondary smelters, extruders, and rolling mills were forced to shut down or decrease production in response to the COVID-19 pandemic.[244] As a result, annual primary aluminum production in the United States dropped by over 7%, and secondary by 14%, while the average annual U.S. market price fell by 11%.[245, 246] Primary production continued to fall in 2021 (by an additional 13%), while secondary production began to recover, with 5% growth that year.

As of 2022, demand has bounced back significantly from the pandemic lows, and now the supply is struggling to keep pace. Delays, shortages, and other supply chain disruptions are increasingly common. Manufacturers of aluminum cans have been feeling an outsized impact of the supply/demand imbalance, which has caused a spike in container prices.[247] While the post-lockdown rebound has played a large role in demand outstripping supply, other factors are at play too. For example, China curtailed aluminum production as part of its plan to reduce carbon emissions and European producers have curtailed production in the face of surging natural gas prices.[248] Sanctions placed on Russian companies and commodities, in response to the country's invasion of Ukraine, have also contributed to the recent price hikes.[249]

Appendix E. Top Importers/Exporters, and U.S. Market Concentration

U.S. Market Concentration

The primary segment of the U.S. aluminum industry has historically been the most concentrated segment of the industry.[250] The segment has continued on a trend of consolidation as underperforming companies have exited the primary market.[251] The industry as a whole, however, maintains moderate levels of market share concentration. In 2022, the five largest manufacturers (see Table E2) in the industry accounted for about 40.2% of the market share. Industry analysts expect the ongoing trend of consolidation to continue over the next five years, where leading companies will gain increasing market share as they continue to outperform competition or acquire smaller firms.[252]

Table E.1 Top Importers and Exporters by Value (USD), 2020

Country	Net Imports (USD)	Country	Net Exports (USD)
USA	9.68B	China	14.46B
Japan	4.31B	Canada	4.60B
Mexico	4.16B	Russia	4.40B
South Korea	2.14B	UAE	3.43B
United Kingdom	1.96B	Norway	2.36B
Vietnam	1.83B	India	1.63B
France	1.57B	Iceland	1.50B
Thailand	1.36B	South Africa	1.15B
Malaysia	1.12B	Qatar	1.06B
Brazil	0.97B	Australia	1.02B

Data source: UN COMTRADE

Table E.2. Major Companies in the U.S. Aluminum Industry

	U.S. Market Share	Headquarters	Description	Notes
Novelis Inc	14.2 %	Atlanta	Operates over 30 facilities across 10 countries, including 12 with recycling operations. Specializes in aluminum-rolled products for food and beverage packaging, transportation equipment, consumer electronics, construction, and other industrial applications	Indirect subsidiary of India-based Hindalco industries, one of the world's largest aluminum-rolling companies. In 2020, Novelis acquired Aleris Corporation, a global supplier of rolled aluminum.
Arconic Inc	11.2%	Pittsburgh PA	Operates more than 25 manufacturing locations around the world, including 14 in the United States. Produces sheet, plate, extrusions, and architectural products	Formed in November 2016 after the split of Alcoa Inc. into two independent companies: Alcoa Corporation and Arconic.
Constellium NV	5.8%	Paris, France	Operates 27 manufacturing facilities across Europe, North America, and China. Produces high value-added aluminum products for the packaging, automotive, and aerospace markets	Founded in 2010, when the Rio Tinto Group transferred assets associated with engineered aluminum product operations into a separate company.
Kaiser Aluminum Corporation	5.5%	Franklin, TN	The company operates 13 plants across North America, 11 of which are in the United States. It produces fabricated aluminum products for several industrial, aerospace, engineering, and automotive applications	
Alcoa Corp	3.6%	Pittsburgh PA	Operates numerous global manufacturing facilities across three business units: bauxite, alumina, and aluminum. The bauxite and alumina segments focus on the mining and refining of bauxite into alumina for sale directly and indirectly to smelter customers and industrial end users. The aluminum segment produces primary aluminum (from internally sourced alumina) for downstream markets	Alcoa Corporation (Alcoa) was formed in November 2016 after the planned split of Alcoa Inc. into two independent companies: Alcoa and Arconic Inc (Arconic).

Source IBIS, IBISWorld Industry Report 33131 Aluminum Manufacturing in the US, 2022.

Endnotes

1 International Energy Agency, *Mineral Requirements for Clean Energy Transitions*, 2022. Available online: **https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions/mineral-requirements-for-clean-energy-transitions**

2 U.S. Geological Survey (USGS), Aluminum Statistics and Information: Annual Publications - Minerals Yearbook 1990-2020. Available online: **https://www.usgs.gov/centers/national-minerals-information-center/aluminum-statistics-and-information**

3 U.S. Bureau of Labor Statistics (BLS), Quarterly Census of Employment and Wages - QCEW NAICS-Based Data Files, 1990-2020. Available online: **https://www.bls.gov/cew/downloadable-data-files.htm**

4 BLS, May 2021 National Industry-Specific Occupational Employment and Wage Estimates: NAICS 331300 – Alumina and Aluminum Production and Processing, 2021. Available online: **https://www.bls.gov/oes/current/naics4_331300.htm**

5 U.S. Census Bureau, Educational Attainment in the United States: 2020, Current Population Survey, 2020 Annual Social and Economic Supplement, 2021. Available online: **https://www.census.gov/data/tables/2020/demo/educational-attainment/cps-detailed-tables.html**

6 International Monetary Fund (IMF), *Manufacturing jobs and inequality: Why is the U.S. experience different?* 2019. Available online: **https://www.imf.org/en/Publications/WP/Issues/2019/09/13/Manufacturing-Jobs-and-Inequality-Why-is-the-U-S-47001**

7 USGS, Aluminum Statistics and Information: Annual Publications - Minerals Yearbook 1990-2020. Available online: **https://www.usgs.gov/centers/national-minerals-information-center/aluminum-statistics-and-information**

8 Global Efficiency Intelligence (GEI), *Aluminum Climate Impact: An International Benchmarking of Energy and CO2 Intensities*, 2022. Available online: **https://static1.squarespace.com/static/5877e86f9de4bb8bce72105c/t/624d11ab5a37a4341fd85a6e/1649217981897/Aluminum+benchmarking+report-+Feb2022+rev2.pdf**

9 USGS, *Mineral Commodity Summaries: Aluminum*, 2022. Available online: **https://pubs.usgs.gov/periodicals/mcs2022/mcs2022-aluminum.pdf**

10 For iron and steel, 100% of materials must be U.S. made to qualify.

11 Another $500 million is available under the Infrastructure Investment and Jobs Act for demonstration projects to help reduce emissions at industrial facilities, potentially including aluminum smelters.

12 The Defense Production Act is a versatile policy toolbox that the Biden administration has started to use to support manufacturing growth for critical clean energy goods. BlueGreen Alliance, "The Defense Production Act: A Toolbox to Spur Clean Manufacturing," 2022. Available online: **https://www.bluegreenalliance.org/resources/the-defense-production-act-a-toolbox-to-spur-clean-manufacturing/**

13 Economic Policy Institute (EPI), *Botched policy responses to globalization have decimated manufacturing employment with often overlooked costs for Black, Brown, and other workers of color.* 2022. Available online: **https://files.epi.org/uploads/239189.pdf**

14 International Monetary Fund (IMF), *Manufacturing jobs and inequality: Why is the U.S. experience different?* 2019. Available online: **https://www.imf.org/en/Publications/WP/Issues/2019/09/13/Manufacturing-Jobs-and-Inequality-Why-is-the-U-S-47001**

15 Economic Policy Institute (EPI), *Botched policy responses to globalization have decimated manufacturing employment with often overlooked costs for Black, Brown, and other workers of color*. 2022. Available online: **https://files.epi.org/uploads/239189.pdf**

16 Alliance for American Manufacturing, *Unmade in America: Industrial Flight and the Decline of Black Communities*, 2016. Available online: **https://s3-us-west-2.amazonaws.com/aamweb/uploads/research-pdf/UnmadeInAmerica.pdf**

17 Global Efficiency Intelligence (GEI), *Steel Climate Impact: An International Benchmarking of Energy and CO2 Intensities*, April 2022. Available online: **https://www.globalefficiencyintel.com/steel-climate-impact-international-benchmarking-energy-co2-intensities**

18 International Monetary Fund (IMF), *Manufacturing jobs and inequality: Why is the U.S. experience different?* 2019. Available online: **https://www.imf.org/en/Publications/WP/Issues/2019/09/13/Manufacturing-Jobs-and-Inequality-Why-is-the-U-S-47001**

19 EPI, *Botched policy responses to globalization have decimated manufacturing employment with often overlooked costs for Black, Brown, and other workers of color*, 2022. Available online: **https://files.epi.org/uploads/239189.pdf**

20 Global Efficiency Intelligence (GEI), *Steel Climate Impact: An International Benchmarking of Energy and CO2 Intensities*, April 2022. Available online: **https://www.globalefficiencyintel.com/steel-climate-impact-international-benchmarking-energy-co2-intensities**

21 Materials and Technology, *Aluminum: Metal of Choice*, 2012. Available online: **http://mail.imt.si/izvodi/mit133/gandara.pdf**

22 The World Bank Group, *Minerals for Climate Action: The Mineral Intensity of the Clean Energy Transition*, 2020. Available online: **https://uploads-ssl.webflow.com/6008a2327223f98143f46e18/6062fc59ae7665175ddf19ec_MineralsforClimateActionTheMineralIntensityoftheCleanEnergyTransition-compressed.pdf**

23 CRU International Ltd. *Opportunities for Aluminium in a Post-Covid Economy*, 2022. Available online: **https://international-aluminium.org/wp-content/uploads/2022/03/CRU-Opportunities-for-aluminium-in-a-post-Covid-economy-Report.pdf**

24 The World Bank Group, *Minerals for Climate Action: The Mineral Intensity of the Clean Energy Transition*, 2020. Available online: **https://uploads-ssl.webflow.com/6008a2327223f98143f46e18/6062fc59ae7665175ddf19ec_MineralsforClimateActionTheMineralIntensityoftheCleanEnergyTransition-compressed.pdf**

25 The Aluminum Association, Electrical. Available online: **https://www.aluminum.org/electrical**

26 Reuters, "Auto Parts Makers Shine Spotlight on Aluminium's Role in Electric Vehicles," July 27, 2020. Available online: **https://www.reuters.com/article/us-aluminium-electric-autos-analysis/auto-parts-makers-shine-spotlight-on-aluminiums-role-in-electric-vehicles-idUSKCN24S1QM**

27 International Renewable Energy Agency (IRENA), *Critical Materials for the Energy Transition*, 2021. Available online: **https://irena.org/-/media/Files/IRENA/Agency/Technical-Papers/IRENA_Critical_Materials_2021.pdf**
Elements, "The Key Minerals in EV Batteries," May 2, 2022. Available online: https://elements.visualcapitalist.com/the-key-minerals-in-an-ev-battery/

28 CRU International Ltd, *Opportunities for Aluminium in a Post-Covid Economy*, 2022. Available online: **https://international-aluminium.org/wp-content/uploads/2022/03/CRU-Opportunities-for-aluminium-in-a-post-Covid-economy-Report.pdf**

29 Ducker Frontier, *2020 North America Light Vehicle Aluminum Content and Outlook*, 2020. Available online: **https://drivealuminum.org/wp-content/uploads/2022/05/DuckerFrontier-Aluminum-Association-2020-Content-Study-Summary-Report-FINAL.pdf**

30 US Bureau of Labor Statistics (BLS), May 2021 National Industry-Specific Occupational Employment and Wage Estimates: NAICS 331300 – Alumina and Aluminum Production and Processing. Available online: **https://www.bls.gov/oes/current/naics4_331300.htm**

31 BLS, May 2021 National Industry-Specific Occupational Employment and Wage Estimates. Available online: **https://www.bls.gov/oes/current/oessrci.htm#44-45**

32 United States Census Bureau, Current Population Survey (CPS). Available online: **https://www.census.gov/programs-surveys/cps.htm**

33 17.9% were union members and an additional 2.2% are covered by covered by a collective bargaining unit. Unioinstats.com, Union Membership, Coverage, and Earnings from the CPS, 2022. **http://unionstats.com/**

34 USGS, Aluminum Statistics and Information: Annual Publications - Minerals Yearbook 1990-2020. Available online: https://www.usgs.gov/centers/national-minerals-information-center/aluminum-statistics-and-informatio

35 U.S. BLS, Quarterly Census of Employment and Wages - QCEW NAICS-Based Data Files, 1990-2020. Available online: https://www.bls.gov/cew/downloadable-data-files.htm

36 Century Aluminum. "Century Aluminum to Temporarily Idle Its Hawesville Smelter Due to Soaring Energy Prices; Issues WARN Notice to Employees." June 22, 2022. Available online: 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

37 Economic Policy Institute (EPI), *Aluminum producing and consuming industries have thrived under U.S. Section 232 import measures*. 2021. Available online: https://files.epi.org/uploads/227032.pdf

38 IAI, *Aluminium Sector Greenhouse Gas Pathways to 2050 Position Paper*, 2021. Available online:https://international-aluminium.org/wp-content/uploads/2021/09/IAI-GHG-Pathways-September-2021-1.zip

39 ibid.

40 ibid.

41 ibid.

42 ibid.

43 ibid.

44 GEI, *Aluminum Climate Impact - An International Benchmarking of Energy and CO2 Intensities*, 2022. Available online: https://static1.squarespace.com/static/5877e86f9de4bb8bce72105c/t/624d11ab5a37a4341fd85a6e/1649217981897/Aluminum+benchmarking+report-+Feb2022+rev2.pdf

45 IAI, *Aluminium Sector Greenhouse Gas Pathways to 2050 Position Paper*, 2021. Available online: https://international-aluminium.org/wp-content/uploads/2021/09/IAI-GHG-Pathways-September-2021-1.zip

46 CM Group, *An Initial Assessment of the Impact of the Covid-19 Pandemic on Global Aluminium Demand*, 2020. Available online: https://international-aluminium.org/wp-content/uploads/2020/05/initial_assessment_of_the_impact_of_the_covid-19_.pdf

47 CRU International Ltd, *Opportunities for Aluminium in a Post-Covid Economy*, 2022. Available online: https://international-aluminium.org/wp-content/uploads/2022/03/CRU-Opportunities-for-aluminium-in-a-post-Covid-economy-Report.pdf

48 ibid.

49 CM Group, *An Assessment of Global Megatrends and Regional and Market Sector Growth Outlook for Aluminium Demand*, 2020. Available online: https://international-aluminium.org/wp-content/uploads/2021/03/cm_2050_outlook_for_al_demand_20200528_4wycD18.pdf; World Economic Forum (WEF), *Aluminium for Climate: Exploring Pathways to Decarbonize the Aluminium Industry*, 2020. Available online: https://www3.weforum.org/docs/WEF_Aluminium_for_Climate_2020.pdf

50 World Bank Group, *Minerals for Climate Action: The Mineral Intensity of the Clean Energy Transition*, 2020. Available online: https://uploads-ssl.webflow.com/6008a2327223f98143f46e18/6062fc59ae7665175ddf19ec_MineralsforClimateActionTheMineralIntensityoftheCleanEnergyTransition-compressed.pdf

51 CRU International Ltd, *Opportunities for Aluminium in a Post-Covid Economy*, 2022. Available online: https://international-aluminium.org/wp-content/uploads/2022/03/CRU-Opportunities-for-aluminium-in-a-post-Covid-economy-Report.pdf

52 Ducker Frontier, *2020 North America Light Vehicle Aluminum Content and Outlook*, 2020. Available online: https://drivealuminum.org/wp-content/uploads/2022/05/DuckerFrontier-Aluminum-Association-2020-Content-Study-Summary-Report-FINAL.pdf; IEA, *Net Zero by 2050: A Roadmap for the Global Energy Sector*, 2021. Available online: https://iea.blob.core.windows.net/assets/deebef5d-0c34-4539-9d0c-10b13d840027/NetZeroby2050-ARoadmapfortheGlobalEnergySector_CORR.pdf

53 CRU International Ltd, *Opportunities for Aluminium in a Post-Covid Economy*, 2022. Available online: https://international-aluminium.org/wp-content/uploads/2022/03/CRU-Opportunities-for-aluminium-in-a-post-Covid-economy-Report.pdf

54 ibid.

55 IEA, *Net Zero by 2050: A Roadmap for the Global Energy Sector*, 2021. Available online: https://iea.blob.core.windows.net/assets/deebef5d-0c34-4539-9d0c-10b13d840027/NetZeroby2050-ARoadmapfortheGlobalEnergySector_CORR.pdf

56 CRU International Ltd, *Opportunities for Aluminium in a Post-Covid Economy*, 2022. Available online: https://international-aluminium.org/wp-content/uploads/2022/03/CRU-Opportunities-for-aluminium-in-a-post-Covid-economy-Report.pdf

57 World Bank Group, *Minerals for Climate Action: The Mineral Intensity of the Clean Energy Transition*, 2020. Available online: https://uploads-ssl.webflow.com/6008a2327223f98143f46e18/6062fc59ae7665175ddf19ec_MineralsforClimateActionTheMineralIntensityoftheCleanEnergyTransition-compressed.pdf

58 ibid.

59 ibid.

60 Dartmouth College Sustainable Transitions Lab and Princeton University ZERO Lab. Effects of Renewable Energy Provisions of the Inflation Reduction Act on Technology Costs, Materials Demand, and Labor, June 2023. Available online: https://doi.org/10.5281/zenodo.8027939

61 ibid.

62 CRU International Ltd, *Opportunities for Aluminium in a Post-Covid Economy*, 2022. Available online: https://international-aluminium.org/wp-content/uploads/2022/03/CRU-Opportunities-for-aluminium-in-a-post-Covid-economy-Report.pdf

63 ibid.

64 Bloomberg, "Supply Chain Snags Are Driving Up Copper and Aluminum Costs in the U.S.," February 7, 2022. Available online: https://www.bloomberg.com/news/articles/2022-02-07/americans-face-record-metals-prices-as-shipping-costs-surge#xj4y7vzkg

65 Financial Times, "Aluminum Nears Record High on Supply Disruptions," February 8, 2022. Available online: https://www.ft.com/content/353605ab-e495-4a82-be06-357f45b4b5af

66 Asia Financial, "Global Aluminium Prices Hit 13-Year High as Inventories Fall," February 9, 2022. Available online: https://www.asiafinancial.com/global-aluminium-prices-hit-13-year-high-as-inventories-fall

67 Trade and Industry Development, "Aluminum Gets Stronger Under Global Pressure," March 28, 2022. Available online: https://www.tradeandindustrydev.com/industry/metals/aluminum-gets-stronger-under-global-pressure-30141

68 Financial Times, "Aluminum Nears Record High on Supply Disruptions," February 8, 2022. Available online: https://www.ft.com/content/353605ab-e495-4a82-be06-357f45b4b5af

69 USGS, Aluminum Statistics and Information: Annual Publications - Minerals Yearbook 1990-2020. Available online: https://www.usgs.gov/centers/national-minerals-information-center/aluminum-statistics-and-information

70 United Nations Department of Economic and Social Affairs, Statistics Division (DESA/UNSD), United Nations Comtrade database. Available online: https://comtrade.un.org/data/

71 IBIS, *IBISWorld Industry Report 33131 Aluminum Manufacturing in the US*, 2022.

72 ibid.

73 S&P Global, "Century to Halt Production at Hawesville Aluminum Smelter on High Energy Costs." June 22, 2022. Available online: https://www.spglobal.com/commodityinsights/en/market-insights/latest-news/metals/062222-century-to-halt-production-at-hawesville-aluminum-smelter-on-high-energy-costs

74 Defense Logistics Agency, *Materials of Interest*. Available online: **https://www.dla.mil/Strategic-Materials/Materials/**; The White House. *Building Resilient Supply Chains, Revitalizing American Manufacturing, and Fostering Broad-Based Growth*, 2021. Available online: **https://www.whitehouse.gov/wp-content/uploads/2021/06/100-day-supply-chain-review-report.pdf**

75 EPI, *Aluminum Producing and Consuming Industries have Thrived Under U.S. Section 232 Import Measures*, 2021. Available online:
https://www.epi.org/publication/aluminum-producing-and-consuming-industries-have-thrived-under-u-s-section-232-import-measures/

76 GEI, *Aluminum Climate Impact - An International Benchmarking of Energy and CO2 Intensities*, 2022. Available online: **https://static1.squarespace.com/static/5877e86f9de4bb8bce72105c/t/624d11ab5a37a4341fd85a6e/1649217981897/Aluminum+benchmarking+report-+Feb2022+rev2.pdf**; USGS, Aluminum Statistics and Information: Annual Publications - Minerals Yearbook 1990-2020. Available online: **https://www.usgs.gov/centers/national-minerals-information-center/aluminum-statistics-and-information**

77 Ember, "As Aluminum Surges in China, So Do Carbon Emissions." February 7, 2021. Available online: **https://ember-climate.org/insights/research/as-aluminium-surges-in-china-so-do-carbon-emissions/**

78 International Trade Union Confederation (ITUC), *2021 ITUC Global Rights Index*, 2021. Available online: **https://files.mutualcdn.com/ituc/files/ITUC_GlobalRightsIndex_2021_EN_Final.pdf**

79 Horizon Advisory, Forced Labor Risks in China's Aluminum Sector. 2022. Available online:
https://www.horizonadvisory.org/backtobasics

80 Fastmarkets, "Demand for Low-Carbon Aluminum Pushes P1020 Differential Higher." June 6, 2022. Available online: **https://www.fastmarkets.com/insights/demand-for-low-carbon-aluminium-pushes-p1020-differential-higher#:~:text=Demand%20for%20low%2Dcarbon%20aluminium%20in%20Europe%20has%20been%20steadily,Fastmarkets%20on%20Monday%2C%20June%206**

81 USGS, Minerals Yearbook - Aluminum, 2000. Available online: **https://d9-wret.s3.us-west-2.amazonaws.com/assets/palladium/production/mineral-pubs/aluminum/050400.pdf**

82 U.S. Department of Interior. Minerals Yearbook - 1990, 1993. Available online: **https://search.library.wisc.edu/digital/AEZRI27J2VYVCG8G/pages/ATSBNF6GTIH3PE9B**

83 U.S. BLS, Quarterly Census of Employment and Wages - QCEW Data Files, 1980 Available online: **https://www.bls.gov/cew/downloadable-data-files.htm**

84 USGS, Aluminum Statistics and Information: Annual Publications - Minerals Yearbook 1990-2020. Available online: **https://www.usgs.gov/centers/national-minerals-information-center/aluminum-statistics-and-information**

85 ibid.

86 U.S. BLS, Quarterly Census of Employment and Wages - QCEW NAICS-Based Data Files, 1990-2020. Available online: **https://www.bls.gov/cew/downloadable-data-files.htm**

87 USGS, Aluminum Statistics and Information: Annual Publications - Minerals Yearbook 1990-2020. Available online: **https://www.usgs.gov/centers/national-minerals-information-center/aluminum-statistics-and-information**

88 ibid.

89 ibid; US BLS, Quarterly Census of Employment and Wages - QCEW NAICS-Based Data Files, 1990-2020. Available online: **https://www.bls.gov/cew/downloadable-data-files.htm**

90 ibid.

91 Congressional Research Services (CRS), *U.S. Aluminum Manufacturing: National Security and Tariffs*, 2021. Available online: **https://crsreports.congress.gov/product/pdf/IF/IF11787/2**

92 IIE Industry Applications Magazine, “Early Aluminum Production in the Pacific Northwest,” 2010. Available online: https://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=5447100

93 Northwest Power and Conservation Council, Aluminum. Available online: https://www.nwcouncil.org/reports/columbia-river-history/aluminum/

94 USGS, Mineral Commodity Summaries: Aluminum, 2022. Available online: https://pubs.usgs.gov/periodicals/mcs2022/mcs2022-aluminum.pdf

95 U.S. BLS, Quarterly Census of Employment and Wages - QCEW NAICS-Based Data Files, 1990-2020. Available online: https://www.bls.gov/cew/downloadable-data-files.htm

96 John Dunham & Associates, *2022 Economic Impact of the Aluminum Industry - Methodology and Documentation*, 2022. Available online: https://www.aluminum.org/sites/default/files/2022-03/Methodology.pdf

97 IBIS, *IBISWorld Industry Report 33131 Aluminum Manufacturing in the US*, 2019.

98 U.S. primary production peaked in 1980 at 5.13 million short tons (4.65 Mt) (National Minerals Information Center, Bureau of Mines Minerals Yearbook (1932-1993))

99 National Minerals Information Center, Bureau of Mines Minerals Yearbook (1932-1993), Available online: https://search.library.wisc.edu/digital/AUWGUQYEEN7ZLH8C/full/AQSI4S7VD7ZEAJ86; USGS, USGS, *Mineral Commodity Summaries: Aluminum*, 2022. Available online: https://pubs.usgs.gov/periodicals/mcs2022/mcs2022-aluminum.pdf

100 ibid.

101 ibid.

102 GEI, *Aluminum Climate Impact: An International Benchmarking of Energy and CO2 Intensities*, 2022. Available online: https://static1.squarespace.com/static/5877e86f9de4bb8bce72105c/t/624d11ab5a37a4341fd85a6e/1649217981897/Aluminum+benchmarking+report-+Feb2022+rev2.pdf

103 GEI, *Aluminum Climate Impact - An International Benchmarking of Energy and CO2 Intensities*, 2022. Available online: https://static1.squarespace.com/static/5877e86f9de4bb8bce72105c/t/624d11ab5a37a4341fd85a6e/1649217981897/Aluminum+benchmarking+report-+Feb2022+rev2.pdf

104 USGS, Mineral Industry Survey - Aluminum in December 2021, 2021. Available online: https://d9-wret.s3.us-west-2.amazonaws.com/assets/palladium/production/s3fs-public/media/files/mis-202112-alumi.pdf

105 USGS, Mineral Commodity Summaries: Aluminum, 2022. Available online: https://pubs.usgs.gov/periodicals/mcs2022/mcs2022-aluminum.pdf

106 This calculation is based on 2019 production data from USGS and 2019 emissions intensity data from GEI, *Aluminum Climate Impact: An International Benchmarking of Energy and CO2 Intensities*, 2022. The calculation assumes that the U.S. only took market share from India and China and production in every other country stayed the same.

107 USGS, Mineral Industry Survey - Aluminum in December 2021, 2021. Available online: https://d9-wret.s3.us-west-2.amazonaws.com/assets/palladium/production/s3fs-public/media/files/mis-202112-alumi.pdf

108 ibid.

109 ITUC, *2021 ITUC Global Rights Index*, 2021. Available online: https://files.mutualcdn.com/ituc/files/ITUC_GlobalRightsIndex_2021_EN_Final.pdf

110 Human Rights Watch, “Bahrain: Revoke Summary Firings Linked to Protests - US to Investigate Compliance With Free Trade Agreement,” July 14, 2011. Available online: https://www.hrw.org/news/2011/07/14/bahrain-revoke-summary-firings-linked-protests

111 IndustriAll Global Union, “Turkey Metal Industry Strike Banned by The Government,” January 26, 2018. Available online https://www.industriall-union.org/turkish-government-bans-metal-strike

112 Horizon Advisory, *Forced Labor Risks in China's Aluminum Sector*, 2022. Available online: https://www.horizonadvisory.org/backtobasics

113 Atlantic Alumina Gramercy Operations, What is Chemical Grade Alumina? Available online: https://atalco.com/atlantic-alumina/chemical-grade-alumina

114 USGS, Mineral Commodity Summaries: Bauxite and Alumina, 2022. Available online: https://pubs.usgs.gov/periodicals/mcs2022/mcs2022-bauxite-alumina.pdf

115 ibid.

116 In 2016, Alcoa split into two companies, Alcoa and Arconic. Alcoa maintains six business divisions: bauxite, alumina, aluminum, cast products, rolled products, and energy. Arconic further split into two standalone businesses in 2019, Arconic Corporation and Howmet Aerospace Inc. The former specializes in transportation, aerospace, industrial, packaging, and commercial building industries, and the latter specializes in engine products, fastening systems, and forged wheels businesses.

117 USGS, Mineral Commodity Summaries: Aluminum, 2022. Available online: https://pubs.usgs.gov/periodicals/mcs2022/mcs2022-aluminum.pdf

118 ibid.

119 Alcoa Corporation, Form 10-k, December 31, 2021. Available online: https://sec.report/Document/0001564590-22-006763/; Century Aluminum, Our Operations, 2022. Available online: https://centuryaluminum.com/products-and-plants/overview/default.aspx; Reuters, "Exclusive: Aluminum Smelter Resurrected on Trump Tariffs May Close as Losses Mount," February 28, 2020. Available online: https://www.reuters.com/article/us-usa-trade-smelter-exclusive/exclusive-aluminum-smelter-resurrected-on-trump-tariffs-may-close-as-losses-mount-idUSKCN20M0IB

120 Lynden Tribune, "No-go on Intalco 'green' restart," December 28, 2022. Available online: https://www.lyndentribune.com/news/no-go-on-intalco-green-restart/article_d79c36ee-86c8-11ed-8ee4-03fb14dc3c00.html

121 U.S. BLS, Quarterly Census of Employment and Wages - QCEW NAICS-Based Data Files, 2020. Available online: https://www.bls.gov/cew/downloadable-data-files.htm

122 The common industry classification systems, such as the North American Industry Classification System (NAICS) and the Standard Industrial Classification System (SIC), group secondary smelting facilities with those that manufacture aluminum alloys.

123 Aluminum Association, *U.S. Aluminum's Economic Impact - Facilities List Reports*, 2022. Available online: https://www.aluminum.org/economy

124 ibid.

125 USGS, Mineral Commodity Summaries: Aluminum, 2022. Available online: https://pubs.usgs.gov/periodicals/mcs2022/mcs2022-aluminum.pdf

126 Resources, Conservation, and Recycling, *Environmental consequences of recycling aluminum old scrap in a global market*, 2014. Available online: https://www.sciencedirect.com/science/article/abs/pii/S0921344914001086#:~:text=Aluminum%20scrap%20is%20categorized%20as%20new%20and%20old%2C,issue%20in%20recycling%20and%20scrap%20supply%20%28JRC%2C%202007%29.

127 The Aluminum Association, Infinitely Recyclable. Available online: https://www.aluminum.org/Recycling

128 U.S. EPA, Aluminum: Material-Specific Data. Available online: https://www.epa.gov/facts-and-figures-about-materials-waste-and-recycling/aluminum-material-specific-data

129 The Aluminum Association, *The Aluminum Can Advantage Key Sustainability Performance Indicators*, 2019. Available online: https://www.aluminum.org/sites/default/files/2021-11/KPI_Report_2019_0.pdf

130 USGS, Mineral Commodity Summaries: Aluminum, 2022. Available online: **https://pubs.usgs.gov/periodicals/mcs2022/mcs2022-aluminum.pdf**

131 U.S. BLS, Quarterly Census of Employment and Wages - QCEW NAICS-Based Data Files, 1990-2020. Available online: **https://www.bls.gov/cew/downloadable-data-files.htm**

132 John Dunham & Associates, *2022 Economic Impact of the Aluminum Industry - Methodology and Documentation*, 2022. Available online: **https://www.aluminum.org/sites/default/files/2022-03/Methodology.pdf**

133 Data for the employment figures in this report were gathered from industry sources, government publications, and the third party data provider Data Axle.

134 U.S. BLS, National Industry-Specific Occupational Employment and Wage Estimates - NAICS 331300 - Alumina and Aluminum Production and Processing, 2021. Available online: **https://www.bls.gov/oes/current/naics4_331300.htm** **https://www.bls.gov/oes/current/naics2_31-33.htm#51-0000**

135 This category does not include public administration occupations.

136 U.S. BLS, National Industry-Specific Occupational Employment and Wage Estimates - Sectors 31, 32, and 33 - Manufacturing, 2021. Available online: **https://www.bls.gov/oes/current/naics2_31-33.htm#00-0000**

137 ibid.

138 U.S. BLS, State Occupational Employment and Wage Estimates, 2022. Available online: **https://www.bls.gov/oes/2021/may/oes_nat.htm** (bls.gov)

139 U.S. Census, Current Population Survey (CPS). Available online: **https://www.census.gov/programs-surveys/cps.html**

140 ibid.

141 EPI, *Botched Policy Responses to Globalization have Decimated Manufacturing Employment with Often Overlooked Costs for Black, Brown, and Other Workers of Color*, 2022. Available online: **https://files.epi.org/uploads/239189.pdf**

142 BLS, "Union workers more likely than nonunion workers to have healthcare benefits in 2019," October 28, 2019. Available online: **https://www.bls.gov/opub/ted/2019/union-workers-more-likely-than-nonunion-workers-to-have-healthcare-benefits-in-2019.htm**

143 17.9% were union members and an additional 2.2% are covered by covered by a collective bargaining unit. Unioinstats.com, Union Membership, Coverage, and Earnings from the CPS, 2022. **http://unionstats.com/**

144 ibid.

145 U.S. BLS, Labor Force Statistics from the Current Population Study). Available online: **https://www.bls.gov/cps/**

146 U.S. Census, Current Population Survey (CPS). Available online: **https://www.census.gov/programs-surveys/cps.html**

147 ibid.

148 ibid.

149 ibid.

150 John Dunham & Associates, *2022 Economic Impact of the Aluminum Industry - Methodology and Documentation*, 2022. Available online: **https://www.aluminum.org/sites/default/files/2022-03/Methodology.pdf**

151 This figure covers the combined impact of the aluminum refining, processing, manufacturing, and wholesaling industry, though does not include aluminum fabricators and downstream production processes.

152 American Iron and Steel Institute, *The Economic Impact of the American Iron and Steel Industry*, 2018. Available online: **https://www.steel.org/wp-content/uploads/2020/10/Econ-Impact-Study-Executive-Summary.pdf**; Bureau of Economic Analysis, "Gross Domestic Product, Fourth Quarter and Annual 2018 (Initial Estimate)," February, 28 2019. Available online: **https://www.bea.gov/news/2019/initial-gross-domestic-product-4th-quarter-and-annual-2018**

153 Induced impacts refer to the total spending by industry employees and by employees of supplier firms whose jobs are directly dependent on the aluminum industry. This spending, which is induced by the manufacturing and distribution of aluminum and aluminum products, is referred to as the "induced impact" or multiplier effect of the industry.

154 Aluminum Association, *U.S. Aluminum's Economic Impact - Facilities List Reports*, 2022. Available online: **https://www.aluminum.org/economy**

155 Calculations for percentage of state's GDP rely on 2021 state GDP figures, from U.S. Bureau of Economic Analysis (BEA), Gross Domestic Product by State and Personal Income by State, 2nd Quarter 2022. Available online: **https://www.bea.gov/sites/default/files/2022-09/stgdppi2q22-a2021.pdf**

156 For iron and steel, 100% of materials must be U.S. made to qualify.

157 See USASpending.gov, advanced search filters: Keyword = aluminum, Fiscal Year = 2021.

158 Id., NAICS Code = 332993 (Ammunition), PSC code = 1325 (Bombs).

159 Id., NAICS Code = 331315 (Aluminum sheet manufacturing), PSC code = 2305 (Ground effect vehicles).

160 Id., NAICS Code = 336612 (Boat building), PSC code = 1940 (Small craft).

161 Id., NAICS Code = 332311 (Prefabricated metal building and component manufacturing), PSC code = 5411 (rigid wall shelters).

162 Matmach.com, "Top 10 Uses of Aluminium in the Industry Today," June 12, 2020. Available online: **https://matmatch.com/resources/blog/top-10-uses-of-aluminium-in-the-industry-today/**.

163 BlueGreen Alliance, *Fact Sheet: Clean Manufacturing Investments in the Inflation Reduction Act*, 2022. Available online: **https://www.bluegreenalliance.org/wp-content/uploads/2022/08/BGA-IRA-Manufacturing-Investments-Factsheet-82422-FINAL.pdf**

164 Another $500 million is available under the Infrastructure Investment and Jobs Act for demonstration projects to help reduce emissions at industrial facilities, potentially including aluminum smelters.

165 The Defense Production Act is a versatile policy toolbox that the Biden administration has started to use to support manufacturing growth for critical clean energy goods. BlueGreen Alliance, *The Defense Production Act: A Toolbox to Spur Clean Manufacturing*, 2022. Available online: **https://www.bluegreenalliance.org/resources/the-defense-production-act-a-toolbox-to-spur-clean-manufacturing/**

166 The White House, Memorandum on Presidential Determination Pursuant to Section 303 of the Defense Production Act of 1950, as amended, on Transformers and Electric Power Grid Components. 2022. Available online: **https://www.whitehouse.gov/briefing-room/statements-releases/2022/06/06/memorandum-on-presidential-determination-pursuant-to-section-303-of-the-defense-production-act-of-1950-as-amended-on-transformers-and-electric-power-grid-components/**

167 United States International Trade Commission (USITC), USITC DataWeb, 2022. Available online: **https://dataweb.usitc.gov/trade/search**

168 USGS, Mineral Commodity Summaries: Aluminum, 2022. Available online: **https://pubs.usgs.gov/periodicals/mcs2022/mcs2022-aluminum.pdf**

169 GEI, *Aluminum Climate Impact - An International Benchmarking of Energy and CO2 Intensities*, 2022. Available online: **https://static1.squarespace.com/static/5877e86f9de4bb8bce72105c/t/624d11ab5a37a4341fd85a6e/1649217981897/Aluminum+benchmarking+report-+Feb2022+rev2.pdf**

170 EPI, *Aluminum producing and consuming industries have thrived under U.S. Section 232 import measures*, 2021. Available online: **https://files.epi.org/uploads/227032.pdf**

171 ibid.

172 CSR, Section 232 of the Trade Expansion Act of 1962. 2022. Available online: **https://sgp.fas.org/crs/misc/IF10667.pdf**

173 Department of Defense, Office of the Undersecretary for Policy (Strategy, Plans, and Capabilities), Department of Defense Climate Risk Analysis, 2021. Available online: **https://media.defense.gov/2021/Oct/21/2002877353/-1/-1/0/DOD-CLIMATE-RISK-ANALYSIS-FINAL.PDF**; Lawfare, "Trump's Trade Strategy Points the Way to a U.S. Carbon Tariff," August 24, 2020. Available online: **https://www.lawfareblog.com/trumps-trade-strategy-points-way-us-carbon-tariff**

174 CSR, Section 301 of the Trade Act of 1974, 2022. Available online: **https://crsreports.congress.gov/product/pdf/IF/IF11346**

175 IAI, Refining Process, 2018. Available online: **https://bauxite.world-aluminium.org/refining/process/**

176 Metals and Surface Engineering, *Production of primary aluminum*, *Fundamentals of Aluminium Metallurgy*, 2011. Available online: **https://www.sciencedirect.com/science/article/pii/B9781845696542500031#:~:text=In%20an%20alumina%20refinery%20bauxite%20is%20processed%20into,raw%20material%20required%20for%20production%20of%20p-rimary%20aluminium**

177 Lawrence Berkeley National Laboratory, *Emerging Energy Efficiency and Carbon Dioxide Emissions-Reduction Technologies for Industrial Production of Aluminum*, 2016. Available online: **https://escholarship.org/uc/item/2327g97d**

178 Aluminum Association, Secondary Production 101, 2021. Available online: **https://www.aluminum.org/secondary-production-101#:~:text=Once%20the%20scrap%20is%20collected%20and%20sorted%2C%20it,cast%20into%20large%20slabs%20called%20ingots%20or%20billets**

179 Aluminum Association, Environmental Product Declaration - Secondary Aluminum Ingot, 2014. Available online: **https://www.aluminum.org/sites/default/files/2022-04/105.1_AluminumAssocication_EPD_SecondaryAluminumIngot.pdf#:~:text=Secondary%20Aluminum%20Ingot%20%28100%25%20Scrap%29%20Products%20of%20Aluminum,product%20declaration%20%28EPD%29%20in%20accordance%20with%20ISO%2014025.**

180 IAI, *Global Aluminium Cycle 2019*. Available online: **https://alucycle.international-aluminium.org/public-access/**

181 Constellium, *The Life Cycle of Aluminum*. Available online: **https://www.constellium.com/sites/default/files/constellium_-_life_cycle_of_aluminium.pdf**

182 Industrial Heating, "Minimizing Melt Loss in Aluminum Recycling," February 4, 2014. Available online: **https://www.industrialheating.com/articles/91516-minimizing-melt-loss-in-aluminum-recycling**

183 Recycling Today, "Hydro adds scrap to primary aluminum recipes," March 18, 2021. Available online: **https://www.recyclingtoday.com/article/hydro-aluminum-scrap-primary-production-norway/**

184 Swinburne University of Technology, *Energy Use in Metal Production*, 2012. Available online: **https://publications.csiro.au/rpr/download?pid=csiro:EP12183&dsid=DS3**

185 IAI, *Aluminium Carbon Footprint Technical Support Document v1.0*, 2018. Available online: **https://www.international-aluminium.org/wp-content/uploads/2021/03/Aluminium-Carbon-Footprint-Technical-Support-Document.pdf?msclkid=f79f6f87d08811ec897b9582b0a6598c**

186 GEI, *Aluminum Climate Impact: An International Benchmarking of Energy and CO2 Intensities*, 2022. Available online: **https://static1.squarespace.com/static/5877e86f9de4bb8bce72105c/t/624d11ab5a37a4341fd85a6e/1649217981897/Aluminum+benchmarking+report-+Feb2022+rev2.pdf**

187 USGS, Aluminum Statistics and Information: Annual Publications - Minerals Yearbook 1990-2020. Available online: **https://www.usgs.gov/centers/national-minerals-information-center/aluminum-statistics-and-information**

188 GEI, *Aluminum Climate Impact: An International Benchmarking of Energy and CO2 Intensities*, 2022. Available online: https://static1.squarespace.com/static/5877e86f9de4bb8bce72105c/t/624d11ab5a37a4341fd85a6e/1649217981897/Aluminum+benchmarking+report-+Feb2022+rev2.pdf; USGS, Aluminum Statistics and Information: Annual Publications - Minerals Yearbook 1990-2020. Available online: https://www.usgs.gov/centers/national-minerals-information-center/aluminum-statistics-and-information

189 Mission Possible Partnership, *Closing the Gap for Aluminum Emissions: Technologies to Accelerate Deep Decarbonization of Direct Emissions*, 2021. Available online: https://www3.weforum.org/docs/WEF_AFC_Unlocking_Technological_Scale_up_2021.pdf#:~:text=Closing%20the%20Gap%20for%20Aluminium%20Emissions%20Page%203,the%20industry%20to%20reach%20net%20zero%20by%202050.

190 Journal of Occupational Medicine, "Occupational and Environmental Health in the Aluminum Industry," 2014. Available online: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4131940/

191 Journal of Exposure Science and Environmental Epidemiology, "Development of a job-exposure matrix for exposure to total and fine particulate matter in the aluminum industry," 2013. Available online: https://pubmed.ncbi.nlm.nih.gov/24022670/; Journal of Occupational Medicine, "Occupational and Environmental Health in the Aluminum Industry," 2014. Available online: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4131940/

192 SpringerLink.com, *Cancer risk in aluminum reduction plant workers (Canada)*, 2006. Available online: https://link.springer.com/article/10.1007/s10552-006-0031-9

193 American Journal of Industrial Medicine, "Cancer and Noncancer Mortality Among Aluminum Smelting Workers in Badin," North Carolina, 2020. Available online: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7890681/

194 Occupational and Environmental Medicine, "Mortality and Cancer Incidence in Workers in Two Australian Aluminum Pre-bake Smelters," 2009. Available online: https://pubmed.ncbi.nlm.nih.gov/19218259/

195 American Review of Respiratory Disease, "Occupational dust exposure and chronic obstructive pulmonary disease. A systematic overview of the evidence," 1993. Available online: https://pubmed.ncbi.nlm.nih.gov/8317812/

196 International Medical Journal Malaysia, "Environmental and Occupational Health Impact of Bauxite Mining in Malaysia: A Review," 2017. Available online: https://journals.iium.edu.my/kom/index.php/imjm/article/view/346/166

197 Aluminum Insider, "Contract Workers At Ghana Bauxite Mining Company Threaten Walkout Over Poor Work Conditions," March 18, 2019. Available online: https://aluminiuminsider.com/contract-workers-at-ghana-bauxite-mining-company-threaten-walkout-over-poor-work-conditions/; Human Rights Watch, "What Do We Get Out of It? The Human Rights IMpact of Bauxite Mining in Guinea, 2018. Available online: https://www.hrw.org/report/2018/10/04/what-do-we-get-out-it/human-rights-impact-bauxite-mining-guinea; Jamaica Environmental Trust, Red Dirt - A Multidisciplinary Review of the Bauxite-Alumina Industry in Jamaica, 2021. Available online: https://www.jamentrust.org/wp-content/uploads/2021/01/JET%20-%20Red%20Dirt%20Book%20FINAL%20-%20For%20print.pdf; Malaysia Journal of Medical Science, Potential Health Impacts of Bauxite Mining in Kuantan, 2016. Available online: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4934713/; Mangabay, "MRN bauxite mine leaves legacy of pollution, poverty in Brazilian Amazon," June 4, 2020. Available online: https://news.mongabay.com/2020/06/mrn-bauxite-mine-leaves-legacy-of-pollution-poverty-in-brazilian-amazon/; Sustainability Science, *A pantropical assessment of deforestation caused by industrial mining*, 2022. Available online: https://www.pnas.org/doi/10.1073/pnas.2118273119; WA Forest Alliance, *A Thousand Cuts - Mining in the Northern Jarrah Forests*, 2022. Available online: https://wafa.org.au/wp-content/uploads/2022/05/A-Thousand-Cuts-NJF-Report-FINAL.pdf

198 Inclusive Development International (IDI), *Guinea: Demanding a fair deal for communities from Alcoa-Rio Tinto bauxite mine*. Available online: https://www.inclusivedevelopment.net/cases/guinea-alcoa-rio-tinto-bauxite-mine/

199 U.S. International Development Finance Corporation, *Information Summary for the Public CBG Expansion*, 2019. Available online: https://www.dfc.gov/sites/default/files/2019-08/PublicSummaryCBGExpansion(1).pdf

200 BankTrack & Inclusive Development International, Compagnie des Bauxites de Guinée (CBG), 2019. Available online: https://www.banktrack.org/project/compagnie_des_bauxites_de_guinee/pdf

201 Romboll, CBG Bauxite Mine Expansion—Environmental and Social Monitoring Report, May 2018. Available online: https://www.banktrack.org/download/cbg_bauxite_mine_expansion_environmental_and_social_monitoring_report_february_2018/cbgbauxitemineexpansionenvironmentalandsocialmonitoringreportfebruary2018esmonitoringrptfeb2018rambollenviron1.pdf

202 BankTrack & Inclusive Development International, Compagnie des Bauxites de Guinée (CBG), 2019. Available online: https://www.banktrack.org/project/compagnie_des_bauxites_de_guinee/pdf

203 BankTrack, Complaint concerning IFC loan to the "Compagnie des Bauxites de Guinée" (CBG), 2019. Available online: https://www.banktrack.org/download/complaint_concerning_ifc_loan_to_the_compagnie_des_bauxites_de_guinee/complaint_concerning_ifc_loan_to_the_compagnie_des_bauxites_de_guinee_cbg.pdf

204 ibid.

205 Human Rights Watch, "What Do We Get Out of It? The Human Rights Impact of Bauxite Mining in Guinea," 2018. Available online: https://www.hrw.org/report/2018/10/04/what-do-we-get-out-it/human-rights-impact-bauxite-mining-guinea

206 ibid.

207 Reuters, "One dead as riots in Guinea mining hub enter fourth day," April 27, 2017. Available online: https://sg.news.yahoo.com/one-dead-riots-guinea-mining-hub-enter-fourth-153213859--finance.html

208 Reuters, "Guinean forces kill one, wound several in bauxite mining town riot," September 13, 2017. Available online: https://www.reuters.com/article/us-guinea-mining/guinean-forces-kill-one-wound-several-in-bauxite-mining-town-riot-idUSKCN1BO2BQ

209 BankTrack & Inclusive Development International, Compagnie des Bauxites de Guinée (CBG), 2019. Available online: https://www.banktrack.org/project/compagnie_des_bauxites_de_guinee/pdf

210 Compliance Advisor Obudsman, Dispute Resolution process between La Compagnie des Bauxites de Guinée (CBG) (the Company) and Representatives of the Thirteen affected villages of Sangarédi, Guinea (the Complainants), 2021. Available online: https://www.cao-ombudsman.org/sites/default/files/downloads/CBG01_Joint%20Statement%20on%20Blasting%20Agreement_ENG.pdf

211 International Trade Administration, Guinea - Country Commercial Guide, 2014. Available online: https://www.trade.gov/country-commercial-guides/guinea-mining-and-minerals

212 Human Rights Watch, "What Do We Get Out of It? The Human Rights Impact of Bauxite Mining in Guinea, 2018. Available online: https://www.hrw.org/report/2018/10/04/what-do-we-get-out-it/human-rights-impact-bauxite-mining-guinea

213 Human Rights Watch & Inclusive Development International, *Aluminum: The Car Industry's Blind Spot*. 2021. Available online: https://www.hrw.org/sites/default/files/media_2021/10/global_bauxite0721_web.pdf

214 BlueGreen Alliance, *Manufacturing Agenda: A National Blueprint for Clean Technology Manufacturing Leadership and Industrial Transformation*, 2020. Available online: https://www.bluegreenalliance.org/wp-content/uploads/2020/06/2020_BGA_Manufacturing_Agenda-vFINAL.pdf

215 EPI, *Aluminum Producing and Consuming Industries have Thrived Under U.S. Section 232 Import Measures*, 2021. Available online: https://www.epi.org/publication/aluminum-producing-and-consuming-industries-have-thrived-under-u-s-section-232-import-measures/

216 USGS, Aluminum Statistics and Information: Annual Publications - Minerals Yearbook 1990-2020. Available online: https://www.usgs.gov/centers/national-minerals-information-center/aluminum-statistics-and-information

217 CRS, *U.S. Aluminum Manufacturing: National Security and Tariffs*, 2021. Available online: https://sgp.fas.org/crs/natsec/IF11787.pdf

218 USITC, *Aluminum: Competitive Conditions Affecting the U.S. Industry*, 2017. Available online: **https://www.usitc.gov/publications/332/pub4703.pdf**

219 ibid.

220 Fastmarkets AMM, "Power Rates Drive U.S. Aluminum Industry's Future," March 31, 2016. Available online: **https://www.amm.com/Article/3541758/Power-rates-drive-US-aluminum-industrys-future.html**

221 CRS, *U.S. Aluminum Manufacturing: National Security and Tariffs*, 2021. Available online: **https://sgp.fas.org/crs/natsec/IF11787.pdf**

222 USITC, *Aluminum: Competitive Conditions Affecting the U.S. Industry*, 2017. Available online: **https://www.usitc.gov/publications/332/pub4703.pdf**

223 IIE Industry Applications Magazine, "Early Aluminum Production in the Pacific Northwest," 2010. Available online: **https://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=5447100**

224 EPI, "Aluminum Producing and Consuming Industries have Thrived Under U.S. Section 232 Import Measures," 2021. Available online: **https://www.epi.org/publication/aluminum-producing-and-consuming-industries-have-thrived-under-u-s-section-232-import-measures/**

225 World Trade Organization (WTO), Dispute Settlement—China Subsidies to Producers of Primary Aluminium, January 12, 2017. Available online: **https://www.wto.org/english/tratop_e/dispu_e/cases_e/ds519_e.htm**

226 WTO, *Role of Subsidies in Creating Overcapacity and Options for Addressing This Issue in the Agreement on Subsidies and Countervailing Measures*, 2017. Available online: **https://docs.wto.org/dol2fe/Pages/SS/directdoc.aspx?filename=q:/G/SCM/W572R1.pdf&Open=True**

227 EPI, *Aluminum Producing and Consuming Industries have Thrived Under U.S. Section 232 Import Measures*, 2021. Available online: **https://www.epi.org/publication/aluminum-producing-and-consuming-industries-have-thrived-under-u-s-section-232-import-measures/**

228 OECD, *Measuring Distortions in International Markets: The Aluminium Value Chain*, 2019. Available online: **https://www.oecd-ilibrary.org/docserver/c82911ab-en.pdf?expires=1655408243&id=id&accname=guest&checksum=6F66F23E8C4380FE116B6DD071F6C677**

229 EPI, *Aluminum Producing and Consuming Industries have Thrived Under U.S. Section 232 Import Measures*, 2021. Available online: **https://www.epi.org/publication/aluminum-producing-and-consuming-industries-have-thrived-under-u-s-section-232-import-measures/**

230 Aluminum Association, *A Trade Policy Framework for the U.S. Aluminum Industry*. Available online: **https://www.aluminum.org/sites/default/files/2021-10/TAA_Trade%20Framework-FINAL.pdf**

231 WTO, *Role of Subsidies in Creating Overcapacity and Options for Addressing This Issue in the Agreement on Subsidies and Countervailing Measures*, 2017. Available online: **https://docs.wto.org/dol2fe/Pages/SS/directdoc.aspx?filename=q:/G/SCM/W572R1.pdf&Open=True**

232 EPI, *Aluminum Producing and Consuming Industries have Thrived Under U.S. Section 232 Import Measures*, 2021. Available online: **https://www.epi.org/publication/aluminum-producing-and-consuming-industries-have-thrived-under-u-s-section-232-import-measures/**

233 USITC, Aluminum: Competitive Conditions Affecting the U.S. Industry, 2017. Available online: **https://www.usitc.gov/publications/332/pub4703.pdf**

234 ibid.

235 Center for Disease Control (CDC), COVID Data Tracker, November 22, 2022. Available online: **https://covid.cdc.gov/covid-data-tracker/#datatracker-home**

236 CDC, Long COVID, October 26, 2022. Available online: **https://www.cdc.gov/nchs/covid19/pulse/long-covid.htm**

237 National Bureau of Economic Research, *The Impacts of Covid Illness on Workers*, 2022. Available online: https://www.nber.org/system/files/working_papers/w30435/w30435.pdf

238 Brookings, "New data shows long Covid is keeping as many as 4 million people out of work," August 24, 2022. Available online: https://www.brookings.edu/research/new-data-shows-long-covid-is-keeping-as-many-as-4-million-people-out-of-work/

239 CDC, Risk for COVID-19 Infection, Hospitalization, and Death By Race/Ethnicity, November 8, 2022. Available online: https://www.cdc.gov/coronavirus/2019-ncov/covid-data/investigations-discovery/hospitalization-death-by-race-ethnicity.html

240 APA Research Lab, "The Color of the Coronavirus," November 22, 2022. Available inline: https://www.apmresearchlab.org/covid/deaths-by-race

241 Federal Reserve Bank of Minneapolis, "Occupational segregation left workers of color especially vulnerable to COVID-19 job losses," February 7, 2022. Available online: https://www.minneapolisfed.org/article/2022/occupational-segregation-left-workers-of-color-especially-vulnerable-to-covid-19-job-losses

242 RAND Corporation, "Laid Off More, Hired Less: Black Workers in the COVID-19 Recession," September 29, 2020. Available online: https://www.rand.org/blog/2020/09/laid-off-more-hired-less-black-workers-in-the-covid.html

243 Al Circle, "Recap 2020: Slowdown in production activities due to COVID19 let down primary aluminum demand & prices; Recovery began in H2," December 25, 2020. Available online: https://www.alcircle.com/news/recap-2020-slowdown-in-production-activities-due-to-covid19-let-down-primary-aluminium-demand-prices-recovery-began-in-h2-62063

244 USGS, Mineral Commodity Summaries, 2021. Available online: https://pubs.usgs.gov/periodicals/mcs2021/mcs2021-aluminum.pdf

245 USGS, Aluminum Statistics and Information: Annual Publications - Minerals Yearbook 1990-2020. Available online: https://www.usgs.gov/centers/national-minerals-information-center/aluminum-statistics-and-information

246 USGS, Mineral Commodity Summaries. 2022, Available online: https://pubs.usgs.gov/periodicals/mcs2021/mcs2021-aluminum.pdf

247 RED, "Weathering the 'Candemic'- Supply-chain Disruptions and Spikes in Aluminum Prices are Hitting Colorado's Beer Industry. Here's What Consumers Can Expect and How Crafty Brewers are Responding," January 7, 2022. Available online: https://red.msudenver.edu/2022/weathering-the-candemic/

248 Supply Chain Dive, "Shortages 2022: 5 Products Expected to be in Tight Supply this Year," January 31, 2022. Available online: https://www.supplychaindive.com/news/shortages-2022-outlook-supply-semiconductors-aluminum-food/617537/

249 Reuters, "Aluminum Spikes to Record After Russia Sanctions Stepped Up," February 28, 2022. Available online: https://www.reuters.com/markets/europe/lme-aluminium-nickel-gain-russian-supply-worries-intensify-2022-02-28/

250 IBIS, IBISWorld Industry Report 33131 Aluminum Manufacturing in the US, 2022.

251 ibid.

252 ibid.