The Aluminum Paradox:

Vital for clean energy, but also a major source of greenhouse gases, air and water pollution

ENVIRONMENTAL INTEGRITY PROJECT

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Executive Summary

As climate change accelerates, aluminum has taken a lead position in the race for a lower-carbon, less polluting industrial future. Lightweight and durable, the metal is a key component in solar panels and wind turbines, more efficient cars and planes, and long-lasting construction materials. Given this, global aluminum demand is projected to be 40 percent higher in 2030 than in 2020.[1]

Yet the aluminum industry accounted for 1.2 billion tons of global greenhouse gases in 2021, the same amount as the energy used by over 150 million U.S. homes—and its contribution to climate change is only set to grow alongside demand.[2]

In addition, aluminum production causes air and water pollution that harms communities and the environment worldwide. For example, three U.S. production facilities (in Kentucky, Missouri, and New York) are a key reason why there is more sulfur dioxide (SO_2) in the surrounding air than allowed by law, posing risks to respiratory and cardiovascular health. The refining of a raw material called alumina has generated over three billion tons of "red mud," a toxic waste that puts people, soil, and groundwater at risk worldwide.[3]

As U.S. businesses, policymakers, and consumers seek more aluminum, its "green" credentials must be balanced against its negative impacts.

As U.S. businesses, policymakers, and consumers seek more aluminum, its "green" credentials have to be balanced against its negative impacts. The following pages assess this aluminum paradox and present ways for the industry to reduce climate emissions and clean up its act as it becomes part of a more sustainable economy.

Fortunately, national and international climate policies are pushing aluminum producers to reduce the industry's heavy environmental footprint. Dozens of large corporations, from Ford to Google, have pledged to purchase metal made in ways that pollute less.[4] Operations will clearly need to change more to satisfy such ambitions, since only about 30 percent of new aluminum produced worldwide currently meets a "low carbon" standard based on using clean energy.[5]

The aluminum industry in the United States is not ready to jump on the decarbonization bandwagon. While there is a potential for the industry's expansion, U.S. operators clearly need to make financial investments and compliance commitments to participate in a lower-carbon, less-polluting, and more economically robust aluminum industry—or be left behind.

Each step in the long process of transforming bauxite into aluminum poses problems for the climate, air and water quality, land, and health.

The production of new aluminum in the U.S. has been on a steady and steep decline due to rising costs and a changing world market. In 2000, there were 23 smelters across the U.S.; by 2017, only six.[6] After being the world's top producer of new aluminum for decades, by 2022 the U.S. ranked ninth and turned out only about one percent of global supply (about 860,000 tons).[7]

The six remaining new aluminum production plants in the U.S., called smelters, are old and use mostly fossil fuel-based electricity. They have exceeded pollution limits dozens of times in recent years, including for substances that harm health like mercury and copper in water and particulate matter and SO_2 in air. Such problems persist despite running at only about 60 percent of collective capacity under regulations and pollution limits that are decades out of date. These old requirements are likely no longer sufficient to protect air and water quality, which has been degraded over time by industrial activities.

Table I: Violations of Pollution Limits at U.S. Aluminum Facilities

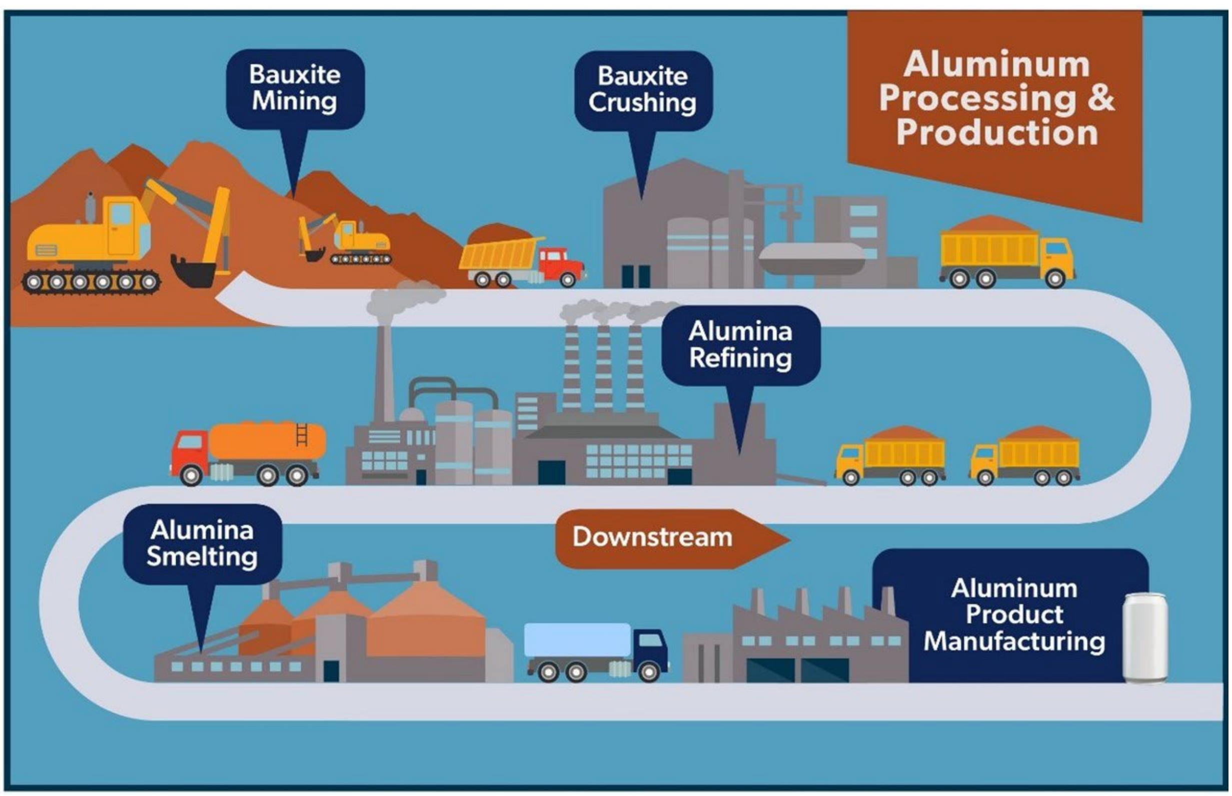
Facility	Year built	Water pollution violations, 2018-2023	Air pollution violations, 2018-2023	Cause of Federal Air Quality Standard Exceedance **
Alcoa Warrick (Newburgh, IN)	1960	101	15	--
Century Aluminum Sebree (Robards, KY)	1972	23	-- *	SO_2
Magnitude 7 Metals (Marston, MO)	1969	9	16 *	SO_2
Alcoa Massena (Massena, NY)	1902	5	--	SO_2
Century Aluminum Hawesville (Hawesville, KY)	1969	2	14 *	--
Century Mt. Holly (Goose Creek, SC)	1980	--	23	--

Sources: *Permit and compliance documents from state regulatory agencies and records in EPA's Enforcement and Compliance History Online (ECHO) database. * For Century Hawesville, Century Sebree, and Magnitude 7 Metals, ECHO lists the results of state and federal reviews of compliance tests as "pending," so it is possible that the number of violations is higher. **As of September 2023.*

Aluminum demand in the United States jumped 30 percent from 2009–2020.[8] It could grow another 45 percent by 2030, primarily for electric vehicles, construction and packaging materials, and clean energy and electrical systems.[9] With demand for aluminum surging, calls to increase domestic primary production are growing louder and focusing on opportunities to revitalize manufacturing, create jobs, and strengthen national security.[10]

A 2021 tariff agreement between the U.S. and the European Union was predicated on reducing the carbon intensity of aluminum production—sending a clear signal to producers on both sides of the Atlantic that climate goals will play a role in markets going forward.[11] U.S. operators were given an additional incentive to evolve in 2022 with passage of the Inflation Reduction Act, which provides public funding to grow supplies of lower-carbon industrial materials like aluminum.

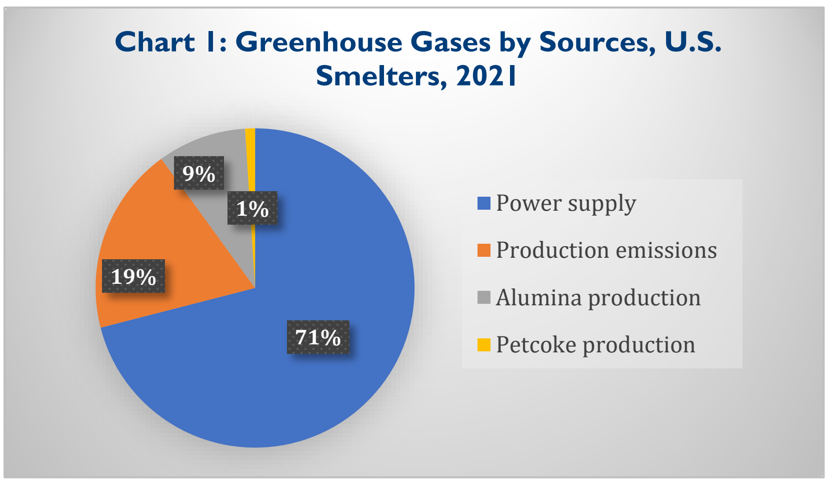
The production of new aluminum generally follows a rule of thumb known as 4-2-1: It takes four tons of bauxite ore to produce two tons of alumina, which then becomes one ton of metal.[12] Although certain newer technologies and equipment are used, the basic mining, refining, and smelting processes have not changed significantly since they were first developed in the late 1800s.[13] An estimated three-quarters of all of the aluminum ever produced still exists in some form today, and about one-third of the aluminum created globally every year is derived from previously used scrap metal.[14]



The process of making aluminum produces environmental and health impacts at every step along the way.

Bauxite Ore Mining destroys forests and grasslands, contaminates water resources, and creates toxic dust and waste. Communities in mining sacrifice zones worldwide bear this heavy burden. For example, residents living near a mine in Jamaica that supplies the U.S. alumina refinery in Louisiana have sued over damage to their health, land, water, and livelihoods (see case study on page 29).[15] In a mining region of Australia, the bauxite industry has cut down more forest than the logging industry, eliminating bird habitat and exacerbating drought.[16]

Alumina Refining turns crushed bauxite into a fine white powder called alumina. This process requires large volumes of water, caustic chemicals, and electricity. Mercury emissions from a refinery in Gramercy, Louisiana, have settled onto nearby waterways, threatening aquatic systems, drinking water, and public health (see case study on page 32).[17] Refining produces vast amounts of "red mud," waste that contains toxic and radioactive substances. Given projected growth in aluminum demand, ten billion tons of red mud could pile up worldwide by 2050.[18] The failure of dams at waste containment ponds poses a constant risk and has spelled disaster for some local residents and environments.[19]



Petroleum Coke Refining. Petroleum coke, or petcoke, is a key material in the production of the devices—called anodes—needed to conduct electricity for the conversion of alumina into aluminum.[20] About half a ton of calcined (highly refined) petcoke is needed to produce one ton of aluminum.[21] Because petcoke contains sulfur, SO_2 emissions are released when it is produced and calcined; when operators make anodes to conduct electricity during smelting; and during smelting itself. Oxbow, the world's largest supplier of petcoke, has exceeded federal SO_2 emission limits many times at a calciner in Port Arthur, Texas, leading the Environmental Integrity Project (EIP) and its partners to file a complaint to the Environmental Protection Agency (EPA) under Title VI of the Civil Rights Act.[22] (See the case study on page 34.)

Aluminum Smelting converts alumina powder into metal. Smelting releases large volumes of greenhouse gases. In addition to emitting carbon dioxide (CO_2), smelters are the leading industrial source of perfluorocarbons, powerful and long-lasting greenhouse gases. (See the case study on page 36.)

For this report, EIP assessed greenhouse gas emissions associated with aluminum production and the feedstocks used at the six operating U.S. smelters, which taken together accounted for nearly 16 million metric tons carbon dioxide equivalent in 2021.[23] That's about the same amount of pollution as four coal-fired power plants release in a year.[24] Over 70 percent of the emissions came from power supply for the smelters and nearly 20 percent from direct production, with the rest attributable to the production of alumina and petcoke as key ingredients. These proportions are generally in line with those seen in the global primary aluminum sector.[25]

Smelters also release pollutants harmful to human health into the air, in particular SO_2, volatile organic compounds, particulate matter, carbonyl sulfide, and polycyclic organic matter. These can cause respiratory, pulmonary, cardiovascular, and immunological problems. In addition, fluoride and mercury emissions can damage soil, vegetation, wildlife, and fish.

Smelters discharge wastewater directly into rivers and streams and store it in open ponds. Wastewater contains pollutants that can harm aquatic life and drinking water supplies, including heavy metals such as mercury, lead, arsenic, and cadmium. For example, the Alcoa Warrick smelter in Newburgh, Indiana, exceeded its legal limits on discharges of mercury to the Ohio River nearly 30 times between 2018-2023.[26]

Smelters produce aluminum in giant tanks called "pots," which have a heavy lining made from carbon that wears down during production. This rock-like material is regulated by the EPA as a hazardous waste because it contains numerous toxic pollutants (in particular fluoride and cyanide).[27] Approximately one ton of this waste is generated for every 40 tons of aluminum produced.[28] That means U.S. operators generated about 22,000 tons of the waste in 2022, enough to fill about 1,500 large dump trucks.[29]

Recommendations

1. Rein in climate emissions. According to the International Aluminium Institute, to be aligned with a climate warming scenario of no more than 2^{o} Celsius, the global aluminum industry will need to reduce emissions from electricity to zero by 2050.[30]

To reach this goal, smelters will need to run on clean energy. Currently, five of six U.S. smelters use fossil-fuel based electricity either from adjacent coal-fired power plants or utility-owned grids that run on coal, oil, and gas. The exception is the Alcoa Massena plant in New York, which runs on hydroelectricity. To reduce pollution for nearby communities and energy costs for smelters, states should adopt policies to rapidly expand renewable energy and operators should commit to transitioning away from fossil fuels.

Aluminum companies have long worked to develop a different kind of anode to conduct electricity during smelting. This new technology (called an "inert anode") releases oxygen instead of CO_2 and perfluorocarbons. Because this technology will be important for decarbonization efforts going forward, aluminum companies need to go beyond the pilot project phase and expedite production of more metal using inert anodes.[31] Once the technology becomes commercially available and used at a U.S. smelter, EPA should require operators to adopt it.[32]

In the meantime, EPA could require operators to conduct more frequent measurements of the process that generates perfluorocarbons (called "anode effects"), in line with internationally recognized best practices.[33] EPA should also move quickly to finalize its proposal in 2022 to advance measurement of lower-level anode effects, which also generate perfluorocarbon emissions.[34]

2. Update federal pollution rules. The EPA has failed to revise technology-based pollution requirements for the aluminum industry to keep pace with technological advancements, as required by the Clean Air Act and Clean Water Act.

Particularly important are Effluent Limitation Guidelines, water pollution standards required under the Clean Water Act to limit discharges of pollutants from industries into waterways.[35] The guidelines for nonferrous metals, including alumina refining and aluminum smelting, have not been revised in 35 years.[36] In addition, New Source Performance Standards required under the Clean Air Act to keep pace with new pollution control methods have not been updated for primary aluminum in 25 years.[37]

3. Reduce sulfur dioxide emissions. U.S. aluminum smelters and the petcoke facilities that support them are notorious for large quantities of SO_2 emissions that threaten air quality and health. Yet U.S. smelters have long operated without equipment specifically designed to control releases of SO_2. These pollution control systems, called "scrubbers," are needed at all U.S. smelters and most immediately at the three (Alcoa Massena, Century Sebree, and Magnitude 7 Metals) that are causing surrounding areas to fail to meet federal SO_2 standards.

Similarly, the installation of modern SO_2 control "scrubber" technology at all petcoke calciners that still lack them (including Oxbow's Port Arthur calciner) would slash air pollution. State and federal regulators could consider requiring operators to use petcoke with a lower sulfur content, which is recognized worldwide as a way to reduce SO_2 emissions. The widespread adoption of inert anodes would also cut SO_2 emissions since they don't contain petcoke.

U.S. aluminum smelters and the petroleum coke facilities that support them are notorious for emitting large quantities of SO_2 emissions that threaten air quality and health.

4. Recycle more, use less. Technology, automotive, and other companies are eager to purchase recycled aluminum in order to meet sustainability targets and more investments are being made to convert previously used metal into new products.[38]

Key to this process is expansion of "secondary production" of aluminum, which recycles and alloys scrap metal. Production of this kind of recycled aluminum requires about 95 percent less energy and has far lower capital and operational costs compared to primary, key reasons why it accounts for nearly 80 percent of the aluminum produced in the United States.[39]

Secondary production currently relies heavily on "new scrap," or pieces of metal discarded at smelters after forms are cut. Less than half is made from "old scrap" taken out of worn-out vehicles, planes, and appliances or from products like cans and foil.[40] Much more could be done to improve systems to recover, sort, remove contaminants, remelt, and alloy previously used scrap.[41]

More metal recovery and reuse could change assumptions about how much more new aluminum will be needed to meet demand. According to the World Economic Forum, increasing global aluminum recycling to 95 percent would reduce demand for primary aluminum by 15 percent and prevent 250 million tons of CO_2 emissions annually.[42] That's the same amount of energy used by over 30 million homes in a year.[43] Federal, state, municipal, and corporate entities should invest in metal recycling and recovery systems so that they are more widespread and effective.

Corporations and consumers can also make different choices and use less aluminum overall. For example, preference in the U.S. for large vehicles is one of the reasons behind surging aluminum demand in the automotive industry, with the average light truck containing about one-third more than a passenger vehicle in 2022.[44]

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Where Aluminum Comes From

Aluminum is a common metallic element in the Earth's crust and different forms of it—from fire-resistant coatings to armor to building materials—have been used for centuries. But it is challenging to turn rock into metal and it was not until the late 1800s that industrial-scale methods were developed to transform mined bauxite ore into refined alumina powder and then into aluminum. Those technologies proved so effective that they were quickly expanded and are still in use today.[45]

Aluminum's popularity for a variety of uses has only grown with time, with boom periods such as the dawn of the aviation industry in the 1920s and military manufacturing during World War II. Modern lifestyles with cars and appliances further boosted aluminum's popularity.

With electric vehicles and solar energy becoming more widespread, global production of new aluminum has more than doubled in just the last 20 years, reaching 69 million metric tons in 2022.[46] The top ten producing countries account for nearly the whole global supply of aluminum and the two materials from which it is made, refined alumina and bauxite ore.

Table 2: Top 10 Global Producers and Share of Supply; Primary Aluminum, Alumina, and Bauxite, 2022

Primary aluminum			Alumina			Bauxite *		
Country	Million metric tons	Share (%)	Country	Million metric tons	Share (%)	Country	Million metric tons	Share (%)
China	40	58.0	China	76	54.3	Australia	100	26.3
India	4	5.8	Australia	20	14.3	China	90	23.7
Russia	3.7	5.4	Brazil	11	7.9	Guinea	86	22.6
Canada	3	4.3	India	7.4	5.3	Brazil	33	8.7
UAE	2.7	3.9	Russia	3.1	2.2	Indonesia	21	5.5
Bahrain	1.6	2.3	UAE	2.3	1.6	India	17	4.5
Australia	1.5	2.2	Saudi Arabia	2	1.4	Russia	5	1.3
Norway	1.4	2.0	Ireland	1.8	1.3	Saudi Arabia	4.8	1.3
United States	0.86	1.2	Spain	1.7	1.2	Kazakhstan	4.4	1.2
Iceland	0.75	1.1	Vietnam	1.5	1.0	Jamaica	3.9	1.0
Total Top 10	*60*	*86%*		*127*	*91%*		*365*	*96%*
Total global production	*69*	*100%*		*140*	*100%*		*380*	*100%*

*Source: U.S. Geological Survey mineral commodity summaries, aluminum and bauxite & alumina, 2023. * The U.S. ranking for bauxite is unknown since USGS considers domestic production to be company proprietary data, but the agency indicates that the volume is small and not used for metal production.*

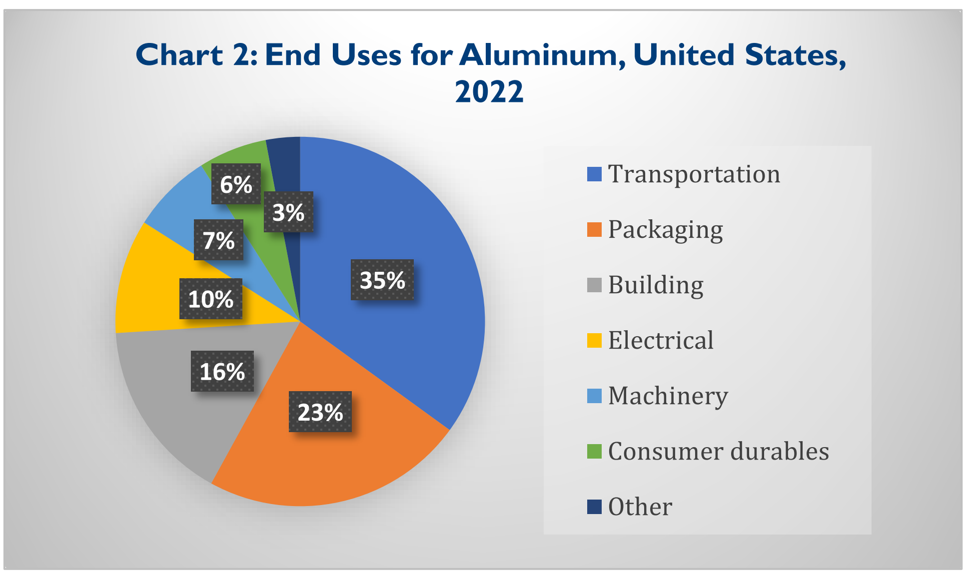
Long an aluminum powerhouse, the U.S. held the top spot for new aluminum production until 2000. But between 2000 and 2017, 17 of the 23 aluminum smelting plants in the U.S. closed.[47] By 2022, the U.S. ranked ninth with just over one percent of global production.[48] This dramatic shift was tied to production costs going up along with energy prices, China's rapid industrial rise and market dominance, and growing investment in aluminum by India, Russia, and the United Arab Emirates.

Given the increasingly busy world stage, even if the remaining U.S. smelters ramped up to their full production capacity (about 1.4 million tons annually), they would represent just two percent of current global smelting capacity.[49] In addition, the U.S. ranks twelfth among refiners of alumina, producing less than one percent of global supply at a single refinery in Louisiana.[50] In contrast, the U.S. holds the second spot globally for production of aluminum made from scrap, with exports of this type of metal and semi-finished products helping to balance trade flows.[51] (See page 27.)

In 2022, half of U.S. imports of new aluminum came from Canada, 60 percent of imported alumina from Brazil, and over 60 percent of imported bauxite from Jamaica.[52] Key export destinations for U.S. aluminum include Canada, Mexico, and the European Union. The overall balance between trade and consumption levels means that the U.S. relies on imports for about half of the finished aluminum it uses.[53]

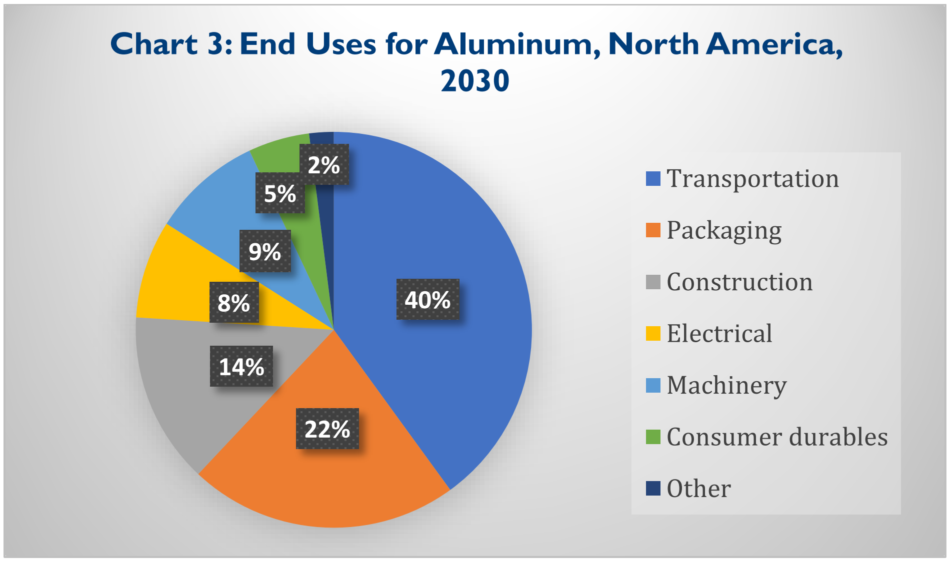
How We Use Aluminum

From cans to computers to cars, aluminum shines in every household. The purposes for which consumers use aluminum have remained fairly constant over the last few decades, with transportation and packaging in the lead.



Source: U.S. Geological Survey, Mineral Commodity Summary, Aluminum, 2023.

Looking ahead, a shift to electric vehicles will boost the share of aluminum going to transportation, while the expansion of renewable energy systems, in particular solar, will increase the electrical share.[54] This forecast applies globally, although the U.S. and Canada will keep using a higher proportion of aluminum for packaging (cans, containers, and foil) than is the case in other world regions.



Source: CRU International, Opportunities for Aluminum in a Post-Covid World, 2022.

Popular Packaging

Americans throw almost four million tons of aluminum—both new and made from scrap metal—in the trash every year, about half of which is containers and packaging (the rest is appliances, electronics, and other goods).[55] Due to shortcomings in consumer habits and recovery and sorting systems, much of that packaging ends up in landfills and only about a third is recycled.[56]

At the same time, both the track record of reuse and public perception of aluminum are better than that of plastic, which is increasingly in the environmental spotlight and visibly piling up in oceans and on land worldwide. As a result, many companies with sustainability pledges are replacing plastic with aluminum for their packaging, as well as increasing the use of recycled aluminum in laptops, smartphones, and other everyday products.[57]

The beverage industry projects significant growth in aluminum as a larger share of beverages are sold in cans rather than bottles.

Nowhere is this trend more obvious than the beverage industry, which projects significant growth in aluminum as a larger and larger share of beverages are sold in cans rather than bottles. Demand for aluminum cans will be strongest in the U.S., where more packaged beverages, such as soda, beer, water, and energy drinks, are consumed per capita than in any other country.[58]

In 2020, Americans used about 100 billion cans, representing about 1.5 million tons of aluminum.[59] Cans are recycled at a somewhat higher rate than other aluminum packaging (for example, take out containers); about 50 percent in the U.S. and 70 percent globally.[60] While previously used metal makes up three-quarters of an average can, the aluminum industry recognizes it needs to increase both recycled content and recovery rates if it is going to uphold the metal's reputation as "infinitely recyclable."[61] Consumers can also feel good about keeping cans out of the trash: recycling just one can saves enough energy from aluminum production to power a light bulb for 13 hours.[62]

New Vehicles

Because aluminum weighs less than steel, it helps make vehicles more fuel efficient when used in standard components like doors, hoods, and chassis. By 2030, aluminum consumption in the global transportation industry could grow nearly 60 percent over 2020 levels.[63]

Although the overall proportion of aluminum in a vehicle by weight (about 12 percent) is not expected to rise much, the total volume of aluminum will. That is because vehicles are on track to become even heavier, particularly due to the accelerating electric vehicle market. Manufacturers are using more aluminum to balance out the weight of batteries, which make electric vehicles far heavier than regular cars. For example, batteries alone weigh 668 pounds in a Nissan Leaf and 1,700 pounds in a Tesla Model Y—about 20-40 percent of total vehicle weight.[64] Looking ahead, the amount of aluminum is set to grow across vehicle types, with electric vehicles containing the most.

Table 3: Aluminum in Vehicles, Present and Future (in Pounds per Vehicle)

Year	Average car	Average light truck	Average electric vehicle
2020	353	496	643
2030	449	564	924

Source: Ducker Carlisle, North American Light Vehicle Aluminum Content and Outlook Study, 2023.

The figures in Table 3 are averages so reflect a range of vehicle sizes—and size really matters when it comes to how much aluminum is used. Americans' persistent preference for trucks and large cars is a key factor driving demand for aluminum by the automotive industry. For example, by 2030 a Toyota Corolla could contain about 280 pounds of aluminum, compared to 570 in a Subaru Legacy.[65]

The automotive industry reports that it recovers and recycles approximately 90 percent of aluminum from cars at the end of their lives.[66] But there is room for improvement when it comes to sorting the different metal pieces so they can be easily reused and incorporating more recycled metal and metal alloys from the start. Today, about half of the aluminum used to make vehicles is brand new, which takes a lot more energy to produce and has far greater impacts on communities and the environment than recycled metal.[67]

Clean Energy Systems

In the race to reduce greenhouse gases, big bets are being placed on the massive expansion of renewable energy. Reaching that goal will require a lot of raw materials. Projections of just how much depends on the emission reduction goal and the pace of change assumed.

A World Bank assessment of numerous minerals needed to help limit planetary warming to 2° Celsius found that demand for aluminum would more than double.[68] The widespread deployment of solar systems to produce electricity would account for 87 percent of that demand, since aluminum is used to make frames and cells for solar panels; another ten percent would be used in wind turbines and platforms; and the remaining few percent for carbon capture and energy storage equipment.[69]

Aluminum accounts for 85 percent of the volume of solar panels.

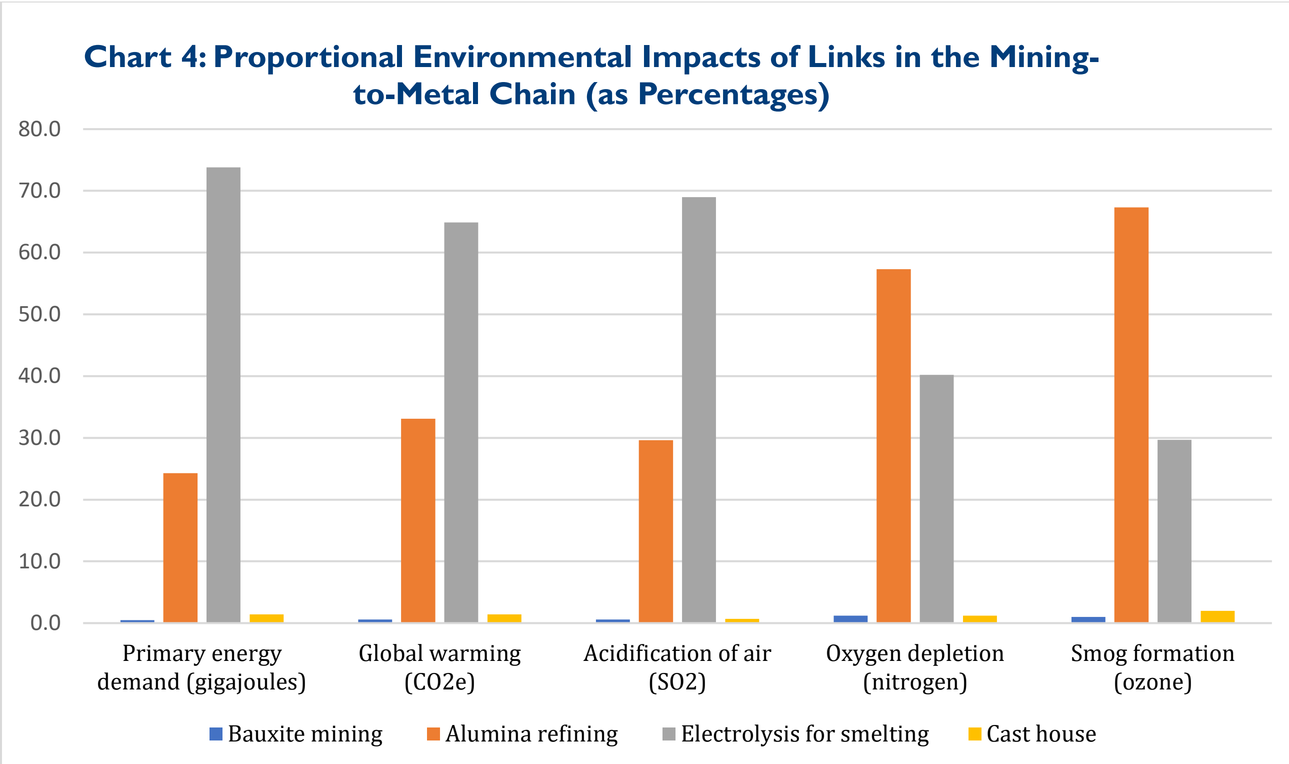
Aluminum accounts for about 85 percent of the volume of solar panels, mostly because of its use in frames.[70] Higher ambitions to limit climate emissions and deploy solar systems will mean even higher aluminum demand. One recent study based on a "net zero" emissions scenario and the rapid scaling up of solar electric systems found that nearly 490 million tons more aluminum would be required by 2050.[71] That is over five times as much total aluminum (both new and made from scrap) as the world produced in 2018.[72]

Greater awareness of the environmental and social impacts of securing vast amounts of metals and minerals for the clean energy transition is pushing the solar and wind industries to find ways to recycle and repurpose their products. Compared to other parts of solar panels, aluminum frames are relatively easy to strip apart and recycle.[73] Going forward, more recycling and the use of synthetic or composite materials for frames could reduce projected demand for aluminum in solar electric systems.

Aluminum's Heavy Environmental and Health Footprint

Even as aluminum's role in clean energy and transportation grows, the way aluminum is currently produced makes it relatively dirty. Each step in the long process of transforming a raw mineral into metal poses problems for the climate, air and water quality, land, and health—and highlights opportunities to find solutions.

The following chart shows the proportional environmental impacts of key parts of the mining-to-metal chain, based on the Aluminum Association's 2022 "lifecycle" analysis of the aluminum forms manufactured in the United States and Canada that are later turned into a variety of products.[74] Overall, aluminum smelting accounts for the largest proportion of energy use, climate emissions, and air pollution, while alumina refining has the biggest impact on water. While the proportional impact of bauxite mining appears very small, it has other severe effects that were not assessed in this particular lifecycle analysis (discussed below and in the case study on page 32).



Source: Based on figures from The Environmental Footprint of Semi-fabricated Aluminum in North America, Aluminum Association, 2022.

The communities living closest to mines, refineries, and smelters bear the heaviest environmental and health burden of the ever-growing demand for aluminum. All of the products that consumers and industries use generate impacts even if they are not directly experienced by the consumer. For example, the aluminum used in the Ford F-150 Lightning electric truck sold in the U.S. has been traced to an alumina refinery in Brazil being sued by communities for contaminating rivers and harming health.[75] Similarly, many of the solar panels and electronics installed in the U.S. are from China, where aluminum production releases very high levels of greenhouse gases.[76]

Data from the Climate and Economic Justice Screening Tool (CEJST) show that residents living near U.S. smelters and other aluminum-related facilities are either part of or very close to areas defined as "disadvantaged."[77] This means they are experiencing considerable air, water, and land pollution, poor health, high living costs, climate disruption, and other problems.

Table 4: Disadvantaged Communities Near Aluminum Facilities

Facility	Within a disadvantaged census tract? *	Number of disadvantaged in tracts within 3 miles	Total population in disadvantaged tracts within 3 miles
Smelters	--	--	--
Alcoa Massena (NY)	Yes	3	13,365
Alcoa Warrick (IN)	No	1	5,973
Century Hawesville (KY)	No	1	2,074
Century Sebree (KY)	No	1	4,240
Century Mt. Holly (SC)	No	3	15,402
Magnitude 7 Metals (MO)	Yes	4	13,298
Alumina refining	--	--	--
Atlantic Aluminum Gramercy (LA)	Yes	4	11,334
Petcoke refining	--	--	--
Oxbow Baton Rouge (LA)	No	2	7,172
Oxbow Kremlin (OK)	Partially *	0	--
Oxbow Port Arthur (TX)	No	5	8,452
Rain CII Carbon Chalmette (LA)	Yes	26	68,259
Rain CII Carbon Gramercy (LA)	No	4	11,334
Rain CII Carbon Lake Charles (LA)	Yes	1	5,396
Rain CII Carbon Norco (LA)	Yes	2	6,124
Rain CII Carbon Purvis (MS)	Yes	2	16,405
Rain CII Carbon Robinson (IL)	No	1	3,131
Graftech International Seadrift (TX)	Yes	2	10,217
Hazardous waste management	--	--	--
Veolia Gum Springs	No	1	4,879
Total	**8 (of 18)**	**63**	**200,937**

*Source: Council on Environmental Quality's Climate and Economic Justice Screening Tool. Data accessed in September 2023. *Census tracts are designated geographical units, the size, boundaries, and population of which can vary considerably across states and regions and are not directly comparable. **Kremlin, OK, is within a tract defined as "partially disadvantaged" due to climate-related risks.*

Bauxite Mining

The first step in aluminum production is strip mining to remove layers of soil and access bauxite ore, the rock that contains aluminum in its mineral form (aluminum hydroxide). Before being transported to refineries, bauxite rock is ground down and washed, a process that requires significant amounts of energy and water. Global bauxite production grew over 160 percent from 2002 to 2022 (from 144 to 380 million tons), with over 75 percent of it now used to produce alumina, the precursor to aluminum.[78]

Bauxite ore contains aluminum in its mineral form.

Bauxite reserves are scattered across the globe, with the largest ones in Australia, Brazil, Guinea, Indonesia, Jamaica, and Vietnam.[79] U.S. reserves are quite small and while production data are not publicly available, domestic bauxite is not used for aluminum production.[80] At 2022 levels of production, global bauxite reserves could last another 85 years, but this timeframe could be shortened by surging aluminum demand (although new reserves might be discovered and developed).[81]

Leading impacts of bauxite mining include loss of farmland, contamination of water supplies, and constant dust that covers buildings and vegetation and causes respiratory and cardiovascular problems.[82] For example, in early 2023, residents near a mine in northern Jamaica sued the operators over impacts to their health, land, water supplies, and livelihoods, and the national Supreme Court temporarily halted operations.[83] (See case study on page 32.) The purpose of that mine is to supply co-owner Atlantic Alumina, a U.S.-based company, with bauxite for the Atalco alumina refinery in Gramercy, Louisiana.[84]

With a global race for bauxite underway, more people are at risk and the consequences can be felt most harshly in poorer countries. As mines spread in Guinea—which has the largest reserves and is now the third biggest producer in the world—large swaths of farmland are being eliminated and villages displaced.[85] Ghana's decision a few years ago to exploit bauxite deposits in a forest reserve could potentially pollute three rivers and the water supply of five million people.[86]

Bauxite mining strips the land clear of forests, grasslands, and nutrient-rich topsoil. On average, an estimated 20 acres of land is cleared for every million metric tons of bauxite ore extracted—a larger proportion than for other types of mining like copper and iron.[87] At current levels of bauxite production, 7,600 acres of new land has to be destroyed every year, about half the size of Manhattan.[88]

Such land clearing can cause lasting damage in places where bauxite deposits and biodiversity "hot spots" overlap. In the western part of Australia, the world's largest bauxite producer, rare native eucalyptus forests are being cut at an accelerating pace. In just the last 20 years, nearly 48,000 acres have been felled for bauxite mining, eliminating the habitat of endangered birds and exacerbating climate change-related drought.[89] Similar problems are found in Brazil's Amazon Rainforest, where bauxite mining has polluted rivers essential for the survival of turtles and other animals.[90]

The Discovery Bauxite facility along Jamaica's northern coast processes mined bauxite for export to U.S.-based alumina refineries.

With the harsh realities of bauxite mining becoming more widespread and garnering more attention, the International Aluminium Association and some companies recently developed voluntary "best practices." These include efforts such as consulting with local residents, minimizing community displacement and health impacts, avoiding mining in natural areas that are protected or particularly rich in plant and animal life, replanting and reseeding trees on razed land, and supporting education and job training.[91] According to corporate participants, such principles are being applied in some locations, but it is unclear the extent to which these voluntary practices will improve conditions for impacted communities in various countries and over the long term.[92]

Alumina Refining

Breaking down and transforming crushed bauxite ore into fine alumina powder involves large volumes of water, caustic chemicals, and electricity. This process occurs at refineries worldwide, both in bauxite mining countries (such as Australia, Brazil, and China) and the largest aluminum producers (such as India, Russia, and the United Arab Emirates).

Global alumina production grew more than 170 percent from 2002 to 2022, from 51 to 140 million tons.[93] During this same period, U.S. production declined over 250 percent, from 4.3 to 1.2 million tons.[94] Today, there is only one operating alumina refinery in the United States, which was built in 1959 and appears to be producing at its full capacity of about 1.2 million tons a year: Atlantic Alumina in Gramercy, Louisiana.[95] Two other alumina refineries have closed in the last few years in Point Comfort, Texas, and Burnside, Louisiana.

Alumina refineries cause air and water pollution. The Atlantic Alumina refinery has been linked to mercury releases into the air that have contaminated nearby waterways.[96] Residents have significant concerns about threats to their drinking water, particularly because the facility operates with a weak permit and under decades-old regulations. (See the case study on page 32.)

The production of one ton of alumina can generate 1.5 tons of waste.[97] This bauxite residue, called "red mud," often contains heavy metals such as arsenic and lead and radioactive elements such as uranium and thorium.[98] Red mud is stored in piles and open pits. By 2016, an estimated three billion tons of the waste had accumulated at active and closed alumina refineries worldwide.[99] Given projected growth in demand for aluminum, there could be ten billion tons of red mud piling up worldwide by 2050.[100]

Dust blowing off the piles and pits can cause respiratory and other health problems and coat houses and land, while the pollutants red mud contains can percolate down into soil and groundwater. Residents near the shuttered Burnside alumina refinery are all too familiar with these problems: 500 acres of red mud is still being contained in pits surrounded by 20-foot levees, and the former operator and the state have yet to fully fund and implement a closure plan. [101]

Some high-profile disasters have cast a spotlight on the big risks posed by the continual production and inadequate management of red mud. In 2010, the collapse of a retaining wall at a refinery in Hungary released 284 million gallons of red mud, enough to fill 28,000 swimming pools. [102] The accident killed ten people, injured hundreds, destroyed aquatic life in nearby rivers, permanently damaged homes, and caused long-term environmental contamination. [103] In 2016, a red mud dam failed in China, leading to the evacuation of hundreds of residents and destruction of villages. [104]

Given the hazards posed by red mud, industry is exploring potential ways to reuse this waste product. Some countries (not including the United States) have approved it as an ingredient in cement, road paving materials, and other products. [105] Yet to date, less than three percent of red mud has ever been reused worldwide. [106] Some companies have proposed extracting rare earth elements and minerals needed to produce electronics and electric vehicle batteries from red mud piles, including a potential project near the Atlantic Alumina refinery in Louisiana. [107]

Until industry innovation and reuse become a reality, alumina refinery operators and governments will continue to hold responsibility for managing red mud. According to the International Aluminium Association, while the industry's gold standard is the environmentally safe closure and remediation of waste sites, "for the near and foreseeable future" most of the world's red mud will be held indefinitely in storage facilities—making the implementation of robust regulatory oversight of waste treatment, stabilization, and monitoring even more imperative. [108]

Petcoke Refining

Petroleum coke, or petcoke, is a by-product of oil refining. Some of this carbon-rich, rock-like material is used as fuel in cement and power plants around the world, including petcoke exported from the U.S. [109] The aluminum industry also needs petcoke to make anodes, a device that conducts electricity for the conversion of alumina into aluminum. About 70 percent of the content of anodes is a type of petcoke that has been refined even further, or calcined. [110] The aluminum industry uses three-quarters of the world's calcined petcoke, which is produced and traded worldwide. [111]

It takes about half a ton of calcined petcoke to create one ton of new aluminum. [112] Even at current rates of global production, aluminum operators worldwide need about 35 million tons of it every year. U.S. smelters are likely consuming over 400,000 tons of calcined petcoke and if they ramp up to full production capacity in the future, they could need nearly 700,000 tons.

Dust blowing off of piles of petcoke at refineries and transport depots can cause respiratory problems for people nearby. [113] And oil refineries—which make the petcoke—are highly polluting, sending benzene and other dangerous substances into nearby communities. [114] In addition, petcoke is made of carbon and contains a lot of sulfur and metals, which means serious pollution impacts occur when it is combusted as fuel, calcined, and used in aluminum anode production and smelting. (See section on air pollution from smelters on page 23).

The calcining process requires heating petcoke in kilns and furnaces to very high temperatures—up to 2500ºF, nearly 12 times the temperature of boiling water—which both breaks down the material and increases its carbon content.[115] Along the way, calciners release carbon dioxide, air toxics, and other pollutants.

As much as 13 percent of the sulfur in petcoke is released from calciners, making them key sources of SO_2.[116] One air monitor near Oxbow's Port Arthur, Texas, calciner revealed that the plant was continually violating federal SO_2 standards, leading EIP and its partners to file a complaint to EPA under Title VI of the Civil Rights Act over the refusal of the Texas state regulator to require Oxbow to install a "scrubber," a proven and available pollution control technology, to rein in SO_2.[117] (See the case study on page 34.)

There are 15 facilities in the U.S. that together have the capacity to produce about five million tons of calcined petcoke annually: ten stand-alone plants and five units within large refineries in California, Louisiana, and Washington (owned by BP and ConocoPhillips).[118] The table below shows the SO_2 and fine particulate matter—called PM2.5 and which directly contributes to asthma, heart disease, and other health problems—released by the stand-alone plants. Data on the calcining units within the refineries are not readily available and some of the operations appear slated for closure as refineries change their operations.[119]

These data indicate that petcoke calcining plants have a significant impact on local air quality and likely health. Most notably, all of the calcining plants are leading sources of pollution in the County or Parish where they are located. All but one of the calciners rank as number one for SO_2 and most account for nearly all of the volume of that pollutant reported by industrial sources in the same area. The calciners also rank high for fine particulate matter, even if the proportions of emissions are lower relative to even bigger polluters in the area (such as oil refineries and fertilizer plants).

Table 5: Sulfur Dioxide and PM2.5 Released by U.S. Petcoke Calcining Plants, by Volume and Compared to all Reporting Sources in the County or Parish

Plant	SO_2, (tons)	SO_2, percentage of emissions / rank	PM2.5 (tons)	PM2.5, percentage of emissions / rank
Chalmette Coke Plant, St. Bernard Parish, LA	1,883	91% / #1 of 8	79	25% / #2 of 9
Gramercy Coke Plant, St. James Parish, LA	4,158	76% / #1 of 19	138	25%/ #1 of 18
Lake Charles Calcining Plant, Calcasieu Parish, LA	4,905	23% / #3 of 37	76	4% / #9 of 37
Norco Coke Plant, St. Charles Parish, LA	2,568	72% / #1 of 27	161	12% / #4 of 27
Baton Rouge Calcining Plant, East Baton Rouge Parish, LA	12,317	93% /#1 of 33	162	9% / #2 of 40
Port Arthur Calcining Plant, Jefferson County, TX	9,359	83% / #1 of 52	138	6% / #5 of 53
Seadrift Coke L.P., Calhoun County, TX	488	98% / #1 of 6	7	3% / #3 of 5
Purvis Calcining Plant, Lamar County, MS *	345	99% / #1 of 3	20	61% / #1 of 3
Robinson Calcining Plant, Crawford County, IL	1,760	90% / #1 of 6	65	29% / #1 of 9
Kremlin Calcining Plant, Garfield County, OK	16,900	99% / #1 of 98	42	18% / #2 of 87

*Source: State Emission Inventories, reporting year 2021. The facility ranking is based on totals for all point sources reporting that pollutant to the inventory. * Data for MS is for 2020, the latest year available.*

The sulfur and metal content of petcoke depends on the original oil source, with heavier crudes (for example from the Canadian Tar Sands) containing more and lighter crudes (for example from the Permian Basin of Texas) less. The "anode-grade" calcined petcoke used in aluminum production is generally defined as having a sulfur content of three percent or less and a relatively low metal content.[120] Yet the large volumes of petcoke used and inadequate pollution controls add up to make SO_2 pollution a global problem. As a result, governments and aluminum producers are increasingly looking to further reduce the percentage of sulfur in the calcined petcoke used for aluminum production.

In 2018, India banned the import of petcoke because of air quality and climate concerns—but made an exception for the two to three percent sulfur petcoke used to produce metals and the one percent sulfur petcoke used to produce electric vehicle batteries.[121] In 2019, China adopted an air pollution reduction plan that prohibited the use of petcoke with more than three percent sulfur in some industrial regions, including where calcining and anode production occur.[122] For its part, the European Commission considers anodes with low-sulfur content to be a practical way for the aluminum industry to reduce air pollution; it recommends a limit of 1.5 percent or less sulfur, which some European smelters are currently following.[123]

In 2022, Washington State issued a plan to bring the now-closed Alcoa Intalco aluminum smelter into compliance with federal SO_2 limits, in part through the use of calcined petcoke with a sulfur content of two percent or less.[124] The SO_2 limits at the Alcoa Massena smelter are based in part on a petcoke sulfur content of 2.5 percent.[125] Century Aluminum long used two percent sulfur petcoke in anodes at its Mt. Holly smelter, but received a permit in 2016 to increase this to three percent as long as production levels came down so overall SO_2 emission levels could be maintained.[126] However, Century recently applied for a permit to increase production even while using higher-sulfur petcoke, which could degrade air quality if allowed.[127]

Low-sulfur and calcined petcoke costs significantly more than high-sulfur, less refined petcoke.[128] What regulators require to protect air quality will in part determine the industry's impacts on health and the environment as demand for aluminum grows.

Aluminum Smelting

The final stage of producing new aluminum takes place at large industrial plants called smelters, where alumina powder is converted into metal. Alumina and a mixture of different minerals called the "bath" are mechanically fed into giant "pots" containing anodes that conduct a continual current of high-voltage electricity.

The reaction that occurs creates metal that is kept in a molten state by maintaining the pots at very high temperatures—up to 1800ºF, nearly nine times the temperature of boiling water.[129] The molten metal is then removed, cooled, and cast into shapes that manufacturers can use to create a variety of products. This complex process generates climate emissions, air and water pollution, and hazardous waste.

Greenhouse Gases

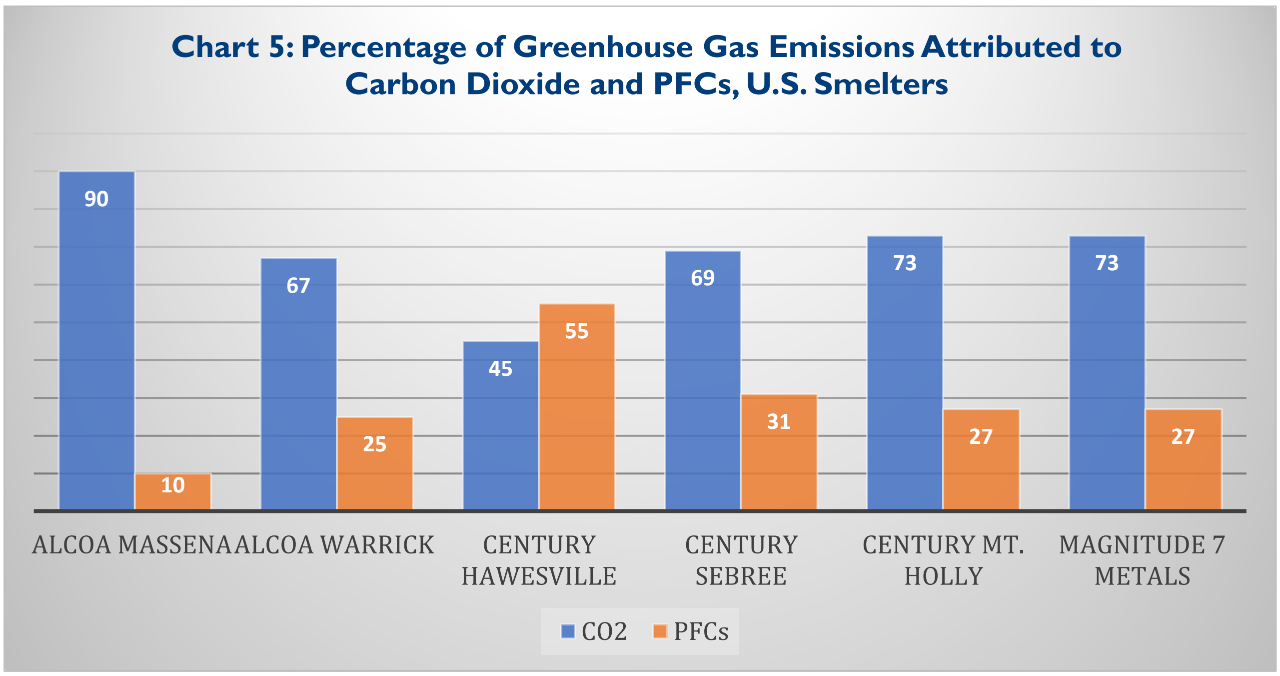
In 2018, the aluminum industry was responsible for about two percent of the world's greenhouse gas emissions, but that is expected to grow along with demand for the metal.[130] In light of national and international commitments to address climate change, operators and policymakers are seeking to increase "low-carbon" aluminum made with renewable energy. Some countries, like Canada and Iceland, already use hydropower for smelting, while others like China and Russia do so for part of their production. The United Arab Emirates recently became the first country to produce aluminum using solar power.[131]

Smelting is an energy-intensive process. EIP's assessment of available data concluded that in 2021, over 70 percent of the greenhouse gas emissions from the six operating U.S. smelters came from power supply alone.[132] That is because five of the smelters rely on fossil fuel-based energy either from nearby power plants or electrical grids; only one, Alcoa Massena in New York, runs on hydropower. Together the smelters used about 14 billion kilowatt hours of electricity in 2021, enough to power over 1.3 million homes for a year.[133]

Aluminum smelters stand out among industrial polluters for emissions of perfluorocarbons (PFCs), greenhouse gases with an outsized climate impact. Compared to the impact of CO_2 over a 100-year period, PFC-14 is 6,600 times more powerful and PFC-116 is 11,000 times more powerful; both gases remain in the atmosphere for thousands of years.[134]

PFC releases happen because of "anode effects," or when the alumina content in the pots falls below levels optimal for production. This creates surface tension that breaks the fluorine and carbon bond, releasing PFCs.[135] The six aluminum smelters accounted for over 95 percent of PFCs reported by metal producers to the EPA in 2021.[136]

About a third of carbon dioxide equivalent (CO_2e)—the measure used for total greenhouse gases—reported by the six smelters in 2021 came from PFCs; carbon dioxide made up nearly all of the rest (less than two percent came from methane and nitrous oxide).[137] There is variation across the smelters, indicating room for improvement by operators when it comes to technologies and practices to reduce anode effects and address the PFC problem.



Source: EPA's Greenhouse Gas Reporting Program, 2021 data. Emissions are calculated as carbon dioxide equivalents based on climate impacts over a 100-year time period.

Air Pollution

Smelters release pollutants that degrade air quality and harm health and the environment. This happens when fuel is combusted during smelting and anode production, because of the metals in alumina and sulfur in petcoke, and other processes. There are federal limits on some air pollutants emitted by aluminum smelters, but most are decades old and haven't been recently assessed.

Table 6: Key Air Pollutants from Aluminum Smelting

Pollutant	Potential health and environmental impacts
Volatile organic compounds	Formation of ozone (smog), respiratory problems.
Particulate matter	Pulmonary, respiratory, and cardiovascular problems. Depletion of nutrients in soil and water. Contributes to haze.
Sulfur dioxide	Respiratory problems, damage to trees and vegetation. Contributes to acid rain and the formation of particulate matter.
Carbonyl sulfide	Skin and eye irritation, exhaustion and confusion.
Fluoride compounds	Damage to trees, crops, livestock, and wildlife. Hydrogen fluoride harms breathing, eyes, and skin.
Polycyclic organic matter (POM) and polycyclic aromatic carbons (PACs)	Toxic for the liver, blood, eyes, immune system. Can increase cancer risk and reproductive and developmental problems.
Mercury	Damages soil, water systems, fish and other aquatic life. When ingested by people, can cause loss of vision, sensory abilities, and muscle function.

Source: Pollutant summaries from the U.S. Environmental Protection Agency, the National Institutes of Health, and the World Health Organization; National Emission Standards for Hazardous Air Pollutants for Primary Aluminum Reduction Plants.

Unfortunately, U.S. smelters have violated air pollution limits many times in the last few years and they continue to rely on old equipment and with insufficient monitoring and pollution controls. For example, a recent investigation classified the area around the Century Sebree smelter as creating a lifetime cancer risk from industrial sources above what EPA defines as "acceptable," primarily because of the facility's emissions of nickel and polycyclic aromatic carbons (PACs).[138]

Currently, three of the six operating U.S. smelters—Alcoa Massena in New York, Century Sebree in Kentucky, and Magnitude 7 Metals in Missouri—are the key reason why surrounding areas fail to meet federal standards for SO_2, putting nearby communities and the environment at risk. The SO_2 concentrations measured in New Madrid, Missouri, near the Magnitude 7 Metals smelter are some of the highest in the country, exceeding the federal air quality standard (75 parts per billion) almost 25 percent of the time during the first half of 2022—and thereby subjecting residents to 60 hours of SO_2 at levels four to six times higher than allowed by law.[139]

While the six smelters report releases of numerous toxics, they all consistently release four: carbonyl sulfide, hydrogen fluoride, polycyclic aromatic compounds, and benzo(ghi)perylene, a known carcinogen. The variation in volumes across smelters can't necessarily be explained by level of aluminum production. For example, from 2018-2021, Century Sebree produced 45 percent of U.S. aluminum but reported 84 percent of PACs from all smelters, while Century Hawesville produced 33 percent of aluminum but 61 percent of naphthalene (a type of PAC) from all smelters.[140]

Table 7: Proportion of Aluminum Production and Releases of Air Toxics at the Three Century Aluminum Smelters, 2018-2021 (in Total Tons)

Smelter	Aluminum production	COS	HF	PACs	Benzo(ghi) perylene	Naphthalene
Century Hawesville (KY)	33%	42%	39%	13%	9%	61%
Century Sebree (KY)	45%	23%	49%	84%	89%	33%
Century Mt. Holly (SC)	23%	35%	12%	3%	2%	6%

Source: Calculations based on Century Aluminum production figures in SEC Form 10-K filings and Toxic Release Inventory data reported by the facilities for each substance.

Water Pollution

Smelters use water in their power systems (boilers), to wash equipment, to cast metal, and in wet scrubbers (a type of pollution filter)—processes that result in large volumes of contaminated wastewater. Operators dump wastewater into ponds and onsite landfills, from where leachate can drain into soil. The wastewater may also be minimally treated and discharged directly into rivers and streams, including ones where water quality is impaired like the Ohio and Mississippi Rivers.

Smelter wastewater contains a host of pollutants that can adversely impact soil and aquatic environments and end up in drinking water supplies (Table 8). Only a handful of these pollutants have federal limits to protect health and the environment.[141] The limits that do exist are decades old and should be updated to keep pace with modern pollution control technologies. In addition, there are no limits for pollutants in contaminated stormwater that streams off smelter sites.

Table 8: Key Water Pollutants from Aluminum Smelting

Pollutant	Potential health and environmental impacts
Total Suspended Solids (sediment)	Reduces water clarity, blocks sunlight and plant growth, depletes oxygen, harms and kills aquatic life.
Mercury	Damages soil, water systems, fish and other aquatic life. When ingested by people, can cause loss of vision, sensory abilities, and muscle function.
Fluoride	Damage to bones, kidney, brain, liver, and thyroid.
Nickel	Skin reactions, digestive problems, kidney damage.
Benzo(a)pyrene	Anemia, immune disorders, developmental and reproductive problems, cancer.
Antimony	Toxic to aquatic life, damages liver and lungs, potential carcinogen.
Cyanide	Toxic to aquatic life, damages thyroid function.
Aluminum	Toxic to aquatic life.

Source: Pollutant summaries from the U.S. Environmental Protection Agency, the National Institutes of Health, and academic studies; Nonferrous Metals Manufacturing Effluent Limitation Guidelines, Primary Aluminum Smelting

Even though they operate with weak wastewater requirements, U.S. smelters regularly violate the limits that do exist. For example, the Alcoa Warrick smelter in Newburgh, Indiana, exceeded its legal limits on discharges of mercury to the Ohio River nearly 30 times between 2018-2023.[142] Sections of the Ohio River near both the Warrick and Century Hawesville smelters are classified as impaired for aquatic life and recreation.[143]

Hazardous Waste

Aluminum smelting generates waste that contains harmful substances. The liner used in the giant smelting tanks called "pots" makes up the largest by volume and most hazardous of these wastes. The liner is a rock-like material that is made up mostly of carbon and contains toxics like silica, fluorine, and cyanide. As the pots wear down over time, the heavy blocks of lining have to be removed.

Smelters generate approximately one ton of this hazardous waste, called spent potliner, for every 40 tons of aluminum produced.[144] With demand for aluminum growing, the volume of this waste generated worldwide increased more than 80 percent between 2005 and 2020, from 0.8 to 1.45 million tons, and could increase another 30 percent to nearly 2 million tons by 2050.[145] Based on production levels, U.S. operators generated about 22,000 tons of this waste in 2022, enough to fill about 1,500 dump trucks.[146]

Currently, less than half of the world's spent potliner waste is reused in other industrial processes like steel and cement manufacturing, while the rest has to be sorted, crushed, treated, and disposed of in landfills.[147] In the U.S., the EPA regulates spent potliner as a hazardous waste and requires specialized disposal.[148]

U.S. smelters dispose of their spent potliner primarily by shipping it by truck and rail to the Veolia hazardous waste facility in Gum Springs, Arkansas, which is classified as a major source of air pollution from waste processing equipment.[149] At the facility, spent potliner is crushed, mixed with limestone and sand, and heated at very high temperatures before being placed in a designated landfill.[150]

Given the long history of U.S. aluminum production, an untold volume of spent potliner remains buried at shuttered smelters, where the toxic substances it contains can leach into soil and groundwater. For example, Alcoa operated the Badin smelter in North Carolina from 1916-2007 and buried thousands of tons of spent potliner there. But Alcoa has yet to clean up the site, which continues to expose local residents to health risks.[151] Similarly, the old Anaconda Aluminum site in Montana is so contaminated by spent potliner buried there over a 30-year period that it is now part of the Superfund program for cleanup of the nation's most contaminated toxic waste dumps.[152]

The Promise and Impacts of Secondary Aluminum

Of all the aluminum produced worldwide today, about a third, or nearly 30 million tons per year, is derived from scrap metal.[153] This "secondary" aluminum production uses 95 percent less energy per unit of aluminum than making brand new metal.[154] Since it does not require additional mining of bauxite or refining of alumina and petcoke, recycled metal is also far less harmful for communities and the climate.

Secondary production plants are less expensive to build and operate than smelters. In just the last few years, companies have announced several new U.S. plants to sort, re-melt, and re-form metal. Today, the secondary sector accounts for nearly 80 percent of the aluminum made in the U.S., which ranks second after China globally for this type of production.[155]

Increasing the proportion of secondary production is widely seen as essential to reducing the aluminum industry's climate, air, and water pollution. As demand for the metal increases and manufacturers commit to using more recycled content in their products, the race for scrap metal is picking up speed and prices are on the rise.[156]

Currently, expanding secondary aluminum remains tied to more production of new aluminum. That's because over half is made from "new scrap," or metal discarded at smelters after forms are cut and waste products collected, while under half is made from "old scrap" taken out of worn-out vehicles, planes, and appliances and discarded products like cans and foil.[157]

Some sectors, in particular aerospace and the military, require new, high-purity aluminum that is not mixed with other metals or contaminants. But secondary aluminum could play a bigger role in other applications. Worldwide, work is underway to develop and improve aluminum alloys that use some copper, zinc, silicon, and other elements.[158] New technologies and a change in practices—for example, sorting out more metal from old cars before they are shredded—could expand the supply of marketable secondary metal.[159] It will also be important to increase the efficiency of systems to remove contaminants and remelt scrap metal.[160]

Like all industries, secondary aluminum poses environmental and health risks that need to be addressed. Sorting, cleaning, crushing, shredding, and remelting a variety of aluminum pieces requires energy-intensive, polluting equipment. These secondary production plants are required to follow EPA rules to limit releases of harmful substances, such as hydrocarbons, particulate matter, and dioxins and furans, a class of air toxics that can cause skin, liver, and reproductive problems.[161]

In addition, the 22 largest U.S. secondary aluminum plants reported over 1.1 million metric tons of greenhouse gas emissions to the EPA in 2021—equivalent to the energy used by about 140,000 homes.[162] But this is only part of the picture since dozens of other plants involved in secondary production—from processing scrap to rolling out sheets and foil—aren't even required to report their climate emissions.[163]

The processing of aluminum in furnaces during secondary production leaves behind a heavy, gravel-like waste that contains a lot of salt and residual metal and alumina.[164] Called "saltcake," this product is not classified as a hazardous waste, but it does require special handling, disposal, and monitoring at landfills. Once buried, saltcake can generate chemical reactions that increase the off-gassing of polluting substances and the risk of explosions.[165]

Living with the Impacts: Case Studies

Below are case studies of four local communities in Jamaica, Louisiana, Texas, and Kentucky that are suffering from the impacts of aluminum production at different points in the "mining-to-metal" chain.

Jamaica: Mining for the Raw Material of Aluminum

A bauxite storage facility at the Discovery Bauxite plant in Discovery Bay, Jamaica, where bauxite is transported via rail from inland mines to be shipped overseas.

Jamaica is renowned for its sultry beaches and vibrant jungle, but a red clay rock is driving a flurry of industrial activity along the island's northern coast, an area with rainforests known for subsistence farming and a tremendous diversity of plants and animals. With mining expanding, local residents and activists are asking the Jamaican Supreme Court to step in and provide relief from air and water pollution and the destruction of their lands.

Aluminum production begins with the strip mining of the raw material bauxite (see page 18). The bauxite for Atlantic Alumina in Gramercy, Louisiana, the only operating bauxite refinery in the U.S., primarily originates along Jamaica's northern shore. The relationship is so tight that the refinery owner ATALCO Alumina has partnered with the Jamaican government to mine and export the mineral ore to the United States for refining, with the Jamaican government owning a 51 percent stake in the enterprise.[166]

In 2018, an expanded mining lease issued to the partnership, which was rebranded Discovery Bauxite in 2022, gave the mining operation access to 12 times the reserves it previously had exploration rights to. This aligns with the company's vision of continuing to produce over five million metric tons of bauxite per year. The bauxite ore is mined in the surrounding countryside and then transported via railway to Port Rhoades, where it is dried and shipped to customers.

Ninety percent of the world's bauxite reserves are concentrated in tropical and sub-tropical regions like Jamaica, with vast, easily accessible deposits also found in West Africa, Australia, South America, and India. In West Africa's Guinea, local people also complain about bauxite mining destroying their water sources and farmlands.[167]

In Jamaica, the government's interest in growing the bauxite industry is substantial. Bauxite mining accounts for two per cent of Jamaica's gross domestic product,[168] even as its role in the global market has declined since the 1960s when the country was the world's largest producer of bauxite.[169] And the government's ownership interest in Discovery Bauxite creates a clear conflict of interest, as the government is also purportedly the regulator of the industry, responsible for protecting residents and the environment.

"One of the big reasons nothing is being done at all is that the government is the owner and they are also the ones who supervise," said Al Gallimore, a retired broadcaster who lives adjacent to the mining operations. "So, who do we have to complain to about what's being done to the ecology and the people?"

Gallimore said the land reclamation and restoration that the government claims to undertake after mining an area is "nastily, insultingly" done on the occasions that it is done at all.

"Everybody who lives within a certain ambit of these mining areas suffers from head and chest colds," said Gallimore, who had glaucoma and is now blind. "There's obvious mining effects on water and air quality. This was the breadbasket of Jamaica. Now the farmers are poor, walking the streets. As a result, kids don't go to school, and those that do can't afford higher education."

A 2020 report from the Jamaica Environmental Trust called "Red Dirt" found that Jamaica's air quality standards are outdated and inadequate to protect public health, and that the bauxite-alumina industry should be held to a higher standard. It also determined that community complaints have been ongoing for decades but have produced little change in lived experiences.[170]

Theresa Rodriguez-Moodie, Chief Executive Officer of Jamaica Environment Trust, said many complaints by the community are dismissed by the Jamaican government and the bauxite industry as persons just seeking some "dust money."

"Complaints about the negative health impacts associated with the bauxite-alumina industry go very far back, but the Government of Jamaica has done very little to address the concerns," she said.

“Jamaicans have a right to a healthy environment but their concerns about this tend to be treated with scant regard.”

Recently, community complaints have coalesced into a Supreme Court case pitting local farmers against Discovery Bauxite, with a hearing date set for the end of 2023. The nine claimants in the lawsuit, nearly all of whom are farmers in St. Ann Parish where the mines are located, allege that the government’s special mining leases for the region breach their constitutional rights and should be struck down.

The lawsuit states that as a result of mining activities carried out by the company, claimants have suffered, “significant injury to their health, damage to their homes, farms, and subsistence crops, contamination of their drinking water sources, loss of their livelihood and rural way of life and/or other financial and personal loss.”[171]

Especially aggrieved is a community of Indigenous West Indians and Africans known as the Accompong Maroons who arrived as runaway slaves before Jamaica’s colonization.[172] Changes to mining leases in 2021 by Jamaica’s minister of Transport and Mining opened up lands that the Maroons consider to cross the boundaries of their ancestral lands—lands they’ve inhabited for hundreds of years with minimal environmental impact.

On top of potentially violating indigenous land rights, the revised mining leases encroach into a biodiverse area of Jamaica known as Cockpit Country, a rainforest on top of a limestone formation perforated with springs and caverns. Nearly half of Jamaica’s fresh water originates in the 500-square-mile area, which is home to half of the island’s 21 species of bats and 37 of its 62 species of amphibians and reptiles.

After many years of advocacy by a cohort of nonprofit groups and community members known as the Cockpit Country Stakeholder Group, the Jamaican government designated a sizeable chunk of Cockpit Country as protected in 2022. But the broader environmental and health concerns for the region remain as mining continues to expand.

“While it is the largest terrestrial protected area in Jamaica it still does not have a buffer, it has no management plan, and no one has been designated to manage its protection so far,” said Rodriguez-Moodie. “There is still much work to be done."

Simon F. Mitchell, a geology professor at the University of the West Indies in Kingston, Jamaica, said Cockpit Country is valued by the Maroon communities as well as by other people living on the fringes of the main area. He said mining changes the character of the forest, bringing in roads, nonnative species like cows, and large trucks that kick up air pollution.

“Former communities in bauxite areas have become ghost towns,” he said, “with original agricultural practices destroyed.”

Louisiana: The Dusty, Toxic Process of Refining Ore into Aluminum's Main Ingredient

Bauxite dust coats the area surrounding the Atlantic Alumina Refinery along the Mississippi River in Gramercy, Louisiana.

The Atlantic Alumina Refinery in Gramercy, Louisiana, sits like a rusty red stain along the Mississippi River in St. James Parish, midway between New Orleans and Baton Rouge along a strip of land often referred to as Cancer Alley for its high concentration of heavy industry.

Opened in the 1950s, the facility processes raw bauxite ore (rust-colored from its iron content) mined in Jamaica into alumina, the primary component of aluminum (see page 18), in a procedure requiring large volumes of water, caustic chemicals, and electricity. From the Gramercy plant, the only operating U.S. alumina refinery, the alumina is transported to smelters for further refining into aluminum.

The industry has left sepia-toned waste piles heaped along the Mississippi River. Dusty particulate matter blows off red mud piles, contaminating surrounding water bodies and threatening ecological balance and public health. Many residents have serious concerns about threats to their drinking water from the refinery, particularly because the facility releases large amounts of mercury, a heavy metal that can damage the nervous and respiratory systems, kidney, and liver. In addition, Atlantic Alumina operates with a weak permit and under decades-old regulations. Workers are also at risk because of a series of safety violations found by federal mine safety regulators.[173]

Jo Banner, lifelong area resident and environmental justice activist, said her community has suffered the presence of the alumina refinery for generations.

“It’s miserable,” she said. “It really has impacted our lives negatively. We get constant odor. Red dust everywhere. I purchased a red car so you won’t see the dust as much.”

Banner said in the fall, around the time school starts, cold fronts start to blow in and push the dust and odors across the river to her community in greater amounts.

“It’s so sad, the smell of bauxite reminds me of school starting,” she said. “Other people think of pumpkin spice in the fall. Not me.”

Wilma Subra, a chemist and environmental advocate based in Louisiana, said the whole facility is red and so is all the area around it. “Everybody on both sides of the river has red mud on their houses and cars—everyone is exposed to it,” she said.

Subra said the main pollutant of concern is mercury, which can cause birth defects as well as damage the nervous systems.

The Atlantic Alumina refinery released mercury vapors into the air for decades without permission until state regulators took action in 2015, requiring the operator to conduct mercury monitoring and reporting and develop a plan to limit releases.[174] According to EPA data, in 2021, Atlantic Alumina Refinery was the top source of mercury releases in Louisiana, accounting for 1,900 pounds of mercury, which can damage the nerves, kidney, liver, and immune systems.[175] In 2021, the refinery was the top source of mercury releases in Louisiana and one of the top 50 in the country.[176]

Now, Louisiana regulators permit the plant to emit up to 1,500 pounds per year of mercury, and those legal limits are scheduled to be lowered over time to 1,200 pounds a year. For years, state regulators have issued health advisories for the high levels of mercury found in fish in the nearby Blind River and nearby groundwater.[177]

“When it’s releasing mercury, it’s getting on both sides of the river in everybody’s yard,” Subra said. “They’re all being exposed to mercury.”

Subra said that when ships unload bauxite mined in Jamaica at the facility’s two docks it blows across the river and goes everywhere.

“I like to use this facility as an example for particulate matter pollution up and down Cancer Alley,” she said. “At other plants, people don’t realize what they’re inhaling, but in this case, it’s red. They can see what they’re breathing.”

Health and safety issues are also a grave concern for the more than 500 workers at the facility. In July 2023, the Federal Mine Safety and Health Administration announced a "pattern of violations" action against ATALCO after the agency determined that the plant had 106 serious violations that were likely to lead to "reasonably serious injury or illness" in the past year. This means that if the plant has another health and safety violation within three months, the regulators must, by law, pull workers off the job in areas where the alleged violation is occurring.[178]

A related inspection report found that ATALCO was not maintaining electrical equipment properly, including by having unsafe electrical cables and missing or damaged cover plates, and for not correcting potentially dangerous conditions.[179]

Subra said that the company invested some money to build domes to cover the dust. But it apparently was not enough, because when she drives by, she said she can still see big red dust stacks "going sideways" and evidence of workers not being protected.

Texas: The Dirty Middleman in Aluminum Production

Pollution from the Oxbow Petroleum Coke Plant in Port Arthur clouds the Texas sunset.

In southeast Texas, a nearly century-old industrial plant belches long trails of black smoke into the sky as it converts a heavy, coal-like waste product of crude oil into a key material needed for aluminum production.

Occupying 112 acres, the Oxbow Petroleum Calcining Plant in Port Arthur, Texas, is small compared to the nearby oil refineries, which occupy thousands of acres. But the 85-year-old plant is a giant polluter, releasing far more sulfur dioxide pollution than any of the refineries. In fact, the Oxbow plant released about 22 million pounds of sulfur dioxide each year from 2016 through 2019—making it one of the state's largest sources of this air pollution, which can trigger lung disease and heart attacks.[180]

The Oxbow Port Arthur plant is one of three U.S. calcined coke plants owned by billionaire William Koch, with the others in Enid, Oklahoma, and Baton Rouge, Louisiana. The Port Arthur plant is located in a city that is 98 percent of people of color and 62 percent lower income.

"In a city already identified as a cancer cluster, Oxbow's unabated pollution poses a significant health risk to a region with over twice the state and national averages for cancer, heart, lung and kidney disease," said John Beard, Founder and Chairman of the Port Arthur Community Action Network. "Port Arthur and Southeast Texas deserve better, and we refuse to be further sacrificed in the Koch Family's pursuit of profit."

The Oxbow plant takes a lumpy, black oil refinery byproduct known as petroleum coke, or "petcoke," and heats it up and into a porous substance called "calcined coke" (see page 20). This material is the key ingredient in the devices that conduct electricity during the smelting process that transforms alumina into aluminum. During calcining, petcoke is fed into massive kilns and heated as high as 2,400 degrees Fahrenheit, which burns away sulfur, heavy metals, and other impurities into the air.

All three of these plants take advantage of a loophole in the 1970 Clean Air Act that allows older facilities to delay installing the most modern pollution control equipment until they make substantial upgrades. By carefully circumventing updates that would trigger the law, these facilities have avoided installing pollution control devices called scrubbers that capture sulfur dioxide and would slash SO_2 emissions. The Texas Commission on Environmental Quality (TCEQ) has also chosen not to require the Port Arthur facility to install scrubbers.

Ninety-two percent of the sulfur dioxide air pollution in Jefferson County, including Port Arthur, comes from the Oxbow plant.[181] About 2,624 residents live within a three-mile radius of the plant.[182] And according to federal data, the asthma rate in West Port Arthur, the neighborhood surrounding the plant, is 70 percent higher than the national average.[183]

A lengthy investigation supported by the Fund for Investigative Journalism recently determined that Oxbow's operators appeared to try to outsmart sulfur dioxide air monitors by shutting down kilns when the wind blew in the direction of the sensors.[184]

Joel Mintz, an emeritus professor of law at Nova Southeastern University in Florida and former EPA enforcement attorney called the maneuvering by Oxbow a clear "criminal violation of the Clean Air Act," and said EPA should open "an investigation with the Justice Department pursuing criminal action."

In 2021, after discovering an air monitor near the plant that was continually violating federal sulfur dioxide air pollution standards, The Port Arthur Community Action Network, partnering with EIP, asked EPA to investigate whether TCEQ violated the Civil Rights Act of 1964 (Title VI), which prohibits discrimination on the basis of race, color, or national origin in any program or activity that receives federal funds. The groups allege that TCEQ violated the law by issuing weak air pollution control permits to Oxbow and failing to require modern pollution control devices. EPA accepted the investigation, which remains open.

"My hope is that [EPA] will thoroughly investigate Oxbow's emissions and their impact on the community," said Beard. "And that they will draw what we believe to be an inescapable conclusion: that Oxbow is an imminent danger to the life and health of people in Port Arthur and southeast Texas."

Kentucky: Pollution from the Final Phase of Aluminum Production

The Century Sebree smelter discharges its wastewater into three tributaries leading to the Green River, which flows into the Ohio River.

The Century Sebree Smelter in Robards, Kentucky, is one of six operating aluminum smelters in the U.S. that conduct the final stage in the aluminum manufacturing process (see page 23). Most of the equipment at the more than 50-year-old Sebree smelter is showing its age and is insufficient to control pollution. Sulfur dioxide pours from its stacks, which can trigger lung disease and heart attacks. These plants also release perfluorocarbons, or PFCs, which are among the most potent and longest-lasting greenhouse gases on the planet.

There are also other toxic pollutants of concern: an investigation by ProPublica classified the area around Sebree as creating a lifetime cancer risk from industrial sources above what EPA defines as "acceptable," primarily because of the facility's emissions of Polycyclic aromatic compounds (PACs), naphthalene, and nickel.[185] From 2018-2021, Century Sebree produced 45 percent of U.S. aluminum but 84 percent of aluminum-related PACs.[186]

Yong Kwon, a Senior Policy Advisor in the Living Economy program at the Sierra Club, said that technologies for curbing post-combustion emissions at aluminum smelters are being tested, including adding new pollution scrubbing equipment to older plants. But he added that the bigger opportunities lie in developing and adopting new technologies and processes to prevent emissions before they occur.

"This would limit both emissions released during the smelting and the emissions produced when the anodes themselves are created," he said.

Anodes are devices used to conduct electricity during the aluminum reduction process. PFCs are released when the bond between fluorine and carbon breaks during aluminum smelting. Kwon said one promising technology is known as an inert anode, which would replace the standard carbon-based anodes—thereby reducing both greenhouse gases and sulfur dioxide pollution.

Sebree is also a major source of water pollution. It discharges its wastewater into three tributaries leading to the Green River, which flows into the Ohio River, as well as two creeks. Sebree's wastewaster discharge permit only limits discharges for a few pollutants. But the company has acknowledged the smelter releases other pollutants that are not limited by its permit, including chromium and copper.[187] Wastewater discharges at Sebree exceeded even its weak permit limits and failed water tests 23 times between 2018–2023 (including for solids, iron, pH, and chlorine), causing EPA to classify the facility as a "significant/category non-complier."[188]

Primary aluminum smelting is also highly energy intensive, with electricity estimated to account for up to 40 percent of production costs.[189] And nearly three-quarters of greenhouse gas emissions related to aluminum production come from the generation of electricity used in primary aluminum smelting.[190] According to Century, Sebree has consumed more than 3.2 million megawatt hours of electricity annually in recent years, which makes up about four percent of the total electricity consumption in Kentucky, a state powered mostly by coal and natural gas.[191]

Century's only aluminum smelter outside the U.S. is located in Grundartangi, Iceland. A newer plant, it emits just one-sixth of the PFC emissions per ton of aluminum compared to the Sebree plant, according to a recent assessment.[192] The Iceland plant is more automated, while the Sebree plant relies on more manual controls, which are often less precise and result in additional pollution, according to the company. The Iceland plant also has access to cleaner, cheaper electricity via hydropower and geothermal sources. The comparison of the two plants, one old and dated, the other newer and cleaner, offers a vivid illustration of the need to retrofit and modernize U.S. smelters.

Pollution Reduction Pathways

The status quo of aluminum production, with its high energy use and dirty emissions, is dramatically out of sync in an era of climate change, compromised air and water quality, and resource constraints. The fact that skyrocketing demand for aluminum is being driven by the need for cleaner energy systems and modes of transportation presents a challenging but promising opportunity for change.

There is an urgent need to transition to new modes of aluminum production and the more efficient use of metal—particularly for U.S. companies seeking to expand domestic operations and consumption. There are clear pathways forward to lighten aluminum's heavy health and environmental footprint. While the journey will be complex and require considerable investment and new practices, simply staying the current course will inevitably cause even more harm to people and the planet.

Rein in Climate Emissions

According to the International Aluminium Institute, to be aligned with a climate warming scenario of no more than 2° Celsius, the global aluminum industry will need to reduce emissions from electricity to zero by 2050.[193] To move in this direction, operators should source more of their power from renewable energy and less from fossil fuels.

Of the six U.S. smelters operating today, five use fossil-fuel based electricity either from adjacent coal-fired power plants or utility-owned grids.

There is historical precedent for this strategy. Throughout the 20th Century, many of the world's aluminum smelters ran on hydropower, but this changed as new producers came on the scene and demand picked up. By 2018, nearly three-quarters of the power supplied to aluminum smelters was based on coal, oil, and gas.[194]

In the U.S. as recently as 2010, a third of the electricity used by smelters came from hydropower, but this proportion declined with the shuttering of large hydro-based smelters in Washington State.[195] Of the six smelters operating today, five use fossil-fuel based electricity either from adjacent coal-fired power plants or utility-owned grids. Only Alcoa Massena in New York—a relatively small facility with just ten percent of U.S. smelting capacity—runs on renewable energy.

As renewable energy becomes more popular, widespread, and competitively priced, aluminum operators stand to gain from using it. Electricity currently accounts for about 40 percent of the cost to operate a U.S. smelter and greatly influences production decisions.[196] Most recently, operators cited the rising cost of oil and gas as the reason for idling the Century Hawesville smelter and curtailing production at the Alcoa Warrick smelter.[197] Some European operators have idled smelters for the same reason.[198]

The transition to cleaner energy is likely to be an incremental process, since five of the six operating aluminum smelters are located in states (Indiana, Kentucky, Missouri, and South Carolina) where only four to eight percent of electricity generation comes from renewable sources.[199] To move forward, these states should support tax and zoning policies to facilitate renewable energy projects and modify electrical grids so they can absorb more renewables-generated power.

Fortunately, smelter states have a foundation on which to build. All but one has adopted a Renewable Portfolio Standard, a policy mechanism to incrementally increase the proportion of electricity generated by renewable sources.[200] Key remaining steps include the adoption of mandatory, time-bound goals for their portfolio standards (following New York's lead) and the development of a standard in Kentucky, home to the Century Sebree and Hawesville smelters. In addition, federal funding is available to assist electrical cooperatives and large property owners with the shift to cleaner energy.[201]

New production technologies will also play an important role in decarbonizing the aluminum industry. Key among such solutions is for operators to switch to a different kind of anode used to conduct electricity during the conversion of alumina to aluminum. This "inert anode" does not contain carbon and would release oxygen instead of carbon dioxide and PFCs.

Following decades of industry interest in inert anodes, recent advances by Alcoa and Rio Tinto in Canada and Rusal in Russia have resulted in sales of aluminum made using them.[202] Given the potential importance of this technology, companies should go beyond initial pilot projects and ramp up the use of inert anodes to produce far larger volumes of aluminum.[203]

Alcoa has stated that inert anodes will become commercially available in the next few years.[204] Once this happens, EPA should then require operators to use the new technology to reduce greenhouse gases and other pollutants. To realize the full potential of inert anode technology, it should be combined with the use of clean energy at smelters, since inert anodes still require the same amount of electricity per unit of aluminum produced as standard anodes.[205]

Even while operators work to transition to cleaner energy sources and adopt new technologies, EPA should strengthen requirements for the aluminum industry under the Greenhouse Gas Reporting Program. These include:

- **More frequent measurement of PFCs,** the very powerful greenhouse gases released by aluminum smelters. Currently, U.S. operators are required to conduct measurements that determine the underlying rate of PFC emissions as seldom as every ten years, which may lead to an undercounting of emissions and delay needed adjustments in operator practices.[206] Both EPA and international experts have recommended measurement every three years.[207] In the meantime, EPA should enforce the ten-year measurement rule on the books. Three smelters last conducted measurements more than ten years ago: Alcoa Warrick (2011), Century Mt. Holly (2011), and Century Sebree (2012).[208]

- **Better measurement and reporting of anode effects, the process that generates PFCs, that occur in smelting pots at low voltage levels.** EPA should finalize its 2022 proposal to require that operators develop and implement methods for such measurement.[209] Accounting for the additional low-voltage PFCs would provide a far more accurate picture of climate pollution from smelters and bring the U.S. in line with standards recommended by international experts and agencies.[210]

- **More transparent and consistent measurement of climate emissions from petcoke calcining facilities**. EPA should finalize its 2022 proposal to add a new category of climate emission sources to the Greenhouse Gas Reporting Program for calciners and to require operators to use more consistent, accurate methods to measure those emissions.[211] This proposal would help measure the aluminum industry's true air pollution impact and facilitate better pollution control at calcining plants.

Update Federal Pollution Rules

Under the Clean Air Act and Clean Water Act, the EPA has the authority to review and revise pollution control requirements so that different industries keep pace with technological advancements. Yet the agency has failed to do so when it comes to the aluminum industry.

U.S. smelters are currently operating under standards that are decades old and likely no longer sufficient to protect air and water quality. Changes are sorely needed to bring key environmental regulations in line with current conditions and push operators to change methods and practices to more effectively limit pollution.

1. ***New Source Performance Standards*** **(NSPS)** required under the Clean Air Act are tied to the adoption of new technologies to reduce pollution.[212] Most importantly, these standards for the primary aluminum sector have not been revised at all in 25 years despite a requirement that EPA review such rules every eight years and determine whether revision of the standards is appropriate.[213]

   Ongoing agency inaction means that U.S. operators can continue to use less advanced and efficient equipment than might otherwise be the case. Some core NSPS provisions do not apply to many parts of the smelters that were constructed before the rules initially took effect in the 1970s. EPA should comply with its obligations under the Clean Air Act to review and potentially revise standards for specific sectors. These revisions will be particularly critical should U.S. aluminum producers decide to retrofit or upgrade facilities in order to expand production.

2. ***National Emission Standards for Hazardous Air Pollutants*** **(NESHAP)** required under the Clean Air Act set limits on specific pollutants that cause serious health and environmental problems.[214] Standards for the primary aluminum industry were first adopted in 1997 and last revised in 2015.[215] Since operators haven't replaced or significantly modified key production equipment at U.S. smelters, they're able to follow NESHAP limits for older facilities, which allow higher levels of pollution and are therefore less protective of health and the environment.

   EPA last amended the NESHAP for secondary aluminum production in 2016.[216] EPA is required to evaluate NESHAPs every eight years and update these standards to account for improvements in pollution control technologies.[217] EPA should review and update the NESHAP for primary production in 2023 and secondary production in 2024.

3. ***Effluent Limitation Guidelines*** **(ELGs)** required under the Clean Water Act set limits on specific pollutants in industrial wastewater released into waterways.[218] The ELGs for nonferrous metals, which cover both aluminum smelting and alumina refining facilities, haven't been revised since 1990—despite significant advances in wastewater treatment technology in the last 30 years.[219] When it comes to the refining of petcoke, there are no ELGs to limit wastewater discharges from calcining plants—despite the fact that most are located in coastal areas and near waterways. In addition, no ELGs exist for the contaminated stormwater streaming off smelter and refinery sites into waterways.[220]

   EIP has repeatedly advocated for the revision of outdated ELGs to keep pace with advances in pollution control technologies, which is required under the Clean Water Act.[221] In early 2023, EIP and several other organizations sued EPA for failing to update ELGs and require the use of widely available modern pollution controls that could dramatically reduce harmful chemicals discharged by seven industries, including nonferrous metals.[222] EPA is required to annually consider whether limits on discharges of contaminants in wastewater need to be revised in light of potential changes in treatment technologies that would provide more protection.[223] EPA should commit to revising the standards for the nonferrous metals industry to reflect improvements in treatment controls for wastewater in its next ELG program plan proposal, which is due in 2025.[224]

   If EPA were to comply with the Clean Water Act and update the ELGs, smelters directly discharging process wastewater would be required to reduce pollution. The current ELGs for primary aluminum plants lack limits on many contaminants released by aluminum smelters—such as arsenic, lead, mercury, and silver—that can harm water quality and aquatic systems.[225] Alumina refineries generate numerous water contaminants, such as arsenic, lead, mercury, copper, iron, and radioactivity.[226] The ELGs prohibit alumina refinery operators from "discharge[ing] process waste water pollutants to navigable waters."[227] However, impoundments holding the process wastewater are allowed to discharge untreated, polluted waters during certain rain events.[228] With storms becoming more frequent and intense due to climate change, EPA should eliminate this exception to further limit wastewater pollution from alumina refineries.

   When EPA developed the ELGs for alumina refining in 1974, the agency included language in the Federal Register notice giving the Atlantic Alumina plant in Gramercy, Louisiana an exception to the ELG requirements because of a negotiated agreement with its prior owner (Noranda Aluminum).[229] Nearly 50 years later, Louisiana still allows the Atlantic Alumina plant to be excluded from the ELGs, permitting it to discharge millions of gallons of untreated industrial wastewater into the Mississippi River upstream of a public drinking water intake.[230] The Louisiana Department of Environmental Quality and EPA should reverse this outdated and inappropriate arrangement and require the current owner of Atlantic Alumina (ATALCO) to follow the "no discharge" requirement.

Reduce Sulfur Dioxide Pollution

U.S. aluminum smelters are notorious for emitting large amounts of SO_2. A comprehensive assessment of SO_2 emissions from smelters concluded that 80-85 percent of the pollution is released from production pots due to the sulfur content in the petcoke used to make production anodes.[231] The rest comes from onsite anode production and the processing of feedstocks and waste products. Petcoke calciners are also large emitters of SO_2 because of the sulfur in the petcoke.

U.S. aluminum smelters are notorious for emitting large amounts of SO_2.

SO_2 greatly reduces respiratory function, damages trees and vegetation, and contributes to acid rain, which harms fish and wildlife.[232] SO_2 also facilitates the formation of particulate matter, which causes respiratory and health problems and reduces visibility.[233] Four of the U.S. smelters are among the industrial facilities contributing to the haze impacting national parks and wilderness areas (Alcoa Massena in New York, Alcoa Warrick in Indiana, Century Hawesville in Kentucky, and Century Mt Holly in South Carolina).[234]

Ultimately, the best solution to SO_2 pollution would be to reduce the use of petcoke for smelting in the first place. The aluminum industry should ramp up the availability and use of "inert anodes," which unlike the current anodes used in production neither contain petcoke nor release carbon dioxide.[235] Even though operators may develop and eventually adopt this new technology, they should take other meaningful steps now to reduce SO_2 emissions.

Develop and Adopt Effective State Implementation Plans

EPA has determined that three of the operating U.S. smelters—Alcoa Massena in New York, Century Sebree in Kentucky, and Magnitude 7 Metals in Missouri—are the main reason why surrounding areas are failing to meet federal SO_2 standards. As a result, the respective states have to submit "State Implementation Plans" to EPA demonstrating how they will address exceedances of current air quality standards and maintain federal SO_2 standards going forward.[236] These plans need to include steps that the smelter operators will take to better control SO_2 .

As of September, 2023, only one of the three states, Missouri, has submitted its SO_2 plan to EPA, despite deadlines mandated by the Clean Air Act. EPA should enforce this long overdue deadline and require New York and Kentucky to submit the required plan to reduce SO_2 emissions.

Unfortunately, Missouri's proposed plan fails to require Magnitude 7 Metals to change any practices that would reduce emissions. Instead, the smelter would be allowed to keep releasing very large volumes of SO_2 as long as the company builds a taller emissions stack to push the pollution higher into the air and further away.[237] EPA should not accept this inappropriate "dispersion solution" and instead require operators to reduce pollution at the source.

Use Lower Sulfur Petcoke

Federal and state regulators have long relied on limits on the sulfur content in petcoke to reduce SO_2 emissions. Limits are also placed on coal tar pitch, a soft substance derived from oil that is used to bind materials in anodes and has a very low sulfur content.

State and federal regulators should require operators to use petcoke with a lower sulfur content than the three percent that the industry currently defines as "anode grade." Using lower-sulfur petcoke is recognized worldwide as a way to reduce SO_2 emissions and U.S. smelters have proven capable of doing this when they've been required to.

Install SO_2 Scrubbers

With SO_2 pollution on the rise and low-sulfur petcoke becoming more expensive and harder to obtain, some countries and aluminum companies are turning to the installation of pollution control equipment specifically designed to control SO_2. Known as "scrubbers," the equipment absorbs SO_2 and mixes it with minerals, which causes a chemical reaction that results in waste for treatment and disposal or conversion into other products (such as gypsum in wallboard).[238]

China, Norway, Russia, and the United Arab Emirates are among the countries that have required the installation of scrubbers to reduce SO_2 at both existing and new aluminum smelters.[239] Currently operating U.S. smelters do not use scrubbers to directly control SO_2, although some may be captured inadvertently by scrubbers designed to reduce fluoride and particulate pollution.

EPA and state regulators should require operators to install and operate designated SO_2 scrubbers at smelters and include these new requirements in State Implementation Plans to ensure compliance with federal SO_2 limits (see above). In 2022, for example, Washington State's plan to bring the now-closed Alcoa Intalco smelter into compliance included the installation of an SO_2 scrubber.[240]

Similarly, state and federal regulators should require the installation of effective SO_2 scrubbers at all U.S. petcoke calciners that still lack them. Oxbow has refused to install scrubbers at its calcining plants in Louisiana and Oklahoma despite the persistent release of high volumes of SO_2.[241] Rain II Carbon has installed scrubbers that achieve varying levels of SO_2 reduction at four of its plants—Lake Charles (60 percent), Chalmette (65 percent), and Norco (40 percent), all in Louisiana, and Vizag in India (98 percent)—but has yet to do so at its other plants in Louisiana, Mississippi, and Illinois.[242]

Recycle More, Use Less

Doing a better job of recovering used aluminum could change current assumptions about how much brand-new metal will be needed to meet future demand. A few recent studies underscore the potential of this strategy:

- According to the World Bank, if all available aluminum were recycled, the need for brand new aluminum would decrease by nearly 25 percent by 2050—and even more if product designs change, more metal is recovered, and demand ends up being lower than currently projected.[243]

- Using a global recycling target of 95 percent, the World Economic Forum estimated that the resulting decrease in demand for new aluminum would prevent 250 million metric tons of greenhouse gas emissions annually.[244] That's the same amount of energy used by nearly 32 million homes in a year.[245]

- The International Aluminium Institute has calculated that improvements in resource efficiency from eliminating "pre-consumer" scrap and the metal lost during casting and recycling processes would prevent 140 million metric tons of greenhouse gas emissions.[246] That's equivalent to the pollution from nearly 324 million barrels of oil.[247]

Technology, automotive, and other companies are eager to purchase recycled aluminum in order to meet sustainability goals and significant investment is being made to expand less-polluting secondary aluminum made from scrap metal.[248] But to truly be more sustainable, secondary aluminum producers should commit to sourcing more post-consumer scrap and less new scrap from smelters. Over time, this practice could potentially incentivize more recycling and recycling system improvements.

Doing a better job of recovering used aluminum could change current assumptions about how much brand-new metal will be needed to meet future demand

For their part, federal, state, and municipal governments should invest in metal recycling and recovery systems so that they are more widespread and effective. Currently, consumers throw significant amounts of aluminum—from cans to appliances—in the trash or lack accessible and affordable recycling services.

Aluminum recovery is further complicated by recyclers often mixing different types of metal or shredding rather than stripping them apart. This makes metal less usable and harder to turn into new products—in turn increasing the volume that is sent to landfills or exported.[249] The automotive, aerospace, and other industries should increase the quality and re-usability of recovered aluminum by improving systems to recover, sort, remove contaminants from, remelt, and alloy used metal.[250]

Corporations and consumers should also make choices that require less aluminum overall. For example, preference in the U.S. for large vehicles is a key reason behind surging aluminum demand in the automotive industry, with the average light truck containing about one-third more than a passenger vehicle in 2022.[251] The size and type of electric vehicles going forward will also drive the relative amounts of aluminum used to make them, with far more needed to balance out the heavier batteries in large cars and trucks.

Similarly, aluminum is increasingly popular in the residential building and construction industry, where it's part of siding, roofing, heating and cooling systems, and other components. But U.S. homes keep getting bigger; the median size of a home built in 2022 was 400 square feet larger than in 1992.[252]

Appendix

Methodology

This report is based on an extensive review of research on the aluminum industry, including scientific studies; industry association data and publications; media articles; summaries of pollutants and regulatory and technological analyses from public agencies; and rulemaking records in the Federal Register.

Mineral commodity analyses by the U.S. Geological Survey (USGS) were the main source of information on trends in bauxite, alumina, and aluminum production over time in both the United States and globally. Securities and Exchange Commission (SEC) filings by smelter operators yielded important data on primary aluminum production levels, power use, and industry trends.

Additional facility-specific information was compiled based on public records obtained from state regulatory agencies and databases of federal and state pollution data. Key among these were the EPA's Enforcement and Compliance History Online, National Emissions Inventory, Toxics Release Inventory, and emissions reports filed by operators. The overall climate impact analysis was based on the latest reporting year data available (2021) in the EPA's Greenhouse Gas Reporting Program (GHGRP).

The assessment of communities near aluminum production facilities discussed in this report (covering smelting, alumina refining, petcoke calcining, and hazardous waste management) is based on the Climate and Economic Justice Screening Tool (CEJST) developed by the U.S. Council on Environmental Quality, which provides an assessment of several environmental and socioeconomic conditions at the census tract level. Because census tract boundaries do not define communities, and these production facilities can impact residents who are nearby but not necessarily located within the same census tract, EIP expanded identification of the population and "disadvantaged" status of nearby communities to include census tracts that are entirely or partially within a three-mile radius around the facilities, based on the center point of the facility.

Differences in state reporting requirements and records, as well as variability in operator reporting, posed challenges when assessing U.S. smelters. When specific smelter data were not available, EIP leveraged available information to develop credible comparative figures across the smelters, including in the following ways.

Production Capacity and Volumes

- Alcoa's SEC Form 10-K filings do not state annual production volumes. The company indicates that Alcoa Massena has been operating at full capacity, so we assumed full production capacity for all related calculations. Production levels at Alcoa Warrick were estimated by subtracting idled capacity from full capacity volumes stated in Form 10-K filings.

- Given the lack of publicly available information on Magnitude 7 Metals, we determined estimated production based on the difference between the production volumes stated by the U.S. Geological Survey for the six operating smelters and the known volumes for the other five.

Power Use and Emissions

- To determine power consumption, we reviewed power provision contracts from the New York Power Authority for Alcoa Massena; agreements filed by the relevant utility with the Kentucky Public Service Commission for Century Hawesville and Sebree; statements in Alcoa's SEC 10-K filings for Alcoa Warrick; and media stories on Magnitude 7 Metals. Century Aluminum provided actual power consumption figures for Hawesville, Sebree, and Mt. Holly in its 2021 report, *Towards the Next Century.*

- For Alcoa Massena, we assumed full power provision use based on stated 100 percent production in Alcoa's SEC Form 10-K filings. For Alcoa Warrick, we based calculations on 68 percent of the power provision figure for the adjacent power plant given in Alcoa's SEC Form 10-K, which is the proportion that feeds the smelter (the remainder goes to the electrical grid).

- EIP adjusted the GHGRP emissions for the Warrick power plant serving the Alcoa Warrick smelter and the New Madrid power plant serving the Magnitude 7 Metals smelter to reflect the proportion of power use attributed to the smelters. For Warrick, this adjustment was based on statements in Alcoa's SEC 10-K filings on electricity supply going to the smelter vs. the electrical grid. For Magnitude 7 Metals, we compared the total volume of electricity generated at the New Madrid Power plant stated in the Energy Information Administration's Form 923 and the electricity consumption estimate (35 percent) for the smelter.

- For the smelters obtaining power from electrical grids, we used the Kentucky energy source profile from Spot for Clean Energy (https://spotforcleanenergy.org/) for Hawesville and Sebree; and energy source statements in the 2021 annual report from South Carolina utility Santee Cooper, which supplies Century Mt. Holly. We then calculated emissions based on estimated electricity use (in kilowatt-hours) using the Energy Information Administration's emission factors for CO_2 per kilowatt hour of electricity derived from coal and natural gas. We did not assess power-related climate emissions from Alcoa Massena since it runs on hydroelectricity.

Feedstock-Related Emissions

- The overall proportion of emissions from alumina refining is based on GHGRP data using Atlantic Alumina in Gramercy, Louisiana (the only operating alumina plant in the U.S.) as a proxy, the facility's production capacity as stated by the USGS, and the industry-standard assumption of two tons per alumina per ton of aluminum produced. The resulting calculation was .8 tons of greenhouse gases from alumina per ton of aluminum produced.

- The overall proportion of calcined petcoke (CPC) emissions is based on the industry-standard level of approximately half a ton of CPC used per ton of aluminum produced. Information on the production capacity and greenhouse gas emissions from stand-alone U.S. calciners was based on the EPA's Office of Air and Radiation, *Technical Support Document for Coke Calcining: Proposed Rule for the Greenhouse Gas Reporting Program*, January 2022. The resulting calculation was .4 tons of GHGs from calcined petcoke per ton of aluminum produced.

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[221] Letter from Eric Schaeffer and Sylvia Lam, EIP, and partner organizations to EPA Administrator Michael Regan, September 22, 2021. The ELG review requirement is in 33 U.S. Code §1314(b).
[222] "Coalition Sues EPA Over Unregulated Water Pollution from Oil Refineries, Plastics Plants, and Other Industries," April 11, 2023, https://environmentalintegrity.org/news/coalition-sues-epa-over-unregulated-water-pollution/
[223] Clean Water Act Section 301(d); 33 United States Code section 1311(d).
[224] This would be the Preliminary Effluent Guidelines Program Plan, known as Plan 15, which is issued every two years; https://www.epa.gov/eg/preliminary-effluent-guidelines-program-plan
[225] *See, e.g.,* EPA, *Development Document For ELGs, Nonferrous Metals Manufacturing Point Source Category*, Vol II, Primary Aluminum Smelting Subcategory, May 1989, Table V-15 (showing the presence of ammonia, antimony, arsenic, beryllium, cadmium, chromium, cobalt, combined metals sum, copper, cyanide, gold, hexachlorobenzene, indium, iron, lead, mercury, molybdenum, nickel, palladium, platinum, selenium, silver, tantalum, temperature, tin, titanium, total phenolics, tungsten, and zinc in the aluminum smelting wastewater); *Land Disposal Restrictions—Phase III: Decharacterized Wastewaters, Carbamate and Organobromine Wastes, and Spent Potliners*, 60 Fed. Reg. 11702, 11723 (March 2, 1995) (discussing the pollutants found in the untreated aluminum potliner [manufacturing] wastes or treatment residuals, including acenapthene, anthracene, benz(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(g,h, i)perylene, chrysene, dibenz(a,h)-anthracene, fluoranthene, indeno(1,2,3-cd)pyrene, phenanthrene, pyrene, arsenic, barium, beryllium, cadmium, chromium, lead, mercury, selenium, silver, and cyanide).
[226] Based on Atlantic Alumina's wastewater sampling reported in Permit Application LA0079961, June 2020.
[227] 40 Code of Federal Regulation §421.13(a).
[228] *See* 40 Code of Federal Regulation § 421.13(b) ("During any calendar month there may be discharged from the overflow of a process waste water impoundment either a volume of process waste water equal to the difference between the precipitation for that month that falls within the impoundment and the evaporation within the impoundment for that month, or, if greater, a volume of process waste water equal to the difference between the mean precipitation for that month that falls within the impoundment and the mean evaporation for that month").
[229] 39 Federal Register 12822, April 8, 1974
[230] Atlantic Alumina Draft Permit and Fact Sheet, LA007996, June 12, 2015; 39 Federal Register 12822, April 8, 1974.
[231] Stephan Broek, "Update on SO_2, Scrubbing Applied in Primary Aluminum Smelters," *Light Metals,* 2020, https://link.springer.com/chapter/10.1007/978-3-030-36408-3_103.
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