Atlantic Council

Decarbonizing the Aluminum Market: Challenges and Opportunities

Nitya Aggarwal, Matthew Piotrowski, and George Frampton

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COVER: Molten metal is poured into carbon anodes at Century Aluminum Company at a Kentucky plant. May 2019. Source: REUTERS/Bryan Woolston

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Foreword

As we head into a new phase of Paris Agreement implementation, industry decarbonization has moved up the international policy agenda. Heavy-industry sectors—steel, aluminum, cement, and chemicals—currently account for 20 percent of global greenhouse gas emissions and have, to date, largely been on the backburner for policymakers, exempt from the most serious climate change efforts. However, these industries are coming under increasing pressure to rapidly decarbonize and approach net-zero emissions by 2050.

Meeting this goal requires overcoming the "trade-trapped" nature of these sectors. Steel, cement, aluminum, and chemicals are traded across borders and face international price competition. This makes it harder for producers to pass through additional costs of investing in more expensive, cleaner technologies without impacting competitiveness. Policymakers have been wary of introducing policies that could affect the competitiveness of their domestic industrial sectors and risk carbon leakage.

Trade policy and a complementary diplomacy strategy are, therefore, key to successfully decarbonizing these sectors. There is a large body of academic literature pointing to the need for well-coordinated international efforts in this space, but few studies diving into the specific case of aluminum. This report fills this gap, describing the current efforts on this front and what actions will enable greater progress. Several of the key industrial decarbonization policies being explored by countries—such as public procurement targets, product requirements, green industrial subsidies, and carbon border measures—run into challenging trade-law territory and risk provoking tensions if not carefully designed, coordinated, and justified. Countries and industry groups should collaborate on research, development, and deployment to ensure the effective use of resources and prevent funding gaps. This would help reduce technology costs and ensure technologies are globally accessible. International alignment on standards and methodologies for low-carbon products and emissions intensity would facilitate knowledge sharing and data collection, ultimately decarbonizing international industrial supply chains.

While the potential for international coordination on industrial decarbonization has historically been underexploited, there has been a recent proliferation of platforms and initiatives providing opportunities for cooperation in this space. These initiatives have focused on cooperation on roadmaps for industrial decarbonization, procurement, innovation, and trade policy, among other things.

Thus, the upcoming year presents a pivotal opportunity to see accelerated momentum on industrial decarbonization internationally.

Executive Summary

Aluminum is one of the most energy-intensive and greenhouse gas-emitting commodities in the world, accounting for approximately 3 percent of all global emissions. Global demand for the metal is expected to increase, and aluminum is central to overall decarbonization efforts in transportation, packaging, building, and the energy transition. While decarbonization pathways for steel and cement have received increased attention recently from policymakers, nongovernmental organizations (NGOs), and industry—and are somewhat analogous to aluminum in that they also involve moving away from coal power and toward new emissions-reduction technologies—policymakers have paid less attention to aluminum. The aluminum industry has begun to take leading steps to decarbonize, but new policy measures will be needed to make significant progress in this hard-to-abate sector. National and international bodies must partner on these measures as aluminum, like steel, is heavily traded. Global production of primary aluminum almost tripled from 2000 to 2021, reaching 68 million metric tons.[1] Countries with greater climate ambition that are now beginning to produce higher-cost clean aluminum will inevitably seek to protect domestic competition and prevent carbon leakage, through trade measures if they perceive them as necessary. Actions to decarbonize the industry must take this into account and stimulate international cooperation rather than trade battles.

This report examines the reasons why the aluminum sector is so difficult to decarbonize, various pathways to decarbonization, and current approaches undertaken by countries with market relevance. The report also provides recommendations for further action by governments, international organizations, and industry to advance progress toward deep decarbonization.

Governments should take the following actions:

- Commit to decarbonization goals for heavy sectors, such as aluminum, that are in line with the Paris Agreement.
- Commit to, embrace, accelerate, and centralize current separate initiatives and coalitions working on decarbonizing heavy industries, including aluminum.
- Acknowledge the importance of climate-related trade instruments and utilize them to reduce emissions in heavy industries, including aluminum.

Governments and international organizations should work together on the following steps:

- Focus on the "emissions intensity" of facilities and products;
- Develop protocols for determining carbon intensity (embedded emissions, i.e., those generated during the manufacturing and production of the metal) in aluminum production facilities and products.
- Ensure that embedded-emissions measurement focuses on lifecycle emissions.
- Consolidate ongoing separate initiatives that are working on setting standards for measuring embedded emissions in key commodities into a single venue and forum.

Industry should play a role in the key areas below:

- Increase collaboration with international forums on data and standard setting.
- Partner with governments to increase the use of scrap aluminum and renewable energy for refining and smelting processes.

1 "U.S. Aluminum Manufacturing: Industry Trends and Sustainability," Congressional Research Service, October 26, 2022, https://crsreports.congress.gov/product/pdf/R/R47294.

Introduction

The aluminum sector is expected to become increasingly important to the global economy, with total global demand growing from 86.2 million tons (Mt) in 2020 to 119.5 Mt in 2030.[2] These demand pressures arise from the transportation, construction, packaging, and electrical sectors, and aluminum plays a crucial role in several technologies needed for a sustainable energy transition, such as electric vehicles and energy-efficient materials.[3] Requirements for new electric vehicles alone are predicted to drive up more than a third of this increase in demand for aluminum, from 19.9 Mt in 2020 to 31.7 Mt in 2030.[4] Aluminum is similarly vital to the production of solar panels and copper cabling for power production. Demand for environmentally friendly packaging in canned drinks is also expected to motivate increased demand for aluminum packaging. Aluminum can be recycled indefinitely without loss of quality—approximately 75 percent of all aluminum ever produced is still in use—but the size of the aluminum market and the demand pressures it faces necessitate increased production. The sheer size and expected continual growth of the aluminum industry complicate the challenge of decarbonizing the aluminum sector, which currently produces about 3 percent of all global emissions.

Currently, the production of aluminum is energy intensive and emits large quantities of greenhouse-gas (GHG) emissions. Pure aluminum must be extracted from bauxite ore by crushing, grinding, and then refining to produce "alumina" (aluminum oxide), which is then smelted—processes that necessitate a significant, constant energy load during both the refining and smelting stages.[5] Many countries rely on coal to generate the required electricity, with about 55 percent of the energy needed to smelt aluminum coming from coal-powered power plants.[6]

Global reliance on aluminum makes it increasingly important to decarbonize its production processes so that the world can meet its long-term climate goals. Currently, producing one metric ton of aluminum emits, on average, 15.9 metric tons of carbon dioxide (CO_2).[7] To stay consistent with the 1.5-degrees Celsius target outlined in the Paris Agreement, the aluminum industry must lower its carbon intensity to less than 0.5 metric tons of CO_2.[8] The challenge of doing so lies in decarbonizing the refining and smelting processes, due to their high energy intensity. Successfully greening these production processes will require innovative solutions, combining renewable energies with new technologies.

Understanding the difficulties and opportunities for decarbonizing the aluminum sector requires first exploring how aluminum production functions and what measures are currently in place to decarbonize the industry. With these factors and existing remedies outlined, the path for deep decarbonization becomes clear.

2 "Report Reveals Global Aluminium Demand to Reach New Highs After Covid," International Aluminum Association, March 23, 2022, https://international-aluminium.org/report-reveals-global-aluminium-demand-to-reach-new-highs-after-covid/.

3 Pedro Assunção, et al., "Aluminum Decarbonization at a Cost that Makes Sense," McKinsey & Company, April 20, 2023, https://www.mckinsey.com/industries/metals-and-mining/our-insights/aluminum-decarbonization-at-a-cost-that-makes-sense#/.

4 "Report Reveals Global Aluminum Demand to Reach New Highs After Covid."

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

6 Assunção, et al., "Aluminum Decarbonization at a Cost that Makes Sense."

7 "Making Net-Zero Aluminum Possible," Mission Possible Partnership, April 2023, https://missionpossiblepartnership.org/wp-content/uploads/2023/04/AluminiumTSExecutiveSummary.pdf.

8 Assunção, et al., "Aluminum Decarbonization at a Cost that Makes Sense."

Current Processes for Producing Aluminum

Producing aluminum requires significant amounts of energy on a continuous basis, a demand currently met largely by carbon-intensive fossil fuels. Additionally, carbon dioxide is emitted during the smelting process as a byproduct. Decarbonization pathways must address the carbon intensity of both the energy demands of aluminum production and the release of carbon dioxide during the metal's manufacturing.

The primary industrial process for aluminum smelting is the Hall–Héroult process, in which alumina is dissolved in the mineral cryolite.[9] Pure aluminum can then be extracted from the alumina through electrolytic reduction. Electrolysis requires an anode and a cathode: in aluminum production, the anode is made of carbon. Carbon is often used in electrolysis because it is an efficient conductor and has free electrons, which are necessary in electrolysis.[10] In this reaction, positively charged aluminum ions gain electrons from the cathode, forming pure, molten aluminum.[11] Negatively charged oxide ions lose electrons at the anode, which generates oxygen. Because the anode is carbon, when oxygen is generated at the anode, CO_2 is produced. The process is energy intensive, continuously requiring high amounts of power.

Aluminum production through electrolytic reduction with a carbon anode, therefore, presents two challenges for decarbonization. Using a carbon anode is currently the standard way to produce aluminum because of its conductivity and free electrons but, as a result, the smelting process itself emits substantial amounts of CO_2. In addition, electrolysis requires significant continuous energy, a demand that in most producing countries is met by using coal. The smelting process as a whole is responsible for about 80 percent of the greenhouse gases emitted during aluminum production.[12] Of the emissions arising from smelting, about 81 percent are from the coal-powered generation of electricity for electrolysis. Power generation accounts for 70 percent of total direct and indirect CO_2 emissions from the entire aluminum production process.[13]

9 Reinsch and Benson, "Decarbonizing Aluminum."

10 "Why Are Carbon Electrodes Used In Electrolysis?" M. Brashem, Inc., last visited November 12, 2023, https://www.mbrashem.com/why-are-carbon-electrodes-used-in-electrolysis/.

11 Assunção, et al., "Aluminum Decarbonization at a Cost that Makes Sense."

12 Ibid.

13 "Aluminum," International Aluminum Association, last visited November 12, 2023, https://www.iea.org/energy-system/industry/aluminium.

Potential Decarbonization Pathways

Decarbonizing primary aluminum production from ore through smelting requires reconsidering various emissions-intensive aspects of the Hall–Héroult process. The sector can address the carbon intensity of the process by substituting greener energy for coal or by reducing the carbon production of electrolysis. The former is the clearest pathway to address the energy intensity of the process, as renewable energy technologies are already well developed. To cut carbon emissions from smelting, the industry could also substitute a newer technology metal or inert anode in place of the carbon anode. Additionally, capturing and storing carbon and replacing fossil fuels with nuclear power or green hydrogen both offer potential alternative long-range solutions, but not in the immediate future.

CLEAN ENERGY

The energy intensity of smelting could be largely addressed by using clean energy sources instead of coal. Transitioning to clean energy would mitigate up to two-thirds of the emissions caused by aluminum production.[14] Using solar or wind energy to power the production process has enormous potential to green the aluminum process. However, because smelting requires a continuous, high-intensity energy source, the intermittency of these renewables renders them currently unable to reliably power smelting, barring significant battery-efficiency technologies or other improvements to energy storage.[15] Hydropower and nuclear energy are also clean options, but come with their own challenges: hydropower is geographically limited and, therefore, not always available to new aluminum production, while nuclear energy has to contend with high costs, long lag times from approval to operation, and the need to maintain waste sites.

Directly sourcing clean energy to meet aluminum-plant energy demand can be challenging, but sleeved or virtual power-purchase agreements have the potential to address this hurdle.[16] These agreements ensure that substantial supplies of clean power would be sourced from the grid to meet most of a producer's energy demands throughout the year. However, in periods when renewable energy is not available, producers would still be able to use fossil fuel-generated energy to fill the supply gaps. The reduced costs of renewable energy make this a relatively low-cost option for decarbonization. It would also address the inconsistency of renewables, as producers could fund renewable energy while having fossil fuel generated energy as a backup. With power-purchase agreements in the United States providing electricity as cheaply as $15 per megawatt hour, renewables are becoming cost competitive with coal power in most of the world. While these agreements can move the industry toward renewables, they would not entirely remove reliance on fossil fuels from the production process.

Because producing aluminum requires so much reliable, consistent electric power, many aluminum producers today own or control their own power sources. This pattern suggests that in considering pathways to zero carbon for the industry, acquiring dedicated renewable power, conjoined with improved battery storage, would be an important strategy for producers.

RECYCLING

Recycling is another key option available for aluminum decarbonization. Aluminum has high recycling potential, as it can be recycled several times without losing quality or integrity, unlike many other materials.[17] Recycling of scrap aluminum can reduce total facility emissions by up to 90 percent, because of the reduced power required to recycle the metal versus producing it anew and the absence of process emissions from the smelting conversion. Thus, when available, the use of recycled material is extremely effective in emissions reduction. However, today, recycling aluminum is associated with less than 5 percent of the carbon footprint of producing aluminum on an overall global basis. Expanding aluminum recycling requires increased collection and recovery of scrap aluminum, which could reduce the need for primary aluminum by up to 15 percent.[18] New "circular economy" planning for reuse of aluminum products and improved sorting technology could both contribute to increased use of scrap.

While recycling of industrial equipment (vehicles, machine parts, building material) is significant, at rates higher than 90

14 Ramon Arratia and Nancy Gillis, "Purifying the 'Miracle Metal': How to Decarbonize Aluminum," GreenBiz, February 3, 2023, https://www.greenbiz.com/article/purifying-miracle-metal-how-decarbonize-aluminum

15 Assunção, et al., "Aluminum Decarbonization at a Cost that Makes Sense."

16 Julia Attwood, "Green Aluminum is Competitive Today. It's Time to Start Transforming," BloombergNEF, June 16, 2021, https://about.bnef.com/blog/green-aluminum-is-competitive-today-its-time-to-start-transforming/.

17 Ibid.

18 "Aluminium for Climate," World Economic Forum, November 2020, https://www3.weforum.org/docs/WEF_Aluminium_for_Climate_2020.pdf.

percent, consumer recycling also presents a significant opportunity to reduce the need for primary aluminum.[19] Consumer aluminum recycling rates vary significantly from country to country: while Germany recycles 99 percent of its aluminum cans, Brazil 97 percent, and the European Union (EU) about 75 percent, the United States recycles less than half.[20] In the United States, the problem is twofold: a lack of consumer awareness, and inadequate recycling infrastructure and technology. Outdated sorting technology, for example, mistakenly categorizes aluminum cans as plastics, sending them to landfills. This outdated technology is becoming increasingly limiting as more aluminum alloys are developed for industry-specific purposes.[21] Technology that can differentiate alloys would enable recyclers to process recycled aluminum more accurately and specifically, further closing the loop of aluminum production. While technology that can pinpoint the differences in certain alloys exists, it is significantly more expensive. As demand for aluminum and its alloys increases, governments must promote and fund updated recycling technologies. Thus, to more effectively implement recycling as a decarbonization tool by increasing consumer recycling rates, investments in infrastructure and education are required.

ELECTRODE TECHNOLOGY

The secondary aspect of the decarbonization challenge in primary aluminum production is CO_2 emissions caused by using a carbon anode during electrolysis. Successfully decarbonizing this process would address another 25–30 percent of emissions caused by aluminum production.[22] The main alternative to using a carbon anode, as used by the Hall–Héroult process, is an inert anode.[23] Inert anodes are constructed of non-consumable materials like metal or ceramic. Like carbon, they are conductive and carry free electrons. During the electrolysis of aluminum oxide, oxygen attaches to the anode; with a carbon anode, this results in the production and release of carbon dioxide. When using an inert anode, pure oxygen, rather than carbon dioxide, is released as a byproduct. This provides a well-established alternative to carbon anodes that could prevent the release of CO_2 during electrolysis.

Developments in inert-anode technology have increased the efficiency of electrolysis. One promising approach is the use of wetted cathodes, which are cathodes treated with titanium diboride.[24] This renders the cathode inert, which allows producers to reduce the distance between the anode and the cathode during electrolysis. Because the electrons have less distance to traverse, the voltage can be lower, reducing the energy demands of electrolysis. Combining wetted cathodes with inert anodes would eliminate CO_2 emissions arising from electrolysis, while simultaneously increasing energy efficiency.

Inert-anode technology is considered the aluminum-decarbonization pathway most likely to become commercially viable in the short term.[25] Elysis, a joint project from Alcoa, Apple, Rio Tinto, and the Canadian government, is currently running a pilot project in Canada with inert-anode technology to verify its performance and determine when it can be adopted on an industrial scale. Elysis is expected to host a demonstration of its technology and develop a commercial package in the next few years. The World Economic Forum projects the capital costs of inert anodes to be 10–30 percent less than carbon-based anodes.[26] However, initial research shows that electrolysis with an inert anode could be more energy intensive than with a carbon-based anode, reiterating the importance of renewable energy pathways. Government grants or incentives can help encourage the use of this technology once it is commercially available.[27]

19 “Infinitely Recyclable,” Aluminum Association, last visited November 12, 2023, https://www.aluminum.org/Recycling.

20 Janice Lee, et al., “What’s Holding Back Aluminum Recycling in the US?” Boston Consulting Group, May 10, 2022, https://www.bcg.com/publications/2022/whats-holding-back-aluminum-recycling-in-the-us.

21 Brian Taylor, “Sorting Technology Can Turn Aluminum Green,” *Recycling Today*, September 14, 2021, https://www.recyclingtoday.com/news/steinert-hoffmann-aluminum-sorting-technology-recycling/.

22 “Aluminium for Climate.”

23 Assunção, et al., “Aluminum Decarbonization at a Cost that Makes Sense.”

24 Ibid.

25 Ibid.

26 “Aluminium for Climate.”

27 Assunção, et al., “Aluminum Decarbonization at a Cost that Makes Sense.”

GREEN HYDROGEN AND CARBON CAPTURE, UTILIZATION, AND STORAGE

The need for a consistent energy source throughout aluminum production complicates a transition to renewable energy, making hydrogen-based production a possible option. Hydrogen and hydrogen-based fuels are increasingly seen as crucial to the decarbonization of heavy industry sectors.[28] Hydrogen produced using renewable energy, known as green hydrogen, is a clean, low-carbon energy source, releasing only water when burned as fuel. For hydrogen to become a truly viable decarbonization solution, innovation and action are needed to reduce the cost of its production and to increase demand for it. Moreover, green hydrogen will likely be in short supply for some time given its high current cost, and there may be much more efficient uses for it elsewhere in industrial decarbonization of steel, for aviation and maritime fuel, and for fuel cells. Nonetheless, aluminum companies are already exploring green hydrogen as an option for decarbonization. Norsk Hydro, a Norwegian aluminum and renewable energy company, recently produced the world's first aluminum made using green hydrogen.[29] This fall, Hydro will release a report on its efforts to demonstrate the potential of hydrogen in aluminum production.

As progress toward reducing the cost of green hydrogen at scale continues, carbon capture, utilization, and storage (CCUS) technologies could fill some gaps by capturing emissions arising from the current aluminum production process. CCUS entails capturing carbon, either for use in the production process or for storage in deep geological formations.[30] It is often suggested as a solution in hard-to-abate sectors, such as steel. However, for aluminum, the off-gas, or the byproduct emitted by aluminum smelters, has a low concentration of CO_2 relative to other industries, at about 1 percent CO_2.[31] By comparison, carbon capture technologies have previously worked with off-gas at a concentration of CO_2 above 4 percent or much higher, as is the case with ethanol refineries. Moreover, aluminum production also releases perfluorochemicals (PFCs), which are not captured by existing carbon capture technologies. PFCs are greenhouse gases that, although they are released in small amounts, have a far higher Global Warming Potential than CO_2, and remain in the atmosphere for thousands of years.

To overcome these challenges, Oslo-based Hydro is currently working to develop capture technology that could be retrofitted to its existing aluminum plants.[32] Early results show that off-gas capture could remove most of the CO_2 released during aluminum smelting, while direct air capture technology could remove other emissions.

Each of the solutions mentioned above provides significant potential to help decarbonize the aluminum market. Moving forward, a combination of them all—renewable energy, recycling, inert-anode technologies, and, eventually, perhaps nuclear, CCUS, and hydrogen—will likely be key to mitigating emissions in the aluminum production process.

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28 Abhinav Chugh and Emanuele Taibi, "What Is Green Hydrogen and Why Do We Need It? An Expert Explains," World Economic Forum, December 21, 2021, https://www.weforum.org/agenda/2021/12/what-is-green-hydrogen-expert-explains-benefits/.

29 Jonas Cho Walsgard and Mark Burton, "Norway Firm Produces World's First Aluminum Using Green Hydrogen," Bloomberg, June 15, 2023, https://www.bloomberg.com/news/articles/2023-06-15/hydro-produces-world-s-first-aluminum-using-green-hydrogen.

30 "Carbon Capture, Utilisation and Storage," International Energy Agency, last visited November 12, 2023, https://www.iea.org/energy-system/carbon-capture-utilisation-and-storage.

31 "Developing Carbon Capture and Storage Technology for Aluminium Smelters," Hydro, January 19, 2022, https://www.hydro.com/en-US/media/on-the-agenda/hydros-roadmap-to-zero-emission-aluminium-production/developing-carbon-capture-and-storage-technology-for-aluminium-smelters/.

32 "Hydro Invests in Carbon Capture to Eliminate Emissions from Aluminum Production," *Light Metal Edge*, March 21, 2022, https://www.lightmetalage.com/news/industry-news/smelting/hydro-invests-in-carbon-capture-to-eliminate-emissions-from-aluminum-production/.

Trade of Low-Emissions Materials

While there are promising pathways for aluminum decarbonization, trade policies play a significant role in determining whether the industry pursues those paths. Emerging agreements in the EU and the United States have shown potential to capitalize on this opportunity and encourage decarbonization.

CARBON BORDER ADJUSTMENT MECHANISM

The EU's Carbon Border Adjustment Mechanism (CBAM) is a policy measure responding to the concern that EU industries attempting to decarbonize emissions-intensive products, like aluminum, could be priced out of the market.[33] Higher costs created by the EU's carbon prices and industry standards could make EU products less competitive, allowing for carbon leakage, in which greener products are priced out of the market by cheaper carbon-intensive alternatives, or producers respond to climate policies by relocating to countries with less ambitious green standards. The CBAM responds to carbon leakage by implementing a fee on carbon for carbon-intensive goods entering EU borders.[34] This is intended to create a level playing field among domestic and foreign goods as EU industries work toward decarbonization.

The CBAM, part of the EU's overall Fit for Fifty-Five green deal, considers aluminum—alongside cement, iron and steel, fertilizers, electricity, and hydrogen—to be one of the carbon-intensive sectors most subject to competitive disadvantage from increasing carbon prices imposed by the EU Emissions Trading System, and at risk of carbon leakage from companies offshoring to lower-cost countries.[35] As such, when the EU CBAM entered into force in October 2023, it began a transition process requiring filing of reports on the embedded carbon emissions contained in a series of designated imported aluminum products, leading in 2026 to phasing in of fees on each import keyed to its reported emissions. This is intended to protect EU producers working toward sustainability versus imports from competitors that produce goods that are high in carbon, while incentivizing global producers to similarly prioritize decarbonization. These intentions are panning out among some EU trade partners, such as Turkey and Bosnia and Herzegovina, which have indicated their willingness to fast track their decarbonization efforts in response to CBAM.[36] However, India and China, as well as many other countries from the Global South, argue that CBAM is an unfair violation of the World Trade Organization (WTO) rules on free trade, particularly the most favored nation (MFN) rule, which prohibits discriminating among similar products from different trading partners.[37] For example, developing countries have fewer resources to counteract emissions intensity, leading to higher carbon prices at the EU border and disadvantaging them. EU officials, however, argue that the CBAM will follow all WTO rules on international trade.

In light of the EU CBAM, the United States and the United Kingdom (UK) have also begun to consider similar policies, as have Canada (consultations completed), Australia (consultations announced), and Taiwan (Climate Change Response Act enacted). Japan appears to oppose the EU CBAM over concerns that its disclosure requirements could violate the confidentiality of price and cost data.[38] In partial response, Japan is planning to launch its own domestic carbon levy and trading system.[39] In the United States, legislators from both political parties have publicly expressed support for some kind of charges taxing imports of steel and aluminum more emissions-intensive than US-average products, although support for any carbon charge on domestic production of the same product for which the import charges would compensate is much less wide-spread.[40] Similarly the UK launched consultations on the possibility of enacting a CBAM to support domes-

33 "Carbon Border Adjustment Mechanism (CBAM) Starts to Apply in Its Transitional Phase," European Commission, September 29, 2023, https://ec.europa.eu/commission/presscorner/detail/en/ip_23_4685.

34 "Carbon Border Adjustment Mechanism," European Commission, last visited November 12, 2023, https://taxation-customs.ec.europa.eu/carbon-border-adjustment-mechanism_en.

35 Ibid.

36 Silvia Weko, "The Future for Global Trade in a Changing Climate," Chatham House, December 5, 2022, https://www.chathamhouse.org/2022/12/future-global-trade-changing-climate.

37 Bart Le Blanc, "Potential Conflicts between the European CBAM and the WTO Rules," Norton Rose Fulbright, February 2023, https://www.nortonrosefulbright.com/en/knowledge/publications/9c5d9ec6/potential-conflicts-between-the-european-cbam-and-the-wto-rules.

38 "Japanese Industry Groups Resist EU Carbon Border Rules," Argus Media, August 1, 2023, https://www.argusmedia.com/en/news/2474953-japanese-industry-groups-resist-eu-carbon-border-rules.

39 Yuka Obayashi and Katya Golubkova, "Explainer: Japan's Carbon Pricing Scheme being Launched in April," Reuters, March 30, 2023, https://www.reuters.com/markets/carbon/japans-carbon-pricing-scheme-being-launched-april-2023-03-30/.

40 John Milko, "How a Carbon Border Adjustment Mechanism Can Strengthen US Competitiveness, Workers, and Climate Efforts," Third Way, February 2, 2023, https://www.thirdway.org/memo/how-a-carbon-border-adjustment-mechanism-can-strengthen-us-competitiveness-workers-and-climate-efforts.

tic decarbonization efforts.[41] Together, the EU, Canada, the United States, and the UK represent a significant share of the aluminum market. If all four enact and harmonize CBAM-like policies, they could have a widespread impact on embedded emissions in traded aluminum products, prompting a global race to the top in all heavy industries.

GLOBAL ARRANGEMENT ON SUSTAINABLE STEEL AND ALUMINUM (GASSA)

In the fall of 2021, in recognition of this opportunity in several heavy-emitting sectors, the United States and the EU announced their intention to work together on an arrangement that would incentivize countries and industry actors toward reducing the carbon intensity of their traded goods, including aluminum. The initiative, the Global Arrangement on Sustainable Steel and Aluminum (GASSA), aims to bring states together to limit market access for carbon-intensive steel and aluminum.[42] This proposal was negotiated as part of a temporary US-EU trade “time out,” in which the United States suspended tariffs imposed during the Donald Trump administration on steel and aluminum imported from the EU and agreed to seek a long-term solution that combined a new trade approach with increased cooperation to promote decarbonization of these industries.[43] The time out was later extended to Japan and the UK. In return, the EU suspended its retaliatory tariffs on US products. The proposed arrangement also created a technical working group with the goal of combining innovative trade approaches and decarbonization efforts. An essential proposed component of the arrangement is the development of a methodology to measure embedded carbon emissions in traded steel and aluminum imports into the EU to guide trade instruments that would advantage trade in cleaner, lower-emissions products. Measuring carbon emissions intensity will be important for countries and companies to determine progress in their efforts to reduce carbon emissions and develop markets for climate-friendly goods and services. Improvements in the quality and transparency of data to measure carbon emissions can help increase coordination among major economies and develop trade policies that reduce emissions. The GASSA initiative runs parallel to the Group of Seven (G7) Climate Club, an inclusive alliance with the goal of uniting ambitious countries toward the trade of low-carbon commodities.[44]

The Joe Biden administration announced a proposal in December 2022 that outlined its version of what a trade agreement under GASSA could look like.[45] This proposal detailed an international consortium of ambitious states encouraging trade in low-carbon steel and aluminum. To join the coalition, countries would have to meet emissions standards and commit to avoiding overproduction of steel or aluminum. At the same time, member states would enforce tariffs on countries with high emissions intensities that did not join, such as China. Member countries would have more favorable trade terms among themselves. Finalization of this arrangement was originally promised for October 2023

However, the US proposal was fundamentally inconsistent with the EU CBAM which, by the fall of 2023, had been finally approved as EU law and in October 2023 went into effect. With the parties of the US-proposed consortium so far apart, they announced at the EU-US Leaders Summit in October that while some progress had been made, discussions would continue with a new deadline of Earth Day 2024. There is some expectation that no agreement other than continued suspension of the tariffs will eventually emerge from these discussions. While the

41 “UK Government Launches Consultation on a Carbon Border Adjustment Mechanism and Other Measures,” EY Global, March 30, 2023, https://www.ey.com/en_gl/tax-alerts/uk-government-launches-consultation-on-a-carbon-border-adjustmen.

42 Ana Swanson, “U.S. Proposes Green Steel Club that Would Levy Tariffs on Outliers,” *New York Times*, December 7, 2022, https://www.nytimes.com/2022/12/07/business/economy/steel-tariffs-climate-change.html.

43 Timothy Meyer and Todd N. Tucker, “How the US and EU Can Rewrite Trade Rules to Fight the Climate Crisis,” Roosevelt Institute, March 15, 2023, https://rooseveltinstitute.org/2023/03/15/how-the-us-and-eu-can-rewrite-trade-rules-to-fight-the-climate-crisis/.

44 “G7 Establishes Climate Club,” BMWK, December 12, 2022, https://www.bmwk.de/Redaktion/EN/Pressemitteilungen/2022/12/20221212-g7-establishes-climate-club.html.

45 Swanson, “U.S. Proposes Green Steel Club that Would Levy Tariffs on Outliers.”

United States and the European Union are under some pressure to harmonize their trade approaches for steel and aluminum to both address global overcapacity and encourage decarbonization, the EU's CBAM and the Biden administration's position differ fundamentally because of their divergent climate strategies. The EU's CBAM is predicated on progressive increases in the price of carbon, which are intended to make emissions unprofitable. By contrast, the United States uses government expenditures to incentivize decarbonization, rather than using carbon pricing to disincentivize emissions. The United States is unlikely to implement a carbon pricing scheme in the near future, complicating the potential for a homogenized strategy going forward.

Alongside GASSA's plans, major industry actors are partnering to set decarbonization goals, creating coalitions, such as Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA), Global Cement and Construction Association, and Decarbonizing Transport Initiative.[46] These coalitions have set ambitious decarbonization targets for their respective industries. For example, the Global Cement and Construction Association's objective is to achieve carbon-neutral concrete by 2050, and CORSIA aims to make all new growth in international flights carbon neutral.

Since its inception, many discussions about GASSA have focused primarily on steel, but the trade policy and geopolitical implications for aluminum are similar. For both commodities, China produces roughly half of global output, while India is second and increasing production rapidly. In the case of steel, India has the highest emissions intensity of any major country from production of primary steel; China is seventh. For aluminum, China has the highest average emissions intensity of any country; India is second. With respect to both commodities, while it appears that the EU and US positions may be significantly at odds due to the EU's newly adopted regulations to implement its CBAM, discussed below, either approach will heavily disadvantage imports from China and India.

46 "Aluminium for Climate."

International Progress—and Obstacles—Toward Green Aluminum

Beyond efforts through GASSA and the EU CBAM to incentivize the decarbonization of aluminum, states are individually taking significant actions to achieve the same goal. Key aluminum producers are instituting pathways to reduce carbon in the production and trade of aluminum.

UNITED ARAB EMIRATES (UAE)

As both the fifth-largest producer of aluminum, with 3–4 percent of the global market, and the next host of the United Nations (UN) Climate Change Conference (known as COP), the UAE's actions and priorities on green aluminum could have substantial influence on global action toward decarbonization. The UAE's largest aluminum producer, Emirates Global Aluminum (EGA), is the country's biggest industrial conglomerate outside the oil and gas sectors.[47] EGA recently announced plans to decarbonize, developing its own technologies to do so, in order to access the market for green aluminum. EGA has already begun taking steps to achieving decarbonization through expanding its use of renewable energies. For instance, in 2021, EGA became the first company to produce commercial aluminum using solar power, and has now announced plans to shift completely to nuclear and solar energy to produce aluminum.[48]

EGA has also helped launch the UAE's Aluminum Recycling Coalition to promote aluminum recycling among consumers.[49] This coalition plans to finance a study by the International Aluminum Institute on recycling rates and behaviors among consumers in the UAE, in order to assess the type of intervention needed to motivate more recycling. Following this study, the coalition intends to support the government in using the results to develop aluminum recycling regulations and infrastructure. The UAE's simultaneous reliance on fossil fuels and deepening decarbonization priorities suggest that it could incentivize similar action from other fossil fuel-reliant countries through its upcoming COP leadership.

CHINA

As the world's largest producer of aluminum, responsible for more than 55 percent of global aluminum production and demand, China's aluminum industry holds significant potential for decarbonization.[50] However, it is also the world's highest-emitting aluminum industry due to its reliance on coal-powered electricity, and also accounts for 81 percent of the global industry's PFC emissions.[51]

In recognition of this emissions intensity, the Chinese government has begun exploring pathways to decarbonization by expanding the production of recycled aluminum and increasing access to renewable energy to lower aluminum emissions.[52] China has announced several recycling projects, bolstered by significant regulatory support.[53] Currently, China uses aluminum scrap to make about 21 percent of its aluminum.[54] If its recycling efforts materialize, its production of secondary aluminum could nearly triple, from 7.6 million tons in 2020 to 20 million tons by 2030.[55]

The viability of expanding new aluminum production to areas where renewable energy is produced in China is complicated

47 Fareed Rahman, "EGA Aims to Decarbonise Its Operations as Demand for Green Aluminum Spikes," *National News*, November 25, 2021, https://www.thenationalnews.com/business/economy/2021/11/25/ega-aims-to-decarbonise-its-operations-as-demand-for-green-aluminium-spikes/.

48 Aarti Nagraj, "EGA Plans Shift to Nuclear and Solar for Aluminum Production as Demand Soars," *National News*, April 14, 2022, https://www.thenationalnews.com/business/energy/2022/04/15/ega-plans-shift-to-nuclear-and-solar-for-aluminium-production-as-demand-soars/.

49 Liz Nastu, "United Arab Emirates Launches Aluminum Recycling Coalition," *Environment and Energy Leader*, January 16, 2023, https://www.environmentalleader.com/2023/01/united-arab-emirates-launches-aluminum-recycling-coalition/.

50 Attwood, "Green Aluminum is Competitive Today."

51 Phil McKenna and Lili Pike, "Why Chinese Aluminum Producers Emit So Much of Some of the World's Most Damaging Greenhouse Gases," *Inside Climate News*, December 23, 2022, https://insideclimatenews.org/news/23122022/china-aluminum-immortals/.

52 "How China Is Decarbonizing the Electricity Supply for Aluminium," World Economic Forum, April 21, 2022, https://www.weforum.org/agenda/2022/04/how-china-is-decarbonizing-the-electricity-supply-for-aluminium/.

53 "Rusal Sees China's Recycled Aluminium Output Almost Tripling by 2030," Reuters, June 16, 2021, https://www.reuters.com/article/us-metals-aluminium-rusal-china/rusal-sees-chinas-recycled-aluminium-output-almost-tripling-by-2030-idUSKCN2DS0ZB.

54 Brian Taylor, "ISRI2023: China Opens Door Wider for Nonferrous Scrap," *Recycling Today*, April 25, 2023, https://www.recyclingtoday.com/news/china-aluminum-copper-scrap-recycling-2023-isri-cmra-alter/.

55 "Rusal Sees China's Recycled Aluminium Output Almost Tripling by 2030."

by geographic constraints, intermittency in available renewables, and the high cost of grid power.[56]

> In provinces rich with hydropower capacity, aluminum production has become less carbon intensive. In the southern province of Yunnan, the region's 70 percent mix of hydroelectric power and cheap energy rates drew millions of tons of new aluminum production over the past few years, though a drought then led to an unprecedented hydropower shortage, forcing provincial authorities to order a 30 percent reduction in aluminum production until the end of 2021. The fragility of the situation in Yunnan has led the central government's NDRC to issue a directive to aluminum companies to diversify future plants away from hydroelectric power and toward wind and solar, which could complicate China's attempts to reach peak aluminum emissions by 2025.[57]

China's carbon emissions trading system is expected to expand to industry, including aluminum, by 2025, which could help incentivize transition from high- to lower-emitting production.[58] Moreover, the government has plans to create a carbon price to raise coal prices as well as the cost of coal-fired power by 2025, increasing the carbon-price incentives process.[59]

CANADA

Canada stands in contrast to China, which has a long way to go to cut aluminum emissions. Also one of the top five aluminum producers globally, Canada is home to what is sometimes called the world's "most sustainable aluminum industry" because of its use of hydropower and high percentage of scrap.[60] Quebec produces 90 percent of Canadian aluminum; its geographic position and existing capacity enable production to be powered almost entirely by hydroelectricity. In response, global leaders in the aluminum sector are launching projects in Canada. Rio Tinto recently announced new plans to invest in low-carbon smelting technology in Quebec.61 Moreover, Alcoa and Rio Tinto have announced a joint project based in Canada to develop the world's first carbon-free aluminum-smelting facility.[62] The companies say that this project, called Elysis, will revolutionize the process of making aluminum by using anodes made of nonreactive materials instead of carbon, thus producing oxygen in place of greenhouse gas emissions. The companies plan to expand and commercialize their process and begin selling the technology in 2024. Quebec's case demonstrates the green potential of producing aluminum in locations with access to consistent, reliable renewable energies.

RUSSIA

A Russian aluminum producer, En+ Group IPJSC, was one of the world's largest producers of low-carbon aluminum, through its extensive use of available hydropower.[63] The country's green aluminum efforts have been derailed, however, by the international response to its invasion of Ukraine. Due to trade restrictions, Russian aluminum companies have faced difficulty in acquiring the alumina needed to produce aluminum. Additionally, tariffs on Russian products following Russia's invasion of Ukraine have caused demand for its low-carbon aluminum to drop significantly as companies turn to other producers, including those with higher emissions intensities. For example, prior to the war, Budweiser had announced plans to partner with En+ to produce low-carbon cans as part of the company's net-zero goals. These plans are now on hold.[64] As demand for Russian aluminum has fallen, Indian aluminum, which produces more GHG emissions, has taken its place.[65]

INDIA

India, the world's second-largest producer of aluminum, has seen increasing demand following Russia's invasion of Ukraine and subsequent trade restrictions, but the country is expected

56 "How China Is Decarbonizing the Electricity Supply for Aluminium."

57 Reinsch and Benson, "Decarbonizing Aluminum."

58 Ivy Yin, "China's Compliance Emission Trading System to Accelerate Coverage of CBAM-Eligible Sectors," S&P Global, May 9, 2023, https://www.spglobal.com/commodityinsights/en/market-insights/latest-news/energy-transition/050923-chinas-compliance-emission-trading-system-to-accelerate-coverage-of-cbam-eligible-sectors.

59 "How China Is Decarbonizing the Electricity Supply for Aluminium."

60 Attwood, "Green Aluminum is Competitive Today."

61 "Rio Tinto to Expand Aluminum Smelter with $1.4B Investment Using Greener Technology," *Global News*, June 12, 2023, https://globalnews.ca/news/9763017/rio-tinto-quebec-aluminum-smelter-green-technology/.

62 "Rio Tinto and Alcoa announce world's first carbon-free aluminum smelting process," Rio Tinto, press release, May 10, 2018, https://www.riotinto.com/fr-CA/can/news/releases/First-carbon-free-aluminium-smelting.

63 Jael Holzman and Corbin Hiar, "War Threatens Supply of 'Green' Aluminum for Cars, Beer Cans," *E&E News*, March 3, 2022, https://www.eenews.net/articles/war-threatens-supply-of-green-aluminum-for-cars-beer-cans/.

64 Ibid.

65 "Russian Aluminium Stocks at LME Grow, Boosting Demand for Indian Alternative," Reuters, June 12, 2023, https://www.reuters.com/markets/commodities/share-russian-aluminium-london-metal-exchange-warehouses-jumps-2023-06-12/

to soon face significant trade repercussions from the EU's CBAM.[66] India's aluminum industry has a higher emissions intensity than average, meaning that the EU CBAM will likely impose tariffs on Indian aluminum when fees enter into force in 2026. The Global Trade Research Initiative in Delhi predicts that the effects of the EU's CBAM on the Indian aluminum industry will be significant, with a projected 6 percent tariff. India has challenged the EU on the legality of its CBAM, on the basis that it poses the type of trade barrier banned by the WTO.[67] The country is seeking exemptions for its small and medium-sized manufacturers, arguing that that they need more time and resources to meet the guidelines laid out by the EU.[68] Although much of India's growing demand for more aluminum is domestic, it also has a significant export flow of fabricated aluminum products. Reports conflict on whether India will raise this as an official complaint at the WTO's next meeting or continue discussing this privately with EU officials.

Regardless, the passage of CBAM likely motivated the Indian government to develop its own national carbon market, which may lead domestic carbon pricing to similarly incentivize decarbonization. Leaders in India's aluminum industry have already begun to respond to these incentives. In 2022, Vedanta Aluminum, India's largest aluminum producer, launched "Restora," India's first low-carbon aluminum.[69]

UNITED STATES

The US aluminum industry has made significant strides toward decarbonization by increasing its recycling efficiency.[70] Since 1991, the sector has reduced its carbon intensity by 43 percent. President Biden's administration has demonstrated ambition in supporting global decarbonization and additional national efforts to lower emissions. At COP26, Biden, in collaboration with the World Economic Forum, launched the First Movers' Coalition.[71] This initiative seeks to bring together companies using their purchasing power to create early markets for clean technology through corporate pledges to use low-embedded carbon commodities. Aluminum is one of its key sectors, meaning that members must invest in low-intensity aluminum. This program has the potential to be an important leadership initiative stimulating the financial capital necessary to drive both production and demand for sustainable aluminum.

Domestic policies such as the Infrastructure Investment and Jobs Act (IIJA) and the Inflation Reduction Act (IRA) have facilitated financial opportunities for investment and innovation in CCUS and green hydrogen. The IIJA contains $12 billion in funding for carbon capture investments and infrastructure.[72] It also created $9.5 billion in funding for hydrogen, with $8 billion dedicated to "hydrogen hubs" supporting research and development.[73] The IRA built upon these funding opportunities, creating two tax credits: one for carbon capture technologies and one wherein the value of the credit is dependent on lifecycle emissions. These policies support the development of decarbonization technologies applicable not only to aluminum, but also to other hard-to-abate industries.

AUSTRALIA AND BRAZIL

Australia and Brazil are both tackling emissions in the refining stage of aluminum production.[74] For example, a Norsk Hydro facility in Brazil implemented electric boilers at one of its refineries, replacing its previous coal-fired machinery.[75] In Australia, the Australia Renewable Energy Agency is exploring the potential of mechanical vapor recompression, which would similarly electrify the production of steam.[76] Both countries are also conducting feasibility studies on hydrogen as an alternate power source, demonstrating their commitment to exploring varied pathways toward decarbonization.

66 Peter Jarka-Sellers and Shayak Sengupta, "Canceling Carbon: The Global Context of India's New National Carbon Market," Observer Research Foundation America, July 18, 2023, https://orfamerica.org/newresearch/cancelling-carbon-global-india.

67 Manoj Kumar and Neha Arora, "India Plans to Challenge EU Carbon Tax at WTO," Reuters, May 16, 2023, https://www.reuters.com/world/india/india-plans-challenge-eu-carbon-tax-wto-sources-2023-05-16/.

68 Adrija Chatterjee, Vrishti Beniwal, and Swansy Afonso, "India Prefers Negotiating With EU on Carbon Tax to WTO Complaint," Bloomberg, June 5, 2023, https://www.bloomberg.com/news/articles/2023-06-06/india-prefers-negotiating-with-eu-on-carbon-tax-to-wto-complaint#xj4y7vzkg.

69 "Vedanta Aluminium Launches Restora, India's First Low-Carbon Aluminium," *Economic Times*, February 25, 2022, https://energy.economictimes.indiatimes.com/news/renewable/vedanta-aluminium-launches-restora-indias-first-low-carbon-green-aluminium/89829681.

70 Attwood, "Green Aluminum is Competitive Today."

71 "First Movers' Coalition: Sectors," World Economic Forum, last visited November 12, 2023, https://www.weforum.org/first-movers-coalition/sectors.

72 "Carbon Removal in the Bipartisan Infrastructure Law and Inflation Reduction Act," World Resources Institute, December 22, 2022, https://www.wri.org/update/carbon-removal-BIL-IRA.

73 Alan Krupnick and Aaron Bergman, "Incentives for Clean Hydrogen Production in the Inflation Reduction Act," Resources for the Future, November 9, 2022, https://www.rff.org/publications/reports/incentives-for-clean-hydrogen-production-in-the-inflation-reduction-act/.

74 "Aluminum," International Energy Agency, last visited November 12, 2023, www.iea.org/energy-system/industry/aluminium#tracking.

75 Elena Brito Pantoja, "Alunorte Alumina Plant Fires Up First Electric Boiler," Hydro, March 10, 2022, https://www.hydro.com/en/media/news/2022/alunorte-alumina-plant-fires-up-first-electric-boiler/.

76 "Mechanical Vapour Recompression for Low Carbon Alumina Refining," ARENA, September 15, 2023, https://arena.gov.au/projects/mechanical-vapour-recompression-for-low-carbon-alumina-refining/.

Multilateral Efforts to Promote Decarbonization

Advancing a sector-wide transition toward decarbonization requires insights and participation from all levels of stakeholders and investors. Toward this goal, a global alliance of climate leaders, including the We Mean Business Coalition and the World Economic Forum, created the Mission Possible Partnership (MPP), focused on supporting and unlocking decarbonization across several industries.[77] The MPP has released sectoral transition strategies for seven of the world's most energy-intensive, hard-to-abate industries, including aluminum.

The MPP's strategy for aluminum describes power decarbonization and recycling as the biggest pieces in this puzzle. The strategy would require multiple elements: government investment in renewable energy, particularly as it relates to access and reliability; policies that incentivize companies to invest in renewables; and expanded electric grids with capacity for more renewables, improvements in storage, and allowances for cross-border electricity flows. The MPP strategy has been endorsed by the leading global trade association, the International Aluminum Institute. The G7's Industrial Decarbonization Agenda also covers aluminum.

The First Movers' Coalition (FMC) similarly commits to action on industrial decarbonization. The FMC, started by the United States at COP26 and now supported by the World Economic Forum, is a coalition of thirteen government partners and dozens of leading companies, including Ford, GM, Volvo, Apple, and PepsiCo.[78] This coalition commits to leverage its purchasing power to create and support markets for green technology in eight high-intensity sectors. These sectors collectively account for 30 percent of global emissions and are projected to contribute to more than 50 percent of emissions in the coming years. The coalition's initial launch at COP26 committed to action on aviation, shipping, steel, and trucking. In 2022, the collation further committed to aluminum and carbon removal.

77 "Making Net-Zero Aluminum Possible."

78 "First Movers' Coalition."

Developing Standards for Measuring Embedded Carbon Emissions

Developing commonly accepted measurement protocols for determining embedded GHG emissions in aluminum production facilities and products is a key threshold objective and a prerequisite not only to fashioning effective trade instruments to incentivize trade of cleaner aluminum, but for design of other policies such as public purchase programs, subsidies, mandates, and consumer labelling.

In the cases of steel and cement, meaningful progress has been made over the past three years on standard setting for embedded carbon and greenhouse gases by several partnerships and multilateral coalitions working in parallel. These include the Industrial Deep Decarbonization Initiative (IDDI), a project of the Clean Energy Ministerial hosted by the United Nations Industrial Development Organization (UNIDO) but located at the International Energy Institute (IEA) in Paris working with the Steel Committee of the Organization for Economic Development (OECD), the SteelZero/Responsible Steel partnership, and the MPP, FMC, and others mentioned above.[79]

Urgency to coordinate and centralize these initiatives for official governmental endorsement and adoption, however, has been lacking. A decision by leading governments to select a single venue to coordinate the development of measurement methodology, and to help organize a data facility for steel and cement facilities that would allow credible application of these standards to be applied in a transparent manner, is probably essential to further progress in those sectors. A similar initiative and selection of a venue and responsible parties with a mission to do the same for aluminum could part a significant part of the decision-making process for steel and cement.

Similar to, and in parallel with, the current direction of work on steel and cement methodologies, measurement standards for embedded emissions in aluminum should also focus on lifecycle emissions, including appropriate upstream emissions. This goal may be somewhat complicated by the EU CBAM entering its two-year transition phase this year. As the only official operating "compliance" system for trade purposes for measurement of embedded emissions in aluminum, the CBAM methodology is not a "lifecycle" measurement but instead designed to mirror only direct emissions (scope one) from aluminum production, since it is only those emissions that European aluminum companies report and are covered by the EU ETS. While the transition phase of the CBAM will also require reporting by importers of aluminum products of the amount of electricity used and corresponding emissions, these indirect emissions will not be included in the tariffs that will go into effect in 2026 according to current guidance. Moreover, during the transition reporting period, default use of the importing (producing) country's overall average grid emissions intensity is permitted. This approach may well result in inaccurate reporting of actual lifecycle embedded emissions in many aluminum products. As the CBAM program develops in parallel with efforts to set lifecycle measurement standards for steel, cement, aluminum, and other such products, resolving anomalies in measurement of emissions will require focused attention.

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79 The Clean Energy Ministerial Industrial Deep Decarbonization Initiative (IDDI) is a coalition of public and private organizations that aims to grow demand for low-carbon industrial materials. Working with national governments, IDDI is working to establish ambitious public and private-sector procurement targets, incentivize investment in low-carbon product development, and design industry guidelines.

Recommendations

The decarbonization of heavy industries like aluminum will be vital to reaching long-term climate goals. With aluminum both a major commodity in global trade and an important input into green goods that are essential for a cleaner economy, it is urgent for policymakers and companies to accelerate the sector's decarbonization. Governments should elevate the need to decarbonize the industry at both the domestic and international levels, and work together with the private sector to continue making progress in solutions for reducing emissions in both the production and trade of aluminum. Because the aluminum market is tightly linked to international trade, data quality, data transparency, and trade policies that are aligned with climate goals are necessary for deep decarbonization and a quicker transition. This section provides recommendations on decarbonizing aluminum and similar industries, building on those already put forth by the Consortium for Climate-Aligned Trade (CCAT) and the IEA.

To advance decarbonization of aluminum and similar industries, we recommend the following.

RECOMMENDATION 1: Governments should commit to decarbonization goals for heavy sectors, such as aluminum, that are in line with the Paris Agreement.

The G7 and major producing countries of the most emissions-intensive industrial commodities should commit to specific decarbonization goals on a sector-by-sector basis, beginning with steel, aluminum, and cement, then moving to fertilizer and chemicals. These goals should be compatible with the Paris Agreement.

RECOMMENDATION 2: Governments should acknowledge the importance of climate-related trade instruments and utilize them to reduce emissions in heavy industries like aluminum.

Both producing and consuming country governments should acknowledge that climate-related trade instruments tied to emissions intensity of traded products are appropriate measures to use in the overall effort to incentivize mutual and global efforts to advance industrial decarbonization in sectors such as aluminum. Climate-aligned trade rules are needed to promote innovation, reduce costs, and stimulate demand for cleaner goods. Smart climate and trade policies are also needed to minimize carbon leakage and increase overall climate ambition.

RECOMMENDATION 3: Governments and international organizations should craft policies that target the "emissions intensity" of facilities and products.

In these hard-to-abate sectors, embedded GHG emissions, or "emissions intensity," of the facilities and products should be the primary focus of overall efforts, including market-creation policies (public purchase, subsidies, corporate customer voluntary commitments), mandates, consumer commitments, and trade instruments.

RECOMMENDATION 4: Governments and international organizations should develop protocols for determining carbon intensity in aluminum production facilities and products, as they are doing for steel and cement.

Developing commonly accepted measurement protocols for determining embedded GHG emissions in aluminum production facilities and products is a key threshold objective and a prerequisite to moving forward with any and all policies, including trade instruments. Meaningful progress has been made over the past three years on standard setting for steel and cement by several different partnerships and coalitions working in parallel, but urgency to combine and coordinate these initiatives for official governmental adoption has been lacking. A similar initiative, more centralized, should be undertaken for aluminum.

RECOMMENDATION 5: Major producer countries should work with international organizations to consolidate and centralize ongoing separate initiatives and partnerships currently working on setting standards for measuring embedded emissions in key commodities—including aluminum—into a single venue and forum.

Given the plethora of coalitions and entities now working on setting standards for measuring embedded carbon in steel and cement, consolidating this effort within the OECD/IEA—together with the IDDI, a project of the Clean Energy

Ministerial hosted by the UNIDO but located at the IEA in Paris—would provide a productive venue to develop a common standard for lifecycle embedded GHG emissions in the aluminum industry, as well as the steel and cement industries. An aluminum forum at this same venue could be a part of the Climate Club or separate from it, but should be an official forum open to all producing and consuming countries to join as members, and would be charged with structuring a global data facility adding aluminum data to steel and cement data. Key aluminum producers to recruit to any new initiative are the United States, China, India, Canada, the UAE, Bahrain, Norway, Iceland, and Australia.

RECOMMENDATION 6: Industry associations and international forums should increase collaboration on data and standard setting.

The Organisation for Economic Co-opeartion and Development (OECD) team on aluminum standards should also work with major aluminum trade associations—including the International Aluminum Institute, the Aluminum Association (United States), the Aluminum Association of Canada (AAC), Norsk Hydro, and Emirates Global Aluminum—as well as representatives from industry in China and India. The G7 and aluminum-producing countries also should commit to working together, directly and via international institutions, to improve data transparency, availability, and quality. Creating a global data facility for aluminum—just as will be necessary for the steel sector—would initially rely on existing industry databases. Thus, they must create an open venue where steel-producing member countries join to construct such a data facility for steel, and could also serve as the venue for a similar facility for data on aluminum manufacture to verify measurements of emissions attributable to aluminum manufacturing plants and their products.

RECOMMENDATION 7: Governments and international organizations should ensure that embedded emissions measurement focus on lifecycle emissions.

Standards for measurement of embedded emissions in aluminum should also focus on lifecycle emissions, including appropriate upstream emissions. Resolving differences in measurement of emissions adopted in the CBAM program as it develops in parallel with separate efforts to set lifecycle measurement standards for steel, cement, and aluminum for other policy purposes will require increased attention.

RECOMMENDATION 8: As their highest priorities in aluminum decarbonization, governments and industry should adopt increased use of scrap aluminum and renewable energy for the refining and smelting processes involved in primary production.

Policymakers and industry should aim for the greater use of scrap aluminum, and for increased renewable energy for the refining and smelting processes used in primary production.

The use of scrap can cut 90–95 percent of the power used to produce aluminum and reduce other unhealthy emissions; it also eliminates emissions from mining and transportation of ore and is less expensive. Scrap will not, however, be available in equal measures across producing countries. Current estimates are that, by 2050, a substantial amount of aluminum will still need to be produced by primary processes.

The use of renewable energy rather than coal-based power in the primary refining/smelting process could reduce emissions by as much as 70 percent. While progress has been made in many countries on recycling of aluminum cans (though, in the United States, the percentage has fallen), policies to implement a more circular economy that captures other post-use aluminum can be important. The possibility of international cooperation to encourage construction of new primary aluminum smelters could be explored in countries where nearly 100 percent renewable energy is used.

Conclusion

With aluminum as one of the most energy-intensive and greenhouse gas-emitting commodities in the world, and demand expected to continue to grow sharply in the coming decades, decarbonization of the aluminum sector, along with all heavy industries, will be vital to reaching global long-term climate goals. Policymakers, industry officials, and NGOs have the opportunity to collaborate to grow the green aluminum market, keeping up momentum seen in recent years.

The pathways to decarbonization of aluminum production are relatively clear and straightforward, if challenging: increase use of recycled scrap material (because relatively pure aluminum can be recycled indefinitely, cutting emissions by close to 90 percent, as well as reducing mining and transportation); supplying more clean renewable energy to new production facilities; increasing efficiency through new technology, primarily the use of non-carbon anodes. In the long run, nuclear power may provide another important pathway, while hydrogen and CCUS are less likely to do so. Moving along these pathways will require mandates and commitments including further regulations and carbon pricing, financing incentives, and market creation through required public and private purchase commitments and labelling/public education.

Trade policies are another important tool to decarbonize the aluminum market. Trade policies initiated among the dozen largest producing and importing/customer nations can enhance and incentivize these steps, but may leave trade competitiveness as a possible drag on international cooperation. Currently, the EU and United States have taken the lead in beginning to resolve these issues, which will require not only greater G7 approval but outreach to China and India as the largest producers and major future markets. It is vital that major economies put aside trade differences and increase coordination, including collaboration on decarbonizing key industries such as aluminum.

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