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THE CASE FOR PRIORITIZING BAUXITE

There is wide agreement that climate change is upon us, and the principal question is no longer whether, but how painful the consequences of alteration of our climate will be.

There is also wide agreement that making the transition away from carbon intensive energy systems will require unprecedented amounts of a long list of mineral products. In the rush to develop these minerals, we cannot overlook the fact that minerals development in past eras has often been a source of great injustices, serious damage to the environment, and significant conflict.

Frequently there is a great disconnect between those who reap great benefits from mineral development and those who experience its negative impacts.

These great disparities in impacts and benefits have frequently generated social conflicts, many of them violent, which have frequently slowed or prevented mineral development – the very outcome we must seek to avoid, if accessing these 'transition minerals' is as important as we are being told.

Some of these materials are hardly household names. Others, such as aluminum, are better known, though many of us are still not entirely clear exactly where they come from, or might in the future come from, or the environmental and social costs of their production.

While there is much attention to the new, exotic materials such as rare earths, the reality is that the biggest challenge may be aluminum. Aluminum is one of the most widely produced and used metals on earth. The body of new Tesla is made mostly from aluminum, and the same can be said of many 'energy transition' products.

Annual global aluminum production averages roughly 65 million metric tons of primary aluminum and 30 of recycled aluminum.[1] [2] "Today more aluminum is produced than all other non-ferrous metals combined."[3]

The International Aluminum Institute expects annual global aluminum demand to nearly double by 2050, an increase of 35% and 170% in primary and recycled production respectively.[1]

Aluminum is listed as a "critical mineral" by the government of the United States[4] and a "critical material" by the European Union.[5] The US Agency for International Development and the World Bank both recognize aluminum as both a high-impact and 'cross-cutting' mineral - it is used widely for both energy generation and storage technologies and is therefore critical regardless of which of these technologies are used in a given mitigation scenario.[6] [7]

Carbon Impacts of Aluminum Production

Finding and producing the necessary aluminum will in itself have a massive impact on carbon emissions and carbon cycles, for two principal reasons:

- For reasons having to so with the process of ore generation, aluminum deposits tend to be located in forested tropical and semi-tropical areas (e.g., Guinea, Vietnam, Australia, Brazil, Indonesia) that currently sequester large amounts of carbon. Damaging or destroying those forests in pursuit of bauxite may liberate large quantities of the very carbon we are hoping to keep out of the atmosphere.
- Producing aluminum is one of the most electrically intensive processes on earth. If we obtain aluminum by smelting it with coal based electricity, as is still the case in much of the world, it is highly questionable whether we will see the carbon reductions we need to achieve in the energy transition. Even smelting it with hydroelectricity is far from a free lunch.

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[1] International Aluminum Institute. (2021). *Global Aluminum Cycle*. Retrieved May 18, 2022, from https://alucycle.international-aluminium.org/public-access/

[2] International Aluminum Institute. (2022). Primary Aluminum Production [Database]. https://international-aluminium.org/statistics/primary-aluminium-production/

* These properties of Aluminum are conditional based on certain criteria. Details on these subjects will be fully discussed in later sections.

[3] BREAKING NEW GROUND, the report of the Mining Minerals and Sustainable Development Project, at 93. (2002). https://pubs.iied.org/sites/default/files/pdfs/migrate/G00897.pdf

[4] 2022 Final List of Critical Minerals, 87 FR 10381, Feb. 24, 2022.

[5] European Comission. (2020). Study on the EU's list of Critical Raw Materials [Final Report]. European Union. https://ec.europa.eu/growth/sectors/raw-materials/areas-specific-interest/critical-raw-materials_en

[6] De Jong, T. U., Sauerwein, T., & Wouters, L. (2021). Mining and the Green Energy Transition: Review of international development challenges and opportunities. USAID. https://land-links.org/wp-content/uploads/2021/11/Green-Energy-Minerals-Report_FINAL.pdf

[7] The World Bank & Climate Smart Mining Initiative. (2020). Minerals for Climate Action: The Mineral Intensity of the Clean Energy Transition. The World Bank. https://pubdocs.worldbank.org/en/961711588875536384/Minerals-for-Climate-Action-The-Mineral-Intensity-of-the-Clean-Energy-Transition.pdf

Aluminum Ores Tend to be Located in Tropical and Subtropical Climates that are Forested

"Bauxite deposits and mines are predominantly found in sedimentary rocks in lowlands and the majority of economic reserves (around 90%) are located in tropical and sub-tropical regions (Bardossy and Aleva, 1990)."[8]

This is in part because climate conditions seem to play an important role in forming bauxite deposits.

> "The climatic conditions necessary for bauxite formation are:
> (1) A temperature above 20°C and (2) alternating wet and dry seasons
> which favour chemical processes of leaching and removal of silica and concentration of iron oxide and alumina. Thus laterite bauxites (and
> Indeed, all bauxites) are now recognized as typical terrestrial or
> Continental deposits formed under the conditions of a tropical (tropical-savannah), or sub-tropical climate"[9]

This means that aluminum production may have disproportionate impacts on forested landscapes.

Bauxite mines tend to occupy large surface areas. Because bauxite occurs in relatively shallow deposits near the surface, extraction typically occurs through open cast mining. Bauxite deposits cover many square kilometers and typically range from three to ten meters in depth[10] with an average of four to six meters.[11] So they are vertically thin and horizontally extensive which means the mines may tend to have large surface areas for a given amount of production compared to other minerals.

There are Important Additional Land Use Impacts

Bauxite production has additional land use impacts which can lead to significant forest loss.

- **Land is Needed for Storage of Wastes**

So-called "Red Mud" is an industrial waste of the Bayer aluminum production process. The impacts are therefore felt where bauxite is converted to alumina.

[8] Urguia et al., *Global direct pressures on biodiversity by large-scale metal mining: Spatial distribution and implications for conservation*, Journal of Environmental Management (2016).
[9] Geological Society of Jamica, Origin of Bauxite (1977).
[10] Donoghue, A. M., Frisch, N., & Olney, D. (2014). Bauxite Mining and Alumina Refining: Process Description and Occupational Health Risks. Journal of Occupational and Environmental Medicine, 56, S12. https://doi.org/10.1097/JOM.0000000000000001
[11] International Aluminum Institute. (2018). Mining and Refining – Process. https://bauxite.world-aluminium.org/mining/process/

> "The Bayer process produces not only the highly desired Al oxide from the bauxite ore, but it also produces an undesired by-product, called red mud. It contains toxic heavy metals and its high alkalinity makes it extremely corrosive and damaging to soil and life forms, creating a huge challenge for such disposals. This debris which is both valuable and toxic is one the biggest problems in Aluminum making."[12]

The rate of Red Mud production is from 0.8 - 1.8 tons of Red Mud per ton of alumina.[13] There is therefore considerably more Red Mud than aluminum produced.

The typical "disposal" method for Red Mud used in industrial alumina operations involves discharging it as a slurry into holding ponds or dams.[28] But the Red Mud does not "go away," and the need to control it persists indefinitely. It is simply in a form of storage or confinement, which can ultimately fail. If red mud leaches from its storage area, whether by groundwater infiltration or large rain events, its high alkalinity and chemical components will result in impacts to water, soils, and air of the surrounding area.

"More than 150 million tons of bauxite residue are produced every year …., The majority of this highly toxic (and in part also valuable) waste is deposited as landfill.

- Worldwide more than 100 Bayer plants are operative. The total stockpile of this bauxite residue exceeds 3500 million tons."[14]

As much of the production is occurring in forested areas, the need for large areas of land for perpetual storage of these wastes will have an additional significant impact by reducing forest cover, and likely releasing the carbon stored in these forests to the atmosphere.

- **Forests are Impacted by Dust**

Forests in large areas surrounding aluminum mines are demonstrably impacted by dust from mining operations. This reduces the quantity and vigor of vegetation and presumably the forest's ability to store carbon.

Carbon Emissions from the Smelting of Alumina

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[12] Dierk Raabe, Max Planck Institute. https://www.dierk-raabe.com/what-is-red-mud-and-why-is-it-dangerous/

[13] Tang, W., Khavarian, M., & Yousefi, A. (2022). 14—Red Mud. In R. Siddique & R. Belarbi (Eds.), *Sustainable Concrete Made with Ashes and Dust from Different Sources* (pp. 577–606). Woodhead Publishing. https://doi.org/10.1016/B978-0-12-824050-2.00013-9

[14] Ibid. (29)

It is unfortunate but true that production of a material intended to reduce greenhouse gas emissions is itself a major source of such emissions. The impacts are global in scale. "The world's aluminum smelters consume about 3.5% of the total global electric power."[15]

Greenhouse gases within the aluminum industry represent a major environmental impact and a significant contributor to the climate crisis.[16] Emissions from aluminum come several significant sources: (1) combustion of fuel and electricity use for mining, (2) industrial heat and steam, and electricity use in refining, (3) production of other materials used in refining and smelting, (4) fossil fuel-based electricity to power electrolytic smelting, (5) Direct CO_2 emissions from electrolysis, (6) thermal energy to generate heat and steam during fabrication, (7) transportation to different sites for manufacturing and retail, (8) waste processing and disposal.[17]

As much as two thirds of total greenhouse gas emissions from primary aluminum production stem from use of electricity in smelting. The level of emissions of course depends on the type of generation used in electrical production. Aluminum smelting requires immense amounts of electrical energy. It seems that a considerable part of those carbon emissions come from coal powered electricity used in smelting operations.[18] The impacts of these emissions are of global significance. Though hydroelectric power once accounted for most of the electrical energy used in aluminum smelting, coal now dominates the mix.

Hydropower Must be Evaluated on a Case-by-Case Basis

In most cases, hydropower is a 'reduced carbon' alternative for generating electrical power. However, this is not uniformly the case, especially in tropical regions, which is where most bauxite deposits are formed.

> "Hydropower has been promoted as a climate-friendly alternative to meet the world's growing electricity demand[1]. Globally, hydropower dam construction is expected to reach unprecedented rates in the coming decades, especially in countries with emerging economies[2]. One hotspot for future hydropower expansion is the Amazon[3,4,5], the world's largest river basin. Although dams have already been built in several regions of the basin, the Amazon hydropower potential remains largely untapped, and electricity generation is the primary motivation for new dam construction[2]. Existing evidence suggests that most global hydropower projects have total greenhouse gas (GHG)

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[15] Sagnik Banerjee and Manishankar Ray, Energy Reduction in Aluminium Smelting: An Overview, AL Circle Blog, February 17, 2017. https://blog.alcircle.com/2017/02/17/energy-reduction-aluminium-smelting-overview/#:~:text=The%20world%E2%80%99s%20aluminium%20smelters%20consume%20about%203.5%25%20of,production%20is%20derived%20from%20electricity%20from%20fossil%20fuel.

[16] https://www3.weforum.org/docs/WEF_Aluminium_for_Climate_2020.pdf

[17] https://www.aluminum.org/sites/default/files/2022-04/104.1_AluminumAssocication_EPD_PrimaryAluminumIngot.pdf

[18] *https://www.aluminum.org/sites/default/files/2022-04/104.1_AluminumAssocication_EPD_PrimaryAluminumIngot.pdf*

emissions per unit electricity generated (also known as carbon intensity, Table 1) within the range of other renewable energy sources like solar and wind power[6,7,8].

However, about 10% of the world's hydropower facilities emit as much GHGs per unit energy as conventional fossil-fueled power plants[6]. **Some existing dams in the lowland Amazon have been shown to be up to ten times more carbon-intensive than coal-fired power plants[9,10,11]**. In light of the expected boom in construction of new hydropower dams in the Amazon basin, it is critical to identify whether future dams will produce low-carbon energy.'[19]

Our evaluation also must include the reality that hydroelectric impoundments tend to be large in low lying relatively flat areas, and that the are they occupy will in many cases previously been forested. Indeed, emissions from rotting inundated vegetation are at some sites the source of poor performance in greenhouse emissions.

Conclusions

There is obviously reason to be concerned about some of the other adverse impacts, biodiversity high among them.

It is not clear whether the reduction in emissions resulting from more extensive use of aluminum in renewable energy or electromobility applications actually results in a decrease in carbon loading in the atmosphere, given:

- Forest areas lost to mining;
- Forest areas lost to waste storage; and
- The immense amount of coal being burned to generate the electricity needed to smelt alumina into aluminum.

But here we are simply looking at the question of ramping up aluminum production in terms of carbon balance. How necessary is aluminum to the energy transition? Can we be more efficient in its use?

Can we decrease the negative climate impacts of aluminum production? If so, how? If aluminum is as big a part of the energy transition as we are being told, learning how to reduce these negative impacts needs to be at or near the top of our list of priorities.

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[19] Almeida et al, Reducing greenhouse gas emissions of Amazon hydropower with strategic dam planning, Nature Communications (2019). Emphasis supplied.