Energy Transition
and the Demand for Aluminum in the Brazilian Amazon

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Authorship
Luiz Jardim Wanderley
Pedro Catanzaro Rocha Leão

Translation
Cíntia Mendonça Garcia

Graphic design
Irmãs de Criação

Apoio

Ford Foundation

EMBAIXADA DA NORUEGA

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Comissão Pró-Índio de São Paulo

cpisp@cpisp.org.br
www.cpisp.org.br

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Introduction

This publication discusses energy transition policies and their effects on aluminium demand, with a specific focus on the Brazilian Amazon. The work was built from bibliographic surveys and secondary data produced by different private, non-governmental and multilateral institutions, which debate and produce information on the subject of global warming and greenhouse gas emissions.

In the scenario of political concern and irreversibility of some changes in climate conditions, a series of solutions is being thought, proposed and requested to reverse or at least slow down the ongoing changes. For the Intergovernmental Panel on Climate Change (IPCC), the main goal of the Paris Agreement, to achieve a maximum growth of 1.5^{0}C in global average temperatures by 2100, would require a 45% reduction in CO_2 emissions by 2030 and zero emissions by 2050. To this end, a general policy of energy transition from fossil fuels to other forms of energy – mostly solar and wind – is projected, and with the massification of cars, machinery and electrical equipment, both in buildings and in the production process. However, this transition demands a finite, non-renewable mineral base that is unevenly distributed around the world (Milanez, 2021). Although this new technological architecture of electrified renewable energy requires different ores for its construction, the great demand will occur mainly on cobalt, lithium, copper, lead, nickel, rare earths and aluminium.

Because of this, different agents and market analysts have been indicating the possibility of a new cycle of appreciation of mineral commodities to meet the demand of the energy transition. Such extra demands will reverberate, above all, in search of minerals linked to the new technologies of the "low carbon" economy and will trigger territorial conflicts in greater quantity and intensity (Milanez, 2021; Deniau, Herrera, Walter, 2021). In this article, we evaluate the growth of the demand of the energy transition on the consumption of aluminium and its possible effects from mineral extraction in the Brazilian Amazon and particularly for the municipality of Oriximiná, in Pará, where the largest bauxite producer in the country is located.

Highlights

- The energy transition to a "clean" energy system will increase mineral demand, as new solar PV plants, wind farms and electric vehicles require more mineral resources than other facilities and vehicles, especially high-content minerals.
- CO_2 emissions from global mineral extraction increased by 50% between 2005 and 2018.
- In Brazil, mineral products and metals processing accounted for 1.9% and 3% of the country's total emissions in 2020.
- Aluminium is one of the key metals in the energy transition and could see a 29% global growth in demand by 2030.
- CO_2 emissions from aluminium production almost doubled between 2005 and 2018 and already account for 2% of global emissions.
- The Amazon is an important producer of bauxite – the raw material for aluminium – and aluminium and may suffer from the growth of socio-environmental conflicts due to the new demand, with deforestation of native forest areas inhabited by traditional populations, an increase in the number and volume of tailings dams and demand for energy sources.
- Today, Brazil is the fourth largest bauxite producer in the world, as well as having the fourth largest international reserves of ore, after Australia, Guinea and Vietnam. The State of Pará holds approximately 75% of the national reserves.
- Mineração Rio do Norte (MRN) is the largest bauxite mining company in Brazil and operates in the Brazilian Amazon, in the State of Pará, in the municipality of Oriximiná.
- Over its more than 40 years of operation, MRN has already caused the change of land cover in 10,800 hectares for the construction of bauxite mines and tailings dams within the current Saracá Taquera National Forest, in areas originally used by local communities.
- Extreme events, increasingly recurrent due to climate change, tend to raise the risks of mining dam disasters. In the case of MRN, in the area where the largest complex of mining dams in the Amazon is located, attention needs to be redoubled.
- The new demand for aluminium could accelerate the extraction and depletion of MRN mines, increasing tailings production, deforestation, and aggravating socio-environmental damage to local communities.

Energy Transition and the Increase in Demand for Mineral Resources

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Supported by the political proposals to combat global warming, whose central focus is on the energy transition and the promises of robust economic packages of the large nation states, widely known as the "Global Green New Deal" (Polychroniou, Chomsky, Pollin, 2020), market analysts bet on a new cycle of commodities, especially mineral goods.

The goal of the European Union and the United States to meet the Paris Agreement is to achieve a zero-emission energy matrix and carbon neutral emission by 2050. For this, economist Robert Pollin (Polychroniou, Chomsky, Pollin, 2020) estimates that an investment of 2.5% of the world GDP per year or 2 trillion dollars in public and private investments, in exaggerated figures, is necessary. More conservatively, Flowers (2020) estimates that in the mineral sector alone, in order to increase the production of the five main metals for energy transition technologies, 1 trillion dollars will be needed in 15 years: 525 billion for copper, 335 billion for aluminium; 150 billion for nickel, 50 billion for lithium and 5 billion for cobalt.

The implementation of such economic policies may result in an international movement of valorisation of both the ores mentioned above and traditional ores, such as iron ore, used by the industrial and infrastructure sector.

According to a report by the International Energy Agency (IEA, 2021) , industries producing "clean energy" technologies will become a relevant segment of mineral consumption as the energy transition is implemented and encouraged with more intensity. That's because the energy transition to a "sustainable green economy" proposes, among other things, replacing dependence on fossil fuels – such as oil – with renewable energy sources such as solar and wind. In this sense, the share of wind and photovoltaic energy in the generation of electricity in the world will need a jump from 10% to 70% in 30 years, if we want zero net carbon emissions by 2050 (IEA, 2021).

The energy transition to a "clean" energy system will increase mineral demand since photovoltaic solar plants, wind farms and electric vehicles require more mineral resources in their composition than other facilities and vehicles. For example, an onshore wind farm requires nine times more mineral resources than a gas-fired power plant (Fisher; Cuéllar, 2022). In addition, to connect the new power generation structures to urban and industrial consumer centres, the electric power transmission network will need to be expanded. In addition, the transition will require the replacement of the fleets of vehicles currently in circulation, since an adaptation of the existing fleet is not, in principle, under consideration.

Thus, copper, nickel, cobalt, lithium, manganese, graphite, zinc, rare earths and aluminium are among the minerals that will be most required to compose a new fleet of automobiles in the context of the energy transition (Fisher; Cuéllar, 2022). The IEA (2021) shows that the use of these critical minerals, which are of high relevance to the transition industry, should go from about 8 million tons per year in 2020 to 40 million in 2050.

The Growth in Consumption of Aluminium

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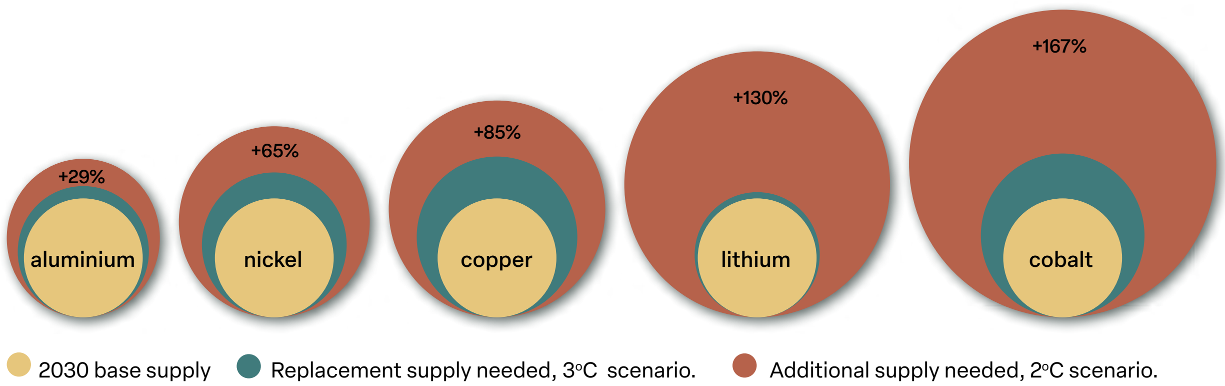
Aluminium will increasingly be a fundamental metal, associated with the energy transition, whose demand tends to rise until 2050. A decarbonised future depends on an increase in the global production capacity of the metal, given that it is used in the manufacture of different products and equipment of low-carbon technologies: battery packaging; hydrogen fuel cells; wind turbine blades; permanent magnets; photovoltaic panels; power transmission infrastructure, etc. (Hache, Barnett, Seck, 2021).

It should be considered that, among the critical minerals, aluminium is the one that will suffer the least demands proportionally. The metal is already the second most used in the world, after iron (IFP Energies Nouvelles, 2021), with a large volume in the current market, with 67.2 million tons produced in 2021 (International Aluminium, 2022). Still, by 2030, aluminium production is expected to have increased by about 29% in relation to the expected base supply, considering the scenario of a 2ºC increase in global average temperature over the next ten years (Wood Mackenzie, 2021).

Increase in Mineral Demand with Energy Transition Policies



Source: Wood Mackenzie, 2021

To get an idea, 236 kg of aluminium is needed per unit of Intelligent Electric Vehicle (EVs). For a photovoltaic energy production unit (solar panels), 22 kg of aluminium is required per Kw generated. The demand for offshore wind energy platforms is 3 kg per Kw, in addition to copper, nickel, zinc and cobalt (Wood Mackenzie, 2021). That is, aluminium is the metal with the most demand, in absolute volume, for the production of the energy technologies indicated below.

Metal Usage in Energy Transition Technologies

	Intelligent Electric Vehicle (EVs) + charging	Photovoltaic energy	Offshore wind power platform
Al	236kg/unit	22kg/Kw	3kg/Kw
Cu	140kg/unit	4kg/Kw	8kg/Kw
LCE	36kg/unit		
NI	13kg/unit		
Co	5kg/unit		
Zn		5kg/Kw	0.7kg/Kw

Al =Aluminium, Cu = Copper, LCE = Lithium, Ni = Nickel, Co =Cobalt, Zn = Zinc

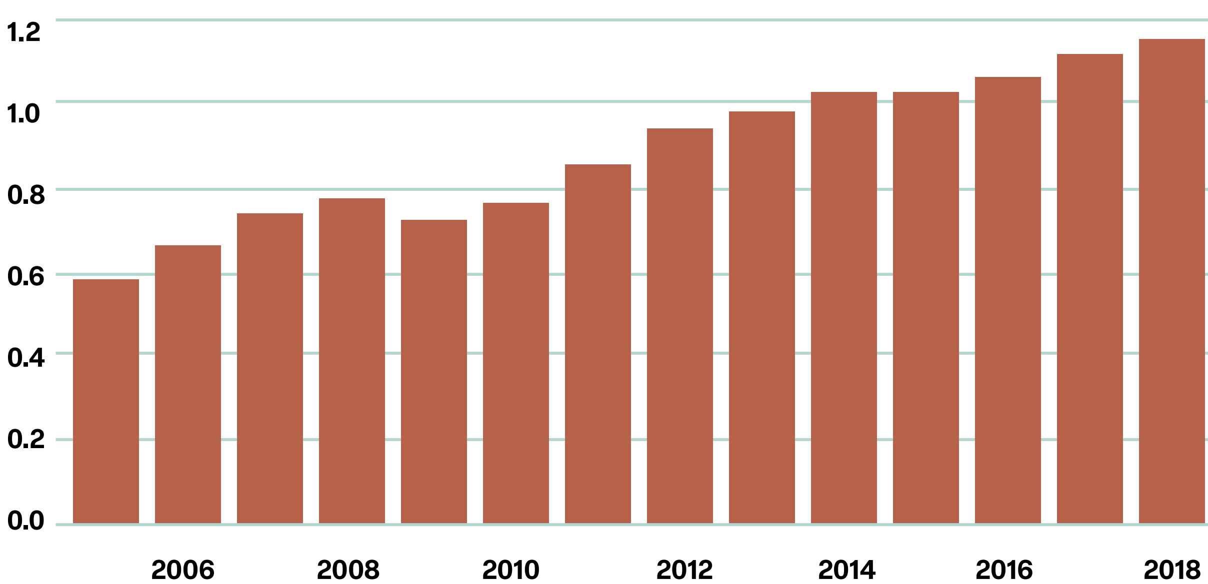
Source: Wood Mackenzie, 2021.

However, aluminium is also a source of greenhouse gas emissions, given that the production sector of this metal was responsible for 2% of total emissions in 2018 (Hache, Barnet, Sech, 2021). In fact, the aluminium production sector has been showing an increase in emissions since 2004, almost doubling its share and reaching 1.12 billion tons of CO_2e in 2018 (Davis, 2021), as can be seen in the following chart.

Thus, to meet the targets set in the 2ºC scenario, the carbon footprint of primary aluminium production would need to be reduced from 16.7 tons CO_2e/ton of aluminium (from the 2018 global average) to 2.5 tons CO_2e/ton (IAI, 2021). According to the IAI, this would require an estimated investment of US$ 500 billion to US$ 1.5 trillion over the next 30 years, in carbon-free electricity, new production and recycling technologies.

Even though the mineral extraction sector associated with aluminium in the world has a small carbon footprint in relation to the rest of the chain, it increased its emissions per year by 50%, from 2 million tons of CO_2 to 3 million, between 2005 and 2018 (IAI, 2022).

Global Emission from Aluminium Sector (billion tons CO_2e)



Source: International Aluminium Institute apud DAVIS, 2021.

Increase in Demand for Bauxite

In target scenarios of a global average temperature rise by 4ºC or 2ºC above pre-industrial levels, IFP Energies Nouvelles (2021) estimates a cumulative demand for bauxite in the coming decades, alumina-rich ore (AL203) and iron oxides. Under the most optimistic resource estimate, the level of criticality associated with bauxite ranges from 25.2%, in the 4ºC scenario, to 63.9% in the 2ºC scenario. These indices increase 34.4% and 87.1%, respectively, if the most pessimistic estimate is assumed (Hache, Barnet, Seck, 2021). Once extracted, bauxite is refined into an intermediate product, alumina, and then melted into aluminium.

Today, Brazil is the fourth largest bauxite producer in the world, besides having the fourth largest international ore reserve, with 2.7 billion tons, behind Australia, Guinea and Vietnam (US Geological Society, 2022). Brazil accounts for 9.1% of the world's bauxite reserves and 9.4% of production.

The bauxite reserves are distributed in nine states with a total of 3.6 billion tons, where 3.3 billion are metallurgical bauxite (more than 90% of the reserves), according to the Brazilian Mineral Yearbook-AMB (DNPM, 2006). The state of Pará holds approximately 75% of the national reserves, followed by Minas Gerais.

It is recorded that in the country the bauxite reserves are of the trihydrate type, which has a low cost in the transformation into alumina, since they require lower pressure and temperature than the monohydrate bauxites found in Greece, for example (Mártires, 2001).

Data from the Brazilian Aluminium Association (2022) help understand the country's bauxite mining and aluminium production companies. In 2020, the total bauxite produced in Brazil was 32.9 million tons. Mineração Rio Norte (MRN) accounted for 37% of this total, followed by Hydro Brasil Ltda. (26.2%), Alcoa Alumínio S.A. (22.5%) and Companhia Brasileira de Alumínio (3.5%).

MRN is the largest bauxite mining company in Brazil and has operated in the Brazilian Amazon, in the state of Pará, in the municipality of Oriximiná, since 1979. The company's shareholders are Vale (40% of the shares); South32 (33%); Rio Tinto (12%); Companhia Brasileira de Alumínio (10%) and Hydro (5%)[1].

The operations of Hydro and Alcoa together with MRN total 90% of the bauxite extracted in Brazil, with Pará being the state of origin. The remainder is extracted in Minas Gerais (4%) and Goiás (3.3%). With much lower numbers, São Paulo, Santa Catarina and Espírito Santo still appear as aluminium producing states (ANM, 2021).

1. On April 27, 2023, the Anglo-Swiss company Glencore announced that it will take over 45% of Mineração Rio do Norte through the purchase of the equity stakes from Vale (40%) and Hydro (5%) in the Glencore company. Available at < https://www.glencore.com/media-and-insights/news/glencore-announces-the-acquisition-of-equity-stakes-in-mineracao-rio-do-norte-s-a-and-alunorte-s-a-from-norsk-hydro-asa > accessed April 27, 2023.

Emissions from Mining Activity

Mineral extraction has several mechanisms for inducing climate change. The equipment used in large mining in the excavation of mines (trucks, backhoes, and tractors) require a large volume of fossil fuels to operate. There is equipment in mining that consumes more than 400 liters of fuel per hour, such as ore transport trucks[2].

However, the biggest effect of the sector on climate change is in mineral transformation, in the field of metallurgy and steel, where the share of emissions is significant. It is estimated that the mining and metallurgy sector may already be responsible for 28% of global emissions, and the contribution of mining can reach up to ¼ of this amount – from 4% to 7% (Delevingne et al, 2020). The world's 16 largest miners emit about 2.5 billion tons of carbon equivalent annually (APIB and Amazon Watch, 2022).

In Brazil, the Brazilian mining and metallurgical sectors consume the equivalent of 9.2% of the total energy generated in the country, according to 2020 data from the Energy Research Company (MME, 2022). Much of this energy comes from hydroelectric plants, as is the case of the Aluminium processing industries in Barcarena (PA) supplied by the Tucuruí Power Plant, in Pará.

Hydro alone, in Barcarena, consumes 50-150 MW at the Hydro Alunorte alumina refinery and 800 MW at Albrás (Hydro, 2018). The metallurgical aluminium producer, the main destination of MRN's bauxite ore, became Brazil's largest free consumer of electric power (CCEE, 2018). Another MRN bauxite consumer is Alumar, in the City of São Luis, State of Maranhão. The metallurgical company can consume up to 500 MW of energy to produce alumina and aluminium (*O Estado do Maranhão*, 2012).

According to the Greenhouse Gas Emission Estimation System (Potenza et al, 2021) of the Climate Observatory (*Observatório do Clima*, 2021), the processing of mineral products and metals in Brazil was responsible, respectively, for 29.1 million tons of CO_2 and 46.3 million tons in 2020. This corresponds to 1.9% and 3% of the country's total emissions, which may not even seem much in the total national emission. However, when comparing the share of mining and steel in the national Gross Domestic Product, we identify that the sectors contribute less to GDP, specifically, 1.1% and 1.3% (MME, 2019, 2018 data), than to climate change.

It should also be noted that emissions from the processing of mineral products and metals in Brazil have shown upward trends in the last three decades, with the exception of the last decade for metallurgy. The processing of mineral products almost doubled its emissions in this period, from 15 million in 1990, thus more than doubling its contribution to the national CO2 balance, from 0.8% to 1.9%. On the other hand, metal production increased its emissions by 60% and its share of the national total doubled, from 1.5% to 3%.

That is, to look at the full extent of greenhouse gas emissions from the mining sector as a whole, and from MRN in particular, we have to start from the three scopes within the production chain:

- **Scope 1:** emissions resulting from the extraction activity itself, in Oriximiná in this case, that is, all the fuel that is burned to carry out the extraction using machinery (for extraction and processing), transport systems (trucks, railway train, conveyors and automobiles) and the structure of housing itself and services;

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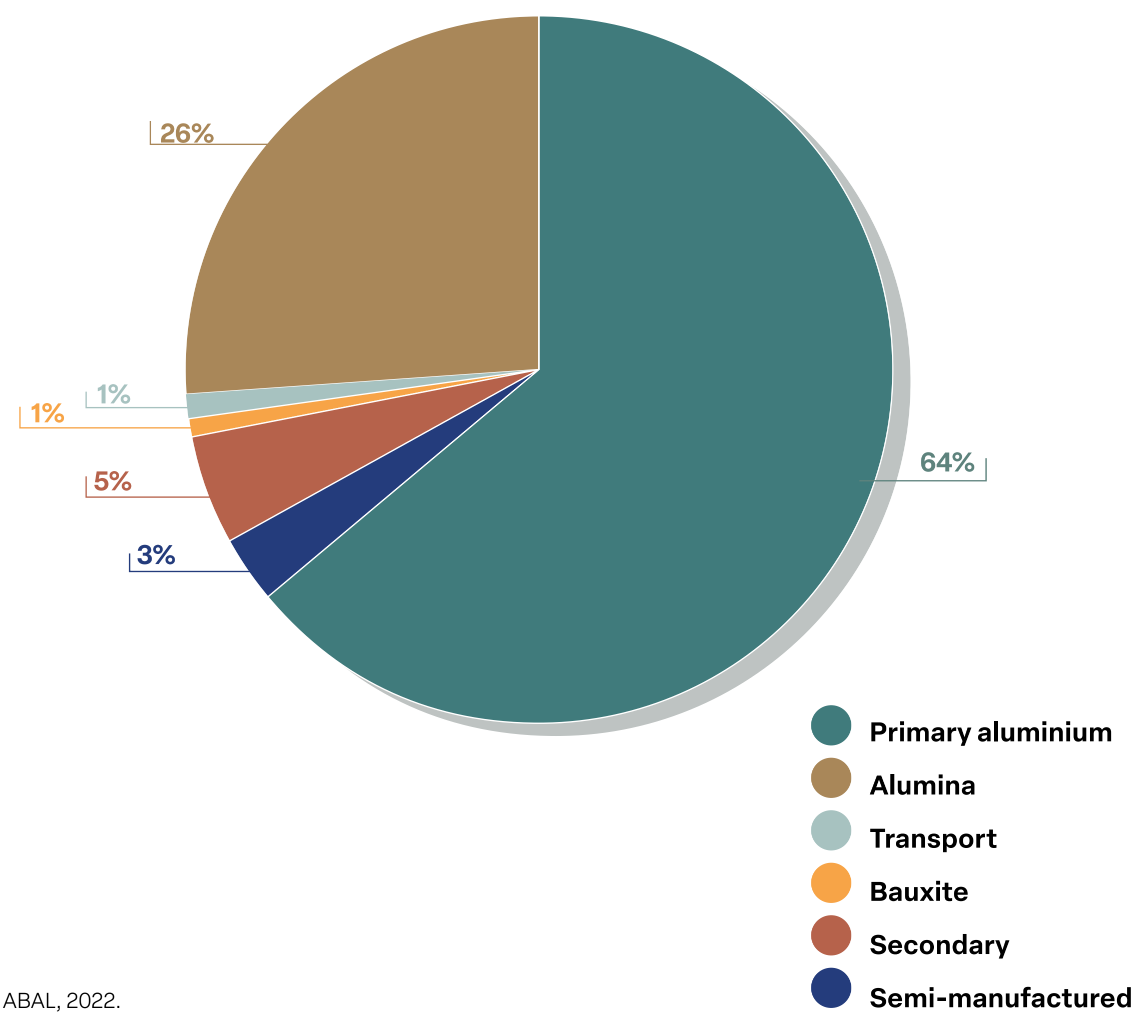
2. Mobil™, available at: https://www.mobilindustrial.com.br/topicos-tecnicos/casos-de-sucesso-post/mobil-delvac-1esp-5w-40-ajuda-a-reduzir-as-emissoes-em-1-9-para-economia-de-combustivel-anual/>. Accessed on 19 Mar 2023.

- **Scope 2:** emissions from the energy source of the mining company, that is, where the energy consumed comes from and its emission, in the case of MRN would be their own diesel thermal plants;
- **Scope 3:** comprises the transport of ore by vessels and the mineral transformation into alumina and aluminium, especially by Hydro Alunorte and Albrás, in Barcarena-PA, and Alumar in São Luís, Maranhão.

Mineração Rio do Norte uses a series of equipment that consumes diesel fuel such as trucks, excavators, trains to transport ore from the processing plant to the port, rotary dryer for processing, small and large vehicles. In addition, MRN has two "Thermoelectric Generation Plants that supply the electricity demand of its production process and the residential village of Porto Trombetas. Both are powered by GMP fuel oil and have, respectively, the net Powers of 45.8 MW and 14.8 MW, which meets the average demand of 25 MW" (MRN, 2021, p. 248).

If we consider the entire aluminium chain in the Brazilian Amazon, from extraction in MRN to the production of plates by Albrás and Alumar, we are talking about a total consumption of almost 1500 MW. However, we cannot say that bauxite mining is the main vector of greenhouse gas emissions in the Amazon. According to data from CNI and ABAL (2017), based on the year 2010, mineral transformation corresponded to 90% of the CO2 emissions of the aluminium chain in Brazil, while bauxite mining accounted for 1%.

CO_2 Emission in the Aluminium Chain by Process



Source: ABAL, 2022.

Due to the intensive use of hydroelectric power, the ecological footprint of aluminum in Brazil, 4.2 tons of carbon per ton of aluminium, is below the world average of 9.7 tons of CO_2 (CNI, ABAL, 2017). On the other hand, CO_2 emissions in the production of primary aluminium increased between 62% and 74%[3] between 1990 and 2010, from 1574.1 thousand tons to 2749.4 thousand tons (ABDI, 2012). Such new emissions took place mainly in the Amazon, as a result of expansions and establishment of aluminium metallurgical plants in the states of Pará and Maranhão.

Deforestation

According to a report by the newspaper *Folha de S.Paulo* (2022), Global Forest Watch recorded, in 2021, the emission of 2.5 gigatons of CO_2 as a result of clearing native tropical forests. Also according to the report, Brazil accounted for 40% of the deforestation of tropical forests in the world in 2021, with the loss of 1.5 million hectares, mostly in the Amazon. In Brazil, deforestation is the main emitter of greenhouse gases.

With regard to deforestation produced by mining activity, we must add that it is not only due to illegal mining, and regular activities are also directly and indirectly responsible for suppression of vegetation. According to studies by Sonter et al. (2017), mining projects can significantly increase forest losses at a distance of up to 70 kilometers from the mines. Thus, large-scale mineral operations in the Amazon can generate deforestation up to 12 times greater than the area granted for mining. As a consequence, these projects accounted for 9% of deforestation in the region between 2000 and 2015. Only the deforestation of legal and illegal mining areas, Deter/INPE (2021) accounted for 405,36 km^2 deforested in the Legal Amazon between 2015 and 2020 (Modelli, 2020).

MRN, over its more than 40 years of operation, has already caused the change of land cover in 10,800 hectares for the construction of bauxite mines within the current National Forest (Flona) of Saracá Taquera, and part of these areas are under induced restoration process. The deforestation rate in the last five years (from 2016 to 2020) was the highest since the construction period, with an average annual deforestation of 413 hectares per year, 56% above the annual average of deforestation for mineral mining purposes since 1979 (264.50 hectares per year) (Wanderley, 2021). According to the Flona Management Plan (Ibama, MMA, SPTC, MRN, 2001), the mining zone within the conservation unit is more than 142 thousand hectares or 33% of the total preservation area. Of these, more than 19,000 are also overlapped with quilombola[4] territories (CPI-SP, 2011).

3. There is a divergence between the ABDI study and the data on the ABAL website regarding total CO2 emissions. Although the ABAL data are from 2010, it has a lower emission than in 2007, ABDI data. Therefore, we chose to leave the second data because it is the maximum emission quota.
4. Quilombo is the denomination for communities of black slaves who resisted the slavery regime that prevailed in Brazil for over 300 years and was abolished in 1888. The quilombos continued to exist even after the end of slavery throughout Brazil.

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Final Considerations

According to the forecasts highlighted earlier, of higher demand for ores, and in particular for aluminium, the trend is to have an acceleration of mineral extraction, expansion of current mines and the opening of new mines to meet global demand. In the case of MRN, the largest producer of bauxite ore in Brazil and whose shareholders are large aluminium producers, the growth in demand may lead it to expand its mines more quickly, putting pressure on Flona Saracá Taquera and quilombola territories (CPI-SP, 2011).

Depending on the growth of global aluminium production, an expansion of the Porto Trombetas plant to surpass the current 18 million tons of bauxite per year is not ruled out. It is worth noting that any increase in the extraction rate will result in greater generation of tailings (which may require new dams or complexifying the management of current structures), increase of environmental impacts on new plateaus, growth in deforestation and faster depletion of mines. The reflections may even be felt in the different economic and social impacts of the early closure of the mines due to the acceleration of production. It should be remembered that the municipality and the surrounding communities do not have any preparation for this moment of closure of the mineral activity.

Extreme events, increasingly recurrent due to climate change, tend to raise the risks of disasters with mining dams, as experts point out (Rodrigues, 2022). Rainfall of greater intensity should be considered in the analysis and policies of dam safety, considering that they can be triggers for ruptures or even for the wear of the structures. In the case of MRN, in the area where the largest complex of mining dams in the Amazon is located (Wanderley, 2021), attention needs to be redoubled, as well as the implementation of more conservative policies that protect the populations and environments downstream of the dams.

The mining sector has increased its contribution to the emission of greenhouse gases in Brazil, both in absolute and relative terms, especially when it comes to Scope 3, which includes the transportation of ore by vessels and the mineral transformation into alumina and aluminium. The tendency is for the sector to further aggravate its participation in climate change due to the need to accelerate metal production to build a new “green”, “low carbon” and “decarbonised” economy. This growth will be even more intensive in the areas with priority metals for the energy transition, especially in the Amazon, where mining is associated with deforestation and where the largest bauxite reserves are located.

In response, the sector, on the one hand, has been positioning itself as essential to curbing climate change. At a Seminar “Mining, Energy Transition and Climate” in the Chamber of Deputies in 2021, in Brazil, the CEO of the International Council on Mining and Metals (ICMM), Rohitesh Dhawan, stated that “Mining will become even more important for the global fight against climate warming as metals and ores are crucial for decarbonizing technologies, such as electric cars and renewable energy” (Chamber of Deputies, 2021). On the other hand, companies in the sector, such as Vale, have been pointing out different ways to reduce their own emissions in all scopes and even neutralise in Scopes 1 and 2 (Vale, 2021).

To achieve its goal, the sector invests in new technologies, innovations and extraction techniques to optimise the production process and use of “low carbon”; replacement of energy matrices, such as the use of biofuels and electrification; execution of financial support in preservation areas; and operations in the carbon credit market to offset its emissions. To this end, IBRAM – The Brazilian Mining Association (2021) and the large mining companies defend the pricing of carbon and the creation of a global market, and also the implementation of payments for environmental services, the latter regulated by Law 14.119/21 sanctioned by the Bolsonaro government.

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Finally, a critique of a discourse that defends the possibility of “green mining” has been presented by leading non-governmental organisations that debate the sector, such as Mining Watch Canada and Friends of the Earth Europe. They claim that the idea of “green mining” and the energy transition has facilitated the implementation of ventures and been the reason for mineral expansion, especially in the global periphery. On the other hand, activity-specific environmental impacts in the evaluation of mineral projects are ignored, which go beyond mines and processing plants; the conflicts arising from the operation of mining and the transformations caused; and human rights violations (Mining Watch Canada, 2020; Bolger et al, 2021; Deniau, Herrera, Walter, 2021).

The tendency is for the demand for metallic and non-metallic ores to grow in the world, as we have seen. According to the OECD (2018), the demand for metals by 2060 will rise from 7 to 19 Gigatons (Gt), and for non-metallic minerals from 35 Gt to 82 Gt, which will produce an overall increase in mining of the order of 1.6 times by 2030 and 2.6 times by 2060. With this, the impacts and conflicts of mining should multiply in the world and in Brazil (Milanez, 2021). According to the OECD itself (2018), the projected global environmental impacts of the use of metals such as iron, aluminium, copper, zinc, lead and nickel are likely to more than double, and in some cases quadruple, by 2060. In short, in the context of climate injustice, communities affected by mining projects, such as the traditional peoples located in Oriximiná, will tend to suffer more from the acceleration of mineral extraction and the opening of new mines and mining projects in Brazil, particularly in the Amazon.

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The Authors

Luiz Jardim Wanderley

Professor at the *Universidade Federal Fluminense* in the Department of Geography and the Postgraduate Program. Coordinator of the Research and Extension Group PoEMAS - Policy, Mining, Environment and Society, and funded by FAPERJ public notices Proc. 211.394/2019 and 211.129/2019.

Pedro Catanzaro Rocha Leão

Geographer graduated from the *Universidade Federal Fluminense* and member of the Laboratory of Studies on Social Movements and Territoriality – LEMTO.

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de São Paulo