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EXTRACTION OF BRAZILIAN MINERALS FOR THE PRODUCTION OF BATTERIES, SUSTAINABILITY AND PROSPECTS

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Abstract: This paper aims to discuss the sustainability of mining in Brazil for the production of batteries. Factors such as the importance of these processes and their perspectives were presented from a bibliographic analysis, based on data obtained from Brazilian government agencies and non-government institutions. The sustainability of the extraction processes is discussed, considering that most of this material is exported and that Brazil is not sustainable in the production of batteries for the domestic market. Factors such as deforestation and pollution caused by mining were also briefly addressed and presented through data. The general results of the research indicated that the extraction of noble minerals in Brazil generates large social and environmental impacts, factors such as Amazon deforestation and mining accidents are often related to this productive process. That way, technological solutions become necessary so that new technologies of extraction and production of materials for batteries are discovered and effectively applied in the country. Only in this way could Brazil produce noble metals in more sustainable ways, and in the future, try to become sustainable in the battery sector.
Keywords: Batteries, sustainability, minerals, Amazon, pollution, deforestation.

INTRODUCTION

In 2021 the 26th United Nations Climate Change Conference (COP26) was held. Organized by the United Nations in the city of Glasgow, Scotland (COP26, 2021). COP26 also included the 15th meeting of the Kyoto Protocol (CMP16) and the 2nd meeting of the Paris Agreement (CMA3), (COP26, 2021). In the COP26 most of the countries made a commitment to decrease the consumption of fossil fuels and to decrease the pollution emissions, from the development and use of new energy sources, less polluting and more sustainable (COP26, 2021). The main alternatives for renewable sources are: wind, solar, hydraulic, geothermal and biomass, which together already correspond to 16.8% of the world energy matrix (IEA, 2021). Having as a goal the use of more sustainable energy sources, it also becomes essential to use storage devices, such as batteries (Zhang, et al, 2022).

Batteries are devices extensively used in cars, cell phones and electrical equipment, among others (Degen, Schutte, 2022). The use of batteries can contribute to the goal of using more sustainable energy sources, since it enables the storage of several types of energy, such as solar energy (COP26, 2021), (Nações Unidas, 2021). For this, these devices need to have high storage capacity, large number of cycles and high density charge over time (Liu, et al, 2020) thus leading to more efficient equipment that contributes to sustainability (Nações Unidas, 2021). As a highlight, we mention electric cars that need more robust batteries so that the use of fossil fuels can be replaced (Zhang et al, 2022).

But is battery energy storage so sustainable? When we think of the point of view of the energy source used, the advantages are evident, such as the capacity of storing the sun's energy, which is practically an inexhaustible source (Guney, 2022). Nevertheless, when we think about the production and disposal of batteries, the processes involved are far from ideal and the sustainability should already be reconsidered (Guney, 2022). The use of rare minerals on a large scale, some of them heavy metals, should be considered as well as the impacts that the mining processes cause in emerging countries, such as Brazil.

This paper presents a brief review regarding the mining of minerals in Brazil for the production of batteries. For this purpose, statistical data from Brazilian agencies and non-government institutions were collected and compiled. Factors such as pollution, deforestation, environmental and social impacts were considered, (Santos, et al, 2022) in addition to the development of new technologies in the sector, since mineral extraction can directly impact the sustainability of energy storage systems, such as batteries.

THE PRODUCTION OF BATTERIES

The evolution of the use of new technologies has happened at an accelerated pace in the last few years. For instance, we have the development and gradual modernization of the electrical power systems (Zhang, et al, 2022). Among them, we mention batteries, which are devices for energy storage and play a central role in the evolution and feasibility of using new technologies (Wang, Yan, 2022). As main examples, we list the batteries of cell phones, laptops and electric cars. The batteries of these devices need to have long cycles, high energy density and resist an extensive number of cycles, without overheating and without losing power (Wang, Yan, 2022), (Zhang, et al, 2022).

The most used batteries at the moment and with the highest technological potential are the lithium-ion batteries. (LIBs), (Zhang, et al, 2022), (Harlow, et al, 2019). Although LIBs present a large number of cycles and a high capacity density, it may display heating problems and formation of lithium dendrites in the electrodes (Harlow, et al, 2019). Therefore, there is a growing demand for new technologies which has led to the development of new devices.

An example of these new devices are the hybrid capacitors, which are systems that unite two devices, a battery and a supercapacitor working together (Harlow, et al, 2019) leading to results of power, number of cycles and energy density higher than normal batteries. We also highlight the importance of developing new materials for the production of this equipment, such as gel electrolytes, functionalized nanofibers for electrode separators, membrane separator and, finally, the use of different chemical elements for the production of electrodes and electrolytes (Li, et al, 2021), (Warner, 2015). In order to make these devices smaller, lighter, resistant and safe. . For all this to be possible and scalable the use of rare metals is a reality.

Based on what was mentioned above**,** it is clear that the use of batteries can contribute to technological development and the possible replacement of unsustainable energy sources. However, for this to happen, battery production also needs to be sustainable and present the maximum of processes that involve green chemistry and that reduce the environmental and social impacts caused by mineral extraction.

MINERAL EXTRACTION IN BRAZIL

Brazil is the fifth largest exporter of minerals for battery production in the world, China being the main trading partner and buyer of a large percentage of Brazilian production (IBRAM, 2022). To consider the impact of mining and whether the production of batteries is sustainable, all the processes involved should be considered, starting with the acquisition of raw materials from the mineral extraction (Santos, et al, 2022).

Historically the main minerals used in batteries are: Lithium, Sodium, Cobalt, Nickel, Manganese (Warner, 2015). Among them, the most widely used today is lithium, which has become an essential component for electrodes and electrolytes of lithium-ion batteries and lithium-ion hybrid batteries (Harlow, et al, 2019). When it comes to different chemical elements for the production of electrodes and electrolytes, we are talking about the extraction of minerals that will then be purified and will provide these chemical elements used in the manufacture of the components.

In Brazil, IBRAM is a non-governmental organization composed of about 120 members that are responsible for about 80% of mining in Brazil (IBRAM, 2022). According to IBRAM, Brazil produced around 535 million tons of minerals in 2021 (IBRAM, 2022). Among them are Iron Ore, Bauxite, Phosphate, Manganese, Aluminum, Potassium, Copper, Zinc, Niobium Alloy, Nickel and Gold. The economic value obtained by the sale of these minerals reached 26 billion dollars only in the year 2021 (IBRAM, 2022).

The main states responsible for mining are: Minas Gerais, Pará, Bahia, Goiás, Mato Grosso and São Paulo, as shown in Fig. 1.

In Fig. 1, it is possible to observe that Pará is responsible for 43.7% of the national production and Mato Grosso for 1.8%. These two states are part of the Brazilian Amazon (IBRAM, 2022). We emphasize that the Brazilian Amazon has about 67.0% of the world's tropical forests, is rich in biodiversity and has the largest river basin in the world, containing about 1/5 of the planet's freshwater (IMAZON, 2022), (TNC, 2022). These states extract four mining elements that can be used to produce batteries, among them Iron, Nickel, Manganese and Gold (IBRAM, 2022).

According to Fig. 1, the State of Minas Gerais produced 43.7% and the state of Bahia produced about 1.6% of the national ore production. However, the two states together produced 100% of the lithium exported by Brazil in 2021. Around 91,300 tons of this ore were exported and the vast majority to China, making Brazil the fifth largest lithium producer in the world, in the

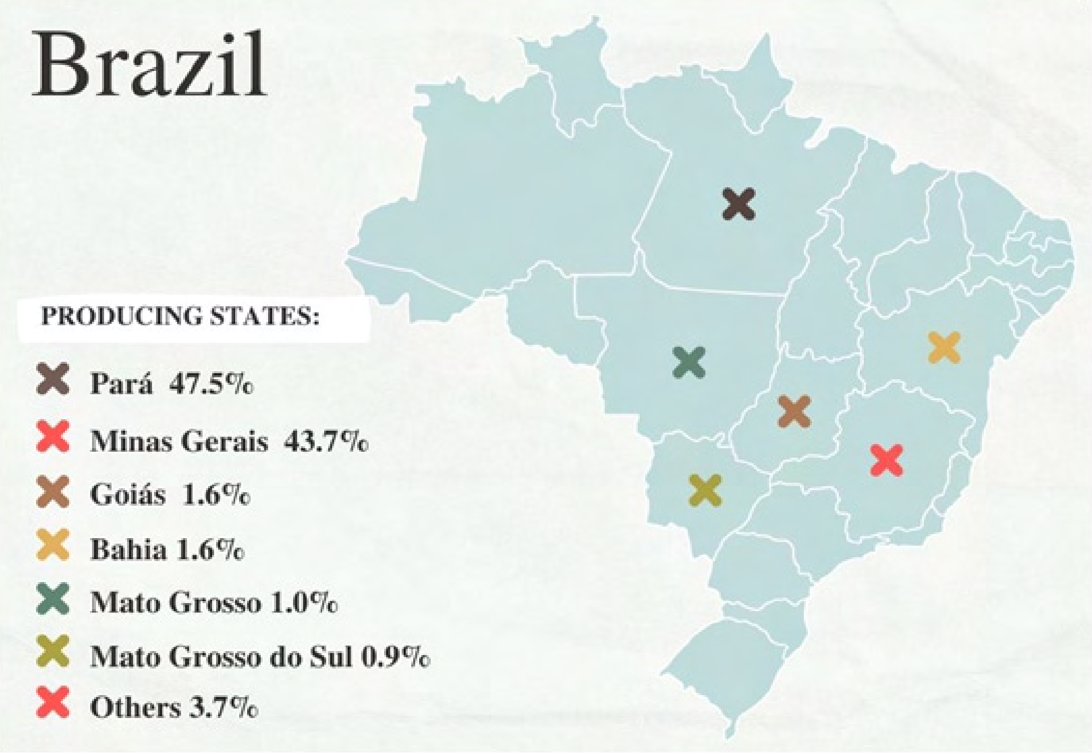

Figure 1. Mining production in Brazil - year 2021.
Data adapted by the author from: (IBRAM, 2022).

year 2021 (Reset, 2022), (ABIFINA, 2022). Remembering that Lithium is the most used metal for the production of batteries. In 2021 the two states were also responsible for exporting 100% of the Vanadium produced in the country (ABIFINA, 2022).

Finally, the State of Mato Grosso do Sul is responsible for 22% of Manganese exports from Brazil, in addition to extracting tons of iron ore (MS Government, 2022). The state of Goiás, though, is a producer of cobalt, niobium, nickel and gold (SGC, 2022). In particular, Goiás is the state with the highest nickel extraction with about 82% of the national production (IBRAM, 2022). The exported nickel is used on a large scale for the production of stainless steel and can be a battery component (IBRAM, 2022).

Brazil also holds about 24% of the world's graphite reserves, spread over its territory, but is still responsible for only 10% of world production. China has 25% of the world's reserves and exports 64% of the world's total. Brazil, China and Turkey have about 80% of the world's reserves. Graphite can also be an important component in the production of battery electrodes (Zide, et al, 2022).

Mining corresponds to an economic and industrial activity consisting of the research, exploitation, extraction (exploitation/mining) and minerals processing present in the subsoil (Stace, 2022). According to IBRAM, the most widely used extraction process in Brazil is called exploitation. The process begins with the search for a place where the ore of interest exists, in this case, a deposit. The exploration process consists of removing the useful material, pieces of rock with the ore present, and separating from the rest of the rocks. For this, the material is broken, separated and cleaned (Stace, 2022). It seems a simple process; however the scale at which it is performed is giant, often-reaching tons per hour. This extraction generates a huge amount of tailings and in general, devastates the flora and fauna of the place where it is extracted (Santos, et al, 2022), (Longhini, et al, 2022). In general, the ores are often broken down, until they reach approximately two centimeters in diameter to be separated and washed. Then comes the question of chemicals used in the washing of minerals, often these products are extremely toxic and rich in heavy metals, such as Mercury (Stace, 2022). According to Brazilian legislation, all water used in the extraction should be stored and recycled (Santos, et al, 2022), (Longhini, et al, 2022). Thus, to lessen the environmental impact caused by extraction and separation, all the tailing obtained is often stored.

In Brazil, most solid and liquid tailings from extraction are stored in gigantic dams (Stace, 2022). These dams can be of two main types: downstream and upstream, being the type upstream most used and characteristic for being built through successive heightening's on the deposited tailing itself. The heightening's are performed in the opposite direction to the water flow (upstream) (Santos, et al, 2022). The dam needs thick tailings for the massif to be built. In Brazil, we have about 790 dams spread throughout the national territory.

SUSTAINABILITY AND ENVIRONMENTAL AND SOCIAL IMPACTS

When dealing with the extraction of Brazilian minerals for the production of batteries, we must think about the environmental impacts caused by this production. In Brazil there are several agencies to monitor the mining activity, among these, we have: Ministry of the Environment, Ministry of Mines and Energy, Geological Survey of Brazil, Brazilian Institute of Environment and Renewable Natural Resources. However, Brazilian legislation makes it clear that the mining companies themselves are responsible for maintaining the integrity of mining areas, as well as safety.

When the activities are not conducted in the ideal way, several environmental problems can occur, among them: serious problems of contamination of water resources, pollution, soil contamination, air pollution, forests degradation, disturbances to the local population, alteration of local geology, damaging of fauna and flora, contamination with heavy metals (Santos, et al, 2022), (Longhini, et al, 2022).

Another serious risk that can occur due to mining is a dam break (Conceição, Lima, 2022), (Santos, et al, 2022), (Longhini, et al, 2022). Brazil experienced one of the largest accidents in the world and a serious environmental crime in 2019, when a mining tailings dam broke down in the state of Minas Gerais. The dam called “Mina do Córrego do Feijão” had about 12.7 million m3 of tailings and had been used since 1976. Over the years the dam had its capacity increased several times and was considered “low risk” and “high damage potential” by the company Vale S.A. On January 25, 2019, the “Mina do Córrego do Feijão” broke and caused a humanitarian and environmental disaster, killing about 270 people. The disaster was the most serious environmental disaster in history and caused complete destruction of freshwater ecosystems, about 500 km of course of the Rio Doce were contaminated by tailings and destroyed (Santos, et al, 2022), (Nunes, et al, 2022).

The UN referred to the disaster as: “the annihilation of freshwater ecosystems, marine life and riparian forest eliminated irreplaceable natural resources for riverside life, fishing, agriculture and tourism”. According to Greenpeace, mining should be carried out strategically and rigorously by the authorities, as they are finite resources.

However, we believe that Brazil has around 790 tailings dams scattered throughout its territory. Recently, in times of torrential rains in Brazil, only in the state of Minas Gerais, about 39 dams have issued warnings of possible disruption (The globe, 2022). This leads us to question whether mining is a sustainable activity and whether the 27 noble minerals extracted from Brazil really contribute to the preservation of the environment (Santos, et al, 2022).

Another huge impact that mineral extraction causes in Brazil is the deforestation of the Amazon, as we have seen most of the production of national minerals occurs in this area, as well as the impact on the lives of riverside and indigenous populations (Pérez, et al, 2022). In 2021, Brazil has been breaking deforestation records, with the loosening of environmental inspections and with economic and political instability.

It is clear that Brazil’s environmental policies, especially for tailing allocation and deforestation, have led to major environmental and social risks. And that it would be necessary to make a profound change in the country regarding the real application of the Brazilian legislation. Although several government agencies are responsible for environmental monitoring, it is clear that not even a minimum of safe conduct has been applied, and this has been happening for years.

In this way battery production needs to be seen not as a clean process that can contribute to the use of more sustainable energies. But rather as a finite resource that should have a strong technological development to use these resources in the best possible way. Preferably recycling and reuse processes should be mandatory, given the major impacts that mining can produce.

It should also be noted that the consequences of mining are not exclusive to Brazil. As a comparison we should note that several countries that extract minerals also have environmental and social impacts. In Congo there are reports of child labor in artisanal mines extracting Cobalt. In Chile lithium mining has polluted regions of the Salar de Atacama, leading to landscapes that show soil contamination and groundwater pollution. These facts have led the UN to question whether the transition to more sustainable technologies is not going the wrong way, and to suggest investments in new technologies that recycle used rechargeable batteries (UN, 2022).

PROSPECTS

Brazil is a third world country and one of the characteristics that keep it in this classification is the current technological and scientific development of the country. Even being one of the largest mineral producers in the world, the country does not have any battery factory in operation (Revista Fapesp, 2022). Thus, Brazil exports the ore at low cost and imports the ready-made batteries at high cost.

To try to change this reality, the Brazilian Ministry of Mines and Energy prepared a strategic map to be developed between 2021 and 2023 (Ministry of Mines and Energy). This adapted map is in figure 2.

Figure 2 presents a summary of the main goals of the Brazilian government between the years 2021 and 2023, which are included in the strategic map of the Ministry of Mines and Energy. In the summary, it is presented the necessary resources, the internal processes that must be carried out by the government and a forecast of what would be the results achieved.

In the long term, for the actions foreseen in Figure 2 to be actually implemented, it is essential to train professionals in the mining area and the development of new technologies. At first, the Brazilian government cut about 500 million dollars in investments in science and technology (-3.8%) and about 5.2 billion dollars in investments in education (-2.8%) in the last 3 years (Senado Federal, 2022). This can have a direct impact on the failure to meet the targets set by the Ministry of Mines and Energy, since two of the necessary resources are “the modernization of technological infrastructure” and the “strengthening of people management”. For this to happen, it is essential that Brazilian education, science development and technology are encouraged. In addition to the low performance in internal education, there is also a phenomenon that is occurring in the country called: “brain drain”. It means that young people with a high degree of technical training, such as doctors, are leaving the country for lack of working conditions (BBC, 2020). This phenomenon in the long run will have a serious impact on the development of technologies and the production of a solid industry.

On the other hand, the Brazilian government increased the budget for The Ministry of Mines and Energy by about 0.5 billion dollars (Senado Federal, 2022). Therefore, as a future prospect we can point out that Brazil will tend to export more and more raw materials, given the growth of exports in recent years (Senado Federal, 2022). What can lead to an increase in GDP, however, should also favor the increase of deforestation and the generation of pollution, creating a high environmental and social cost. On the other hand, the country is not expected to become a battery producer and will possibly not have an internal production in the near future, given the current educational level and the low investments in science and technology. What exists are a few private initiatives that have tried to attract investments to the country. But factors such as political instability and high taxes have hindered the development of the sector via private companies.

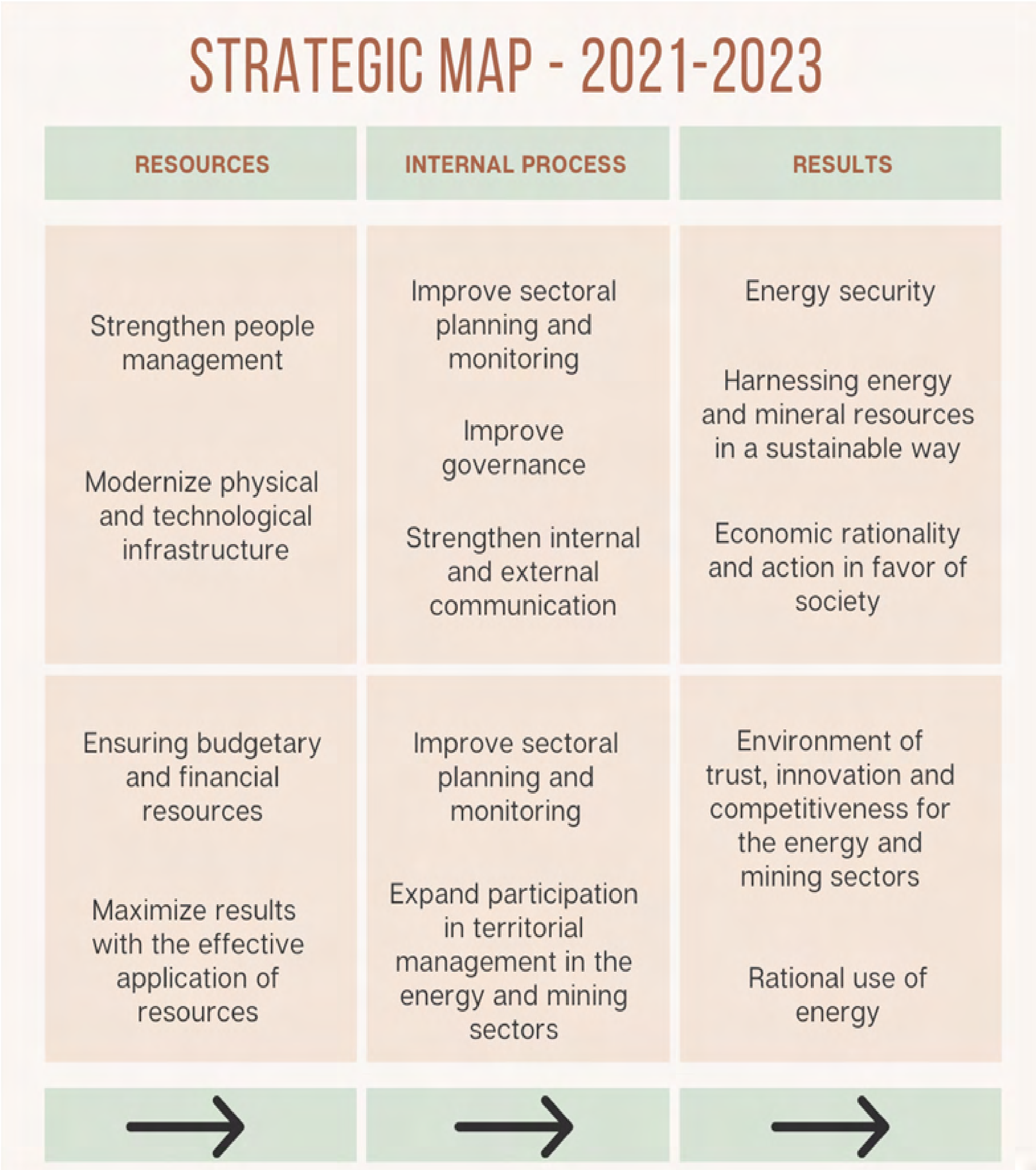

Figure 2. Strategic map of the Ministry of Mines and Energy - 2021 - 2023.

Data adapted by the author from: Ministério de Minas e Energia.

CONCLUSIONS

This study presented a brief description regarding the extraction of Brazilian minerals for the production of batteries, as well as facts about the environmental impacts and sustainability involved in the production of these ores for batteries. The main conclusions were:

- Brazil is one of the world's leading ore producers for battery;
- Brazil has low technology development and despite supplying raw material for the production of batteries, has no manufacturing of its own;
- Mining processes used in Brazil are not always the best, which has recently caused serious environmental and social impacts;
- One of the states that produces the most minerals in Brazil is the state of Pará, which is one of the states that make up the Brazilian Amazon;
- Examples of serious mining impacts include deforestation of the Amazon, pollution of the environment, as well as environmental disasters such as the collapse of dams;

Finally, it is concluded that deep changes are needed regarding the extraction of minerals in Brazil and that the extraction of ores for the production of batteries are not sustainable in the long term.

It is also noteworthy that mining processes in Brazil cause serious environmental and social impacts. That way, the use of batteries should be reevaluated from the point of view of sustainability. In particular, new technologies should be developed, both for the production of less environmentally aggressive mining processes and for the production of batteries that can be reused and recycled.

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