IBRAM
BRAZILIAN MINING

CIRCULARITY PRACTICES
IN MINERAL SECTOR

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September | 2022

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IBRAM

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PRESENTATION

A major challenge for society is maintaining the same level quality of life for all and all, ensuring the reduction of waste generated. In the same way, the productive sectors, including mining, also have to deal with this paradox. To both, efficiency in the use of resources and development of technologies for the use of waste are strategic and fundamental. Ongoing search for efficiency in resource use, the need to increase competitiveness, as well as incentives to innovation and scientific-technological development and sustainable practice dissemination in manufacturing processes and supply chains have been strategic to transition to more sustainable means of production.

A constante busca por eficiência no uso de recursos, a necessidade de aumentar sua competitividade, bem como os incentivos à inovação e ao desenvolvimento científico-tecnológico e à disseminação de práticas sustentáveis nos processos produtivos e nas cadeias de suprimento têm sido estratégicos para a transição a meios mais sustentáveis de produção.

And, here, a new scenario has evolved within sustainability design: mining waste efficient and circular management.

Circular economy foundation is the best natural resource use, avoiding waste. It represents a systemic change that builds long-term resilience and generates economic and business opportunities, and it also enables environmental and social benefits.

Within this path, IBRAM releases the 1st edition of the E-book: Circularity Practices in Mineral Sector, to foster and disseminate knowledge on mining industry in this new approach, and mainly, incentive all mineral sector to search for technological solutions that create additional value and improve environmental results in mining waste and mineral processing.

Have a nice reading!

RAUL JUNGMANN
Chief Executive Officer

INTRODUCTION

Circularity is based on product design, sharing, maintenance, reuse, remanufacturing and recycling of materials and appears as an alternative to the traditional linear model, which involves production, consumption and disposal, as it defends the use of natural resources with less waste. It represents a systemic change that builds long-term resilience and generates economic and business opportunities, in addition to providing environmental and social benefits.

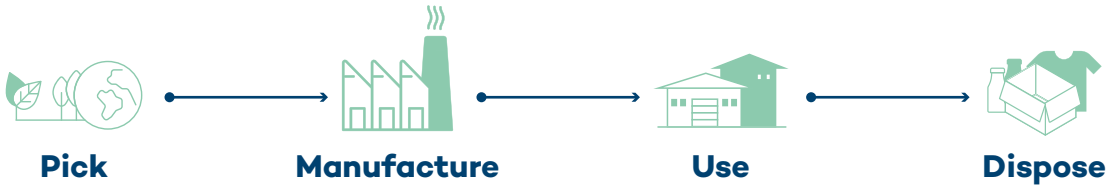
An updated definition for circular economy is being developed within the scope of International Standardization Organization (ISO). According to the entity, "it is an economic system that uses a systemic approach to keep circular resource flow, by means of value addition, retention and regeneration, enabling sustainable development."

Data of CNI (2019) reveals that in Brazil 76% of the companies already develop some circular economy initiative. Practices including water reuse, material recycling and reverse logistics are the main implementations in the country. The same survey reveals that more than 88% of entrepreneurs consider circular economy as very important to Brazilian economy. Industry circular economy presence is due mainly to companies understanding they can contribute to job creation in company itself and/or sector production chain.

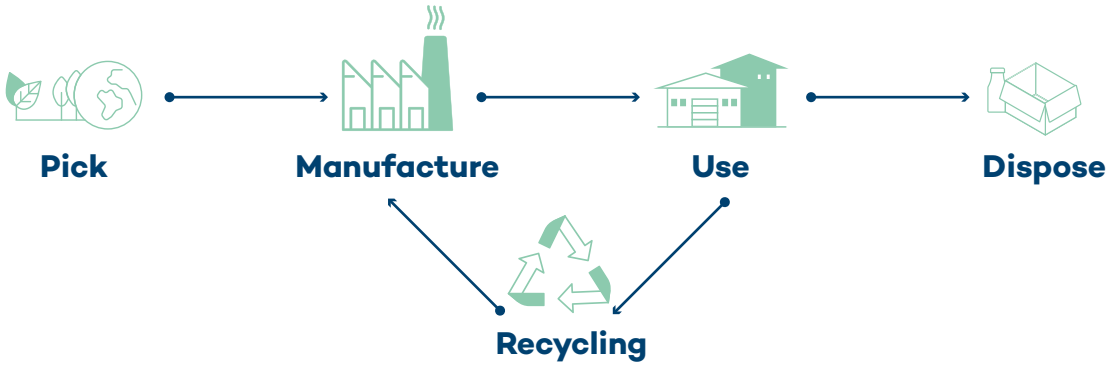
Ores are essential to society and vital to circular economy. However, only a small number of mineral goods have been used as circular products. Knowledge on systemic business models and technologies used in them can be translated into opportunities with significant outcomes to companies, by means of reduction of inputs used and production costs, lower cost with waste disposal, aware consumer attraction, financing possibilities, new markets.

Figure 1- Economic models

Linear Economy



Recycling Economy



Circular Economy

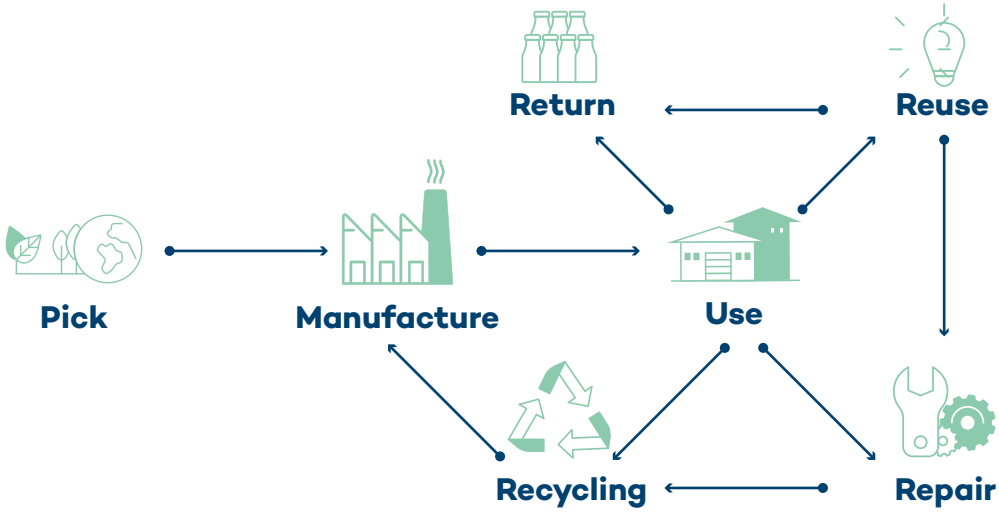


Table 1: Barriers that influence circular economy Investiment

ECONOMIC	TECHNOLOGICAL	SOCIAL AND POLITICAL
• **High pickup cost:** • Transportation costs are high, due to low implementation of selective pickup and reverse logistic. • Low product/material intrinsic value per unit (despite product volume potentially high value). • High capital cost for recycling or manufacturing. **Immature secondary supply chains:** • Lack of local demand for recycled materials or components reused to trigger Investiment. **Circular Economy is not a priority to PME´s** • Businesses and consumers face technological, tax and financial barriers of current systems.	**Complex product design** • Products have not been designed to disassembly, remanufacture, repair or recycling. • Products have not been designed to be durable and/or with obsolescence planning, decreasing life and limiting the capacity to be used. • Product complexity with increasing numbers and mixes of materials, thus they are more difficult to recycle. • Quick technological development, leading to demand for new materials, limits the potential for new product remanufacture using recycled materials. **Lack of data, preventing Investiment:** • Lack of recycling infrastructure, low incentive to recyclers	**Inconsistent and restricted policy:** • lack of articulation between states and municipalities. • National product administration policies cover only a small number of products. • Inconsistent pickup systems among different products. • Lack of policies focused on increasing circularity. • Lack of consumer awareness on recycling options **Preference for purchasing new ones:** • Reluctance to use second-hand or recycled products • Lack of patterns to do that in certain sectors, e.g., construction industry **Electronic household storage:** • Perceived product value prevents pickup by the end of life, leading to large electronic garbage volumes.

Fonte: Adaptado de Wealth from Waste, 2017

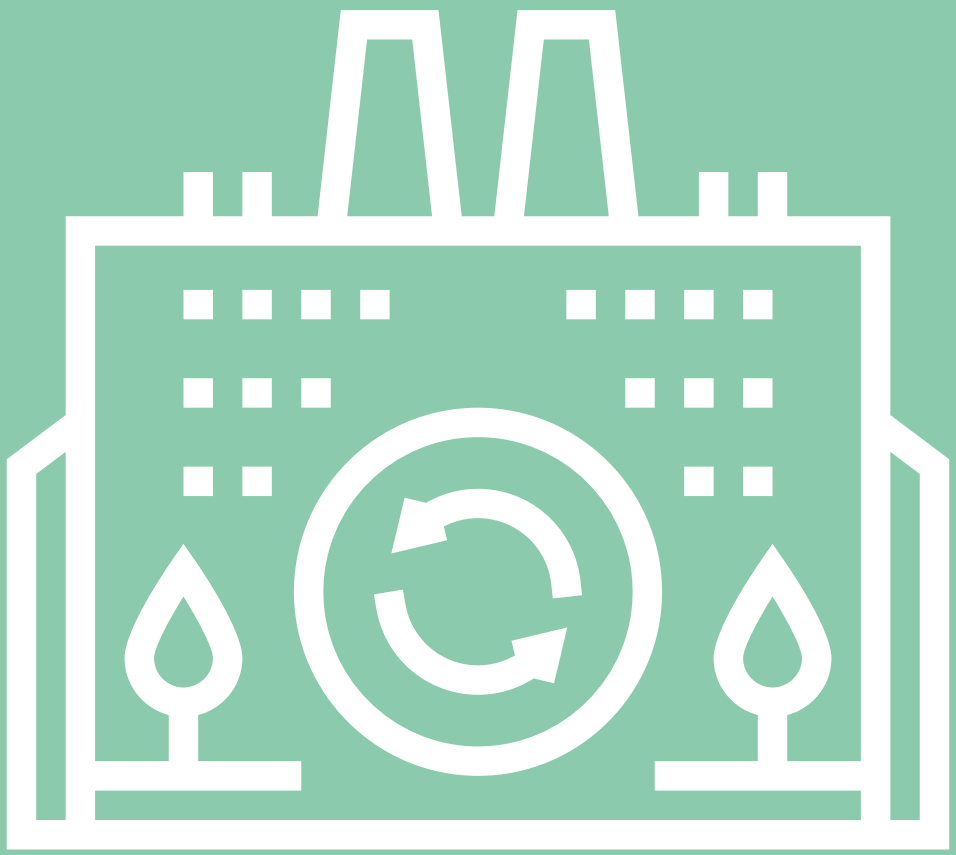
In mining activity, large volumes and masses of materials are extracted and moved. The quantity of waste generated by activity depends on the process used to ore extraction, mineral substance concentration stocked in matrix rock and deposit location in relation to surface. In mining activity, there are two main types of solid waste: spoils and tailings. Spoils are excavated materials, generated by extraction activities (or mining) in mine stripping, they do not have economic value and are generally arranged in piles. Tailings are waste resulting from processing developments to which mineral substances are submitted. Such processes purpose is standardizing fragment size, removing associated minerals without economic value and increasing quality, purity or content of end product. There is also other waste, comprised by a very diverse set of materials, including sewage treatment effluents generated in mining plants, battery housings and tires used by vehicle fleet, waste originated from mineral substance extraction and processing plant operation, including pallets, uniforms, organic waste, etc. (IPEA, 2012)

Over the last few years, mineral input demand increase has enabled a large activity increase, and well as ore mining and processing with successively lower contents. The outcome was increasing rise of mining waste: solid waste from extraction – spoil – and processing – tailings. Thus, end disposal and management have become an increasingly significant topic in this industry.

So, IBRAM presents the 1st edition of E-book, a collection of associate company practical cases, for mineral and non-mineral waste. The purpose is presenting an efficient and circular management background in mineral sector, so that mining systemic logic understanding and practice becomes more widely used. Apart from making it more sustainable, circular economy in mining makes processes more profitable and intends to restore physical resources, that are finite, and regenerate natural system functions, enabling more economical and social opportunities.

PROJECTS

- PROCESS ROUTE DEVELOPMENT FOR BARITE CONCENTRATE PRODUCTION, FROM TAILINGS OF PYROCHLORE CONCENTRATION STAGE
- ROUTE DEVELOPMENT FOR MAGNETITE PRODUCTION FROM TAILINGS OF PYROCHLORE PROCESSING.
- RECOVERY OF NB ORIGINATED FROM SLAG IN BLOCK AND TAILINGS OF SHELL SAND FROM UNMOLDING, THROUGH JIGGING PROCESS IMPLEMENTATION
- WEFTS OF TIME: RECYCLING HISTORY



Project Title	• PROCESS ROUTE DEVELOPMENT FOR BARITE CONCENTRATE PRODUCTION, FROM TAILINGS OF PYROCHLORE CONCENTRATION STAGE
* **Partner Institutions**	• N/A
* **Project Stage**	• ( ) Ongoing ▪ Surveys/Bench/Pilot/Semi-industrial • (x) **Completed**
* **Business Model**	• ( ) Outsourcing • ( ) B2B • (x) **Technology Incubation and Internal Development** • ( ) Others _____
* **Main mineral good**	• **Pyrochlore**
* **Type of Tailings/ Spoil/Non-Mineral Waste**	• Barite concentrate is originated from flotation tailings, comprised by hematite, goethite, barite, and others.
* **Volume Reused**	• 35.000 t (reference 2021)
* **New products generated**	• **Barite concentrate**
* **Investiment**	• **Around BRL 2 million**

Process description

Barite concentration process in CBMM is performed from tailings processing of niobium concentration stage. Part of flotation stage end tailings is thickened in hydrocyclones for later conditioning and direct barite flotation in flotation columns. Product with > 85% $BaSO_4$ is drained for later marketing, as barite concentrate.

Figure 1: Flotation circuit view for barite concentration..

Project Title	• ROUTE DEVELOPMENT FOR MAGNETITE PRODUCTION FROM TAILINGS OF PYROCHLORE PROCESSING.
✱ **Partner Institutions**	• N/A
✱ **Project Stage**	• ( ) Ongoing ◆ Surveys/Bench/Pilot/Semi-industrial • (x) **Completed**
✱ **Business Model**	• ( ) Outsourcing • ( ) B2B • (x) **Technology Incubation and Internal Development** • ( ) Others _____ _____
✱ **Main mineral good**	• **Pyrochlore**
✱ **Type of Tailings/ Spoil/Non-Mineral Waste**	• Pyrochlore processing development magnetic tailings, comprised by hematite and magnetite mainly.
✱ **Volume Reused**	• Performed: 32,000 t (closing from January to June, 2022) • Forecast: 92,000 t (Forecast 2022)
✱ **New products generated**	• **Iron ore**
✱ **Investiment**	• N/A

Process description

Magnetic tailings generated through magnetic separation, where magnetic fraction follows to cycloning stage for contaminant reduction, material with >60% Fe is then drained for later marketing.

Figure 1: Magnetic tailings cycloning.

Project Title	• RECOVERY OF NB ORIGINATED FROM SLAG IN BLOCK AND TAILINGS OF SHELL SAND FROM UNMOLDING, THROUGH JIGGING PROCESS IMPLEMENTATION
✱ **Partner Institutions**	• UFOP – Universidade Federal de Ouro Preto
✱ **Project Stage:**	• ( ) Ongoing ◆ Surveys/Bench/Pilot/Semi-industrial • (x) **Completed**
✱ **Business Model:**	• ( ) Outsourcing • ( ) B2B • (x) **Technology Incubation and Internal Development** • ( ) Others _____ _____
✱ **Main mineral good**	• **FeNb Fragments**
✱ **Type of Tailings/ Spoil/Non-Mineral Waste**	• FeNB production process tailings (non-mineral waste). • Typical Chemical Composition: Nb
✱ **Volume Reused**	• Mass recovery of approximately 10.3% of FeNb, with content of approximately 54.8% of Nb
✱ **New products generated**	• **FeNb** recovered through product process former waste transformation.
✱ **Investiment**	• **BRL 4,200,000.00**

Process description

- Quantification and characterization of slag generated in Metallurgy Department.
- Generated slag storage.
- Generated slag crushing and milling.
- Crushed and milled slag jigging, and consequent FeNb recovery.

Figure 1: Tailings

Figure 2: Silo Supply

Figure 3: Gravitational Concentration

Figure 4: Concentrated Product

Figure 5: Generated Product

Project Title	• WEFTS OF TIME: RECYCLING HISTORY
✱ **Partner Institutions**	• Fundação Cultural Calmon Barreto (FCCB) – Araxá - MG
✱ **Project Stage:**	• ( ) Ongoing ◆ Surveys/Bench/Pilot/Semi-industrial • (x) **Completed**
✱ **Business Model:**	• (x) **Outsourcing** (x) • ( ) B2B • ( ) Technology incubation and internal development • ( ) Others _____ _____
✱ **Main mineral good**	• N/A
✱ **Type of Tailings/ Spoil/Non-Mineral Waste**	• Worn/disposed uniforms
✱ **Volume Reused**	• 30 bales containing disposable uniforms – around 2,400 Kg
✱ **New products generated**	• Handcraft pieces were generated, totaling 127 rugs, 21 carpets, 19 pan holders, and another 20 prototypes (bags).

Process description

Upon CBMM employee uniform wear, they are returned to warehouse and later donated to Fundação Cultural Calmon Barreto to manufacture new pieces from recycling. Every piece is sewn in wooden loom through old "repasso mineiro", a traditional method in the region, generating income for the Foundation support. Eight weavers were directly engaged in the project.

All process consists of:

- Separating parts by tonalities, type of piece/textile and sanitization requirement (different sanitization requirement due to quantity and type of dirt existing in textile and type - heavier or lighter);
- Washing/sanitizing and drying according to requirement;
- Separating parts of clothes, textiles to be transformed into strips, separating bags, parts with seam, parts with zipper and buttons (for pants), collars and parts with buttons (for shirts);
- Cutting strips;
- Wrapping strips in threads;
- Selecting the piece to b sewn;
- Weaving the line to be place in loom;
- Selecting the weft to be developed - "repasso"
- Placing warp in loom and repass;
- Sew the piece; and
- Performing finishing (sewing, macramé or thistle)

Further information:

- https://g1.globo.com/mg/triangulo-mineiro/noticia/2022/03/06/projeto-tramas-do-tempo-de-tecelagem-em-araxa-ressignifica-antiga-tradicao-conheca.ghtml
- https://fliaraxa.com.br/projeto-tramas-do-tempo-reciclando-historia-esta-em-exibicao-no-10-fliaraxa/


na CBM
96,4% de
água.

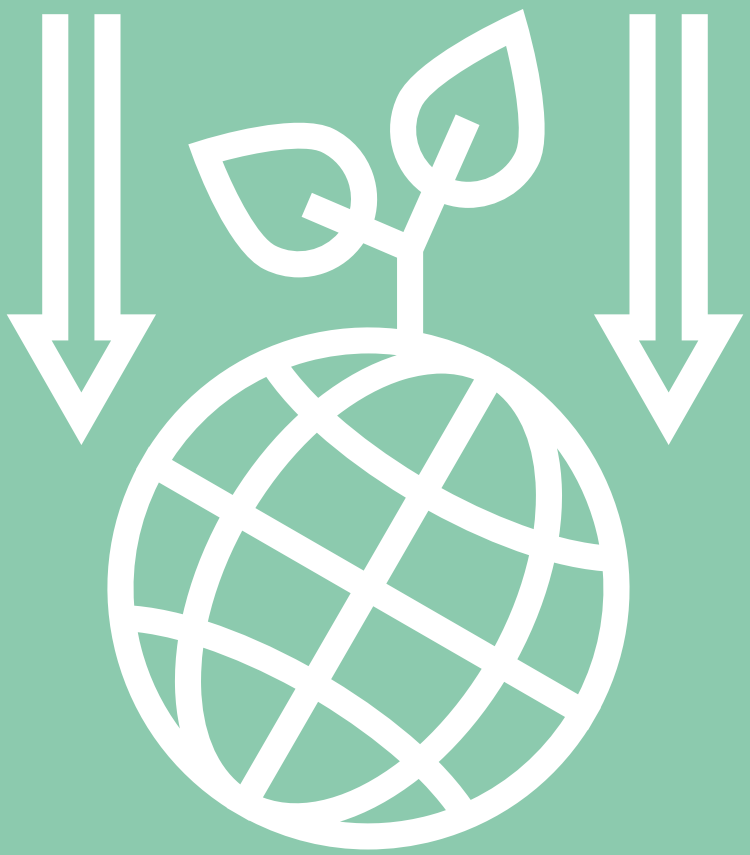

importante
antioxidante
convertido em
vitamina A.
kg de resíduo
orgânico.


maior
fruta e
nte de
erais.
Destaqu
ustentabilidade
em 2021
Aqui no nosso
restaurante,
reaproveitamos as
cascas das frutas
deixamos de gerar
cerca de 100 kg de
resíduo orgânico.

lundin mining

REUSE OF TAILINGS, MINERAL WASTE OF COPPER CONCENTRATE PRODUCTION PROCESS OF LUNDIN MINING FOR AGRICULTURAL REMINERALIZER GENERATION.

PROJECT



lundin mining

Project Title:	• REUSE OF TAILINGS, MINERAL WASTE OF COPPER CONCENTRATE PRODUCTION PROCESS OF LUNDIN MINING FOR AGRICULTURAL REMINERALIZER GENERATION.
✱ **Partner Institutions**	• Technical support of Mineragro - a private agronomic research company specialized in the topic and that has partnership with UnB, Embrapa, UFG, Unesp and IFMS.
✱ **Project Stage:**	• (x) **Ongoing (Piloto em campo)** ◆ Surveys/Bench/Pilot/Semi-industrial • ( ) Completed
✱ **Business Model:**	• Outsourcing • (x) **B2B** • ( ) Technology Incubation and Internal Development • (x) **Others**: **B2C – Business to Consumer.**
✱ **Main mineral good/**	• **Mica schist remineralizer categorized as silicate agromineral.**
✱ **Type of Tailings/ Spoil/Non-Mineral Waste**	• Tailings, copper concentrate production process mineral waste of Lundin Mining categorized as silicate agromineral.
✱ **Volume Reused**	• Potential of 9.6 million tons/year for alternative use.
✱ **New products generated**	• **Mica schist agricultural remineralizer.**
✱ **Investiment**	• **BRL 461,746.25**

Process description

Lundin Mining, considering its ESG values, searches for alternatives to use the tailings, considering mainly Goiás state mid-northern region economy, which, among others, has agricultural call. At present, Lundin Mining operation located in Alto Horizonte, Goiás, generates around 24 million tons of tailings a year.

Tailings, copper concentrate production process mineral waste of Lundin Mining is categorized by MAPA - Ministry of Agriculture, Cattle Raising and Supply, as soil remineralizer silicate agromineral. Brazil imports currently 85% of agricultural fertilizers. National Fertilization Plan target is producing 50% internally by 2050. In this scenario, remineralizer contribution potential cannot be neglected. Today, the country uses 3 million tons/year of agricultural remineralizers. The expectation is achieving 75 million tons/year by 2050.

From such understanding, researches have been performed with technical support of Mineragro, which is a private agronomic research company specialized in the topic and that has partnership with UnB, Embrapa, UFG, Unesp and IFMS. Upon performing experiments in controlled environment, vegetation house, and seeing promising results, soy planting was performed, crop 2021/2022, by using remineralizer in a 900-hectare experimental station for agronomic efficiency tests in Ipameria - GO municipality

Soy harvest results confirmed the promising expectations. Main nutrients provided by remineralizer include potassium and copper. Potassium is one of the most required nutrients by plants, only behind nitrogen. This nutrient regulates plant nutrient translocation. It enables carbohydrate transportation and storage. It increments nitrogen absorption and protein synthesis. It also acts providing ripening to fruits and grain filling.

Average planting productivity with remineralizer use originated from Lunding Mining tailings achieved 82.5 bags/ha, higher performance than the area planted with market benchmark remineralizer, and area planted without any remineralizer application. Another significant productivity indicators include number of plants per hectare and weight of a thousand seeds (PMS), also presenting higher performance.

After soy harvest, sorghum planting was performed in the same location, and off-season crop started in the firs week of August, 2022. The goal is also checking off-season remineralizer benefit.

Finally, tailings use as source of raw material for agricultural remineralizer production has been seen as a promising tool for circular economy promotion, and it also denotes being one of the possible answers to increasing challenge for the mining sector to find technical alternatives and tailings buildup in dams.

Figure 1: Initial tests with the use of remineralizer in controlled environment. Photo credit: Lundin Mining.

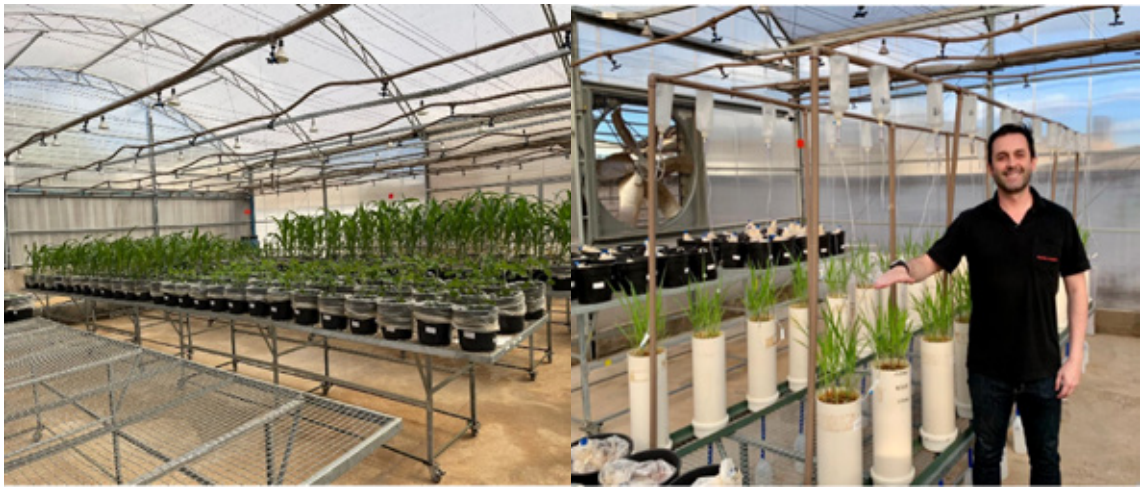


Figure 2: Soy planting with the use of remineralizer in ergonomic efficiency Experimental Station. Photo credit: Mineragro.

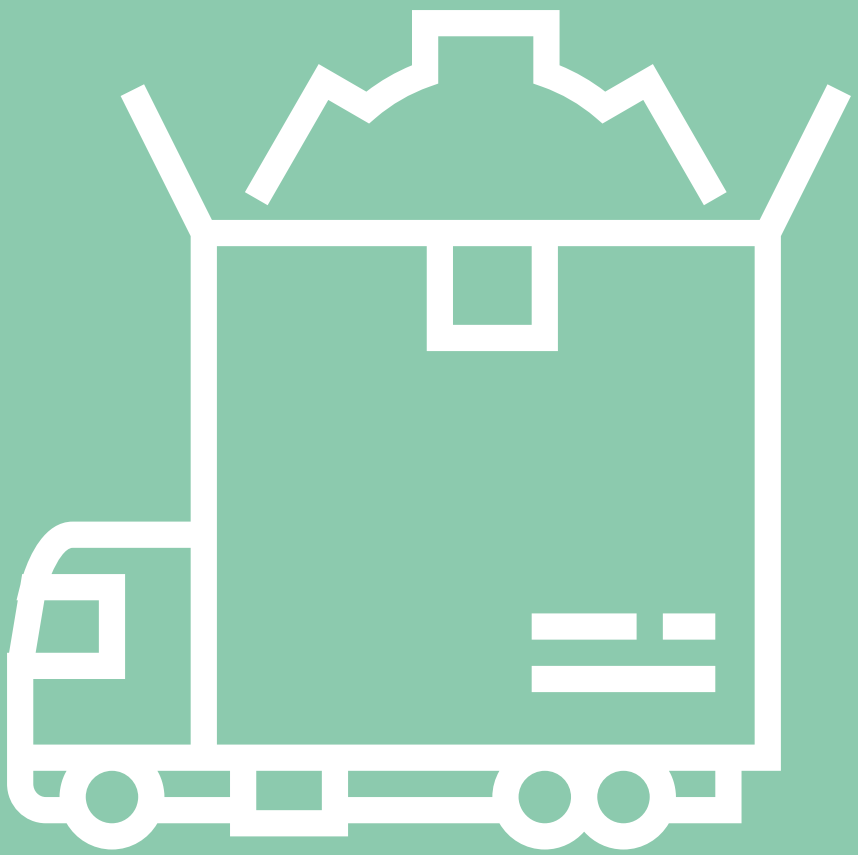
Figure 3: Off-season 2022 sorghum experimental planting with remineralizer use. Photo credit: Mineragro.

Figure 4: Off-season 2022 sorghum planting ready to harvest. Photo credit: Lundin Mining

VALE

PROJECTS

- SUSTAINABLE SAND PROGRAM
- PICO MINE BLOCK PLANT
- PAVING



VALE

Project Title	• SUSTAINABLE SAND PROGRAM
* **Partner Institutions**	• The University of Queensland, UNEP, University of Geneva, UFMG, CEFET, UNIFEI, IPT, CDTN, UFOP, among others.
* **Project Stage:**	• (x) **Ongoing** • ( ) Completed
* **Business Model**	• (x) **Researches/bench** • (x) ***Industrial scale research** • ( ) Outsourcing • ( ) B2B • ( ) Technology incubation and internal development • (x) ***Marketing/donation**
* **Mineral good produced**	• **Sand**
* **Type of Tailings/ Spoil**	• Quartz and hematite
* **Volume Reused**	• 250 thousand tons (2021 data)
* **New products generated**	• **Concrete pre-cast** (interlocked floors, masonry blocks and sealing, curb prefabricated)

Process description

At present, Vale generates around 41 Mta of tailings, 80% sandy and 20% ultra-fine. Thus, there is generation potential of around 33Mta of sustainable sand, from sandy tailings treatment. The first mine to implement this transformation was Brucutu Mine, located in São Gonçalo do Rio Abaixo, Minas Gerais. Since 2021, around 250,000 t of Brucutu sand have been reused in different initiatives and applications. In 2022, Viga Mine, located in Congonhas/Minas Gerais, was Vale´s second manufacturing plant to put into practice circular economy, with reuse capacity of 200 thousand tons a year. Mined iron ore geological characteristics in this Mine, along with sandy tailings processing innovation, enabled Vale to expand its sand portfolio with thicker granulometry material and higher silica content. Vale´s target will be reusing around 1.0 million tons of sand in 2022, and in 2023, this volume will be two times higher.

In Vale Sustainable Sand Program research portfolio there are several other fronts that aim at certifying the technical potential of Vale´s sand and other types of tailings. As tailings generation scale is substantially higher than disposal capacity, the path adopted was diversifying application possibilities of Vale´s sand and other tailings. There are more than 30 R&D projects, that include 20 market niches, including paving, concrete artifacts, concrete and mortar, cement, nanomaterials, plastic wood, sand, ceramic, artificial rock and agriculture. This open innovation ecosystem relies on the partnership with 40 universities, partner companies of different sectors and governmental bodies with US$ 10 million investment, by 2021.

The strategy adopted by Vale is working in two fronts in parallel: reuse and search for solutions that prevent or minimize tailings generation. One of the pillars of this plan consists of creating a partnership ecosystem with other companies, community, research centers and the government, in order to foster the insertion of this material in another manufacturing chains. Within this strategy, the operating way crosses different business models, according to consumption potential of tailings/niche, logistic and technological maturity. Apart from this aspect, it is worth mentioning that, to assure quality control of such tailings, reuse initiatives prioritize tailings that are being generated in current processing plants. It shall be highlighted that tailings reuse innovations have satisfactory results in terms of technical feasibility, including tailings application in highway pavements and tailings use in artificial rocks. Thus, the scenario described shows the existence of an opportunity, in which mining waste can become products for another manufacturing chains.

Such co-product reuse enables reducing two environmental liabilities, including reduction of volume arranged in piles and dams, and at the same time, non-renewable natural resource consumption reduction, including sands. As such waste potential is identified, and as technological routes are found, that enable reuse, it is possible to move forward

towards a more sustainable economy. Thus, fostering the research will be the easiest way of convincing the consumer market to use this new type of sand and promote mindset change of all manufacturing chain, for more sustainable sand acquisition.

In order to trigger all such initiatives, several company sectors participated. There were more than 100 people involved, directly or indirectly. Concerning technical cooperation fostering with universities and research centers, there were more than 1000 students benefited by means of undergraduate research, master´s degree, doctorate. That also resulted in more than 30 papers and patents published.

Due to a scenario in which tailings generation scale is substantially higher than potential solution scale for tailings consumption/reuse, as well as potential market demand and runoff logistic costs, strategy adopted by Vale is combining different business models, philanthropy actions and internal work destination. Therefore, the company has proactively searched to participate of sustainable development of the territory where it is inserted, and the world, globally. So, iron ore tailings reuse front progress is a company participation lever within circular economy, sharing value with society. Various co-product initiatives aim at transforming tailings in resource, generating new business, economic development, professional opportunities, collection increment, local cluster development, and mitigating environmental problems.

What is more, this initiative reinforces first to market Vale strategy, as Vale the world´s first mining company to reuse its tailings in large scale, extrapolating lab shelves and managing to generate positive outcomes to business and society. Most mining companies have reuse initiatives, but in lab scale. That made **Vale´s Sustainable Sand Program** to be one of the 10 studies chosen to be part of UNEA -5 report on the topic Programme Resolution on Mineral Resource Governance. One of the conclusions of this report is that Vale´s Sand can be an environmentally correct solution for predatory sand mining; reduction of geotechnical structure requirement and environmental impacts; sustainable alternative to future sand scarcity in the world, and a product that also acts by reducing climate change effects.

At every one (1) ton of Vale´s Sand disposed, one (1) ton of tailings will no longer be deposited in dams or piles. Moreover, for the mines there is no geotechnical structure possibility, sand disposal becomes vital to the company core business maintenance (iron ore), as at every one (1) ton of Vale´s sand disposed, around 1.6 t of ore are released to be produced. Another interesting data is that Vale´s sand can decrease GHG emissions 10 times, compared to natural sand. All such metrics reinforce how much Sustainable Sand Program is important and crucial.

In a recent Harvard Business School paper, it is highlighted that one of ESG policy greatest challenges is generating results that are capable of promoting a significant change in environment and society. Due to that, it is seen how much Vale´s tailings reuse project or sand originated from their treatment materializes ESG. It is worth noting that Vale´s Sustainable Sand Program not only acts by fostering circular economy, but also by promoting inclusion, diversity. Like, for instance, the first tailings pre-cast plant 100% operated by Pico Mine women.

PROJECT WITH UNEP/THE UNIVERSITY OF QUEENSLAND/ UNIVERSITY OF GENEVA

Project developed since 202 jointly with The University of Queensland, UNEP, University of Geneva, to assess Vale´s sand as a more sustainable alternative to solve predatory mining problem (river bed and marine), and this resource scarcity in the world.

Report results point out a convergence with what Vale was already doing. Thus, validating all strategy adopted.

It was an independent and impartial study, with the goal of providing practical and under implementation cases. Options assessed include ore-sand, civil construction demolition waste, slag and sands from other sources.

- Vale funded studies through a donation. .
- The goal was fostering the study, not intervening in progress.
- Our case study was one of the 10 cases chosen to be part of a larger report that intends to address at UNEA -5 the topic Programme Resolution on Mineral Resource Governance.
- Brucutu sand was used as this study analysis object.
- Research results led to the following conclusions:
    - As our sand is assessed in comparison to all other types, they created a technical nomenclature to categorize our sand type. Thus, all sands originated from tailings processing would be within ore-sand group.
    - So that it is possible to reuse tailings including sands, it is necessary to invest in processes to improve tailings quality, creating thus products the market is willing to consume. That matches what we are already doing.
    - This study evidences that Vale´s sand does not present toxic potential (significantly below environmental thresholds and average levels for most soils)
    - Sand is becoming a strategic resource. According to data pointed out by the study, sand is a vital resource for economic development to contain climate change. What is more, demand for this resource will increase significantly within the next few years, due to population growth and infrastructure improvement requirements.
    - The study pointed out that Vale´s sand can reduce GHG emissions up to 10 times, compared to sands originated from river bed.

- Moreover, the research showed that ore-sand will only be competitive in relation to CO2 emissions, up to 50 km distance via highway, and up to 200 km via railway. That reinforces Vale´s sand competitiveness.

- Ore-sand can be an alternative to small aggregates in several applications, especially civil construction. They highlighted that granulometry is one of the main challenges. It shall be highlighted that Vale´s researches have already found a solution to this challenge.

- For high added value applications, the study shows the need to increase silica content, including additional stages in sand processing. The University of Queensland has performed some bench tests that evidence it is possible to achieve high purity quartz of up to 99.7% of SiO2, which also corroborates our own internal developments, especially the one were are doing in Mine Program.

- This Project places Vale in the center of all discussion on sand problematic. Ore-sand definition was based on Vale´s sand.

- This Project places Vale in the center of all discussion on sand problematic. Ore-sand definition was based on Vale´s sand.

- According to the study, fostering the research will be the easiest way of convincing the consumer market to use this new type of sand and promote mindset change of all manufacturing chain, for more sustainable sand acquisition.

- This started in 2020, was completed and presented in March, this year, at UNEA-5 (United Nations Environment Assembly).

Thus, the report concluded that ore-sand, whether of Vale or another mining company, can be an environmentally correct solution to sand predatory mining and to reduce geotechnical structure requirement.

Figure 1: Vale´s Sustainable Sand originated from Brucutu Mine

Figure 2: Vale´s Sustainable Sand originated from Viga Mine

VALE

Project Title	• PICO MINE BLOCK PLANT
✱ **Partner Institutions**	• CEFET MG
✱ **Project Stage:**	• (x) **Ongoing** • ( ) Completed
✱ **Business Model**	• ( ) Researches/bench • (x) **Pilot scale research** • ( ) Industrial scale research • ( ) Outsourcing • ( ) B2B • (x) **Technology incubation and internal development**
✱ **Mineral good produced**	• **Iron ore**
✱ **Type of Tailings/ Spoil**	• Quartz and hematite
✱ **Volume Reused**	• 300 thousand tons/year
✱ **New products generated**	• **Concrete pre-cast** (interlocked floors, masonry blocks and sealing, curb prefabricated)
✱ **Investiment**	• **Approximately BRL 31 million**

Process description

Pico Mine Block Plant Project is intended to study technical and economic feasibility of different types of iron ore tailings for civil construction pre-cast production. It relied on plant implementation inside Vargem Grande Mining Complex, in Minas Gerais, Brazil and with approximately 1,000 m2 area; with up to 4.0 MM production capacity of pre-cast for civil construction. This production will enable reuse of up to 30,000 tons/year of mining tailings, and that will be equivalent to coating potential of up to 90,000 m² /year, considering a production of only interlocked floors (pavers). Production will be aimed a donations as considerations of licensing and internal consumption.

During the first two years, this plant has a research feature, as it will be developed jointly with a research center from the state of Minas Gerais, Brazil. Block Plant will complete its research stage in December, 2022. For future model, the plant will no longer be pilot and will become an industrial plant, increasing its manufacturing capacity.

Figure 1: Medium strength interlocked floors produced by PICO MINE BLOCK PLANT

PICO MINE BLOCK PLANT translates the new ways of making business more sustainable, inclusive, safe and innovative. All production is automated, reducing operator exposure to risk at maximum. It shall be highlighted that, in this project, all operation and leadership is performed by women. A highlighted point is the model proposed to this project in which the research and operation take place together, so that technology transfer and knowledge generated in CEFET labs are submitted in real time for operation. This hybrid operation enables knowledge and practice exchange, providing more assertiveness to results.

Product portfolio assumption number 01 is that iron ore or sand originated from its treatment is the main pre-cast development input. Products that enter the production line need to be validated technically in lab and prototype production tests by CEFET. The choice of types takes into account the most request typology by Vale internal areas.

Production system is comprised by five main stages. At pre-cast manufacturing process start, inputs will be put in buffer piles in raw material bays, and supplied in input silos. Raw material loading to silos, which capacity is 10m³, takes places through shovel loader. Cement is bulk and stored in an exclusive silo with 70 m³ capacity. Later, inputs are aimed by means of a conveyor belt to the mixer. There will be a bi-planetary system in the mixer, similar to a churn, that will enable mix homogenization.

There is also a water and additive control and dosage system. Mix residence time in mixer is approximately 60 to 180 seconds. Mix will then be aimed by means of a conveyor belt to vibro press. In such equipment, vertical pressure and synchronized vibration enable forming pre-casts and achieving strength required. In this stage, it is possible to vary molds and achieve different types of artifacts. Such equipment capacity is 4 cycles/minute. The numbers of artifacts by time interval will depend on type of mold used.

Pre-casts produced will be removed from the belt in the end of the line by a forklift, and stored in cure area, where they must remain for up to 36 hours. This stage will be performed at room temperature, and cure time will influence in artifact strength. Upon cure, the product will be stored in bales and places in pallets by means of automated palletizer, this stage is called scale. Bales will be stored outdoors in normal temperature conditions until application.

Figure 2: Manufacturing Process Flow Chart

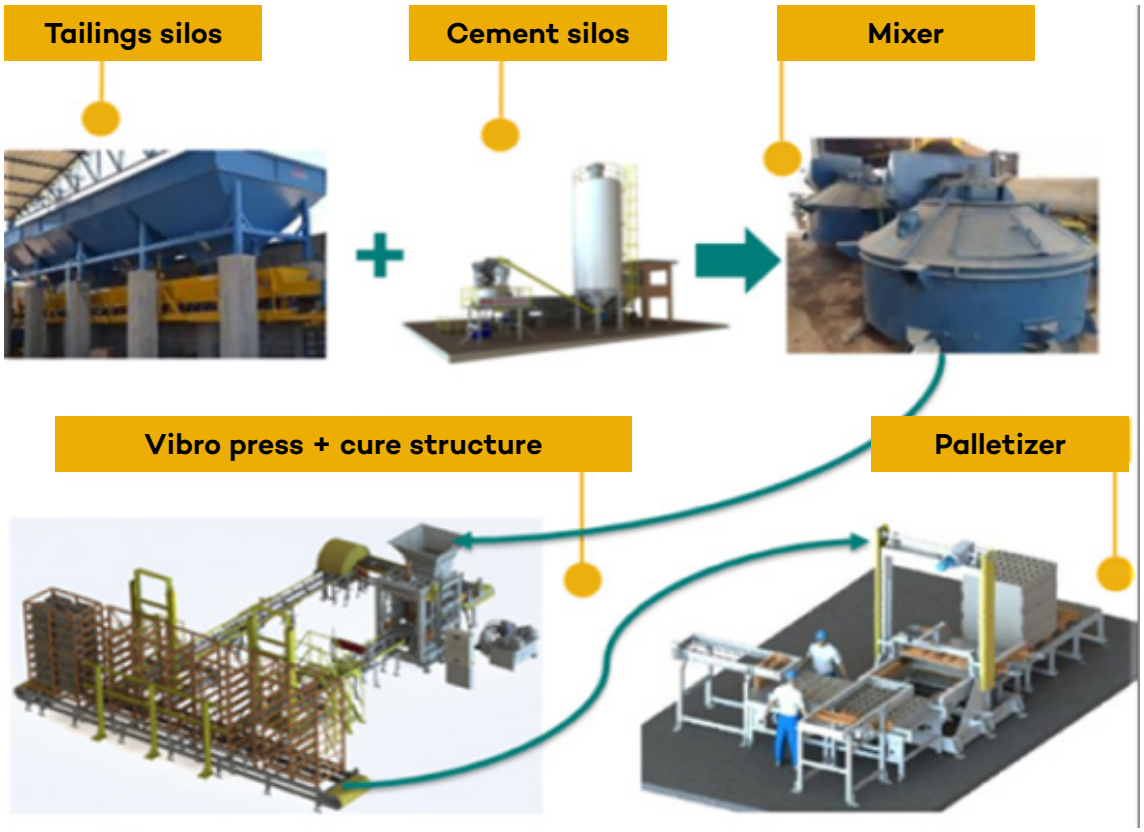


Figure 3: Team involved in PICO MINE BLOCK PLANT project

Figure 4- Pre-cast in PICO MINE BLOCK PLANT scale stage

Figure 5- Operation and Research Team acting jointly in PICO MINE BLOCK Plant

VALE

Project Title	• PAVING
✱ **Partner Institutions**	• UNIFEI - Universidade Federal de Itajubá (Campus Itabira)
✱ **Project Stage:**	• (x) **Ongoing** • ( ) Completed
✱ **Business Model**	• ( ) Researches/bench • (x) **Pilot scale research** • ( ) Outsourcing • ( ) B2B • (x) **Technology incubation and internal development**
✱ **Mineral good produced**	• **Sand**
✱ **Type of Tailings/ Spoil**	• Quartz and hematite

✱ **Volume Reused**	• 200 thousand tons (2021 data)
	• Potential:
	  • Highway Pavement: 7 thousand tons/km
	  • Local Pavement: 2.5 thousand tons/km

✱ **New products generated**	• **Concrete pre-cast** (interlocked floors, masonry blocks and sealing, curb prefabricated)
✱ **Investiment**	• **BRL 20 million**

Process description

HIGHWAY PAVING

Reuse Project of tailings and sands originated from their treatment in paving is a partnership between Vale and Universidade Federal de Itajubá (UNIFEI), and can be divided into 2 stages: lab tests and experimental track. In the first stage, chemical, mineralogical, granulometric and mechanical analyses of sandy tailings to certify its application potential in every layer of a flexible pavement for heavy highway flow. In the second stage, lab test results will be applied in internal highway pavements. The first experimental road, built in 2018, applied 1200 ons of iron ore tailings in base and sub-base layers in approximately 600-meter section.

Due to such tailings granulometric characteristics, it was required to do granulometric stabilization, i.e. a granulometric range correction in which this material is found, in order to mix it with larger size aggregates.

A second experimental track construction was completed in 2022, inside Cauê Mine, in Itabira complex. This highway replica was divided into 4 different sections, in which different mixes containing sand were tested, originated from tailings treatment, in every pavement layer (coating, base, sub-base and sub-bed reinforcement).

What is more, sensors were installed between layers, that will identify pavement deformities and anomalies, which will be monitored for two years. Moreover, there will be an environmental follow-up, in the same time interval, to assess long-term sand performance.

According to technical results, soil mix behavior was assessed with sand originated from Cauê Mine in 25%, 50% and 75% proportions in mass, aiming at such mix application in sub-bed layers, sub-bed and sub-base reinforcement. ISC (California Support Index) value increase was verified of the soil with iron ore tailings addition, and expansion decrease, evidencing iron ore processing co-product potential as sub-bed, sub-base and base reinforcement material, depending on traffic magnitude.

Another result of this project showed that Vale´s sand addition enabled asphalt binder consumption reduction, with lower project contents than conventional mixes, and it also enables strength gain for mechanical properties, in compliance with standard specifications. There was up to 6.0% saving of CAP (Asphalt Petroleum Cement), which is considered higher value input.

Figure 1: Cauê Experimental Track - Execution Stage

Figure 2: Cauê Experimental Track - Execution Stage

LOCAL PAVING - CREATING PATHS

In 2020, a low cost solution program was created to local pavings, which goal will be promoting infrastructure improvement of Vale operation neighboring communities, and a more sustainable destination to sands originated from tailings treatment. From a partnership between Vale, associations of municipalities, city halls, Universidade Federal de Itajubá (UNIFEI) and communities, rural road paving is being performed with a mix containing type 02 sand, binder and soil.

To analyze sustainable solution performance, lab analyses, experimental field tests and experimental section monitoring are being performed. This initiative is part of the first stage of Local Paving with Tailings Social Program, Creating Paths. To assess performance in loco, mixes set in lab tests are being applied in a municipal local section of up to 5 km long and 7 to 10 m wide. The section construction is followed, and its performance is monitored within 6 months.

Creating Paths is in its experimental stage, and only in 2021, around 5 km were built in 3 different municipalities of Iron Quadrilateral. In 2022, some sections are still in construction and monitoring process. Preliminary results pointed out a particulate matter emission reduction, traffic improvement and strength increase compared to conventional solutions. In this program, Vale is responsible for donating sand and binder, apart from technical qualification. Creating Paths signatory municipalities are responsible for providing equipment and people for section execution.

Figure 1: Experimental sections in test

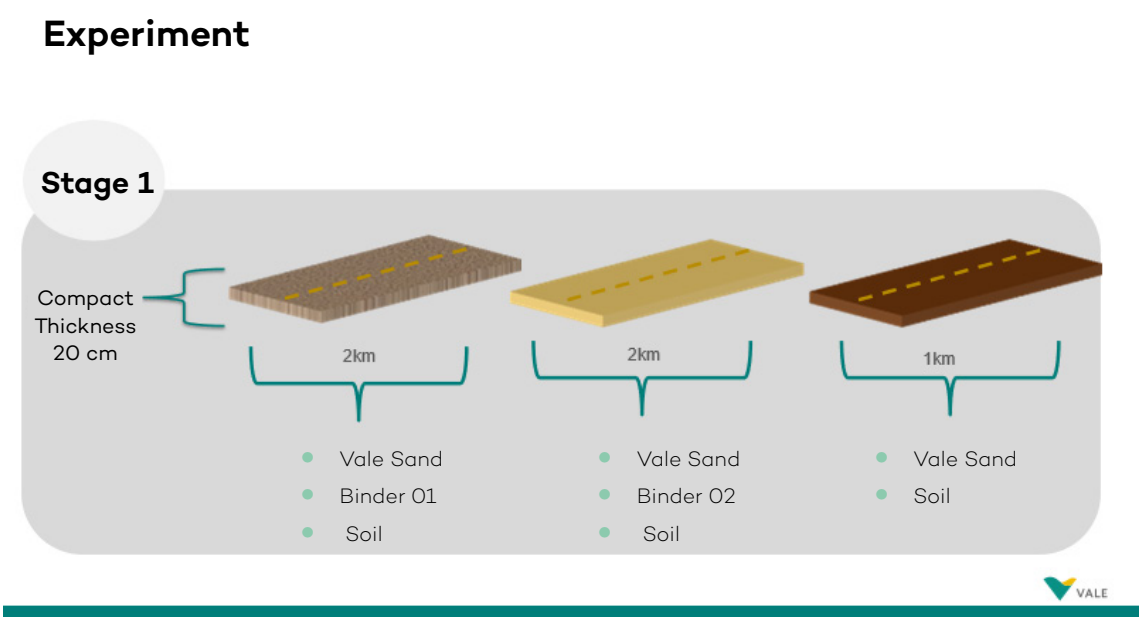


Figure 2: Texture of one of experimental sections upon rainy period containing one of test solutions with Vale´s sand.

RIGID PAVEMENT - PARTNERSHIP WITH CONTRACTOR

In 2020, Vale, jointly with the company Contractor, formalized a partnership to assess Vale´s sand potential. In 2021, around 80 thousand tons of sand were applied, originated from Brucutu sandy tailings processing in experimental way in Contorno Mestre Álvaro highway (BR101/ES).

- Application: Highway BR-101/ES - Contorno Mestre Álvaro
- Length: 19 Km
- Type of pavement: Rigid Pavement
- Mix density: 1.6 t/m³
- Width: 28 m
- Thickness: 60 cm (final landfill layer)
- Mix with 40% of Vale type 01 sand

Results point out that Vale sand increased support capacity, reduced soil expansion, increased compaction.

Figure 1: Contorno Mestre Álvaro highway work with Vale´s Sand

PROJECTS

- ZINCAL
- AMBROSIA AGGREGATE
- IRON CONCENTRATE

nexa

Project Title	• ZINCAL
* **Partner Institutions**	• Commercial dealers: Calcário Noroeste, Calcário Marathg. • Certified lab: Laboratório CAMPO.
* **Project Stage:**	• ( ) Ongoing • (x) **Completed**
* **Business Model**	• ( ) Researches/bench • (x) **Outsourcing** • ( ) B2B • (x) Technology incubation and internal development
* **Mineral good produced**	• Process consists of change performed in processing plant to assure contaminants within specifications for plant dolomite tailings to be classified as agricultural limestone. This limestone is sold with the assistance of two partner dealers for the agricultural market within the plan surroundings.
* **Type of Tailings/ Spoil**	• Dolomite deposited in Morro Agudo Dam. With specifications below filed in MAPA.

Discrimination	Guarantee	Measure Unit
• CaO	26.0000	%
• MgO	16.0000	%
• Peneira 2,00 mm (ABNT n°10)	100.0000	%
• Peneira 0,84 mm (ABNT n°20)	85.0000	%
• Peneira 0,30 mm (ABNT n°50)	82.0000	%
• PRNT	73.7000	%
• SOMA CaO + MgO	42.0000	%
• PN	85.0000	%

* **Volume Reused**	• Currently, plant supply is around 1Mt/year. Over the last 2 years, 1.3Mt/year were market, finalizing the old process stock deposit in yards.
* **New products generated**	• Soil acidity corrective for agricultural purposes.

Project Title	• ZINCAL
✱ **Investiment**	• Equipment used in this process is leased with approximately BRL 14M/year OPEX, including operators that operate it, fleet description is provided as follows. • 7 loaders • 8 tanker trucks • 7 trucks • 4 tire tractors • 1 caterpillar tractor • 4 excavators • motor grader operation

Process description

Plant tailings, whenever within specifications, is forwarded to Dam 1, where they are constantly excavated and submitted to the site limestone yards, when this yard reaches the maximum height allowed, material is broken and dried at the sun, by using tire tractors with agricultural inputs, after it is dry, this material is reassembled with shovel loaders and loaded with them for dispatch, upon quality control validated in external lab certified by MAPA.

nexa

Project Title	• AMBROSIA AGGREGATE
✱ **Partner Institutions**	• Calcário Noroeste LTDA
✱ **Project Stage:**	• (x) **Ongoing** • ( ) Completed
✱ **Business Model**	• ( ) Researches/bench • (x) **Outsourcing** • ( ) B2B • ( ) Technology incubation and internal development
✱ **Mineral good produced**	• Process treats ashlar masonry stone deposited in Ambrósia Sul site pile, forwarding it to sale as crushed stone after comminution and classification process.
✱ **Type of Tailings/ Spoil**	• Dolomite deposited in Ambrósia Sul site. • 90% $CaMg(CO_3)_2$; 9% SiO_2; 4% Fe_2O_3; 3% • Al_2O_3, 2% ZnS; 2% others.
✱ **Volume Reused**	• 80,000 tons a year (expectation). • In 2021, between January and April, 18,450 t were marketed.
✱ **New products generated**	• Civil construction aggregate.
✱ **Investiment**	• Investment to start operation was BRL 250,000.00 • 1 year of dedication of +10 company professionals.

Process description

- **Selection** (material is selected according to its chemical characteristics)
- **Planning** (material removal plan is executed)
- **Loading** (material leaves Ambrósia site and is transported to partner company)
- **Crushing** (material has granulometry reduced to be marketed as crushed stone)
- **Classification** (material passes through sieves, so that crushed stone types are separated for market forwarding)
- **Sale**

nexa

Project Title	• IRON CONCENTRATE
✱ **Partner Institutions**	• LTM - USP • Gaustec • Inbrás

✱ **Project Stage:**	• Ongoing Industrial Test
	  • FEL 1 Completed
	  • FEL 2 Ongoing

✱ **Business Model**	• (x) **Researches/bench** • ( ) Outsourcing • ( ) B2B • ( ) Technology incubation and internal development
✱ **Mineral good produced**	• Iron concentrate, hematite-rich product.
✱ **Type of Tailings/ Spoil**	• Tailings achieved from willemite ore mineral processing (zinc) with dolomitic fitting rock. Tailings comprised by dolomite, hematite, quartz, willemite, galena.
✱ **Volume Reused**	• 100 tons a year (industrial test) • 120 thousand tons a year (project to be implemented)

✱ **New products generated**	• Ongoing process generates 2 flows:
	  ◆ Iron concentrate, hematite-rich fraction.
	  ◆ Dolomite

✱ **Investiment**	• BLR 1.5 M (R&D, Industrial Test, FEL 1 and FEL2 stages)

Process description

Ebb tailings processing technological route will use the material generated in sunken in zinc flotation stage, that will be submitted to draining stage to match solid percentage in pulp, followed by a magnetic concentration in two stages, Rougher and Cleaner. Magnetic fraction produced will be drained and forwarded to sale as metallurgical iron concentrate. Non-magnetic fraction will be arranged according to current operation.

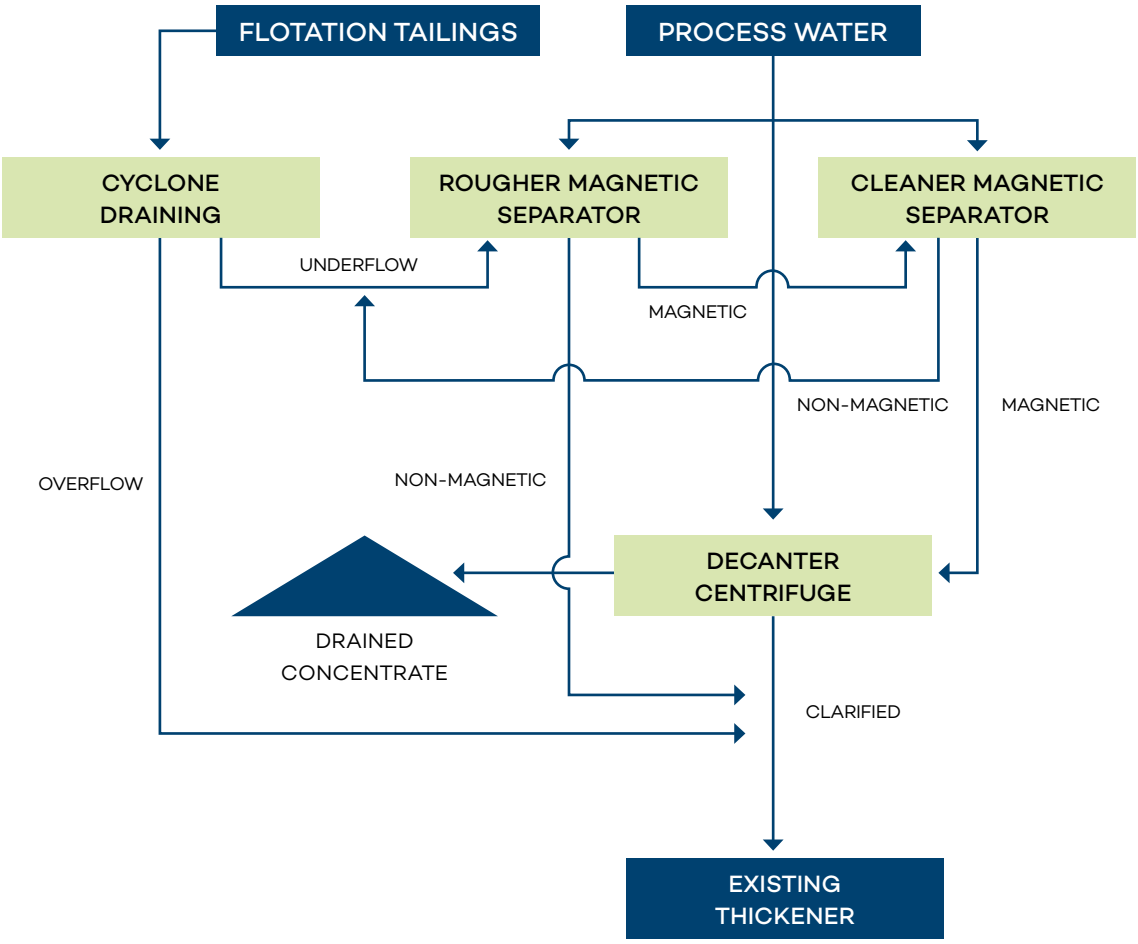


Figure 1: Ongoing Industrial Test

Figure 2: New products generated generated

Magnetic Fraction - Iron Concentrate

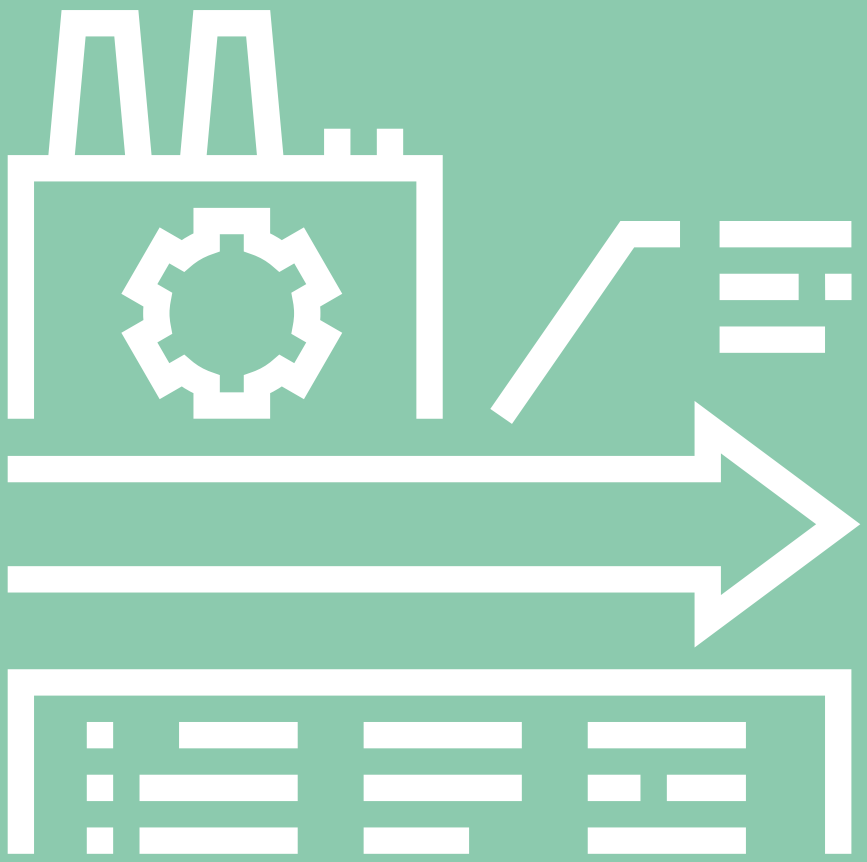
Non-Magnetic - Dolomite

SAMARCO

APRENDER PARA EVOLUIR E TRANSFORMAR

PROJECTS

- MUD USE FOR LOCAL ROAD PAVING
- SANDY TAILINGS USE TO MANUFACTURE GEOPOLYMER
- PAPER WASTE USE TO PERFORM HYDROSEEDING



Project Title	• MUD USE FOR LOCAL ROAD PAVING
✱ **Partner Institutions**	• SAMARCO, ECOMUD, NEO VENTURES, UFOP, UFMG, CDTN, INCT Midas, Escalab, Prefeitura de Mariana.
✱ **Project Stage:**	• (x) **Ongoing** Surveys/Bench/Pilot/Semi-industrial, PoC completion in 11 km of local roads • ( ) Completed
✱ **Business Model**	• ( ) Outsourcing • (x) **B2B** • ( ) Technology incubation and internal development • ( ) Others: _____ _____
✱ **Mineral good produced**	• Iron ore.
✱ **Type of Tailings/ Spoil**	• Ultrafine tailings generated in iron ore concentration plant desludge process, comprised predominantly by goethite, quartz and hematite.
✱ **Volume Reused**	• 11,872 tons to execute local road paving PoC.
✱ **New products generated**	• Raw material comprised by ultrafine tailings and used to local road paving.
✱ **Investiment**	• BRL 1,305,384.72 (MinerALL Challenge by initiative plus PoC costs)

Process description

Solution proposed is performed by ECOMUD startup, comprised by a team that underwent acceleration, pre-escalation and go to market stages of MinerALL Challenge - program started in September, 2018, that aimed at transforming tailings use technologies in undertakings, performed by SAMARCO and NEO VENTURES, supported by UFOP, UFMG, CDTN, Escalab and INCT Midas.

ECOMUD executed an experimental section in SAMARCO mine (200mx15m), with the goal of solving problems, including dust dispersion in drought periods and mud and quagmire development in rainy periods. As test success is assured, POC was executed in 11 km of local roads of Mariana municipality.

ECOMUD uses ultrafine tailings generated in iron ore processing development, along with inorganic binder and location soil, to perform a mix that will be compacted along with soil, according to patent achieved before INPI in 2021.

In 2022, a route is being surveyed for draining part of the mud generated in processing development, in order to meet supply demand already mapped by ECOMUD, and supply logistic process discussion.

Project Title	• SANDY TAILINGS USE TO MANUFACTURE GEOPOLYMER
✱ **Partner Institutions**	• SAMARCO, GEECO, NEO VENTURES, UFOP, UFMG, CDTN, INCT Midas, Escalab.
✱ **Project Stage:**	• (x) **Ongoing** Surveys/Bench/Pilot/Semi-industrial, PoC completion in UFMG Model Farm • ( ) Completed
✱ **Business Model**	• ( ) Outsourcing • (x) **B2B** • ( ) Technology incubation and internal development • ( ) Others: _____ _____
✱ **Mineral good produced**	• Iron ore.
✱ **Type of Tailings/ Spoil**	• Sandy tailings generated in iron ore concentration plant flotation process, comprised predominantly by quartz.
✱ **Volume Reused**	• 3,800 tons to execute PoC, floor coating manufacturing for geopolymer made of sandy tailings.
✱ **New products generated**	• Raw material comprised by filtered sandy tailings and used to geopolymer manufacturing.
✱ **Investiment**	• BRL 116,827 (MinerALL Challenge by initiative plus PoC costs)

Process description

Solution proposed is performed by GEECO startup, comprised by a team that underwent acceleration, pre-escalation and go to market stages of MinerALL Challenge - program started in September, 2018, that aimed at transforming tailings use technologies in undertakings, performed by SAMARCO and NEO VENTURES, supported by UFOP, UFMG, CDTN, Escalab and INCT Midas.

GEECO uses sandy tailings generated in iron ore processing development, along with additives, to produce a geopolymer, that was used in a POC of 20m² of floor, with 50 x 50m boards applied in UFMG LGG, located in Model Farm in Pedro Leopoldo.

Upon board technical validation in POC, GEECO keeps on developing its business model.

Project Title	• PAPER WASTE USE TO PERFORM HYDROSEEDING
✱ **Partner Institutions**	• SAMARCO / Environment Management
✱ **Project Stage:**	• (x) **Ongoing** Surveys/Bench/Pilot/Semi-industrial, using a small quantity of paper waste in hydroseeding process internally in Germano site for test • ( ) Completed
✱ **Business Model**	• ( ) Outsourcing • (x) **B2B** • ( ) Technology incubation and internal development • ( ) Others: _____ _____
✱ **Mineral good produced**	• Raw material with crushed paper to replace inputs.
✱ **Type of Tailings/ Spoil**	• Paper waste generated in company administrative sites
✱ **Volume Reused**	• 1.8 tons a month
✱ **New products generated**	• Raw material comprised by paper crushing to replace inputs used in hydroseeding process.
✱ **Investiment**	• BRL 30,000 (shredder purchase and environmental education campaign)

Process description

Solution proposed is using paper generated in administrative areas in hydroseeding process, replacing process components. Hydroseeding is hydromechanical application of a soft paste comprised by fertilizers, seeds, protecting layer, adhesives and live organic matter, which characteristic feature is determined by the need for soil correction and nutrition of vegetation to be introduced. In Figure 01 below, inputs used in Samarco area process are presented.

Figure 1: Inputs used in hydroseeding process

Input	Unit	ha quantity
Dolomitic Limestone	Kg	2.000
Manure NPK 4-14-8+MICRO	Kg	600
Organic Manure	m^5	3
Manure NPK 20-05-20	Kg	300
Natural Phosphate	Kg	500
Crotalaria (Crotalia spectabilis)	Kg	50
Guandu Beans (Cajanus cajan)	Kg	50
Black Oat (Avena strigosa)	Kg	50
Azevem (Lolíum multifloreum)	Kg	50
Turnip (Raphanus sabvus)	Kg	50
Brachiaria (Brachiana decumbena)	Kg	50
Molasses grass (Melmis minutrflora)	Kg	50
Dolomitic Limestone	Kg	2000
Manure NPK 4-14-8+MICRO	Kg	600
Organic Manure	m’	3
Manure NPK 20-05-20	Kg	300
Natural Phosphate	Kg	600
Crotalaria (Crotalia spectabilis)	Kg	50
Guandu Beans (Cajanus cajan)	Kg	50
Black Oat (Avena strigosa)	Kg	50
Azevem (Loitum multifloreum)	Kg	50
Turnip (Raphanus sativus)	Kg	50
Brachiaria (Brachiana decumbens)	Kg	50
Molasses grauss (Melmis minutrflora)	Kg	50
Mega Mulch	Kg	4.500
Organic glue	L	200

Project consists then of waste that would be disposed, and is inserted in hydroseeding process, replacing mega mulch and organic glue.

For project execution, environment management perform legal-size paper collection campaign from different Samarco areas, as a replacement for raw material in hydro-seeding process. The action has generated different environmental and financial gains, as well as sustainable practice fostering aligned with Samarco purpose.

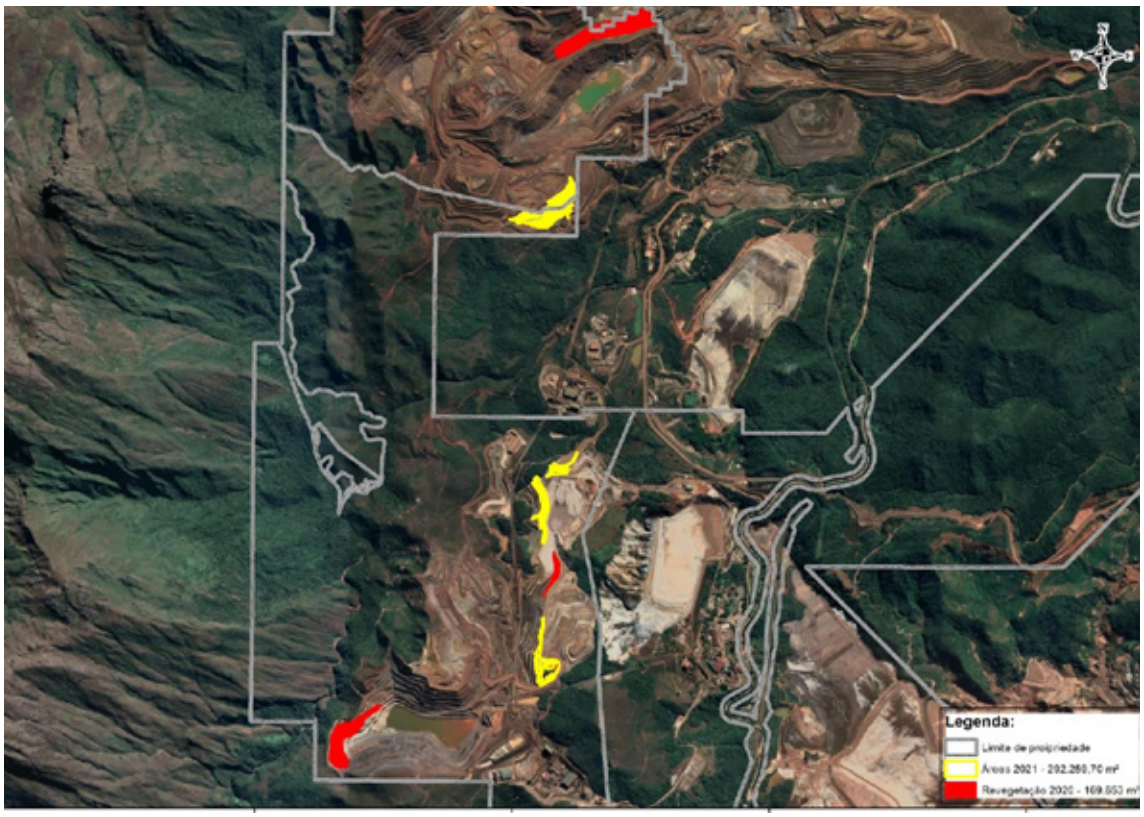
A paper shredder was acquired for material crushing in adequate granulometry for usage, as provided in Figure 02 below.

Figure 2: Internal campaign performed for paper pickup

Figure 3: Test area being revegetated with fragmented paper usage

In 2021, 461,000 m^2 of areas were revegetated. 2022 forecast is 400,000 m^2 of revegetation by means of hydroseeding. Approximate financial gain with paper usage and input replacement is BRL 350,000.00 a year.

Figure 04: Company areas to be revegetated by using hydroseeding



AngloAmerican

REUSE OF SLAGS FROM IRON-NICKEL ALLOY PRODUCTION

PROJECT

AngloAmerican

Project Title	• REUSE OF SLAGS FROM IRON-NICKEL ALLOY PRODUCTION
✱ **Partner Institutions**	• Concessionária Ecovias do Araguaia S.A. • Universidade Federal do Espírito Santo (UFES)
✱ **Project Stage:**	• (x) **Ongoing** Surveys/Bench/Pilot/Semi-industrial • ( ) Completed
✱ **Business Model**	• ( ) Outsourcing • ( ) B2B • ( ) Technology incubation and internal development • **(x) Others: Termo de Cooperação Técnica e Convênio**
✱ **Mineral good produced**	• Iron-nickel production industrial co-product
✱ **Type of Tailings/ Spoil**	• Silica, Magnesium, Alumina, Lime • Finely particulate material
✱ **Volume Reused**	• 10 thousand tons of slag (Pilot), with 17 million ton reuse potential, avoiding the need for new areas for waste disposal.
✱ **New products generated**	• Asphalt Binder mixes, including hydraulic binds, soil enhancer additives, and aggregates to be used in asphalt concretes and micro asphalt coatings • Industrial co-products for geotechnical purposes and supplementary cement materials; • Soil corrective and fertilizer • Civil construction usage to produce pavements and bricks; • Usage in landscape rehabilitation and infrastructure projects in mining areas.
✱ **Investiment**	• BRL 4,000,000

Process description

Steel and iron alloy production originates several concentration and processing development waste types, as well as high furnace slags that are calcination process waste, that represent around 60% of waste generated in steelworks industry. This co-product is used in civil construction industry, with major potential in several applications. Researches have been performed for their reuse also to fertilizer production, asphalt paving, soil enhancement (earthworks works) and landscape rehabilitation.

At present, main hydraulic bind used globally in Portland cement. Portland cement types include cements with mineral addition, and the slag can replace clinker, raw material to manufacture cement, to 75%, as per NBR 16697/2018, and iron-nickel production co-product fosters high interest due to environmental and economic issue, and high technical performance potential from its use, whether in natural state or in processed form.

Finally, thus granular residual material reuse is an opportunity to avoid natural resource exploration and minimize the need for mining waste storage areas, enabling more sustainable nickel exploration within circular economy concept.

Figure 1: Current slag deposit

Figure 2: New slag deposit

Figure 3: Fe-Ni Production Slag Deposit

Figure 4: Co-product transportation for large scale test through Araguaia Ecovias

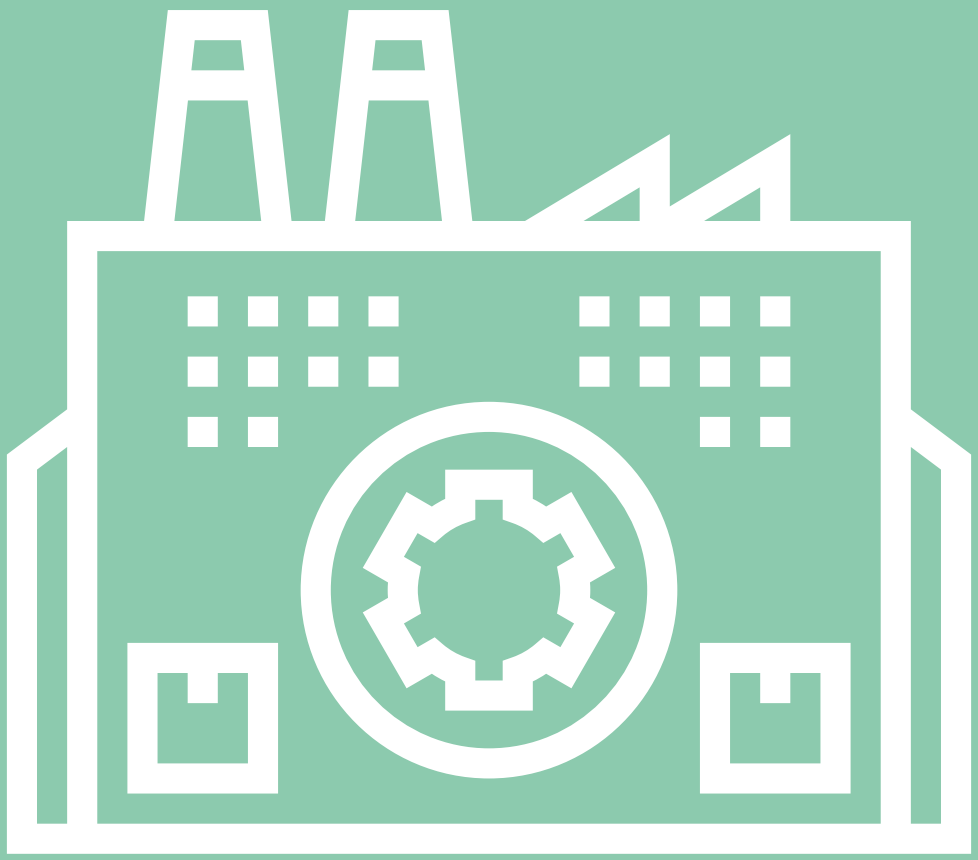
Figure 5: Co-product application detail in asphalt pavement composition

Figure 6: Paving area expansion activities with slag usage at the margin of Concessionaire Highway

PROJECTS

SPODUMENE PLANT – SP1

EFFLUENT REUSE PROJECT MACHINE WASHER AND MINING EQUIPMENT



Project Title	• SPODUMENE PLANT – SP1
✱ **Partner Institutions**	• N/A
✱ **Project Stage:**	• ( ) Ongoing Surveys/Bench/Pilot/Semi-industrial • (x) **Completed**
✱ **Business Model**	• ( ) Outsourcing • ( ) B2B • ( ) Technology incubation and internal development • **(x) Others: Tailings processing of Tantalum Plant and Dams VG 01 and VG 02 for spodumene concentration production.**
✱ **Main mineral good**	• Spodumene
✱ **Type of Tailings/ Spoil**	• Tailings of Tantalum Plants and material of Dams VG01 and VG02
✱ **Volume Reused**	• 90,000 t/year
✱ **New products generated**	• Spodumene Concentrate
✱ **Investiment**	• BRL 164 Million (Spodumene Plant – SP1)

Process description

AMG Brasil is a company that aims at promoting improvement and development of people, economy and environment, through location and need knowledge and acknowledgment where it acts.

One of AMG main focuses is currently ESG practices that, clearly, translate sustainability concept. AMG BRASIL – Volta Grande Mine undertaking, develops its activities in Nazareno and São Tiago municipalities, Minas Gerais, and produces tantalum/tin concentrates from pegmatitic rock. Apart from the abovementioned, there is feldspar production for porcelain tile and glass industry. An authentic example of sustainable practice effort is the object proposed to Mining Circular Economy Practice Guide.

Its environmental licensing is in force, LO 068/2018, in operation since May/2018. It refers to an Ore Processing Plant – UTM, named Spodumene Project – SP1 for reuse of tailings, previously released to disposal in Dams VG 01 and VG 02. This UTM produces Spodumene Concentrate for lithium oxide production.

Main tantalum mineral-ore is Tantalite, which is part of columbite-tantalite isomorphic series (Fe,Mn)(Nb,Ta)2O6, in which Nb and Ta, respectively, replace themselves in every proportion. Apart from Tantalite, tantalum is achieved from Microlite (Na,Ca)2Ta2O6(O,OH,F). Tin mineral-ore is Cassiterite SnO2. In case of feldspar, the or is potassium feldspar. Lithium concentrate main mineral-ore is Spodumene.

Tailings generated in the operation is only originated fro the first stage of magnetic separation. Around 21t an hour are submitted to Tailings Dam system VG 03. This separation stage generates tailings with neural pH, as there is no acid addition in this stage. Dam stored tailings generation reduction was 80%, from 78 t/h to current 21 t/h. Spodumene Plant – SP1 is supplied by the following processes:

- Material originated from tailings produced instantly in Tantalum Plant 1 and Plant 2;

- Material originated from tailings stored in Tailings Dams VG 01 and VG 02.

Dams VG 01 and VG 02 have been built using tailings by upstream method. At present, Volta Grande Dam – VG 01 has already been decharacterized, and total tailings removal has been executed. It was performed through reprocessing in Spodumene Plant – SP1, according to decharacterization process described as follows of Volta Grande Dam – VG 02 Volta Grande Dam – VG 02 removal has started and at present its progress is 50%.

Dam VG 02 does not receive contribution from rainwaters, except for direct precipitation waters, as it is equipped with perimeter channel, for water deviation originated from upstream basin.

Even though it still can be call dam, it works currently as granular tailings drained deposit. Phreatic levels inside the reservoir and next to slope are very low. Current safety factors are substantially higher than the ones required to static, dynamic conditions and in relation to liquefaction, thus they are stable structures.

With tailings removal to be reprocessed, structures will no longer exist, and it is a simple structure decharacterization process. Clearing activities are performed with the goal of reprocessing tailings that comprised the own dam body and relevant reservoir. To do that, it is required to mine tailings and submit them to new processing in Spodumen Plant – SP1.

Dam VG 02 clearing and decomissioning project scope includes definition of excavation stages, drainage and stabilization measures during clearing, monitoring and readaptation process of area impacted. Studies performed include: dam stability analyses in current condition and during tailings removal process; superficial drainage studies to prevent water buildup in reservoir; seismic risk study; tailings dam removal and monitoring plans, as well as readaptation study upon tailings removal.

Study results showed that Dam VG 02, at current condition, is stable (with safety coefficients above minimum required by standards and codes in force). And the structure will keep stable during dam and reservoir clearing operations. To assure dam stability, existing piezometers must be monitored, and piezometric levels kept within safety levels established.

Figure 1: Dams VG 01 and VG 02

So that AMG Brasil could achieve its goals to reprocess tailings, decharacterization project proposes that only works in dam and reservoir were executed. With the goal of assuring dam safety and compliance with relevant laws and regulations during mining process, it follows that:

- Tailings reservoir perimeter channel construction to lead superficial runoff waters originated from hydrographic basin. Thus, tailings submersion is prevented during mining period. Channels must be built at every excavation stage;
- Tailings removal (mining) in horizontal layers;
- Dam overflow successive lowering, along with excavation progress, to assure mining hydraulic safety;
- Dam height lowering, along with mining progress;
- Existing piezometer monitoring during mining process;
- Impacted area readaptation upon tailings removal.

During clearing and decomissioning period, all technical requirements must be complied with in relation to dam safety. After these activities, dam will no longer exist, and can be considered as disabled. Thus, the valley in its original conformation must be left, as it existed before tailings deposit construction.

Figure 2: Dam VG 02

Project Title	• EFFLUENT REUSE PROJECT MACHINE WASHER AND MINING EQUIPMENT
✱ **Partner Institutions**	• TEGA ENGENHARIA E MEIO AMBIENTE
✱ **Project Stage:**	• (x) **Ongoing** Surveys/Bench/Pilot/Semi-industrial • ( ) Completed
✱ **Business Model**	• ( ) Outsourcing • ( ) B2B • ( ) Technology incubation and internal development • **(x) Others: : Effluent Treatment Plant of Machine Washer and Mining Equipment for recirculation.**
✱ **Main mineral good**	• Water
✱ **Type of Tailings/ Spoil**	• Machine Washer and Mining Equipment end effluent.
✱ **Volume Reused**	• approximately 10,000 m³/year
✱ **New products generated**	• Reuse of 100% of washer end effluent, eliminating release to sink and new water consumption reduction
✱ **Investiment**	• approximately BRL 800 thousand

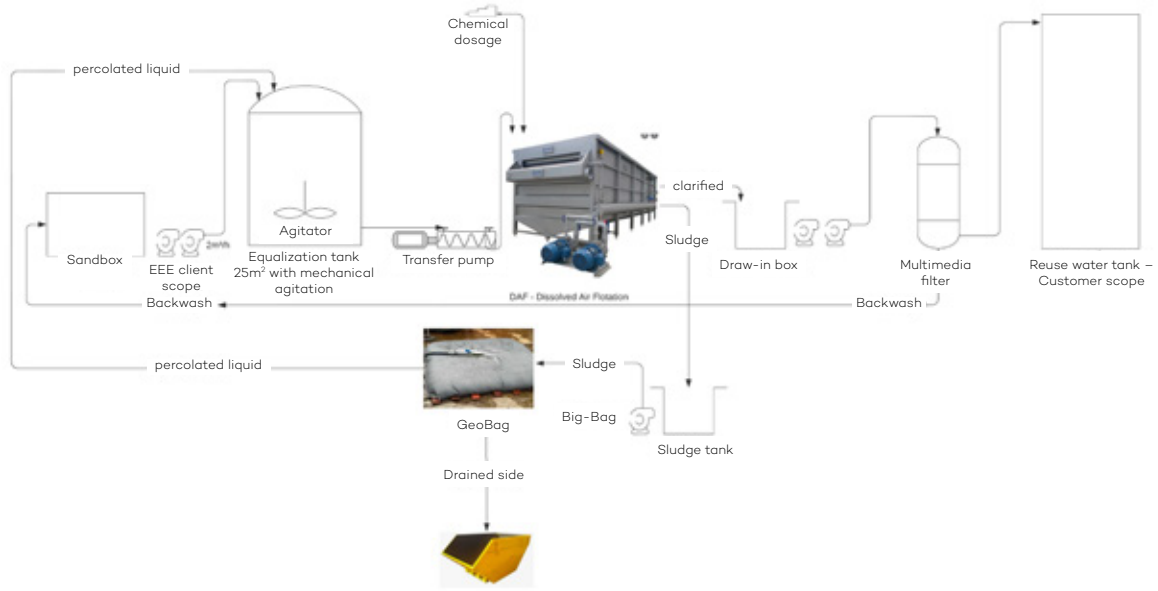
Process description

AMG Brasil is a company that aims at promoting improvement and development of people, economy and environment, through location and need knowledge and acknowledgment where it acts. One of AMG main focuses is currently ESG practices that, clearly, translate sustainability concept.

AMG BRASIL – Volta Grande Mine undertaking, develops its activities in Nazareno and São Tiago municipalities, Minas Gerais, and produces tantalum/tin concentrates from pegmatitic rock. Apart from the abovementioned, there is feldspar production for porcelain tile and glass industry. An authentic example of sustainable practice effort is the object proposed to Mining Circular Economy Practice Guide, that approaches Machine Washer and Mining Equipment end effluent use, that will be presented as follows.

Upon washer end effluent first decanting, it is pumped to mix equalization tank through mechanical agitator, with pumping for clarifier supply, where chemical reagents are dosed for oil and supernatant flotation with total solids and other impurities. This process sludge is forwarded to a tank and drying pumping in GeoBAG, with liquid effluent recirculation and sludge disposal in bucket for later end disposal.

Clarifier treated effluent is forwarded to draw-in box, pumped to filtering and conditioned in a reservoir for reuse in washer itself. Illustrative flow chart of Effluent Treatment Plant of Machine Washer and Mining Equipment for Recirculation is provided as follows.



PROJECTS

ANGLOGOLDASHANTI

- Tailings Reprocessing and Reuse Project
- Technological route development of concentration reduction of metallurgical plant effluent sulphates
- FLOTABASE
- Industrial waste use for ceramic glass and/or porcelain tile production

ANGLOGOLDASHANTI

Project Title	• TAILINGS REPROCESSING AND REUSE PROJECT
✱ **Partner Institutions**	• Partner institutions are Consultoria i9, UFMG and SGS-GEOSOL
✱ **Project Stage:**	• **1st stage (exploratory, 2020-2021):** sample collection, mineral-metallurgical characterization, dam geochemical and hydrochemical modeling, exploratory tests for gold recovery and other byproducts. • **2nd stage (conceptual, 2022-2023):** Cocuruto project is in conceptual stage,where metallurgical test deepening is being performed, with the goal of increasing and optimizing pre-concentration route metallurgical recovery via flotation. The following activities are also being performed: process route assessments, equipment general survey, economic feasibility analyses (CAPEX, OPEX and NPV), and sampling mesh refinement for better reserve size inferring.
✱ **Business Model**	• ( ) Outsourcing • ( ) B2B • (x) **Technology incubation and internal development** • ( ) Others:_____ _____ • Remark: This project business model in conceptual stage is internal development, with future outsourcing possibilities in later engineering stages.
✱ **Main mineral good**	• Mineral good is the residual gold contained in material deposited in Cocuruto dam reservoir. This material is originated from old process routes that experienced technological developments.

Project Title	• TAILINGS REPROCESSING AND REUSE PROJECT
✱ **Type of Tailings/ Spoil**	• Main minerals include quartz, ankerite, oxide and iron hydroxides, siderite, chlorite, muscovite, calcite and subordinate sulphides
✱ **Volume Reused**	• Cubed volume based on geochemical modeling to be reused of material deposited in Cocuruto dam reservoir has approximate total mass of 3.3350 Mt.
✱ **New products generated**	• At first, tailings usage potential was mapped as aggregate for civil construction and fertilizers, apart from contained gold recovery.
✱ **Investiment**	• Investment foreseen is around 75 to 100 million reais.

Process description

Among several process routes analyzed, one of the most plausible will be concentration via flotation. Flotation tailings is submitted to filtering, and concentrate will be forwarded to an existing process in Queiroz metallurgical plant.

Fine and coarse fractions of new tailings generated will be assessed for fertilizer and aggregate product generation for civil construction, respectively.

ANGLOGOLDASHANTI

Project Title	• TECHNOLOGICAL ROUTE DEVELOPMENT OF CONCENTRATION REDUCTION OF METALLURGICAL PLANT EFFLUENT SULPHATES.
✱ **Partner Institutions**	• CIT-SENAI, UFMG e EMBRAPII
✱ **Project Stage:**	• (x) **Ongoing** Surveys/Bench/Pilot/Semi-industrial • ( ) Completed
✱ **Business Model**	• ( ) Outsourcing • ( ) B2B • (x) **Technology incubation and internal development** • ( ) Others:_____
✱ **Main mineral good**	• N/A
✱ **Type of Tailings/ Spoil**	• non-mineral waste is sulphate ion
✱ **Volume Reused**	• N/A
✱ **New products generated**	• Elementary sulfur is a product with potential to be produced by sulphate treatment route, and it can be reused in current gold manufacturing process.
✱ **Investiment**	• initial investment is BRL 1,000,000

Process description

The project is in analysis stage of existing process route, focused on effluent treatment station (ETE) to identify specific points to collect samples for CIT-SENAI bench tests. The goal is studying sustainable process route development for sulphate treatment, which, on the other hand, can generate a by-product (elementary sulphur) that can be reused in manufacturing process, decreasing operating costs. Effluent generated in Queiroz plant with sulphate concentration can be treated in biological process.

ANGLOGOLDASHANTI

Project Title	• FLOTABASE
✱ **Partner Institutions**	• i9, EMPRAPII TECNOGREEN and USP.
✱ **Project Stage:**	• (x) **Ongoing** Surveys/Bench/Pilot/Semi-industrial • ( ) Completed
✱ **Business Model**	• ( ) Outsourcing • ( ) B2B • (x) **Technology incubation and internal development** • ( ) Others:_____
✱ **Main mineral good**	• Quartz-rich coarse fraction use for civil construction, and fine fraction use, that is rich in clay minerals, for instance muscovite, with potential use in fertilizer industry.
✱ **Type of Tailings/ Spoil**	• Non-mineral waste: quartz-, carbonate- and feldspar- rich flotation tailings
✱ **Volume Reused**	• 180,000 tons a year.
✱ **New products generated**	• Products generated from flotation plant tailings will be fine fraction, to be used as fertilizer base, and coarser fraction, as muscovite mineral is missing, to be used as concrete aggregate.
✱ **Investiment**	• Initial investment of BRL 4,000,000.00.

Process description

Concentration process via flotation, separation by size via pneumatic classification and selective milling.

ANGLOGOLDASHANTI

Project Title	• INDUSTRIAL WASTE USE FOR CERAMIC GLASS AND/OR PORCELAIN TILE PRODUCTION.
✱ **Partner Institutions**	• 1st stage: Dundee Technologies • 2nd stage: to be defined
✱ **Project Stage:**	(x) Ongoing Surveys/Bench/Pilot/Semi-industrial • ( ) Completed • Remark: The project is in initial bench test stage and survey of new waste disposal forms.
✱ **Business Model**	• ( ) Outsourcing • ( ) B2B (x) Technology Incubation and Internal Development • ( ) Others:_____
✱ **Main mineral good**	• Elements with pozzolanic potential.
✱ **Type of Tailings/ Spoil**	• Non-mineral waste: sulphates containing several elements, including zinc, iron, copper and arsenic.
✱ **Volume Reused**	• It is intended to reuse around 4500 tons a year of industrial waste.
✱ **New products generated**	• Vitreous ceramic and porcelain tile materials that are commercially attractive.
✱ **Investiment**	• under definition.

Process description:

Industrial waste is mixed with ingredients and binding solution in a power mixer. Mixer product is forwarded to equipment that changes mixed ad homogenized powder in briquettes. Briquettes are submitted to a dryer that operates around 200°C. Dry briquettes are transported to furnaces to be transformed in vitreous materials.

PROJECTS

- MAGNESIAN LIMESTONE PROCESSING, AND CALCITIC LIMESTONE AND FOSCÁLCIO PRODUCTION
- MAGNETITE PROJECT
- GYPSUM DISPATCH IN UBERABA

Project Title	• MAGNESIAN LIMESTONE PROCESSING, AND CALCITIC LIMESTONE AND FOSCÁLCIO PRODUCTION
✱ **Partner Institutions**	• Draw Engenharia

✱ **Project Stage:**	• **Magnesian Limestone Processing**
	(x) Ongoing
	Surveys/Bench/Pilot/Semi-industrial
	( ) Completed
	• In Execution
	  • Detailed project for magnesian limestone concentration is completed (Figure 1).
	  • Semi-industrial plant for magnesian limestone processing is in final implementation stage (Figure 2).
	• **Calcitic limestone production**
	( ) Ongoing
	Surveys/Bench/Pilot/Semi-industrial
	(x) Completed
	• **Foscálcio production**
	( ) Ongoing
	Surveys/Bench/Pilot/Semi-industrial
	(x) Completed

✱ **Business Model**	• ( ) Outsourcing • ( ) B2B ( ) Technology Incubation and Internal Development • (x) Others: .Desenvolvimento interno
✱ **Main mineral good**	• Calcite
✱ **Type of Tailings/ Spoil/ Resíduo não minerais**	• Present in Cajati (SP) phosphatic rock, one of the waste generated is dolomitic limestone (dolomite, silica and calcite) • Calcitic limestone and Foscálcio, that are originated from apatite processing plant

Project Title	• MAGNESIAN LIMESTONE PROCESSING, AND CALCITIC LIMESTONE AND FOSCÁLCIO PRODUCTION
✱ **Volume Reused**	• For magnesian limestone processing project, the volume to be used will be 6 m^3/h of calcitic limestone. For calcitic limestone, achieved from apatite processing, in 2021, 1Mt was dispatched (Figure 3), and for Foscálcio, it was 161 k/t.
✱ **New products generated**	• Products generated are apatite and calcite (Figure 4).
✱ **Investiment**	• Magnesian limestone processing project investment was 3.5 Million.

Process description

Calcitic limestone and Foscálcio production project intends to achieve such specialties from apatite processing, according to Figure 5.

On the other hand, dolomitic limestone processing project intends to process Cajati-SP flotation plant tailings, which magnesium is above 7%, and upon two flotation states, achieve calcitic limestone (mineral of interest calcite). In the first flotation, it is possible to remove a good part of dolomite with a small quantity of calcite. In the second flotation stage, a purer calcite is achieved (calcitic limestone). See route figure below (Figure 6).

Figure 1: Detailed Project - Magnesian Limestone Processing (Mosaic Fertilizantes)

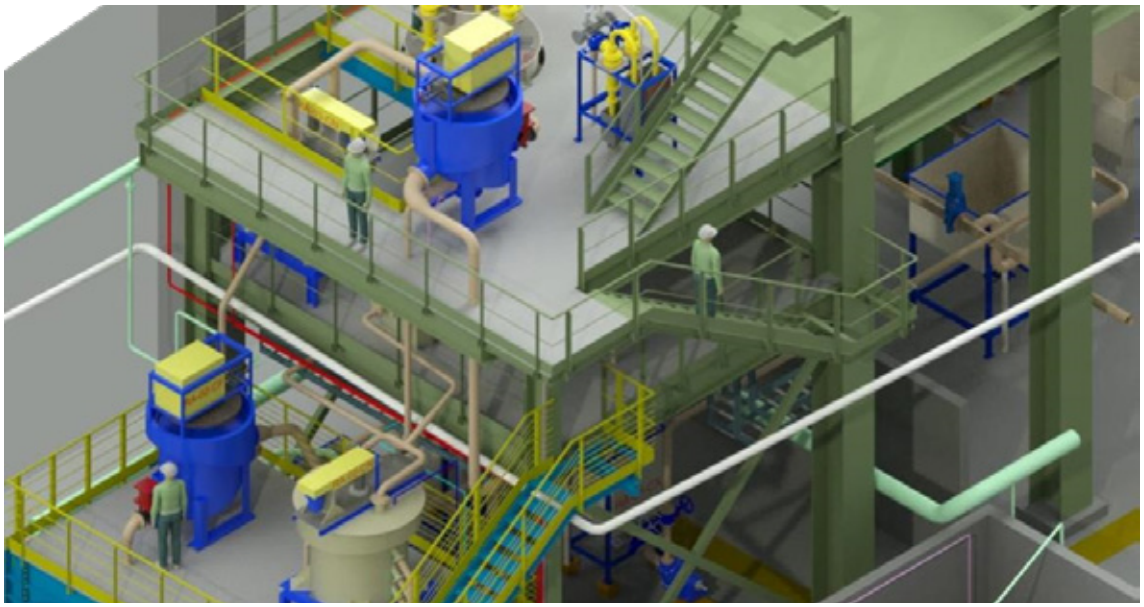


Figure 2: Semi-industrial plant - Magnesian limestone processing

Figure 3: Limestone (Cajati – SP, Mosaic Fertilizantes)

Figure 4: Limestone flotation (Cajati – SP, Mosaic Fertilizantes)

Figure 5: Calcitic and magnesian limestone achievement flow chart

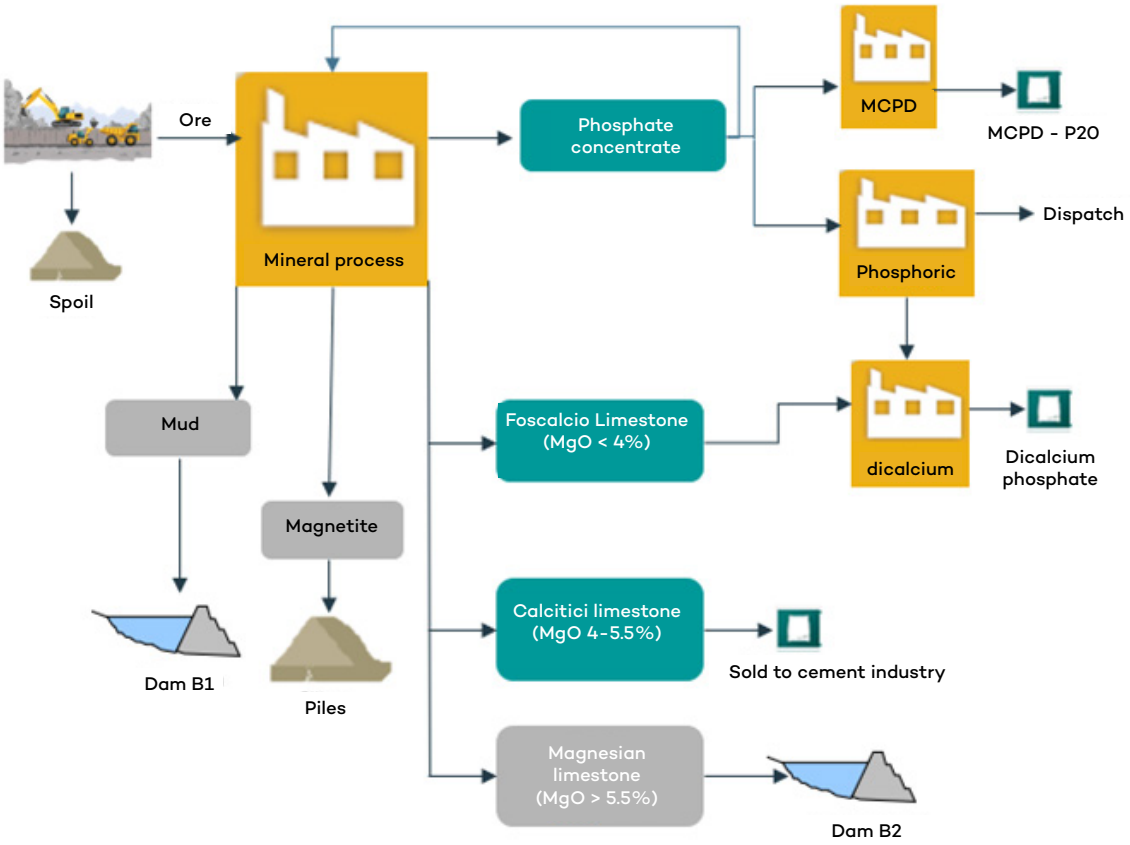
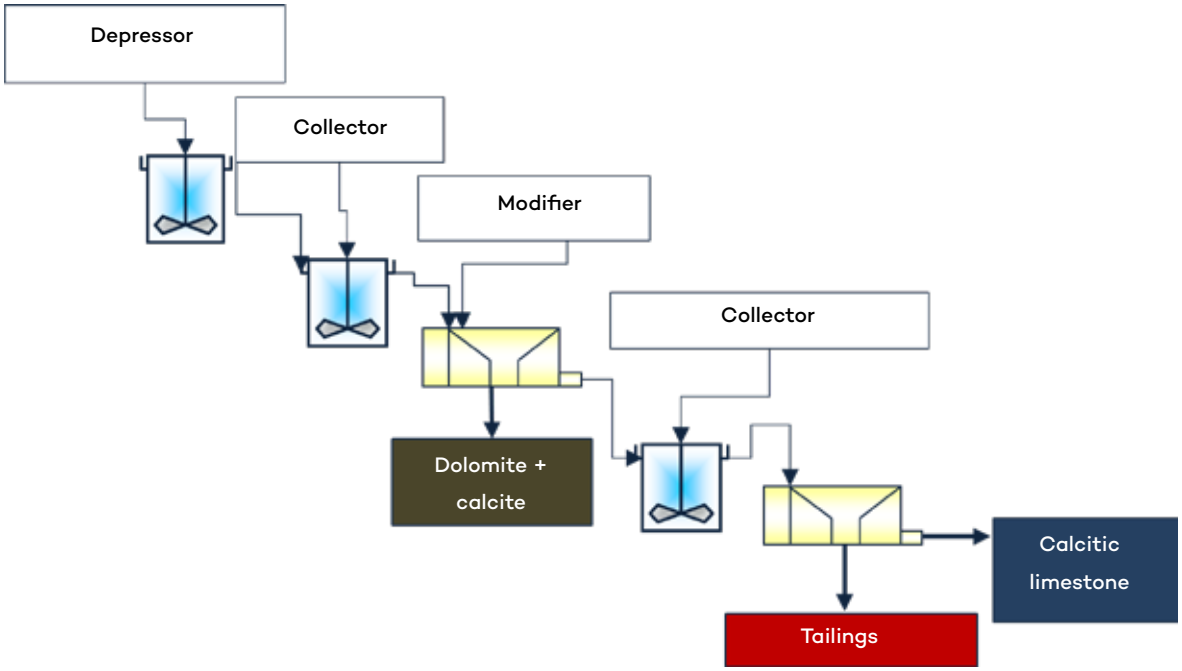


Figure 6: Magnesian limestone processing (Cajati – SP, Mosaic Fertilizantes)



Project Title	• MAGNETITE PROJECT
✱ **Partner Institutions**	• N/A
✱ **Project Stage:**	( ) Ongoing Surveys/Bench/Pilot/Semi-industrial • (x) **Completed**
✱ **Business Model**	• ( ) Outsourcing • ( ) B2B (x) **Technology Incubation and Internal Development** • ( ) Others:_____
✱ **Main mineral good**	• Magnetite
✱ **Type of Tailings/ Spoil/Non-Mineral Waste**	• Magnetite,removed from low field magnetic separation, which enabled higher phosphatic rock use (Figure 1).
✱ **Volume Reused**	• Volume reused was 1.8 Mton, adding value to the company, as the product is marketed, in spite of being disposed as tailings in dams. To due that, quality controls of material stored in piles are performed (Figure 2).
✱ **New products generated**	• There are none, as magnetite is one of the specialties generated in apatite concentration route.
✱ **Investiment**	• BRL 200,000.00

Process description

Sale as it is stored, for steelworks industries, including iron ore, and cement industries, in concrete and mortar manufacturing.

Figure 1: Low field magnetic separation (Mosaic Fertilizantes)

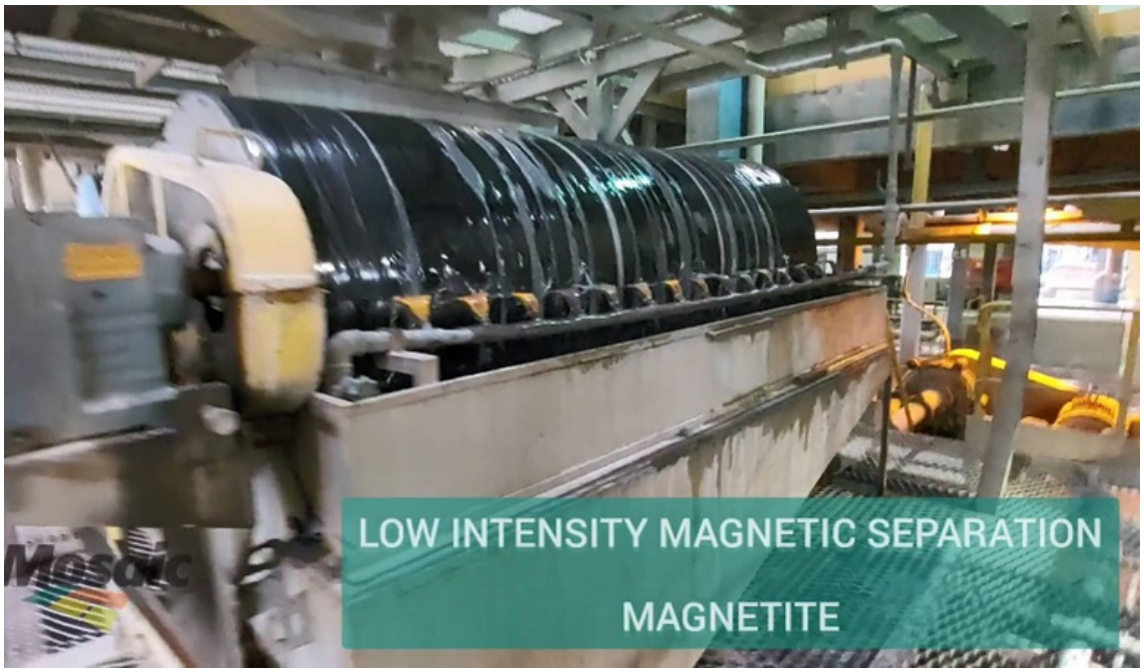


Figure 2: Magnetic stock (Mosaic Fertilizantes)

Project Title	• GYPSUM DISPATCH IN UBERABA
✱ **Partner Institutions**	• N/A
✱ **Project Stage:**	• ( ) Ongoing Surveys/Bench/Pilot/Semi-industrial • (x) **Completed**
✱ **Business Model**	• ( ) Outsourcing • ( ) B2B (x) **Technology Incubation and Internal Development** • ( ) Others:_____
✱ **Main mineral good**	• Gypsum
✱ **Type of Tailings/ Spoil/Non-Mineral Waste**	• Phosphoric acid production waste
✱ **Volume Reused**	• Gypsum dispatch current capacity of • 5,500 t/year.
✱ **New products generated**	• Gypsum
✱ **Investiment**	• BRL 46.1 million

Process description

In Uberaba Industrial Complex (CIU), there are currently four diluted phosphoric acid manufacturing units (U-150, U-160, U-170 and U-180), with total daily production capacity of 2,950 t/day. Phosphoric acid is achieved by means of phosphatic concentrate acidulation (rock) with Sulphuric Acid, which are supplied in agitated reactors.

In U-150, U-160 e U-180 units, Technip technology, the reaction occurs in agitated single bowl reactors. In Prayon U-170 unit, reaction occurs in multi-compartmented reactor and three digesters. In both processes, it is proceeded to humid production route, where dihydrate gypsum is achieved, as main simplified reaction shows:

$$Ca_3(PO_4)_2 + 3H_2SO_4 + 6H_2O \longrightarrow 2H_3PO_4 + 3[CaSO_4.2H_2O] \downarrow$$

Phosphate Concentrate — Sulphuric Acid — Water — Phosphoric Acid — Dihydrate Gypsum

As shown, dihydrate gypsum is the main byproduct of this process, and acid is separated by means of vacuum filtration. Gypsum is removed from filters by worm or tilted screws in a hopper, and follows to pulping tanks with acidic water (forming pulp with 25% of solids), and then is transferred to U-640 plant, or directly to gypsum pile active compartments, via relevant unit pumps. Compartment operation is defined according to operation and mining plans.

Alignment (directly from phosphoric or via U-640), is dynamic, and is selected according to gypsum pile operation quota.

Figure 1: U-640 Gypsum **Pumping Unit (Mosaic Fertilizantes)**

Figure 2: Air view of gypsum pile and existing gypsum pumping lines (Mosaic Fertilizantes)

Gypsum pulp is unload in existing pond in pile top for sedimentation. Acidic water generated is recovered to a pond circuit, along with pluviometric contributions, and it is recycled to process in a large part. Surplus is forwarded to effluent treatment system (ETEL).

Figure 3: Pile pond gypsum sedimentation (Mosaic Fertilizantes)

Figure 4: Gypsum operation, mining and dispatch (Mosaic Fertilizantes)

With second ordinance dispatch in 2022, gypsum dispatch capacity rose from 3,800 to 5,500 t/year, providing further longevity and sustainability to initiative.

KINROSS

ReUse – online platform

PROJECT

KINROSS

Project Title	• REUSE – ONLINE PLATFORM
✱ **Partner Institutions**	• Go & Grow
✱ **Project Stage:**	• ( ) Ongoing Surveys/Bench/Pilot/Semi-industrial • (x) Completed Project implemented in Kinross internal system, which is currently in use by employees.
✱ **Business Model**	• ( ) Outsourcing • ( ) B2B (x) Technology incubation and internal development: Developed internally along with IT internal team and partnership with Go & Grow.
✱ **Mineral good produced**	• Any waste and scrap that is not Class I
✱ **Type of Tailings/ Spoil**	• N/A
✱ **Volume Reused**	• Approximately 100 t of waste reused internally using Reuse + program
✱ **New products generated**	• N/A
✱ **Investiment**	• BRL 30,000

Process description

ReUse + is an online platform, where materials can be registered and queried, that will be available for reuse within Kinross.

Materials including: piping, furniture, packaging, rubbers, scraps, parts, etc.

ReUse + goal is fostering **waste reduction within the company**, stimulating material reuse that are no longer used in its area and that would be disposed.

Online platform to optimize waste management at Kinross Paracatu.

Offering the following opportunities:

- Detailed waste information:
  - Material conditions and type
  - Location
  - Responsible party contact
  - Financial opportunity
  - Cost-cutting with new acquisitions
  - Expense-cutting with waste disposal
  - External sale opportunity
  - Donations
  - 5S
  - Eliminate internal disposal in inadequate locations
  - Eliminate parallel waste and scrap yards

LARGO

Ilmenite Concentration
or Ilmenite Flotation

PROJECT

LARGO

Project Title	• ILMENITE CONCENTRATION OR ILMENITE FLOTATION
✱ **Partner Institutions**	• UFBA, USP, Fundação Gorceix, CEPED, CBPM, SGS
✱ **Project Stage:**	• (x) Ongoing ◆ Industrial Plant Implementation • ( ) Completed
✱ **Business Model**	• ( ) Outsourcing • (x) B2B • ( ) Technology incubation and internal development • ( ) Others: _____
✱ **Main mineral good**	• Ilmenite
✱ **Type of Tailings/ Spoil/Resíduo não minerais**	• Tailings comprised by silicates, mainly pyroxenes and amphiboles
✱ **Volume Reused**	• 23 t at every 120 t of supply (former tailings)
✱ **New products generated**	• Ilmenite Concentrate
✱ **Investiment**	• BRL 170.000.000,00

Process description

Largo Vanádio de Maracás S/A – LVMSA mining company plant is located around 50 km from Maracás municipality headquarters, in rural area, in Bahia State. Ilmenite concentrate production plant (FeTiO3) from non-magnetic tailings will be implemented in LVMSA industrial facilities (Figure 1). Tailings reuse

is aligned with company guidelines of reducing/reusing tailings. Its processing capacity foreseen is 197,648 tons of ilmenite concentrate a year.

There will be no vegetation suppression or another high magnitude environmental impacts, project is located in Largo Vanádio de Maracás industrial park facilities (Figure 2).

Ilmenite is a mineral comprised by iron and titanium with FeTiO3 formula. It is basically used as raw material for titanium compound production, and around 90% of world production of ilmenite is intended to titanium pigment production. It is more usual to find ilmenite in placer deposit, called black sands, that are black color beach sands, due to dark mineral presence. Nevertheless, ilmenite can also be found in rocky deposits, as in the case of Maracás.

At present, in vanadium production, the largest part of ilmenite is segregated from magnetite in a process know as magnetic separation. Magnetite follows the process route, where vanadium is extracted and produced, and ilmenite is arranged in tailings basins. As it is removed from process, ilmenite does not have commercial value, as it is found in low concentration, and aggregated with other silica and iron minerals.

Studies performed by Largo within the last 5 years ended in ilmenite concentration and production route that can be used to rocky deposits. This route uses flotation technology, which, even though it is known in another industries, for instance, iron ore, gold, nickel and talc production, is not widely used to produce ilmenite (Figure 3).

Such development, that engage Largo experts and relied on the assistance of renown Brazilian research centers, was successful, resulting in an ilmenite concentration industrial facility implementation project, which activities are foreseen to start in 2023. This new plant will have rated capacity to produce 145 thousand tons of ilmenite a year, and will create 55 new direct jobs in Maracás.

Ilmenite production will also reduce Maracás plant solid tailings generation around 8%, which means reducing environmental impact, and at the same time, generates job and income to community. Largo ilmenite production will meet own company internal demand to product Titanium pigment (TiO2), new Largo bet in Brazil. White pigment is a product with high added value, indispensable in ceramic, plastic and paint industries, and our target is servicing 2/3 of national product consumption. TiO2 plant project has been conceived under the circular economy view, and will also produce fertilizers from tailings generated in new unit.

Ilmenite production process will be implemented upon vanadium ore processing stage, using non-magnetic fraction, that does not contain vanadium, including ilmenite concentration area supply. Concentrate generated by this plant will represent 20% of non-magnetic material total mass, that at present is arranged in tailings basins, in other words, generated tailings mass reduction will

occur, with consequent basin life increase, and thus, with production process environmental impact reduction (Figures 4 and 5). Ilmenite production plant will include desludge stage to remove aluminosilicates that can damage following concentration processes, three direct flotation stages, in which ilmenite is separated from other minerals through pulp pH adjustment and reagent use make ilmenite hydrophobic, a concentration filtration stage and water reuse. Block diagram below shows the position that ilmenite production plant will occupy in current vanadium production plant process (Figures 4 and 5).

Apart from economic gains and environmental impact reduction already described, this project also has the potential to increase mining undertaking life in Maracás, as a new product generation adds value to mineral resources and enables zone mining that would previously be considered non-economic. Not only this possibility reaches the current deposit, but also neighboring deposits that have similar mineralogy.

Aligned with circular economy concept, the project is not limited only to a new plant, but also provides a vertically integrated model creation, that uses synergy between production process of vanadium pentoxide and ilmenite concentrate, to support the world transition performance towards low carbon future.

Figure 1: Implementation air view.

Figure 2: Ilmenite project delimitation in Largo Vanádio de Maracás industrial area.

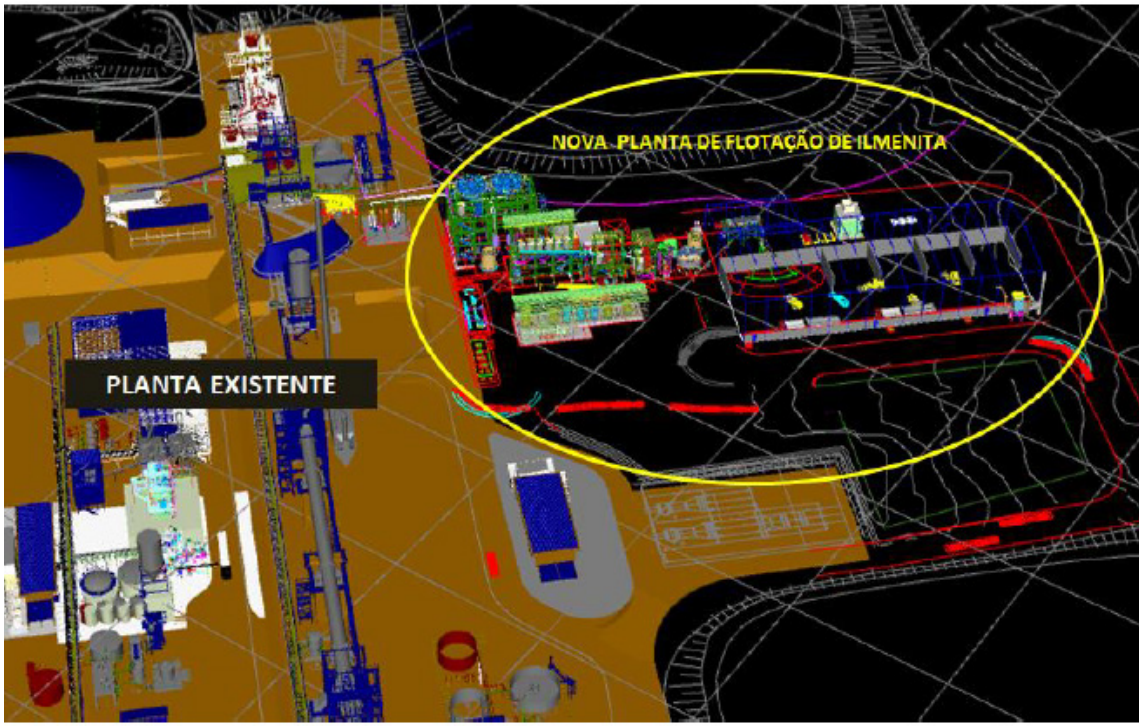


Figure 3: 3D perspective project.

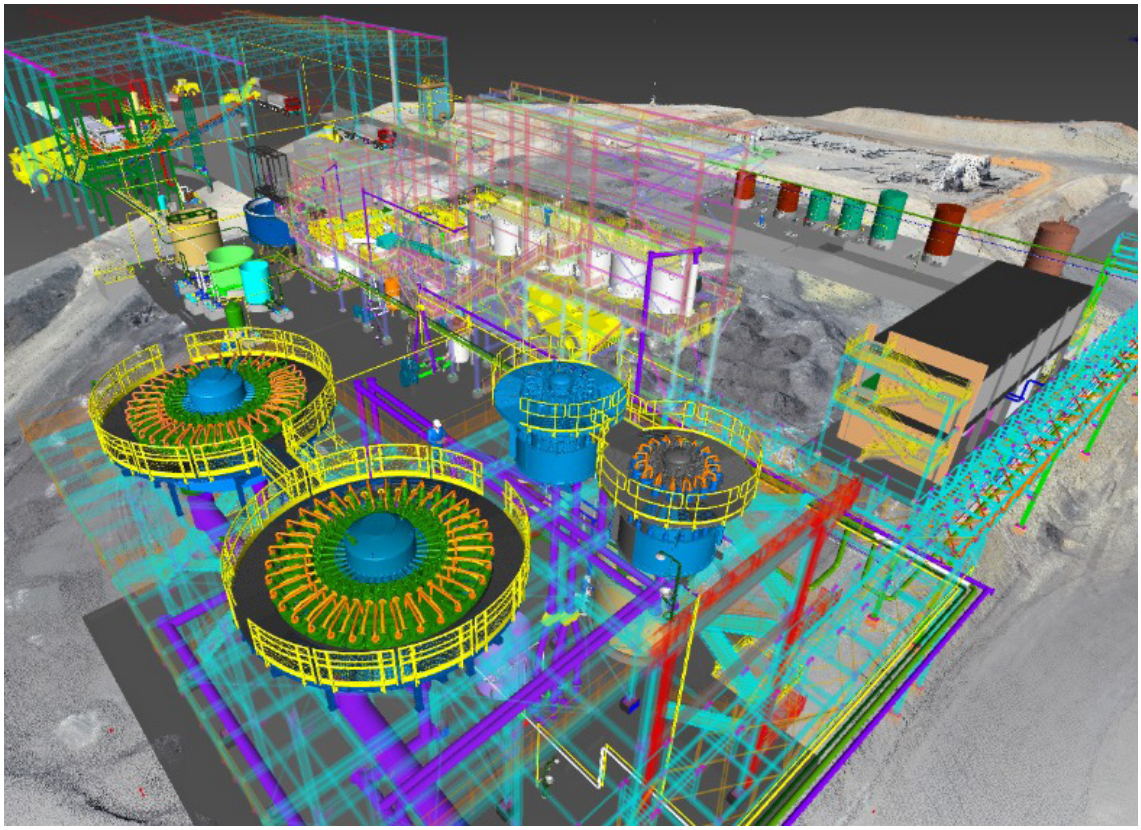


Figure 4: Non-magnetic waste reuse project simplified flow chart

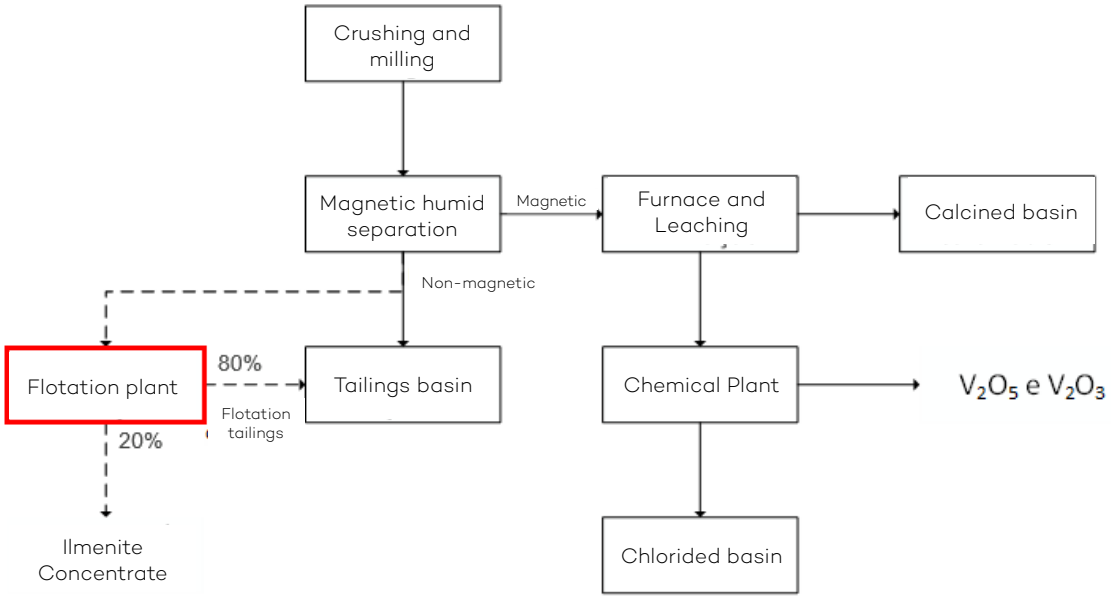
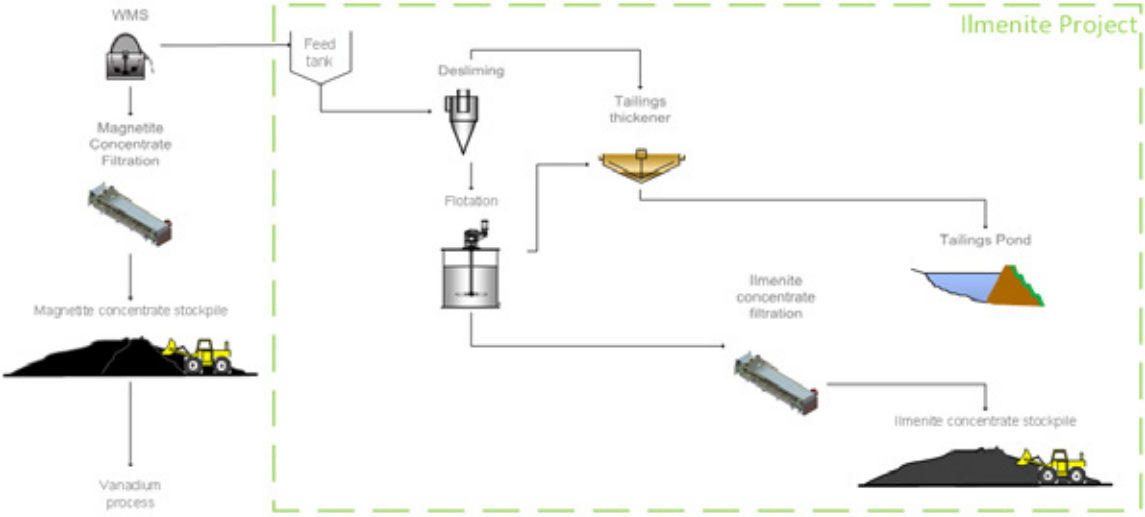


Figure 5: Ilmenite project flow chart.



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