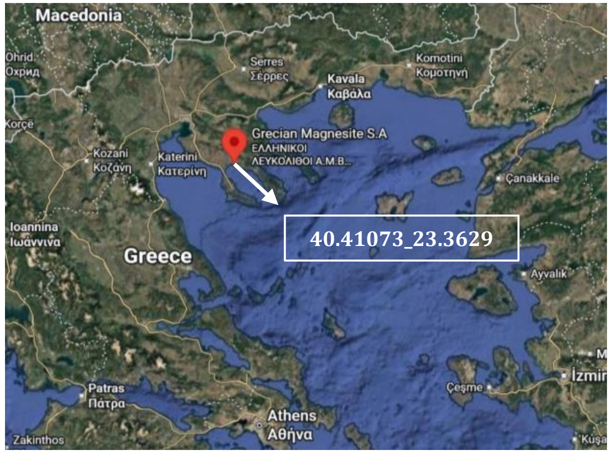
GRECIAN MAGNESITE
ΕΛΛΗΝΙΚΟΙ ΛΕΥΚΟΛΙΘΟΙ

Grecian Magnesite SA-Mining Site



CRM Mg

Overview	CRM Mg	Location
Work Layout Info	VEs Map	Life of Mine VEs
Industrial Applications	Disclaimer	Grecian Magnesite VE

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Overview

General Information

Grecian Magnesite SA is a privately owned company established in 1959 as a mining and industrial concern. However, the magnesite mining expertise goes back to 1914, when J.G. Lambrinides the “eminence grise” of Greek magnesite and a pioneer mining engineer, started the development and exploitation of most of the magnesite activities in Greece.

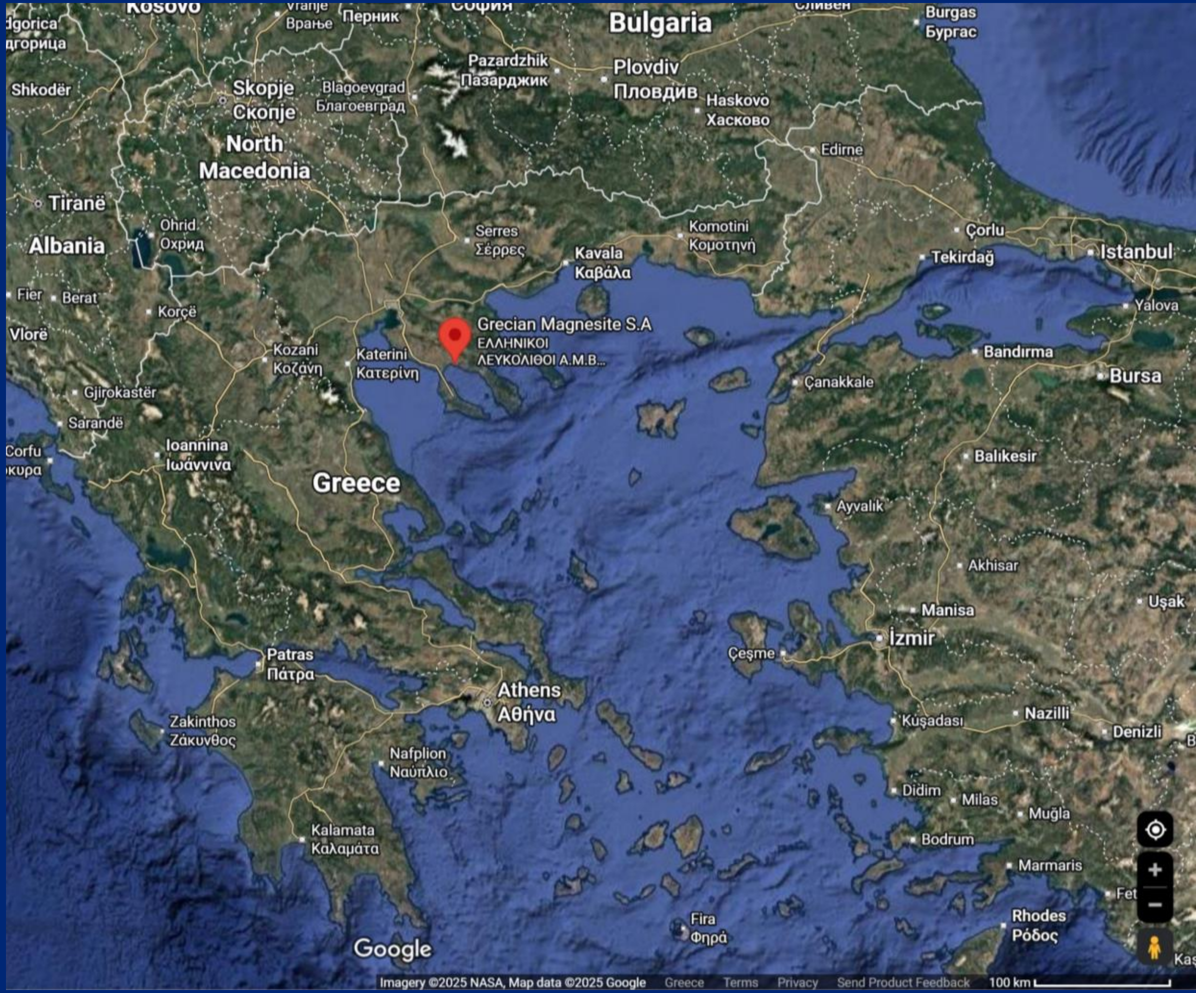
The company’s major deposits and production facilities are located in Chalkidiki, northern Greece, in Eskisehir, central-western Türkiye, and on the island of Euboea, central Greece (small-scale underground mining operation). The "Chalkidiki" & “Eskisehir” deposits consist of six main active concessions totaling 80km^2. The company also owns "reserve" concessions totaling 16 km^2 for future exploitation. Greek magnesite is famous for its whiteness due to the low iron content (as low as 0,02% Fe in the calcined/final product) and the low levels of heavy metals and trace elements. Moreover, low lime content and microcrystalline structure are its additional advantages.

The 360 panoramas in the current VE refer to the Life of Mine (LOM) processes, displaying separately LOM-Taks’ VEs, regarding the exploitation of the CRM-Magnesium that is contained, approximately over 50 %, in the extracted Magnesite, which is applied in a variety of industrial applications.

Map of the Virtual Excursion

<u>Grecian Magnesite SA</u>

- Latitude_40^{o}41’07”
- Longitude_23^{o}36’29”



Flowchart of LOM (Life of Mine)

(LOM) & Environmental Management

The Life of Mine (LOM) includes five basic tasks that should be implemented.

- The first task focuses on the geological survey that evaluates a site area as suitable for exploitation.
- The second task refers to the optimization of mining engineering design, including a memorandum of activities that should be accomplished before the actual primary extraction.
- The third task refers to the implementation of design activities.
- The fourth task involves all the working activities and is crucial for the productivity of the mining site. The final task focuses on optimizing the environmental management action plan based on the physical conditions of each mining site.
- The environmental management system involves the actions of environmental rehabilitation, planting, creating pit lakes, earthworks, or alternative uses of the produced waste in terms of the Sustainable Mining respecting the 4Rs Policy, Green Deal principles, and regulation of the Circular Economy.

It is essential to mention that closure activities have a significant impact on the brand name of a mining company while enhancing social approval, securing funding, and increasing political support for similar activities.

LOM Tasks and VEs

LOM Tasks and VEs

1st Task
Mining Geology
VE

2nd Task
Geotechnical Engineering
VE

4th Task
Mining Extraction
VE

4th Task
Processing
VE

5th Task
Environmental Management
VE

Click on each Task to see the specific teaching material and the corresponding VE

Mining Geology

1. The Gerakini magnesite deposits are vein- and cavity-type magnesite occurrences hosted in an ophiolitic ultramafic sequence (mainly dunite–harzburgite) that has been variably serpetinized.

2. The magnesite formed during late hydrothermal–metasomatic stages: CO_2-rich fluids reacted with serpentinized ultramafics producing pervasive carbonation (magnesitization), with local silicification/listvenitization; this multi-stage alteration is recorded petrographically and geochemically.

3. Ore textures range from massive fine-grained cryptocrystalline magnesite to banded and vein-style fillings, commonly occupying fractures, dunite/harzburgite–host contacts, and tension gashes.

4. Geochemical analyses show high MgO (magnesite/serpentine-related) with variable SiO_2, FeO and minor Cr/Ni reflecting ultramafic protolith and serpentinization; the composition supports a metasomatic carbonation origin.

5. The mining district has both surface-open pit and local shallow underground workings, with mineable depths exceeding ~70 m in places — the geometry and continuity of magnesite veins/dykes is strongly controlled by the ophiolite structural fabric and later brittle fracturing.

Click on the Tabs below for further Information

Source 1 | Source 2 | Serpentinization

Mining Geology-Serpentinization

Serpentinization is the geological process whereby ultramafic rocks, primarily dunite and harzburgite composed of olivine and pyroxenes, react with CO_2-bearing and other low-temperature aqueous fluids. During this alteration, the primary minerals are transformed into serpentine-group minerals (antigorite, chrysotile, lizardite), and brucite ($Mg(OH)_2$) is often formed as a by-product.

In the case of magnesite that contains CRM-Mg in a proportion of approximately >50%:

- Serpentinization acts as a preparatory stage, increasing rock porosity and generating fracture networks.
- This facilitates the subsequent infiltration of CO_2-rich fluids, which replace serpentine with magnesite ($MgCO_3$).
- In simple terms, serpentinization "paves the way" for the formation of magnesite deposits through metasomatic carbonation.

Ultramafic rock (Dunite / Harzburgite)	Serpentinization (formation of serpentine + brucite)	CO_2-rich fluid infiltration	Magnesitization (formation of Magnesite, $MgCO_3$)

Source 1 | Source 2 | Mining Geology Details

Mining Geology-Details

The Gerakini area (also written Yerakini) lies within the ophiolitic complexes of western Chalkidiki (northern Greece), an ophiolite slice made up of ultramafic mantle-derived rocks (dunite, harzburgite, subordinate lherzolite), locally intruded by chromitite lenses and cut by later mafic dikes. This ophiolitic mantle assemblage is the protolith hosting the magnesite.

The immediate host units are dunites and harzburgites that are variably serpentinized. Petrographic studies and analyses show serpentine minerals (antigorite/chrysotile), relict olivine/pyroxene relics, and, in places, chromite intergrowths—evidence that the magnesite replaced or infilled cracks within these ultramafic bodies.

Primarily, the ophiolitic mantle assemblage was serpentinized during emplacement/exposure to hydrothermal fluids, producing serpentine and brucite. Continuously, infiltration of CO_2-rich fluids led to magnesitization—replacement and vein-filling by $MgCO_3$ (magnesite). This is recorded as fine-grained cryptocrystalline magnesite replacing serpentine with/or without olivine, and as distinct magnesite veins and breccia infills. In some localities, silicification/listvenitization (listvenite) developed where silica-rich fluids were involved. The last stage of superimposed oxide/hydroxide phases and minor carbonate re-equilibration occurs locally, reflecting evolving fluid chemistry and temperature.

The Ore occurs principally as vein-type and massive cryptocrystalline magnesite: narrow to metre-scale veins, banded fillings, cavity coatings, and massive pockets. The veins commonly exploit the fracture and shear fabric of the ophiolitic ultramafic, with frequent association with contacts between dunite bodies and harzburgite.

Source 1 Source 2

360-Panoramas
Mining Geology VE

Geotechnical Engineering

1. The magnesite exploitation in Greece is basically an open-pit mine site. There is an occurrence of conventional drilling and blasting processing. Also, there are references to small, low-impact, narrow vein/electric mechanized underground work in specific locations in the Euboea island only.

2. The extracted magnesite ($MgCO_3$) has a density varied from 2.950-3.100 kg/m^3 and unit weight approximately 30,5 kN/m^3. The serpentinite host ore has a density that varies from 2.550-2.850 kg/m3 and a unit weight of approximately 28 kN/m^3.

3. The sterile mining ore (containing screened fines, talus, and low-density aggregates) has a unit weight of 17-22 kN/m^3, while its density equals approximately 2.500 kg/m^3.

Click on the Tabs below for further Information

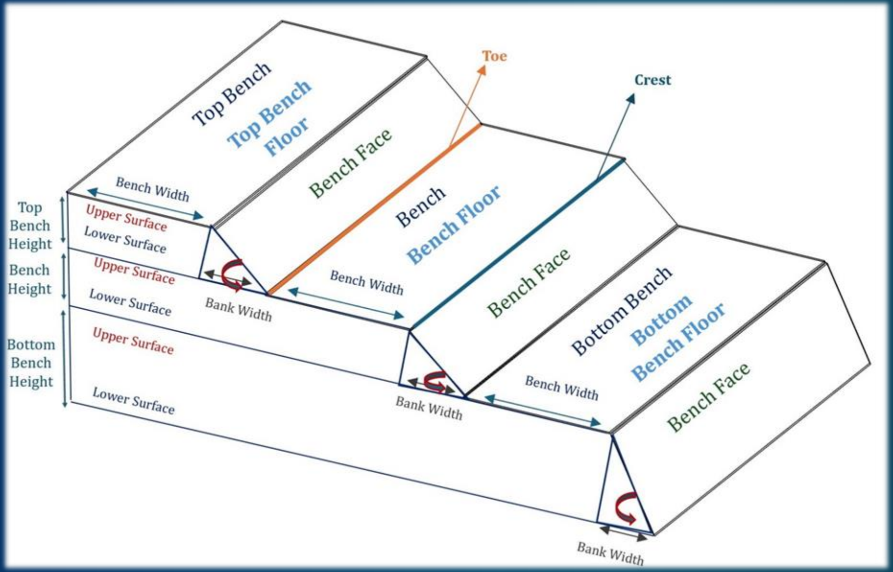
Source 2 | Source 3 | Geotechnical Specs | Exploitation Method

Geotechnical Specs

A/A	Geotechnical specs of the Halkidiki/Chalkidiki-Gerakini/Yerakini Magnesite mining ore	Numerical Values / Description	Click on the Column Tabs to see Scientific Sources / Official Reports / Other Sources
1	Shear Strength of the magnesite mining ore	Typical values for serpentinite rock masses (host rock) Cohesion c ≈ 0.5–1.5 Mpa, friction angle φ ≈ 28–35°.	Diamantis, N. (2023). Engineering properties of serpentinites.
2	Compressive strength of the magnesite mining ore	Typical value for serpentinites: 20–130 Mpa, in some cases up to 200 MPa depending on alteration/weathering.	
3	Hardness of the magnesite mining ore	Mineralogical constituents: Magnesite ($MgCO_3$) Mohs ≈ 3.5–4.5 Serpentine ($(Mg, Fe)_6(OH)_nSi_4O_{10}$] or $X_3Si_2O_5(OH)_4$ (where X can be Mg, Fe, Ni, etc.) Mohs ≈ 3–4.5	Tzamos et al. (2020). Mineralogy and Geochemistry of Ultramafic Rocks from Rachoni Magnesite Mine, Gerakini (Chalkidiki, Northern Greece)
4	Density of the magnesite mining ore	Bulk density of Gerakini by-product samples (sintered): ~2.8–3.0 g/cm^3 (varies with firing).	Pagona et al. (2020), Characterization and evaluation of magnesite ore mining by-products of Gerakini mines (Chalkidiki, N. Greece)
5	Thermal properties of the magnesite mining ore	Thermal decomposition of: a. Serpentine at ~650–680 °C → recrystallization (olivine/pyroxene-$(Mg,Fe)_2SiO_4$) by ~850 °C. b. Magnesite decomposes at ~700–750 °C (release of CO_2)→MgO.	Tzamos et al. (2020). Mineralogy and Geochemistry of Ultramafic Rocks from Rachoni Magnesite Mine, Gerakini (Chalkidiki, Northern Greece)
6	Composition of the magnesite mining ore	a. MgO: 38.7–43 wt % b. SiO_2: 37.5–44.1 wt % c. FeO: 6.5–7.3 wt %.	Tzamos et al. (2020). Mineralogy and Geochemistry of Ultramafic Rocks from Rachoni Magnesite Mine, Gerakini (Chalkidiki, Northern Greece)
7	Concentration in magnesite	Ore veins in Gerakini consist of high-purity magnesite lenses. Reported contents up to >90% magnesite in economic zones.	Grecian Magnesite S.A. company descriptions; general geological summaries.
8	Concentration of the sterile material from the magnesite mining ore	Significant stockpiles of serpentinized ultramafic waste: ~35 million tonnes accumulated. Sterile host rock is mainly serpentinized dunite/harzburgite.	Kalaitzidou et al.2023. MagWasteVal Project—Towards Sustainability of Mining Waste
9	Tectonic characteristics of the Gerakini magnesite mining ore	Magnesite bodies occur in serpentinized ultramafics cut by faults and shear zones. Alteration assemblages: serpentinization, carbonation (listvenite), silicification. Mineralogical zoning is controlled by tectonics.	Tzamos et al. (2020). Mineralogy and Geochemistry of Ultramafic Rocks from Rachoni Magnesite Mine, Gerakini (Chalkidiki, Northern Greece)

Exploitation Method
Benching Characteristics & Terminology

A/A	Terminology	Definition
1	Bench	The uncovered horizontal part or block of the mineral, ore, or overburden is separated by its lower and upper surfaces and is called a bench.
2	Crest	It is the top part or point of a bench face (or bench).
3	Toe	It is the bottom part or point of a bench face (Bench).
4	Bench Height	It is the vertical distance between the uppermost surface (crest) and the lowermost surface (toe).
5	Bench Width	It is the uncovered horizontal distance between the toe & crest measured along the upper surface.
6	Bench Floor	It is the uncovered horizontal bottom surface of the bench.
7	Bentch Face	It is the uncovered sub-vertical surface of a bench.
8	Bench Slope Angle, symbolized with	It is an inclination of a bench face with the horizontal plane.
9	Bank Width	It is the horizontal projection of the slope face.
10	Angle of Repose	It is the maximum slope at which a pile of loose material will stand without sliding.



360-Panoramas
Geotechnical Engineering VE

Primary Extraction

1. The Primary extraction of the magnesite is accomplished using the Benching exploitation method.
2. The Bench height ranges from 6-12 meters.
3. The used machinery equipment involves:

a) Wheeled or crawler excavators that extract the mining ore from the Bench Face

b) Bulldozers that load the extracted mining ore onto dumper trucks

c) Dumper trucks that transfer the extracted mining ore to the processing unit for grinding, sieving, and calcination

The primary extracted mining ore contains approximately 40 % of MgO, 40 % SiO_2, and 7 % FeO. The final product contains extremely low iron content (0,02% Fe) after the calcination. Also, it contains a very low amount of heavy metals and trace elements.

Source 2 | Source 6 | Primary Extracted Raw Material

Primary Extracted Raw Material

The primary extracted mining ore of usually contains 38,7-43% MgO w/w.

Ar(Mg)=24, and Ar (O)=16, Mr (MgO)=40, so, the w/w % concentration of MgO in Mg equals 60 %.

So, the primary extracted magnesite mining ore contains approximately 24 % CRM of Mg.

The primary extracted magnesite mining ore is optically separated into coarse and sterile material.

The stacker machine separates and places the coarse sterile material in stockpiles at the main processing square as shown in Figure 1.

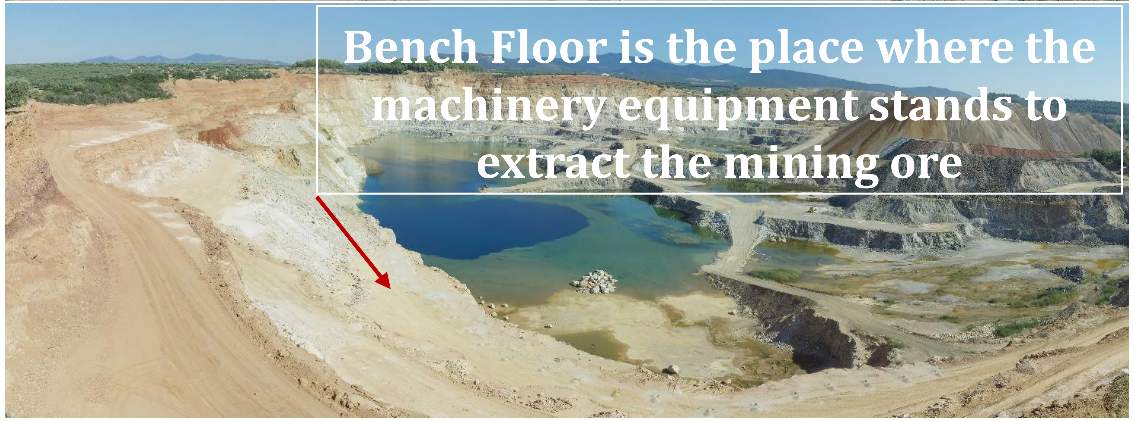
Figure 2 demonstrates the occurrence of coarse beneficial material after the first optical separation.

Coarse Sterile Magnesite mining ore

Macroscopic view of the Primary Extraction and Used Machinery Equipment

Coarse Beneficial Magnesite mining ore

Macroscopic view of the Primary Extraction and Used Machinery Equipment



Wheeled Excavator

Crawler Excavator

Dumper

Bulldozer

360-Panoramas
Primary Extraction VE

Processing

The Processing of magnesite mining ore is separated in two major Steps:

Step 1_The **Pre-Beneficiation Processing**_Physical Methods of Separation.

This Step involves the Grinding procedure of the raw material, and the Sieving procedure of the material after the Grinding. Then the raw material is washed and primarily separated, through the optical sorting and magnetic separators, into coarse and fine.

Step 2_The **Beneficiation/Calcination Processing**_Thermal/Ignition Method of Decomposition.

The raw material produced by the Pre-Beneficiation Processing is washed and enters the magnetic separation to extract the high-purity Mg compounds from the mining ore.

After the magnetic separation, the calcination procedure starts, primarily increasing the temperature to 850^oC to decompose the CO_2 from $MgCO_3$, producing the caustic magnesia, and continuously to 1900^oC to produce the deadburned magnesia.

The produced MgO, is sieved to get the size of 100μm (powder) and disposed in the market.

Source 7 | Source 8 | Pre-Beneficiation Processing

Pre-Beneficiation Processing

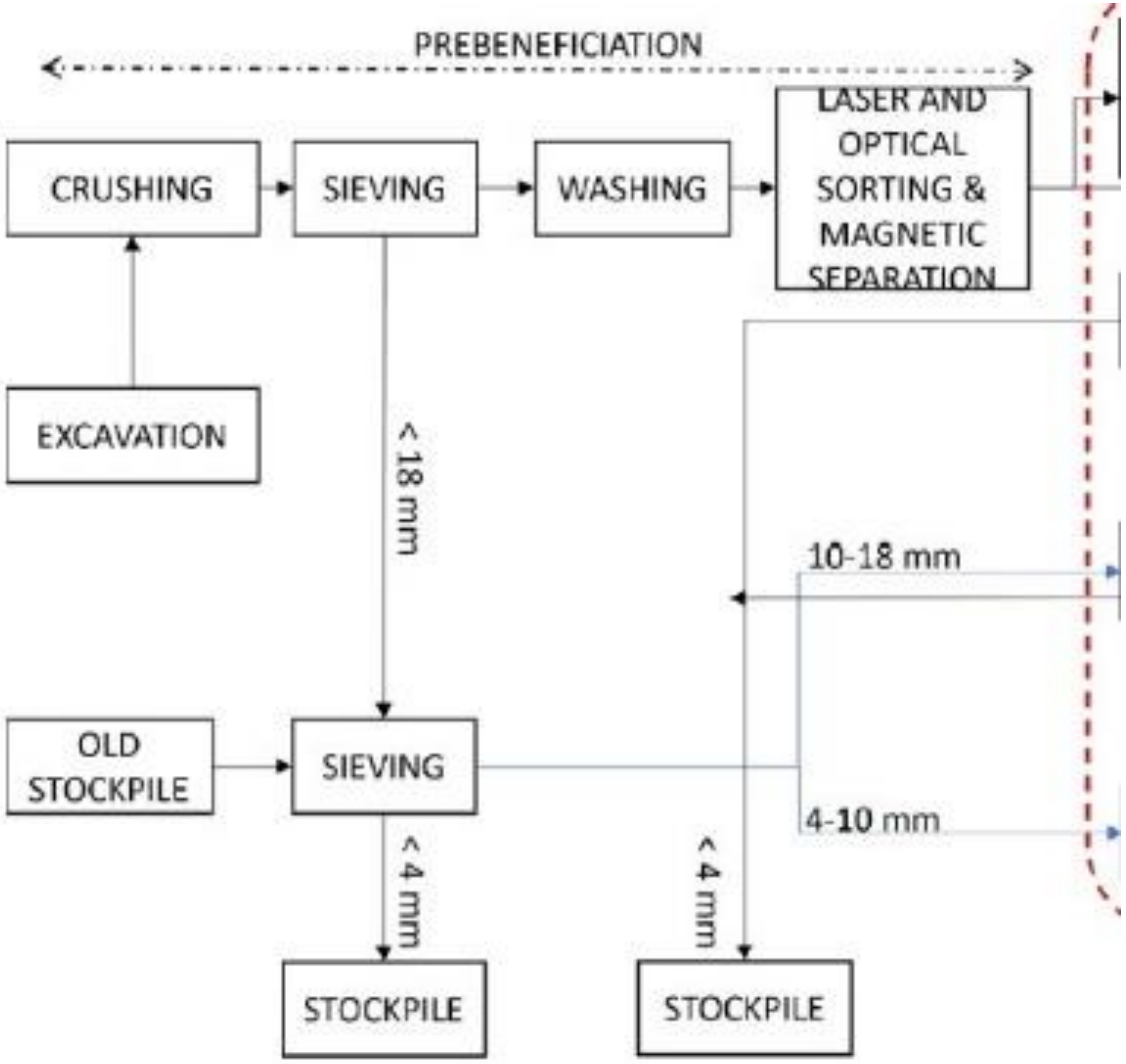
The Pre-Beneficiation Processing of magnesite mining ore involves the Grinding and Sieving procedures:

Grinding
The Grinding procedure of the raw material aims to minimize the size of particles at 18 mm.

Sieving
The 1st Sieving procedure of the grinded material aims to separate the particles' size between the lower and upper 18 mm.

The lower 18 mm particles' size enters to the 2nd sieving to minimize its size at 4mm.

So, the two fractions: a) of 4-10 mm and b)10-18 mm enter to the beneficiation Processing



Beneficiation/Calcination Processing

Source 7

Beneficiation/Calcination Processing

Beneficiation/Calcination Processing of magnesite mining ore aims to produce a high purity of MgO final product.

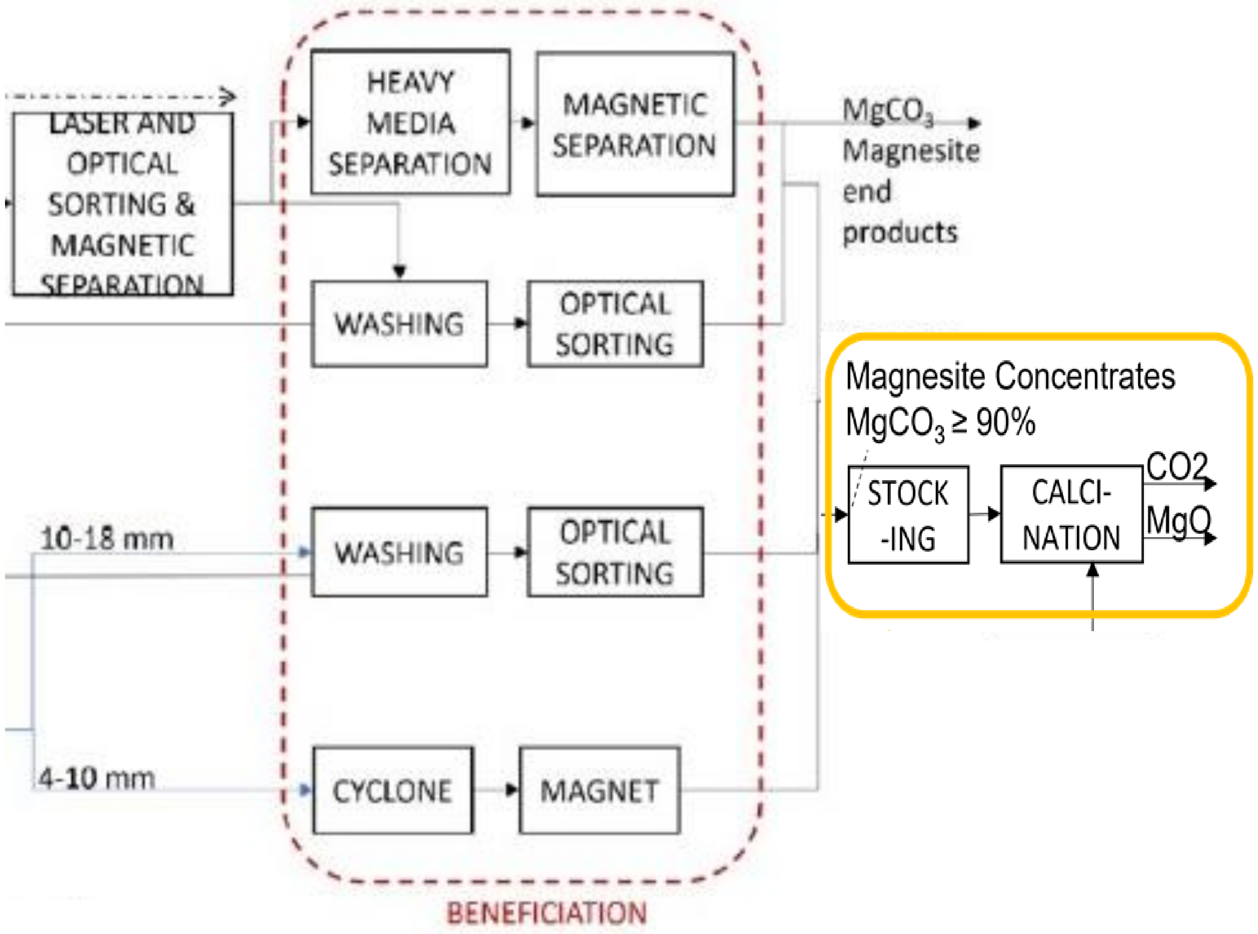
Beneficiation

The Beneficiation Processing of the raw material aims to separate the pure $MgCO_3$ raw material through washing, optical sorting and magnetic separation. The final beneficiated raw material contains 90% of $MgCO_3$ before entering to the Calcination Processing.

Calcination

The Calcination Processing aims to decompose the CO_2 from the $MgCO_3$, through the primary and secondary ignition processing at approximately 850-900 °C, 1800-1900 °C, respectively. The final high purity of >90% MgO powder product has a variety of industrial applications.

$MgCO_3 \longrightarrow MgO + CO_2$



Calcination Processing Unit

Source 7

Calcination Unit

To achieve an efficient thermal processing of calcination, a temperature range of 850-900^oC is required. Based on that, the provided thermal power should be approximately 2000^oC. So, the heating of Pet Coke fuel (containing hydrocarbons) is needed, due to its high thermogenic capacity.

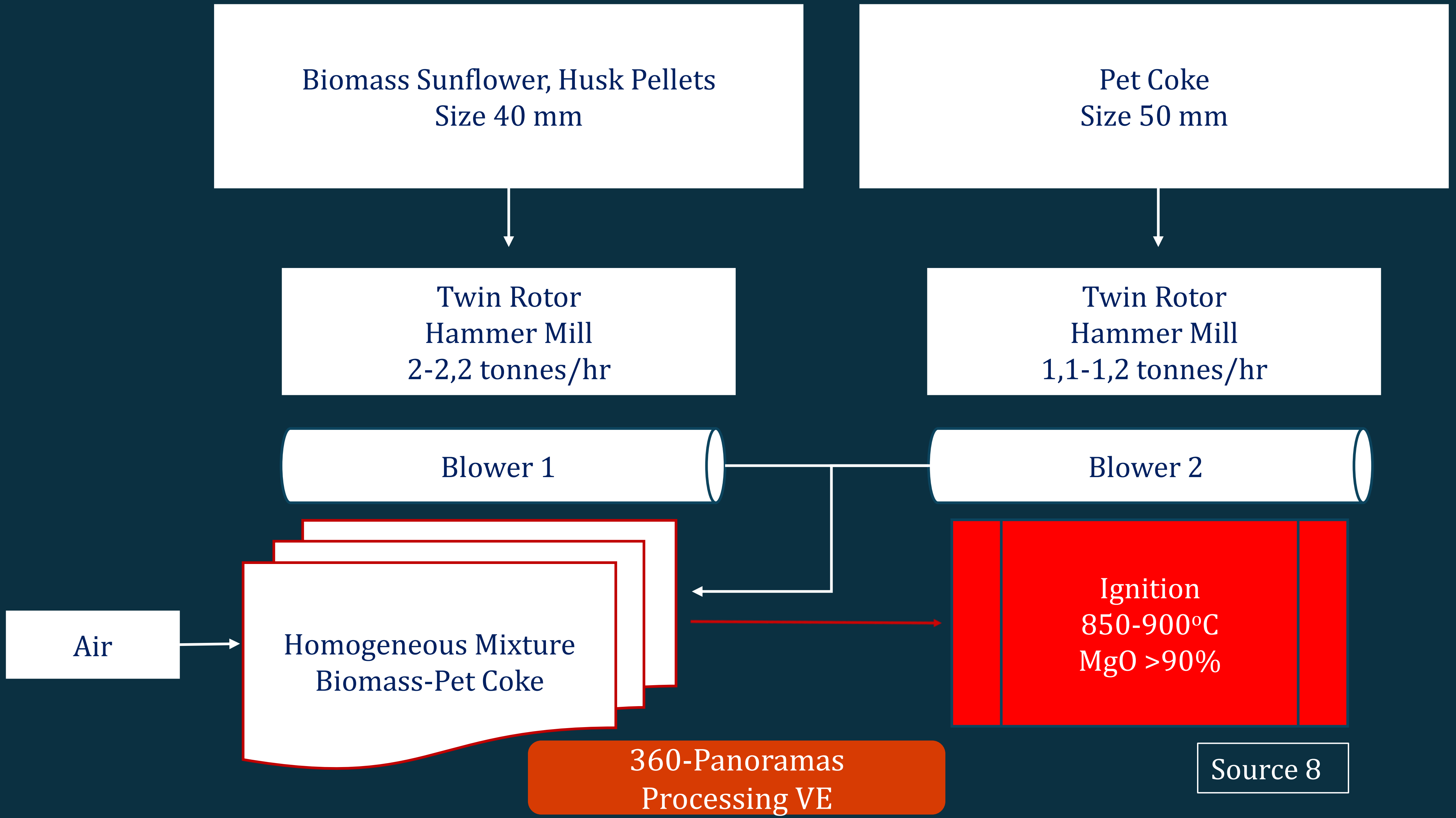
The emissions of CO_2 from the decomposition of $MgCO_3$ are unavoidable.

So, the innovation of the R&D of the Grecian Magnesite SA to minimize the CO_2 pollutants, in respect of the Green Deal principles, focuses on the biomass & pet coke co-combustion.

Calcination-Innovative Ignition Plan

Source 8

Calcination Unit-Innovative Ignition Plan



Work Layout-Info

Primary Extraction to Beneficiation

The entire work layout of the mining activity for the Magnesite extraction and Magnesium beneficiation involves the following working tasks.

1. Primary extraction of the mining ore of magnesite, including coarse, sterile, and beneficial material.

2. Processing-first separation of the coarse sterile material from the coarse beneficial material in the processing unit using the Stacker machine.

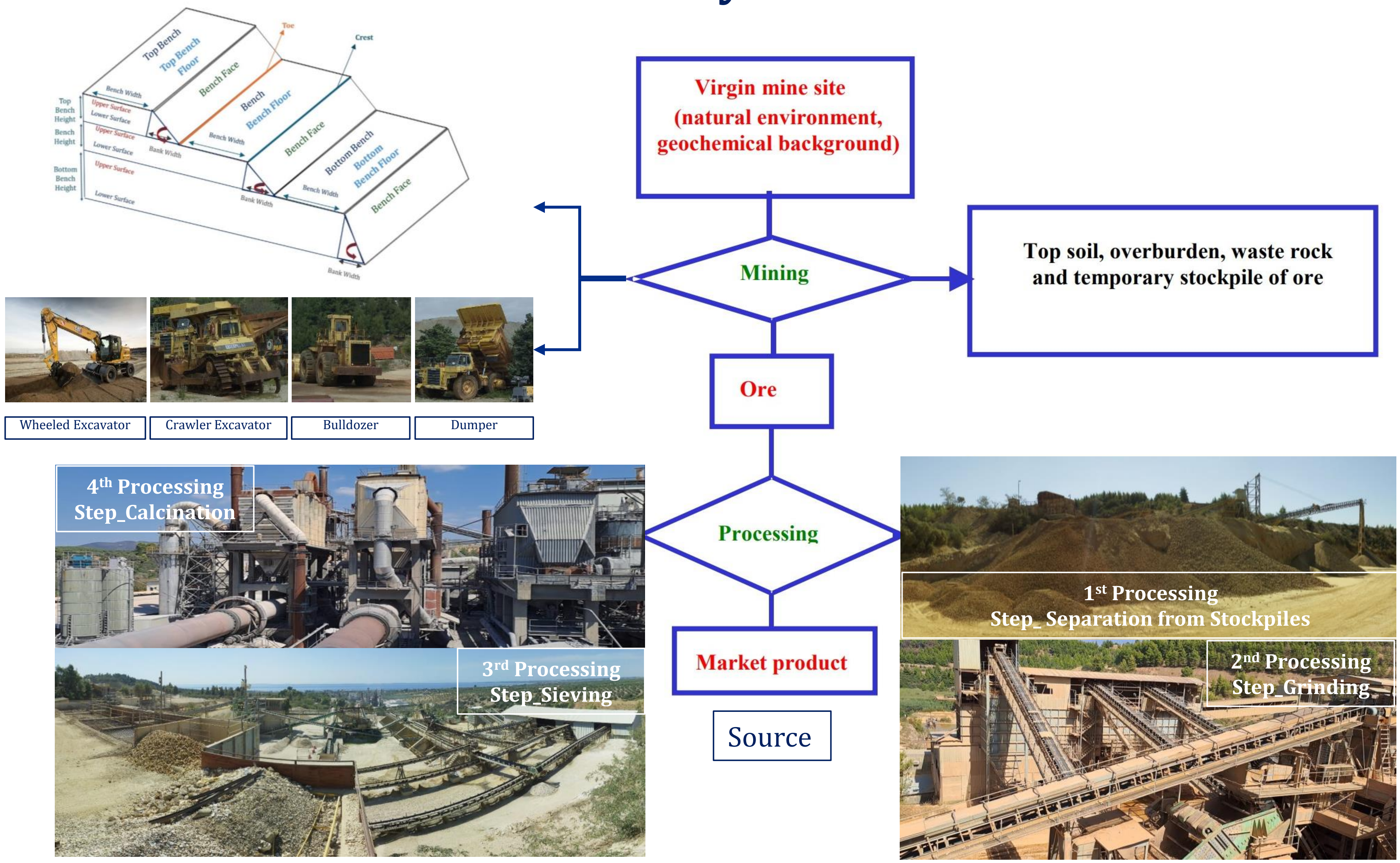
3. Processing-transportation of coarse and fine beneficial materials from the primary square of the extracted mining ore stockpiles to the processing unit for grinding and sieving.

4. The transportation of the beneficial material to the beneficiation/calcination unit using trucks.

5. The beneficiation/calcination unit to transition $MgCO_3$ into MgO that contains a high amount of Mg, ready to be used in a variety of industrial applications.

Work Layout Flowchart

Work Layout Info



Environmental Management

Flows of Environmental Management

The Grecian Magnesite SA mining company is certified with the ISO 14001:2015 Environmental Management System (EMS) and adopts the principles of Green Deal regarding the 4Rs (reduce waste volume, recover, reuse, and recycle) policy.

The Flows of Environmental Management Action Plan are separated into:

1. Environmental Rehabilitation after the end of life of Primary Extraction.
2. Minimization of CO_2 emissions during the Calcination
3. Reuse of the produced by-products a) as structural material in the cement industry, and b) for fertilizing
4. Practical Research for Beneficiation of the mining waste

Source 9

Reforestation

Investment on 4Rs & Green Deal

Environmental Management

Environmental Rehabilitation-Reforestation

The company rehabilitates disturbed areas following the "spoil-to-soil" philosophy with three main techniques: reshaping, soil covering, and reforestation.

To date, over 124.000 trees, shrubs, and saplings have been planted. Wastewater from ore washing is treated naturally in conventional settling tanks, and 90% of the water consumed is reused.

The company systematically manages non-mining waste and ensures a clean and safe working environment for employees.

Based on the specific requirements of each case, appropriate reshaping of the disturbed areas first takes place, followed by resoiling, namely final coverage of the reshaped areas with topsoil. Regreening finally takes place, i.e. selection and planting of the appropriate plant species on the resoiled areas.

The vegetation used comprises such forest species as pine trees, acacia trees, eucalyptus trees, olive trees, different types of bushes etc. Drip irrigation systems supplied exclusively with groundwater are installed in all restored areas.

Source 9 | Reforestation Data

Environmental Management

Environmental Rehabilitation-Reforestation

Land Use - Environmental Rehabilitation│Basic Indicators (Year)	2021	2022	2023	2024
Total land area used for exploitation, at the end of the calendar year (km^2)	2,274	2,295	2,295	2,295
Total land area that has been rehabilitated since the implementation of Law No 998/1979 (km^2)	1,641	1,641	1,651	1,651
Number of trees and seedlings planted since the implementation of Law No 998/1979	123.609	124.697	125.351	125.774
Rehabilitation costs (€) per year	407.703	330.601	279.237	224.118

Source 9

To this day, more than 1,640 km^2 of disturbed areas have been restored by Grecian Magnesite, whereas the overall number of trees and seedlings planted exceeds 124.000. It must be highlighted that the majority of seedlings used in mine rehabilitation campaigns come from the company's proprietary nursery.

Environmental Management

Flows of Environmental Management

Grecian Magnesite is the first Greek company to be eligible for a €4,85 million funding by the National Recovery and Resilience Plan Greece 2.0.

The 10 m€ investment scheme, co-funded by the National Bank of Greece (€2,91 million) and Grecian Magnesite (€2,3 m€), aims for a new green deal enhancing productivity, spurring competitiveness, and promoting environmental and human welfare.

The 5-year plan will particularly focus on 3 pillars:

1. Climate Neutrality - mine electrification project, contributing to zero CO_2 emissions due to battery-electric driven machines.

2. Circular Economy - sustainable use of mineral resources with advanced **Processing** technologies **(Co-Combustion)**, Utilization of Processing by-products, and new Product Development from mining waste.

3. Green Energy Transition - further boost of initiatives already carried by Grecian Magnesite such as the replacement of fossil fuels (Pet-Coke) with sustainably-produced Biomass, the maximization of Energy efficiency, and the use of solar photovoltaic technology.

Source 9

360-Panoramas
Enviro-Management VE

Industrial Applications

Mg CRM has a key role on the final Caustic or Deadburned Magnesia (MgO, 56,4 % Mg) product

The final powder product of Magnesia, which contains approximately 56.4% Magnesium, has a variety of industrial applications due to its Mg content. The chemical and industrial uses are shown in this Table.

Industrial & Chemical Uses of Mg contained into MgO	
Magnesium Compounds	Fuel Additives
Leather Tanning	Mineral Insulated Cables
Dental Applications	Food Additives
Heating Elements (electrical powders)	Nickel Processing
Rubber & Plastics	Specialties
Glass Making	Uranium Ore Treatment
Catalysts	Detergents
Foundries/Metallurgy	Pigments
Fillers	pH adjustor
Pulp & Paper	Brake Lining

Other Uses

Source 9

Industrial Applications

Mg CRM has a key role on the final Caustic or Deadburned Magnesia (MgO, 56,4 % Mg) product

The final powder product of Magnesia, which contains approximately 56.4% Magnesium, has a variety of industrial applications due to its Mg content. The other uses of Mg contained in the produced magnesia are shown in this Table.

Other Uses of Mg that contained in MgO			
Construction	Agricultural	Steel/Refractories	Environmental
Industrial Floors	Animal Nutrition	Spinel Production	Fuel Gas Treatment
Panels	Calf Milk Replacement	Special Refractories	Soil Decontamination
Abrasives	Fertilizers	Slag base	Waste Water Treatment
Ceramic Tiles		Special Ceramics	
		RGFM Bricks	

Source 9

CRM
Magnesium (Mg)
Click to see Criticality Assessment of Mg

Supply Risk: Risk Grade of the material resources

Economic Importance: Grade of the material's price value to the market

Criticality: Grade of material's impact on the Market

CRM	Supply Risk SR	Economic Importance EI	Criticality CR
Magnesium (Mg)	**4.1**	**6.7**	**27.47**
Ranges for SR, EI, CR	**0-5**	**0-9**	**0-45**
Impact on SR, EI, CR (%) (Numerical Value of the CRM) ÷(Maximum Threshold)	$(SR)_{CRM} \div (SR)_{Max}$ **82%**	$(EI)_{CRM} \div (EI)_{Max}$ **74.4%**	$(CR)_{CRM} \div (CR)_{Max}$ **61%**

Source: European Commission: Directorate-General for Internal Market, Industry, Entrepreneurship and SMEs, Grohol, M. and Veeh, C., *Study on the critical raw materials for the EU 2023 – Final report*, Publications Office of the European Union, 2023, https://data.europa.eu/doi/10.2873/725585

Criticality Matrix

Criticality Matrix		Supply Risk (SR)				
		1	2	3	4	5
(CR)=(EI)*(SR)						
Economic Importance (EI)	1	1	2	3	4	5
	2	2	4	6	8	10
	3	3	6	9	12	15
	4	4	8	12	16	20
	5	5	10	15	20	25
	6	6	12	18	24	30
	7	7	14	21	28	35
	8	8	16	24	32	40
	9	9	18	27 **(Mg=27.47)**	36	45

- The **Criticality Matrix** displays a quantitative assessment of the Criticality grade for each examined raw material, based on the information contained in the European Study on CRMs, as shown below on this slide.
- The **Supply Risk (SR)** and **Economic Importance (EI)** refer to variable parameters that depends on the entire resources of raw materials and their configured price values according to their demand, respectively. i.e. the SR of a raw material could fluctuate within a period. Therefore, depending on the global resources data and industrial needs, the corresponding Study for CRMs could be updated, including the existing SR and EI indices for raw materials.
- The **Criticality (CR)** is configured by the multiplication of EI and SR grades. The CR index shows the criticality grade of each examined raw material.

Source: European Commission: Directorate-General for Internal Market, Industry, Entrepreneurship and SMEs, Grohol, M. and Veeh, C., *Study on the critical raw materials for the EU 2023 – Final report*, Publications Office of the European Union, 2023, **https://data.europa.eu/doi/10.2873/725585**

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