The future of Greek laterites in the green transition.

Nickel, with its unique properties, is a strategic metal for many modern industrial processes. The main application where nickel is used is the production of stainless steel and accounts for 65% of global consumption based on 2023 data. In the last five years, there has been a particular increase in the production of electric vehicles which in turn leads to an increase in demand for lithium-ion batteries, which in turn strengthens the need for nickel (500,000 tn/year). This rapidly changing sector of the automotive industry is increasingly favoring technologies with high nickel content, such as nickel-cobalt-aluminum (NCA) and nickel-cobalt-manganese (NCM) batteries that show unique properties such as high energy density and increased storage capacity. It is worth mentioning that in the last two years there has been a shift of city car manufacturers to economical batteries (LFP - Lithium Iron Phosphate). In accordance with the above and the following reports of the International Energy Agency,

- "The Role of Critical Minerals in Clean Energy Transitions" (2021, 2023)

- "Net Zero by 2050: A Roadmap for the Global Energy Sector"

The organization's final projections for nickel and cobalt demand through 2050 state that:

1. the demand for nickel for battery manufacturing will quadruple or even quintuple by 2050 in scenarios that align with the Paris goals (Net Zero Emissions by 2050). Global production will need to increase dramatically, with estimates reaching more than 6 million tons of consumption. tons per year (currently ~3.6 million tons).
2. The corresponding demand for cobalt in batteries is expected to double or triple by 2050, depending on the speed of the transition to high-performance batteries. However, as mentioned, the development of cobalt-free batteries (e.g., LFPs) may limit the increase. In high-demand scenarios, annual consumption can reach 500,000 tons (today ~200,000 tons).

The main factors influencing the demand for nickel and cobalt are the increase in production of electric cars, the development of energy storage systems (batteries), technological developments (e.g., batteries with less cobalt) and governments' policies for the green transition.

Taking into account the above provisions, the European Commission published on 16 March 2023 a Critical *Raw Materials Act,* which is designed to guarantee secure and sustainable supply chains for the EU's green and digital future. The EU Legislative Act (CRM) sets "clear benchmarks for the production of critical raw materials by 2030", Specifically, it states that:

1. At least 10% of the EU's annual consumption of each metal on the CRM list should be mined within the European Union.
2. The processing of each metal on the CRM list should account for at least 40% of the EU's annual consumption.

3. at least 15% of the EU's annual consumption should come from recycling and
4. no more than 65% of the annual consumption of each EU raw material strategy at any relevant processing stage may be imported from a single third country."

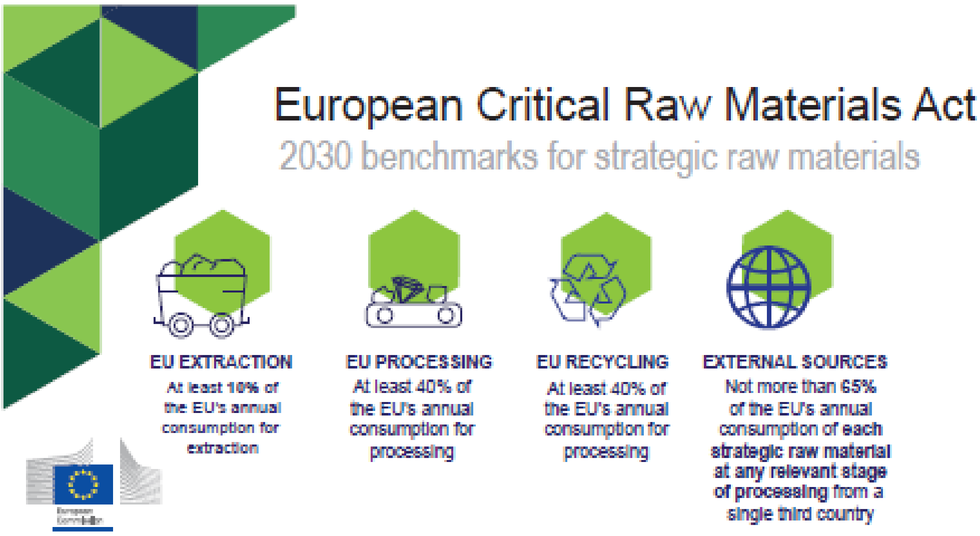

Figure1. European Critical Raw Materials Act

Globally, total global nickel reserves have been estimated to contain more than 350 million tons of nickel, of which 54% is found in laterites and 35% in sulfide deposits. In nickel-containing ores, cobalt is the main companion metal of nickel. The content of cobalt is relatively low, however due to the high demand for cobalt currently, it is also a promising metal for recovery.

The last few decades have been marked by a notable shift towards the increasing use of lateritic ores for nickel production compared to the past when sulfide ores were mainly used. Laterite deposits are widespread in tropical regions of the world, including Caledonia, Australia, Cuba, Brazil, Colombia, the Philippines, Indonesia and India. Based on today's data, Indonesia, with fairly large laterite reserves, is the world's main nickel producer, accounting for about 48% of global nickel production.

The highest quality lateritic ores are industrially processed using pyrometallurgical and hydrometallurgical methods. The choice of method depends on the chemical composition of the ore in order to achieve optimal performance in relation to the cost of production.

Pyrometallurgical methods are used in the processing of ores with a nickel content of more than 1.5%. In this case, the ores are processed through energy-intensive processes, such as drying, calcination, calcination, and melting. The pyrometallurgical method is commonly found in rotary furnace and furnace-electric arc (RKEF) setup, it is widely used to produce ferronickel or nickel cast iron which is the raw material for the However, this process entails high energy costs, generates large amounts of solid waste, and has potential environmental impacts due to greenhouse gas emissions. In addition, the RKEF method is not successful in recovering cobalt as a separate product and is economically vulnerable to reducing the nickel content of the ore.

In the case of hydrometallurgical methods, inorganic acids, inorganic and organic solvents or combinations thereof are used to process ores for the extraction of metals. Basically, hydrometallurgical processing is used for ores with low nickel content, and it is possible to recover cobalt. The main hydrometallurgical method currently applied is acid extraction under high pressure using sulfuric acid (HPAL), while heap extraction (Heap Leaching) is also applied under specific conditions.

In the European Union, the only country that has such ores is Greece, which, of course, due to its size, has significant lateritic reserves which, with proper planning and proper exploitation, could play an important role in the effort to rid Europe of independence from China and to incorporate the production of Nickel in Greece under certain conditions in the Critical Raw Materials Act of the European Union. In order to achieve the above objective, it is necessary to apply hydrometallurgical processing methods to the Greek laterite ores, in order to enable the recovery of nickel and cobalt and to make the overall process economically competitive. The main reason for the change in the processing method of Greek laterites is the reduction of their Nickel content, as after 55 years of exploitation for the production of ferronickel, 95,000,000 tons of laterite have been consumed in the pyrometallurgical unit of LARCO, corresponding to a production of 765,000 tons of Nickel. In the case of Greek laterites, long-term research has been conducted on the recovery of nickel by hydrometallurgical methods, but it has not been applied on an industrial scale in Greece. Of course, the possibility of applying these methods should be reviewed in the light of the new data and the best method chosen. It is worth mentioning, however, that even under the current conditions, Greek laterites could meet the requirements of the European Union for the production of nickel and cobalt for batteries, since with the annual processing of 2,300,000 tons of laterite, which was a normal quantity produced by the mines during the operation of the ferronickel metallurgical unit of LARCO in Larymna, About 17,000 tn of nickel for batteries and 1,500 tn of cobalt can be produced by hydrometallurgical methods. These quantities correspond to 10% of the European Union's requirements and meet the first criterion of the European Union Critical Raw Materials Act.

The hydrometallurgical methods that have been developed and are being applied or are being considered for application in industry to recover nickel from laterites are the following:

1. Caron process,
2. high-pressure acid leaching (HPAL),
3. acid heap leaching (HL)
4. acid extraction in reactors (AAL) with Sulphuric acid,
5. bio - leaching and
6. acid leaching in reactors with hydrogen chloride or other acids.

Among the hydrometallurgical processes for laterite processing, the process of acid leaching, either under HPAL high pressure (Figure 2), or in heaps, is the most efficient, offers a less energy-intensive method for the recovery of nickel and cobalt than the Caron method applied since the 70s and has much lower energy requirements than pyrometallurgical processes.

The acid leaching method with Sulfuric acid (H2SO4) is now successfully used in many regions of the world. With this method, the production of nickel and cobalt, which is a key component, is possible, while it is worth studying the possibility of recovering the third component of manganese batteries contained in Greek laterites. Of course, depending on the method chosen, high capital investments and relatively high operating costs may be required.

In the last 20 years, the application of hydrometallurgical methods to produce nickel sulfate used in batteries or intermediate products such as mixed hydroxide precipitate (MHP) and mixed metal sulfide precipitate (MSP) has exploded, and new plants around the world are being put into operation. Among these intermediates, MHP is increasingly used for the production of battery-grade nickel sulfate, primarily through high-pressure acid extraction technologies.

Figure 2: Glencore's Murrin Murrin hydrometallurgical plant in Australia.

According to the above analysis, it is understandable that there is continuous research for the improvement or development of the methods of either extraction or treatment of the solution. This is because a principal factor in the choice of the hydrometallurgical process is the mineralogical characteristics of each deposit and type of ore, as they directly affect the processing efficiency and its energy requirements.