I4-GREEN

D4.5 – Final public report including ecosystem extension assessment

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Description of the related task and the deliverable. Extract from DoA	T4.5 Ramp-up (M9-M30) Lead Beneficiary: LAIN, Contributors: ATALAYA, ACPMR, JdA The final phase of the I4-GREEN project will be for E-LIX to ramp up to reach the targeted metal production (up to 10kt of metal per year). Metal recovery achievement is a key as it defines the value that can be drawn from the treated mineral as the extracted metals will be the ones sold afterward. The usability of the plant (hours of availability) is also key in that respect as are mineral treatment requirements to balance the economic efficiency of the process. The unitary cost per metal produced will be in line or even below initial estimates to ensure the technology is competitive, scalable, and applicable to other mineral deposits and different types of mineralogy as resulting from T4.1 & 4.2, thus increasing Atalaya's revenues and bringing the possibility of business expansion. Post-I3, E-LIX will generate more than 150 direct jobs in Atalaya and potentially 1000 indirect jobs over its first years of operation, while Lain Tech would reach about 100 direct and 550 indirect additional jobs within 5 years if the process recovery plant approach is mirrored and replicated in other deposits across Andalusia region. The ramp-up will synchronise with the replication work that JdA and ACPMR will carry out in the study of possible similar deposits and mining tailings in which applying the E-LIX plant, what could generate a new paradigm in the sustainable supply of particularly Cu, Zn and Cobalt in the south of Europe, generating employment and recovering depressed zones where the mining was abandoned leaving a collection of mining tailings that can be now used as a global source of supply for the Green transition. We aim to publish a public report on the ELIX experience with the aim to further consolidate the tech diffusion along the interregional ecosystem and promote this success story.			
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Glossary	
Acronym	Meaning
IPB	Iberian Pyrite Belt
SX-EW	Solvent extraction - Electrowinning
TRL	Technological Maturity Level

1. Executive summary

This deliverable within the I4-GREEN project, led by Lain Technologies, presents the results of the ramp-up phase of the E-LIX industrial plant located in Riotinto, Huelva. This pilot, funded by the I4-GREEN project, aims to enhance the production capacity of metals, specifically copper and zinc, through an innovative and sustainable process.

During the last months of operation of the I4-GREEN project, the ramp-up of the industrial plant has taken place, favouring the increase in metal production capacity, which is the main objective of the project: improve the company's productive capacity. As a result, several significant milestones have been achieved. The plant has increased its efficiency, optimizing production times and improving the quality of the final product. Additionally, a 94% reduction in CO2 emissions compared to the baseline scenario has been achieved, thanks to the implementation of new technologies that allow operation at lower temperatures, significantly reducing energy consumption. Since the beginning of the project, Lain Tech has experienced growth in its workforce, reaching 72 employees, with expectations to increase to between 100 and 120 direct employees in the coming years.

The E-LIX process has proven to be an innovative industrial electrochemical solution, producing high-purity copper cathodes directly at the mine, eliminating the need to transport concentrates to smelters in other countries. This advancement represents a paradigm shift in metal production, making it more profitable and sustainable. The success of the project in Riotinto opens the possibility of replicating this technology in other regions with similar mineral deposits, both at the regional level (Andalusia) and interregional level (Portugal). In Andalusia, the Iberian Pyrite Belt presents high potential for the application of this technology, while in Portugal, the E-LIX technology could improve recovery rates and extract critical raw materials in deposits such as Neves-Corvo and Aljustrel.

Lain Tech positions itself at the forefront of the metal production industry thanks to this project. The expansion of the industrial plant and the acquisition of new assets will allow the company to maximize its capabilities and offer more efficient and sustainable solutions. The E-LIX technology will not only increase production capacity but also reduce environmental impact, improving the company's reputation and social responsibility. This project has enabled Lain Tech to advance through the different phases, allowing continued production at the current plant up to 10,000 tons of metal per year, opening new doors to future projects for industrial development and innovation, consolidating itself as a productive, sustainable, and innovative industry.

2. Introduction

Lain Tech's plant located in Riotinto, Huelva, has demonstrated the feasibility of this system with results indicating that the process is capable of effectively treating the impurity levels typical of complex sulphides present in the Pyritic Belt.

FIGURE 1. E-LIX PLANT LOCATION

The plant maintains a processing capacity of 5 tons per day of copper concentrate, starting with a dissolution phase (leaching) where specific catalysts and special physicochemical conditions are applied. The implementation of the E-LIX system at the Riotinto mine has made it possible to produce high purity copper cathodes directly at the mine, eliminating the need to transport concentrate to smelters in other countries. The process overcomes the classic problem of "passivation" in the leaching of complex sulphides, culminating in the application of SX-EW (solvent extraction – electrowinning) technology for the selective extraction and electrowinning of dissolved metals. This represents a radical change in production philosophy, making viable the exploitation of deposits that were previously considered unviable, making profitable old exploitations in the region that were closed and allowing production in the mine itself. The industrial scale implementation of the E-LIX process at Riotinto represents a paradigm shift, allowing final copper production on site and significantly reducing the costs associated with transporting and smelting concentrates.

FIGURE 2. LAIN TECH'S INDUSTRIAL PLANT IN ATALAYA'S LAND AT RIOTINTO (HUELVA)

In addition to improving production capacity, the construction, commissioning and ramp-up of the new process-based plant has represented a significant advance in terms of sustainability and environmental friendliness. As a green, zero-discharge technology, it

would significantly reduce greenhouse gas emissions and minimize the generation of hazardous waste, thus contributing to the fight against climate change and the protection of the natural environment. In this way, the I4-GREEN project would be in line with the sustainable development goals of the united nations and would position itself as a leader in technological innovation and corporate social responsibility in the metal production and renewable energy sector.

3. Objectives achieved with the plant ramp-up

During the last months of operation in the scope of I4-GREEN project, the ramp-up of the industrial plant has taken place, favoring the increase of the metal production capacity, being this the main objective of the project to improve the productive capacity of the company. As a result, the following milestones/objectives have been achieved.

- Improved efficiency. This greatly favors the increase of the previously developed capacity and its better positioning as a company, increasing the amount of mineral concentrate treated to 35k tons per year
- Reduced production times. New equipment has been obtained improving the quality of obtaining metals as an industrial product, which translates into greater speed when executing the project, in addition helped by the process's automatization.
- Plant usability. Currently, the plant is operating 24 hours a day with several shifts of operators, thus confirming the plant's start-up objectives.
- Increased product quality. The improvements provided by each of the new assets will contribute to greater customer satisfaction, which will have a positive economic impact on the company and its reputation.
- Optimization of production processes. The new assets must be optimally integrated into the company's production processes, which will allow more efficient management of resources and greater flexibility in production.

It should be noted that all these technical objectives that are currently happening to the project are in addition to the general objectives of Lain Tech, which propose to achieve a remarkable sustainability and respect for the environment by reducing the carbon footprint or reducing emissions into the atmosphere.

In turn, Lain Tech is committed to sustainability and part of the following environmental objectives have been achieved during these months:

- Carbon footprint reduction. The carbon footprint represents the total volume of greenhouse gases in the atmosphere. At the business level, it can be increased during manufacturing, transportation or energy consumption. That is why Lain Tech reduces these factors, such as transportation or energy, to contribute to improving the quality of the air around us. We have achieved a 94% CO2 reduction compared to the baseline scenario.
- Optimization of energy consumption. With the new technology implemented in this metal production process, it is not necessary to work at high temperatures, as was previously the case. This allows considerable energy savings.
- Reduction in the emission of environmentally harmful gases. Lain Tech has worked on designing a plant that works at the foot of the mine. This, apart from other advantages mentioned above, helps to avoid the need to transport the materials to the operation site, which is a clear example of savings and reduction of polluting gases derived from fuels.

- Optimization of consumables and reagents used in the processes. With the operating conditions of the process during the ramp-up, the reagents used for metal production can be optimized in a better way.

Another of the major objectives achieved with the collaborations of this project has been the exponential growth in the number of employees that Lain Tech has experienced since the beginning of the project in 2022, thanks to the different phases, and in particular the operational ramp-up of the plant, there has been a growth to 72 employees that now make up Lain Tech. Following this growth, an increase is expected over the next few years to 100-120 direct employees thanks to this first industrial plant.

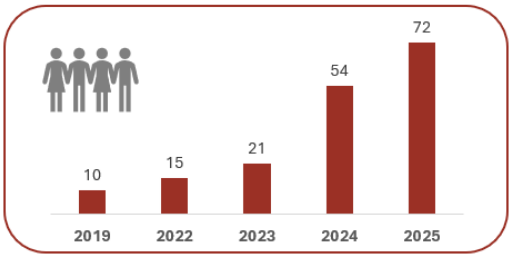

FIGURE 3. LAIN TECH'S EMPLOYMENT GROWTH

4. Metal production

FIGURE 4. MINERAL CONCENTRATE STORAGE TO BE TREATED

The E-LIX process is a completely innovative industrial electrochemical process, which also offers great environmental advantages, being a sustainable and safe technology, since it does not present continuous process effluents and, unlike other industrial metal production processes, it works under non-aggressive operating conditions.

The E-LIX process has been consolidated after 6 years of metallurgical tests at laboratory, pilot plant and industrial scale.

In the current project I4-GREEN, with a technological maturity level 9 (TRL9), we have achieved during the ramp-up the final products of the plant, being them zinc and/or metallic copper in the form of cathode, we have explored also the possibility to produce an intermediate product of zinc and/or copper precipitate (hydroxide or carbonate).

FIGURE 5. LAIN TECH'S TEAM WITH A COPPER CATHODE

5. Replicability

In addition to its technological innovation, Lain Tech is in a strategic position, as with more than 200 million tons of copper and zinc mineral reserves in this project alone, and an estimated 1.6 billion tons of mineral resources in the Iberian Pyrite Belt, the company has access to a constant and abundant supply of raw materials. It is important to highlight that the complex polymetallic minerals where this technology is competitive exist in various parts of the world, meaning the impact of this technology can have an international reach. With the ability to exploit these mineral reserves more efficiently and sustainably, Lain Tech is poised to lead metal production towards a cleaner and more profitable future.

5.2. At regional level (Andalusia)

Of all the possible scenarios in which a mineral deposit or ore body may be found, one understands that, to apply the processing technology developed by Lain Tech, it is advisable to focus on those deposits with the potential for mineral extraction in the short or medium term. That is:

- Those that are currently extracting ore,
- Those expected to do so within the next 2-4 years (having permits or being in the final stage of obtaining them but still needing to build the mining infrastructure to access the ore),
- Those that could begin operations within 5-10 years (not yet permitted but with significant resources identified to justify medium-term investment), and finally,
- Old mining waste deposits that, due to the technology used at the time, the type of ore mined, and their dimensions, could have potential interest for exploitation within the next 5-10 years.

In this regard, it should be noted that Andalusia has a high potential for mineral resources, particularly metallic sulphides. This includes the Iberian Pyrite Belt in parts of the Huelva and Seville provinces, the vulcano-sedimentary complexes in the Northern part of Cordoba

province, and the metallogenic zone of Linares-La Carolina in Jaen province. Additionally, metallic sulphide deposits of lesser scale still exist in the province of Almeria.

All these regions have experienced intense mining activity since the late 19th century, continuing through part of the 20th century, and in some cases—such as the Iberian Pyrite Belt—extending to the present day.

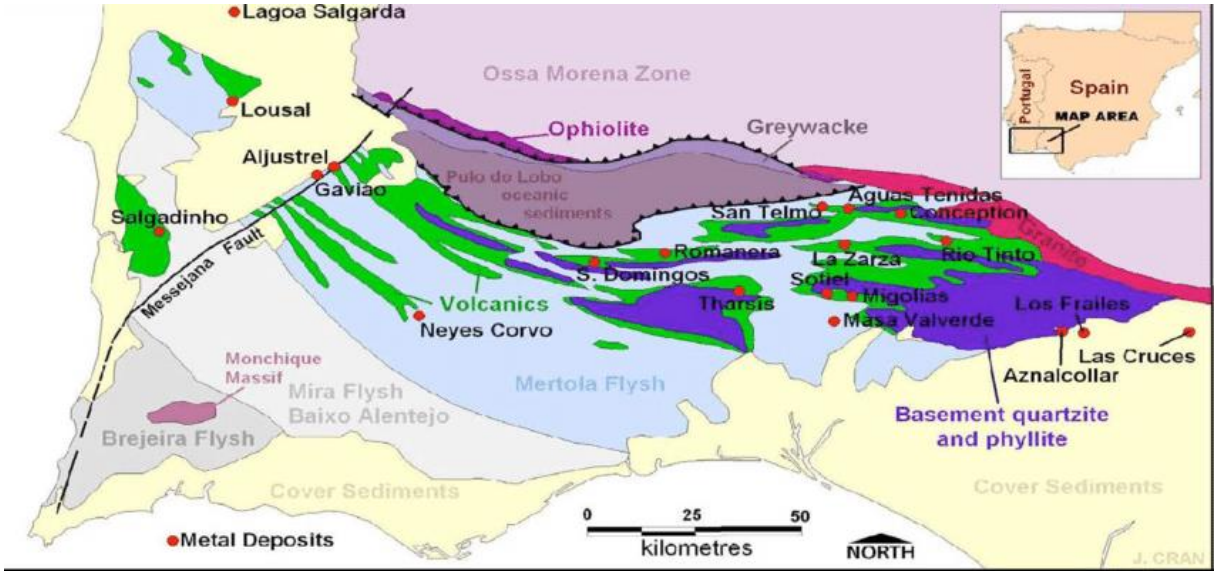

FIGURE 6. IBERIAN PYRITE BELT MAP

Currently, the most active area is the Iberian Pyrite Belt, where four metallic sulphide deposits are in operation: Aguas Teñidas-Magdalena and Sotiel (operated by MATSA), Rio Tinto (operated by ATALAYA MINING), and Las Cruces (operated by COBRE LAS CRUCES). Additionally, two deposits are in the ramp-up phase: Masa Valverde (ATALAYA MINING) and Los Frailes (MINERA LOS FRAILES), along with several others in various stages of exploration.

Furthermore, there are significant deposits under exploration, such as Tharsis, La Zarza, and Concepción-Ponderosa.

Regarding mining waste deposits, more than 25 million cubic meters of metallic mining waste have been inventoried in the Iberian Pyrite Belt. These materials vary in composition and potential economic interest and could be subject to further study. Some of the main sites include Tharsis, La Zarza, San Telmo, and Rio Tinto.

In the northern part of Cordoba province, around Villanueva del Duque and Alcaracejos, several lead and zinc sulphide waste deposits exist, each with distinct characteristics and mineral content. These could be analysed to assess the applicability of the E-LIX treatment method. However, due to their small size (thousands of cubic meters), economic viability would depend on a joint study of the deposits in the region.

Similarly, the mining district of Linares-La Carolina has significant accumulations of lead sulphide waste in small to medium-sized waste dumps, which could be of interest if analysed collectively to achieve a sufficient scale for economic feasibility.

5.3. At interregional level (Portugal)

Potential for the E-LIX technology application in mineral deposits and mining tailings of Alentejo, Portugal.

A complex and diversified geology endows Portugal with a considerable mineral potential, leading to the occurrence of considerable number of ore, industrial and ornamental stone deposits.

In the Portuguese area covered by the I4-GREEN project, Alentejo, two geotectonic units occur. In the northern part, the Ossa - Morena Zone, which is an extremely complex and diverse unit which begins with a polymetamorphic Precambrian, followed by Cambrian and Silurian formations, and ends with a flysch sequence from the Late Devonian period.

The most important mineral occurrences are base metals, which are associated with the Cambrian-Ordovician volcanic sedimentary complex, precious metals, chiefly related with the Precambrian formations, and tungsten and tin in the Sta. Eulália granitic complex, not to mention the potential for chrome, nickel, cobalt and platinum in the basic and ultrabasic rocks on the north and south margins of this zone.

There are several exploration projects going on (Borba, Assumar, Barrancos), for precious and base metals, but all of them in an early stage.

Nevertheless, Alentejo is geologically dominated by the Iberian Pyrite Belt (IPB) which is considered one of the main metallogenic provinces of the European Union, with several important polymetallic massive sulphide deposits like Neves-Corvo and Aljustrel, in its Portuguese sector. The IPB is the main primary source of base metals in the EU.

This province occurs on the South - Portuguese Zone, which is characterised by the existence of a volcanic sedimentary complex from the Late Devonian - Early Carboniferous period, overlain by a Culm flysch sequence; underlying this complex is the so-called "Phyllite-Quartzite Group".

The acid volcanic rocks in the volcanic sedimentary complex constitutes the metallotect of the massive polymetallic sulphides that are characteristic of the Iberian Pyrite Belt, the most important metallogenetic province in Portugal in which the producing and former (Lousal, Caveira, São Domingos) mines are located.

The producing mines, Aljustrel and Neves Corvo, use, in a consolidated way, flotation as their ore processing method to produce zinc, copper and lead concentrates. It will be difficult to introduce new processing techniques, like leaching, but there is a potential for the E-LIX technology, improving recovery rates and to extract some critical raw materials, like indium, as byproducts.

There are two more mining concessions, but without production, Alvalade (Sesmarias deposit is currently under evaluation) and Lagoa Salgada. This last one is in an advanced stage and with a positive definitive feasibility study (Proven and Probable Reserves of 14.6Mt at an average NSR of US$66.1/tonne), only pending the environmental impact study approval. Despite the metallurgical studies were focused on flotation, this deposit will be the ideal one for testing the E-LIX technology, due to its characteristics and stage.

There are also some exploration projects going on, Santiago, Cercal, Ourique, Ermidas, Almodôvar, Mértola, Rosário, Neves, some of them with promising results and where the E-LIX method can be tested, if their economic potential is confirmed, in a near future.

Concerning the tailings existing in the IPB, there are 1 770 000 cubic meters in the Aljustrel and Lousal areas, but all of them are already sealed, consequence of the rehabilitation works conducted by Empresa de Desenvolvimento Mineiro (EDM), a public mining company, responsible for the recovery of abandoned mines in Portugal. So, these tailings are not available for testing the E-LIX method. There are also 15 000 000 cubic meters of tailings in the Caveira and São Domingos areas. Those are still not sealed (but they will be soon) and the E-LIX technology could be tested there.

6. Future and conclusions

It is important to note that, thanks to the support and boost of the E-LIX technology withing the scope of I4-GREEN project, Lain Tech will be positioned at the forefront of the metal production industry. The acquisition of the new assets and the expansion of the industrial plant, defined in this project, will allow Lain Tech to maximize the scope of its capabilities and further enhance the advantages that already existed in the process, offering more efficient and effective solutions for its clients. This is crucial for Lain Tech's growth and development, its leading position in metal production, and its ability to respond to market demands. In addition, the technology will enable greater production capacity (up to 10k tons of metal) and efficiency in industrial processes, resulting in improved quality of the metals produced and greater ease of execution. This technological innovation will also allow the company to reduce its environmental impact and become more sustainable, improving its reputation and social responsibility.

With respect to the previous study of the exploitation capacity of the pyritic belt, the future of E-LIX technology appears ambitious and with high possibilities of expansion due to these geographic situations. The idea with the new industrial plant will be to diversify the capacity of treated mineral concentrate, being able to process mineral concentrate from the different mines mentioned in the previous locations of Andalusia and Portugal. In addition, it will be possible to replicate in small pilot projects, in which the different mineralogies of these concentrates will be tested, in order to study their exploitation potential, which thanks to E-LIX will be greatly increased, thus increasing the potential and useful life of these mines.

FIGURE 7. LAIN TECH'S TEAM

Lain Tech addresses a significant technical challenge in the metal concentrates processing industry through design and detail engineering, development of specific components and validation of technological improvements of new industrial processes capable of demonstrating the capability of the revolutionary new E-LIX technology. The inherent complexity of defining this new process requires an innovative and experimental approach, which is not limited to standard modifications, but involves defining new processes, prototyping and pilot testing to implement effective solutions. Therefore, the future lies in the evolution towards a new future industrial plant, where there is a growth at industrial level that allows the processing of large tons of concentrate, which will allow to serve several mines in the pyritic belt, in addition to generating a profitable business model for the company, which will allow its growth towards a large company.

All the progress made during the present I4-GREEN project has allowed us to advance during the different phases, allowing us to continue with the production of the current plant up to 10k tons of metal, opening new doors to future projects and interregional collaboration, both for industrial development and innovation, as well as industrially validating the technology to make the leap to consolidate ourselves as a productive, sustainable and innovative industry.