

## Energy Efficient Comminution using Pulsed Power

*A breakthrough in mineral extraction to enable the energy transition*

I-ROX's pulsed-power technology solution aims to break rock using a fraction of the energy used by traditional milling equipment, thereby radically reducing emissions, and saving billions of dollars across the mining sector.

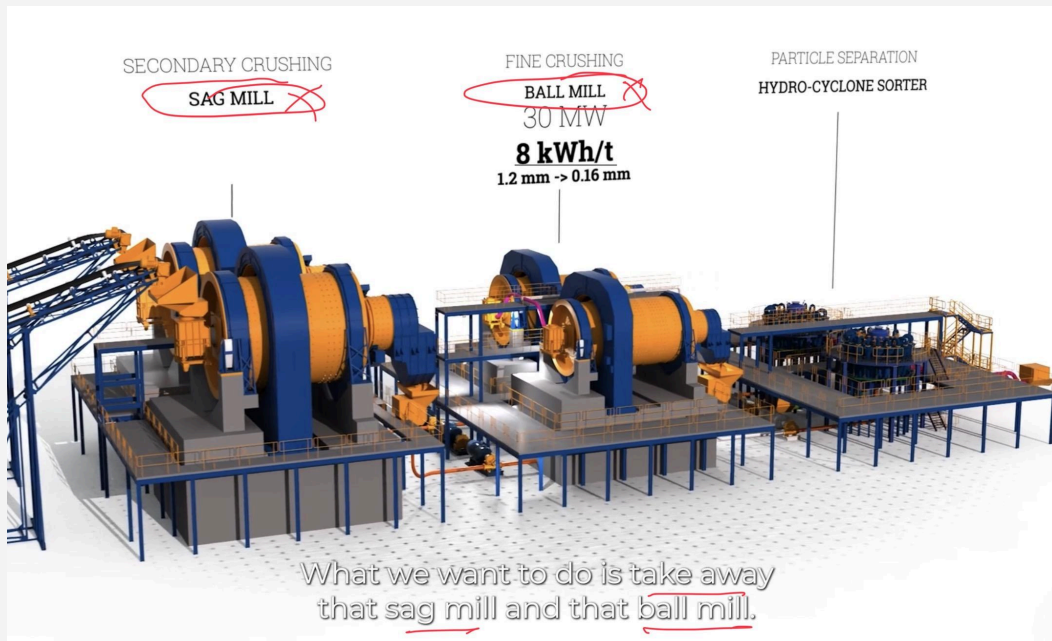


### Introduction

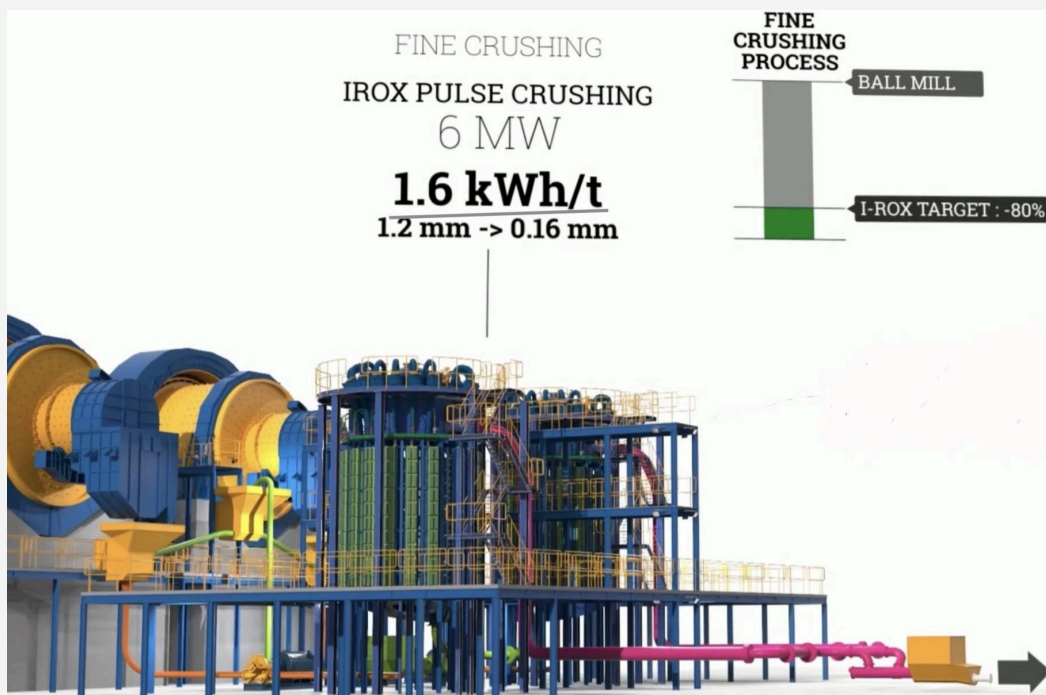
Between now and 2050, global copper demand is set to double, driven by increasing demand for electricity due to the macro trends of decarbonisation and data processing.

However, the world's primary copper producing region of Chile and Peru, which last year accounted for around 35% of the world's copper mine supply, are facing unprecedented headwinds. The Andean Copper Belt has been a critical source of global copper production for decades, due to the region's massive porphyry deposits. However, many of the largest mines in South America have been operating for decades, and as these mines grow in size and depth two trends are clearly evident: grades are declining and the ore is getting harder – trends which are expected to continue into the future.

It is in this context that I-ROX seeks to make a difference. I-ROX has developed and patented a unique electrode design to efficiently and uniformly break mineral ore using high pulsed power. Pulsed electrical power produces fast and short high-voltage pulses capable of passing electrical arcs through mineral ore, causing it to burst from the inside using tiny amounts of energy.



I-ROX is collaborating with BHP to advance the development of this disruptive new technology, which has the potential to replace traditional grinding mills in a comminution circuit. Our objective is to reduce the energy consumption of conventional grinding mills by 80%, while increasing metal recovery during flotation as a result of increased mineral liberation and a reduction in the production of ultrafine particles. Both energy savings and increased flotation recovery have been demonstrated at our lab in Toulouse, using material from the Escondida mine in Chile.



I-ROX was established in 2022 by **I-Pulse** (which has been successfully commercialising various applications of pulsed power for the past 15 years), and Breakthrough Energy Ventures (a clean-energy investment firm founded by Bill Gates, that has supported 100+ start-up companies working on emissions reductions). I-ROX is collaborating with BHP and lately Codelco to advance the technology, including plans for a pilot plant at one of their mines. What makes I-ROX unique is its deep expertise in the field of pulsed power, which allows the team to build bespoke pulsed power generators in-house that are designed specifically to break rock in the most energy efficient way.

## Background

Mining plays a pivotal role in enabling the energy transition, as renewable technologies require a vast array of minerals, many of which have been labelled as “critical” by western countries. Demand for these minerals, including copper, is skyrocketing as the world shifts to cleaner energy systems. Electric vehicles (EVs), solar panels, wind turbines, battery storage systems and data centres depend on these minerals, making them essential for achieving global climate goals. In particular, the demand for copper is projected to increase significantly, largely driven by the global energy transition, which includes electric vehicles (EVs), renewable power generation, and energy storage systems.

The increase in demand for these critical minerals shows the enormous role that mining must play in delivering the energy transition. By providing the raw materials required for renewable energy systems, the mining industry will be at the forefront of the energy transition, helping to accelerate the global shift towards a low-carbon future. However, the mining industry faces the dual challenge of expanding production to meet this demand while significantly reducing its own carbon footprint. Incremental changes to existing mineral extraction processes are unlikely to be sufficient and more disruptive innovation is necessary to shape the next chapter in mining and enable the energy transition.

The extraction of minerals from the earth’s crust generally requires some degree of crushing and grinding. This process of reducing the size of a material is referred to as **comminution**. For some minerals, like copper, large rocks must be reduced to tiny particles, often less than 100 microns in size in order to expose the tiny particles of metal inside the rock so it may be separated from gangue (the unwanted material

surrounding the metal). The current process requires an incredible amount of energy and yet 10-20% of the metal is often left behind, ending up in waste dumps.

Today, the comminution of mineral ore is performed by mechanical equipment that crushes and grinds rock into progressively smaller sizes. This process applies a compressive force to the outside of the rock to break it. Variations of this process have been in use since Roman times. The process of breaking rock is energy-intensive, with energy intensity rising as the particle size decreases. Globally, the energy consumption associated with mineral comminution is growing as the volume of mineral demand continues to rise, as the contained mineral content declines, and as the hardness of rock increases – particular in the case of aging copper porphyry deposits. The result is that up to half a mine's energy consumption is related to mineral comminution. Globally, around 2% of the world's electricity is used for mineral comminution, equating to about 300Mt CO<sub>2</sub>e – similar to the emissions of a country like the UK.

I-ROX is therefore truly disruptive – by proposes an entirely different way of pulverising rock into fine particles – using a tensile force and electrical energy to burst rocks from the inside, rather than a compressive force and mechanical energy to crush them from the outside.

## **I-ROX summary**

I-ROX is based in Toulouse, France with a growing team of nearly 30 people. Following initial research and development at batch scale, the company has progressed to the development of flowing systems and is now in the process of building a demonstration unit capable of operating at ~1-2 tonnes per hour. By the end of this year we plan to construct our first pilot plant with throughput capacity of ten tonnes per hour. This will initially operate in Toulouse before being deployed at a mine site.

Key achievements since the company was formed in late 2022 include:

- The design and construction of various pulsed power generators, employing both solid state and spark gap technology. Our latest generator has been designed to showcase that long duration operation without maintenance is achievable. This generator, which employs a combination of solid state switches and spark gaps, has been running continuously (24/7) for over 60 million pulses (at 10 Hz) and continues

to climb towards our target of 100 million pulses. Our goal is to build a future generator capable of a billion pulses without maintenance.

- The development of a proprietary Coarse Comminution system, capable of efficiently breaking copper ore from ~150 mm (SAG mill feed size) to ~10 mm (ball mill feed size). This system is capable of processing Escondida copper ore with just half (50%) of the energy consumption of the Escondida SAG mill. We believe this can be reduced to 30% with additional optimisation. Notably, there is a low correlation between ore hardness and energy consumption, making I-ROX particularly useful for efficiently grinding very hard ore.
- The construction of a 100 kg per hour flowing system for Fine Comminution. This system is design to break rock from ~10 mm to ~0.2 mm.
- We have conducted Mineral Liberation Analysis tests using a scanning electron microscope on ore samples that we have pulverised using pulsed power. This analysis shows that mineral liberation is materially improved (+10%) via pulsed power due to the breakage of the ore along mineralogical boundaries, positively impacting flotation recovery.
- We have conducted flotation tests on the pulverised ore, which shows up to 5% higher copper recovery versus the recovery achieved for the same ore using a conventional mill.
- We have analysed the particle size distribution (PSD) of the ore which has been pulverised using pulsed power, which shows we can achieve a more discrete PSD than conventional technologies. This is crucial, because if the ore is ground too fine, then it does not float and the contained minerals will not be captured. If the ore is ground too coarse, then it must be re-ground.

I-ROX has developed a flowing system with multiple chambers which will allow us to fine-tune the PSD thereby avoiding losses due to ultrafine particles and in turn recovering even more of the valuable minerals contained in the ore.

## **Conclusion**

While scale-up challenges remain, I-ROX pulsed power comminution technology has demonstrated the potential for material benefits, including:

- Lower energy consumption during the comminution process

- Increased metal recovery; higher grade concentrate
- Reduction in milling consumables, such as grinding media and mill liners
- Higher mineral liberation at a larger particle size, which paired with coarse particle flotation could improve tailings stability

I-ROX will continue to advance the development of its technology with a focus on scaling up to larger throughput capacity as it works towards its first on-site pilot plant at a mining operation.