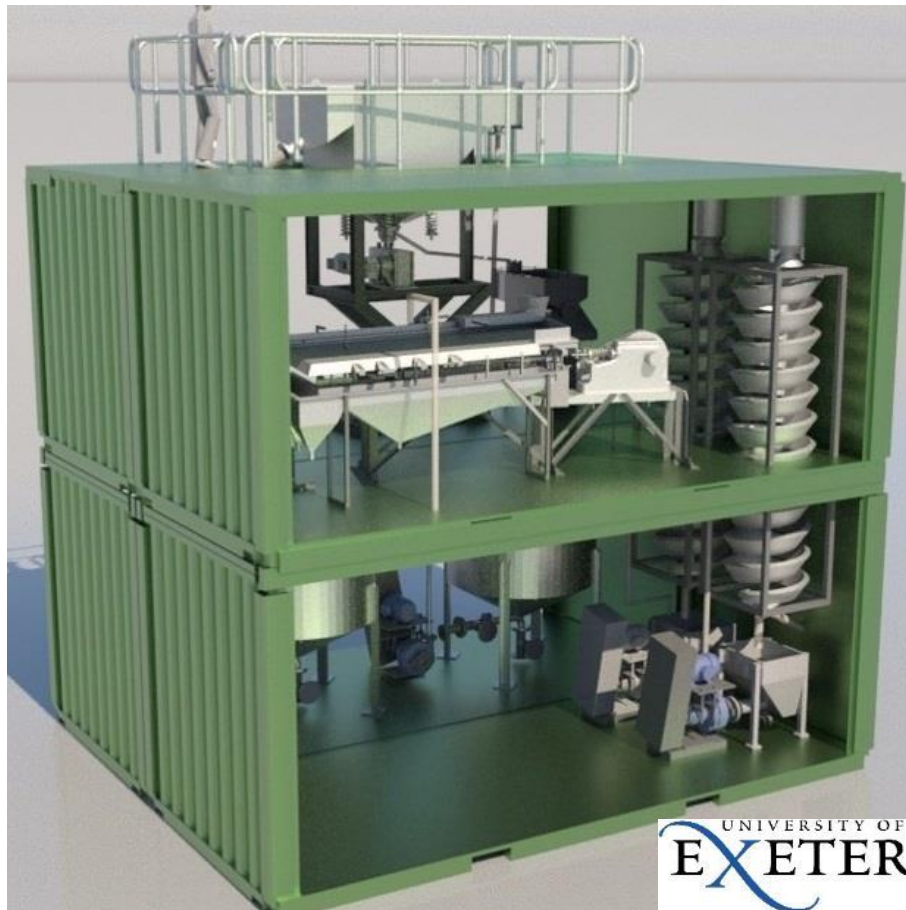


H2020 IMP@CT – SMALL-SCALE MINING TECHNOLOGIES DEVELOPMENT – PILOT PLANT OPERATION FEEDBACK

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Integrated Mobile modularised Plant and Containerised Tools for selective, low-impact mining of small high-grade deposits



- ❖ Horizon 2020 project: 7 M€, ongoing, until May 2020
- ❖ Coordination: University of Exeter, Kathryn Moore



- ❖ To unlock, secure access and foster a sustainable supply of resources in Europe, particularly critical raw material
- ❖ Proposes and develops a new ‘switch on-switch off’ mining paradigm of small high-grade deposits





Source: Review of the list of the Critical Raw Materials, 2017



Olovo, Bosnia Herzegovina

Challenges of small-scale mining

- ❖ Deal with risk to supply of critical raw material in Europe
 - Restricted geographical distribution
 - Price volatility
 - Market forces
 - Responsible sourcing of critical metals

- ❖ Challenges associated to any mining paradigm
 - Geological and metallurgical variabilities
 - Environmental sustainability
 - Economic sustainability
 - Social and ethical responsibilities to mining-affected communities through social licence to operate (SLO)

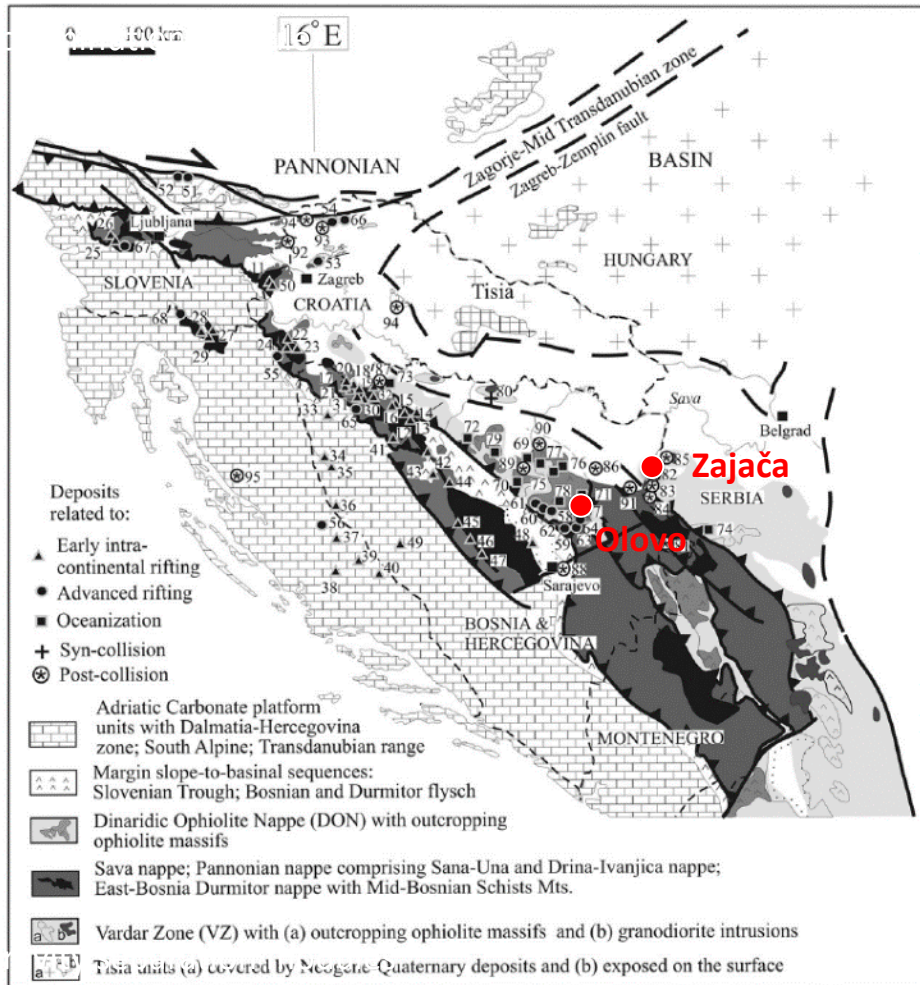


Small-scale mining technologies development

- ❖ Develop mechanisms to enhance the response of raw material supply to rapid fluctuations in market forces, utilising high grade or small complex deposits in Europe
- ❖ Optimize mobile and flexible technological solutions to rapidly ‘switch on’ or ‘switch off’ production at short duration operations
- ❖ Minimise extraction and energy consumption (reduced throughput)
 - Potential for renewable energy solutions to make a greater contribution to off-grid energy provision
- ❖ Enhance environmental and social sustainability through dedicated policies



Study cases



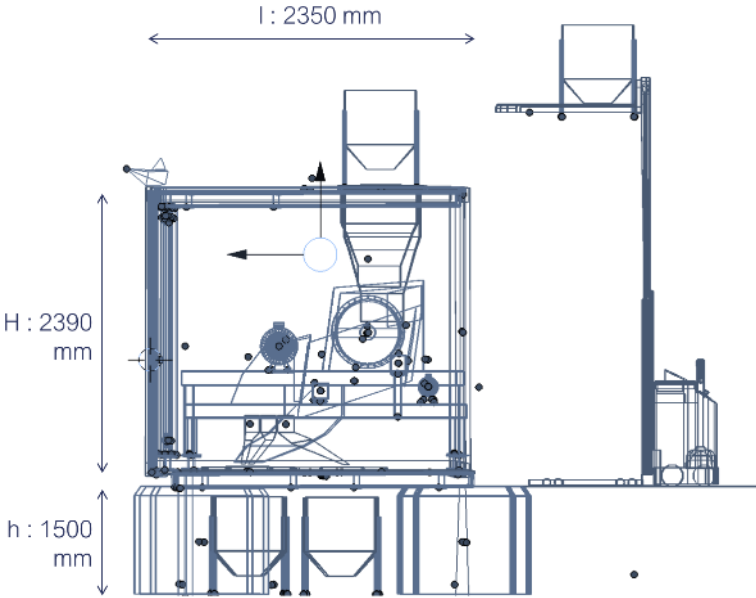
- ❖ Olovo Pb deposit (MVT type) in Bosnia and Herzegovina
 - Hosted in Middle Triassic carbonate rocks predominantly limestones
 - Mainly cerussite $PbCO_3$ as ore mineral
- ❖ Zajača Sb deposit in Serbia
 - Mesothermal Sb hosted in granitoids
 - Sb in form of stibnite Sb_2S_3 and Sb-oxide minerals
- ❖ Deployment, commissioning and testwork performed in Olovo from May 2019 to July 2019
 - Selective mining tool
 - XRF ore sorter
 - Comminution module
 - Gravity beneficiation modules



Comminution module

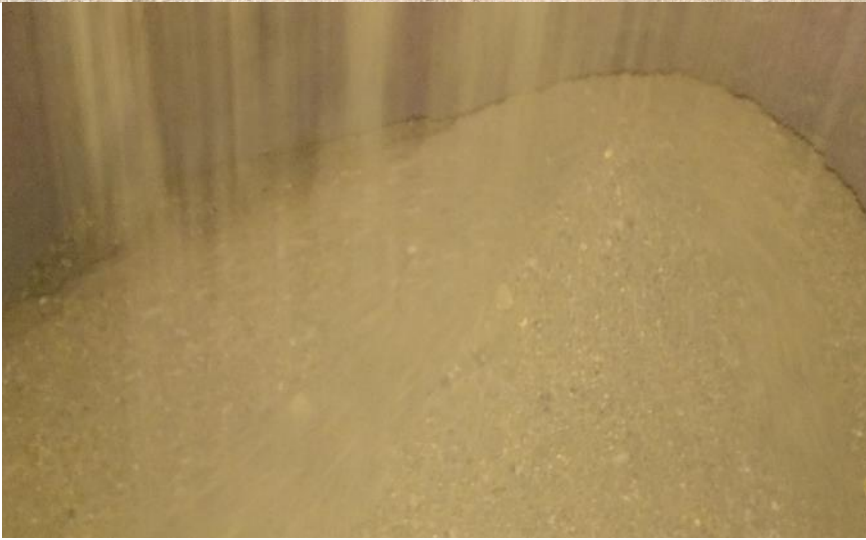
❖ How it was build

- Each piece of equipment is positioned on a standardized slide
- Each skid can be independently positioned and operated inside the container



Comminution module

- ❖ How it was commissioned
 - Up and running in 3 hours time
 - Throughput: 5 t/h
 - Total of 200 t of milled ore
 - Particle size 90 % < 5 mm, 30 % < 3 mm



Gravity beneficiation modules feed



- ❖ Vibrating feeder to be implemented for the next deployment in Serbia in order to minimize solid throughput variability
- ❖ Feed by shovelling: solid throughput is strongly operator dependent
 - $\approx 8\text{kg}$ of solids per shovel
 - 2 shovels per minute
 - Average throughput: 1 tph
- ❖ Three types of ores:
 - High grade ore
 - Medium grade ore
 - Low grade ore (using the prototype selective mining tool)



Gravity separation of coarse particles

- ❖ No saleable cerussite concentrate could be produced using jigs
 - Low content of cerussite within the size fraction +1-5 mm
 - Would require further grinding operation in order to liberate locked cerussite within the +1-5mm size fraction

- ❖ Large pieces of rocks (> 5mm) discovered within the glass balls layer of the rougher jig
 - These large piece of rocks were not able to go through the jig perforated plate, nor to the overflow
 - accumulating and putting jigs performances at a disadvantage

Gravity separation: high grade ore vs low grade ore



Rougher spiral: high grade ore



Shaking table: high grade ore



Rougher spiral: continuous miner ore (low grade)



Shaking table: continuous miner ore

Solid content monitoring

- ❖ One of the most challenging part of the process
 - Main parameter allowing to monitor the viability of the process in order to reach steady-state
- ❖ Marcy scales give an accurate idea of the slurry solid content provided that an homogenous slurry sample is taken
- ❖ Several easy-to-use sampling points:
 - Sampling boxes designed by SWMS for spirals: concentrates, mids & tails
 - Flexibles pipes of spirals feed, shaking table feed
 - These sampling points were also used in order to calculate slurry flowrate





Slurry transfer with slurry pumps

- ❖ Most of issues we faced were related to slurry transfer, due to high head losses around each slurry pump, and resulting in:
 - Feed pumps lower flowrates than originally designed
 - Flowrate bottlenecks
 - Pipes clogging
- ❖ Opt for flexible pipes rather than stainless steel pipes with bends at pumps outlet
 - Decrease head losses, increase flowrate range capability

Slurry transfer by gravity



- ❖ Gravity transfer of slurry from spirals
 - Particularly where solid content of slurry is high (i.e. concentrates and midlings)
 - Sometimes results in pipes clogging
 - Add water in order to let the slurry flow towards the sampling box

- ❖ In regard to the management of solid content in slurry, it is best to avoid water addition:
 - by placing each sampling box directly beneath each spiral
 - thus taking advantage of a steeper slope towards the slurry tank

Slurry tanks

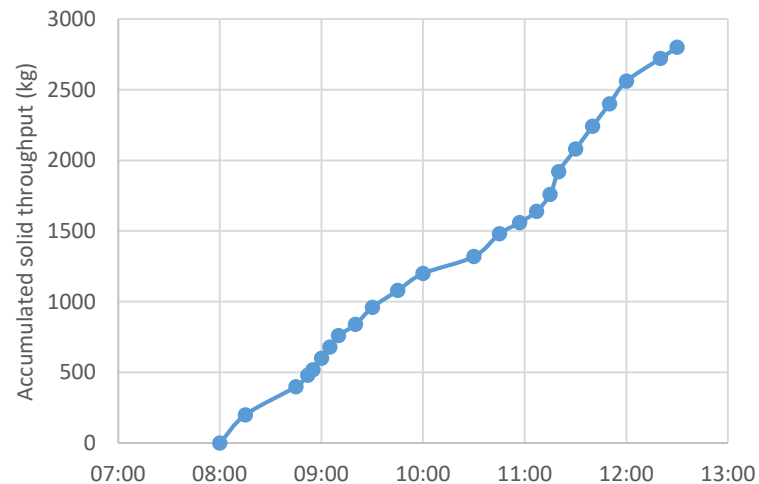


- ❖ Square-shaped containers used as slurry tanks: not the best option
 - settling of cerussite ($SG = 6,5$)
 - increase the time until steady state operation is reached
 - increase the time needed for cleaning the plant at the end of the day
- ❖ Shape of the impeller is critical as well in order to mix homogeneously the slurry and to avoid particles settling
 - opt for 45 degrees inclined blade turbine (axial flow) with high power number N_p

Continuous operation



24th July: pilot plant accumulated solid throughput



- ❖ On the 24th July (last day on-site)
 - 4h of work on continuous mode at steady-state
 - we have been able to process 350 shovels of high grade ore
 - assuming an average 8 kg per shovel, this represents around 2800 kg of ore
 - Average throughput: 0.7 tph
 - Three operators only to run the pilot plant
 - That day the objective was to produce as much as concentrate as possible

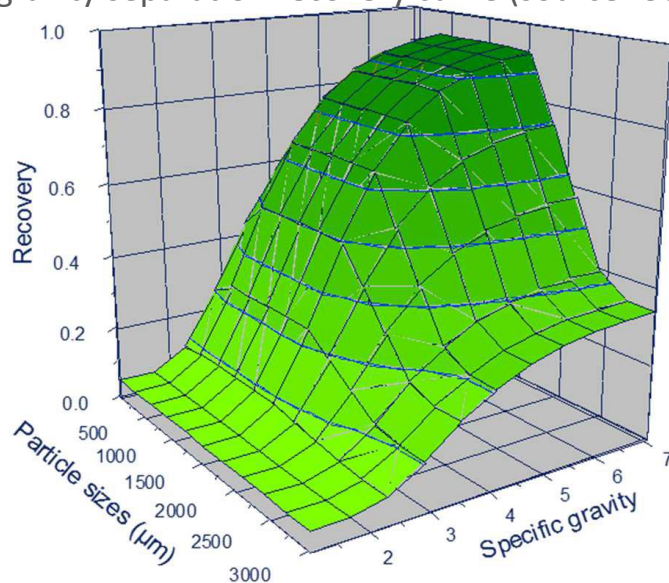




Mineral processing simulation

- ❖ Widely use for early process plant design, feasibility studies, engineering, plant commissioning, plant operation and upgrading
- ❖ Contains a large amount of mathematical models: formalise the current scientific knowledge of mineral processing operations

Typical gravity separation recovery curve (source: USIM-PAC©)



- ❖ Steady-state simulator to forecast plant performances by computing key performances indicators (KPIs)
- ❖ Provides a coherent mass balance of the plant, and a description of all material stream (solids, slurry, water, leachates, etc.)
- ❖ Provides energy, water, reagent(s) consumptions

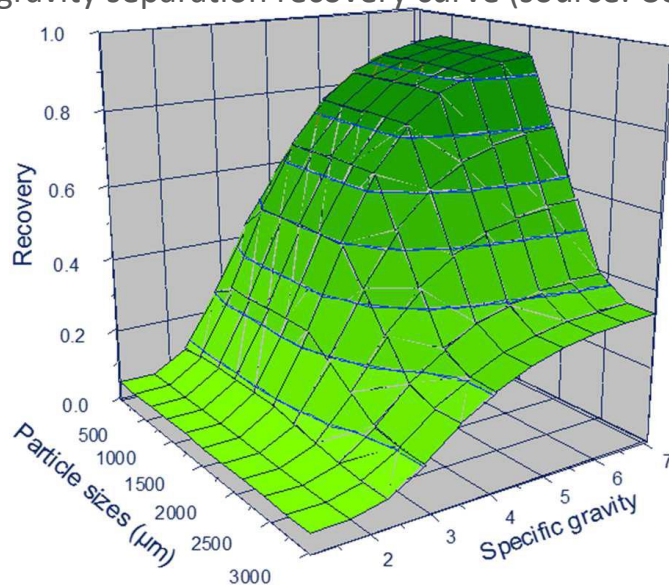


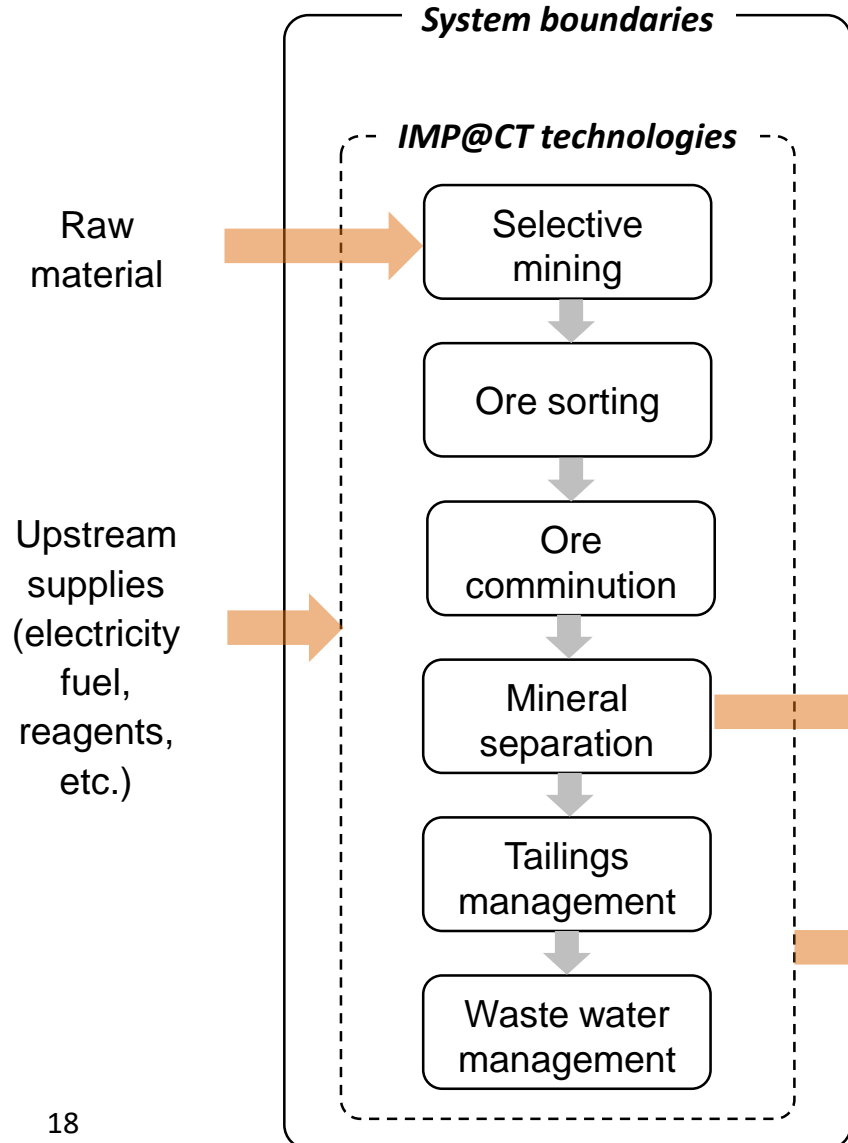


How to build a steady-state simulator?

- ❖ Design a flowsheet that describe the process in terms of successive unit operations and streams
- ❖ Set up a solid phase model describing physical and chemical characteristics of solids:
 - particle size distribution
 - density distribution within each size class
 - mineralogical composition of each particle type (e.g. QemScan)
- ❖ Experimental data reconciliation through a mass balance algorithm
- ❖ Set up and calibration of mathematical models for each unit operation within the process

Typical gravity separation recovery curve (source: USIM-PAC©)





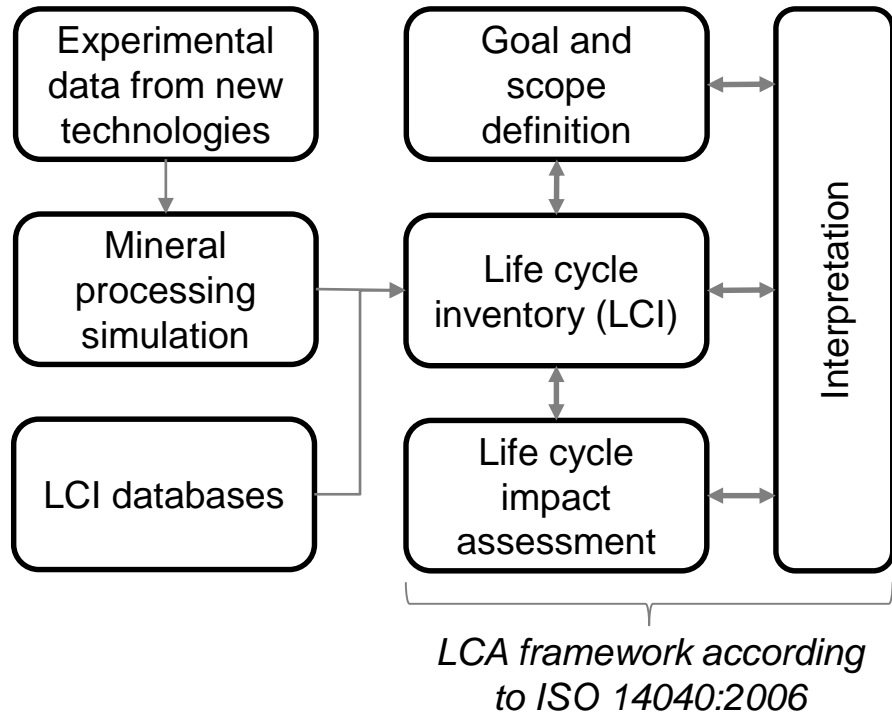
Life cycle assessment (LCA)

- ❖ LCA quantifies and assesses, the consumption of resources (inputs), the emissions (outputs) and the pressure on the environment (potential impact) attributed to different products or processes over their entire life cycle.
- ❖ Results from LCA give decision-makers a set of environmental performance indicators, and show in which extend a product or a process is more eco-efficient than another one.

« The production of one ton of concentrate containing xx% of metal using IMP@CT technologies »

Potential environmental impacts?





Simulation-based environmental footprint

- ❖ To deal with the data gap in order to provide reliable and consistent data
- ❖ To deal with the upscaling gap between technologies at different TRLs (*technology readiness level*): lab/pilot vs industrial scale
- ❖ Given the particularity of modularity of IMP@CT technologies, the LCI foreground modeling must adapt to the type of treated mineral ores regardless of the geological and geographical contexts
- ❖ To deal with metallurgical variability and to inform results uncertainty towards LCA

Outlooks

- ❖ To design an simulation-based LCA tool that will allow a custom-made analysis to account for specificity of each mining and processing strategy
- ❖ To conduct a comparative potential impacts assessment of these different scenario
- ❖ To identify environmental hotspots within the process, which could help to drive a process eco-design feedback
- ❖ To illustrate the benefits of switch-on switch-off mining paradigm relative to traditional mining methods





THANK YOU FOR YOUR ATTENTION

Let's keep in touch

More information at www.impactmine.eu and [@IMPACTMining](https://twitter.com/IMPACTMining)

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