Green mining and refining: yes this is possible

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While the global production of minerals has doubled over the last 40 years pushed by the energy transition, the share of Europe has steadily declined during the same period from 25.1 to 6.8%. To maintain sufficient strategic autonomy, Europe must develop green mining and refining operations, green thanks to low CO_2 emissions, low energy consumption, low water usage and low production of solid waste. Ten technologies already tested would allow to produce minerals in Europe. If we do not loose it all with multiple standards and slow permitting processes.

Key is first to realize, as the CEO of Boliden, Mikael Staffas reminded us at World Materials Forum (WMF) 2023, that while the global production of minerals has doubled over the last 40 years, the share of Europe has steadily declined during the same period from 25.1 to 6.8% – see below slide (Figure 1).

And this happened exactly in parallel to the growing consciousness that we needed to go for more renewable energies with these renewable energies requiring huge quantities of minerals to be extracted, refined and be used to "make" them.

So how can we Europeans come back into the race? By developing new mining and refining capacities that are truly green... and this is clearly possible.

First at WMF we think that "green" does not only mean "zero CO_2" but also low energy consumption, low water consumption and low production of solid wastes.

We track these 4 KPIs for scoring the "Ultra Low Mining Footprint" that we want to reach. And we track them both on a regional basis – for example the nickel mining project of Terrafame in Finland has a very low footprint on CO_2, energy and solid wastes… and uses lots of water... but water is extremely abundant in Finland so no problem – and on the whole supply chain – for example importing nickel extracted in Indonesia while using a coal power plant is not a great idea.

Also we think that we need not only to think but to act… and to act quickly. And to be quick we need to act not

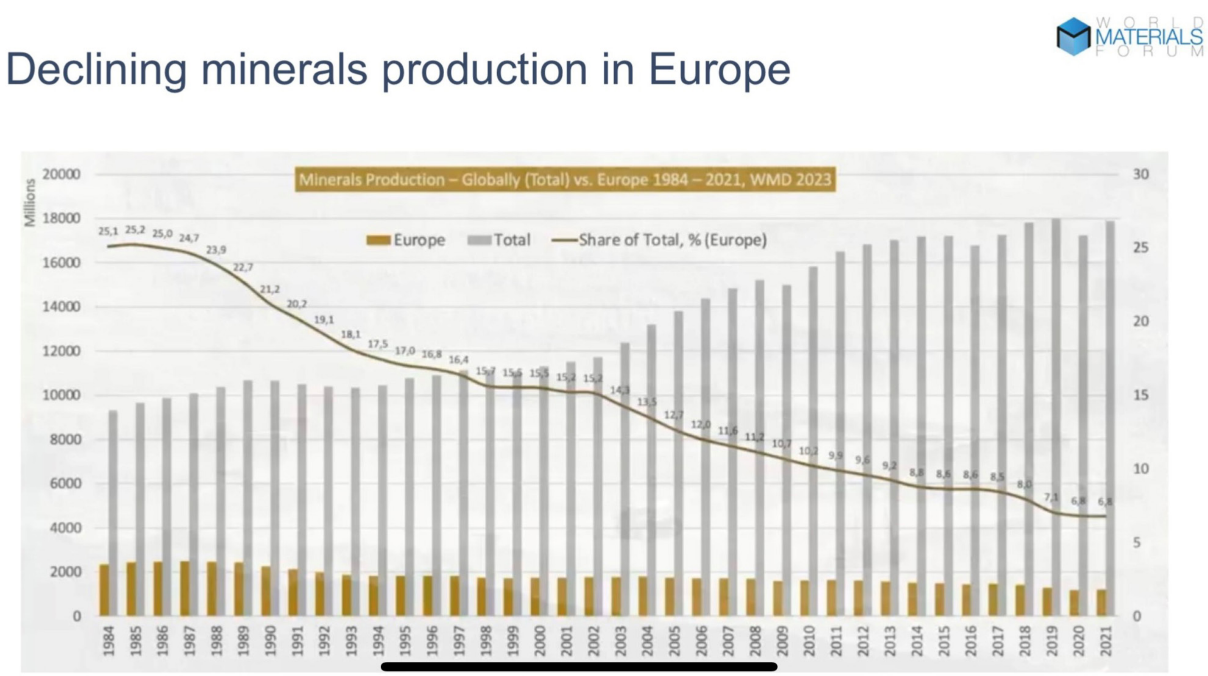


Figure 1: Declining minerals production in Europe (WMF).

on thousand of projects to try and make everybody happy… but to focus on a short number of projects: these that can have the highest impact if we get the best possible people to work efficiently together.

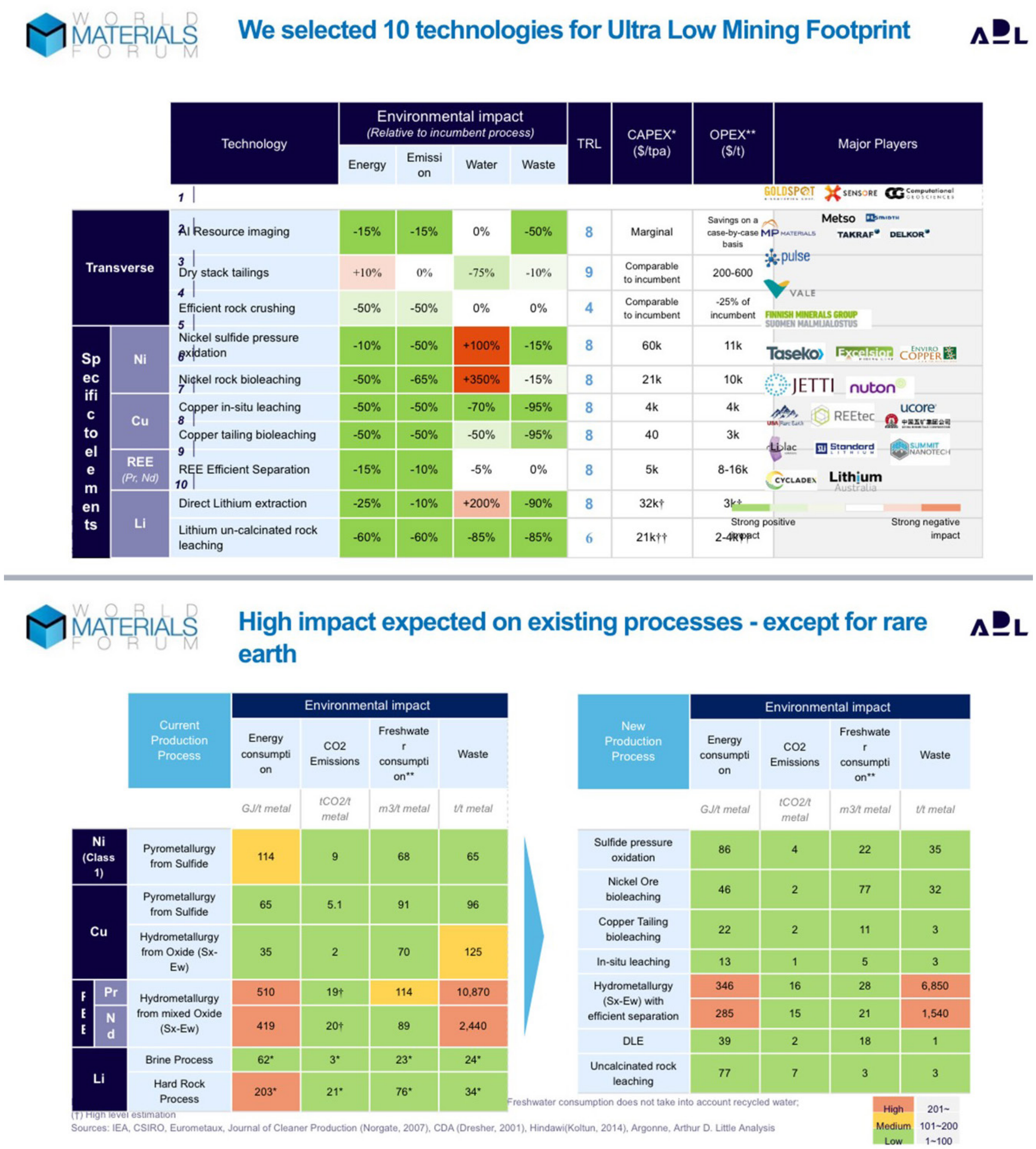
So we selected the Top 10 Technologies we are convinced will help us to reach the Ultra Low Mining Footprint we are aiming for and we show how using them on existing processes can have huge impact except maybe for rare earth – see below 2 slides (Figure 2) that WMF has put together with Arthur D Little for WMF 2023.

I have already mentioned a Finnish project and a Swedish group so I shall now extract the example of a French technology – this of I-Pulse started in Toulouse by an ex CEA Scientist, initially funded by a Canadian entrepreneur, further developed with Private Equity funds from France and the UK and now experimented in the USA and in Saudi Arabia.

I-Pulse has mastered the art of compressing very small increments of electrical energy into very brief but gigantic bursts of power. With applications for example in disaggregating rock and rapidly penetrating extremely hard rocks for deep drilling or tunneling. And a result of using 5 times less energy for the same result.

So today the picture is clear: these Top 10 technologies can have a huge positive impact and the WMF team will be happy to connect any interested reader with the companies operating them.

Let's just hope that heavy taxes, multiplication of standards and slow permitting processes will not jeopardize the immense benefit that these technologies can offer to us European citizens.



		Technology	Environmental impact (Relative to incumbent process) Energy	Emission	Water	Waste	TRL	CAPEX* ($/tpa)	OPEX** ($/t)	Major Players
Transverse		1 AI Resource imaging	-15%	-15%	0%	-50%	8	Marginal	Savings on a case-by-case basis	
Transverse		2 Dry stack tailings	+10%	0%	-75%	-10%	9	Comparable to incumbent	200-600	
Transverse		3 Efficient rock crushing	-50%	-50%	0%	0%	4	Comparable to incumbent	-25% of incumbent	
Specific to elements	Ni	4 Nickel sulfide pressure oxidation	-10%	-50%	+100%	-15%	8	60k	11k	
Specific to elements	Ni	5 Nickel rock bioleaching	-50%	-65%	+350%	-15%	8	21k	10k	
Specific to elements	Cu	6 Copper in-situ leaching	-50%	-50%	-70%	-95%	8	4k	4k	
Specific to elements	Cu	7 Copper tailing bioleaching	-50%	-50%	-50%	-95%	8	40	3k	
Specific to elements	REE (Pr, Nd)	8 REE Efficient Separation	-15%	-10%	-5%	0%	8	5k	8-16k	
Specific to elements	Li	9 Direct Lithium extraction	-25%	-10%	+200%	-90%	8	32k†	3k†	
Specific to elements	Li	10 Lithium un-calcinated rock leaching	-60%	-60%	-85%	-85%	6	21k††	2-4k††	

	Current Production Process	Environmental impact: Energy consumption (GJ/t metal)	CO2 Emissions (tCO2/t metal)	Freshwater consumption** (m3/t metal)	Waste (t/t metal)
Ni (Class 1)	Pyrometallurgy from Sulfide	114	9	68	65
Cu	Pyrometallurgy from Sulfide	65	5.1	91	96
Cu	Hydrometallurgy from Oxide (Sx-Ew)	35	2	70	125
REE Pr	Hydrometallurgy from mixed Oxide (Sx-Ew)	510	19†	114	10,870
REE Nd	Hydrometallurgy from mixed Oxide (Sx-Ew)	419	20†	89	2,440
Li	Brine Process	62*	3*	23*	24*
Li	Hard Rock Process	203*	21*	76*	34*

New Production Process	Environmental impact: Energy consumption (GJ/t metal)	CO2 Emissions (tCO2/t metal)	Freshwater consumption** (m3/t metal)	Waste (t/t metal)
Sulfide pressure oxidation	86	4	22	35
Nickel Ore bioleaching	46	2	77	32
Copper Tailing bioleaching	22	2	11	3
In-situ leaching	13	1	5	3
Hydrometallurgy (Sx-Ew) with efficient separation	346	16	28	6,850
Hydrometallurgy (Sx-Ew) with efficient separation	285	15	21	1,540
DLE	39	2	18	1
Uncalcinated rock leaching	77	7	3	3

Figure 2: Top 10 Technologies (Arthur D Little for WMF 2023).