Minerals recovery from beneficiation waste in mining industry: prospective LCA of Grecian Magnesite case study

Hazem Eltohamy[1], Giuseppe Cecere[1], Haris Yiannoulakis[2], Duong H. Hoang[3,4], Lucia Rigamonti[1]

[1]Department of Civil and Environmental Engineering, Politecnico di Milano, Milan, Lombardia, 20133, Italy
[2]Research and Development, Grecian Magnesite, Vassilika, Thessaloniki, 57006, Greece
[3]Maelgwyn Mineral Services Ltd., Ty Maelgwyn, Cathays, Cardiff, CF24 4PA, United Kingdom
[4]Helmholtz Institute Freiberg for Resource Technology, Helmholtz-Zentrum Dresden-Rossendorf, Freiberg, 09599, Germany
Keywords: Life cycle assessment, mining solid waste, emerging technology, froth flotation.
Presenting author email: lucia.rigamonti@polimi.it

Froth flotation is one of the most known methods employed in mining industry to concentrate precious minerals for downstream refining stages. Currently, an innovative flotation technology is being developed under FineFuture (FF) project, funded by the European Union Horizon 2020 research and innovation programme (grant agreement No 821265). The project will expand the basic understanding of fine particle flotation phenomena (below 20 µm in size). If proves effectiveness, this technology will have the potential to valorise fine mineral particles rather than disposing them as waste. As part of the project, the environmental sustainability of this new technology is to be evaluated, hence Life cycle assessment (LCA) methodology was adopted to fulfil this target.

The environmental evaluation of technologies at this early stage of development has a huge potential to direct the technology towards better environmental outcomes. Nevertheless, applying LCA on emerging technologies or as usually called in literature "prospective LCA" is associated with some challenges related to lack of data, scale-up, uncertainty about the way the new technology will be deployed and market conditions, and sometimes absence of incumbents against to compare (Hetherington *et al.*, 2014; Bergerson *et al.*, 2020; Moni *et al.*, 2020).

Grecian Magnesite (GM), one of the industrial partners in FF project, is a Greek mining company specialized in magnesite concentrate ($MgCO_3$) and magnesia production (MgO). The beneficiation plant under study is in Yerakini Mines and Works in Chalkidiki, Greece.

A prospective LCA study has been applied to GM case study. The goal of the LCA is to compare the current beneficiation system of GM with the future one that will have FF flotation implemented on full scale to benefit from the very fine particles with granular size < 4 mm that are currently discarded as waste.

The current system of GM (Figure 1) starts with magnesite ore acquisition from an open pit mine using explosives then it is transported to the pre-beneficiation steps. During pre-beneficiation, the ore is crushed, screened at various size fractions and washed. The fraction below 18 mm is separated to go through further sieving, while the > 18 mm fraction passes through laser sorting and magnetic separation to remove the largest portion of colored or magnetic impurities, and then enters the main beneficiation stage. Here it either passes through camera sorting or a combination of dense media and magnetic separation stages depending on the desired chemistry of the kiln-feed magnesite at calcination stage. The intensive washing before optical sorting generates fines (< 4 mm) that contain pre-beneficiated magnesite ore. Another source of these unexploited mineral-rich fines is the washing step in the other line that benefits from the < 18 mm fraction of ore. These fine particles generated from the washing units are not utilized currently and is discarded as waste in stockpiles despite its high mineral content which is around 79% $MgCO_3$.

The system is considered a waste management system as it primarily deals with currently rejected flow of material as a principal function. The functional unit on which the baseline (i.e. present) and future scenarios have been compared is thus the management of 1 tonne of < 4 mm fines (Marmiroli *et al.*, 2021). Nonetheless, a useful product will be available for market (i.e. magnesia) at the end of the concentration process of the fines using FF flotation technology which adds another function to the system from LCA perspective. Substitution by system expansion will be done to solve the multifunctionality issue.

The system boundary for the proposed LCA model is illustrated in Figure 2. The units which are common between present system and potential future system were omitted since it is a comparative LCA. As shown in future system in Figure 2, the deployment of the FF flotation unit requires adding some treatment units which are: fine milling of the feed, and dewatering, drying and briquetting of the resulting $MgCO_3$ concentrate from the flotation before being fed to calcination.

The results of this comparison will help detect the environmental hot spots in this early design stage hence improve them, in addition to supporting the decision-making in GM regarding the implementation and operation on industrial scale. Moreover, we believe that real-world studies such as this one can encourage methodological developments of LCA based on real experience of current method's drawbacks when addressing future systems.

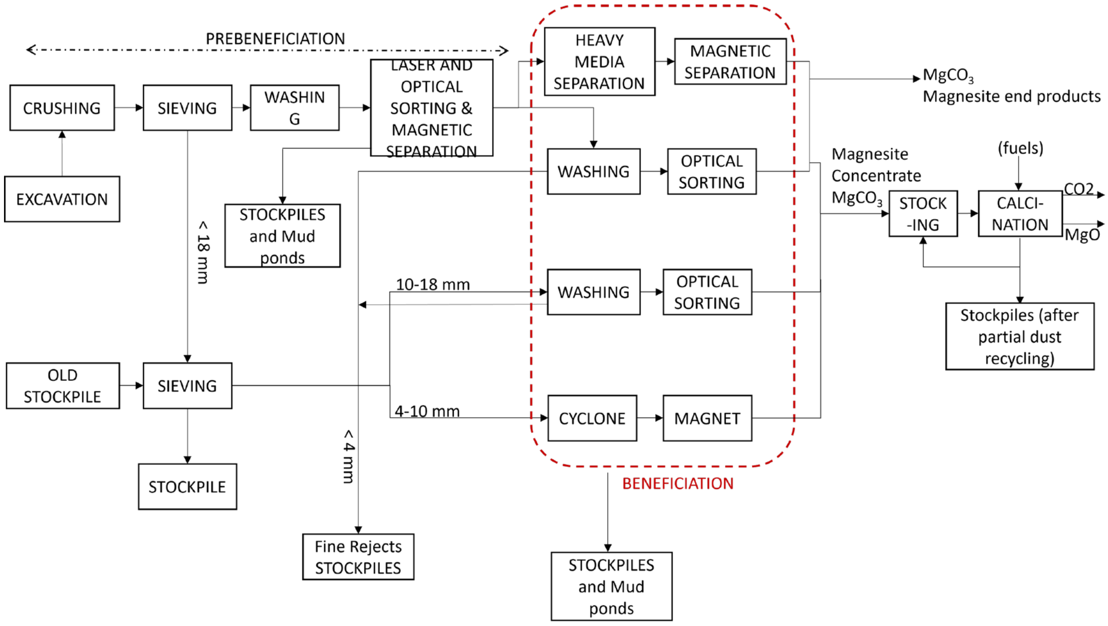

Figure 1. Current system of Grecian Magnesite.

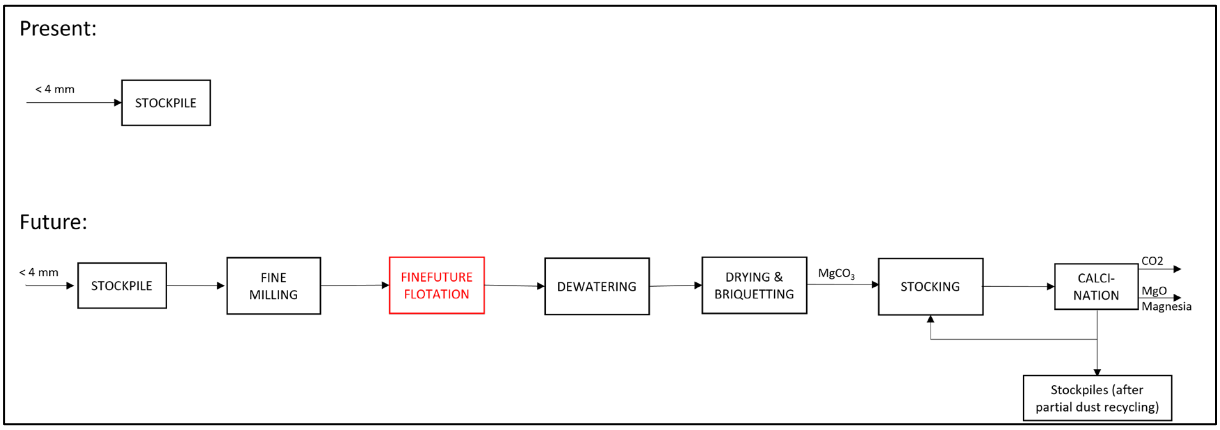

Figure 2. System boundary of present and future scenarios.

Acknowledgments

We would like to express our immense gratitude to the European Union's Horizon 2020 research and innovation programme for funding FineFuture project under Grant Agreement No. 821265.

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