88th LCA Discussion Forum

Frontiers in Life Cycle Sustainability Assessment – How can Life Cycle Thinking embrace the Triple Bottom Line?

Wädenswil, 22.11.2024

FineFuture

Innovative Technologies and Concepts for Fine Particle Flotation: Unlocking Future Fine-Grained Mineral and Critical Raw Materials Resources for the EU

FROM THEORY TO PRACTICE: CHALLENGES AND RECOMMENDATIONS FROM FINEFUTURE PROJECT

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The technology under development

Novel froth flotation technology in the mining industry

"Froth flotation is a physicochemical separation technique that utilizes the variation in the surface wettability of mineral particles. From a heterogeneous mixture of solids, hydrophobic particles are made to attach to gas bubbles then they are carried to the froth phase and recovered as a froth product (typically the value mineral concentrate), while hydrophilic particles remain in the pulp phase and discharged as tailings" (Wang & Liu, 2021)

to efficiently deal with fine particles which are currently lost as tailing deposits or as fine-grained mineral by-products due to lack of adequate technology to process them

https://cordis.europa.eu/project/id/821265

Sustainability assessment in FineFuture

Sustainability assessment

Ex-ante environmental Life Cycle Assessment (LCA)

- Full LCA 1: mineral recovery from waste fines
- Full LCA 2: upgrade existing concentrates

Social Life Cycle Assessment (S-LCA)

- Social hotspot analysis general for the sector in the specific country

Material Flow Cost Accounting (MFCA)

- MFCA applied to case 1 (mineral recovery from waste fines)

GRECIAN MAGNESITE
ΕΛΛΗΝΙΚΟΙ ΛΕΥΚΟΛΙΘΟΙ

FINE FUTURE INNOVATION: The three pillars of sustainability were addressed in Grecian Magnesite case study

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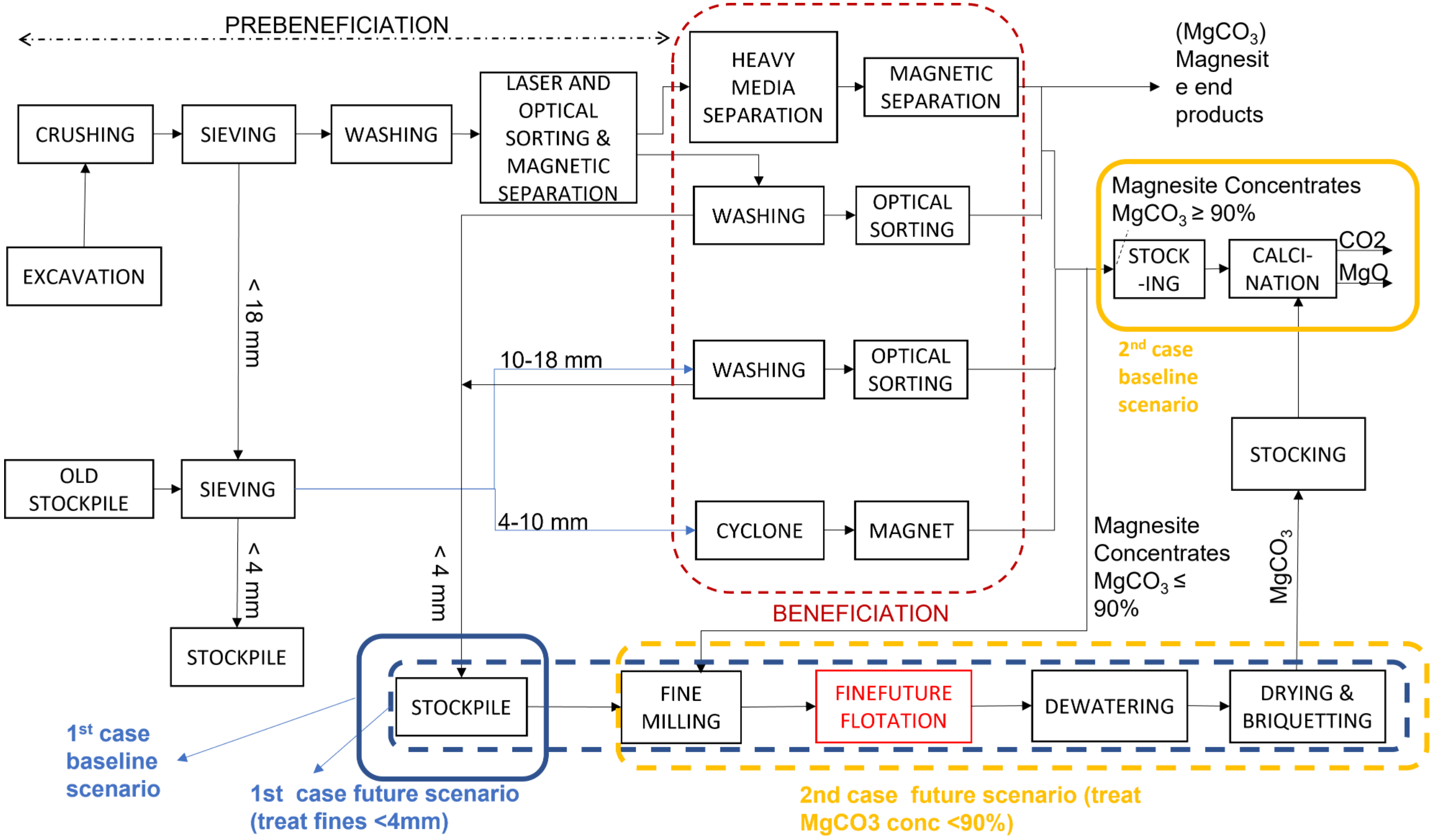
Grecian Magnesite Case Study: LCA



Environmental LCA: challenges and solutions

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- FineFuture flotation technology can have different applications

→ set a range of predictive scenarios to tackle uncertainties about the industrial implementation of the FineFuture technology

- Lack of necessary data due to absence of adequate monitoring systems in place

→ comparative LCA (present vs future) to include only the processes that differ

- Flotation process and more generally beneficiation stage is typically overlooked in traditional LCA literature with flotation being rarely investigated as a stand-alone process in the system

  - Which functional unit (FU) adopt in comparison? → review paper and choice of input-based FU

  - How to solve multi-functionality? + There is a lot of uncertainty regarding the ecoinvent dataset representing average Magnesia production in Europe → tested different methods i.e. 1) substitution by system expansion including also a substitution ratio for magnesia 2) physical allocation based on mass property

Environmental LCA: challenges and solutions

- How to properly scale-up the system for a fair comparison?

→ Worked step by step: 1) projected technology scenario definition 2) projected LCA flowchart 3) data estimation by "manual calculations" on available primary data + minor use of proxy data (this step was done in close coordination with the technology experts of the consortium and of GM R&D department)

- Efficiency uncertainty due assumptions in the scale-up

→ knowledge that some results can be overestimate because of the linearity assumption in the upscaling from lab tests + sensitivity analyses

- Avoided raw magnesite ore consumption is not characterized under the EF impact assessment method

→ add this information separately

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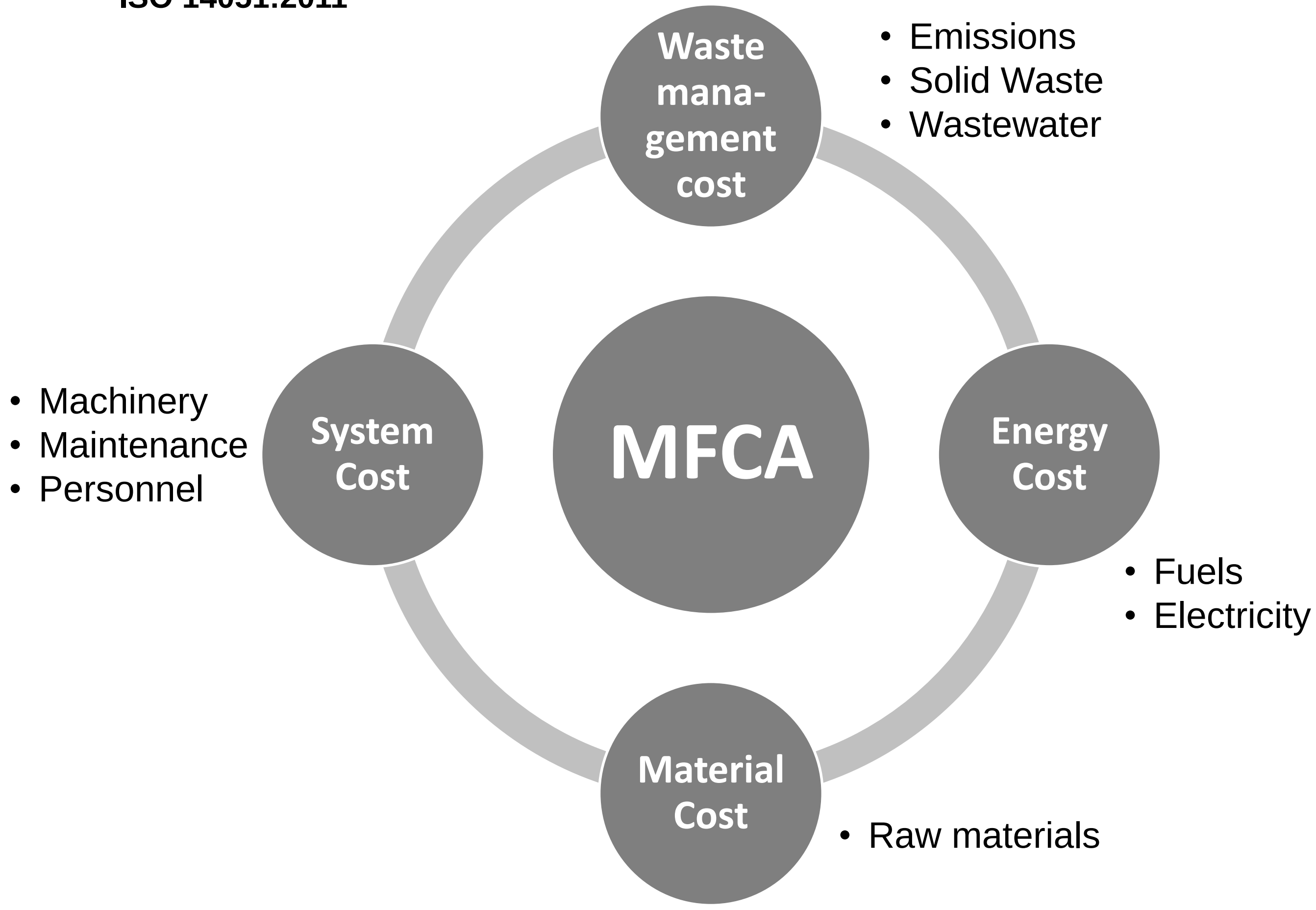
Environmental LCA: main conclusions for Grecian Magnesite

- The LCA results **did not decisively support the application of FineFuture technology**
- The **calcination** after flotation is the **environmental hotspot**
- Cleaner fuels and burners are highly encouraged
- Upgrading low-quality concentrate is slightly preferred over treating the fines
- A big advantage of FineFuture technology applied to residues upgrade is **raw material preservation**

Material Flow Cost Accounting (MFCA)

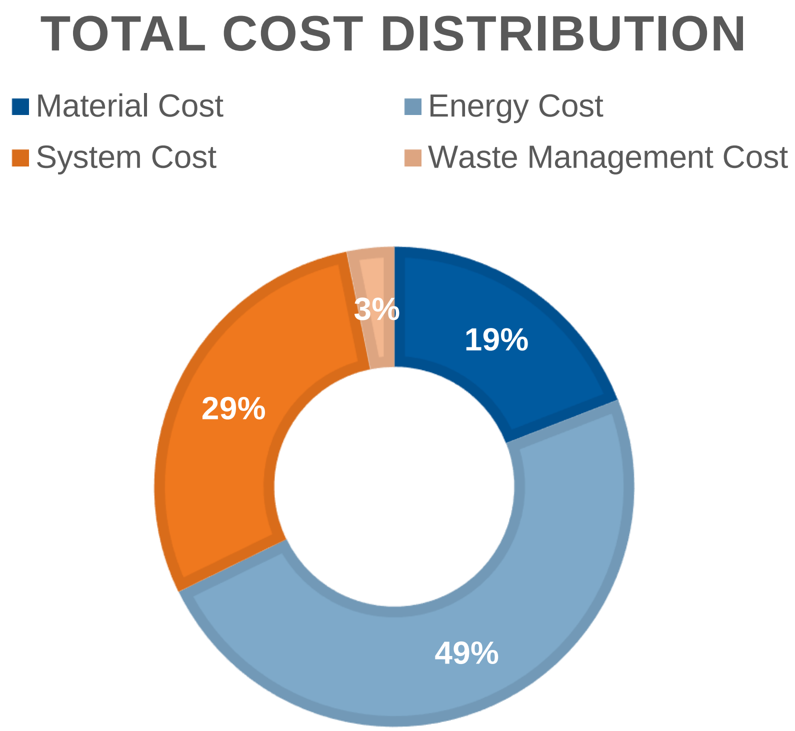
Methodology

ISO 14051:2011



Main results for Grecian Magnesite (first case study)

In the future scenario, 24% of the total costs is transformed into the positive product (intermediate or final products), while the share of negative product is 76% (losses in different forms)



MFCA: challenges and solutions

- Data confidentiality and costs related to the development and application of a technology (i.e. not a product)

→ MFCA instead of LCC

- Very limited literature resources on application of MFCA to a waste management service. Most revolve around economic optimization of production losses.

→ we followed ISO 14051, identifying the “quantity centers” of the current and future scenarios

- Difficulties in data collection

→ comparative MFCA + multiple data sources (online interviews and questionnaires to Grecian Magnesite, literature analysis, online databases and statistics)

- The ISO standard does not consider cost savings from internal recycling. Instead, it suggests that all wastes should be treated as material loss, even if recycled internally.

→ Sensitivity analyses

Social LCA: challenges and solutions

- At present, very few studies question the social impacts of the mining sector
- The application of the methodology to low TRL technologies is even less common
- S-LCA of low TRL technologies is challenging because of the difficulties to obtain data that accurately represents future industrial-scale applications
- Potential social impacts are difficult to predict and can be underestimated in the process of scaling up from lab or pilot projects to market-level production

→ internal survey among the project partners to identify the main affected subcategories by the development of the technology for each stakeholder category

→ Social Hotspot Analysis by using the PSILCA database (sector “Other mining and quarrying - Greece”)

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Social LCA: main results

Survey results		Social Hotspots Analysis results	
Local community	• Local employement • Access to material resoruces • Safe and healthy living conditions • Community engagement • Access to immaterial Resources	• Access to material resources • Migration • Safe and healthy living conditions	Local community
Value chain actors	• Respect of intellectual property rights • Fair Competition • Supplier Relationship	• Corruption • Fair competition • Promoting social responsibility	Value chain actors
Society	• Technology development • Contribution to economic development • Public commitment to sustainability issues	• Fair salary • Workers' rights • Discrimination • Child labour • Forced labour	Workers
Consumers	• End-of-life responsibility • Health and Safety • Trasparency • Feedback Mechanism		
Workers	• Health and Safety		

It was possible to identify:

→ some social issues to pay particular attention during the FineFuture technology implementation and when evaluating potential partners entering the life cycle through technology implementation

→ potential positive impacts of the technology

→ the processes that give a relevant contribution to the total impacts of the analysed industrial sector

Table 4 Process upstream impacts with the highest potential impact

Process upstream impacts	Country	% of the contribution to the upstream impact
Coke, refined petroleum products, and nuclear fuel	GR	20
Manufacture of coke, refined petroleum products, and nuclear fuels	GR	20
Crude petroleum	IR	12
Collection, purification, and distribution of water	IR	11
Mining and quarrying (energy)	RU	7
Land transport; transport via pipelines	GR	3
Electrical energy, gas, steam, and hot water	GR	3
Wholesale trade and commission trade, except of motor vehicles and motorcycles	GR	3
Other mining and quarrying products	GR	3

Final recommendations

- LCA:
  - define a range of future scenarios to deal with the uncertainty of emerging technologies application
  - be transparent about the data TRL level and how upscaling was done
  - perform sensitivity analyses of potential hotspots in the upscaled system
- MFCA:
  - repeat the analysis as data evolves
  - investigate how to deal with internal material recycling
- Social LCA:
  - combine a Social Hotspot Analysis by using an (updated) social LCA database with a questionnaire to be administered to the technology developers
  - do research to improve the applicability of the methodology to cases with low TRL
- LCSA:
  - the application to case studies involving low TRL technologies must be tailored on the type of data that can be collected
  - strict collaboration with the industrial partners: enhanced communication of data, while addressing confidentiality concerns, is crucial for modelling the system consistently with reality

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Main publications

"Life Cycle Assessment in mineral processing – a review of the role of flotation"

B. MARMIROLI, L. RIGAMONTI, P.R BRITO-PARADA

The International Journal of Life Cycle Assessment**,** 27, 62-81, 2022 (open access)

https://doi.org/10.1007/s11367-021-02005-w

"Ex-ante Life Cycle Assessment of FineFuture Flotation Technology: Case Study of Grecian Magnesite"

H. ELTOHAMY, G. CECERE, L. RIGAMONTI

The International Journal of Life Cycle Assessment (open access)

https://doi.org/10.1007/s11367-023-02221-6

"A socio-economic assessment of an emerging technology in the mining industry".

CECERE G., HASSAN R., ELTOHAMY H., RIGAMONTI L.

The International Journal of Life Cycle Assessment, 2024

https://doi.org/10.1007/s11367-024-02392-w


The International Journal of Life Cycle Assessment (2022) 27:62–81
https://doi.org/10.1007/s11367-021-02005-w

LIFE CYCLE MANAGEMENT

Life Cycle Assessment in mineral processing – a review of the role of flotation

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Abstract
Purpose The aim of this literature review is to investigate the role of the beneficiation stage in the Life Cycle Assessment (LCA) of metals and minerals with a focus on the flotation process.
Methods The systematic literature search included LCA studies comprising the beneficiation stage in their system boundaries

The International Journal of Life Cycle Assessment (2023) 28:1348–1365
https://doi.org/10.1007/s11367-023-02221-6

LCA OF WASTE MANAGEMENT SYSTEMS

Ex-ante life cycle assessment of FineFuture flotation technology: case study of Grecian Magnesite

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SOCIETAL LCA

A socio-economic assessment of an emerging technology in the mining industry

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Abstract
Purpose This article provides methodological insights to evaluate the socio-economic risk of an emerging froth flotation technology for the mining sector with the goal of guiding the design and development process. This technology is used to separate valuable particles based on surface properties among minerals and, if properly developed, could be used to valorize fine particles that currently existing technology cannot separate and thus become waste material.
Methods The Social Hotspot assessment utilized the Product Social Impact Life Cycle Assessment (PSILCA) database to analyze social hotspots in the relevant industrial sector. In addition, a survey captured the viewpoints of technology developers regarding additional potential social risk and opportunities. The final results were defined by combining these two analyses, conducted according to the 2020 UNEP guidelines for Social Life Cycle Assessment of Products and Organizations. For the economic assessment, the Material Flow Cost Accounting (MFCA) methodology (ISO14051) was applied, considering material costs, system costs, energy costs, and waste management costs for both the current situation and a future industrial-scale scenario.
Results and discussion The study emphasizes the importance of tailoring methodological approaches for case studies involving low Technology Readiness Level (TRL) technologies based on available data. The state of technology development has led to different results for the economic and social analyses, primarily due to the difficulty in accurately predicting potential social impacts at this stage. The social analysis identified potential risks and 28 subcategories of impacts across different stakeholder categories. The economic assessment found that energy costs (49%) were the highest contributor to the MFCA cost of the future scenario, followed by system costs (29%).
Conclusions and recommendations The study concludes that conducting a socio-economic analysis during the developmental stage of a technology is valuable for identifying critical hotspots that require monitoring, effectively guiding the research and development phase. This application represents a unique case in the mining sector and could be a first step in defining a methodological approach suitable for low TRL technologies. Analyzing both social and economic risks provides a more comprehensive perspective on sustainability, complementing environmental risk assessments.

Keywords Emerging technologies · Social life cycle assessment · Material Flow Cost Accounting · Social hotspots analysis · Socio-economic assessment · Flotation technology

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Questions?