Implementation of LCA to support circular process development for extraction of CRMs from seawater brines

LCM 2021

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Dr. Özge Yılmaz

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Ensuring sustainable development through circularity

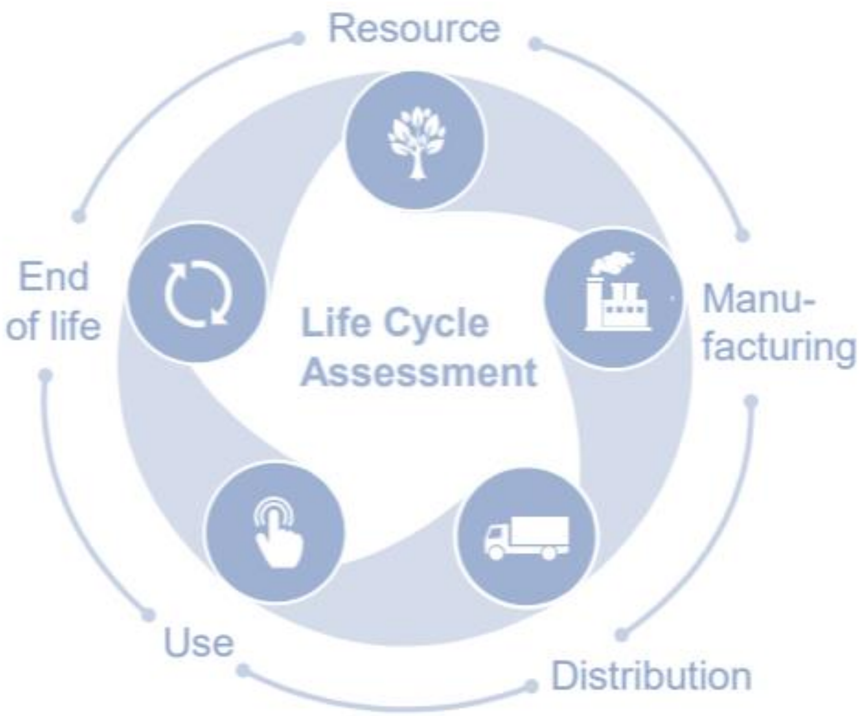
SEArcular MINE

While the notion of CE is widely accepted as a vital component to ensure sustainable development, ***not all circular strategies are inherently sustainable***.

It is increasingly important to develop frameworks for evaluating not only specific measures and improvements but also their overall contribution to closing the material cycles in the economy and taking advantage of ecological material cycles.

LCA is very well suited to assess the sustainability impacts of CE strategies by substantiating environmental claims of CE, identify hotspots, and evaluate trade-offs.

Specifically, LCA can account for any changes along the value chain when progressing to a circular model. LCA highlights ***burden shifting***, where impacts can be reduced at one point and increased at another.



Visual: American Center for Life Cycle Assessment,

https://aclca.org/wp-content/uploads/ACLCA-Business-Value-of-LCA-Flyer-v2.pdf

Creating a sustainable, circular approach to mineral extraction

SEArcularMINE builds on the ancient and still widely used process of **saltworks** where seawater goes through natural evaporation and crystallization in shallow basins.

The resulting brine (bittern) contains high concentrations of **valuable trace elements**.

The project will develop technologies that will contribute to securing European access to **Critical Raw Materials (CRMs)** through **circular** processing of the abundant bittern resources which meets the highest expectations in terms of performance, cost and green credentials.

Critical Raw Materials

Supply Risk
(sorted largest to smallest)

Very high	LREEs HREEs
High	Magnesium Niobium Germanium Borates Scandium
Moderate	Strontium Cobalt PGMs Natural graphite
Low	Indium Vanadium Lithium Tungsten Titanium Gallium, Hafnium Silicon metal
Very low	Manganese Chromium Zirconium Tellurium Nickel, Copper

EU aims to diversify the supply from third countries and developing the EU's own capacity for extraction, processing, recycling, refining and separation of rare earths.

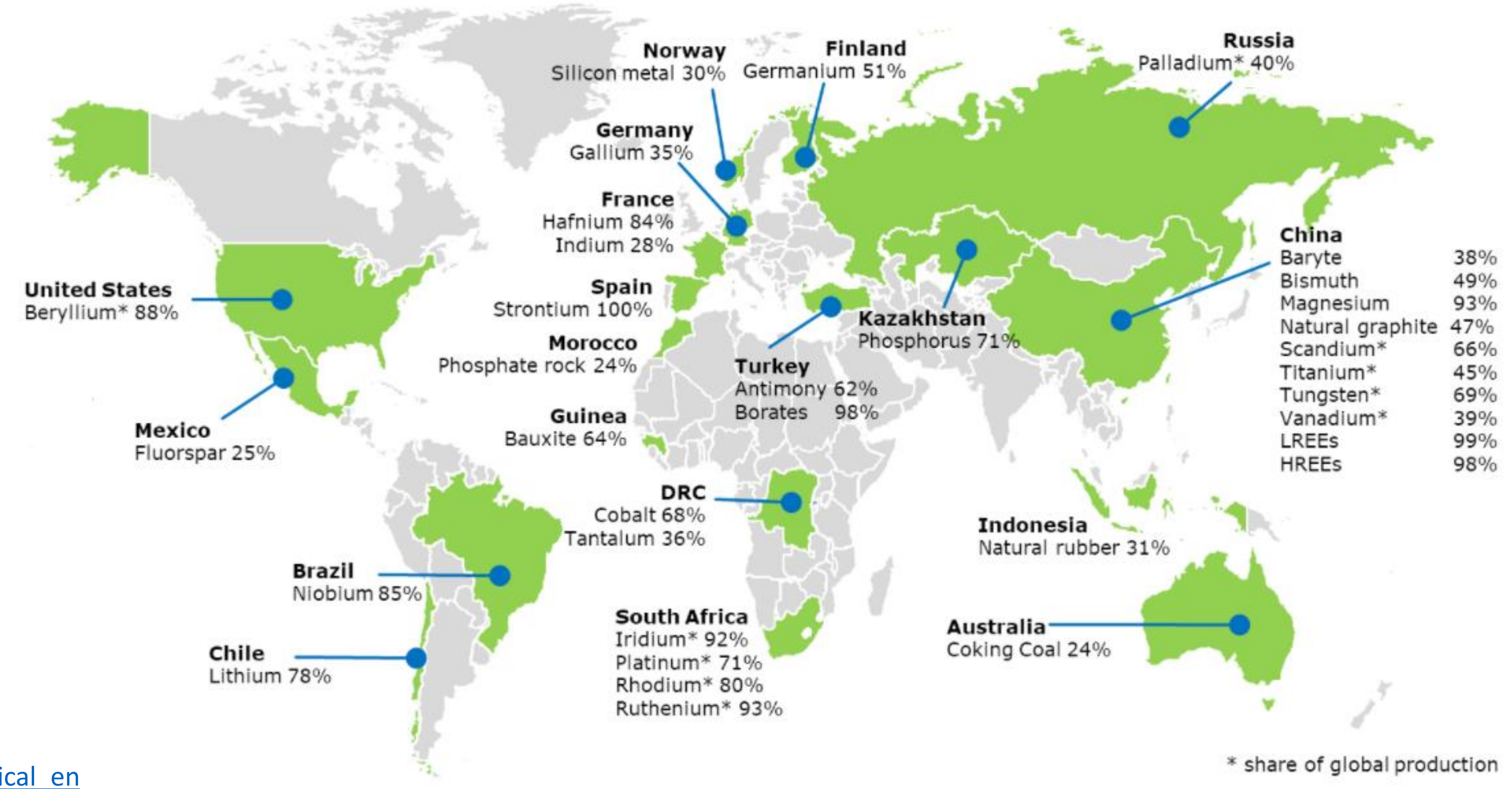
The ***Action Plan on Critical Raw Materials*** is aimed to:

- develop resilient value chains for EU industrial ecosystems;
- reduce dependency on primary critical raw materials through circular use of re-sources, sustainable products and innovation;
- strengthen domestic sourcing of raw materials in the EU;
- diversify sourcing from third countries and remove distortions to international trade, fully respecting the EU's international obligations.

Critical raw materials

2020 critical raw materials (new as compared to 2017 in bold)		
Antimony	Hafnium	Phosphorus
Baryte	Heavy Rare Earth Elements	Scandium
Beryllium	Light Rare Earth Elements	Silicon metal
Bismuth	Indium	Tantalum
Borate	Magnesium	Tungsten
Cobalt	Natural graphite	Vanadium
Coking coal	Natural rubber	**Bauxite**
Fluorspar	Niobium	**Lithium**
Gallium	Platinum Group Metals	**Titanium**
Germanium	Phosphate rock	**Strontium**

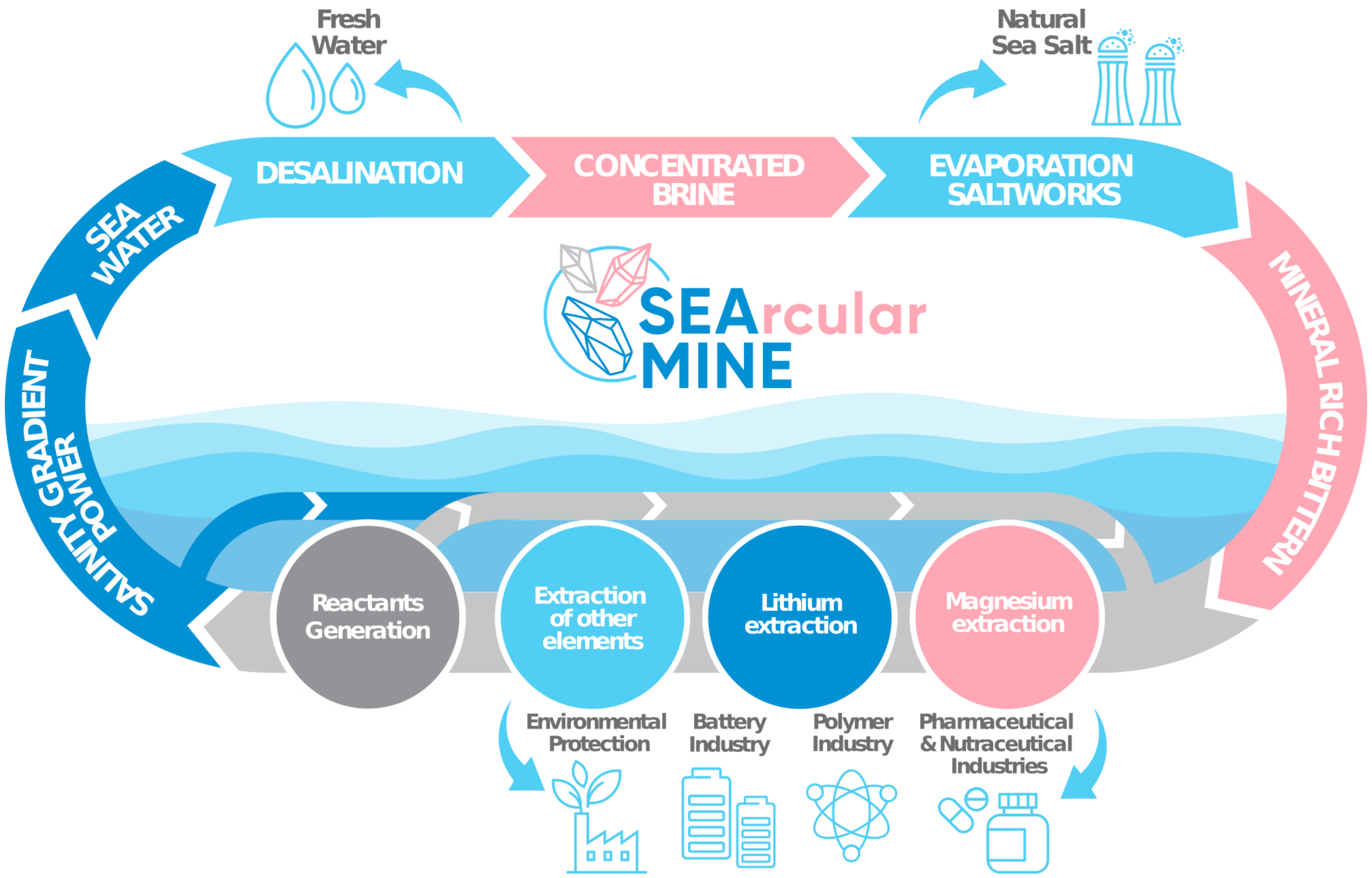
Countries accounting for largest share of EU supply of CRMs



Reference: European Commission,

https://ec.europa.eu/growth/sectors/raw-materials/specific-interest/critical_en

SEArcularMINE Project



Circular Processing of Seawater Brines from Saltworks for Recovery of Valuable Raw Materials

SEArcularMINE will prototype an innovative integrated process aimed at recovering energy and critical raw materials such as ***magnesium, lithium, rubidium*** and other trace elements, from waste brines in Mediterranean basin saltworks.

SEArcularMINE Project

Supply Risk	Material									
3,91	Magnesium		●				●	●	●	●
1,64	Lithium	●	●				●	●		
2,57	Strontium		●				●	●		
3,89	Germanium					●		●		●
1,26	Gallium					●	●	●		●
2,54	Cobalt	●	●	●			●	●	●	●

The project will target very low energy consumption, alongside generating electricity from salinity gradients of seawater. The circular approach maximizes resource efficiency and economic viability.

Life cycle approach

SEArcularMINE

SEArcularMINE utilizes LCA and LCC to evaluate the impacts of the different CRM valorization processes and of the integrated system, guiding the development process and leading to economic viability and lower environmental impact compared to traditional production processes.

LCA is positioned within the project to provide continuous support for development of sustainable technologies with highest possible added benefits.

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LCA for technology development

Decisions made at early development stages have far reaching influences on the future functionality, cost, and environmental consequences of the technology.

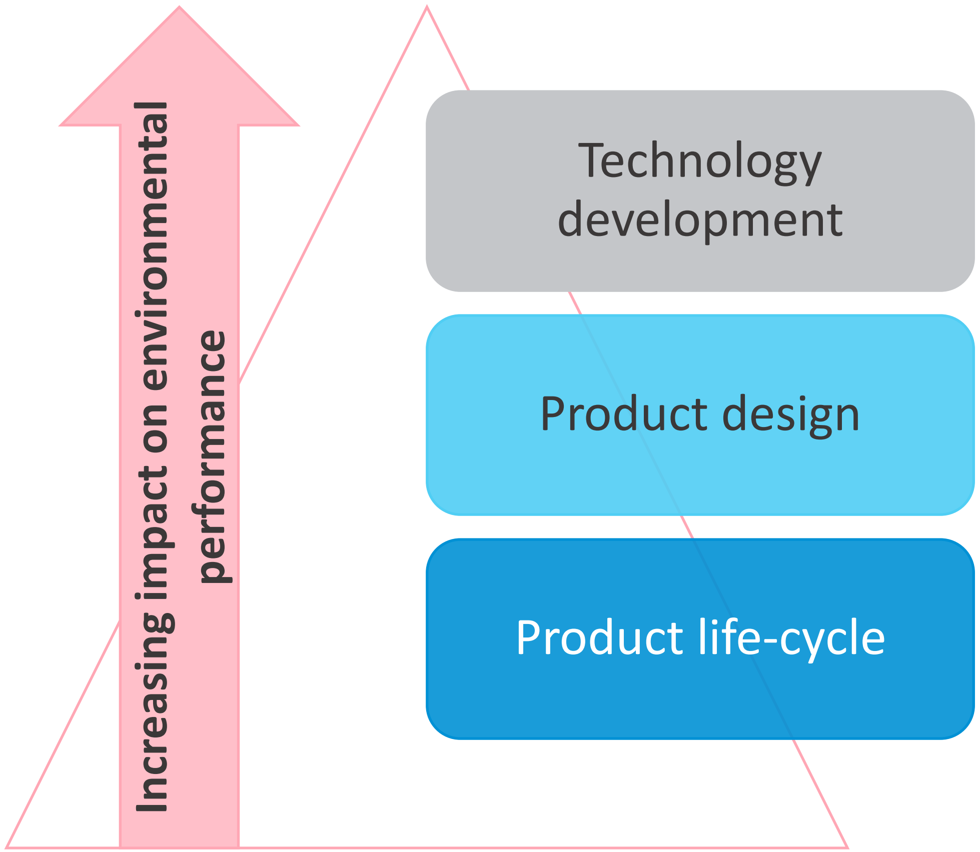
Application of LCA has great potential to drive the development of emerging technologies with improved environmental performance by identifying ***environmental hotspots*** and comparing with existing alternatives when used at early design stages.

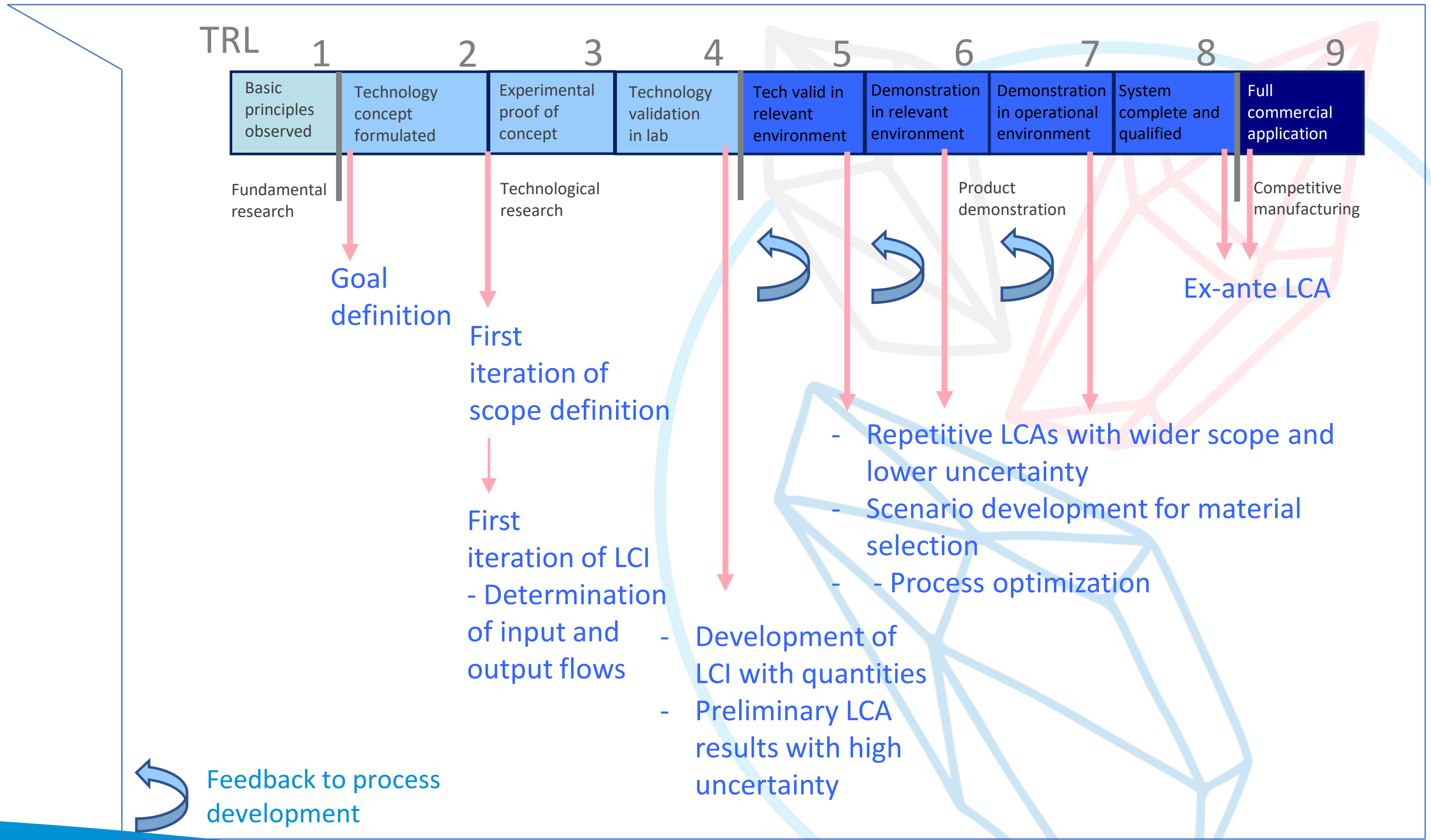
As TRL increases, the environmental impact per unit output may decrease as a result of improved material and energy efficiency.

"It has been estimated that about 80% of all environmental effects associated with a product or process are locked in during the design phase"

Tischner, U., S. Masselter, and B. Hirschl. 2000. How to do EcoDesign?: a guide for envrionmentally and economically sound design. Verlag Form: Frankfurt Am Main

LCA for technology development





LCA for technology development

There are several methodological challenges to employ LCA for emerging technologies

- TRL 3: System not integrated, material and energy balances are not yet set

  TRL 4-6: Comparability, scale up issues, data and model uncertainties

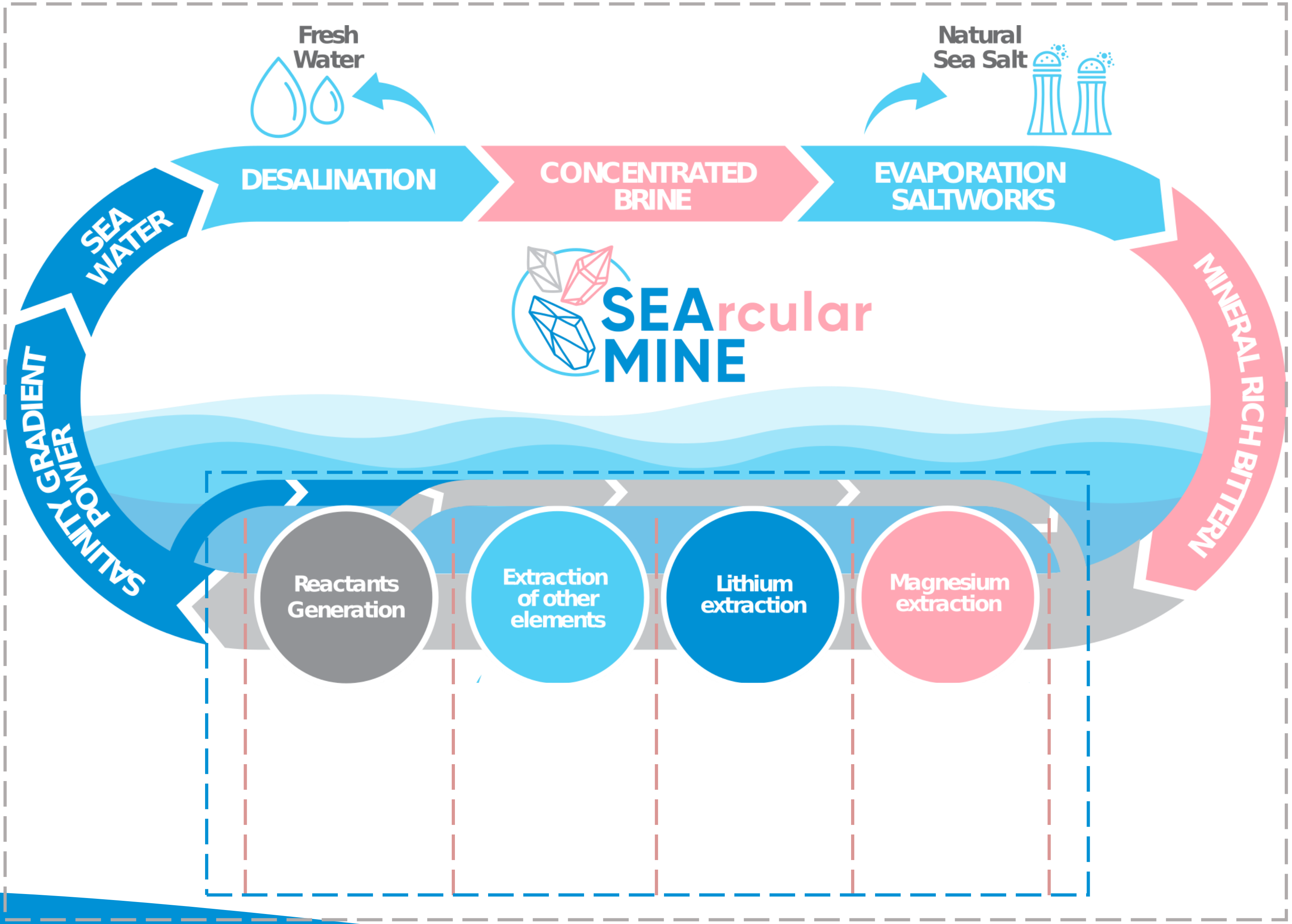
  TRL 7-8: Scale up issues due to change in material and energy efficiency, data uncertainty
- ***Scope and functional unit:*** During iterative LCA while TRL is increasing, different functional units may be used, which may be too limited to provide LCA results for the integrated technology.
- ***Missing data***: between TRL 2-5, the inventory data needs to be supplemented with scale up assumptions to better represent the environmental performances.
- ***Comparability***: LCA of the developing technologies does not yield conclusive results on whether they present a more environmentally friendly solutions than technologies on market
- ***Data specificity***: Often, during technology development, the LCA practitioner would have certain information on the geography of production or transportation distances
- ***End-of-life stage***: The EoL stage is still not clear in terms of identifying all circular opportunities.

SEArcularMINE LCA - scope

Tier 1: preliminary LCA
LCA for individual process steps
- During development
- Low TRL
- Repetitive LCAs

Tier 2: final LCA
LCA for the integrated system
- Following scale-up
- Higher TRL
- Field data

Tier 3: Impact of resource valorization on overall saltworks



SEArcularMINE LCA – initial progress

Project consortium is working on the design and laboratory testing of the individual recovery processes.

Initial LCA efforts have been focused on:

- Identification of energy consuming hotspots within the process (pumping, mixing, drying/dewatering etc.)
- Simple scenario development for the energy sources (energy mix vs different renewable energy sources)
- Chemicals consumption for extraction processes and comparisons between different chemicals – manufacturing of the chemicals and transportation aspects

Periodic updates of the life cycle inventory will be made as the technology development progresses.

To be continued….

SEArcularMINE LCA – outlook

TRL

1	2	3	4	5	6	7	8	9
Basic principles observed	Technology concept formulated	Experimental proof of concept	Technology validation in lab	Tech valid in relevant environment	Demonstration in relevant environment	Demonstration in operational environment	System complete and qualified	Full commercial application

Fundamental research | Technological research | Product demonstration | Competitive manufacturing

Focus on conceptual technology

Focus on ***hotspots*** with partial FUs as necessary. ***Scenario development*** to tackle different hotspots. Continuous feedback. Comparison with commercialized technologies should be avoided (impacts for new technology would be overestimated)

Focus on ***process optimization*** particularly ***energy*** optimization accompanying process and equipment scale-up as well as ***material*** efficiency including use of exact raw material selection. ***Scenario development*** for optimization and background system. ***Highest potential for impacting the environmental performance***. LCA results of commercial technologies can be used for ***benchmarking*** and target purposes.

Mature LCA with nearly finalized inventory. Less chance to impact the environmental performance of the technology. Focus on ***end-of-life stage*** and ***allocation.*** ***Comparisons*** can be made with commercial technologies (with reservation).

SEArcularMINE LCA – outlook

Multiple functional units can be used for different process steps.

Constant **bi-directional *communication*** with technology providers is the key where they play crucial role in identifying benchmark technologies and finalized raw materials for production.

Step-by-step approach to create ***incremental improvements*** in the technology.

Predictive and worst-case scenarios can be developed.

A ***scale-up frameworks*** such as by Piccinno et. al. (2016)* can be used for TRL 4-6.

Scenarios should consider the ***background system*** including energy mix and transportation keeping location of production in assumptions.

Rigorous sensitivity analysis is planned.

* Piccinno, F., R. Hischier, S. Seeger, and C. Som. 2016. From laboratory to industrial scale: a scale-up framework for chemical processes in life cycle assessment studies. Journal of Cleaner Production 135: 1085–1097. http://dx.doi.org/10.1016/j.jclepro.2016.06.164.

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Thank you!

Dr. Özge Yılmaz - ozge.ylmz@gmail.com

Project Coordinator: Andrea Cipollina
Email: andrea.cipollina@unipa.it

Communications & Press: Tara Murphy
Email: tara@erinn.eu

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