Prospective life cycle assessment for nickel slag valorization by mineral carbonation

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Prospective life cycle assessment for nickel slag valorization by mineral carbonation
The issue of nickel slag in New-Caledonia and the project for a solution

- One of the five largest nickel producers in the world.
- Per year:
  - 5.8 million tons of nickel and ferronickel
  - 9.5 million tons of slag, very little recycled, filling a stock of 20-25 million m³
  - More than 1 million tons of CO₂ from the thermal power plants supplying the pyrometallurgical plants

Mineral carbonation

Supplementary cementious material (SCM)

Best conditions for the environmental performance of SCM production?
How to reach our objective?

Study a low TRL process (lab scale)?

Prospective LCA

“Studies of emerging technologies in early development stages, when there are still opportunities to use environmental guidance for major alterations” (Arvidsson et al., 2018)
The prospective Life Cycle Assessment model

The time-horizon for the industrial level: 2035
The system: production of 1 kg cement with clinker substitution of 40% by SCM (target for the future to meet the climate mitigation policies)
The prospective Life Cycle Assessment model

The decision variables, defined according to the territory

108 scenarios to assess

Crushing & grinding → Carbonation → CO₂ capture and compression → Drying → Market launch → Mixing

- Direct output stream, oxy-fuel combustion or post-combustion?
- Gas, oil or coal?
- Thermal power plant or electricity grid?
- Where?

Cement production
The prospective Life Cycle Assessment model

The technological issues

Carbonation rate?  
In lab, 30 to 70%.  
Assess to determine the best value.

Carbonation electricity consumption?  
In lab, high consumption: from 0.6722 to 3.2063 kWh per carbonated slag.  
Reduction is mandatory. Assess from 0.1 to 1 kWh to obtain the maximum acceptable value.

Crushing & grinding  
Carbonation  
CO₂ capture and compression  
Drying  
Market launch  
Mixing  
Cement production
How to reach our objective?

Study a low TRL process (lab scale)?

Prospective LCA

“Studies of emerging technologies in early development stages, when there are still opportunities to use environmental guidance for major alterations” (Arvidsson et al., 2018)

- Parametrized LCA model with the database Ecoinvent 3.7.1 cut-off
- Python script to create the sets of scenarios and parameters, to adapt the LCA model and to calculate the LCA impacts

Assess a large number of scenarios and parameters?

- Automatic projection of the Ecoinvent database
- Manual projection (e.g. electricity production mix for New-Caledonia).

Adapt the background to the future time horizon?

- Brightway
- Premise
What are the most favorable scenarios and technological values?

Example on the climate change impact with 30% of carbonation and 0.1 kWh

Up to 33% reduction

All scenarios are better. But this is only for climate change.
What about the other environmental impacts?

Assessment on the 16 impacts of the ILCD 2.0 midpoint method

- The higher the electricity consumption, the lower the number of impacts improved.
- The higher the carbonation rate, the lower the number of better scenarios. → when the climate change impact decreases (due to CO₂ capture), the other impacts generally increase.

The most favorable technological solutions are 30% for the carbonation rate and 0.1 kWh of the electricity consumption.
What are the most favorable scenarios?

8 scenarios perform better than future ordinary Portland cement on the 16 impacts of the ILCD 2.0 midpoint method

<table>
<thead>
<tr>
<th>Decision variable</th>
<th>2 solutions for a coal power plant</th>
<th>6 solutions for a gas power plant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electricity for CO\textsubscript{2} capture and compression</td>
<td>0 power plant and 2 electricity grid</td>
<td>4 power plant and 2 electricity grid</td>
</tr>
<tr>
<td>CO\textsubscript{2} capture technology</td>
<td>0 direct output stream, 2 oxy-fuel combustion and 0 post-combustion</td>
<td>0 direct output stream, 2 oxy-fuel combustion and 4 post-combustion</td>
</tr>
<tr>
<td>Fuel to dry carbonated slag</td>
<td>2 gas, 0 oil and 0 coal</td>
<td>6 gas, 0 oil and 0 coal</td>
</tr>
<tr>
<td>Market</td>
<td>1 New-Caledonia, 1 Australia, 0 Japan</td>
<td>3 New-Caledonia, 3 Australia, 0 Japan</td>
</tr>
</tbody>
</table>

To be further coupled with an economic analysis
Conclusion

Highlights of the prospective LCA study

• There is an environmental interest for the production of SCM from nickel slag valorization
• The conditions to reach the best environmental performance are identified:
  • The best scenarios → decision making to settle the valorization process on the territory of New-Caledonia
  • The technological values → targets to continue the development of the process

Perspectives

• Assess the economic viability of the selected scenarios
• Compare the SCM with other future SCMs
THANKS FOR YOUR ATTENTION

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