Studying innovative applications for the valorisation of white slag in the lime value chain

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National Research Council of Italy (CNR)
National Research Council of Italy (CNR) has totally 8,600 employees consisting of researchers, technicians, and administration staff. It has the highest number of researchers in Italy.

STIIMA (Institute of Intelligent Industrial Technologies and Systems for Advanced Manufacturing) is one of the institutes of CNR.

STIIMA’s headquarter is located in Milan and there are four other branches in Biella, Lecco, and Bari (two branches).
- Around 41% of the crude steel produced in EU-28 is electric-based (World steel association 2020), with Italy’s share of 29%. In Italy, almost 90% of crude steel is produced via scrap-based steel production.

- Overall, the two regions, Lombardy and Friuli-Giuglia Venezia produce the highest volume of scrap-based steel production accounting for more than 70%.

- Almost 90% of crude steel in Italy is via scrap-based production route with a volume of slag from secondary metallurgy (SMS; white slag) of around 900,000 tons, out of which 450,000 tons are produced in Lombardy.
A multiple case study has been carried out, with the participation of 5 Italian scrap-based steel producers. Each producer represents a different approach for slag.

The companies under study constitute almost one third of the Italian crude steel production volume.

Apart from the landfilling, the applications of white slag include the internal use as the EAF feedstock in substitution of lime, cement, and road construction. In addition, the process of metal separation is a source of home scrap for EAF.
The main challenges are analysed based on 5 factors: legislation, technology, production rate, market, and economy.

- Regarding both types of slag, the legislation limits the application in some industrial sectors.
- The main challenge for small steelmakers is the high investment costs for slag treatment.
- The technologies and market are more challenging for the white slag rather than black slag, due to:
  1. **Volume instability of the mix**: Due to the high proportion of lime, the direct use of white slag, without any special treatment, is challenging.
  2. **Volatile composition** of slag based on the production methodology.
  3. **Exposure to the stockpiles**, which results in the formation of powder and makes it difficult for handling and transportation.

<table>
<thead>
<tr>
<th>Challenge</th>
<th>Steelmaker1</th>
<th>Steelmaker2</th>
<th>Steelmaker3</th>
<th>Steelmaker4</th>
<th>Steelmaker5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Legislation</td>
<td>L</td>
<td>H</td>
<td>L</td>
<td>M</td>
<td>M</td>
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<tr>
<td>Technology</td>
<td>L</td>
<td>H</td>
<td>L</td>
<td>L</td>
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<tr>
<td>Production rate</td>
<td>M</td>
<td>M</td>
<td>M</td>
<td>M</td>
<td>L</td>
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<tr>
<td>Market (potential customers)</td>
<td>M</td>
<td>H</td>
<td>L</td>
<td>L</td>
<td>M</td>
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<tr>
<td>Economy (investment cost)</td>
<td>M</td>
<td>M</td>
<td>L</td>
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<td>L</td>
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</tbody>
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L: Low, M: Medium, H: High

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**Main challenges in the black and white slag value chain**
1. Extrapolation and analysis of statistical data on the white slag and identification and mapping of steelmaking plants in Italy and Lombardy.

2. Market analysis of the lime producers in Lombardy.

3. Analysis and mapping of the potential slag customers, such as glass, road, and building.

4. Technological and economic analysis of white slag, lime and other potential industries in Lombardy, resulting in a new framework for the white slag value chain.

5. Analysing the new framework by utilising the economic indicators and supply chain flows derived from case studies.
Based on the literature, the features of lime products, and the characteristics of the interviewed SMs, a technological mapping of the white slag is developed.


A pre-treatment can be one or more than one of the following activities:

- **Physical pre-treatments**: such as grinding, and sieving, and combination with the other material
- **Chemical pre-treatments**: such as hydration and carbonation
- **Temperature variations**: such as cooling and heating
Most **lime producers** are vertically integrated, which means they are involved in all steps in the production process (Stork et al. 2014).

We have developed a general framework, where the existing flows in the lime value chain are elaborated and combined with the potential applications of white slag in this value chain.
- Economic profitability
- Investment and payback time
- Market demand

- Supply chain collaboration
- Location of potential treatment units

- Industrial symbiosis
- Location of potential treatment units
- The role of an external actor
- Proximity of treatment units
Ferrous slag can be defined as *by-product* or *waste*, which then can be further defined as product/secondary raw material.

In case of recovery activities and a consequent *end-of-waste* status of slag, the handling and supply chain is a critical issue.

The use of by-products, end-of-waste or waste has to be equally supported, irrespectively of their legal status. (EUROFER Position Paper: ‘The New Circular Economy Roadmap – Summary & Priorities’)

One of the priorities in the EU is the *localization* of the industrial *waste management*. This aspect is more crucial for the white slag due to its specific structure.
A new framework for the white slag value chain is developed by considering the following approaches:

1. From the perspective of a **single steelmaker**
2. The **collaboration** among a few steelmakers
3. From a **regional perspective**, to assess the full network of companies in a geographical area.

<table>
<thead>
<tr>
<th>Alternatives</th>
<th>decision maker</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Owned treatment centre- sell to user industries</td>
<td>Steel producer</td>
</tr>
<tr>
<td>2. Owned treatment centre- internal use</td>
<td>Steel producers</td>
</tr>
<tr>
<td>3. Pre-treatment &amp; sell to external actor</td>
<td>Steel producers</td>
</tr>
<tr>
<td>4. sell as-received slag to external actor</td>
<td>Steel producers</td>
</tr>
<tr>
<td>5. Shared treatment centre- sell to user industries &amp; internal use</td>
<td>Steel producers</td>
</tr>
<tr>
<td>6. Shared treatment centre- pre-treatment at SMs- sell to user industries and internal use</td>
<td>Steel producers</td>
</tr>
<tr>
<td>7. Treatment centre(s) – to sell to user industries and re-use in steel production</td>
<td>External actor</td>
</tr>
<tr>
<td>8. Treatment centre- pre-treatment at SMs- sell to user industries &amp; re-use in steel production</td>
<td>External actor</td>
</tr>
</tbody>
</table>
• The alternatives are evaluated based on the following factors:
  • Economic and financial performance
  • Technology
  • Legislation
  • Market demand
  • Supply chain

• We are designing a questionnaire to evaluate the alternatives, linking them to the changes in the external challenges.

• The study is under development principally from the technological perspective.
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Thank you