# InSGeP

Investigations of Slags from Next Generation Steel Making Processes

# Deliverable 6.2

## Market analysis and stakeholder consultation

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## Abstract

The historical usage of slag underscores its importance as a versatile and sustainable material in various industries, from ancient civilizations to the present day.

Blast furnace slag is mostly utilized as a substitute for cement in concrete, while steel slag is predominantly used as a filler or bulk material in embankment construction. This is because steel slag has no latent hydraulic properties (solidification behavior) and can experience issues with volumetric expansion.

The slag product market exhibits a dynamic and complex nature, driven by a broad spectrum of industrial sectors and evolving trends related to technological innovation, resource efficiency, and sustainability. As industries continue to seek environmentally friendly and cost-effective solutions, the demand for slag-based products is expected to remain strong, offering opportunities for growth and innovation in the global market.

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## List of abbreviations and acronyms

| | |
|---|---|
| B.C. | before Christ |
| BF | blast furnace |
| BOF | basic oxygen furnace |
| D | deliverable |
| DRI | direct reduced iron |
| EAF | electric arc furnace |
| EAFC | electric arc furnace carbon steel slag |
| e.g. | exempli gratia |
| EU | European Union |
| GGBS | ground granulated blast furnace slag |
| HBI | hot briquetted iron |
| HPSR | hydrogen plasma smelting reduction |
| Mio | million |
| OPC | ordinary Portland cement |
| WP | work package |

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# 1 Introduction

Next generation iron and steelmaking processes to decrease $CO_2$ by using direct reduced iron (DRI) with varying metallization degrees, hot briquetted iron (HBI), hydrogen plasma smelting reduction (HPSR) or by operating electrical smelters for low-grade iron ores will result in an increase of electric arc furnace (EAF) slag and other slag with different properties. This requires the understanding of the possibility to valorize future slag in the present value chain and define innovative applications to assure a smooth transition process without disrupting the steel industry as well as other sectors (such as road construction or cement), who currently rely on slag as input material for their processes. To understand and move forward the transition of the steel industry, the InSGeP project is investigating slag resulting from next generation steelmaking in Europe. The project relies on the limited amount of currently produced slag from next generation steel production in Europe and abroad as well as on laboratory, pilot scale and industrial scale tests that are going to be performed based on the needs of the involved partners.

Utilizing slag instead of natural resources is a sustainable and environmentally friendly option and in 2021, approximately 70 % (~ 29 million tons) of the slag produced in Europe by the iron and steel industry was recycled and used in different applications [1]. Deliverable 6.2 conducts a comprehensive analysis of the slag product market, providing insight into existing dynamics, developing trends, and future potential. With an analysis of market trends and regulatory impacts, the deliverable intends to give a detailed understanding of the variables influencing the existing and future state of the slag product market.

This deliverable D6.2 was prepared by consulting publicly available literature and the experience of the project partners. Additionally, an online stakeholder survey was carried out that targeted different stakeholder groups: slag processor, slag user, slag producer and scientific community [2].

[1] EUROSLAG, Online: www.euroslag.com (accessed on 16 February 2024).
[2] An overview of the questions used in the stakeholder survey can be found in the Annex.

# 2 Market overview

Slag is a by-product within the iron and steel production and is generated at different stages of the process in varying amounts and compositions. It is an imperative part of the iron and steel sector, resulting in over 45 million tons of slag produced annually in Europe [1]. Its valorization has gained importance in various branches of industry due to its characteristics resulting in a wide range of possible applications and environmental benefits.

Ferrous slag, as industrial by-product, has an extensive history as the material dates back to the beginning of iron making by mankind [1]. One of the first documented examples of slag utilization is attributed to Greek physician Aristotele in 350 B.C. He indicated that slag may be utilized as a medicine, explaining that “When iron is purified by fire, there forms a stone known as iron slag. It is wonderfully effective in drying out wounds and results in other benefits” [1, 3]. Over the years, slag has been utilized for many reasons. For instance, in 1589, it was employed in Germany to produce cast cannon balls [4]. In 1652, slag was used in England to construct wharf structures [5] and in the early 1800s, the first roadways formed from slag were erected in England [6]. In 1862, the German businessman Emil Langen identified the latent hydraulic activity of ground granulated blast furnace (BF) slag and the initial application of slag in cements occurred in Germany in 1865 [1, 7]. During these time periods, however, applications were rather occasional. It was not until the early 20th century that the valorization of slag became customary, and they were employed for multiple purposes [1]. Military equipment requirements during the two World Wars contributed to a rise in steel demand [8]. As a result, the production of steel slag increased. Efforts were undertaken to identify useful applications for slag in order to handle its expanding quantities.

The aforementioned examples illustrate the historical evolution of the slag product market, which progressed from considering slag to be just a by-product to acknowledging its significant value across various industries.

## 2.1 Types of slag available on the market

Slag can be used in many applications and industries due to their diverse composition, cooling conditions and resulting properties. A classification of the iron and steel slag market is possible according to the slag type, final consumer industry, and region [9].

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[3] Ciocan A.: Assessment of blast furnace slag transformation into value added by-products on basis on knowledge of slag characteristics, 2012.
[4] Joulazadeh, M.H. and Joulazadeh, F.: Slag; Value Added Steel Industry Byproducts, Archives of Metallurgy and Materials, Volume 55, Issue 4, 2010, 1137-1145
[5] Meena A. and Roy P.K.: Analytical Synthesis and Evaluation of the Effects of Sand Replacement with Slag on Concrete Strength Properties; in: IJSRD - International Journal for Scientific Research & Development, Vol. 11, Issue 11, pp. 16 - 17 2024.
[6] Pasetto, M., Baliello, A., Giacomello, G. et al.: The Use of Steel Slags in Asphalt Pavements: A State-of-the-Art Review. Sustainability 2023, 15, 8817.
[7] Matthes W., Vollpracht A., Villagrán-Zaccardi Y. et al.: Ground Granulated Blast-Furnace Slag, in: Properties of Fresh and Hardened Concrete Containing Supplementary Cementitious Materials, pp. 1 - 53, 2018.
[8] Worldsteel Association: The Steel Story: Tracing steel’s development from 2,000 BC to the innovations of today, 2024.
[9] MarkWide Research: Iron and Steel Slag Market Analysis- Industry Size, Share, Research Report, Insights, Covid-10 Impact, Statistics, Trends, Growth and Forecast 2024-2032, Online: markwideresearch.com/iron-and-steel-slag-market, 2024 (accessed on 16.04.2024).

Ferrous slags that are available on the market include:

- Blast furnace slag;
- Basic oxygen furnace slag;
- Electric arc furnace slag (from carbon steel production or from stainless / high alloy steel production);
- Secondary metallurgical slag and
- Other slag.

BF slag is produced in two forms: air cooled and granulated. Like natural rock, air-cooled BF slag is appropriate for use as a construction aggregate, whether in bound or unbound form [1, 10]. Additional applications involve the utilization as stone wool and in the field of water treatment [10].

As a result of its cementitious qualities, granulated BF slag is used as a latent hydraulic binder to produce cement, concrete, mortar, and grout. To accomplish this, the substance is either ground individually or in combination with calcium sulphate and ordinary Portland cement clinker (OPC). The resultant mixture shows structural and durable characteristics and is known as ground granulated BF slag. Unprocessed granulated BF slag can serve as a suitable aggregate for road construction, among other applications. [1]

Basic oxygen furnace (BOF) slag has enhanced skid resistance as well as greater strength in comparison to natural rocks, making it a suitable aggregate for road construction and surface layers [1, 13]. Additional areas of application include the manufacturing of fertilizers, armourstones for hydraulic engineering purposes or as a filling material (backfilling applications) [10, 11]. Legal status and technical requirements for its application vary between European Union (EU) member states and sometimes also by regions within a country. Due to lack of market need or regulatory restrictions certain proportion of BOF slag is landfilled or stored internally.

EAF slag's strong resistance to polishing and affinity for bitumen makes it an appropriate aggregate for asphalt surface materials and road surface treatments [1, 10]. In the majority of EU member states, EAF slag is a widely recognized and socially and legally acceptable material for this purpose. In preparation for an anticipated increase in the proportion of steel production through the EAF in Europe, it is necessary to create new areas of application. The next generation of EAF slag, which are based on DRI, possess distinct characteristics compared to existing EAF slag. For instance, it has lower chromium content, which creates new possibilities for its utilization in areas that were previously restricted to slag due to low chromium requirements [12]. However, the impact on physical / technical properties of EAF slag when using DRI are not yet known.

Ladle furnace slag is generated within secondary metallurgy. Options for the recycling of ladle furnace slag includes its internal use as feedstock in the EAF process or as a substitute for lime as well as its use in cement production, road construction and as fertilizer. The difficulties associated with using ladle furnace slag are: legal requirements, technological aspects (such as volume instability and volatile composition), production speed, market conditions, and economic factors. [12] Resulting in significant portion of the ladle furnace slag to be landfilled in the EU as a final stage.

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[10] Bollen J., Hanrot, F., Deruwe, A. et al.: Slags valorisation in the EU: Tapping the full potential, 6th International Slag Valorisation Symposium, 2019.
[11] Dohlen M., Homm, G. and Schebek L.: Ökobilanzielle Untersuchung von LD-Schlacke für verschiedene Einsatzbereiche, Mineralische Nebenprodukte und Abfälle 4: Aschen, Schlacken, Stäube und Baurestmassen, pp. 193 – 203, 2017.
[12] Rieger J., Colla V., Matino I. et al: Residue Valorization in the Iron and Steel Industries: Sustainable Solutions for a Cleaner and More Competitive Future Europe; In: Metals 2021, 11, 1202, 2021.

Deliverable 2.3 Compilation of regulatory information about slag use in Europe contains a comprehensive list and description of the specific uses of particular slags, taking into account the regulatory environment in the European Union.

### 2.1.1 Metallurgical use (internal recycling)

The internal recycling of iron and steel slag plays a significant role in enhancing sustainability within the steel industry, helping to conserve resources, reduce waste, and minimize environmental impacts. For instance, BOF slag can be reintroduced into the steel production process thereby reducing the need for primary iron and calcium carriers [13, 10]. However, the trade-off between steel quality requirements (main limitation is phosphorus content, phosphorus from BOF slag is normally completely reduced in the reduction process and an undesired phosphorus circle is generated) [14] and the pursuit of high performance (lower energy consumption, $CO_2$ emissions, and tap-to-tap periods) limits the internal application of BOF slag as secondary raw material.

### 2.1.2 Cement / concrete

The cement industry is making significant efforts to incorporate secondary raw materials into cement production, primarily driven by the imperative to decrease $CO_2$ emissions in the manufacturing process [15]. Using slag-based products offers an environmental benefit in terms of carbon footprint when compared to operating the same process using primary raw materials. In particular, BF slag possesses distinctive characteristics that make it a valuable material for the production of Portland cement. The replacement of clinker with granulated BF slag in cement production can significantly reduce $CO_2$ emissions. Clinker is obtained by a process that requires a lot of labor and produces a substantial amount of carbon dioxide emissions (approximately 0.82 tons of $CO_2$ per ton of Portland cement clinker [16]), coming mainly from the raw materials which makes it unavoidable. Granulated slag has the capacity to substitute up to 80 % of the clinker in CEM-II and CEM-III cement types, thereby significantly reducing the carbon dioxide emissions in the cement industry [17].

Steel slag, such as EAF slag, is only used in very small amounts in cement and concrete, and its use is highly restricted and localized. Nevertheless, the suitability of steel slag as a raw material for cementitious matrices has recently been the subject of several studies [18, 19, 20, 21].

In 2015, 11 billion $m^3$ of concrete were utilized globally, making it one of the most essential building materials available [16]. As a result, the cement and concrete industry is a substantial and valuable market for slag. Due to the transition of the steel industry towards a $CO_2$-lean steel production and the shift

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[13] voestalpine: LD-Schlacke: Daten und Fakten, 2014.
[14] RFCS project SLAGREUS Reuse of slag from integrated steelmaking, Online: www.k1-met.com/en/non_comet/slagreus (accessed on 29.04.2024).
[15] Ruppert J., Wagener, C., Palm S. et al.: Prozesskettenorientierte Ermittlung der Material- und Energieeffizienzpotentiale in der Zementindustrie, 2020.
[16] Wulfert, H., Ludwig H.M., Ruhkamp W. et al.: Mobilization of the Hydraulically Active Phases in LD Slags by Producing Ultrafine Material, Mineralische Nebenprodukte und Abfälle 6: Aschen, Schlacken, Stäube und Baurestmassen, pp. 282 – 302.
[17] Handley P. and Basuyau, V.: Legal and environmental bottlenecks and opportunities for slag-based products valorisation, 6th International Slag Valorisation Symposium, 2019.
[18] Pellegrino, C., Cavagnis, P., Faleschini, F. et al.: Properties of concretes with Black/Oxidizing Electric Arc Furnace slag aggregate. Cem. Concr. Compos. 2013, 37, 232–240.
[19] Adegoloye, G., Beaucour, A.-L., Ortola, S. et al.: Concretes made of EAF slag and AOD slag aggregates from stainless steel process: Mechanical properties and durability. Constr. Build. Mater. 2015, 76, 313–321.
[20] Wulfert H., Ludwig H.M., Wimmer G. et al.: A New Process for Production of Cement Clinker from Steelmaking Slags, Mineralische Nebenprodukte und Abfälle 6: Aschen, Schlacken, Stäube und Baurestmassen, pp. 270 – 281, 2019.
[21] Algermissen D.: Development of New Products from BOF-Slag, Mineralische Nebenprodukte und Abfälle: Aschen, Schlacken, Stäube und Baurestmassen, pp. 298 – 309, 2018.

away from the carbon-intensive BF-BOF production route, in the future BF slag will no longer be available to the cement and concrete industry. Each BF that is replaced will result in the disappearance of 150 000 – 800 000 tons of granulated BF slag annually, depending on the capacity of the furnace [22]. European cement producers will face severe consequences as a result of this. It is crucial to develop solutions that ensure the next generation of slag possesses the necessary qualities and remains suitable for use in the cement and concrete industry.

### 2.1.3 Road construction

Traditional aggregates, such as crushed stone or gravel, can be substituted with slag in the construction of roads. This practice mitigates the demand for quarrying and promotes the conservation of natural resources. Prior to employing slag in road construction, it is critical to verify compliance with the legal standards and specifications governing the materials utilized in infrastructure projects. In certain cases, certification and testing procedures may be necessary to verify that slag is suitable for a given application.

While BF slag is predominantly utilized in the cement and concrete industry, it also finds application in the construction of roads. Depending on regional regulations, BOF slag, EAF slag, and ladle furnace slag are currently employed in road construction.

The road construction market has experienced steady growth worldwide, driven by urbanization, population growth, economic development and government investment in infrastructure, and therefore represents a large market potential for the use of slag.

### 2.1.4 Agriculture and soil amendment

In some European countries slag is employed in agriculture as soil supplements. For example, in Germany BF lime and converter lime have been permitted for use for over 60 and 30 years, respectively [1]. Slag is enriched with many minerals that have the potential to enhance soil fertility and maintain optimal pH levels [23]. It serves as a liming agent and provides micronutrients for crops.

In addition to the BF slag and BOF slag already mentioned, ladle furnace slag can also potentially be used as a fertilizer [24] and extensive study is being conducted in this field [25, 26]. However, careful consideration of factors such as soil conditions, crop requirements, and regulatory requirements is essential to maximize its benefits and minimize potential risks.

The application of next generation EAF slag in agriculture is feasible owing to its composition of essential elements such as silicon, iron, calcium, and aluminum oxides. However, it is important to note that the EAF slag contains magnesium and manganese oxides as minor constituents. EAF slag possesses characteristics that enable it to alter the acidity of water and soil resources, in addition to providing nutrients to the soil [27]. Phosphorus, iron, potassium, and manganese are elements that promote plant

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[22] Ehrenberg A.: The steel production transformation process in Europe: New slag types will substitute granulated blast furnace slag, in: ZKG Cement Lime Gypson, Issue 6/2023, 2023.
[23] Branca, T.A., Pistocchi, C., Colla, V. et al.: Investigation of (BOF) converter slag use for agriculture in Europe. Rev. DeMétallurgie Int. J. Metall. 2014, 111, 155–167.
[24] Branca T.A., Colla V., Algermissen D. et al.: Reuse and Recycling of By-Products in the Steel Sector: Recent Achievements Paving the Way to Circular Economy and Industrial Symbiosis in Europe, in: Metals 2020, 10, 345, 2020.
[25] Branca, T., Colla, V., Algermissen, D. et al.: The use of steel slags for agriculture purposes. Presented at the Residue Valorization in Iron and Steel Industry—Sustainable Solutions for A Cleaner and More Competitive Future Europe, Virtual Workshop, ESTEP Brussels, Belgium, 27 November 2020.
[26] Pistocchi, C., Ragaglini, G., Colla, V. et al.: Romaniello, L. Exchangeable sodium percentage decrease in saline sodic soil after basic oxygen furnace slag application in a lysimeter trial. J. Environ. Manag. 2017, 203, 896–906.
[27] Teo, P. T., Zakaria, S. K., Salleh, S. Z. et al.: Assessment of electric arc furnace (EAF) steel slag waste's recycling options into value added green products: A review. Metals, 10(10), 1347, 2020.

growth. Nonetheless, trace amounts of hazardous elements, including cadmium and lead, may be detected in the EAF residue and are potentially reducible to safe thresholds. Furthermore, EAF slag can be processed via flotation, selective agglomeration, and magnetic separation to increase its phosphorus content [28, 29].

### 2.1.5 Other and emerging applications

Ferrous slag can also be utilized as a filter medium or rock wool, among other things. Moreover, new fields of applications are currently being developed. These research activities involve, for instance, the development of new materials for restoring seaweed beds [1], marine fertilizer products to restore sea desertification areas [1], hazardous waste stabilization and heavy metal adsorption [1], dephosphorization of sewage [1], application as ceramic tile [30] or biomedical applications [31].

Additionally, slag may be utilized in 3D printing. This process can be carried out using many methods, where material is placed, connected, or hardened under computer control, typically following a layer-by-layer approach. Slag, a sandy material, can be effectively utilized as a raw material for 3D printing by employing 3D printers specifically designed for working with sand. These methods are typically used in the construction industry to create enormous building blocks with unique and intricate structures. In the majority of these methods, the sand is combined with a binder that facilitates a chemical reaction, resulting in the solidification of the substance. Slag-based feedstocks can exhibit desirable properties such as high temperature resistance, mechanical strength, and corrosion resistance, making them suitable for a possible application in 3D printing.

## 2.2 Geographical distribution

The steel industry is the major producer of slag. China, India, Japan, the United States, and European countries like Germany, which produce large amounts of steel, play a vital role in the worldwide slag product market.

According to Euroslag statistics, 17.9 million tons of BF slag and 12.5 million tons of steel slag (BOF slag, EAF slag and other slag) were produced in **Europe** in 2021[1]. The following table (Table 1) shows the production quantities of BF and steel slag between 2012 and 2021.

[28] Guo, J., Bao, Y., and Wang, M.: Steel slag in China: Treatment, recycling, and management. Waste management, 78, 318-330, 2018.
[29] Matino, I., Colla, V., Branca, T. A. et al.: Optimization of by-products reuse in the steel industry: valorization of secondary resources with a particular attention on their pelletization. Waste and Biomass Valorization, 8(8), 2569-2581, 2017.
[30] He, M., Li, B., Zhou,W. et al.: Preparation and Characteristics of Steel Slag Ceramics from Converter Slag; Springer: Berlin/Heidelberg, Germany, 2018; pp. 13–20, 2018.
[31] Oge, M.; Ozkan, D.; Celik, M.B. et al: An overview of utilization of blast furnace and steelmaking slag in various applications. Mater. Today Proc. 2019, 11, 516–525, 2019.

Table 1: BF and steel slag production in Europe between 2012 and 2021 [1]

| Year | BF slag production [million t] | Steel slag production [million t] | Comment |
|---|---|---|---|
| 2021 | 17.9 | 12.5 | The results are based on data from the United Kingdom, Bulgaria, Finland, France, Germany, Greece, Luxembourg, the Netherlands, Poland (partly), and Slovenia.<br>Extrapolating the received data and based on World Steel's hot metal and crude steel production figures (World Steel in Figures 2022), it can be assumed that about 25.2 million tons of BF slag and 16.8 million tons of steel furnace slag were produced. |
| 2020 | 16.2 | 11.5 | The results are based on data from Belgium, Bulgaria, Finland, France, Germany, Greece, Italy (partly), Luxembourg, Netherlands, Poland (partly), Slovenia, Spain and United Kingdom<br>Extrapolating the received data and based on World Steel's hot metal and crude steel production figures (World Steel in Figures 2021) it can be assumed that about 23.5 million tons of BF slag and 17.0 million tons of steel furnace slag were produced. |
| 2019 | 19.9 | 13.9 | The results are based on data from Belgium, Bosnia-Herzegovina (partly), Bulgaria, Finland, France, Germany, Greece, Italy (partly), Netherlands, Poland (partly), Portugal, Slovenia, Spain and United Kingdom.<br>Extrapolating the received data and based on World Steel's hot metal and crude steel production figures (Steel Statistical Yearbook 2020) it can be assumed that about 25.3 million tons of BF slag and 21.4 million tons of steel furnace slag were produced. |
| 2018 | 20.7 | 16.3 | The results are based on data from Belgium, Bosnia-Herzegovina, Bulgaria, Czech Republic, Finland, France, Germany, Greece, Italy (partly), Luxembourg, Netherlands, Poland, Portugal, Romania, Slovak Republic, Slovenia, Spain and Sweden.<br>Extrapolating the received data and based on World Steel's hot metal and crude steel production figures (Steel Statistical Yearbook 201) it can be assumed that about 25.2 million tons of BF slag and 22.6 million tons of steel furnace slag were produced. |
| 2016 | 24.6 | 18.4 | The results are based on data from Austria, Belgium, Bosnia-Herzegovina, Bulgaria, Czech Republic, Finland, France, Germany, Greece, Luxembourg, Poland, Portugal, Romania, Slovak Republic, Slovenia, Spain, Sweden, the Netherlands and the United Kingdom. |
| 2014 | 26.2 | 21.4 | The results are based on data from Austria, Belgium, Bulgaria, Finland, France, Germany, Greece, Italy, Luxembourg, Romania, Poland, Slovakia, Spain, Sweden, the Netherlands and the United Kingdom. |

Europe largely utilizes BF slag for the production of Portland cements. Steel slag is mostly utilized in road construction, with additional applications found in the cement or concrete industry, hydraulic engineering, as fertilizer, and in metallurgical processes (Figure 1).

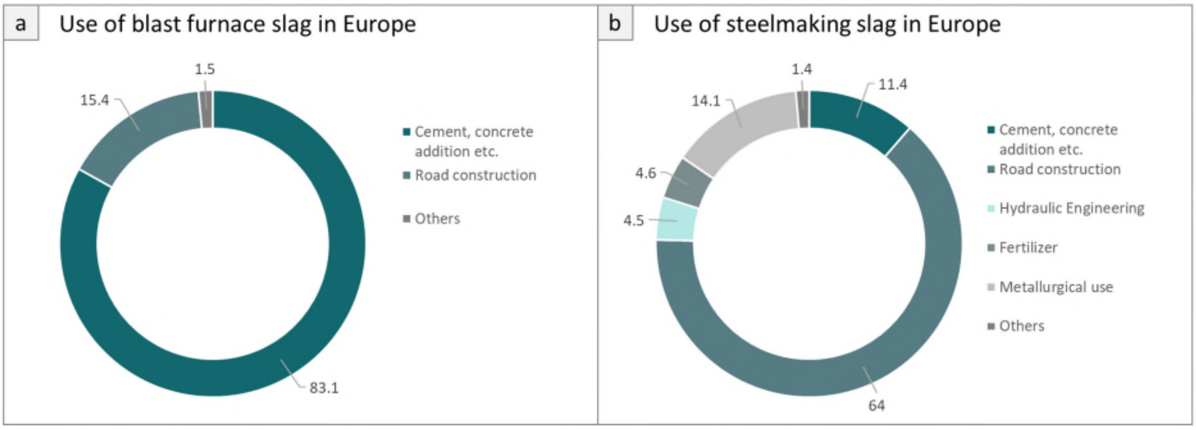


Figure 1:Utilization of BF slag (a) and steel slag (b) in [%] in Europe (2021) [1]

There is no published data on the actual amount of ferrous slag produced in the **United States**. However, it is projected that domestic sales of slag in 2022 reached 15 million tons. Approximately 49 % of the total quantiy sold consisted of BF slag, which also accounted for 87 % of the overall value of slag. The majority of this slag was in the form of granulated slag. The sales of steel slag was mostly composed of the BOF slag and EAF slag. [32]

Air-cooled iron slag and steel slag is typically utilized as aggregates in concrete, asphaltic paving, fill, and road bases. Both slag typs can also serve as a feedstock for cement kilns. The majority of ground granulated BF slag is utilized as a partial replacement for Portland cement in concrete mixes or blended cements. Pelletized slag is employed as a lightweight aggregate, however it may also be pulverized to produce a substance like ground granulated BF slag. Due to their low unit values, most varieties of slag can only be transported short distances by vehicle. However, rail and water transportation enable longer travel lengths. Due to the cost-effectiveness of shipping ground granulated BF slag across vast distances, a significant portion of the ground granulated BF slag used in the United States is imported. [32]

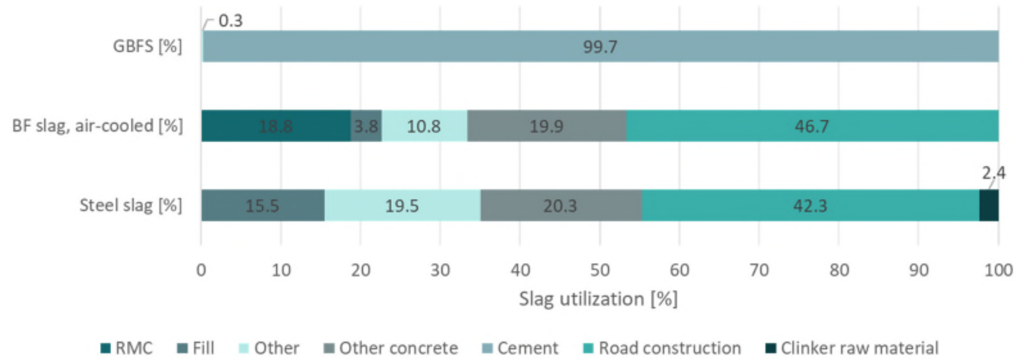


Figure 2: Recycling of slag in the United States (2016) [33]

**Japan** has a long history of using slag from the iron and steel industry in various applications [34]. The majority (76.7 %) of it is used in the cement industry. Additional areas of use include road construction (12.5 %), concrete aggregates (7.7 %), other uses (1.6 %), civil engineering (1.4 %), and soil

[32] U.S. Geological Survey, Mineral Commodity Summaries: Iron and steel slag, online: pubs.usgs.gov/periodicals/mcs2023/mcs2023-iron-steel-slag.pdf, (accessed on 12 April 2024), 2023.
[33] Harder J.: Valuable by-products: Slag recycling, in: recovery Recycling Technology Worldwide, 2,2020, 2020.
[34] Ueki, Y.: History and Utilization of Portland Blast Furnace Slag Cement. NIPPON STEEL & SUMITOMO METAL TECHNICAL REPORT No. 109, July 2015, pp. 109-113, 2015.

enhancement (0.1 %) [35]. In Japan, the BF slag achieves a recovery rate of 100 % [33]. Table 2 shows an overview of slag applications by the Nippon Slag Association in Japan.

Table 2: Primary characteristics and applications of iron and steel slag in Japan [35]

| | | **Characteristics** | **Applications** |
|---|---|---|---|
| BF slag | Air-cooled slag | Hydraulic property | Road base course material |
| | | No alkali-aggregate reaction | Coarse aggregate for concrete |
| | | Low $Na_2O$ and $K_2O$ | Cement clinker raw material (replacement for clay) |
| | | Thermal insulation and sound absorption effects when made into a fiber | Raw material for rock wool |
| | | Fertilizer component ($CaO$, $SiO_2$) | Calcium silicate fertilizer |
| | Granulated slag | Strong latent hydraulic property when finely ground | Raw material for Portland BF slag cement |
| | | | Blending material for Portland cement |
| | | | Concrete admixtures |
| | | Low $Na_2O$ and $K_2O$ | Raw material for cement clinker (replacement for clay) |
| | | Latent hydraulic property | Material for civil engineering works, ground improvement material (backfill material, earth cover material, embankment material, road subgrade improvement material, sand compaction material, ground drainage layers, etc.) |
| | | Lightweight, large angle of internal friction, large water permeability | |
| | | Does not contain chlorides. | Fine aggregate for concrete |
| | | No alkali-aggregate reaction | |
| | | Fertilizer component ($CaO$, $SiO_2$) | Calcium silicate fertilizer |
| | | | Soil improvement |
| Steel slag | Converter slag, EAF slag | Hard, wear-resistant | Aggregate for asphalt concrete |
| | | Hydraulic property | Base course material |
| | | Large angle of internal friction | Material for civil engineering works, ground improvement material (material for sand compaction piles) |
| | | $FeO$, $CaO$, $SiO_2$ components | Raw material for cement clinker |
| | | Fertilizer components ($CaO$, $SiO_2$, $MgO$, $FeO$) | Fertilizer and soil improvement |

[35] Nippon: Online: https://www.slg.jp/pdf/Amounts%20of%20Blast%20Furnace%20Slag%202017FY.pdf (accessed on 12 April 2024).

The use of iron and steel slag has been growing in **China** during the past few years, although it is still relatively new [33, 36]. China generated an estimated 225 million tons of BF slag and 122 million tons of steel slag in 2018 [33]. Strong growth has been observed in the quantity of granulation facilities for BF slag. Currently, it is estimated that 95 % of the BF slag is granulated and utilized exclusively in the cement and concrete industry [33].

Almost 70 % of the steel slag is disposed (Figure 3). Usage as a raw material for the manufacturing of clinker and recycling within the metal sector accounted for 9.3 % and 10.1 % of the total usage, respectively [33].

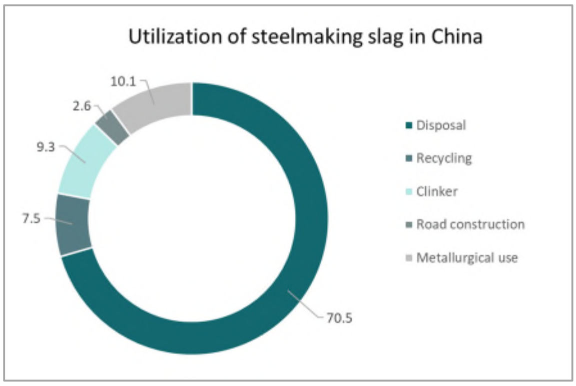


Figure 3: Overview of valorization of steel slag in China (2017) [28, 33]

Variations in utilization rates for iron and steel slag can be observed across various regions and countries and the slag market is influenced by factors such as industrial development, infrastructure investments and construction activities as well as regulatory policies (e.g. regulatory framework for waste management and environmental protection), and transportation networks [9]. Certain areas have strict restrictions that encourage the recycling and reutilization of industrial wastes. As a result, there is a greater usage of slag-based materials in building and other industries. The European market is distinguished by the presence of severe environmental legislation and a significant emphasis on sustainability and environmental responsibility [9].

Infrastructure development initiatives, urbanization, and the expansion of the construction industry are initial drivers of the slag market's substantial potential in Latin America, especially Argentina, Brazil, and Mexico are significant markets in the region. The Middle East and Africa present promising prospects for the application of iron and steel slag in infrastructure and construction. The market demand is influenced by the region's emphasis on sustainable practices, urban development, and industrial expansion. [9]

The effectiveness and accessibility of transportation infrastructure, encompassing rail, road, and maritime systems, are essential variables influencing the distribution of slag products. Proximity to steel plants and other industrial facilities that generate slag can reduce transportation costs and logistical challenges associated with the supply chain, influencing market dynamics in specific regions.

Overall, the geographical distribution of the slag product market is dynamic and influenced by a combination of industrial activities, economic trends, regulatory frameworks, and market dynamics. Understanding these factors is essential for stakeholders to identify growth opportunities and develop strategies to effectively address regional market demands and challenges.

[36] Gao W., Zhou W., Lyu X. et al.: Comprehensive utilization of steel slag: A review, in: Powder Technology 422 (2023) 118449, 2023.

# 3 Industrial landscape and key players in the slag product market

The industrial landscape of slag products comprises several aspects of production, processing, and utilization of slag. It involves essential components, such as production facilities, processing technologies, application areas, and the incorporation of slag products into different sectors.

Mayor players in the market include steel manufactures, slag processors, construction material suppliers, agriculture material supplier and industry associations.

The largest processing companies of iron and steel slag worldwide include steel works and slag processing companies [37]:

- JFE Steel Corporation
- Harsco Corporation
- JSW Steel
- NLMK
- Steel Authority of India
- Edw. C. Levy CO., Stein
- Arcelor Mittal
- POSCO
- TATA Steel
- Nippon Steel & Sumitomo Metal
- TMS International

Companies operating in the cement and construction industry, such as Heidelberg Materials, Lafarge Holcim, and Cemex, play a significant role in the slag product market. Waste management companies specializing in recycling and processing of industrial by-products, provide slag-based products to various industries making them a key player in the slag product market.

Furthermore, industry associations, like Euroslag [1], Global Slag [38], National Slag Association [39], Slag Cement Association [40], Nippon Slag Association [41], Australasian (iron & steel) Slag Association [42], play a role in representing and promoting the interests of slag producers and processors. These associations contribute to knowledge sharing and the advancement of sustainable practices within the industry.

# 4 Market dynamics and developments

The slag product market has different stakeholders involved in varying segments of production, processing, and utilization of slag. The slag market is influenced by such aspects as the steel production levels, state of the local market, availability of natural materials, compliance with environmental regulations and standards, technological advancements in slag processing, demand from end-user industries and fluctuations in raw material prices as well as infrastructure and presence of steel plants [9]. Slag utilized within a 150 km radius of a steel facility is estimated to be economically viable [17]. Once beyond that range, transportation expenses begin to accumulate, and the estimated maximum distance

[37] Global Iron and Steel Slag Market Size, Share and Industry Analysis by Regions, Countries, Types, and Applications, Forecast to 2028, Online: www.linkedin.com/pulse/iron-steel-slag-market-landscape-emerging-yyibf (accessed on 10 April 2024).
[38] Global Slag Association - www.globalslag.com/
[39] National Slag Association in USA - www.nationalslag.org/
[40] Slag Cement Association in USA - www.slg.jp/e/
[41] Nippon Slag Association in Japan - www.slg.jp/e/
[42] Australasian (iron & steel) Slag Association - www.asa-inc.org.au/

to reach the point of break-even is 200 km [17]. The majority of slag produced in EU are traded within the EU, and the amount traded outside of the EU is relatively small, below 1% [17].

The proportion of imported ferrous slag in relation to the total quantity produced in the EU is below 1 %. This is primarily due to the bulky nature of slag and the proportion of transport expenses to slag prices. Additionally, the development of EU-level recognized standards for slag-based building materials could benefit the single market. [17]

Within the InSGeP stakeholder survey conducted, participants were asked to prioritize several aspects and evaluate their impact on the slag market. Figure 4 shows the findings of the three types of stakeholder groups: slag processor, slag user and slag producer. With a score of 100 %, all respondents agree with this option, while a score of 0 % indicates that no respondents chose this option.

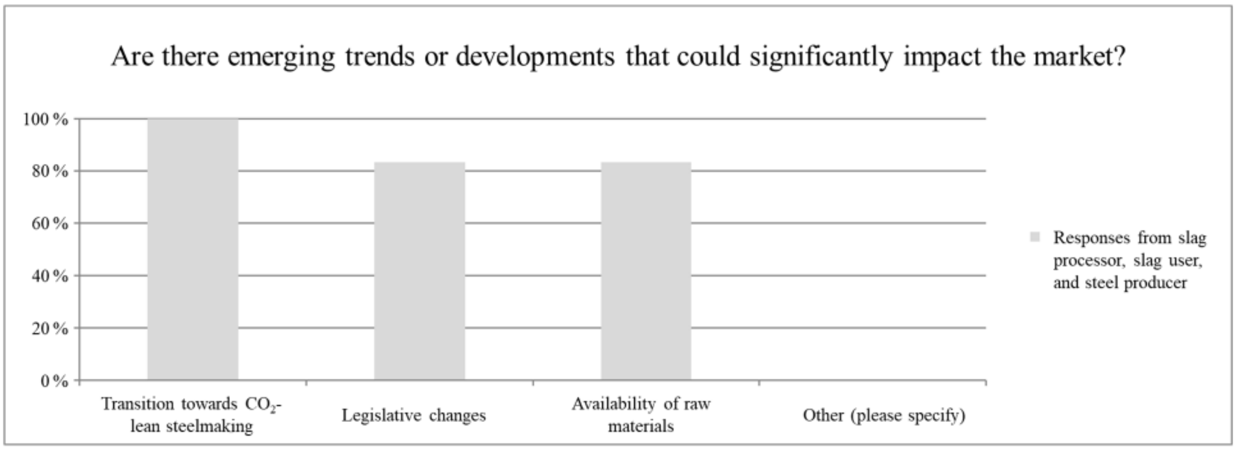


Figure 4: Ranking within the InSGeP stakeholder survey regarding emerging trend or developments on the slag market

The three stakeholder groups, slag processor, slag user and slag producer, were furthermore asked to describe, how they envision the future of slag utilization in their industries. The responses can be compiled as follows:

- Reduction and reuse of the generated slag within the own production process;
- Increased valorization considering that new applications may necessitate particular properties that need the development of novel slag processing technologies;
- Higher value applications making greater use of the slag's potential as technical material (including $CO_2$ capture potential and hydraulic properties of the slag);
- Proceed with the handling of the slag as a product and offer it to the market;
- Utilization of EAFC (carbon steel) slag as an artificial aggregate to replace raw material (e.g. basalt);
- Utilization of steel slag in cement process to replace OPC;
- Utilization of white slag as additives for cements and mortars and
- Utilization of black slag to replace gravel and basalt.

The survey also asked the scientific community about their predictions for future advancements and trends in slag utilization, based on present research trends. The answers received can be summarized as follows:

- Development of novel applications for slag products (e.g. 3D printing, use of steelmaking slag as iron and calcium carriers in other processes than the sinter plant or the BF);
- Adaptation to the new steel production routes and the generated slag;
- Enhancement of slag valorization rate (e.g. increase use in the cement and concrete industry to mitigate $CO_2$ emissions) and
- Further improvement in resources recovery (energy- low temperature, material) in line with energy savings and circular economy.

## 4.1 Drivers influencing the growth of the slag market

Several variables have the potential to influence the market for slag-based products, for example the development of infrastructure, research to improve or find new applications and societal push for circular economy.

The demand for building materials has risen due to infrastructure expansion and construction activity, particularly in emerging nations [9]. The cement industry is a major consumer of slag products, particularly ground granulated BF slag. As the global demand for cement continues to rise, so does the demand for slag-based products. The increasing awareness about environmental sustainability and the need for sustainable construction materials are driving the demand for iron and steel slag [9].

Continuous research and development activities aiming at enhancing properties as well as exploring novel uses for slag products are driving the growth of the market [9]. The advancements in manufacturing processes and the creation of novel slag-based materials create new opportunities for application.

A further significant aspect is the emphasis on circular economy and sustainability [9]: Governments and industries are increasingly focused on waste reduction and recycling. Slag fits into the framework of waste reduction initiatives, driving interest in its utilization and reducing reliance on landfill disposal. The push towards sustainable and environmentally friendly practices has led to a heightened interest in slag products as industries are exploring ways to reduce their carbon footprint.

Within the stakeholder survey conducted for the project, participants were requested to prioritize several aspects and evaluate their capacity to encourage the utilization of slag products. The participants were given the option to select from the categories of low, medium, high, and very high. Figure 5 shows the survey results, with the green bars indicating the weighted average of the scientific community and the gray bars showing the weighted average of the slag processor, slag user, and steel producer.

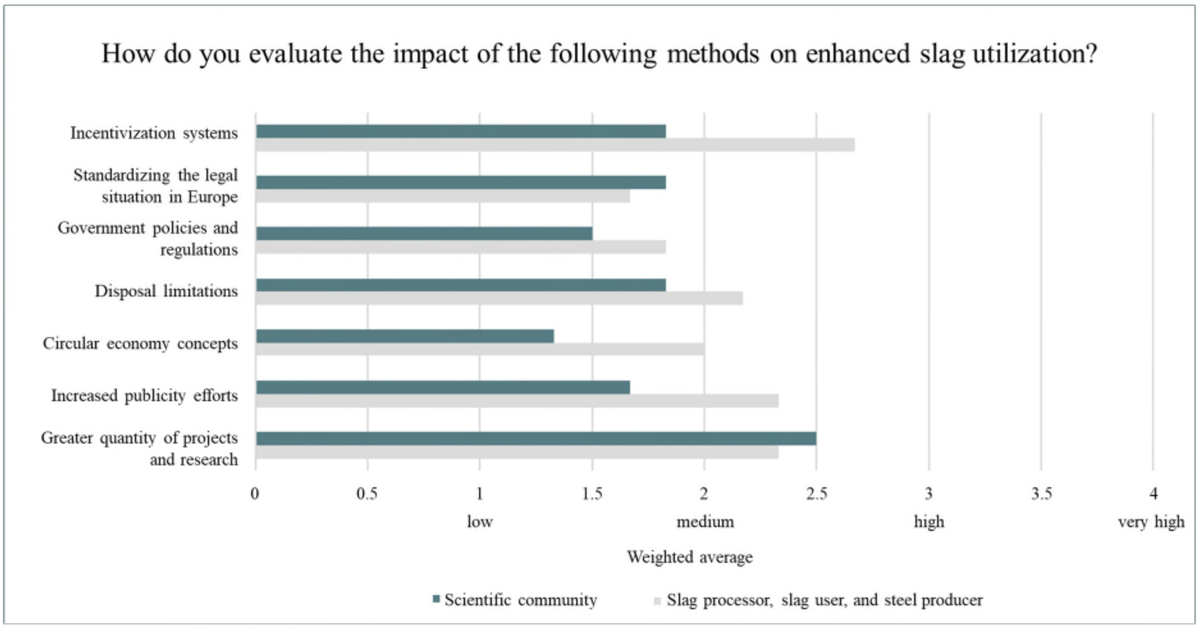


Figure 5: Findings of the stakeholder survey regarding the identification of key drivers influencing the slag market

Although the group consisting of slag processors, slag users, and steel producers opted for the implementation of incentive systems, the scientific community deems it necessary to undertake a larger number of projects and research.

## 4.2 Challenges and market barriers

Although the utilization of iron and steel slag offer various advantages, bringing them to the market can be challenging. One of the challenges is changing the perception of slag. Overcoming the historical view of slag as a by-product and convincing stakeholders of its performance and environmental benefits can be a hurdle. Furthermore, lack of awareness and information among consumers, construction professionals, and other industries regarding the characteristics and potential applications of slag products can hinder their valorization [9]. Education and promotion efforts are essential to address this issue.

Environmental limitations can serve as the further obstacles within the slag market. Steel slag is composed of many chemical compounds that, if not properly managed, can have negative impacts on the environment. Consequently, government and regulatory organizations implement stringent restrictions to guarantee the secure management, processing, and disposal of steel slag. [43]

In addition, the quality of slag can vary depending on the source and the metal production process. Inconsistencies in quality may create challenges in meeting specific standards required for certain applications.

Despite positive growth prospects, the market for slag products may face challenges related to economic volatility, geopolitical tensions, raw material availability, and fluctuations in demand from key end-user sectors. Cost fluctuations of iron and steel slag's primary materials, including coke and iron ore, may

[43] Fortune Business insights, Steel Slag Market Size, Share & COVID-19 Impact Analysis, By Type (Blast Furnace and Steelmaking Slag), By Application (Construction, Cement & Concrete, Fertilizers, and Others), and Regional Forecast, 2023-2030, Online: www.fortunebusinessinsights.com/steel-slag-market-104124 (accessed on 16.04.2024), 2023.

have an effect on production expenses [9]. The instability of prices could present difficulties for producers in sustaining a stable and competitive supply [9].

As part of the stakeholder surveys, participants were requested to assess and prioritize several factors that could impede the effective management of slag-based products, using a scale ranging from low to very high. Figure 6 presents the survey findings, where the green bars represent the weighted average of the scientific community, and the gray bars represent the weighted average of the slag processor, slag consumer, and steel producer.

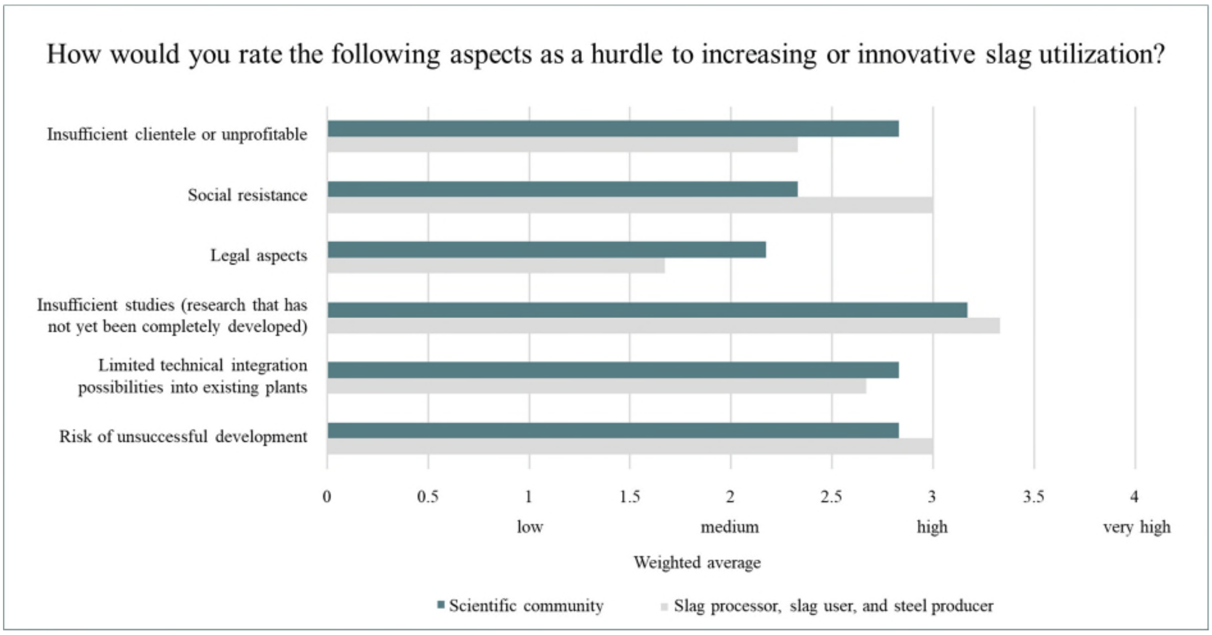


Figure 6: Outcome of the stakeholder survey regarding the classification of specific challenges in the slag market

Inadequate knowledge was identified as the primary barrier to the utilization of slag in both groups.

## 4.3 Regulations and standards

Diverse regulations and standards regulate the application of slag products in order to guarantee their safety in various contexts. Regulatory frameworks to waste management, environmental protection, and construction standards play a significant role in shaping the market structure of slag products and influence the processing, handling, and use of slag products. These regulations may vary depending on the geographical region and specific industry requirements.

Deliverable 2.3 Compilation of regulatory information about slag use in Europe provides a comprehensive review of the legislation, standards, and specific sectors where slag is used in several European countries.

## 4.4 Research and development

Research and development efforts as well as collaborations between industrial companies, research institutions, and governments focus on finding innovative ways to utilize slag products effectively and sustainably. This includes exploring new applications, optimizing processing techniques, and enhancing the properties of slag-based materials. The following is a synopsis of a few projects that have investigated the use and characteristics of slag, with short summaries of the related fields of study.

**SLAGFERTILISER - Impact of long-term application of blast furnace and steel slags as liming materials on soil fertility, crop yields and plant health (2011-2015)**

The project investigated the effects of chromium and vanadium from iron and steel slag on soils and plants as a basis for further environmental discussions on liming agents in the EU. The steel industry has a problem with fine slag which cannot sell to the building industry while farmers get a positive yield from using slag as a liming / fertilizer material. The effects of iron and steel slag on soil and crop yields in different conditions throughout Europe were assessed. Also, possible negative effects of trace elements such as chromium and vanadium were tested on the soil and plants. The project was coordinated by FEhS – Institut für Baustoff-Forschung e.V. together with project partners AG der Dillinger Hüttenwerke, Arbeitsgemeinschaft Hüttenkalk e.V., voestalpine Stahl GmbH, Österreichische Agentur für Gesundheit und Ernährungssicherheit GmbH, Sant'Anna School of Advanced Studies, ILVA S.p.A., SSAB Europe Oy.

**SLACON - Control of slag quality for utilisation in the construction industry (2012 – 2015) [44]**

Within the SLACON project, research activities and various tests were conducted to solve environmental problems of different EAF slag to increase the utilization of it in the construction industry by improving the quality. The treatment was performed during the liquid stage of the slag as well as after solidification though water treatment. The project team consists of the following companies and research centres: FEhS – Institut für Baustoff-Forschung e.V., VDEh-Betriebsforschungsinstitut GmbH, Rina Consulting Centro Sviluppo Materiali S.P.A., Sidenor investigacion y Desarrollo SA and Riva Acciaio SPA.

**ACTISLAG - New Activation Routes for Early Strength Development of Granulated Blast Furnace Slag (2017-2020)**

This project aimed at creating an efficient route to create ground granulated blast furnace slag (GGBS) that can be used for concrete or dry-mix mortar. The goal was to increase GGBS value by improving short-term reactivity and develop new products containing more than 80 wt.-% of GGBS with at least as good mechanical performance as CEM II class products. The project was coordinated by Arcelormittal Maizieres Research SA with project partners FEhS – Institut für Baustoff-Forschung e.V., Technische Universitaet Clausthal, Centre National de la Recherche Scientifique FR, Université Paul Sabatier Toulouse, ECOCEM Materials Limited.

**ECOSLAG - Eco-friendly steelmaking slag solidification with energy recovery to produce a high quality slag product for sustainable recycling (2018 – 2022) [45]**

The project addressed heat recovery techniques from EAF, ladle furnace and BOF slag, ladle furnace dry slag granulation and utilization paths for the slag after heat recovery devices aiming to overcome logistical barriers at different steelworks while trying to recovery heat from the slag. The project was coordinated by FEhS – Institut für Baustoff-Forschung e.V. together with project partners from Germany (Max Aicher Umwelt GmbH), Spain (Centro de investigacion cooperative de energias alternativas fundacion, CIC energigune fundazio, Sidenor investigacion y Desarrollo SA), Italy (A.C.P. SPA, Tenaris Dalmine S.p.A., Rina Consulting Centro Sviluppo Materiali S.P.A., Tenova S.P.A.), Sweden (Swerim) and Finland (SFTec Oy).

[44] European Commission, Directorate-General for Research and Innovation, Algermissen, D., Morillon, A., Wendler, B. et al., Control of slag quality for utilisation in the construction industry (SLACON) – Final report, Publications Office of the European Union, 2017, https://data.europa.eu/doi/10.2777/84385.

[45] Schüler S.and Mudersbach D.: Products made by EAF-slag for Applications in Road Construction and Earth Works: Potential and Obstacles, Mineralische Nebenprodukte und Abfälle 6, Aschen, Schlacken, Stäube und Baurestmassen, 2019.

**REUSteel - Dissemination of results of the European projects dealing with reuse and recycling of by-products (2019 – 2022)** [46]

REUSteel was a dissemination project to valorize important results achieved in various EU research projects on the reuse and recycling of by-products from the steel production, and the exploitation of by-products from other industrial sectors. A critical analysis of the achieved results in previous projects was performed by six project partners (Sant'Anna School of Advanced Studies (coordinator), VDEh-Betriebsforschungsinstitut GmbH, Rina Consulting Centro Sviluppo Materiali S.P.A., FEhS – Institut für Baustoff-Forschung e.V., SWERIM and ESTEP), to establish a road map for future research and to promote the synergies with other industrial sectors.

**SLAGREUS – Reuse of slags from integrated steelmaking (2019-2022)** [14]

SLAGREUS was a RFCS project (Grant Agreement no. 847260) focusing on BOF slag and on the development of a process chain resulting in an iron-enriched product and a reactive calcium silicate rich fraction. The treatment process consisted of a liquid iron-enrichment by slag circulation, a microwave treatment of the solidified enriched iron-fraction, grinding and a magnetic separation. Different reuse options were investigated, such as the substitution of iron ore fines with the iron-enriched fraction. The project was coordinated by VDEh Betriebsforschungsinstitut GmbH and the consortium further comprised of FEhS – Institut für Baustoff-Forschung e.V., Oulu University, voestalpine Stahl GmbH, and K1-MET GmbH.

**iSlag - Optimising slag reuse and recycling in electric steelmaking at optimum metallurgical performance through online characterization devices and intelligent decision support systems (2020 – 2023)** [47]

The project focused on the application of innovative measurement devices and simulation tools to provide information on the slag features to be exploited by decision support systems. These devices and tools intent to support the operators and plant managers for optimal valorization of the slag inside as well as outside the steelmaking cycle. The project consortium consisted of nine partners involving Scuola Superiore Sant'Anna (coordinator), Tenaris Dalmine S.p.A, Sidenor, VDEh-Betriebsforschungsinstitut GmbH, Rina Consulting Centro Sviluppo Materiali S.P.A., FEhS – Institut für Baustoff-Forschung e.V., Tenova SpA, Acciaierie di Calvisano S.p.A. and Deutsche Edelstahlwerke GmbH.

**SAVE CO2 (2021 – 2025)**

The project focuses on the upcoming submerged arc furnace slag, that is based on a production with 100 % of DRI. The aim is to produce a material, similar to granulated BF slag or pozzolanic material that can be used beneficially in the cement industry. The project consortium involves FEhS – Institut für Baustoff-Forschung e.V (coordinator), thyssenkrupp Steel Europe, Heidelberg Materials, Institut für Technologien der Metalle der Universität Duisburg-Essen and Fraunhofer UMSICHT.

**DRI-EOS - Using of DRI based EAF slag for cement industry (2022 – 2026)**

The DRI-EOS project focuses the composition of upcoming EAF slag, based on a certain amount of HBI, that will be used besides scrap. Other secondary raw materials should be used to treat the slag to produce a material with cementitious properties. The project is coordinated by FEhS – Institut für Baustoff-Forschung e.V. and consists of the partners Salzgitter Mannesmann Forschung GmbH, the Federal Institute for Materials Research and Testing, Friedrich Rohstoffe GmbH, Holcim Deutschland GmbH and LOI Thermprocess GmbH.

[46] REUSteel project website: Online www.reusteel.eu/index.html (accessed on 12 April 2024).
[47] iSlag project website: Online: www.islag.eu/ (accessed on 10 February 2024).

# 5 Market forecast

Ongoing innovation in processing technologies and the discovery of new applications continue to shape the slag product market. The market is expected to play a significant role in the future of sustainable construction and circular economy practices.

The construction industry is a major consumer of slag products, particularly in concrete production and road construction. As urbanization and infrastructure development projects continue globally, the demand for slag-based materials is expected to rise steadily.

The Global Slag Conference predicts that granulated BF slag production will experience a growth, rising from 331 million tons in 2021 to over 450 million tons by 2030. This growth will be accompanied by declines in North America and Europe, while all other regions are expected to see a rise in output. The global slag granulation rates are projected to rise from 86 % in 2021 to 93.5 % in 2030. By 2025, China aims to granulate all of its BF slag, whereas North America is expected to granulate only 45 % even by 2030. Over the past five years, there has been a significant concentration of orders for slag and slag / cement mills in South Asia, namely in India, as well as in Southeast Asia and the Middle East. The global commerce of slag is projected to rise from approximately 27 million tons in 2021 to approximately 38 million tons in 2030. [48]

The International Energy Agency forecasts a global increase in slag production in the upcoming years. It is projected that global steel consumption will rise by 30 % by 2050, compared to the present, with countries like India expected to experience a 400 % increase [49] and the global slag production will continue to increase accordingly [33].

As a result of sustainable building practices, infrastructure expansion, and environmental awareness, the iron and steel slag market appears to have a promising future. As governments continue to prioritize sustainable development and industries advance in their recognition of the advantages that iron and steel slag can offer, the market is anticipated to expand. Collaborations, technological advancements, and production innovations will determine the future of the market, allowing for increased application diversity and market expansion. [9]

[48] Global slag: Review of the 15th Global Slag conference 2023, Online: www.globalslag.com/conferences/global-slag/review/global-slag-review-2023 (accessed on 13 April 2024).
[49] Levi, P.: IEA Technology Roadmap The global iron and steel sector. International Energy Agency, Presentation at OECD Steel Committee, Paris, 22 March 2019.

# 6 Conclusion

Depending on its point of origin along the steel production route, the properties of ferrous slag differ. Not all slag is suitable for all applications and the rate at which slag is utilized may vary according to factors such as the variety of slag, the country, or individual steelworks [50].

The availability of specific applications does not guarantee that the steelwork or slag processor can valorize the slag for the following reasons: chemical and physical properties of the slag, the cost of transportation to reach applications, market demand, competition with natural resources, the cost of utilization in comparison to landfilling, or the absence of or restrictions in regulations [50]. In relation to these concerns, research must be conducted not only on emerging utilization pathways but also on augmenting the quantity of slag that meets the criteria for the existing pathways. A more comprehensive understanding of the composition, formation, and physical properties of slag is essential for maximizing their reutilization in various fields and for internal purposes [24].

The market for slag products continues to grow as industries seek sustainable solutions and ways to reduce waste generation. With ongoing advancements in technology and increased emphasis on sustainability, the industrial landscape of slag products is likely to evolve, opening up new opportunities and applications across various sectors.

The minimum aim must be to produce a next generation slag that meets the requirements for road construction in the different regions. However, also higher value application must be evaluated to test the potential benefit of this slag types. This brings an advantage to the circular economy in the EU and not just prevents disadvantages.

[50] Dissemination of results of the European projects dealing with reuse and recycling of by-products in the Steel sector (REUSteel), Deliverable 5.1: Road map for future research and development directions.

# 7 ANNEX

The annex includes information on the conducted stakeholder survey.

## 7.1 Online stakeholder survey

Survey Monkey was utilized to conduct the online stakeholder questionnaire. Slag producers, processors, government and regulatory bodies, and the scientific community are the stakeholders invited to provide feedback. Through email, LinkedIn, presentations, and the individual project participants, an invitation and QR code were distributed for survey participation. In total, the survey was started by 37 people and completed by 12 people from the stakeholder groups slag processor or slag user, steel producer and scientific community.

The information and inquiries that were posed during the survey are provided below.

InSGeP project is a research project funded by the European Union aiming to identify the types of slags that can be expected in future steelmaking processes. The scope of the project also explores the potential paths for slag's valorization within the existing value chain. This project brings together 13 partners from Austria, Belgium, France, Germany, Italy and Spain, including 5 steelworks, 6 research and technology organizations (RTOs), and 2 suppliers.

This online survey is an essential part of the project and will consider present situations, such as market and technological trends, market barriers, drivers (also from societal perspective), and future trends. The results of the survey are used to create a publicly accessible deliverable, whereby the data is published in such a way that it cannot be attributed to a specific respondent.

The survey has been designed to take approximately 15 minutes.

If you wish to receive further information regarding this survey or the InSGeP project, please feel free to contact us (info@insgep.eu).

Thank you for your valuable input!

Confidentiality disclaimer Data and information provided in this questionnaire will be processed by the InSGeP consortium for the sole purpose of carrying out this research project and will not be disclosed to any third party. Survey results will be published so as not to be attributable to any specific respondent, unless otherwise agreed upon with the specific respondent in written form.

- ☐ I agree.
- ☐ I don't agree. (Survey ends)

Respondent's profile

Full name:
Company
*County:
Email:
(If you would like to receive the survey results, please provide your e-mail address.)

*Field of expertise:

- ☐ Slag processor or slag user
- ☐ Steel producer
- ☐ Government & regulatory body
- ☐ Scientific community

**Questions for slag processors or slag user or steel producer**

## Present situation

What types of slag are currently processed in your company?

- ☐ BF slag
- ☐ BOF slag
- ☐ EAF (S) slag
- ☐ EAF (C) slag
- ☐ Secondary slag (e.g. ladle furnace slag)
- ☐ Other (please specify):

Which sector/products do you utilize slag in?
BF slag / BOF slag / EAF (S) slag / EAF (C) slag / secondary slag / other

- ☐ Road construction
- ☐ Cement / concrete
- ☐ Fertilizer
- ☐ Hydraulic engineering
- ☐ Wastewater treatment
- ☐ Other (please specify):

What is the current production volume of slag processed in your company?

- ☐ 0.5-1 Mio t/a
- ☐ 1-1.5 Mio t/a
- ☐ 1.5-2 Mio t/a
- ☐ > 2 Mio t/a

Which characteristics limit the permitted use of slag?

- ☐ Phosphorus content
- ☐ Chlorine content
- ☐ Basicity
- ☐ CaO content
- ☐ MgO content
- ☐ Chromium content
- ☐ Other (please specify):

Please provide limit values for the chosen properties.

Which interactions between the slag's components must be considered?

What is the maximum metallic content of utilized slag?

Are there any specifications regarding the mineralogical structure?

- ☐ No
- ☐ Yes, please specify:

Are there any specifications regarding grain size?

- ☐ No
- ☐ Yes; please specify:

Are there any regulations in your country about using iron and steel slags in:

Cement

***1*** Yes; please specify:
- ☐ No
- ☐ I don’t know.

Concrete

- ☐ Yes; please specify:
- ☐ No
- ☐ I don't know.

## Market and technological trends

How do you envision the future of slag utilization in your industry?

Are there emerging trends or developments that could significantly impact the market?

- ☐ Transition towards $CO_2$-lean steelmaking
- ☐ Legislative changes
- ☐ Availability of raw materials
- ☐ Other (please specify):

## Market barriers

How would you rate the following aspects as a hurdle to increasing or innovative slag utilization? (very high - high - medium - low)

- Risk of unsuccessful development
- Limited technical integration possibilities into existing plants
- Insufficient studies (research that has not yet been completely developed)
- Legal aspects
- Social resistance
- Insufficient clientele or unprofitable
- Other (please specify):

Please specify the regulations or standards affecting the utilization of slag within your sector.

## Drivers

How do you evaluate the impact of the following methods on enhanced slag utilization? **(very high - high - medium - low)**

- Greater quantity of projects and research
- Increased publicity efforts
- Circular economy concepts
- Disposal limitations
- Government policies and regulations
- Standardizing the legal situation in Europe
- Incentivization systems
- Other (please specify):

**Questions for government & regulatory body**

## Present situation

Are there any government incentives or initiatives to promote increased slag utilization?

- ☐ No
- ☐ Yes, please specify:

Are there forums or committees, where industry representatives and government officials discuss issues related to the slag industry?

- ☐ No
- ☐ Yes, please specify:

Does the government align its standards for slag utilization with international standards?

- ☐ No
- ☐ Yes, please specify:

Does the government involve local communities in decisions related to slag utilization projects?

- ☐ No
- ☐ Yes, please specify:

Are there any regulations in your country about using iron and steel slags in:

Cement

- *2* Yes; please specify:
- ☐ No
- ☐ I don't know.

Concrete

- ☐ Yes; please specify:
- ☐ No
- ☐ I don't know.

## Market and technological trends

Are there any upcoming regulatory changes that could impact the slag market?

- ☐ No
- ☐ Yes, please specify:

Do you have a long-term vision for the role of slag utilization in the overall industrial and economic landscape?

- ☐ No
- ☐ Yes, please specify:

Are there strategic plans or initiatives in place to promote sustainable and widespread slag utilization?

- ☐ No
- ☐ Yes, please specify:

## Market barriers

How would you rate the following aspects as a hurdle to increasing or innovative slag utilization? (very high - high - medium - low)

- Risk of unsuccessful development
- Limited technical integration possibilities into existing plants
- Insufficient studies (research that has not yet been completely developed)
- Legal aspects
- Social resistance
- Insufficient clientele or unprofitable
- Other (please specify):

## Drivers

How do you evaluate the impact of the following methods on enhanced slag utilization? **(very high - high - medium - low)**

- Greater quantity of projects and research
- Increased publicity efforts
- Circular economy concepts
- Disposal limitations
- Government policies and regulations
- Standardizing the legal situation in Europe
- Incentivization systems
- Other (please specify):

**Questions for scientific community**

## Present situation

Do you have any research projects or activities in the subject of steel slag processing and/or valorization?

- ☐ No
- ☐ Yes

If yes, what are the main areas of your research?

- ☐ Properties of steel slags
  - o If yes, please specify:
- ☐ Utilization of slag
  - o If yes, please specify:
- ☐ Processing of slag
  - o If yes, please specify:
- ☐ Other (please specify):

Can you highlight any recent technological advancements or initiatives related to the utilization of slag?

- ☐ No
- ☐ Yes, please specify:

Are there any regulations in your country about using iron and steel slags in:

Cement

- *3* Yes; please specify:
- ☐ No
- ☐ I don't know.

Concrete

- ☐ Yes; please specify:
- ☐ No
- ☐ I don't know.

## Market and technological trends

Based on current research trends, what are the anticipated future developments / trends in slag utilization?

Are you involved in any research and development activities to explore new applications or improve slag utilization?

- ☐ No
- ☐ Yes, please specify:

## Market barriers

How would you rate the following aspects as a hurdle to increasing or innovative slag utilization? (very high - high - medium - low)

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- Other (please specify):

# InSGeP

Investigations of Slag from Next Generation Steel Making Processes

**START DATE** | 01-07-2023
**PROJECT DURATION** | 48 months
**TOPIC** | RFCS-02-2022-RPJ
**BUDGET** | 4.5 M€
**COORDINATOR** | FEhS
**CONTACT** | info@insgep.eu