Grant Agreement Number: 839227

Project Acronym: REUSteel

Project title: Dissemination of results of the European projects dealing with reuse and recycling of by-products in the Steel sector

Deliverable 1.2

Collection of the abstracts of the developed publications in journals and conferences

Table of Content

1. Project Summary and purpose of the present document

Within the project and intensive dissemination has been pursued concerning the most important results achieved in the EU research projects (ECSC, RFCS, FP3, FP4, FP5, FP6 and Horizon 2020) on the reuse and recycling of by-products, deriving from the steel production cycle, as well as the exploitation of by-products coming from other industrial sectors outside the steelmaking cycle, such as alternative carbon sources (e.g. biomasses and plastics). A list of projects to be evaluated has been compiled (in deliverable 2.2) and the REUSteel-project aims at performing an integrated critical analysis to improve the dissemination of the achieved results in the previous projects, to establish a roadmap for future research in the topic as well as to promote synergies with other industrial sectors, according to the concepts of Circular Economy (CE) and Industrial Symbiosis (IS).

The pursued dissemination action aimed at providing a vision of the state-of-the-art to promote both the exploitation of the outcomes and the synergies with other industrial sectors. Moreover, the dissemination activities targeted stakeholders and new audiences, to get new and deeper indications for the new roadmap and explore potential synergies with other sectors.

In the context of the dissemination activities, all the partners of the project participated to seminars, workshops and conferences by presenting and discussing some of the outcomes of the project as well as the treated topics.

The present document collects the abstracts of the interventions held during international conferences and of the papers submitted to journals. At the present date, not all submissions have been accepted, some of them are still pending.

Due to the COVID-19 Pandemic, many physical events were cancelled, postponed or held on-line. The present document includes also the abstracts of the contributions to events, which will be held after the project completion, as the contents of such contributions were elaborated during the project itself.

2. List of abstracts of contributions to conferences and workshops

The consortium was committed to hold presentations and write papers concerning the analyses and outcomes of the REUSteel project during scientific and technical conferences, which were relevant with respect to the topic of reuse and recycling of residual material in the steel sector and in the process industry, in general. The final goal was to spread the outcome of the analyses pursued within the projects and to disseminate the Roadmap. As this last product became available at the end of the project, the Consortium is committed to continue the dissemination action also beyond the conclusion of the project.

Table 1 shows a list of the conference and workshops, which were attended by at least one of the partners of the REUSteel Consortium.

Table 1. List of Workshops and Conferences where presentations concerning the REUSteel project were provided.

Event and Location	Date	Org.	Responsible project partner	Contribution from REUSteel
BFI Colloquium 2020 Online	13/5/2020	BFI	BFI	Presentation of the project.
Resi4Future, four-part web-workshop Online	6, 13, 20, 27 /11/2020	ESTEP	ESTEP and REUSteel	Presentation of first results + specific presentations.
9th ICSTI Conference Bremen, Germany	22-26/3/2021 Postponed to 7-11/3/2022	Steel Institute VDEh	FEhS and BFI	Recycling of residual material from blast furnace and sinter.
BFI Colloquium 2021 Online	5/5/2021	BFI	BFI	Presentation of the project in general as well as specific presentations.
Society and Materials Conference SAM-15 Online	10-12/5/2021	SSSA	SSSA	General outcomes of the project research.
5th ESTAD Online	30/8-2/9/2021, REUSteel symposium 31/8	Jern-kontoret	Swerim	Symposium with several presentations Collecting information and ideas for the roadmap.
General Assembly of the Euroslag association	25/11/2021	Euroslag	FEhS	General outcomes of the project research.
Raw Materials & Recycling Bergamo, Italy	1-2/12/2021	AIM	SSSA	Presentation of the roadmap.

2.1 BFI Colloquium 2020

Title: Results of European projects on the recycling of residues from the steel industry - REUSteel

Authors + Affiliation (acronym) Roland Pietruck (BFI), Valentina Colla, Teresa Annunziata Branca (SSSA), Unberto Martini (RINA-CSM), Agnieszka Morillon, David Algermissen (FEHS), Hanna Granbom, Sara Rosendahl (SWERIM)

SpeakerRoland Pietruck

Since 2000, more than 45 EU research projects have investigated the reuse and recycling of residues as by-products.

EU increasingly supports the evaluation and dissemination of the results of EU research projects, as their use is seen as a key factor of the RFCS research funding programme. The aim is to achieve that the results of European projects are taken more into account in industrial practice, that Synergies are achieved by comparing research projects with different approaches but very similar objectives, indications of future developments and future research activities are given, that Follow up promising results after project completion will be carried out.

The project comprises the analysis, dissemination and valorisation of EU-funded steel research projects from 2000 onwards on the recycling of residual materials in order to promote the use of the results, to increase synergies with other industrial sectors, and to define future research topics in this area. A review of the databases revealed 45 research projects, of which 34 were selected for analysis.

The relevant projects are evaluated according to selected criteria and collected in a database, which is continuously updated with new projects and the associated results throughout the project duration.

Results will be integrated into ESTEP's strategic research agenda.

2.2 ESTEP Resi4Future Workshop 2020

RFCS Project REUSteel

Authors: Valentina Colla, Teresa Annunziata Branca (SSSA), Roland Pietruck (BFI), Unberto Martini (RINA-CSM), Agnieszka Morillon, David Algermissen (FEHS), Hanna Granbom, Sara Rosendahl (SWERIM)

Speaker: Valentina Colla

Over the last few decades, the EU steel sector has increased the reuse and the recycling rate of by-products resulting from both the integrated and electric steel production routes, such as slags, sludge, scale and dust. This was due to more and more stringent legislation, that is often not homogeneous in the different European countries, as well as to the increase of disposal

costs. In addition, the Circular Economy concept has been the driving force for the European manufacturing sectors cooperation, according to the principle of Industrial Symbiosis, identifying new business opportunities for underutilized resources outside the boundary of the production chain, in order to reach the "zero-waste" goal. On this subject, the scientific and technical communities have been committed to put synergies with industrial sectors to improve by-products reuse and recycling both inside and outside the steelmaking cycle.

The dissemination project, *"Dissemination of results of the European projects dealing with reuse and recycling of by-products in the steel sector," REUSteel* (GA 839227), started on 1st June 2019 (end date: 31/05/2021), and it has received funding from the Research Fund for Coal and Steel of the European Union. REUSteel aims at the dissemination and valorization of the most important results on the reuse and recycling of by-products achieved in the last few decades in the relevant EU-funded projects. The ongoing activities within REUSteel concern an in-depth and critical integrated analysis of the projects, aiming at the results exploitation according to the concepts of Circular Economy and Industrial Symbiosis, at the increase of reuse and recycling of by-products as well as at promotion of synergies between the steel industry and the other sectors. In addition, this analysis will allow defining the future research activities, taking also into account technical and non-technical barriers as well as future needs and ambitions of the EU steel industry. In the next few years, this will allow to move towards new aspects of research and the implementation of innovative solutions that aim at improving the by-products reuse and recycling. Finally, the key results will be implemented in the ESTEP's Strategic Research Agenda, by also contributing to the low carbon Europe and Big-Scale initiative of EUROFER.

Addressing the right by-product recovery steps in steelmaking chain: support tools for slag recovery, recycle and reuse

Authors: Ismael Matino, Valentina Colla, Teresa Annunziata Branca (SSSA)

Speaker: Ismael Matino

The production of by-products is parallel to main product making in all the industrial routes and steelmaking is a good example both in its integrated and electric route. Several kind of by-products are always produced together with steel and they are often valuable sources to be exploited internally or externally for raw material replacement. Sometimes, these by-products are ready to be reused. In other cases, they require some pre-treatments or need to combined with further materials. Among others, slags are one of the main by-products of both the steelmaking routes. Their recovery/recycle/reuse is sometimes hampered by the lack of knowledge related to the consequences of this reuse or because pre-treatments need to be ad-hoc customized in order to obtain the desired recovery of materials.

In order to solve the lack of this information and to help in decision making, simulation and optimization tools can provide significant support. A simulation tool and related scenario analysis will be presented, which allow evaluating the consequences of the internal reuse of

slags in EAF route. Furthermore, the combination of different simulation and optimization tools will be presented, which support the evaluation of BOF slag pre-treatment steps and optimization of the reuse of separated parts internally or externally with or without the combination with further by-products.

The potential of these system lies in the possibility to make preliminary evaluations in order to address specific solutions before the real application, by thus avoiding waste of resources, efforts and undesired consequences.

The use of slags for agriculture purposes

Authors: Teresa Annunziata Branca, Valentina Colla, (SSSA), David Algermissen, Agnieszka Morillon (FEHS)

Speaker: Teresa Annunziata Branca

The composition of iron and steel slags depends on different aspects, such as raw materials, type of steel made, furnace conditions, etc. However, they usually contain some components and compounds suitable for fertilizer and amendment purposes, such as CaO, MgO, SiO_2, P_2O_5, FeO, and MnO. In agriculture, slags can be used as fertilizers and as correctives of soil acidity, due to their calcium and magnesium silicates content, having neutralizing action due to the SiO_3^{2-}, by raising the pH in acidic soils. Steel slags application can also improve soil quality, increase soil nutrient availability and yield, can immobilize heavy metals, such as Cd and Pb, in soil, resulting in lower concentrations in crops. Furthermore, Cr(III) leaching is very low in the slag and oxidation risk of Cr(III) in the soil to Cr(VI), promoted by MnO_2 presence in the soil, is very low, due to the pH of slag. In addition, slags can improve the physical properties of soft soils.

Main results

Although slag is not currently used in Italy, recent studies have provided preliminary knowledge about slag use for agriculture purposes in Italy soils. In particular, Basic Oxygen Furnace slag has been tested in column tests, showing that BOF slag can enhance the available P content in the topsoil (**Figure 1**). By testing different soils, it has been observed that in the loamy soil, rich in organic matter, BOF slag increased the cation exchange capacity, resulting in increase of the nutrient retention capacity of the soil, and, consequently, in soil fertility improvement as well as in groundwater protection [1]. In addition, a preliminary assessment of the technical and economic viability of a slag treatment plant to evaluate the introduction of this material to the fertilizer market has been performed [2]. Furthermore, the application of Basic Oxygen Furnace slag to saline sodic soils has shown significant effects in decreasing the exchangeable sodium content also resulting in improving yields (**Figure 2**).

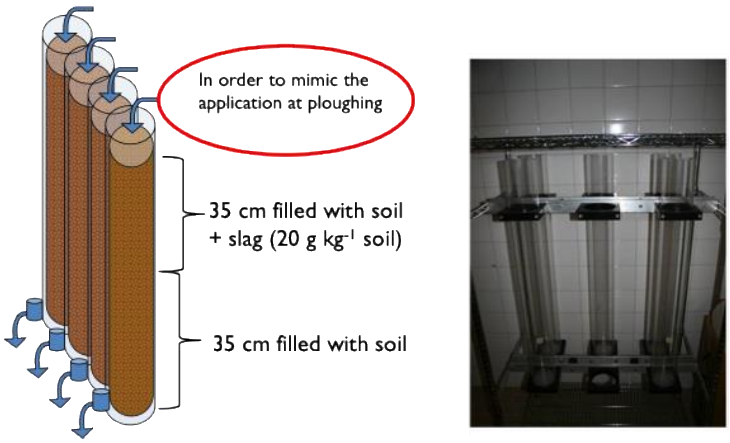

Figure 1: Column test design.

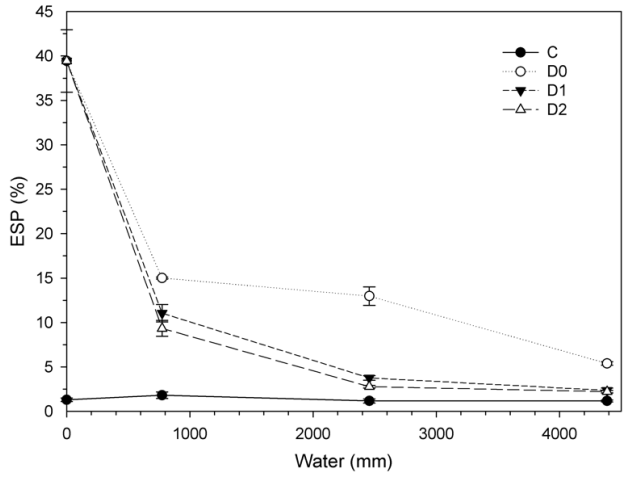

Figure 2: Exchangeable Sodium Percentage variation according to received water in mm (rain + irrigation) [3].

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[2] Branca, T. A., Fornai, B., Colla, V., Pistocchi, C., & Ragaglini, G. (2019). APPLICATION OF BASIC OXYGEN FURNACE (BOFS) IN AGRICULTURE: A STUDY ON THE ECONOMIC VIABILITY AND EFFECTS ON THE SOIL. *Environmental Engineering & Management Journal (EEMJ)*, *18*(6).

[3] Pistocchi, C., Ragaglini, G., Colla, V., Branca, T. A., Tozzini, C., & Romaniello, L. (2017). Exchangeable Sodium Percentage decrease in saline sodic soil after Basic Oxygen Furnace Slag application in a lysimeter trial. *Journal of environmental management*, *203*, 896-906.

2.3 9th International Conference on Science and Technology of Ironmaking (ICSTI)

Title Review of European research projects dealing with by-products from sintering and blast furnace and their re-use and recycling (REUSteel)

Authors + Affiliation Roland Pietruck (BFI), Valentina Colla, Teresa Annunziata Branca (SSSA), Unberto Martini (RINA-CSM), Agnieszka Morillon, David Algermissen (FEHS), Hanna Granbom, Sara Rosendahl (SWERIM)

Speaker Roland Pietruck (BFI)

In the European steel industry many research initiatives and projects have been undertaken in the last years in order to improve reuse and recycling of by-products which are produced in different stages of the steel production cycle (e.g. slags, sludge and scale) and for recovering valuable materials, reducing the environmental impact and meeting the goal of "zero waste".

Recently the dissemination project "Dissemination of results of the European projects dealing with reuse and recycling of by-products in the steel sector (REUSteel)" funded by the Research Fund for Coal and Steel (RFCS) has been started in order to select and review the most relevant, previous European projects dealing with by-product reuse or recycling. The main results are extracted for further dissemination. The reviewed projects are also analysed focusing on the principles of circular economy and industrial symbiosis. Additional issues will be identified that have not been previously addressed but were recommended for further studies. Barriers will be indicated that the steel industry is facing with respect to by-product recycling and utilization. Collaboration with respect to environmental issues is necessary in Europe to better meet current expectations and harmonize steel production within its communities.

The present paper is focused on the main outcomes achieved by the research projects dealing with by-products from sintering and ironmaking in blast furnace of the European steel industry and its synergies with other industrial sectors. The impact of the reviewed research results and innovative aspects is assessed and presented, including environmental issues.

2.4 BFI Colloquium 2021

Title Overview of BFI's work in the area of processing and recycling of metallurgical residues

Authors + Affiliation (acronym) Pietruck (BFI)

SpeakerRoland Pietruck (BFI)

An overview of the BFI's work in the framework of international or national multi-year research projects in the field of reprocessing and recycling of solid metallurgical residues in the steel industry over the period 2000 - 2020 is given. The analyses also flow into the RFCS project Reusteel "Dissemination of results of the European projects dealing with reuse and recycling of by-products in the steel sector.

The work on projects in the field of the sintering plant, the blast furnace, the converter and also the electric arc furnace is presented.

2.5 15th Society and Material Conference SAM15

Analysis of EU-funded research activities on reuse and recycling of by-products in the steel sector

Authors: Valentina Colla, Teresa Annunziata Branca (SSSA), Agnieszka Morillon, David Algermissen (FEHS), Hanna Granbom, Sara Rosendahl (SWERIM), Umberto Martini (RINA-CSM), Roland Pietruck (BFI)

Speaker: Valentina Colla

In the last few decades, one of the main commitments of the European steel industry consisted in improving by-products management in a sustainable way, not only by increasing their reuse and recycling rate, but also by applying new solutions supported by new studies and new techniques application in order to meet the "zero waste" goal. The resulting benefits, such as reduction of natural resources depletion and environmental impacts, and increase of energy efficiency, can affect not only the steel industry, but also other sectors, in the perspective application of Industrial Symbiosis and Circular Economy concepts.

The present work concerns the main achievements of the ongoing dissemination project, *"Dissemination of results of the European projects dealing with reuse and recycling of by-products in the steel sector" REUSteel (GA 839227)*, co-founded by the Research Fund for Coal and Steel of the European Union. The project aims at valorising and disseminating the results achieved over the last few decades in the most relevant EU-funded projects focused on reuse and recycling of iron and steel by-products. Both internal and external uses have been analysed.

Within the REUSteel project, a critical and in-depth review analysis of previous projects was performed in order to exploit the main outcomes and follow-up, to promote synergies among sectors and to define future research directions, by considering technical and non-technical barriers as well as future ambitions of the EU steel sector. In particular, the impact of the research results was classified, by highlighting innovative aspects of researches. The main outcomes were analysed, considering the achieved level of practical application and value inside the steel community including some economic aspects. In addition, the reason for success or failure of each project was assessed.

The review developed in REUSteel is expected to promote research activities and technological innovations leading to novel solutions for improving reuse and recycling rate of by-products. In addition, the crucial outcomes will be implemented in the Strategic Research Agenda of ESTEP, by contributing to the realisation of the low carbon Eu-rope and the Big-Scale initiative of EUROFER.

2.6 5th European Steel and Applications Days ESTAD 2021

REUSteel symposium – *Reuse and recycling of residual materials in iron and steelmaking: analysis of relevant results, trends and perspectives*

Authors: Valentina Colla, Teresa Annunziata Branca (SSSA), Roland Pietruck (BFI), Agnieszka Morillon, David Algermissen (FEHS), Umberto Martini (RINA-CSM), Hanna Granbom, Sara Rosendahl (SWERIM)

Moderators: Hanna Granbom, Sara Rosendahl

Abstract:

The steel sector is deeply committed to sustainable management of its residual materials, in order to reduce the natural resources exploitation, reduce the environmental impact of the steel sector, and to achieve the steel sector's "zero-waste" goal.

The ongoing project titled "Dissemination of results of the European projects dealing with reuse and recycling of by-products in the Steel sector (REUSteel)", funded by the Research Fund for Coal and Steel (RFCS), is mapping the research done in this area. The project aims at a valorisation of the most important research results on residual materials reuse and recycling, both internally within the steel sector and in other industrial sectors. This is based on an integrated critical analysis of many finalized EU-funded projects, in order to promote results exploitation and increase the synergies with other industrial sectors. The analysis will allow to identify the most urgent needs and ambitions of the European steel sector and define a sequence of future research topics in this field. The project is coordinated by SSSA and other partners are Swerim, BFI, FEhS, RINA-CSM.

The symposium will start with a presentation of the concluded and ongoing research within the REUSteel project. This will be followed by an in-depth look at three topics identified within the dissemination project. The three topics are slag use, residual material use in BF and sinter plant, residual material use in EAF. The symposium will be concluded with an outlook about the future of residual materials within steel industry. In connection to all the presentations there will be time for questions and comments from the audience. During the symposium we are also looking for the opinions and feedback from the audience.

Agenda

8.30-10.00 Two presentations including time for questions.

- General presentation of the REUSteel project and the symposium – Valentina Colla (SSSA)
- Research of use of slag from the steel industry – Agnieszka Morillon (FEhS)

10.00-10.30 Coffee break

10.30-12.00 Two presentations including time for questions followed by an outlook, together with the audience, on future use of and research on residual materials.

- Research of the use of sludge, dust, refractory, millscale, and other residual materials from the steel industry and external secondary raw material in the BF and Sinter – Roland Pietruck (BFI)
- Research of the use of sludge, dust, refractory, millscale, and other residual materials from the steel industry and external secondary raw material in the EAF – Umberto Martini (CSM)
- An outlook: How will the use of residual material change in the future? – Valentina Colla (SSSA)

More detailed descriptions of the five presentations are given below.

General presentation of the REUSteel project and the symposium

Authors: Valentina Colla (SSSA)

Speaker: Valentina Colla (SSSA)

A general presentation of the REUSteel project is provided, by explaining the objectives, the intermediate and final goals as well as the results of an analysis pursued on a selected number of EU-funded projects, which were analysed during the project. Some indications for future research direction are identified and the overall skeleton of the roadmap that is being developed within the project is outlined.

Research of use of slag from the steel industry

Authors: Agnieszka Morillon (FEHS)

Speaker: Agnieszka Morillon (FEHS)

In the Reusteel project 24 projects were analysed that deal specifically with slag. Within these projects different areas of slag recycling or utilization were investigated over the past 25 years. The investigated topics were divided into internal slag use/recycling, external slag use/recycling or slag analysis. A description of each project and its main findings with respect to slag was presented.

Research of the use of sludge, dust, refractory, millscale, and other residual materials from the steel industry and external secondary raw material in the BF and Sinter

Authors: Roland Pietruck (BFI)

Speaker: Roland Pietruck (BFI)

In the Reusteel project 43 research topics were analysed in the area of Reuse and Recycling of Dust, Sludge, Refractory and Mill scale in the European steel industry distributed in 34 RFCS projects carried out in between 2000 and 2020. The main part of the residues and by-products from this area are already recycled internally in the steel industry whereas only a small part is still landfilled. As an example, RFCS projects are described that have dealt with the important recycling routes, the sintering plant and the blast furnace. In addition, a short outlook on future developments is given.

Research of the use of sludge, dust, refractory, millscale, and other residual materials from the steel industry and external secondary raw material in the EAF

Authors: Umberto Martini (RINA-CSM)

Speaker: Umberto Martini (RINA-CSM)

In REUSteel, 14 projects are specifically devoted to the EAF. The topics faced regard the reuse and recycling of dust and other by-products from steelmaking production cycle and the use of alternative carbon sources instead of fossil coal. The presentation includes examples taken from the investigated projects. The recycling of steel by-products faces of course the EAF dust recycling with different methods (pyro, hydro and combination of them for favouring an internal virtuous recycling way) that are obviously not exhaustive of all the possibilities given by the industrial environment linked with the EAF route. In fact, cases on how to reuse various steelmaking by products at once (dust, sludges, scale, undersized fractions of iron ores, alloying materials and slag formers) previously agglomerated or forming briquettes not necessarily by the re-introduction of them into the EAF but also using devoted furnaces working in parallel with the EAF have also been included to demonstrate the feasibility and the potentiality of these actions. Furthermore, an important trend that is expected to be very sensitive as directly related with the CO2 emissions and climate change issues, is the progressive substitution of coal in EAF operations with alternative sources of carbon. Examples using pyrolysis of waste plastics (car fluff and PVC) for scrap pre-heating and surface cleaning and of plastics in replacement of coal for EAF operations showed the possibility to achieve a double benefit in valorizing waste materials and decreasing the use of fossil fuels at the same time without impacting the plant productivity. On the same thematic, biomass (e.g. forest and agriculture residue) have been shown as feasible carbon sources in substitution of coal for both injection and charging (with scrap) possible modalities in EAF production. The important results achieved in the projects discussed are emphasized but indications about further refinements (and related research activities) that can be interesting objects of future studies (with related research activities) are also given in the presentation.

An outlook: How will the use of residual material change in the future?

Authors: Valentina Colla (SSSA)

Speaker: Valentina Colla (SSSA)

The presentation aims at stimulating the discussion on the future direction of the research in the field of reuse and recycling of residual materials in the steel sector, by analyzing major obstacles, technical and not technical barriers that are currently experienced, evolution of national and international regulations on this topic, as well as factors, which mostly favor the by-products reuse and recycling.

2.7 Raw Materials & Recycling International Meeting

Circular Economy and Industrial Symbiosis in a recent analysis of the relevant European projects related to the steel industry

Authors: Valentina Colla, Teresa Annunziata Branca (SSSA), Agnieszka Morillon, David Algermissen (FEHS), Hanna Granbom, Sara Rosendahl (SWERIM), Umberto Martini (RINA-CSM), Roland Pietruck (BFI)

Speaker: Valentina Colla

The steel sector is deeply committed to the sustainable management of its by-products, in order to reduce the natural resources exploitation, its environmental impact, and to achieve its "zero-waste" goal.

The present paper is based on a part of work developed in the current dissemination project entitled "Dissemination of results of the European projects dealing with reuse and recycling of by-products in the steel sector (REUSteel)", co-founded by the Research Fund for Coal and Steel (RFCS). This project aims at analyzing the results coming from the most relevant projects focused on the reuse and recycling of the steel sector by-products, both internally and in other industrial sectors, according to the principles of Circular Economy and Industrial Symbiosis.

In the present paper, the achieved results on these topics are discussed. On one hand, a global vision of the relevant results of the state-of-the-art, particularly focused on the main outcomes achieved by the European steel industry and its synergies with other industrial sectors, is provided. On the other hand, an analysis of the results of the European projects in the field of steel sector by-products reuse and recycling is performed. In particular, the impact of the research results and innovative research is assessed and presented, by taking into account some significant aspects, such as the achieved level of practical application and value, including economic and environmental aspects as well as the reasons for full or partial achievement of the projects objectives. In addition, the possible identified barriers and the follow-up of the analyzed projects are discussed.

2.8 General Assembly of the Euroslag association

Dissemination of results of the European projects dealing with reuse and recycling of by-products in the steel sector

Authors: Agnieszka Morillon (FEHS)

Speaker: Agnieszka Morillon

Brief description of the Reusteel project was provided with some specific examples of research dealing with slag that was conducted in the past 25 years. Emphasis on need for feedback from the participants was stressed with respect to future needs of the steel industry with respect to by-products. The survey was provided for participants to complete. After the presentation and link to survey was fwd to all Euroslag members.

3. List of abstracts of Journal papers

The REUSteel Consortium produced a first paper on the international Journal *Metals* at the beginning of the project, by exploiting and summarizing the outcome of a preliminary investigation of the state of the art on the topic of the reuse and recycling of by-products in the steel sector. This paper, which is published in Gold Open Access form, according to the statistics provided by the publisher was frequently downloaded and was cited within numerous paper that were published afterwards.

A second paper on the same journal was published as a summary of the discussions held during the ESTEP Resi4Future Workshop. Although the paper does not deal exclusively on the topic treated by the REUSteel project and the corresponding Author (Dr. Johannes Riesger) does not belong to the REUSteel Consortium, it is mentioned here, as some contributions from all the partners of REUSteel on the concerned topic are included.

Further journal publication are planned specifically targeting the dissemination of the Roadmap. Clearly, such publication will be finalised after the conclusion of the project, being the Consortium committed to continue the dissemination action on this aspect. For instance, a paper will be produced after the presentation at the RawMat meeting, to be submitted for possible publication on La Metallurgia Italiana. Moreover, the Coordinator is currently guest editor of a Special Issue of the Journal *Metals*, which is entitled *"Reuse and Recycling of By-Products in the Steel Sector"*[1] and plans to submit a paper co-authored by all the partners of REUSteel dealing with a detailed description of the pursued analyses, of the outcomes of the interviews and surveys as well as on the developed Roadmap.

3.1 Reuse and Recycling of By-Products in the Steel Sector: Recent Achievements Paving the Way to Circular Economy and Industrial Symbiosis in Europe

Authors: Teresa Annunziata Branca, Valentina Colla, David Algermissen, Hanna Granbom, Umberto Martini, Agnieszka Morillon, Roland Pietruck, Sara Rosendahl

Over the last few decades, the European steel industry has focused its efforts on the improvement of by-product recovery and quality, based not only on existing technologies, but also on the development of innovative sustainable solutions. These activities have led the steel industry to save natural resources and to reduce its environmental impact, resulting in being closer to its “zero-waste” goal. In addition, the concept of Circular Economy has been recently strongly emphasised at a European level. The opportunity is perceived of improving the environmental sustainability of the steel production by saving primary raw materials and costs related to by-products and waste landfilling. The aim of this review paper was to analyse the most recent results on the reuse and recycling of by-products of the steelmaking cycles as well as on the exploitation of by-products from other activities outside the steel production cycle, such as alternative carbon sources (e.g., biomasses and plastics). The most relevant results are identified and a global vision of the state-of-the-art is extracted, in order to provide a

[1] https://www.mdpi.com/journal/metals/special_issues/reuse_recycling_steel

comprehensive overview of the main outcomes achieved by the European steel industry and of the ongoing or potential synergies with other industrial sectors.

Metals **2020**, *10*, 345. https://doi.org/10.3390/met10030345

Freely available at: https://www.mdpi.com/2075-4701/10/3/345

3.2 Residue Valorization in the Iron and Steel Industries: Sustainable Solutions for a Cleaner and More Competitive Future Europe

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The steel industry is an important engine for sustainable growth, added value, and high-quality employment within the European Union. It is committed to reducing its CO2 emissions due to production by up to 50% by 2030 compared to 1990′s level by developing and upscaling the technologies required to contribute to European initiatives, such as the Circular Economy Action Plan (CEAP) and the European Green Deal (EGD). The Clean Steel Partnership (CSP, a public–private partnership), which is led by the European Steel Association (EUROFER) and the Euro-pean Steel Technology Platform (ESTEP), defined technological CO2 mitigation pathways com-prising carbon direct avoidance (CDA), smart carbon usage SCU), and a circular economy (CE). CE approaches ensure competitiveness through increased resource efficiency and sustainability and consist of different issues, such as the valorization of steelmaking residues (dusts, slags, sludge) for internal recycling in the steelmaking process, enhanced steel recycling (scrap use), the use of secondary carbon carriers from non-steel sectors as a reducing agent and energy source in the steelmaking process chain, and CE business models (supply chain analyses). The current paper gives an overview of different technological CE approaches as obtained in a dedi-cated workshop called “Resi4Future—Residue valorization in iron and steel industry: sustaina-ble solutions for a cleaner and more competitive future Europe” that was organized by ESTEP to focus on future challenges toward the final goal of industrial deployment

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Acronym	Name
AIM	Associazione Italiana di Metallurgia
AIST	Association for Iron and Steel Technology
CDA	Carbon Direct Avoidance
CE	Circular Economy
CEAP	Circular Economy Action Plan
COVID-19	Coronavirus Disease 2019
CSP	Clean Steel Partnership
ECSC	European Coal and Steel Community
ESTAD	European Steel Technology and Application Days
ESTEP	European Steel Technology Platform
EGD	European Green Deal
FP	Framework Programme
RFCS	Research Fund for Coal and Steel
SCU	Smart Carbon Usage