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 3.3

Dissemination material

Table of Contents

1. Project Summary and purpose of the present document

Within the project, an 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. Abstracts of the developed publication in journal and conferences have been included in **Deliverable D1.2**.

The present document is aimed at giving indications about the actions and related material prepared for disseminating the concepts of reuse and recycle of steel by-products that have been addressed to a wider audience including people attending to masters, in job training, students.

The COVID-19 Pandemic crisis implied the need to focus on communication methods based on on-line ways. Web conferencing specific software, specifically Zoom Video Communications and Microsoft Teams have been used for this purpose. These actions have been done with the support of web pages including specific sections on estep.eu[1] and on santannapisa.it[2] that integrated the project website[3].

Videos, presentations, leaflets etc. produced as support for the dissemination activities are integrated in the REUSteel project website. Short descriptions including details on the single events are included in the next section.

[1] https://www.estep.eu/events/reusteel/
[2] https://www.santannapisa.it/en/research/projects/reusteel-dissemination-results-european-projects-dealing-reuse-and-recycling
[3] https://www.reusteel.eu/

2. Description of dissemination materials and events

The dissemination material is briefly described in the following sub-paragraphs. The following subdivisions are based on the different dissemination events. Electronic copies of the dissemination material (including pdf files of the original presentations and linkable movies of some events) are available through the REUSteel website. The dissemination material available for consultation is reported in **Table 1**: for each event an indication of the different format types (e.g. pdf, video) is given.

Table 1. Dissemination material available for consultation (through REUSteel website)

	Dissemination occurrence	Dissemination material available for consultation
a	Paper on specialized review	T.A. Branca, V. Colla, D. Algermissen, H. Granbom, U. Martini, A. Morillon, R. Pietruck and S. Rosendahl, Reuse and Recycling of By-Products in the Steel Sector: Recent Achievements Paving theWay to Circular Economy and Industrial Symbiosis in Europe, Metals 2020, 10, 345; doi:10.3390/met10030345, www.mdpi.com/journal/metals
b	Outcomes of the analysis carried out by REUSteel project	Video with narrating voice
c	EUROSTEELMASTER	Leaflet of the event (pdf)
		Copies of the 4 presentations (merged, pdf)
d	Open Webinars	Copies of the 13 presentations including the leaflet of the event (merged, pdf)
		Videos of the presentations including the discussions held at the end of each of the 3 days
e	REUSteel symposium at ESTAD 2021	Copies of the 5 presentations and of the leaflet of the event (merged, pdf)
		Videos of the presentations including the discussions held at the end of the symposium
f	Dissemination material for high schools	Copy of the presentation on dry slag granulation (pdf)

2.1 Preparation of a paper for publication

A document has been prepared and submitted to a specialized technical journal, namely "Metals", at the beginning of 2020, hence in advance respect the planned start data of Task 3.1. Such document is devoted to a general analysis of the most recent results on the reuse and recycling of by-products in the steelmaking cycles and on the exploitation of by-products from outside the steel production cycle. The document has been prepared taking into account the

state of the art analysis that is described in **Deliverable D1.1** in which relevant and recent literature sources have been considered to complete the frame of the investigation based on the EU financed project in these topics.

The document has been conceived to give the reader a clear indication of the context touching thematic that are considered of primary importance for the EU strategies in the next years regarding the steel production sector such as moving closer to "zero-waste", saving primary raw materials, moving towards a smarter carbon usage. In this context, the concept of Circular Economy assumed a great importance and the Industrial Symbiosis (see **Figure 1)** is clearly indicated as the "virtuous way" for maximizing the benefits achieved in terms of environmental and economic advantages.

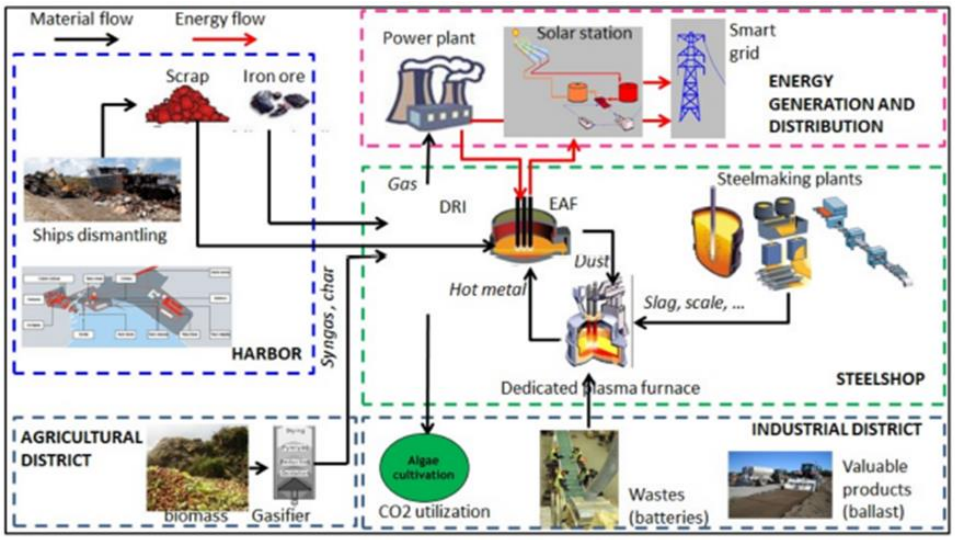


Figure 1. Sketch showing possible examples of industrial symbiosis

Examples of reuse of the main steel by-products such as slag and dust are included in the document together with examples showing a large set of possibilities suitable for the recycling and valorization of these materials both internally and externally the steelmaking cycle with the aim to stimulate the interest of the reader that could find ideas applicable to its proper activities and/or business. Just to cite some of the given examples, new techniques to improve the properties of the exhausted slag (from BF, BOF, EAF, LF) to facilitate its reuse for e.g. cement production or road construction are discussed as well as different ways of recycling of other by-products (dust, mill scale, refractories) both internally and externally, this last action favoured by the creation of consortiums involving different industrial sectors.

The document has been accepted in March 2020 and then published as a paper. **Table 1-row a** includes all the information about the paper.

2.2 Outcomes of the analysis carried out by REUSteel project

The video (see also **Table 1-row "b")** shows the approach the REUSteel team used in the analysis of the European projects of interest with respect to the reuse and recycling of residual materials from steel production. The objectives of REUSteel analysis are clearly explained as well as the basis and criteria adopted for carrying out the evaluation. An overview of the results is provided, together with indications of the challenges for the different by-products (e.g. slag, dust etc.) and needs of the steel industry. Needs and challenges emerged from the discussions which were held during webinars (see later in the document) and during the symposium at ESTAD 2021 (see also **Deliverable D1.2** and paragraph 2.4), and from the outcomes of an on-line questionnaire promoted during such events. The questionnaire has been compiled by stakeholders and/or steel producers. **Figure 2** shows an example of the results related to the question "in which area of slag do you see research needs?".

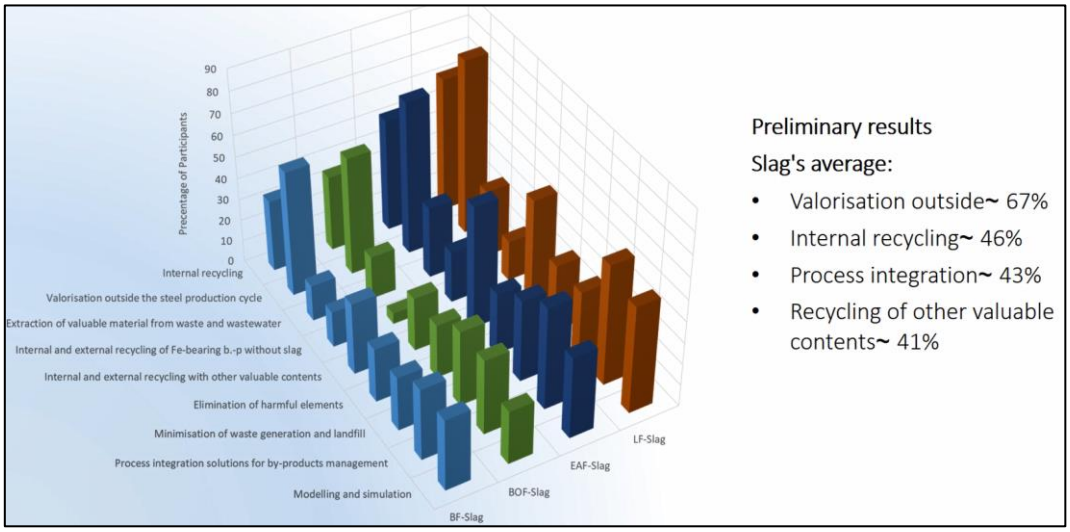


Figure 2. Example of the questionnaire results related to slag.

Furthermore, an important trend that is expected to be very important as it directly relates to the CO_2 emissions and climate change issues, is the progressive substitution of coal in Electric Arc Furnace (EAF) operations with alternative sources of carbon. In this context, the approach used in recent and still ongoing projects for the use of alternative source of carbon such as biochar and plastics instead of fossil coal in EAF operations are shown. Considering the expected increase of steel production through the EAF route in the next two decades and the parallel increase of application of industrial symbiosis concepts, these topics must be considered having a high relevance for future scenarios.

The future of steel production will also involve a massive use of modelling and simulation tools coupled with the control/acquisition systems. In such context an increase of the use of techniques based on Artificial Intelligence (AI) and Machine Learning (ML) is expected as well as a massive use of Cyber-Physical Systems (CPS), Interned of Things (IoT), Big-Data and Edge Computing. The whole process already started but it is expected to have an ever-increasing deployment due to its potential not only for improving flexibility and reliability of

the process but also for favouring an intensified reuse and recycling of residual materials (see **Figure 3**).

The outcome of the analyses pursued by REUSteel team within the project are spread in the proper ways (workshops, conferences, etc.). On the basis of all the activities, the identification of the industrial needs, technological challenges, and research needs, will lead to the definition of a Roadmap that will become available at the end of the project. The Consortium is committed to continue the dissemination action also beyond the conclusion of the project.

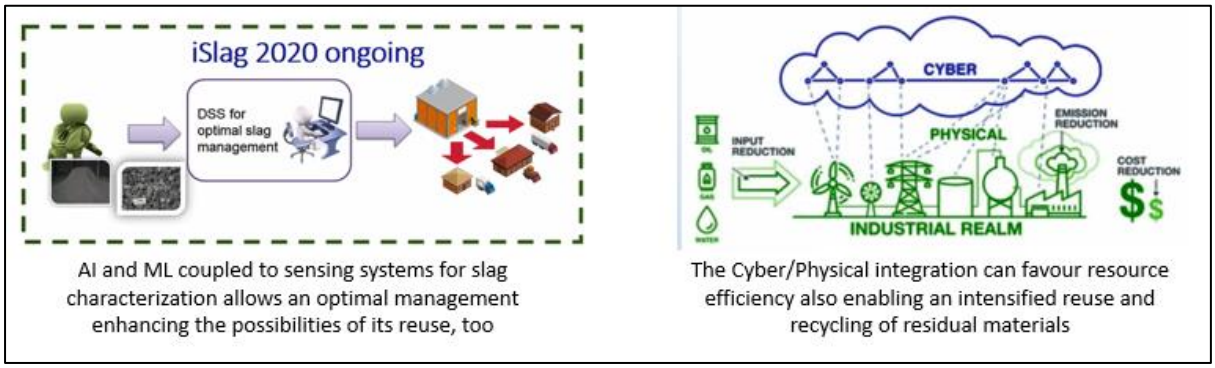


Figure 3. How the implementation of cyber-physical systems can help in reuse/recycling of steel by-products.

2.3 EUROSTEELMASTER - European Advanced Training Course for the Worldwide Steel Sector

EUROSTEELMASTER course was held (online because of the covid pandemic) in the period 03-07 May 2021. The course is specifically aimed at managers, researchers, students and other professionals operating in the entire value chain of the steel sector. Participants have a university (or equivalent experience) degree. **Figure 4** shows a comprehensive list of the professional profiles of participants including the companies to which they belong. REUSteel seminar has been included as associated to the course program just before the official start of the course. **Figure 5** shows a copy of the section of EUROSTEELMASTER leaflet where the REUSteel seminar has been included. The seminar duration was from 9:30 a.m. to 1:00 p.m. on 3rd May.

N.	Company	Job position
1	Acciaierie d'Italia Holding S.p.A.	Research Engineer
2	Acciaierie d'Italia Holding S.p.A.	R&D Engineer
3	EUROFER	Manager, Market Analisys&Economic Studies
4	Compañia Española de Laminación S.L.	Industrial PhD Student
5	ArcelorMittal Italia S.p.A.	R&D Engineer
6	Acciaierie d'Italia Holding S.p.A.	Research Engineer
7	ARVEDI	Process engineer
8	EUROFER	Senior Manager Chemicals, Water and Sustainability
9	EUROFER	Junior Manager, Energy and Climate
10	RINA	SENIOR BUSINESS DEVELOPMENT MANAGER
11	Acciaierie d'Italia Holding S.p.A.	Research Engineer
12	ARVEDI	Scrap purchasing manager
13	Acciaierie d'Italia Holding S.p.A.	Research Engineer - R&D Department
14	Acciaierie d'Italia Holding S.p.A.	Research Engineer - R&D Department
15	RINA Consulting - Centro Sviluppo Materiali SpA	Funded Research
16	ArcelorMittal Italia	Research Engineer
17	ACERINOX S.A.	Sustainability analyst
18	Marcegaglia	SUPPLIER DEVELOPMENT
19	Wirtschaftsvereinigung Stahl / German Steel Federation	Deputy Head of Capital Office; Research and Innovations Policy
20	ACERINOX Europa S.A.U.	Environmental Coordinator
21	EUROFER	Manager, Process emissions
22	Acciaierie d'Italia Holding S.p.A.	Research Engineer - R&D Department
23	Feralpi	R&D
24	RINA CONSULTING SPA	CONSULTANT, INDUSTRY TENDER SCOUTING
25	Compañía Española de Laminación S.L.	Phd Student
26	ArcelorMittal Holding and Services Belgium	Government Affairs & Trade Policy Manager
27	ArcelorMittal-Flat Products-CTO Products	Strategic projects - Funding
28	RINA Consulting - Centro Sviluppo Materiali SpA	Process engineer
29	RINA Consulting - Centro Sviluppo Materiali SpA	Advanced Mechanics & Fitness for Service
30	ABP Induction Systems GmbH	Sales Manager Systems

Figure 4. EUROSTEELMASTER 2021 – Comprehensive list of the professional profiles of participants including the companies to which they belong.

RFCS Project REUSteel Seminar

Valorisation and dissemination of RFCS projects results and experience in steel surface quality issues: on as-cast cracks formation

3 May 2021 (09.30 - 13.00)

"Dissemination of results of the European projects dealing with reuse and recycling of by-products steel sector (REUSteel)" is a project co-founded by the Research Fund for Coal and Steel (RFCS).
The project is framed in the context of more eco-friendly and sustainable solutions in the steel industry. 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) are the proper actions to move towards a saving of the natural resources together with a reduction of the environmental impact, hence being closer to a "zero-waste" goal.

The aim is to provide bridging solutions to lead the steel industry towards a reduction of its environmental impact with an obvious saving of natural resources, hence in being closer to a virtuous objective of "zero waste" goal. These thematic fields are perfectly framed in a concept that is strongly emphasized at a European level and that is receiving increasing attention in the scientific and technical community in the latest years, namely the so called Circular Economy.

"REUSteel" aims at an extensive action of dissemination and valorisation of the most important research results on by-products reuse and recycling, based on an integrated critical analysis of many EU-funded projects, in order to promote results exploitation and increase the synergies with other industrial sectors. This analysis will allow identifying the most urgent needs and ambitions of the European steel sector and defining a sequence of future research topics in this field.

A joint critical analysis, carried out by all the partners, belonging to different institutions, will provide new insights and guidelines for future research topics in this field, in order to promote the dissemination and, consequently, the implementation of the achieved results. The project will also organise the results, in order to present selected groups of topics at planned workshops and seminars. This will provide a clearer vision of the outcomes to stakeholders and new audiences, in order to get new and deeper indications for a new roadmap, future synergies with other sectors and industrial trends.

"REUSteel" will contribute to an update of the steel roadmap for a low carbon Europe 2050 and the current BIG-Scale initiative of EUROFER.

The partners involved in the project are

Sant'Anna Scuola Universitaria Superiore Pisa · BFI · RINA · FEHS · SWERIM

RFCS Project REUSteel Seminar

09.00 - 09.30 | Welcome and Introduction
Pietro Gimondo, *RINA*

09.30 - 13.00 | Dissemination of the REUSteel RFCS projects results

Figure 5. Copy of the EUROSTEELMASTER leaflet section in which the REUSteel seminar was advertised.

Five different presentations have been shown and discussed with the audience:

[1] REUSteel Project – General Discussion (by Valentina Colla and Umberto Martini)[4]

[4] Valentina Colla (Scuola Superiore Sant'Anna, Pisa), REUSteel Project coordinator. Umberto Martini (RINA Consulting – Centro Sviluppo Materiali SpA)

[2] EAF and decarbonization – the role of EU Research (by Filippo Cirilli)[5]
[3] Fostering Circular Economy in Steel Decarbonization (by Michele De Santis)[5]
[4] Industrial Symbiosis in Energy Intensive Industries (by Daphne Mirabile)[5]

The REUSteel Project is described in presentation [1], including the aims, the reasons, the approach, and the operating ways pursued by the team. Examples of different ways to reuse and recycle the steel by-products (e.g. slag, dust, etc.) taken either from the EU projects considered for interest in the REUSteel investigation or from recent developments found in international literature are included in the presentation. With these examples, the most interesting trends and modalities of steel by products recycling were given including aspects that will be considered for REUSteel Project Roadmap.

Presentation [2] has the aim to show the contribution of EAF to the decarbonisation of the steel industry. The forecasted scenario indicates a worldwide production through EAF route to increase consistently in the next decades. The future processes pass through progressive steps involving the substitution of fossil coal with other sources of carbon (Smart Carbon Usage) as first phase and then moving towards the use of green electricity and hydrogen (Carbon Direct Avoidance). The process already started as biomass and torrefied have been used in substitution of coal for EAF operations and plastics (from wastes) are starting to be used for the same purpose. Examples from finished or in progress European projects on these topics are shown. Then the presentation introduces and describes the future trends aiming at the use of H2 in EAF operations both for the DRI production and in substitution of natural gas for EAF burners. To finish, the implementation of technologies aimed at the CCU lists a series of options including the current TRLs reached. In this context, the EAF becomes can be considered as a new focal point of a revolution in progress in the steel industry where considerably reductions of EU emissions can be achieved from a more circular economy (and industrial symbiosis) for steel, plastics, aluminium, and cement.

Presentation [3] shows the EU funding support initiatives taken, in progress, as well as future perspectives fostering circular economy as pathway towards decarbonization. In the presentation, RFCS priorities, needs and trends are discussed as well as initiatives such as the Clean Steel Partnership as virtuous example not only for supporting a climate-neutral and competitive steel production in the EU but also having the possible diffusion and adoption of EU technologies worldwide. Afterwards, the specific objectives to decarbonization are discussed including these lasts aspects such as smart carbon usage in steel production, improvement of energy and resource efficiency, increase the recycling of steel scrap and residues. Circular economy is intended to have a primary role in this complex but feasible scenario moving towards the ambitious targets set such as the climate neutral by 2050.

Presentation [4] describes an approach that facilitates Industrial Symbiosis application using the example of the H2020 project CORALIS (still ongoing). The approach consists in the combination of new business and management strategies to obtain viable industrial symbiosis. The validity of such approach is demonstrated in three different industrial areas covering

[5] RINA Consulting – Centro Sviluppo Materiali SpA

different sectors, geographical dimensions and resources. The presentation includes a description of the initiatives and main results achieved up to now in the demo case located in Brescia Industrial complex. The industrial synergy allows powder and metal recovery from steel production, biochar use as coke substitute, metal recovery in secondary aluminium production. The expected benefits will be an increase of the recovery of the metal powder, oxides, and other industrial waste moving towards the 100%, the reduction of raw materials usage, the maximization of energy efficiency, and the reduction of CO2 emissions.

The dissemination material available for the event is included in **Table 1-row "c"**.

2.4 Open Webinars

A three day open webinar series has been held on 14, 15 and 16 June 2021 with each session having a duration of about 2 hours. The topics treated in each of the webinars have been organized on the basis of the different types of steel by products (and secondary raw materials) adopted by REUSteel team (**Figure 6**).

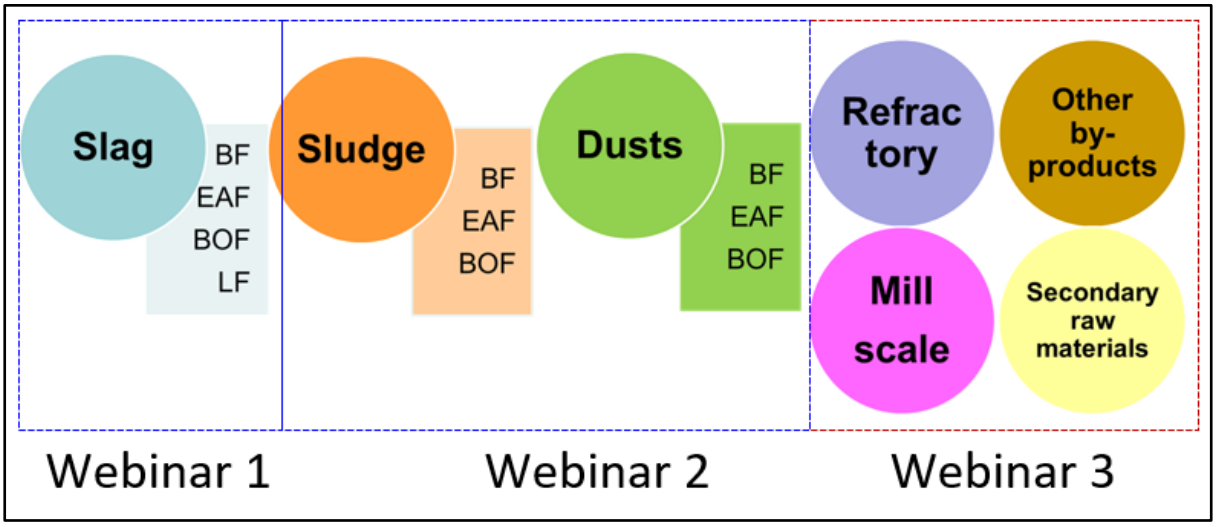


Figure 6. Subdivision of the webinar series with respect to different types of steel by-products (and secondary raw materials).

The three events have been organized by ESTEP with related advertisement in a devoted web-page[6] that included the leaflet, the registration form and a link to SSSA webpage[7] which includes a short description of the project. The events are also included in the events section on the REUSteel website (www.reusteel.eu).

[6] https://www.estep.eu/events/reusteel/
[7] https://www.santannapisa.it/en/research/projects/reusteel-dissemination-results-european-projects-dealing-reuse-and-recycling

Figure 7 to **Figure 9** show the program for each day of the webinar including the titles of the different presentations with the name of the presenter.

Day 1 – 14.06.2021 9:00-11:00 – Webinar on Slag			
Time	**Speaker**	**Speaker Organization**	**Presentation**
09:00	Valentina Colla (*Chairman*)	Scuola Superiore Sant'Anna	*General description of the REUSteel project*
09:15	Agnieszka Morillon	FEHS	*Overview of the EU-funded research on slag*
09:30	Andreas Ehrenberg	FEHS	*ActiSlag - A broad approach to optimize granulated blast furnace slag*
09:45	Uwe Pihl Teresa Annunziata Branca	FEHS Scuola Superiore Sant'Anna	*Slag as a fertilizer with respect to current EU regulations and Italian situation*
10:00	Guozhu Ye	SWERIM	*Metal recovery from slag*
10:15	Ismael Matino	Scuola Superiore Sant'Anna	*Modelling, simulation and digital tools to improve slag reuse and recycling*
10:30	All		***Plenary Discussion with speakers***
11:00	Valentina Colla (*Session Chairman*)	Scuola Superiore Sant'Anna	***Closure of the Webinar***

Figure 7. Program of Day 1 – Webinar on Slag

Day 2 – 15.06.2021 10:00-12.00 – Webinar on Sludge and Dust			
Time	**Speaker**	**Speaker Organization**	**Presentation**
10:00	Roland Pietruck (*Chairman*)	BFI	*Overview of the EU-funded research on sludge and dust*
10:10	Roland Pietruck	BFI	*Recovery of dust and sludge in the sinter plant*
10:30	Gerald Stubbe	BFI	*Metal recovery from iron and steelmaking dust and sludge residues*
10:45	Simon Wölfelschneider Steffen Möhring	BFI	*Briquettes from dust and sludge for shaft furnace charging*
11:00	Jörg Adam	BFI	*Lowering local blast furnace hearth wear by TiO_2-materials injection*
11:15	Lena Sundqvist	SWERIM	*Flexible injection of alternative carbon material into the blast furnace*
11:30	All		***Plenary Discussion with speakers***
12:00	Roland Pietruck (*Chairman*)	BFI	***Closure of the Webinar***

Figure 8. Program of Day 2 – Webinar on Sludge and dust

Day 3 – 16.06.2021 8:00- 10:00 *Webinar on Refractory, Millscale, other residual material from inside and outside of the steelwork*			
Time	**Speaker**	**Speaker Organization**	**Presentation**
08:00	Umberto Martini (*Chairman*)	RINA-Centro Sviluppo Materiali	*Overview of the EU-funded research on Refractory, Millscale and other residual material from inside and outside of the steelwork*
08:10	Umberto Martini	RINA-Centro Sviluppo Materiali	*Use of external sources of carbon (biomass and plastic) in EAF*
08:40	Johan Björkvall	SWERIM	*Residual material for slag foaming in EAF*
09:00	Mikael Larsson	SWERIM	*Processes and technologies for environmentally friendly recovery and treatment of scrap*
09:30	All		***Plenary Discussion with speakers***
10:00	Umberto Martini (*Chairman*)	RINA-Centro Sviluppo Materiali	***Closure of the Webinar***

Figure 9. Program of Day 3 – Webinar on Refractory, Millscale. Other residual material from inside and outside of the steelwork

Figure 10 shows the list of companies represented by professionals of the steel sectors and of consultants attending the webinars in the three different days. A total number of 89 people per day (88 in the second day) coming mostly from Europe but including also a not negligible fraction from outside Europe (Brazil, India, Canada, China, Iran) and working for primary companies in the steel sector has been involved.

Company	Country	Session 1	Session 2	Session 3
ESTEP	Belgium	1	1	1
Institute for Chemical Processing of Coal	Poland	1	1	1
ESTEP	Belgium	1	1	1
ACCIAIERIE BERTOLI SAFAU S.P.A.	Italy	1	1	1
ArcelorMittal Luxembourg	Luxembourg	1	1	1
ArcelorMittal Global R&D	France	1	1	1
ALFA ACCIAI	Italy	1	1	1
ArcelorMittal Poland	Poland	1	1	1
Tata Steel	Netherlands	1	1	1
ORI Martin spa	Italy	1	1	1
Sidenhol	Spain	0	0	1
University of Oulu	Finland	1	1	1
CELSA Group	Spain	1	1	1
ArcelorMittal Tubarao	Brazil	1	1	1
Tata Steel NL R&D	Netherlands	1	1	1
Metal One Deutschland GmbH	Germany	1	1	1
Primetals	United Kingdom	1	1	1
ETS Nordic Oy	Finland	1	1	1
Liberty Steel India	India	1	1	1
SIJ Acroni d.o.o.	Slovenia	1	1	1
SFTec Oy	Finland	1	1	1
SIJ d.d. (Slovenian Steel Industry)	Slovenia	1	1	1
Sij d.d.	Slovenia	1	1	1
SIJ d.d.	Slovenia	1	1	1
SFTec Oy	Finland	1	1	1
ArcelorMittal Global R&D	Spain	1	1	1
ArcelorMittal Spain	Spain	1	1	1
PLATEA - Spanish Steel Technology Platform	Spain	1	1	1
ArcelorMittal Global R&D	Spain	0	1	1
ArcelorMittal Brasil	Brazil	1	1	1
Tata	Netherlands	1	1	1
Sidenor I+D	Spain	1	1	1
ETS engineered trade solutions GmbH	Germany	1	1	1
ArcelorMittal Belgium	Belgium	1	1	1
voestalpine Stahl Donawitz GmbH	Austria	1	1	1
Primetals Technologies Austria GmbH	Austria	1	1	1
voestalpine High Performance Metals GmbH	Austria	0	1	1
voestalpine High Performance Metals GmbH	Austria	1	1	1
EUROFER	Belgium	1	1	1
ArcelorMittal	Belgium	1	0	0
Jernkontoret	Sweden	1	1	1
SIJ Metal Ravne	Slovenia	1	0	1
Scholz AUstria GmbH	Austria	1	1	1
Vargon Alloys AB	Sweden	1	1	1
Csic	Spain	1	0	0
arcelormittal	Spain	1	1	1
Feralpi Siderurgica	Belgium	1	1	1
voestalpine Stahl GmbH	Austria	1	1	0
Feralpi Siderurgica SpA	Italy	1	1	1
Feralpi Siderurgica SPA	Italy	1	1	1
Liberty Steel Group	India	1	1	1
Höganäs Sweden AB	Sweden	1	1	1
Swerim	Sweden	1	1	1
Tata Steel Ltd.	India	1	1	0
QuantoLux	Germany	1	1	1
University of Oulu	Finland	1	1	1
Swerim	Sweden	1	0	1
Swerim AB	Sweden	1	1	1
FEhS	Germany	1	1	1
Lhoist	Belgium	1	1	1
Lhoist	Belgium	1	1	1
Chalmers University of Technology	Sweden	1	1	1
Diproinduca	Canada	1	1	1
KTH	Sweden	0	0	1
CRM Group	Belgium	1	1	1
K1-MET GmbH	Austria	1	1	1
Vanadium R&D	Switzerland	1	1	0
ARCELORMITTAL GLOBAL R&D	France	1	1	1
CRMGroup	Belgium	1	1	1
Primetals Technologies Austria	Austria	1	1	0
Primetals Technologies Austria GmbH	Austria	1	1	1
Primetals Technologies Austria GmbH	Austria	1	1	1
University of Oulu	Finland	1	1	1
University of Oulu	Finland	1	1	1
celsa group	Spain	1	1	1
shu	China	1	1	1
Primetals Technologies Austria GmbH	Austria	1	1	1
Primetals Technologies Austria	Austria	0	1	0
LTU	Sweden	1	1	1
voestalpine Stahl Donawitz GmbH	Austria	1	1	1
FUNDACION IDONIAL	Spain	1	1	1
ircelyon	France	1	0	0
INEGI - Institute of Science and Innovation in Mechanical and Industrial Engineering	Portugal	1	1	1
ArcelorMittal	Luxembourg	1	1	1
VDEh-Betriebsforschungsinstitut GmbH	Germany	1	1	1
VDEh Betriebsforschungsinstitut GmbH	Germany	1	1	1
BFI	Germany	1	1	1
Acerinox	Spain	1	0	0
Innovate UK, UKRI	UK	1	1	1
ArcelorMittal	Spain	0	1	1
Tata Steel Europe	Netherlands	1	1	1
University of Oulu	Finland	1	1	1
University of Oulu	Finland	0	1	1
ArcelorMittal	France	0	0	1
Liberty Steel Group	India	0	0	1
Swerim	Sweden	1	1	1
Consultant	Belgium	1	1	1
Consultant	Iran	1	1	1

Figure 10. ***Open Webinars*** **-** Comprehensive list indicating the number, the country and the company of the participants in the three-days webinars

Description of Day 1: On the first day of the webinar a general presentation of REUSteel project was given by the project coordinator and chairwoman Valentina Colla[8]. The presentation provided an overview of the completed and ongoing activities within REUSteel, by including a detailed description of the analysis of the considered projects and the main issues, which emerged from such analysis and which provide inputs for the development of the roadmap. The main elements of the roadmap have also been discussed, so as to prepare the audience for the other presentations and for the final discussion.

The next five presentations were slag related:

[1] Overview of the EU-funded research on slag, presented by Agnieszka Morillon[9]
[2] ActiSlag – A broad approach to optimize granulated blast furnace slag, presented by Andreas Ehrenberg[9]
[3] Slag as a fertilizer with respect to current EU regulations and Italian situation, presented by Uwe Pihl[9] and Teresa Annuziata Branca[8]
[4] Metal recovery from slag, presented by Guozhu Ye[10]
[5] Modelling, simulation and digital tools to improve slag reuse and recycling, presented by Ismael Matino[8]

Presentation [1] was an overview of all the analysed European projects with respect to slag over the last 25 years. Most of the 24 projects described were funded by RFCS or ECSC. The presentation described the type of research which was done on slag internal or external use or recycling (e.g. recycling of LF slag to replace lime in EAF, recovery of metal from the slag, use of slag in cement/clinker, use of slag in road construction, use of slag as liming/fertilizer material, or analysis of slag, etc...).

Presentation [2] was an overview of an ongoing RFCS project ActiSlag, which investigated new activation routes for early strength development of granulated blast furnace slag. The target of the project was to preserve and increase the use of GGBS in cement by (early) strength optimization, open new markets for GGBS and keep costs reasonable.

Presentation [3] was an overview of slag use as a liming material. Comparison and effects of slag on crops and soil was presented. In addition, history and current regulatory statues in using slag-based fertilizers was discussed, especially with respect to the new European fertilizer regulation (FPR) EU 2019/1009 which currently excludes slag. Specific case studies were presented of research done on slag in the context of Italian soil, where currently slag is not being used as a fertilizer.

[8] SSSA
[9] FEhS
[10] SWERIM

Presentation [4] was an overview of the recovery of valuables from steel slag and other residues in the context of specific projects, e.g. IPBM, IPBM II-REWA, VILD, IPX-NSC and other international slag projects.

Presentation [5] discussed the importance of modelling and simulation tools in promoting reuse and recycling of by-products in the steel sector, by depicting some exemplar cases of work developed within past and ongoing EU-funded project. In particular, physical-based, machine learning-based and hybrid modelling approaches were presented and discussed.

Description of Day 2:

The second day of the webinar focussed on the recycling of dust and sludge related to the steel sector. The session was hosted by Roland Pietruck. With his introductory presentation (presentation [6]) he gave a short overview of the EU funded research in the area of dust and sludge, before introducing the speakers and the topics they were presenting:

[6] [Recovery of dust and sludge in the sinter plant, presented by Roland Pietruck
[7] Metal recovery from iron and steelmaking dust and sludge residues, presented by Gerald Stubbe[11]
[8] Briquettes from dust and sludge for shaft furnace charging, presented by Simon Wölfelschneider and Steffen Möhring[11]
[9] Lowering local blast furnace hearth wear by TiO2-materials injection, presented by Jörg Adam[11]
[10] Flexible injection of alternative carbon material into the blast furnace, presented by Lena Sundqvist10[10]

Presentation [7] focussed on the recycling of dust and sludge in the sinter plant. The RFCS project IMSIMI was used as an example how the particle size distribution and water loading of the dust and sludge influences the sinter process. The need for further research in terms of granulation to prepare the sinter feed is identified. The EU-project ACASOS was also reviewed to highlight the difficulties involved in substituting the coke breeze used traditionally in the sinter process. Alternative carbon sources result in different burning behaviour limiting its use in the sinter process.

Presentation [8] reviewed a wide range of pyrometallurgical processes that can be used to recover the metal, especially valuable components like zinc, from dust and sludge. The range of processes included kiln- and hearth-based processes like the Waelz and the RedIron process, as well as melt based processes like the HlSarna and ZEWA process or the direct injection into an EAF. These processes usually result in the formation of zinc enriched product dust suitable for zinc smelting. A brief overview of hydrometallurgical processes in general and how to combine them with pyrometallurgical processes was also given.

[11] BFI

In Presentation [9] the option to produce briquettes as an alternative way to recycle dust and sludge was highlighted. Briquetting can be used to either reduce the load of residues in the sinter plant or to substitute metallurgical coke in shaft furnace operation. Self-reducing briquettes are also reviewed. In order to obtain suitable briquettes the right humidity, particle size distribution and binder selection are key. Applied examples on industrial scale in the scope of the EU-projects "Briquetting of self-reducing blendings of waste iron oxide mixtures", "Alternative Processing of Sinter Plant Recycling Materials" and INNOCARB are also reviewed.

Presentation [10] dealt with the innovative concept of TiO2 directly through the blast furnace tuyere during operation to protect zones subjected to high wear. The Ti is reduced and dissolved in the hot metal and when it sees zones of high heat transfer due to high wear it forms TiCN layers. These build a scaffolding protecting blast furnace lining. The concept has proven itself in an industrial environment.

In Presentation [11] the RFCS-project FLEXINJECT was used to demonstrate the possibility to directly BF-dust back into the BF at tuyere level. Industrial test campaign have proven that the direct recycling of BF-dust is very much possible and primarily limited by the increase of pressure drop through the furnace. Another issue is the abrasiveness of the dust, thus the injection system has to prepared for increased wear. The direct injection of BF-sludge is limited by its zinc content, hence the sludge has to be pre-treated through e.g the Tornado process.

Description of Day 3

The presentation used as introduction of the day by the chairman Umberto Martini summarizes the ways materials such as of refractory, millscale, other by-products, and secondary raw materials are reused/recycled both internally and externally in the steel production based on the analysis carried out by REUSteel workgroup on the selected European Projects (**Deliverable D2.3**).

Three specific presentations have been showed as examples of research, design, and implementation of recycle/reuse concepts applied to specific cases following the approach of European Projects:

[11] Use of external sources of carbon (biomass and plastic) in EAF, presented by Umberto Martini[12]
[12] Residual material for slag foaming in EAF, presented by Johan Björkwall[13]
[13] Processes and technologies for environmentally friendly recovery and treatment of scrap, presented by Mikael Larsson[13]

The presentation [12] includes examples of use of biomass and of biochar derived from biomass torrefaction in substitution of coal for EAF operations. The cases of European projects

[12] RINA Consulting – Centro Sviluppo Materiali SpA
[13] SWERIM

GREENEAF and GREENEAF2 have been used to show the approach followed to make possible the use of biochar/biomass in substitution of coal for both charging and injection operations in EAF. The description includes techno-economic and logistic aspects related to this new way to operate. As a further step forward, the use of plastic as source of carbon for EAF operations is also shown by means of the example of project POLYNSPIRE (still in progress).

The presentation [2] describes the approach used in RINFOAM project that is coherent with new possibilities and synergies with other sectors regarding the EAF procedures. The basic idea is to use waste material blends containing both metal oxides and hydrocarbons as slag foaming agents in the EAF operations. Trials (at pilot and industrial scale) have been done using different material mixtures anthracite, rubber, Petrit-t, EAF dust or mixtures containing plastic fines, rubber powder, Automotive Shredder Residue (ASR), wood sawdust pellets. The results for both pilot and industrial trials have been promising to guarantee a stable foaming without alteration of the normal EAF operations except for a little increase of sulphur. Furthermore, the possibility to use ASR by charging in EAF has also been demonstrated as a feasible.

The presentation [13] describes the approach used in PROTECT project that is aimed at the new attention needed to the scrap quality in a context oriented to increase the production through EAF route also giving the possibility to produce high quality steels. The approach used in the project is the use of waste materials from outside steelwork, namely plastics including ASR and PVC, for producing a syngas Cl rich to be used as primary source for scrap pre-heating. The advantages obtained by this approach is to have a simultaneous heating and cleaning (removal of oil, paints, etc.) of the scrap surface making also possible the capture of tramp elements such as Zn and Hg that are removed as chlorides.

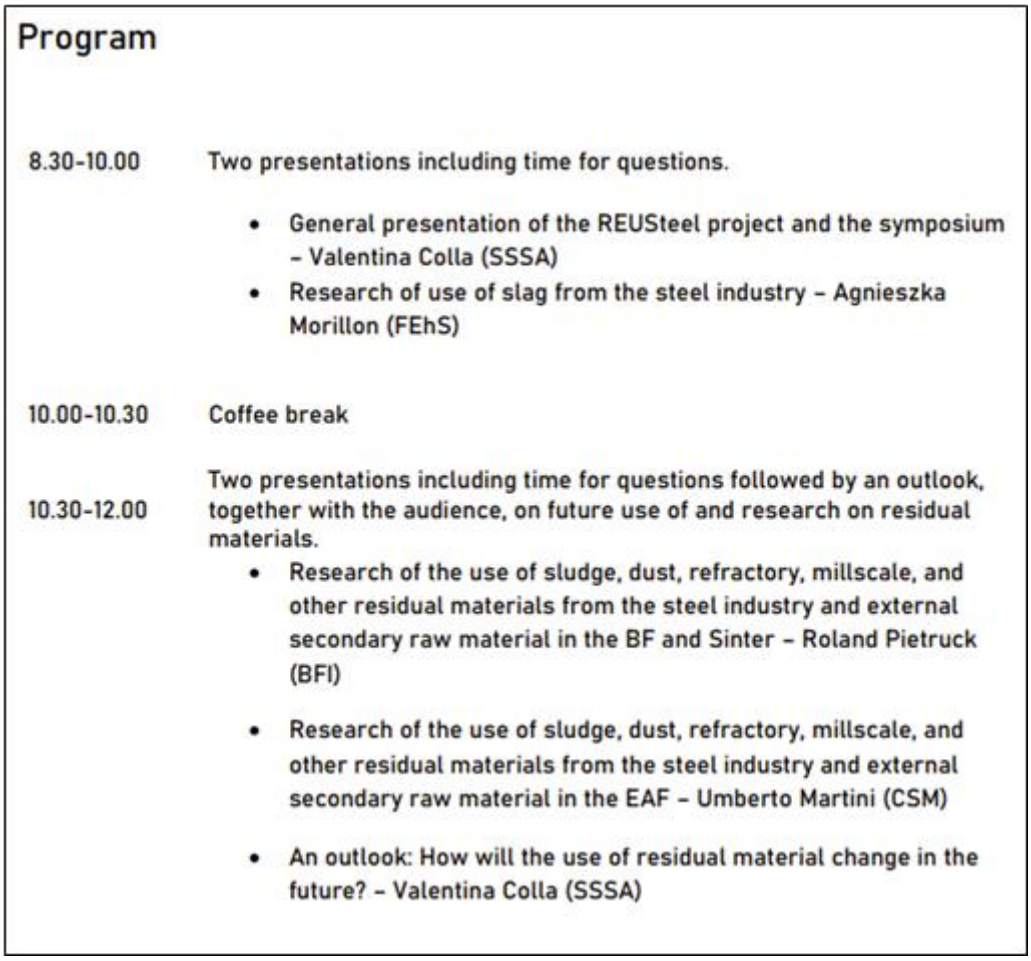
The dissemination material available for the event is included in **Table 1-row "d"**.

2.5 REUSteel symposium at ESTAD 2021

In addition to the previously described webinar series, the REUSteel consortium held a half day symposium at 5th ESTAD on 31st August 2021, presenting results and analyses from the REUSteel project activities. **Figure 11** shows the program of the event. A description of the five presentations prepared by REUSteel team for the symposium has been already included in the **Deliverable D1.2**.

The symposium served as an opportunity to gather the opinions of the audience on the potential for reuse and recycling within the steel industry and to have useful indications for the refinement and completion of the roadmap, this last described in **Deliverable D5.1**.

The dissemination material available for the event is included in **Table 1**, **row-"e"**.



Program

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)

Figure 11 Program of the 5th ESTAD REUSteel symposium**.**

2.6 Dissemination material for high schools

A general presentation has been purposely designed considering the possible use for teaching purposes in high schools (see **Appendix A**). The presentation includes two main videos taken from activities carried out at laboratory level in a first phase and then at industrial level as a final validation of a relatively novel approach to produce slag granulation by air cooling applied to EAF and LF slags. Other pages of the presentation are used for framing the context giving the possibility to stimulate the attention of the students.

Considering the audience and the aims it is intended for, the subjects are treated in a very simplified way without too many technicalities. In practice the example of slag granulation is used to communicate the students at high school a series of concepts; obviously, recycle/reuse are concept already fixed in mind of young people but the other important aspect that the presentation wants to emphasize is that "the study could appear somewhat boring, but it is the first and mandatory step for maintaining the hope in a future having a sustainable industry that can assure to live on a healthy planet".

A video with a narrating voice of the whole presentation (in English language) has been created and it is ready to be used for didactic purposes only and without any commercial aim. This last

condition, indeed, is imposed by the parts owner of the video and photos contained in the presentation. Hence, the REUSteel consortium decided to make directly available via web the pdf copy of the presentation only (**Table 1-row "f"**). The interested people (typically high school teachers) will have the possibility to request the video directly by REUSteel website contacts declaring and signing their aims that must guarantee the compliance of their use with the limitation above indicated.

3. List of figures

4. List of tables

5. List of symbols, indices, acronyms, and abbreviations (besides International Standards)

Acronym	Name
BF	Blast Furnace
BOF	Basic Oxygen Furnace
EAF	Electric Arch Furnace
LF	Ladle Furnace
AI	Artificial Intelligence
AIM	Associazione Italiana di Metallurgia
AIST	Association for Iron and Steel Technology
ASR	Automotive Shredder Residue
CDA	Carbon Direct Avoidance
CE	Circular Economy
CEAP	Circular Economy Action Plan
COVID-19	Coronavirus Disease 2019
CPS	Cyber-Physical Systems
CSP	Clean Steel Partnership
EAF	Electric Arc Furnace
ECSC	European Coal and Steel Community
ESTAD	European Steel Technology and Application Days
ESTEP	European Steel Technology Platform
EGD	European Green Deal
EU	European Union
FP	Framework Programme
H2020	Horizon 2020
IoT	Interned of Things
IS	Industrial Symbiosis
ML	Machine Learning
RFCS	Research Fund for Coal and Steel
SCU	Smart Carbon Usage

Appendix A: Video for the high-schools

In the following You will find the presentation, which was designed for teaching purposes in high schools, especially technical schools. The presentation includes two main videos taken from activities carried out at laboratory level in a first phase and then at industrial level as a final validation of a relatively novel approach to produce slag granulation by air cooling applied to EAF and LF slags. Other pages of the presentation are used for framing the context giving the possibility to stimulate the attention of the students.

The presentation is the basis for a video, as all the slides are commented, and basic explanations are provided in a didactical way, to help students in understanding how the process is developed in practice.

DRY GRANULATION OF EAF AND LF SLAGS

Video realized in the frame of REUSteel project activities. The video is aimed at improving the sensitivity of future generations to the importance of having an industrial competitiveness with an improved environmental awareness

Narrating Voice: Umberto Martini (Rina Consulting Centro Sviluppo Materiali SpA)

REUSteel – *Project Number 839227 (2019)*

Slag is a steel by products.

On a chemical point of view it is a complex oxide mixture including CaO, SiO_2, Al_2O_3 MgO and iron oxides as main components.

Slag is immiscible with the steel and typically it tends to float because of the different of densities of the two liquids.

Example of a ladle containing steel and slag during a phase of secondary steel refining operations

Research Fund for Coal & Steel

REUSteel – *Project Number 839227 (2019)*

Slag is a steel by products.

On a chemical point of view it is a complex oxide mixture including CaO, SiO_2, Al_2O_3 MgO and iron oxides as main components.

Photo from archives of RINA CONSULTING – Centro Sviluppo Materiali S.p.A. (all rights reserved)

Slag is immiscible with the steel and typically it tends to float because of the different of densities of the two liquids.

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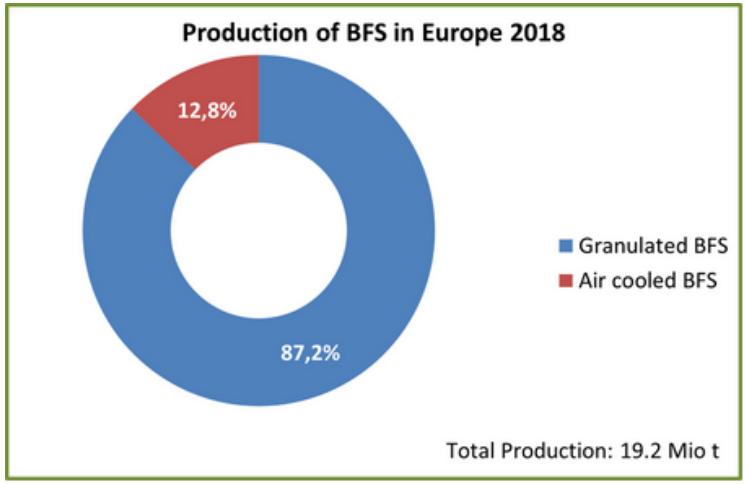
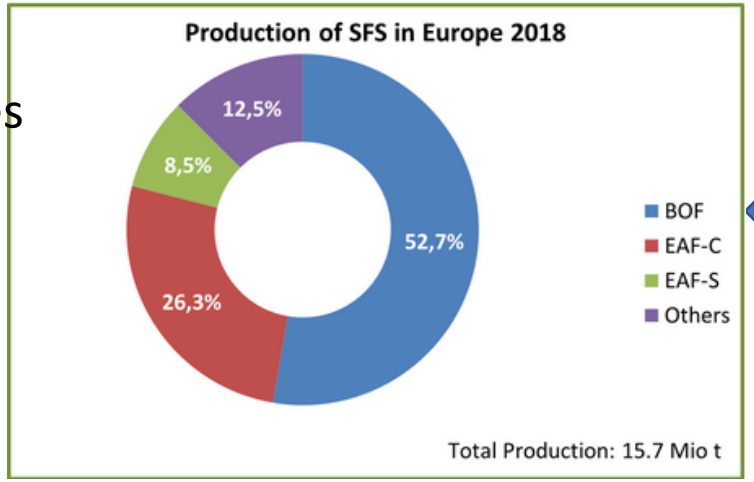
Every year millions of tons of slag are produced worldwide

Blast Furnace



Other Furnaces



Data from Euroslag

The transformation of the slag from waste material to resource for other industrial sectors is feasible. However, the achievement of such target requires some post processing actions on the slag. Processes allowing to produce **granulated slag** can be considered of primary importance.

Example of total slag production by the different steelmaking processes in Europe, year 2018

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SLAG GRANULATION PROCESS

The steelmaking slags can have typically problems related to:

- Pollution of soils due to water percolation and leaching
- Pollution of environment due to dust release

The granulation process is aimed at stabilizing the slag obtaining a glassy/amorphous material through a fast cooling and solidification of the slag itself in its liquid state.

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Slag granulation by water (the so called wet granulation) is the most established method for granulating slag.

The use of water guarantees high cooling capacity and makes possible the treatment of large quantities of materials.

Granulated Blast Furnace slag

(photo from EUROSLAG Technical Leaflet Nr. 1)

The granulation of **Blast Furnace Slag** produces a good product to be used to make concrete structures in combination with ordinary Portland cement and other pozzolanic materials.

DRY GRANULATION OF EAF AND LF SLAGS

A novel and promising approach

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REUSteel – *Project Number 839227 (2019)*

The use of an air stream as cooling agent for fast cooling of **E**lectric **A**rc **F**urnaces (**EAF**) and **L**adle **F**urnaces (**LF**) slags promoting the granulation of these slags just after the process, has several advantages.

EAF slag (black slag)

- Reduction of handling problems in slag pit
- Avoid leaching of some elements
- Possible valorisation as a product

LF slag (white slag)

- Avoid disintegration of slag with dust generation
- Easy handling
- Possible valorisation as a product

Examples of exhasted slag

Photos from archives of Institut fur Baustoff Forshung. (all rights reserved)

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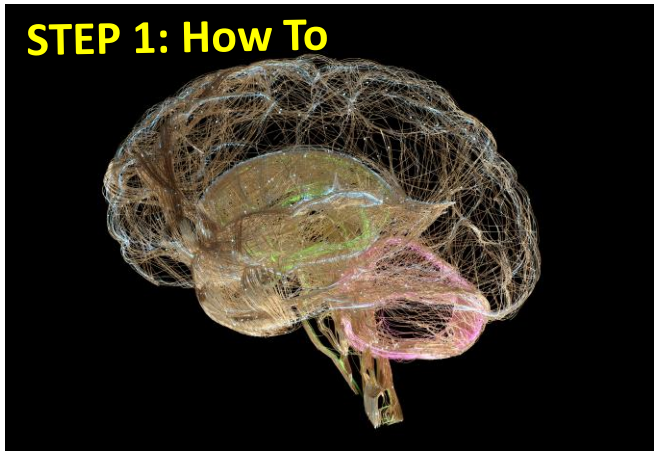
DRY SLAG GRANULATION OF EAF AND LF SLAGS

Process optimization



Theoretical approach

- Ideas
- Process design

STEP 2

Small scale (laboratory)

- Verification of the feasibility
- Process refinement and optimization

STEP 3

Scaling up to industrial scale

- Required plant modification and implementation

STEP 4

Full scale production

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Process optimization in laboratory scale

Choice of the proper experimental system

- laboratory furnace for slag melting
- pouring modalities of the molten slag
- optimization of air stream for fast slag cooling

and…

Photos from archives of RINA CONSULTING – Centro Sviluppo Materiali S.p.A. (all rights reserved)

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Small scale (laboratory)

Pouring of molten slag

...things in practice

Collection and cooling (by air stream) of molten slag for fast solidification

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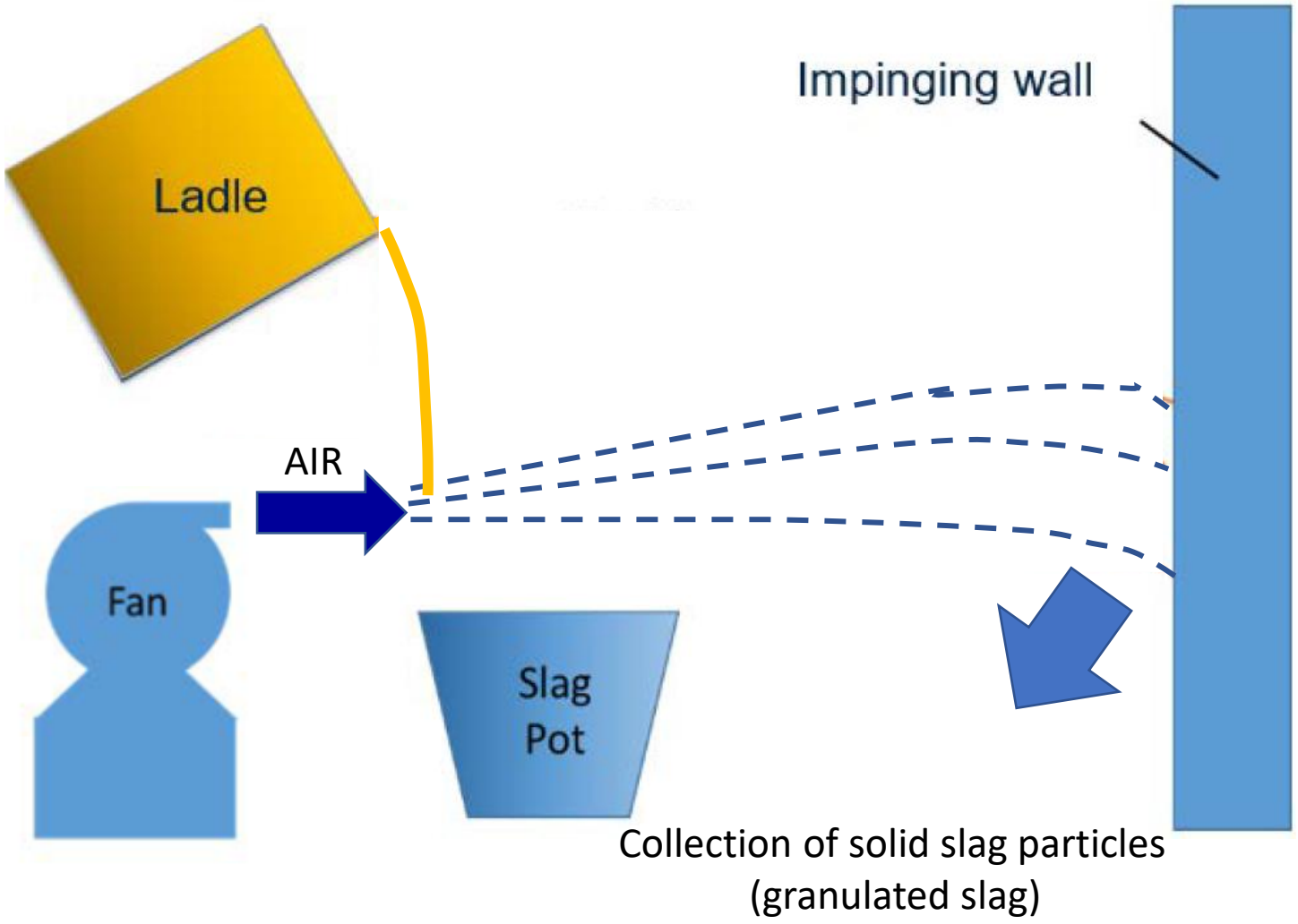
Small scale (laboratory)

Photo from archives of RINA CONSULTING – Centro Sviluppo Materiali S.p.A. (all rights reserved)

The process produces a proper slag granulation (example of the results obtained from EAF slag)

Scaling up (industry)



Collection of solid slag particles
(granulated slag)

The optimal conditions for slag granulation are reproduced in full scale,

and…

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...things in practice

Video from archives of RINA CONSULTING – Centro Sviluppo Materiali S.p.A. (all rights reserved)

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EAF slag (black slag)

- Road ballast materials
- Water-treatm
- Fill
- …aterials

…lag (white slag)

- New component for cement
- Injection in EAF as lime substitution
- Component on hydraulic road binder

A waste material becomes a resource

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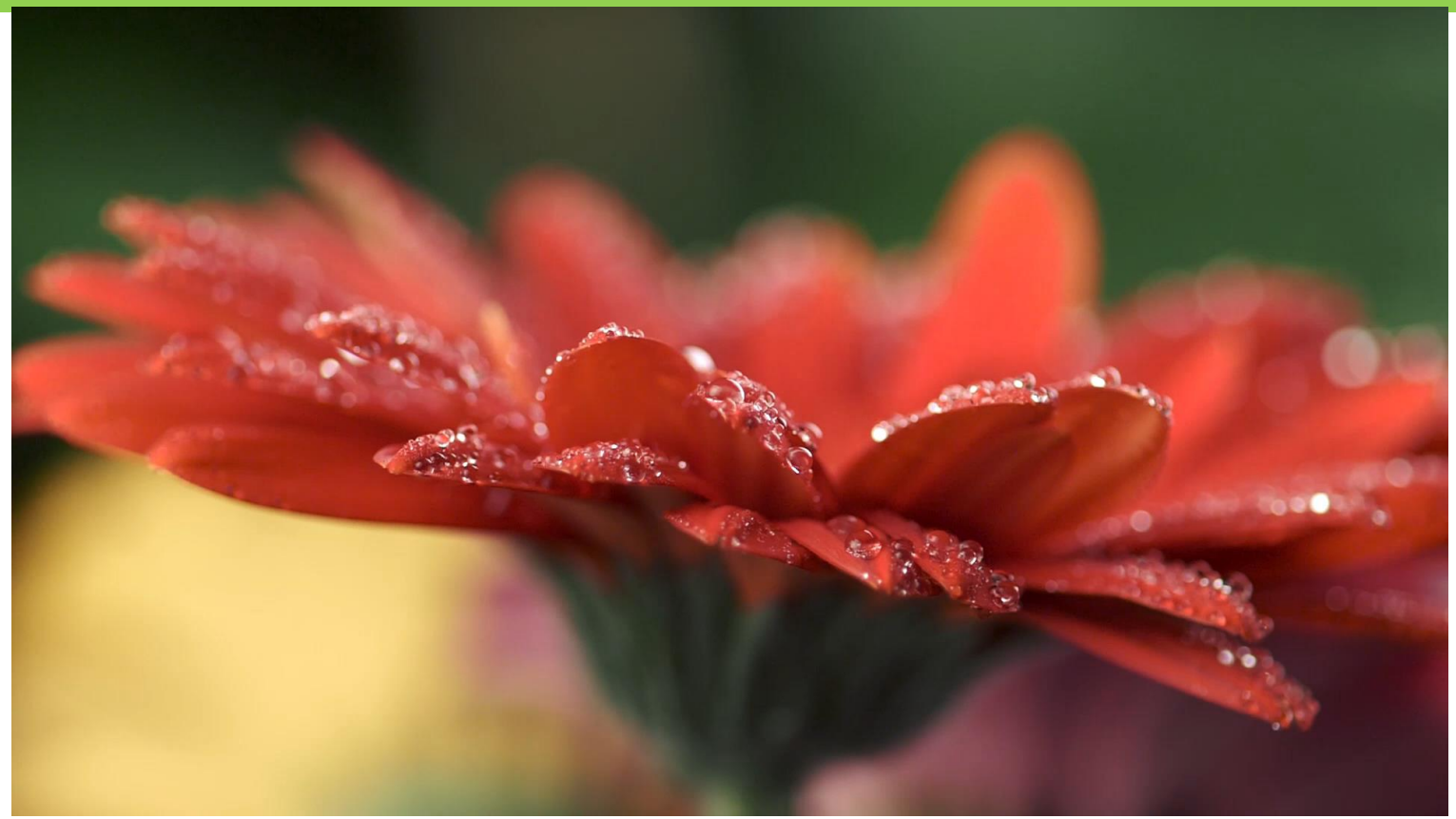
We shall require a substantially new manner of thinking

if mankind

is to survive

Albert Einstein



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Many thanks from REUSteel Consortium

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