PURity improv**E**ment of **SCRAP** metal

Deliverable 1.1

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Requirements for the produced material and the purification processes

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Abbreviations and acronyms

BOF	Basic Oxygen Furnace
EAF	Electric Arc Furnace
EFR	European Ferrous Recovery and Recycling Branch
GA	Grant Agreement
WP	Work Package

Abstract

This document represents deliverable D1.1 “Requirements for the produced material and the purification processes” of the Horizon Europe project entitled "Purity improvement of scrap metal" (project acronym: PURESCRAP; grant agreement no: 101092168 [1]).

The objective of Work Package 1 is to understand what needs to be improved in the scrap handling process in order to meet the needs from the steel industry. This deliverable is the result of task 1.1 in which the needs and expectations of the steel industry are mapped out and compared with the potential at the scrap recycler (sorting) plant.

1 Introduction

This deliverable is a result of work done in task 1.1

1.1 Summary of task 1.1

The needs from the steel industry are mapped out both, in terms of requirements set upon the current standards as well as the need for improved scrap handling. The aim is to enable a more efficient use of scrap for charge planning and to utilize currently unused waste streams.
The focus is first on the steel plants and the identified needs are then aligned with the possibilities for improved scrap handling at the scrap recycler (sorting plant). Based on the information gathered, a functional design of the PURESCRAP system will be given in the following deliverable D1.2.

1.2 Description of deliverable

The description of the deliverable in the GA Annex 1 is the following:

List of detailed requirements containing functional analysis outcomes and layout that will be investigated at the recycling plant

2 Vocabulary

The Table 1 below lists vocabulary being of importance for sharing concepts relevant to scrap handling during steelmaking. The purpose is to ensure a unified use of terminology as the premise for a shared semantics for the PURESCRAP project. Scrap classes are referred to as the EFR specifications and the Swedish Scrap book (Skrotboken). [2,3]. The EFR classes will be labelled E[class number] and those from the Swedish Scrap book SB[class number]. The primary target for PURESCRAP is the shredded and old scrap. Also new scrap could be of interest if it is realised that the analysis is not good enough for that type. Other scrap standards come from Institute of Scrap Recycling Industries (ISRI). [4]

Table 1. Vocabulary of importance for the project

Term	Explanation
The Metallurgy Process	
Charge	The raw material (ore or scrap) to be loaded in the furnace (EAF or BOF)
Heat	A batch of liquid steel produced in the steel plant (190 ton/heat at SSAB Oxelösund)
The Material	
Metal	The base metals such as Iron, Copper, Aluminium. In steel, the base metal is iron
Alloy element	Elements that are added to the metal (In Steel e.g., Cu, Ni, Mo)
Weight-% / Mass-%	The amount of alloying element expressed as the mass ratio
Base element	A major alloying element (typically >10 wt-%)
Trace element	A low amount of alloying element (typically <1%)
Micro alloying elements	Alloying elements in low amounts (“wanted” trace elements)
Tramp elements	Unwanted trace elements which are difficult / impossible to remove from the melt.
Penalty Elements	Same as Tramp elements. In PURESCRAP the term Tramp elements will be used.
Scrap types*	
Shredded	Fragmentized scrap processed by shredder. E40, SB 117, E46
Old scrap	E1 (thin), E3 (thick) SB 112 (mix of pieces / SB 11-12, and sheets / SB 31-38)
New scrap	E2 (thick), E8 (thin)
Turnings	E5, SB 21. (not target for PURESCRAP)
Cooling Scrap	Term used by the recycler. New scrap or production waste of well-known composition. Cut or shredded in small pieces.
Non-Ferrous (NF)	The reject from magnetic sorting

**Classes “E” are according to EU-27 Steel Scrap Specification [2] and “SB” are according to the Swedish Scrap book [3]*

3 Material requirements

For the recycling process, the separation and removal of unwanted material is important because scrap is sold with a specified maximum content of specified elements. For a proper charge planning within the steel plant, the maximum values are not enough and instead, the exact average chemical composition of the charge is what matters, which can enable a proper

charge planning. A desire from the steel plants is therefore that the PURESCRAP project should develop a method to accurately estimate the chemical composition of certain elements in a manageable batch of scrap. For the recycler, it is then of importance to understand the desired and useful scrap mixes in order to have an efficient scrap handling where unwanted material is removed and at the same time make sure that as much material as possible is made useful.

3.1 The elements

The elements Cu, Ni, Mo, and Sn are present as alloying elements in the steel and are identified as the most important elements for improved control of the scrap in order to enable a more efficient charge planning. These are therefore also the elements having target values for KPI's monitoring listed in deliverable D1.4. In addition to those elements, also Sb and As are of particular interest. SSAB and voestalpine have similar needs because they produce similar types of steel. The useful ranges and desired accuracies (precision in analysis) are given in Table 2 and Table 3.

Table 2. SSAB: desired elemental levels and precision

Element	Range (wt%)	Accuracy (wt%)
Cu	0.05 – 0.40	+/- 0.05
Sn	0.004 – 0.010	+/- 0,002
Mo	0.05 – 0.40	+/- 0.05
Ni	0.10 – 1.0	+/- 0.05
Sb	0.002 – 0.010	+/- 0.002
As	0.002 – 0.010	+/- 0.002

Table 3. VASD: desired elemental levels and precision *

Element	Range (wt%)	Accuracy (wt%)
Cu	0.05 – 0.15	+/- 0.05
Ni	0.10 – …	+/- 0.10
Mo	0.02 - …	+/- 0.02
Sn	0.03 – …	+/- 0.03

**according to DIN EN 13674*

The elements P, Cr, Mn, Si, C, Al are also important for the steel quality but are not considered as primary targets for the scrap analysis.

3.1.1 Other troublesome elements

Further undesired material to look out for is:

- Galvanized material can be a problem because the Zn boils at lower temperatures than steel and is then caught in the gas cleaning system.
- Pb from painted steel which may affect the health of exposed employees.
- Closed containers, which may cause explosions.

Also, radioactive material is avoided by standard radioactive controls of oncoming and outgoing material from the recycling plant.

3.2 Batch of sorted material

The material will be delivered from the recycling plant to the steel maker in pre-sorted batches. Each batch will be used in its entirety for one charge, but several batches may be combined. During the project, there will be trials both, using an induction furnace in the experimental facilities of VASD to simulate an EAF operation, and also on industrial scale using BOF at SSAB.

3.2.1 Melt trials in induction furnace

For trials in experimental furnace of VASD, each melt needs ca. 5 ton of material. The scrap is preferably delivered in Big Bags (size: about 800-1000 kg per Big Bag). The elemental composition may be chosen freely according to Table 3 and depending on the available material.

For the experimental furnace, the material needs to be maximum 0.3 m and sharp edges needs to be avoided for health reasons and potential damages to the furnace. Shredded scrap with shape similar to E40 is preferable. Galvanized and painted material needs to be avoided. In the event of excessive smoke due to such material, it may be necessary to stop the trials.

3.2.2 Validation in BOF

The scrap batches delivered to SSAB will be melted in the BOF together with hot metal of known composition. Based on chemical composition of the raw steel produced, it is possible to determine the "actual" chemical composition (Cu, Sn, Mo, Ni, Sn, As) in the scrap batch. This will make it possible to validate the chemical analysis received from work done this project. Batch sizes of 20 (+/- 5) ton enable validation of the average composition through melt tests in BOF.

A total number of 12 batches has been planned. There should be significant difference in the chemical compositions of the different batches (determined by the equipment developed in this project) delivered to SSAB such that the analysis can be properly verified. Suggested variation is given in Table 4, in agreement with the range and accuracies given in Table 2.

Table 4. Example of variations between different batches for SSAB

Element	Range (wt%)
Cu	0.05 – 0.10 – 0.15 – 0.20 – 0.25
Ni	0.05 – 0.15 – 0.25 (max 1)
Mo	0.05 – 0.25 – 0.45
Sn	0.005 – 0.008 – 0.010

Each scrap type should follow the size recommendations as specified in the Swedish Scrap book (Skrotboken). [3] Scrap types of particular interest are:

- Fragmented scrap (E40/ SB117)
- Old scrap (E1/E3, SB11/12)

The size restrictions are given in Table 5.

Table 5. Size restrictions for validation in BOF.

Crap class	Thickness	Max dimensions	Weight
SB 11	> 3 mm	1500 x 1500 x 500 mm	< 1 ton /piece
SB 30	< 3 mm	2000 x 750 x 750 mm	< 1 ton /piece
Fragmented		50 – 150 mm	1.0 ton/m^3

3.2.3 Future use in EAF

For future use when the charge planning of EAF should be done based on the material, the average composition of batches of 20 ton is useful. If the batch size is larger (1000 – 5000 ton), also the standard deviation in addition to the average composition is needed.

4 Material handling at the recycling plant

Material is today treated by shredder or shear. In both cases, the best opportunity for an improved material sorting is through better treating the input material. This can be done if there is a continuous analysis of the output material as foreseen by the PURESCRAP sensor stations as depicted in Figure 1. Manageable sizes of the output material is from 10 to 300 ton. For the purpose of charge planning, the smaller sizes of 10 – 20 ton is preferable.

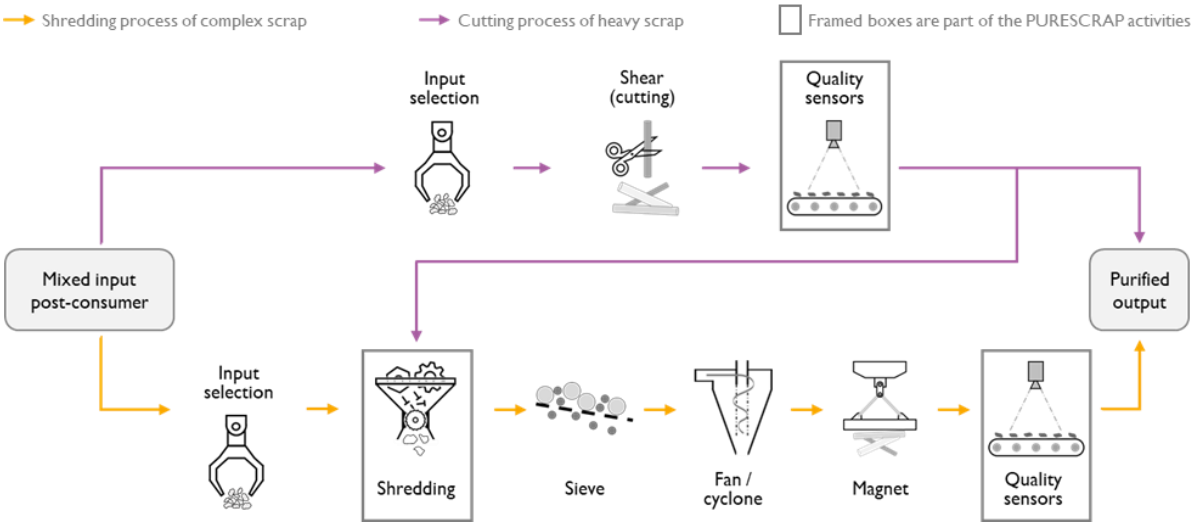

Figure 1.Schematic sketch of the ferrous sorting at the recycling plant.

4.1 Sorting in the shredder plant

Complex scrap, which is composed of several parts that need to be separated, are treated by the shredder. The scrap is first fragmentised in desired sizes, typically 50 – 150 mm according to the specified scrap qualities. The light fraction is removed by fans and the non-magnetic

parts are removed as the rejected fraction from magnetic sorting. The non-magnetic is sent to further treatment to separate the different metals (e.g., brass, copper, aluminium, magnesium, zinc, etc..). Also, some magnetic steel is part of the non-magnetic fraction but is not considered as a primary source for PURESCRAP project. Hand picking is used as a final sorting step in the ferrous sorting to clean the scrap from e.g., Cu (such as wire bundles called “meatballs”). The resulting material is sold as a shredded scrap.

The content for the E40 class is total Cu content <0.25 wt.% and total Sn content < 0.02 wt.%. The quality control is done through weekly tests of density and sampling for control of Cu pieces and other unwanted material.

4.2 Treatment of the heavy scrap with the shear

The simple scrap, which does not need to be separated is simply compressed and cut in appropriate sizes by the shear. There are many different scrap classes depending on the origin and composition of the scrap.

4.3 Batch production

At the end of the sorting facility for both the shredder unit and shear, a belt conveyor creates the piles of shredded scrap. This conveyor has with the possibility of differentiating the piles according to the algorithms that will identify the quality of the scrap and it could be used to prepare batches, that would be characterized according to the average value of analysis (from integrated sensors and visual systems) within the timeframe.

Reference

[1] PURESCRAP, GRANT AGREEMENT - NUMBER 101092168, Final Version 2022

[2] EU-27 Steel Scrap Specification, European Ferrous Recovery and Recycling Branch, May 2007

[3] Skrotboken 2020. The Swedish Scrap Book is distributed by JBF (AB Järnbruksförnödenheter) and available on https://jbfab.com/en

[4] Scrap Specifications Circular 2022, Institute of Scrap Recycling Industries, http://www.scrap2.org/specs/

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