Retrofitting Equipment for Efficient Use of Variable Feedstock in Metal Making Processes - REVaMP

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Charge mix optimization implemented in steel plants

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Dissemination level

PU   public   ☒

CO   Confidential, only for members of the consortium (incl. the Commission Services)   ☐

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1. About REVaMP

The main objective of the project "Retrofitting Equipment for Efficient Use of Variable Feedstock in Metal Making Processes" (REVaMP) is to develop, adapt and apply novel retrofitting technologies to cope with the increasing variability and to ensure an efficient use of the feedstock in terms of materials and energy.

For this purpose, existing metal production plants shall be retrofitted with appropriate sensors for scrap analysis and furnace operation. Furthermore, the selection of the optimal feedstock in terms of material and energy efficiency shall be improved by application of appropriate process control and decision support tools. Also, a solid scrap preheating system operated with waste derived fuel shall increase the energy efficiency of the melting processes. To monitor and control the process behaviour in an optimal way, model-based software tools will be developed and applied.

The retrofitting solutions will be exemplarily demonstrated within three different use cases from the metal making industry, namely electric and oxygen steelmaking, aluminium refining and lead recycling. The performance of the different technologies will be assessed, and the benefits will be evaluated in terms of economic and ecological effects, as well as cross-sectorial applicability in other process industries.

2. Introduction and Summary

This deliverable D 5.1, "Charge mix optimization implemented in steel plants", is included in the work package WP 5 "Demonstration of retrofitting solutions in Steelmaking use case" of the project.

This report presents a description of the implementation of the decision support tools for characterizing steel scrap and determining the optimal charge material mix, which have been developed in WP 4, in the steelmaking use cases:

- Stand-alone software for SID with connection to inventory data and production planning functionality for single heats and heat sequences
- Stand-alone software for AMB for single heats

3. Optimal charge mix model for steelmaking use cases (BFI)

For the **steelmaking use cases** at SID and AMB, a decision support system for determining the optimal charge material mix in terms of product quality and costs was developed within Work Package 4. It uses up to date information regarding the properties (yield, composition, meltdown energy demand, etc.) of the different feedstock materials as input, which has been determined with the help of statistical models developed in Task 2.1. The working principles of the software with optimization targets and user interface have been described in detail in Deliverable 4.3. A scheme of the considered processes is shown in Figure 1 for the two steelmaking use cases.
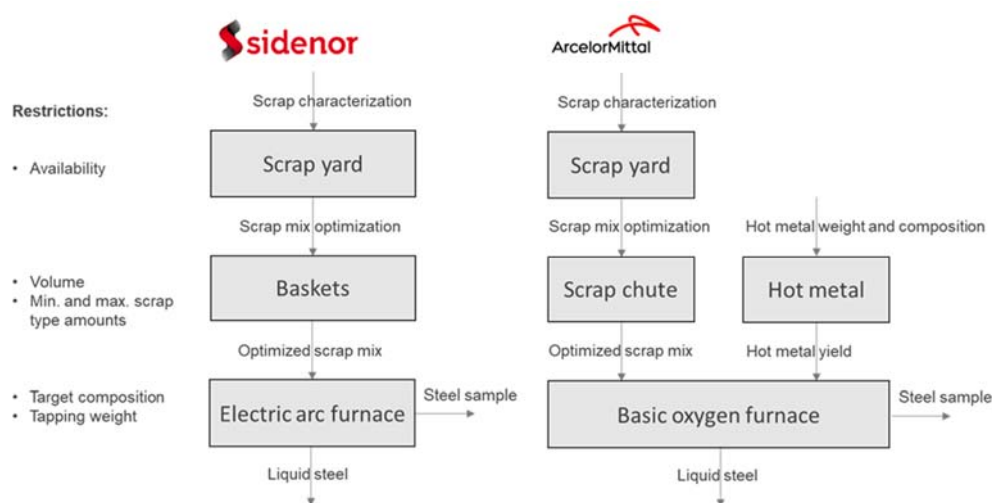

Figure 1: Process workflow for the steelmaking use cases at SID and AMB.

3.1. Software implementation at steel use cases

For each steel grade to be produced, the developed tool determines the optimal charge mix, consisting of different scrap types, hot metal (for AMB Basic Oxygen Furnace (BOF) process) and alternative iron sources. It considers the purchase costs of the materials, but also the costs for electrical and chemical energy sources to melt down the materials and their availability, either on the plant internal scrap yard or on the market.

The software has been developed in Matlab using the 'Optimization Toolbox' and the 'Matlab Compiler' for deployment as stand-alone application. The following installation guide has been provided for the two steelmaking use cases:

1. Unzip the archive by using the provided password.
2. Run SMO.exe on a 64 bit windows system. It will install the MatLab current runtime, which is free, and the scrap mix optimisation tool.
3. Copy the **new** file SMO.exe (from the installation folder) into the folder with all the Excel files (application data) from the zip-archive.
4. Run SMO.exe (Excel has to be installed on the computer)

5. New process data are provided via Analysis.xls, HotMetal.xls, TapWeight.xls and ScrapInput.xls
6. The steel quality related information can be entered in quality.xls

3.2. Decision Support System implementation

The decision support system for the steelmaking use cases at SID and AMB is programmed in Matlab using the Matlab GUI designer for the graphical user interface (GUI) and the optimization toolbox for the regression and optimization calculations. Data is acquired via Excel sheets in the first version of the developed tool, but interfaces to databases and other existing tools will be considered as the project progresses (WP5).

The different steps (see Deliverable 4.3) required for the scrap mix optimization can be accessed through the main menu of the developed software and are described in more detail in the following sub-sections using the SID use case as an example.

3.2.1. Main menu

The main menu (see Figure 2) is used to manage the different steps required for the scrap mix optimization. Scrap properties are determined and updated via the menus "metallic yield", "effective element yield" and "scrap types costs". The steel qualities to be produced are managed via the menu "quality management", settings for data filtering for example can be performed in the "settings" menu and the scrap mix optimization for single and consecutive heats is done in the "single heat" and "heat sequence" menus. Note that the heat sequence menu is not available for the AMB use case as the hot metal analysis and weight is not available for scrap mix optimization of consecutive heats.
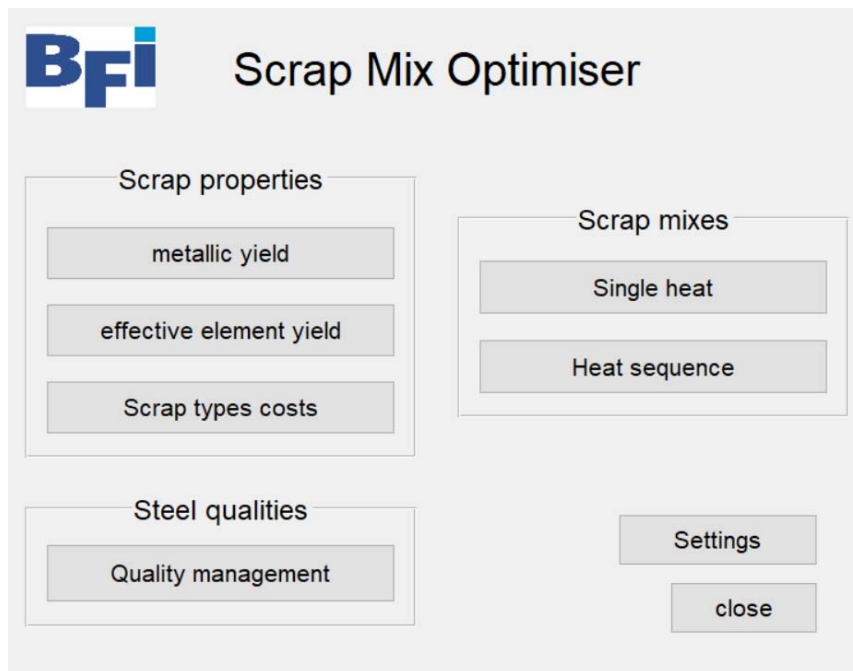
Figure 2: Main menu of Scrap Mix Optimizer for SID use case.

3.2.2. Scrap characterization

The main function of the "metallic yield" and "effective element yield" menu is to determine and update these scrap properties by applying the scrap characterization methods that were developed in Task 2.1. Figure 3 shows an example for the metallic yield regression using 6020 heats produced at Sidenor. Information that is shown includes the different scrap types with metallic yield, the number of usage of each scrap type, average weight fraction in the scrap mix and some statistical information about the regression accuracy as well as a plot for measured and calculated tap weight, which is used as target for the regression calculation.
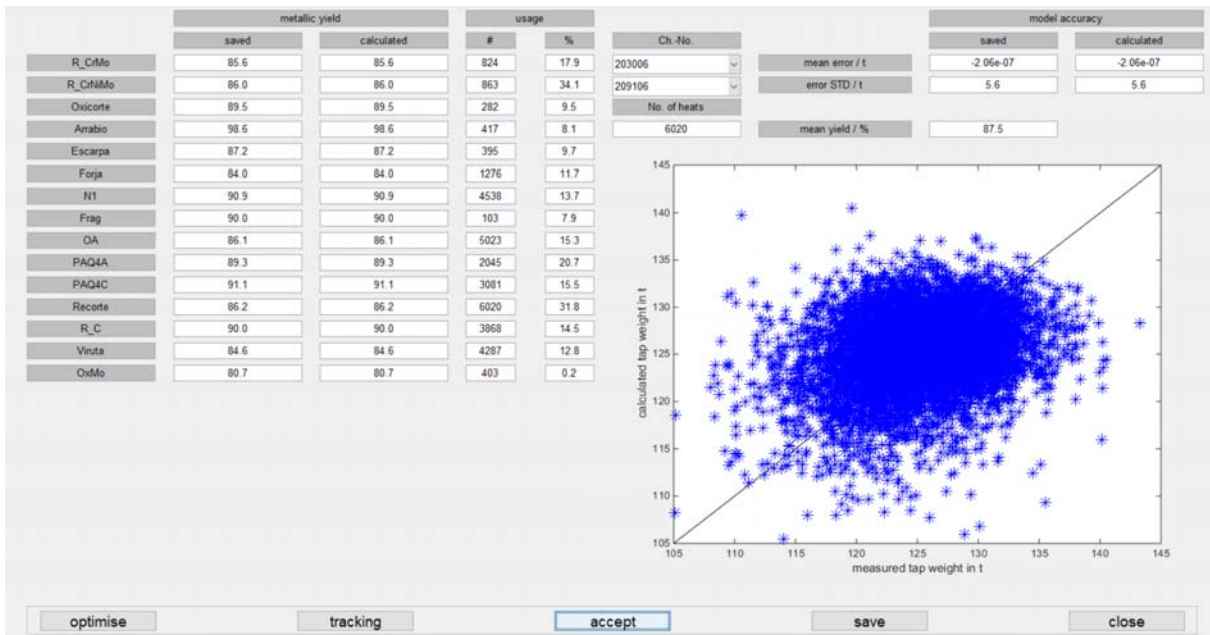
Figure 3: Metallic yield menu of Scrap Mix Optimizer for SID use case.

The "effective element yield" menu follows the same principal and is shown in Figure 4 using the element copper as an example. In this case, the steel analyses are used as targets for the regression, and calculated against measured mass fractions of the selected element are plotted in the diagram. A dropdown menu allows to cycle between the different considered elements.
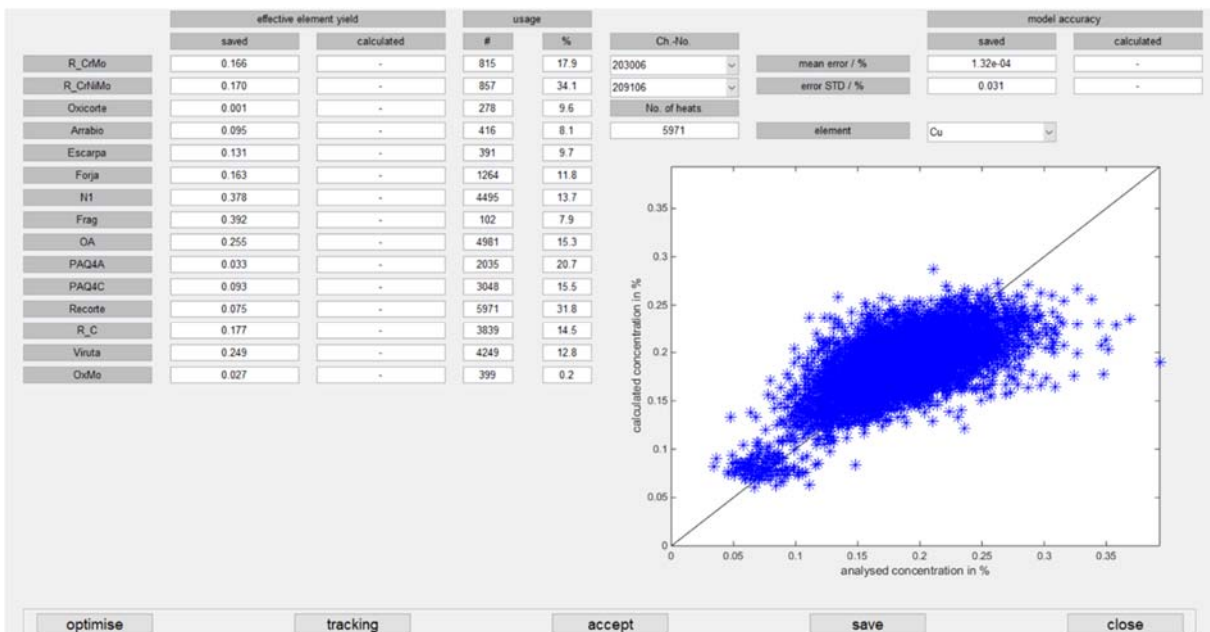

Figure 4: Effective element yield menu of Scrap Mix Optimizer for SID use case, exemplified for copper

3.2.3. Scrap and quality management

Boundary conditions, restrictions and other scrap information necessary for the scrap mix optimization can be managed via the "scrap types costs" menu (see Figure 5). The depicted information includes the different scrap types and their availability, min. and max. values for charging, density, purchase and meltdown costs. The composition button at the bottom opens an additional window with the current metallic yield and element yield properties of each scrap type.

	availability / t	density / m³	basket 1 / %	part of scrap mix minimum / %	maximum / %	Restriction 1	costs purchase / t	process / t	el. energy
PAQ4A	50000	1.5	20	0	100	○	2.1176	0.19649	0.19649
Recorte	50000	1.5	20	30	100	○	1.8235	0.18865	0.18865
Oxicorte	50000	1.5	20	0	100	○	1.8529	0.2	0.2
PAQ4C	50000	1.5	20	0	100	○	2.0588	0.19306	0.19306
Bobinas	0	1.5	20	0	30	○	1.6471	0.2	0.2
Forja	50000	1.5	20	0	50	○	1.6471	0.15778	0.15778
OA	50000	1.5	20	0	100	○	1.6765	0.17003	0.17003
N1	50000	1.5	20	0	100	○	1.5882	0.14504	0.14504
Frag	50000	1.5	20	0	50	○	1.6882	0.2	0.2
Escarpa	50000	1.5	20	0	40	○	1	0.24353	0.24353
R_CrMo	50000	1.5	20	0	50	○	1.0824	0.20335	0.20335
R_CrNiMo	50000	1.5	20	0	50	○	1.0824	0.20629	0.20629
R_C	50000	1.5	20	0	50	○	1.0824	0.19943	0.19943
Viruta	50000	1.5	20	0	30	○	1.6282	0.23128	0.23128

Min / % [0] [100] Max / %

composition   save   close

Figure 5: Scrap types cost menu of Scrap Mix Optimizer for SID use case.

The quality management menu is built in a simpler way and includes mainly information on the different steel qualities that are produced with the respective min. and max. values for the target steel composition.

3.2.4. Scrap mix optimization

Once all the scrap and quality specific information is provided and generated, the scrap mix optimization can be performed using the single heat menu for a single heat and the heat sequence menu for a sequence of scheduled heats (SID use case only). An exemplary result of an optimization for a single heat for the SID use case is depicted in Figure 6 with the optimized scrap mix composition shown on the left side as well as its distribution to the two scrap baskets for charging to the furnace. In the middle column the target tap weight, the selected steel quality, basket filling grades, total scrap volume and the relative costs are visible. On the right side, the predicted steel composition is displayed together with the registered maximum values for the selected steel quality, which also takes a safety margin into account. Red fields indicate that the maximum value for an element will be achieved with the selected scrap mix.

Figure 6: Single heat menu of Scrap Mix Optimizer for SID use case.

The heat sequence menu (Figure 7) further allows to schedule multiple steel qualities to be produced. This optimization problem puts more emphasis on the scrap availability and efficient use of the resources at hand, and also the fact that the remaining part of the melt in the furnace (hot heel) of the previous heat influences the analysis of the next heat. This is important when in a sequence of heats a significant change in the target analysis of the produced steel grade occurs. By cycling through the scheduled steel qualities in the menu, the suggested scrap mix for every heat can be inspected.

Figure 7: Heat sequence menu of Scrap Mix Optimizer for SID use case.

3.3. Charge mix optimization at Sidenor

The charge mix optimization at Sidenor was deployed, and during the testing phase a bug was reported that prevented the supply of new data. The bug was fixed and proper operation of the software was verified at BFI with new data supplied by Sidenor.

In the next step, the adapted software will be deployed at Sidenor again and tested for charge mix optimization of various steel grades. Feedback for improvement will be provided to BFI. An online connection to the planned inventory system will be established once this system is available.

3.4. Charge mix optimization at AMB
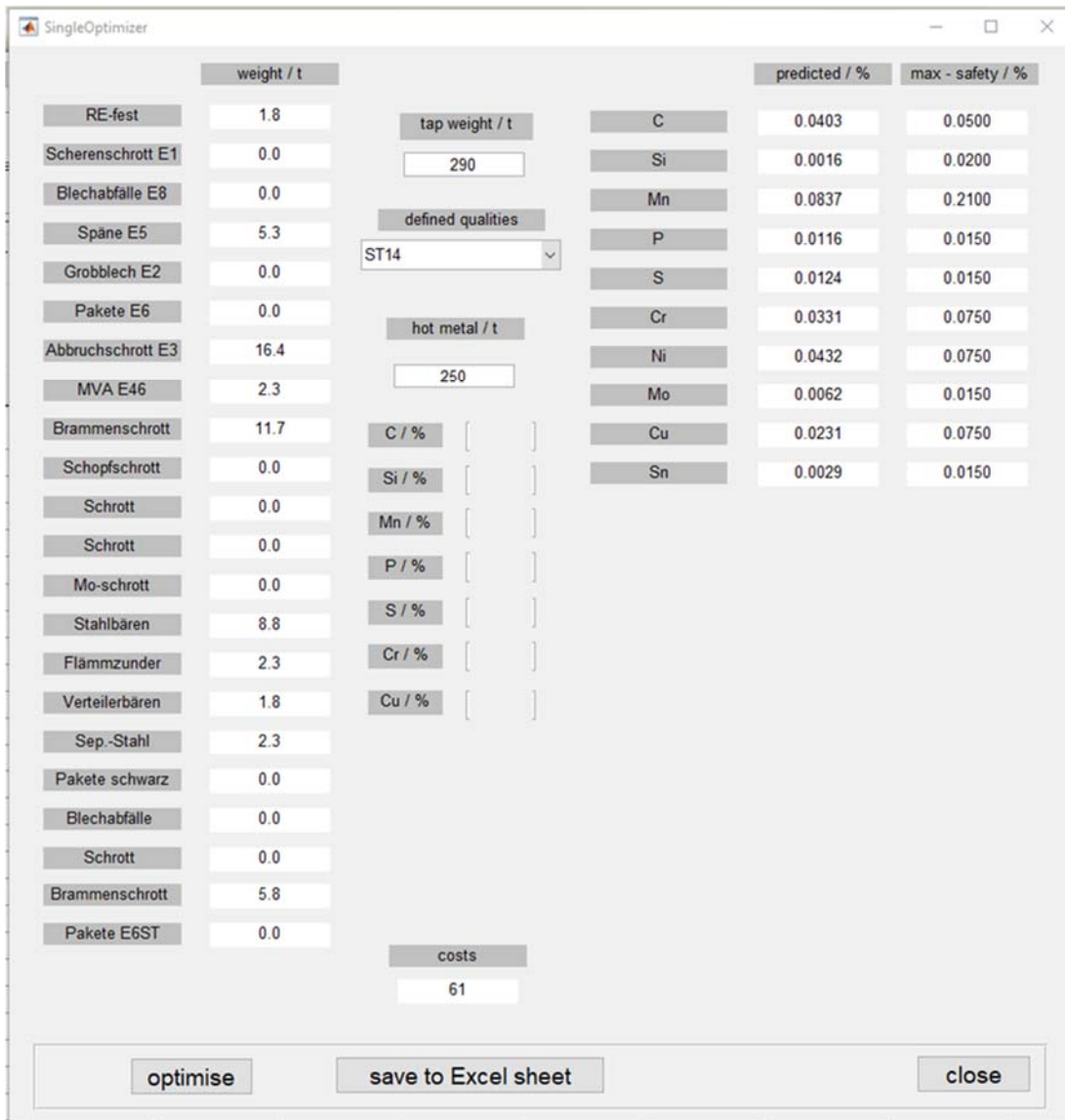
The charge mix optimization software has been installed at AMB and the operability was verified with new data similar to the use case at Sidenor. AMB prepared a protocol on testing the software to provide valuable feedback for improvements. The software was tested with default settings and adapted settings for a typical production scenario, leading to the following optimal scrap mixes with default (Figure 8) and adapted settings (Figure 9).

Figure 8: Scrap mix optimisation with default settings.

Figure 9: Scrap mix optimisation for typical scenario.

The scrap mix optimisation with default settings puts too much emphasis on recovering internal scrap types, which caused issues with quality related target values, but kept the costs very low. After adaptation of the scrap mix restrictions to a typical production scenario, the overall costs increased, but the predicted steel composition does not reach the maximum values.

During the testing phase, the following issues were identified:

- 'Save' button for scrap properties in menu 'Scrap Types Costs' missing

- Naming issues with long scrap names – User interface (UI) shows incomplete names

Figure 10: UI naming issues.

- Many different qualities in practice. Scrap mix restrictions should be assigned to critical elements instead of qualities.

- Element concentrations should be depicted in ppm and not %.

- Elements like C and P are controlled in the BOF process; therefore difficult to optimize without considering the operating practice
    - Integration of process model in scrap mix calculations
    - Coupling with hot metal ratio

- Depiction of scrap weight sum in UI

- Distribution of scrap mass to multiple scrap chutes

- Inconsistencies with applying changes to restrictions; changes are not immediately applied

This feedback will be considered, and adaptations implemented by BFI as WP5 progresses. As AMB is currently reworking its own scrap mix calculations, which are connected to other metallurgical process models, a better integrated deployment of the BFI software within a new framework will be considered and discussed with AMB. If this approach turns out to be unfeasible, the BFI software will be mainly used to provide values for comparison and validation of the AMB scrap mix calculations.

4. Conclusions

For the steelmaking use case at SID and AMB, a software was developed and deployed to calculate optimal scrap mixes, considering the determined scrap properties and restrictions of the processes. A connection to use case specific systems and databases will be considered once those systems are available. Furthermore, feedback from SID and AMB from the software testing phase will be considered and implemented as far as possible.