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

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Material flow analysis applied and validated for aluminium plant at Grupal Art

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Dissemination level

PU public ☒

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

Note: Since this report is public, no numerical values for the process parameters of the industrial partners have been included.

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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 6.5, “MFA applied and validated for Aluminium plant at GRU”, is included in work package 6 “Demonstration of retrofitting solutions in Aluminium use case” of the project.

Within this task, the Material Flow Analysis (MFA) for the aluminium use case shall be validated and updated if needed in order to accurately represent the current aluminium recycling process at Grupal Art. The MFA methodology is described in more detail in the previous Deliverable 2.5, in which the first version of the MFA models was created. Due to the iterative nature of the process, further evaluation is necessary and can still lead to changes and an improvement of the model.

3. MFA evaluation for aluminium use case

The MFA model created for the aluminium use case in Deliverable 2.5 aims to provide an accurate representation of the aluminium recycling process at Grupal Art. For this purpose, all relevant input and output flows for the most import process steps were identified and quantified with production data from the plant of Grupal Art. Additional information on the production processes and the MFA model are given in the reports on Deliverable 1.4 and Deliverable 2.5.

The goal in this deliverable is to further evaluate the model and verify that all relevant material and energy flows have been accounted for in the model. The amounts for each flow included in the model are also critically evaluated. For this purpose, the model is compared with other publicly available life cycle assessments as well as other literature data. If necessary, the results are discussed with the industrial partner and adaptations to the model are carried out. As this report is scheduled as public no specific numeric process data for the plant of Grupal Art is mentioned.

Current state of the model

The production system under review comprises the following processes: creation of a bed of liquid aluminium, screening of the aluminium chips, filling up of the furnace, refilling of the furnace. The analysis also covers all processes from the natural resources down to the creation of liquid aluminium alloys. Due to the applied cradle-to-gate approach, all processes after the melting furnace are not considered.

The flowchart below (figure 1) shows all analysed processes and their regarding input and output flows. These flowcharts with the defining system parameters were created in close collaboration with the industrial partner. It is important to point out, that the electric energy is not only used for the dross removal step, but rather represents an overall figure also used for various other equipment.

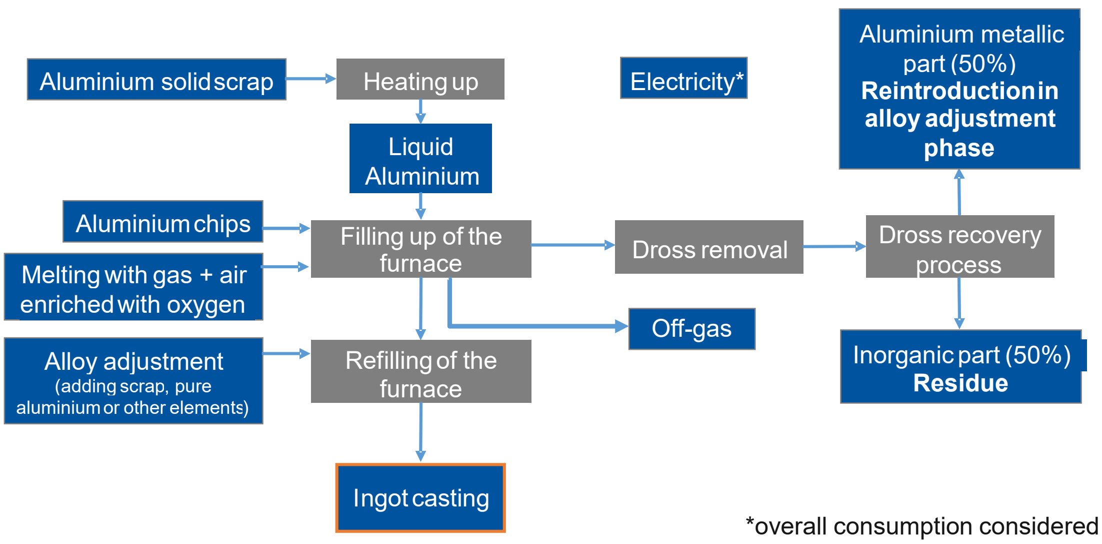

Figure 1 – Flowchart of the aluminium recycling process

The values for the created parameter list have been provided by Grupal Art to closely represent their process. The final list of all parameters and their corresponding values are implemented in the model.

The removal and reusage of the dross is a central part of the process. Half of the dross is being disposed as inorganic residue, the other half is being reintroduced into the furnace as part of the alloy adjustment. The electric energy in this model is being supplied by an average Spanish electricity mix from the ecoinvent database. The natural gas is once again sourced from Algeria. The produced CO_2-amount is given by the ecoinvent database for this process and the respective input of natural gas. All other input materials are provided by an international market modelled after the ecoinvent database. The quantity of alloying materials is currently modelled as a mix of 50% silicon and 50% zinc according to mean values from the ecoinvent database.

Evaluation and literature comparison

The evaluation of the model consists mainly of two parts: evaluating the completeness of the considered flows and evaluating the numerical values of the individual flows. Both are necessary to rule out grave mistakes in the data collection phase.

The numerical values of the flows were compared with data from similar processes available in the literature. Due to this report being public, no explicit production figures or data are named. The data is nonetheless closely documented for confidential usage. First the process data available in the Best Available Techniques (BAT) Reference Document for the Non-Ferrous Metals Industries [1] is compared to the data used in the model. Specifically, the BAT data for rotary furnaces in secondary aluminium production is used for comparison, as this is the same furnace type and application used at Grupal Art. Here, the models process data regarding usage of natural gas, feedstock per hour, waste gas rate and waste gas components was found to be in line with the ranges mentioned in the BAT document.

LCAs of comparable applications from the literature are used to estimate the completeness of the input and output streams. This can be used to estimate whether important flows that have a major impact on the environmental assessment have been missed. First, Paraskevas et al [2], who describe an environmental assessment tool as a decision support tool for the aluminium recycling process, is used for this purpose. Here, the detailed and itemized LCA indicator values are listed for various alloys produced. The described process steps are very similar to the process of Grupal Art, and also the structure shows similarities with the created MFA model. Therefore, a comparison can be made based on the indicator results to assess the quality of the model for the Grupal Art process. It can be seen that the indicator values presented for the relevant processes are very similar to the values obtained for the Grupal Art process. The relationship between the individual process steps (filling, refining, etc.) was also evaluated in the same way. These results could also be used to validate assumptions about upstream processes in the model. For example, the input flow of the aluminium chip has shown to be the main contributor to the environmental evaluation. This is to be expected as it is the largest material flow by far. It could be confirmed through comparison with other LCA levels, that the assumption of this flow being covered completely from secondary sources is correct. Other LCAs from the secondary aluminium sector, such as Soo et al [3] or Gilstad and Hammervold [4], unfortunately either have a different calculation method or deal with other processes, which is why they cannot be used for a comparison.

However, Gilstad and Hammervold [4] demonstrate the influence of the alloy produced on the environmental assessment in their LCA. Therefore, the modeling of the alloying elements used and the alloying adjustment for the GrupalArt process was investigated in more detail.

In the table below (figure 2), various alloying materials are listed on the left. These materials are used in different quantities for the alloy adjustment step (see figure 1) to adjust the alloy to be produced. The materials have high contents of alloying elements (e.g. Si, Cu, Ti, Mg...) to adjust the content of the respective element in the alloy. For this comparative analysis it was assumed that the material flow of the alloying elements was completely covered by the respective material A1, A2 etc. in each case.

	GWP	FDP	FEP	HTP	MDP	NLTP	ODP	POFP	TAP	WDP
A1	93,65%	98,94%	82,56%	95,31%	77,59%	96,88%	98,10%	98,67%	96,43%	95,95%
A2	93,66%	98,94%	82,57%	95,32%	77,60%	96,89%	98,10%	98,67%	96,43%	95,95%
A2_2	93,66%	98,96%	82,54%	95,33%	77,52%	96,92%	98,12%	98,68%	96,44%	95,95%
A3	93,64%	98,90%	82,57%	95,33%	77,63%	96,89%	98,07%	98,65%	96,40%	95,95%
A4	98,76%	103,81%	89,84%	100,95%	78,36%	104,64%	104,45%	102,16%	100,20%	99,27%
A5	97,62%	102,47%	121,51%	101,18%	82,87%	103,49%	102,85%	106,42%	131,35%	101,02%
A6	97,11%	101,80%	87,88%	99,81%	78,15%	102,33%	101,84%	100,14%	98,76%	97,69%
A7	97,59%	102,35%	88,46%	100,20%	78,20%	102,84%	102,41%	100,53%	99,18%	97,90%
A8	93,04%	97,19%	83,04%	96,83%	79,07%	98,07%	97,00%	97,43%	95,20%	95,76%
A9	93,12%	97,59%	185,30%	115,10%	136,57%	99,40%	97,71%	100,14%	100,25%	98,32%
A10	94,74%	98,99%	84,58%	99,68%	277,70%	99,24%	98,01%	100,33%	97,61%	97,18%
A11	94,28%	98,83%	157,97%	110,86%	121,32%	100,27%	98,92%	100,21%	99,89%	98,17%
A12	129,02%	100,66%	85,66%	97,11%	78,69%	101,11%	102,23%	99,02%	95,99%	115,15%
A13	130,14%	100,59%	85,53%	96,97%	78,81%	101,04%	102,22%	98,96%	95,87%	115,76%
Avg.	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%

Figure 2 – Influence of different alloying materials on the environmental assessment

It can be seen that the different alloying materials sometimes have a significant influence on the environmental evaluation. Materials containing particularly high amounts of copper and manganese (A9 - A11) result in strong deviations from the average. It is therefore important that the adopted alloy composition corresponds to the production practice at Grupal Art.

Based on last year's production figures, it was decided in cooperation with Grupal Art which alloying elements are the most relevant and occur in the majority of alloys produced. Si is by far the most important alloying element used in the largest quantities. Although no change is expected for this material stream as a result of the retrofit solutions, omitting this stream would greatly distort the model. The relative changes of other streams could then no longer be evaluated appropriately. In addition to Si, Cu, Ti and Ni are the most relevant alloying elements for Grupal Art products. Others, such as Mg, are hardly used because the corresponding alloys are produced very rarely. Therefore, even if elements such as Mg have a great influence, they can be neglected. For the alloying elements Si, Cu, Ti and Ni, used material quantities were determined in cooperation with Grupal Art. These now form the assumed alloy of the model, which is also considered after installation of the retrofit solutions. The material flows of natural gas, oxygen and electric energy were also adjusted. Within the framework of other work packages, it was possible to carry out more precise investigations which provided more accurate figures for these flows. The quantities of these flows used are now also consistent with observations in other work packages.

4. Summary

In this Deliverable, the material flow analysis created for the aluminium recycling use case of Grupal Art has been evaluated. The model created was developed in close cooperation with the industrial partner and compared with other LCAs of secondary aluminium production processes for verification. The modelling of the alloying materials in the model and the inputs of natural gas, oxygen and electric energy have been updated. The figures now accurately represent the production praxis at Grupal Art. Errors in the modelling and calculation parts could also be ruled out thanks to the comparison with other LCAs from this sector. The model for the base line process can therefore be considered as final.

The created model will be used as a baseline in the further course of the project. The state of the processes under consideration after installation of the retrofitting solutions will also be recorded and presented as a second version of the model. The results of these secondary models can then be compared with their corresponding baseline created here. This will ensure an assessment of the impact of the new technologies according to the standard practice of Material Flow Analysis and Life Cycle Assessment.

5. List of Abbreviations

LCA	Life Cycle Analysis / Assessment
MFA	Material Flow Analysis
GWP	Global Warming Potential
FDP	Fossil Depletion Potential
FEP	Freshwater Eutrophication Potential
HTP	Human Toxicity Potential
MDP	Metal Depletion Potential
NLTP	Natural Land Transformation Potential
ODP	Ozone Depletion Potential
POFP	Photochemical Oxidant Formation Potential
TAP	Terrestrial Acidification Potential
WDP	Water Depletion Potential
BFI	VDEh Betriebsforschungsinstitut GmbH

EUT	Eurecat Centre Tecnològic
GRU	Grupal Art
RWTH AACHEN	Rheinisch-Westfälische Technische Hochschule Aachen

6. References

[1] Cusano, G. et al.: “Best Available Techniques (BAT) Reference Document for the Non-Ferrous Metals Industries”, European Commission Industrial missions Directive 2010/75/EU IPPC, JRC Science for policy report (2017)

[2] Paraskevas, D. et al.: “Environmental modelling of aluminium recycling: a Life Cycle Assessment tool for sustainable metal management”, Journal of Cleaner production, accepted article (2014)

[3] Soo, V. K. et al.: “Economic and Environmental Evaluation of Aluminium Recycling based on a Belgian Case Study”, Procedia Manufacturing, Vol. 33, pp. 639-646 (2019)

[4] Gilstad, G. Hammervold, J.: “Economic and Environmental Evaluation of Aluminium Recycling based on a Belgian Case Study”, Procedia Manufacturing, Vol. 33, pp. 639-646 (2019)