REVaMP Deliverable 1.4

Definition of economic, technological and regulatory challenges and goal and scope of the Life Cycle Analysis in Metal Making Processes - REVaMP

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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 D1.4, “Economic, technological and regulatory challenges, scope of LCA”, is included in the work package WP 1 “Analysis of variable feedstock to identify challenges for retrofitting” of the project.

Within this task, the issues to anticipate challenges in market, technology and regulatory spheres shall be identified for the steelmaking, aluminium refinery and lead making sectors. The industrial partners tackled several issues by estimating current developments and stating how they would have to react to them. These issues vary greatly from sector to sector and are therefore determined individually for each industry. The topics dealt with are described in more detail in Chapter 3.

Furthermore, the first of the four phases of a Life Cycle Analysis (LCA) was carried out in this report. The four phases that form a LCA are shown in Figure 1. They are defined by the European standards ISO 14040 and 14044. LCA can be used for a wide range of applications. Therefore, the execution can vary significantly and these frameworks must be defined in advance. This definition can also change during the course of the LCA due to its iterative nature, which must be documented in detail.

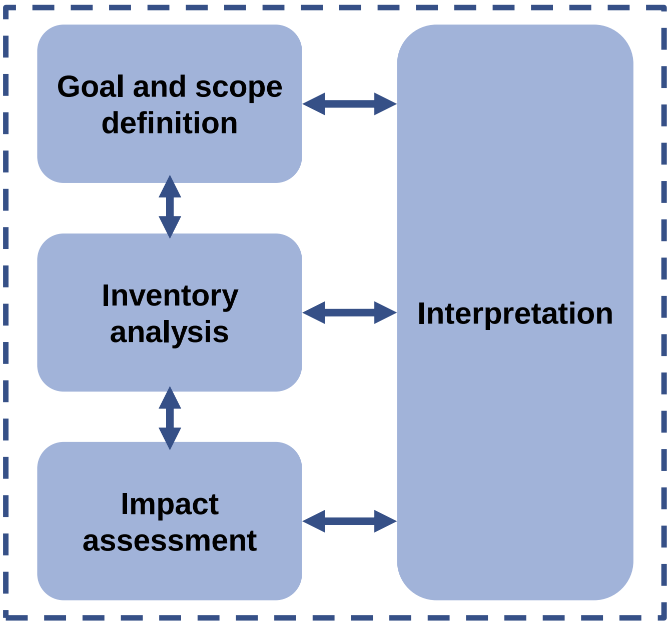

Figure 1 – Basic structure of an LCA according to ISO 14040 and 14044

The goal and scope definition is conducted for the different use cases in Steelmaking, Aluminium production and Lead production separately. The questions specified by the standards, which must be answered to define the goal and scope of an LCA, are examined in more detail in the respective chapters.

3. Economic, technological, and regulatory challenges

In order to identify the anticipated challenges in the market, technology and regulatory spheres, questionnaires have been developed by RWTH Aachen University and sent to the contributing partners within the steelmaking, aluminium refinery and lead making sectors. The partners gave answers regarding their estimation of the following issues within their corresponding sector:

- Increasing or arising of new alloying and tramp elements in scrap
- Charge material & energy market prices
- Targets to increase the yield of melting and refining processes and / or to reduce energy consumption
- Increasingly restrictive waste & emissions legislative targets
- Circular economy EU policies and critical raw materials list
- Higher customer demands on quality of metal products (aluminium ingots, steel bars or sheets, lead)

Increasing or arising of new alloying and tramp elements in scrap

Regarding the aluminium industry, the deployed scrap is becoming richer in magnesium, and the amount of other impurities and tramp elements is also increasing with time. In order to control the level of these tramp elements a strategy could be to diversify the used scrap and try to mix different kinds of scraps. With a lot of post-consumption aluminium an increase or arising of new alloying and tramp elements in scrap is not expected as much. If, on the other hand, there is a much higher increase in new alloying or tramp elements, this could be overcome by using a higher concentration of post-production aluminium or by increasing the efforts in the refining process, with the use of the necessary additions (Cu, Si, Mg, Mn, Ca, Ti, Fe and Zn).

For the steel industry, an increase in tramp elements is generally expected. This results from some elements like Cu, which can't be removed even by multiple steel processing steps. The optimization of the scrap mix could be one way to deal with this development. For this reason, a more precise knowledge of the scrap composition would be essential.

The lead industry has to deal with similar problems, as Lithium and Cd-Ni batteries can be found in the scrap metal if the segregation at the collection point was not correct. Therefore, an exact scrap analysis is also very important.

Charge material & energy market prices

The price of natural gas has highly decreased in the last few months due to Coronavirus Crisis, and predictions about its development in the future are very difficult. The aluminium industry is highly dependent on this development, as an increase in the price of energy would affect the selling price of the produced secondary aluminium. Material costs on the other hand can be compensated more easily but are also affected by the energy costs of its production. Purchasing more heterogeneous scrap is a way to deal with fluctuating material costs, as this leads to a better control of the scrap composition.

The change of scrap prices in the steel industry is dependent on the market and according to the industrial partners mostly unpredictable for now. The companies have to be flexible in order to deal with different scrap types. Analysing the scrap beforehand would lead to an advantage in this regard.

Concerning the lead industry, the price of lead in the market is defined by the London Metal Exchange (LME). Forecasts are also difficult in this case. Low prices, although detrimental to the production margin, are advantageous for battery factories, which are often part of lead recycling companies.

Targets to increase the yield of melting and refining processes and / or reduce to energy consumption

To improve the yield of the process, the pre-treatment of the aluminium scrap is one of the main actions. A cleaning treatment to remove the oil and coolant from the aluminium chips highly reduces the oxidation of the scrap and improves the yield. A detailed analysis of the scrap upon delivery could also contribute to the optimal preparation. Regarding energy consumption, especially the furnace set up has to be optimized.

In the steel industry, a high value is assigned to the optimal preparation of the scrap as well, which could be achieved by a detailed analysis upon delivery. The main targets in this context are increasing the productive capacity, better process management and increasing the profits obtained from each batch.

The main optimization measures in the lead industry also relate to the optimal preparation of the scrap and the ideal furnace set up. Some examples are the correct segregation of materials, adjustment of the mixture in the furnace, the optimal mix of fluxes and energy and the velocity of the extraction dust from the furnace

Increasingly restrictive waste & emissions legislative targets

Concerning the development of restrictive legal targets, the partners generally do not expect legal changes regarding the environmental policy in the near future. In general, a change in environmental legislation would lead to the acquisition of new equipment and an increase of process costs, i.e. the maintenance costs in the flue gas treatment facilities of the plant.

In the steel industry there are also no further restrictions on emissions expected by the industrial partners. A new regulation on slag was just issued in 2019, which also led to an increase in bulk composition and leaching analysis restrictions. The production of the hot metal leads to the most CO_2 emissions, so a further reduction is most likely to become necessary in the future to comply with the targets set by the European Green Deal, which aims for a climate neutral EU in 2050.

The industrial partners in the lead industry fulfil all current regulations. As the emissions are already very low at the moment, further regulations will probably not present a problem in the future.

Circular economy EU policies and critical raw materials list

The influence of the EU policies regarding a circular economy is seen as positive within the aluminium industry. This stems from the fact, that these policies increase the value of their products, as customers value recycled material as well, and not just the mechanical properties of the product. However, some produced alloys contain critical elements, which may be affected by future restrictions. This would have negative effects on the production, but the positive effects mentioned before are larger.

Regarding the steel industry, the policies influence the production as well. The partners expressed their commitment to fulfil all further restrictions issued by the EU commission.

The industrial partners from the lead industry do not currently experience any influence from these EU policies within their industry.

Higher customer demands on quality of metal products (aluminium ingots, steel bars or sheets, lead)

Within the aluminium industry, the exigence of the costumers is increasing in aluminium secondary alloys, as the demand for low-emission products rises. The number of elements they are requesting to have controlled is becoming larger and larger, demanding to control residual elements that years ago were not considered such as Bi, Li, P, Sb, Cr and others. Regarding the effect on the production process, the higher quality demand requires a higher control of all those elements in the initial scrap, being critical any piece of scrap with high content of each of these elements.

Customers in the steel industry have also expressed their demand of cleaner scrap mixes. This can be achieved by optimizing the scrap mix or by purchasing more expensive scrap. It is important to note that although customers want more precise information about the scrap mix used, this should not be reflected in a higher price of the end product. Therefore, the optimization of the scrap mix is the preferred option.

With regard to the processes of the lead industry, it is easier to adapt the recycling process to the needs of the customers. In particular for in-house customers, close coordination is necessary.

4. Goal and Scope of the LCA

In order to perform the following calculations, the goal and scope of the study have to be defined in the beginning. These definitions shall be consistent within the intended application and may change over the course of the LCA due to its iterative nature. In the following, the essential details of the Goal and Scope definition for the three use cases Sidenor (steel), Grupal Art (aluminium) and Exide (lead) are described. Differences or industry-specific characteristics are pointed out separately.

4.1. Goal definition

Definition of the target

The aim of the LCA studies is to compare the environmental impact of different process routes in the respective plants of the partners. The analyses are carried out for one plant per considered branch of the steel, aluminium and lead industry. For this purpose, the current state of the art is to be compared with an alternative use case in which the innovative aspects of REVaMP are implemented: installation of a scrap analysis sensor, comparison of different feedstocks, analysis and mapping of upstream processes, evaluation of recycling rates and other plant-specific applications of further optimisation tools. The associated emissions and their environmental effects will be investigated in this comparative study.

Intended application

The present LCA studies deal with the production of crude steel, secondary aluminium and lead through scrap recycling. The examined plants belong to the Spanish companies Sidenor (steel), Grupal Art (aluminium) and Exide (lead). The product systems are to be investigated using a cradle-to-gate approach. Therefore, the analyses are carried out up to the final raw product, which means that the melting process and all upstream processes are considered. For the steel use case this includes all relevant process steps from scrap yard to EAF tapping. The aluminium use case considers the process steps chips reception and handing, separation of iron particles, cleaning process and the melting to produce new ingots. And finally, the examination of the lead use case includes the following process steps: battery breaking and separation of the components, smelting and refining.

Reasons for execution

The LCA studies will be carried out to evaluate the use of the following retrofitting solutions:

- installation of a scrap analysis sensor
- comparison of different feedstocks
- analysis and mapping of upstream processes
- evaluation of recycling rates
- other plant-specific applications of further optimisation tools

This should improve the productivity and yield of the processes. While the focus of the main research work is on a purely technical evaluation, these studies will provide an ecological assessment.

Intended audience

The studies are part of an international research project. The LCA thus serve to inform the European Commission, the responsible research institutions, the participating industrial partners (especially their plant operators, technical team and R&D Department), their customers, stakeholders and shareholders as well as other interested groups from science, industry and politics.

Reporting of the results

Within the LCA studies, comparative statements will be made. The current state of the art processes will be compared with the processes after the retrofitting solutions like comparison of different feedstocks, analysis and mapping of upstream processes, evaluation of recycling rates, installation of a scrap analysis sensor and other plant-specific applications of further optimisation tools.

4.2. Scope Definition

Product systems

The product system under investigation for the **steelmaking use case** is a process step during the production in electric steelmaking: the melting process in an Electric Arc Furnace. The analysis also covers all processes from the natural and secondary resources down to the creation of liquid steel. This consideration of upstream processes is carried out accordingly for the other two use cases. The electric steelmaking process is depicted as a flow chart in Figure 2 below.

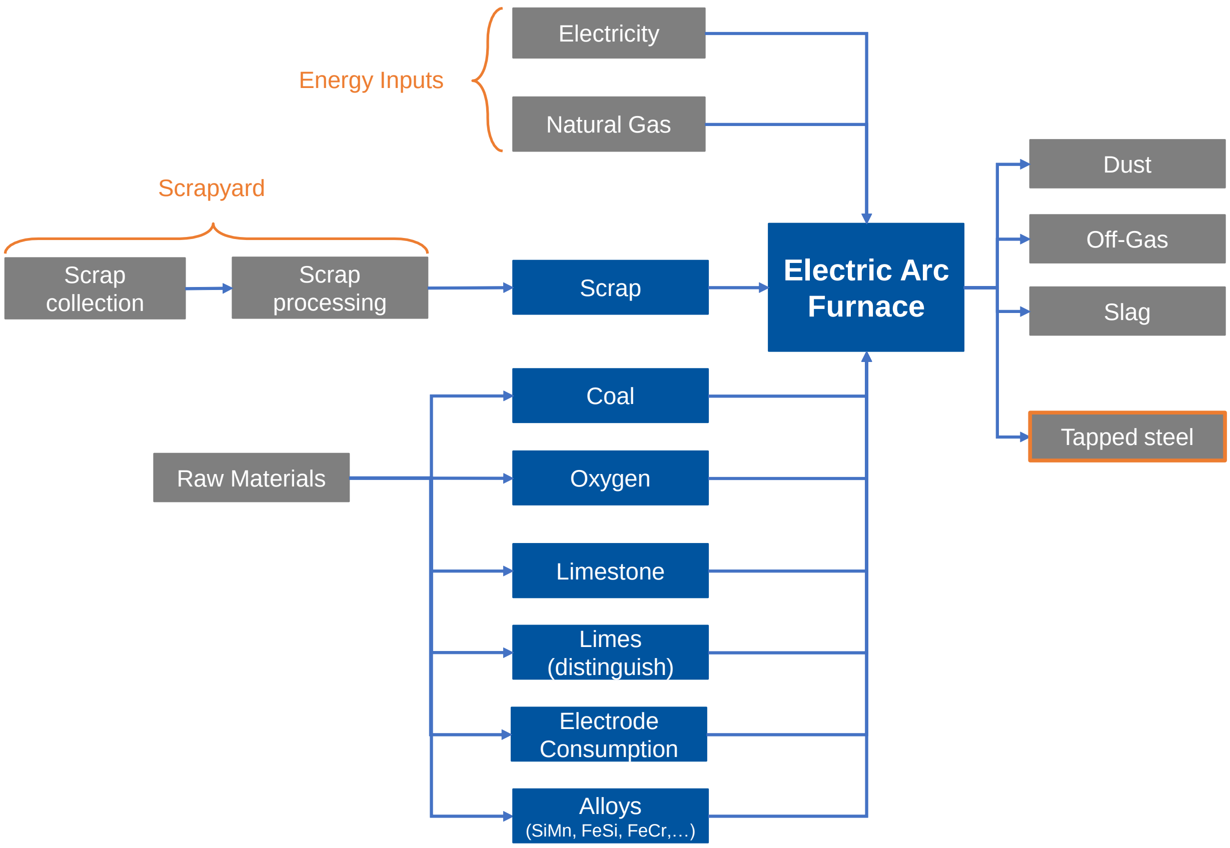

Figure 2 – Flowchart of the steel production through an electric arc furnace

The reviewed product system for the **aluminium use case** 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 aluminium process is depicted as a flow chart in Figure 3 below.

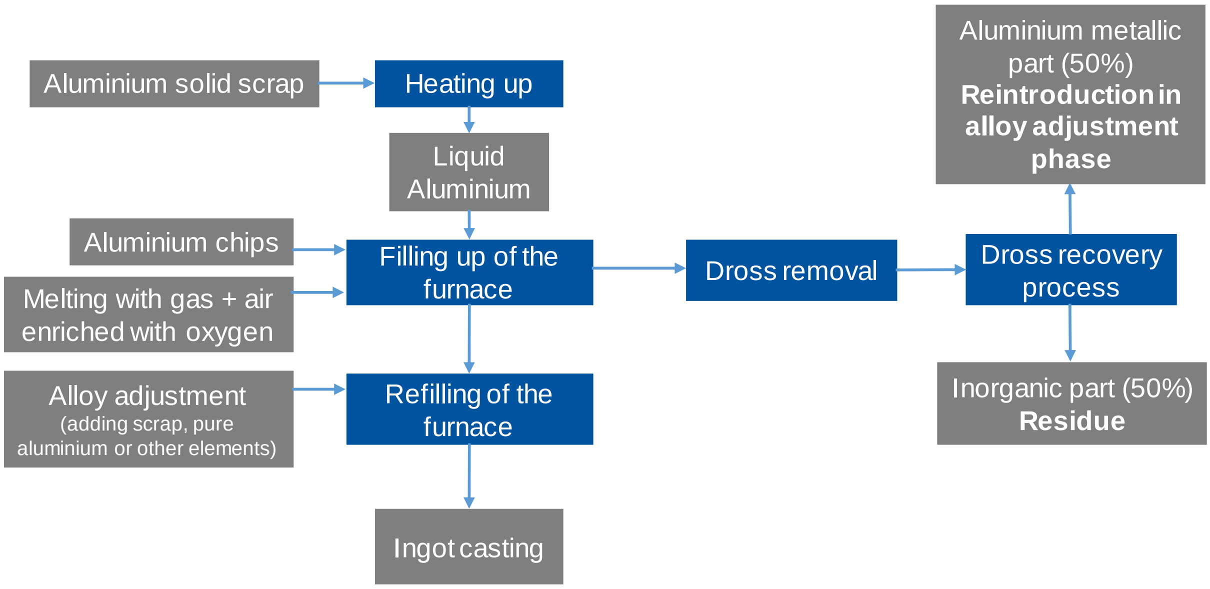

Figure 3 – Flowchart of the aluminium recycling process

The product system for the **lead production use case** includes the following processes: battery breaking and separation of the components, smelting and refining. Within the furnace process all relevant materials, process, energy, fluxes and dust extraction will be considered. The process is depicted as a flow chart in Figure 4 below.

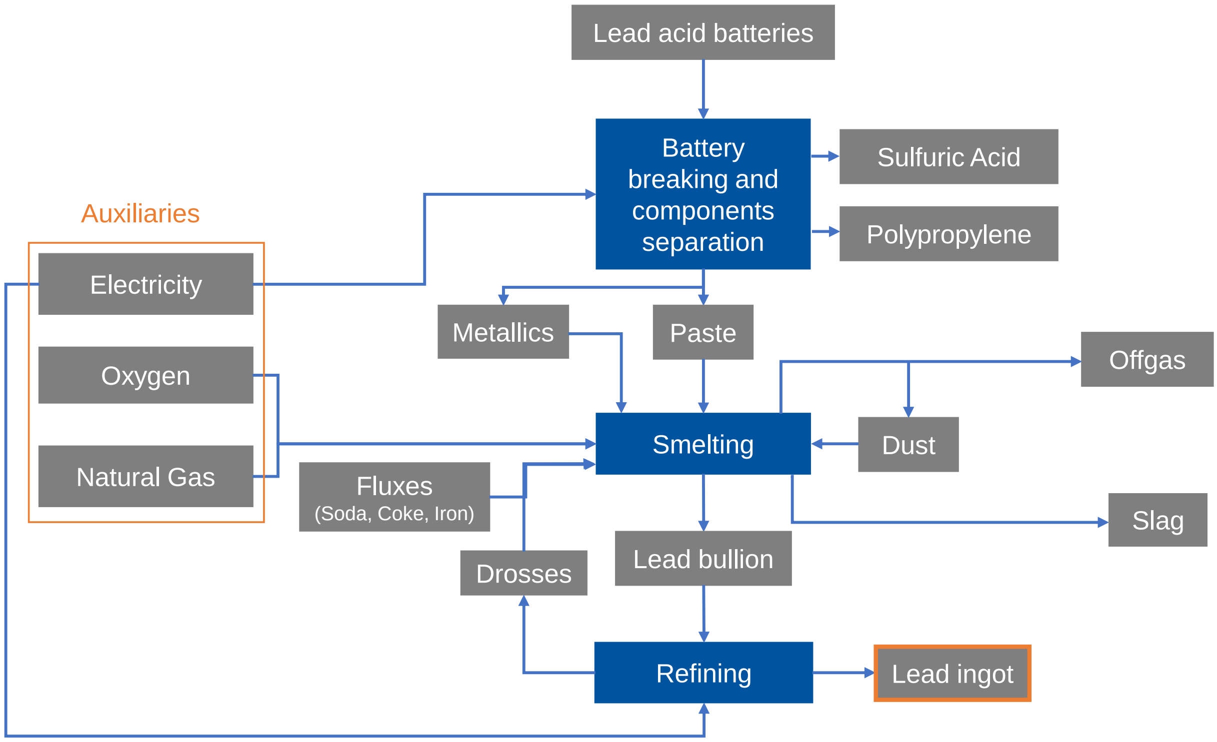

Figure 4 – Flowchart of the lead recycling process

Functions of the product system

The function of all product systems is the production of liquid steel / aluminium alloys / lead from scrap and additional resources.

Functional unit

The functional unit, on which all further calculations are based on, is one ton of tapped steel / aluminium alloys / lead, which are the final products of the analysed system.

System boundary

The boundaries of the plants represent the boundaries of the respective analysed models. As mentioned before, a cradle-to-gate approach is used. Therefore, the upstream production and supply of natural raw materials is also considered.

Allocation procedures

In the superficial product systems, no allocation procedures are used since no cyclical processes are taken into account and a holistic analysis (cradle-to-grave) is not taken. An exception to this is the aluminium use case. Due to the reuse of dross from the furnace in the alloy adjustment phase, an allocation method must be applied. This is necessary because the aluminium ingots are thus not the only products that are further processed. Therefore, all inputs and outputs have to be distributed accordingly between dross and aluminium ingots. Guidelines for allocations relating to primary products can be found in the database used (ecoinvent®). Input flows and by-products that leave the system boundary are considered by means of system area expansion.

LCIA methodology

The impact assessment methodology used is the ReCiPe-Midpoint Method combined with data from the ecoinvent® database.

Types of impacts

The following environmental impact indicators are used to estimate the environmental impacts using the calculated inputs and outputs:

- Global Warming Potential, GWP
- Fossil Depletion Potential, FDP
- Freshwater Eutrophication Potential, FEP
- Metal Depletion Potential, MDP
- Natural Land Transformation, NLTP
- Ozone Depletion Potential, ODP
- Photochemical Oxidant Formation Potential, POFP
- Terrestrial Acidification; TAP
- Human Toxicity Potential, HTP
- Water Depletion Potential, WDP

These indicators cover all major impact categories and were also used for other LCA studies in various metal industries. The values of the respective indicators are determined using LCA software.

Interpretation

To evaluate and analyse the quality of the results, various measures can be carried out. Among others, the applicable standards ISO 14040 and ISO 14044 suggest the following, which are also carried out as part of this study:

- Identification of significant parameters
- Completeness check
- Consistency check
- Sensitivity test

Data requirements

To ensure the data requirements, the following guidelines concerning the data used should be followed:

- temporal: The primary data originates from the year 2020. The secondary data from the database used will be collected between 2020 and 2022. The age of the data is also documented.
- geographical and technological coverage: The data used corresponds to the current state of the art in steel, aluminium and lead production / recycling, and refers to the region of Spain.
- precision: In this study, plant-specific process data is used. If this data can't be measured or precisely determined otherwise, estimations are made based on literature values and expert interviews.
- completeness: The industrial data provided is combined with data sets from the literature and other relevant sources. In addition, data verifications based on mass and energy balances are carried out.
- representativeness: The data reflects the defined temporal, geographical and technological coverage. Thus, the data can be considered to be representative.
- consistency: The methodology of the study is applied on the different components of the analysis uniformly.
- reproducibility: The presented information on modelling and the explanations regarding the data basis enables the results to be reproduced.
- data sources: The primary data comes from the Spanish plants of the respective industrial partners. The secondary data is taken from established databases, scientific literature or from expert estimates.
- uncertainties: Possible uncertainties related to the used primary and secondary data are estimated at a maximum of 5-15%. Uncertainties in relation to the estimations are also valued at a maximum of 5-15%.

In addition, an internal policy by Sidenor on the use and quality assurance of data is taken into account for the steel use case.

Assumptions

Due to the applied cradle-to-gate approach, all processes of the process route after the melting furnaces are not considered. Further assumptions may arise during the modelling phase and have to be added later on accordingly. Due to the iterative nature of LCA, this procedure is common practice.

Value choices and optional elements

Input streams that are less than 5-10 % of the mass of the desired output stream were not considered - unless these input streams or their upstream chains have a significant influence on the environmental assessment of the product system. Therefore, the electrode consumption, i.e. is considered during modelling, since the production and provision of graphite is particularly energy-intensive. Overall, the sum of the neglected quantities of substances should not be more than 5-10 % of the total output. None of the optional elements mentioned in the international standards ISO 14040 and ISO 14044 are necessary to apply in this study.

Limitations

The analysed recycling plants are reduced to their essential processes. Only the most relevant mass, volume and energy flows are considered. In order to enable the execution of the study, these restrictions have to be made. However, if these flows make a major contribution to one of the selected impact categories, they are still considered (as can be the case i.e. with off gases). These decisions are made in close consultation with the project partners. Further restrictions may arise during the execution of the calculations. This procedure is in line with current common practice in LCA.

Critical review

A critical review is not necessary in the context of this study and won't be carried out.

Type and format of the report

The report presented is based on the international standards ISO 14040 and ISO 14044 and summarizes the scientific conclusions regarding the installation of a scrap analysis sensor, comparison of different feedstocks, analysis and mapping of upstream processes, evaluation of recycling rates and other plant-specific applications of further optimisation. In addition, the notes from the standard ISO 14025 are considered. The focus is on the methodical procedure and transparent operation.

5. Abbreviations

LCA	Life Cycle Analysis
LCIA	Life Cycle Impact Analysis / Assessment
EAF	Electric Arc Furnace
LME	London Metal Exchange
ISO	International Organization for Standardization
R&D	Research and Development
EU	European Union
GWP	Global Warming Potential
FDP	Fossil Depletion Potential
FEP	Freshwater Eutrophication Potential
MDP	Metal Depletion Potential
NLTP	Natural Land Transformation
ODP	Ozone Depletion Potential
POFP	Photochemical Oxidant Formation Potential
TAP	Terrestrial Acidification
HTP	Human Toxicity Potential
WDP	Water Depletion Potential
BFI	VDEh Betriebsforschungsinstitut GmbH
AMB	ArcelorMittal Bremen
SIDENOR	Sidenor Aceros Especiales
EURECAT	Eurecat Technology Centre
GRUPAL ART	Grupal Art SL
REFIAL	Refial (Grupo Otua)
INATEC	Fundación Inatec
RWTH AACHEN	Rheinisch-Westfälische Technische Hochschule Aachen
EXIDE	Exide Technologies