Life cycle assessment tools to evaluate the impact of refractories and fluxes for iron and steel production

Bruno Touzo[1], Laurence Canton[1], Emmanuelle Henry-Lannier[2]

[1]Calderys France
43, quai de Grenelle, State, Paris,70015
Email: bruno.touzo@calderys.com, laurence.canton@calderys.com

[2]Imerys France
43, quai de Grenelle, State, Paris,70015
Email: emmanuelle.henry-lanier@imerys.com

Summary

Sustainability has become an integral part of products and processes. Refractories and other minerals used in the iron and steel manufacturing play an important role and need to bring their contribution to help reduce the environmental impact of the industry. A methodology was developed to assess the life cycle of their product, from cradle to gate. It is aligned with the WBCSD framework, consistent with ISO standards and used quantitative and qualitative indicators. This paper will present the methods, some results and how this can help refractory and casting fluxes suppliers optimize new product and solution sustainability.

Keywords

refractory, iron trough, Life cycle assessment, CO_2 footprint, raw materials

introduction

The steel industry is now increasingly attentive and motivated to reduce its emissions, wastes, as well as to improve the safety of their employees. Refractory products are a vital element in all high-temperature processes and are typically used to insulate and protect industrial furnaces and vessels due to their excellent resistance to heat, chemical attack and mechanical stress. The various types of refractories also influence the safe operation, energy consumption and final product quality. Refractory products involve a large range of raw materials, and most refractory raw materials require a large quantity of energy for their production, as they generally require processing of natural minerals, such as sizing, blending and thermal treatment. Transportation over long distances is also often required, as some raw materials are not available in all continents. However, the specific resource consumption of refractory products is low, with in average less than 10 kg of refractories required per ton of steel [1]. The environmental burden associated with the production of refractory raw materials should be balanced with the overall benefits and performance delivered for the final product.

In 2018, a sustainability program was launched in our organization to continuously improve the environmental impact of its product manufacturing and design. The program is aligned with the WBCSD framework. One important part of this program is the life cycle analysis (LCA). A method was developed to calculate LCA for any of the products manufactured. This paper presents the method, gives an example of its use for refractory materials and compare the results for different product types and design.

Life cycle analyses method

The Life Cycle Analysis (LCA) methodology defined by ISO 14040 and 14044 standards (2006) [2] is recognized as the best framework for assessing the environmental impacts of products and services. It provides a clear and comprehensive picture of the energy and materials flows through the whole life cycle of a system and a global and objective basis for comparisons. The environmental pressures and impacts of products could occur at various stages of their life cycle (along production chain, during use phase, disposal of end-life products). Then it is necessary to take in account the full life cycle to compare different product or system, to avoid that the environmental burden is simply shifted to other stages of the life-cycle, or to other geographical areas. LCA approach is used then as a lever to serve sustainable development and to help the product users to reduce their footprint. From a research and development point of view, LCA can be used as a tool for product design improvement and innovation, and to help making the right choices to lower the environmental impact of the new products. In such an approach, the choice of materials, the selection of technologies, the implementation of specific design criteria are the most important parameters to consider. From an industrial point of view, LCA allows the benchmarking of product options and can therefore be used in decision making of purchasing and technology investments. For this purpose, a specific tool, that we name Ekodesigner has been developed. It allows to evaluate the LCA of the products from cradle to gate. Among all possible criteria available for such calculations, 12 were chosen as they are the focus of our organization. These criteria are listed in table 1.

Table 1. Environment criteria taken selected for the Ekodesigner

Land Use, occupation	m^2.yr
Water Used (inventory)	liter
Resource use, minerals and metals (CML)	kg eq. Sb
Resource use, energy carriers (CML)	kg eq. Sb
Climate change (IPCC)	g eq. CO_2
Acidification (EF)	mol H^+ eq
Eutrophication, aquatic freshwater (EF)	g eq. P
Photochemical ozone formation (CML)	g eq ethylene
Ozone depletion (EF)	g CFC-11eq
Human toxicity, cancer effects (EF)	CTUh
Ecotoxicity freshwater (EF)	CTUe

As refractory manufacturers activity is mainly related to formulation, the raw materials data is key to any relevant LCA. There is not a lot of available literature on these materials. A report prepared in 2013 by the European Refractories Producers Federation [1] provides carbon footprint data resulting from a gate to gate exercise focusing on the production phase of different refractory products, and underlines a large range of results, depending on the type of product (shape, composition, firing temperature, usage). Two publications from the Journal of The Technical Association of Refractories in Japan provides inventory data for the production stage of various alumina raw materials [3], graphite and silicon carbide [4] using public literature. Eco-invent LCA database [5] proposes also generic inventory data for processing of mineral resources (quarrying, mining, crushing, drying, burning, BAYER process).

Comparison of two refractory castables

As an illustration of the results of this LCA tool, two castables with different composition are compared. Both are iron runner ultra-low cement castables (ULCC) with similar composition, except for the main aggregate and the carbon containing materials. One is based tabular alumina and coal tar pitch, while the other one contains brown fused alumina (BFA) and more environment friendly carbon compounds. Coal tar pitch has been banned in Europe in 2020 due to its toxicity. Figure 1 shows the result of the carbon foot print. Figure 2 illustrates the difference on other environmental criteria, including toxicity.

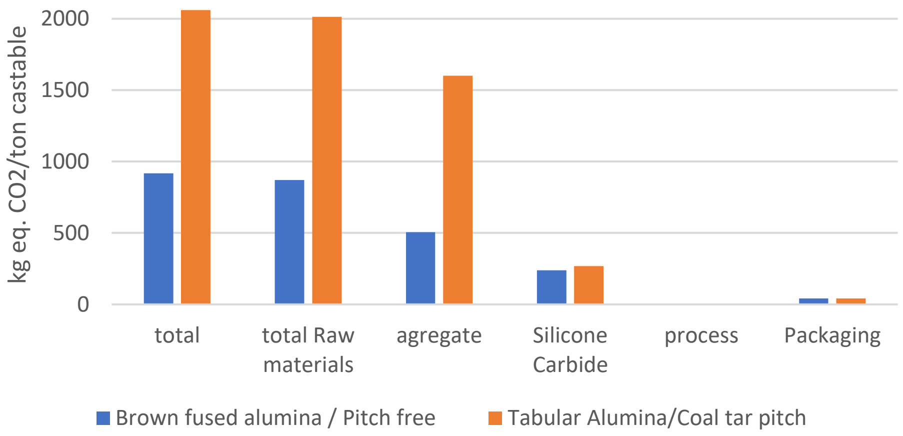

Fig 1. Comparison of 2 iron trough castable with 2 formulations.

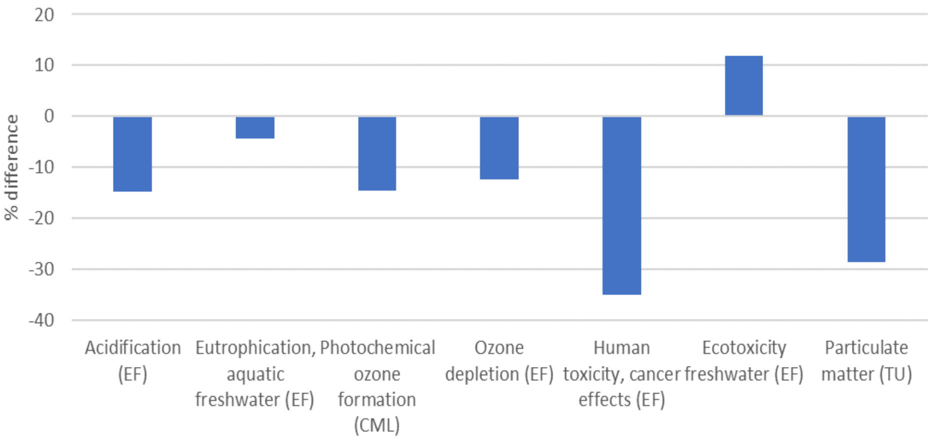

Figure 2. Difference of selected criteria between the iron trough castables made with pitch/tabular alumina and pitch free /brown fused alumina.

The two castables, although they fulfill the same function in iron production have a very different carbon footprint. The main part is linked to the raw materials. And within the raw materials, the main aggregate is the most important contributor. As tabular alumina production is more energy intensive than brown fused alumina, the castable that contains this raw material is more than two times more CO_2 intensive than the one with brown fused alumina. Beside raw materials, it is also interesting to notice that the contribution of the processing to the CO_2 footprint is almost negligible compare to the raw materials. Silicon carbide is also an important part despite its relatively low proportion in the recipes, because its energy content is even higher than tabular alumina. Pitch free castable also confirms a lower product toxicity and environment footprint. Even if one criterium is higher, the overall impact on the environment is noticeably lower.

In order to obtain a fair comparison of these two products, this cradle to gate LCA data will have to be included in a full life cycle analyses of these refractory solutions, including life time in the process, and possible repairs. Indeed, the comparison has to be done for a relevant functional unit. In this case this would be the environmental impact per ton of produced iron. This requires to collect data on the product life in the field. This data is however already available because the behavior of the trough is monitored carefully. The two sets of data will then be grouped to determine the solution with the lowest impact per ton of iron. This will be the next step of our evaluation.

References

[1] PRE/Cerame-Unie. Product carbon footprint report (2013)

[2] ISO Standardization. ISO14040 Environmental management – life cycle assessment – principles and framework (2006)

[3] Tamura, S.; Narita, N.: Life cycle inventory of refractory raw materials – alumina materials. J. Techn. Asso. Refractories Japan 26 (2006) [2] 100–106

[4] Tamura, S.; Narita, N.: Life cycle inventory of refractory raw materials – graphite and silicon carbide. J. Techn. Asso. Refractories Japan 29 (2009) [1] 8–14

[5] ETH Zürich, Ecoinvent database v 3.1, (2014)