Applications of Life Cycle Assessment for sustainable Steel Production in the Electric Arc Furnace

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INTRODUCTION

A Life Cycle Assessment (LCA) is a systematic method of analyzing and evaluating product systems, which takes into account the entire lifecycle of a product. A LCA will monitor all environmental impacts of the production, processing, use and disposal of the respective product. The results of a LCA reveal weaknesses and potentials for improvement within a product system. They also provide information on the interactions of the individual process steps, which can be used to optimize processes and increase sustainable production. During the RFCS Research project GreenEAF2 the environmental impacts of the usage of biochar during electric steelmaking in the Electric Arc Furnace (EAF) were investigated by a LCA study. [1,3]

STRUCTURE OF AN LCA

In general, a LCA study is divided into four phases:

- goal and scope definition: defines the system, system boundary and the complexity of a study
- life cycle inventory or “life cycle Inventory phase” (LCI): a collection of process input/output data should be conducted that are contained in the defined system boundary
- life cycle impact assessment or “life cycle impact assessment” (LCIA): the collected data are transferred into environmental impacts to compare different life cycle stages with each other or compare different studies by standardization and weighting processes
- interpretation: illustrates and totalizes the results of the LCI and/or LCIA phase and refers to the defined aims from the goal and scope definition phase.

The LCA methodology is an iterative process so that all four phases have an influence on each other. [1,3]

MODELLING

During this research project, three separate LCA models were created and evaluated. Therefore, the modelling software Umberto NXT Universal and process data by the participated steel plants were used. In a first step, all relevant input and output materials during the melting process in the EAF were considered (fig. 1). [2]

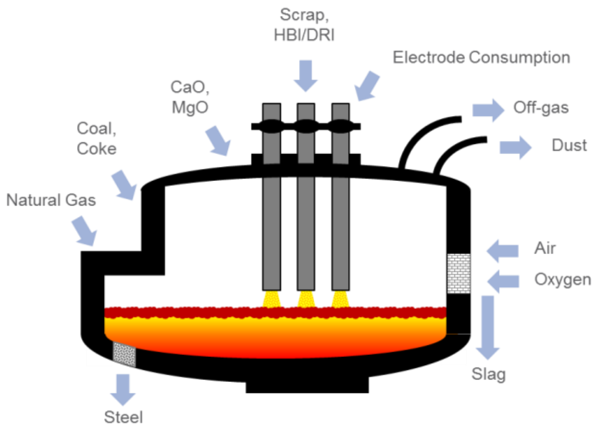

Fig. 1: General mass balance

On this basis, a general process model using the LCA software Umberto NXT Universal was created (fig. 2). The added carbon carriers were divided into biogenic and fossil additives to enable a comparison between the alternative input materials. The electric energy consumption had to be added to the model to ensure a complete calculation of the CO_2 intensity of the steelmaking process.

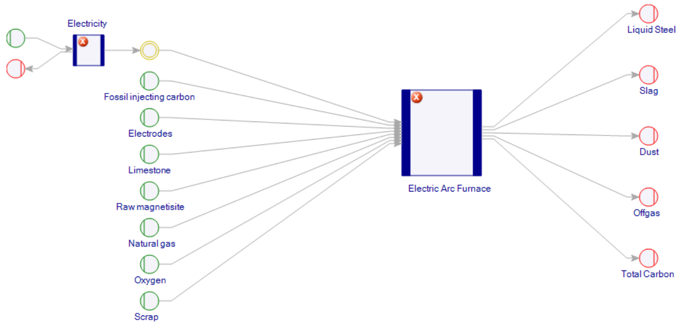

Fig. 2: Reference LCA model

The relevant process data are divided into three Groups by different scenarios concerning the kind of charged carbon:

- Sc.1: 100 % fossil carbon
- Sc.2: 50 % fossil carbon and 50 % biogenic carbon
- Sc.3: 100 % biogenic carbon

Palm kernel shells (PKS) were used as biogenic carbon carriers during the steelmaking process. With regard to the reference process (100 % fossil carbon, scenario 1), data of 185 heats were collected and evaluated. In Case of the mixed campaign (50 % fossil carbon and 50 % biogenic carbon, scenario 2) data of 215 heats and concerning the 100% substitution trials (100 % biogenic carbon, scenario 3) data of 476 heats were collected.

RESULTS

During the Life cycle impact assessment aggregated CO_2 emission factors, off-gas composition, steel composition, slag composition and the specific electric energy consumption were analyzed.

The total CO_2 emissions of scenario 1 are higher in average than the corresponding value of scenario 2 and 3. The mixed campaign (50 % fossil carbon and 50 % biogenic carbon) shows the lowest CO_2 emissions, which means a decrease of 13.31 % in relation to scenario 1 and a decrease of 3.14 % in relation to scenario 3. Furthermore, a lower consumption of oxygen and fossil injecting carbon can be observed in scenario 2 in relation to scenario 1 and 3. If the upstream chains of oxygen were also included in this calculation, the difference in the total CO_2 emissions would be even higher. The biggest differences in the specific emissions are evident in the case of the electric energy consumption:

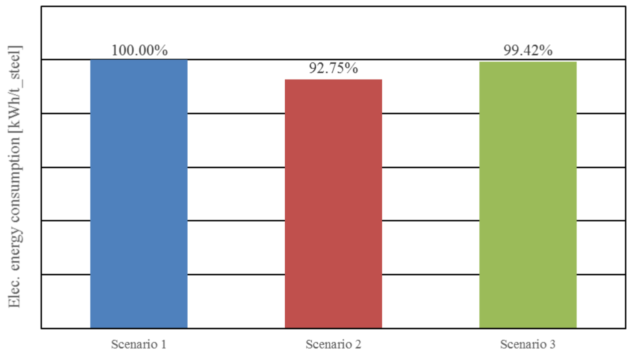

Fig. 3: Electric energy consumption

The use of PKS during the industrial tests (scenario 2 and scenario 3) has no negative consequences for the molten steel or the process control. With respect to the slag, there are also no negative influences caused by the PKS, so that the slag can continue to be used as before. During the industrial long-term trials with PKS a different reaction behavior of the biogenic carbon carriers could be observed. The biochar is characterized by a significant higher reactivity as the fossil carbon, which leads to a high average amount of CO and CO_2 in the off gas.

EXTENDED MODEL

During the Ecosteel research project an extended LCA model within all relevant upstream and downstream process of the electric steelmaking route will be developed. In collaboration with three German steel plants and the ifu Hamburg GmbH a new modeling approach was set to build an holistic LCA study.

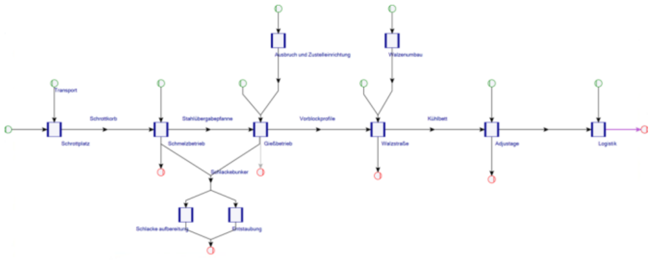

Fig. 4: Extended LCA model

The aim of the project is the development of the prototype of a software application that enables engineers in steel mills to autonomously map the steelmaking process and carry out an LCA. The process model should be able to be adapted to individual circumstances and supported by a sector-specific database.

CONCLUSION AND OUTLOOK

The LCA study shows the feasibility of the usage of biogenic carbon during the electric steelmaking process. The use of PKS during the industrial tests has no negative consequences for the molten steel, other output materials or the process control. The reduction concerning the specific electric energy consumption in scenario 2 shows, that the carbon footprint of the steel production in EAFs, can be reduced by substituting fossil coal with biochar. For further investigations on PKS usage in the EAF, the charging of biomass is implemented in a dynamic EAF process simulation model by Meier et al. [4]. Furthermore, an extended LCA model and a module based software prototype will be developed during the Ecosteel project.

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