Figure 1 / 'Climate transition of the world' Painting 2014

Green Steel – Ecology and economy in secondary steel production – or how to meet the goals of the energy and climate transition with profit.

At the end of June 2022, I participated at the MMSteelClub conference in Barcelona. Among other topics we were taking about the above subject. Indeed, is it possible to produce steel profitably respecting the goals set forth for 2050? And isn't the current energy crisis jeopardizing all the endeavors?

Well, in the first three posts, we talked about the paradigm shift, needed to reduce the gas requirements at the furnace, to **finally get accurate off-gas information** accompagned by lower electrode consumption, and other benefits without losing the operational control of the secondary steel production.

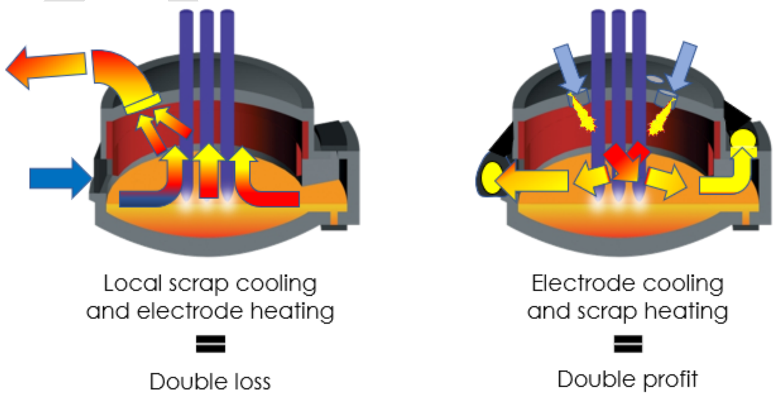

Figure 2 / Convection furnace vs. preheating furnace

We have talked about a completely new two container scrap preheating which opens ways to produce different steel grades with scrap preheating, a scrap preheating system which integrates all possible heat sources and actively cleans the off gas of combustion products and integrates the VOC incineration, a scrap preheating without headaches and maintenance hassles, a scrap preheating without fingers and pushers. We have talked about a simple installation which does not need new buildings and extended furnace modifications. We have noticed that with a minor change the furnace can get a better thermal utilisation with unchanged metallurgical process liberty. Finally we found that the almost dust-free off gas after the scrap preheating can be used for further applications and we have seen the environmental benefit of this new scrap preheating solution.

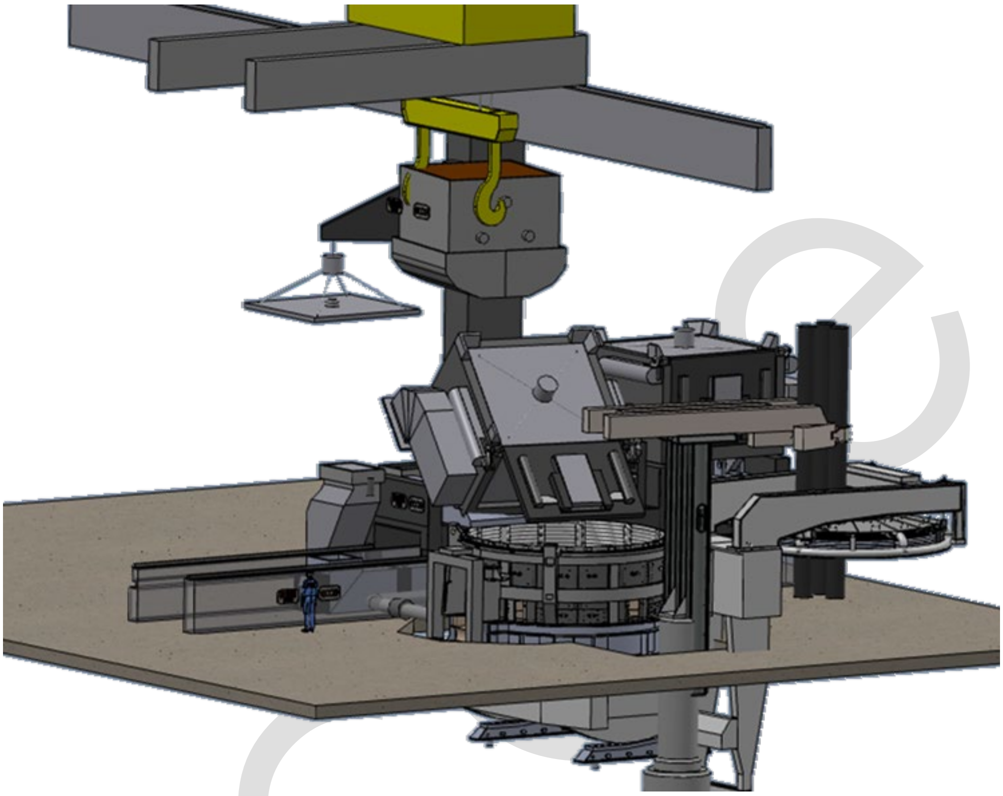

Figure 3 / ECOFEEDER and the modified furnace

Now, we would like to talk about an application which seem us especially valuable and well placed. **The preheating of DRI.**

Among the discussions how to the render the primary steel production less polluting, respectively to produce less GHG, DRI plays a central role. Instead of using the blast furnace to melt the iron ore in the traditional way, the direct reduction process reduces the iron ore by a chemical reaction where natural gas or hydrogen is used to reduce the iron ore. The product of this reduction is DRI, a pellet with a high degree of metallic iron and some gangue, part of the later slag in the arc furnace, and a variable content of carbon (C), variable between 4.5 and 0% C. DRI with 0%C is reduced with hydrogen, preferably green-hydrogen, thus hydrogen produced by means of renewable electricity (see **DRI – future for the steel industry?** (www.eco-eag.com/downloads)).

Well, this DRI is then melted either in a large volume smelter furnace on integrated plants or in a traditional electric arc furnace in minimills.

Let us concentrate on the recycling route, the minimill. For economic reasons the ore will be reduced near the mining area and /or near areas where renouvable energy is available in abondance, thus areas where ore, sun and wind are available, areas like Australia, North-Africa, etc.

Steel is a primary good. **The minimills are among nationally relevant industries.** They are mostly located at areas where transportation of raw materials is not a big issue, that means they have rail, road and sometimes water connection. Up to now minimills mainly melt scrap, local and imported scrap, but will there be enough scrap in futur? In the negative case, minimills will have to switch to the an increasing use of DRI, for better quality and to cope with scrap shortages. Well, the transportation of DRI is not without risk – to avoid any reaction with seawater DRI must be transported covered and under inert atmosphere. On top of that, melting DRI requires more energy than melting scrap. To reduce the energy input it is therefore advisable to preheat DRI. But, DRI cannot be preheated in an oxidating atmophere nor by open flames of burners.

A viable solution: The remaining heat leaving the ECOFEEDER.

Due to the almost constant temperature with which the exhaust gas leaves the ECOFEEDER, it is possible to feed a suitable heat exchanger. A suitable heat exchanger? A slowly rotating tube heat exchanger where the hot gases flow through the cold good which flows slowly in counter direction, would best suit. This is like the rotating kiln at the cement production, but there, instead of a hot off gas, air gas burners are used to heat the material. Sure, the off-gas temperature of the flame of an air gas burner is much higher than the leaving off gas at the scrap preheating, but the principle is identic.

The big advantage of the off gas leaving the two-containers scrap preheating is not only its almost constant temperature but also, and this is important for preheating DRI, its inert atmosphere of CO_2, NOx and N_2. This inert atmosphere inhibits premature burning or oxidation of the DRI. The achievable preheating temperature of the DRI depends on the temperature of the off gas, which is a function of the furnace air, the reactions in the furnace, the state of the burners at the scrap preheating, and the residence time of the off gas in the scrap preheating system, and on the amount of DRI required in the furnace. But this type of DRI preheating makes only sense for small quantities maybe up to 30% DRI addition. The DRI preheating temperature can take any value between 300°C and 600°C.

This solution shows one of many ways to save energy by heat recuperation. In my opinion, the ideal use of the remaining heat in the off gas is either producing steam for vacuum degassing or hot air for the arc furnace. After the heat exchanger for these solutions a low temperature OCR-turbine may use the remaining heat as well.

Now, the last promised topic, the return on investment (ROI).

Of course, it is difficult and extensive to make a clear and easy-to-understand forecast for the break-even and with that a real return on investment (ROI), but it is not difficult to predict a trend. A realistic calculation of the ROI is part of the separate realisation study, which is made on a paid basis. Here are the boundary conditions just to follow and understand the prediction:

Steel production 500'000t/y, cost basis **Q4/2021 Germany** (NG: €107/MWh; bulk and fine carbon €190/t; electrodes €12/kg; El. energy €317/MWh; Oxygen €0.08/Nm^3; slag builder €120/t; scrap €300/t). Electric energy consumption 470kWh/t; chemical energy consumption 230kWh/t; total energy consumption (incl. reactions and pollutions 775kWh/t, no scrap preheating.

For comparison, the cost basis **Q1/2021 Germany**: (NG: €27/MWh; bulk and fine carbon €190/t; electrodes €12/kg; El. energy €40/MWh; Oxygen €0.08/Nm3; slag builder €120/t; scrap €300/t).

The calculated cost of producing one ton of steel in Q4/2021 is €192. With the proposed modifications (without DRI preheating), an energy saving of around 100 € would be possible. Looking at the same cost in Q1/2021, one ton of crude steel amounted to €56 and the potential energy savings to about €40.

The contact: Turnkey order for a stepwise realisation of the project to reduce the GHG emission to the maximum.

- Step 1: modification of the furnace for a better thermal utilisation of the imported energy
- Step 2: addition of the two-container scrap preheating ECOFEEDER E
- Step 3: addition of a appropriate application to use the remaining energy (battery limit media supply to the heat exchanger)

The investment: short realisation, hand-over in 70 weeks, project cost 12 Mio Euro.

About the schedule for such a modification / installation in an existing steel mill, we propose a contract term of about one-year (see "Energy saving – the winning bit.pdf (www.eco-eag.com/downloads) steps 1 and 2 linked).

By simultaneously starting step 1 & 2 the commissioning of step 1 occurs in about 34 weeks after project start. The savings by this modification pay out immediately (orange dotted line). The start-up of step 2 is a little bit latter (48 weeks after project start). Here, the savings add to the savings made by the realisation of step 1. The realization of step 3 is delayed because step 3 requires the two-container scrap preheating (step 2). Commissioning of step 3 therefore only makes sense after the start of step 2 and after finding the right operating points (value-in use).

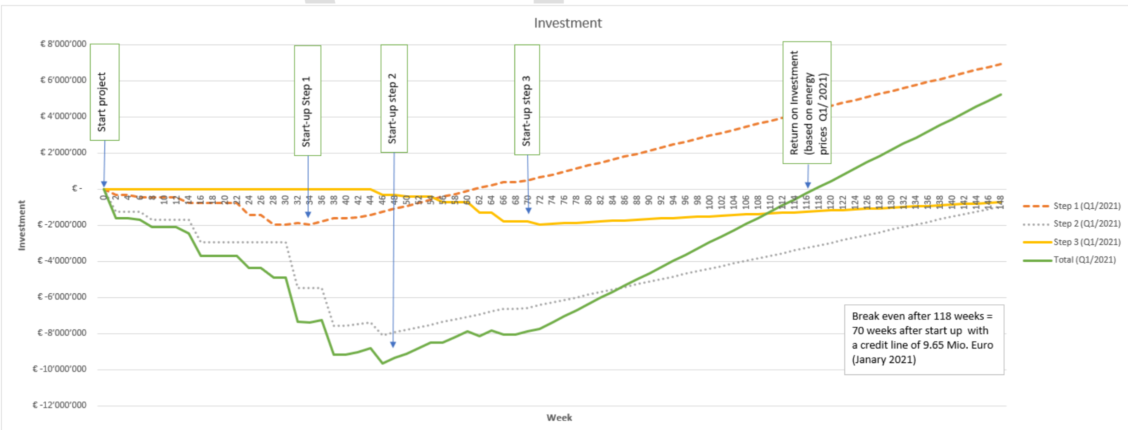

Figure 4 / Cash flow and break-even of the project

The delayed realisation of the different steps influences the cashflow and is adapted to the requirements and availabilities of the preceding steps. Here the cashflow limits to 9.65 Mio Euros instead of 12 Mio Euro and has a break even of 46 weeks after the operational start of the last step, or 116 weeks (2 years and 12 weeks) after signing the contract. The cashflow includes an interest rate of 8%pa.

This noticeably short payback period for a CAPEX project combines with a low OPEX value. The design of the scrap containers of the preheating system is carried out on a wear and repair basis. The concept envisages a non-contact cooling system wherever possible, and the liquid cooling areas are equipped with spray cooling.

Any project is affected by raising costs and changing market prices. As time goes by, the run for energy saving and environmentally friendly projects becomes more intense. But, more importantly, the energy prices are constantly raising too. Based on the evolution of the energy prices in 2021 we have compiled the breakeven calculation for the energy prices beginning and end of the year 2021. The already short payback period of 116 weeks melts down to 70 weeks based on the same contract volume. Due to the shorter payback time the investment costs drop to 8.95 Mio Euro.

Below (Fig. 4) the graph showing the influence of rising energy prices on the return on investment (see page 3 of this article).

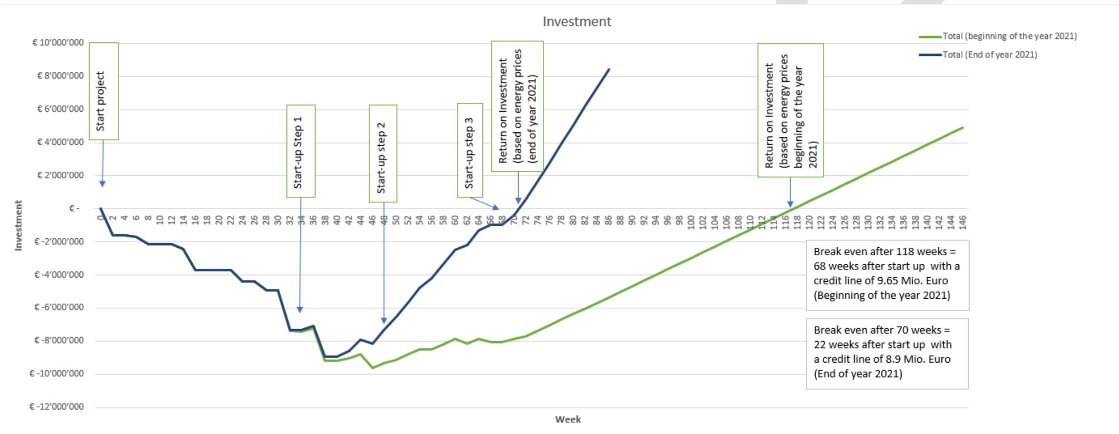

Figure 5 / Return on investment with rising energy prices

In conclusion, there is a solution that makes it possible to achieve the net-zero target, a solution that reduces the heat emitted to an absolute minimum by using the dust-free exhaust gas further than any other scrap preheating solution, and a solution that ultimately allows the remaining heat to be used after scrap preheating with appropriate applications almost to ambient temperature. This solution, realized in a stepwise manner allows to pay back the investment during its realisation and with that allows to save money, interests and to limit risks. A solution which lowers the operation costs by wear and repair practices and a solution which suits to almost any steel plant layout. A solution with a break even of less than a year – a proposal you cannot refuse.

The perfect moment for avoiding the climate change has gone – let us take the second best – and this is NOW!

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