ecology eco economy

GREEN STEEL

Are we on track?

ABSTRACT

Man has always been imagining legends when he was in forlorn situations. Is the climate shift such a forlorn situation and is man inevitably steering into the vortex? The consumption of energy is constantly rising, data storage, mobility, new technologies and well-being are demanding more and more energy in a never-ending vortex – man can only survive when he starts to save energy now and wherever possible. We show how one of the largest energy consumers - the steel recycling industry – can reduce their energy waste to the absolute minimum.

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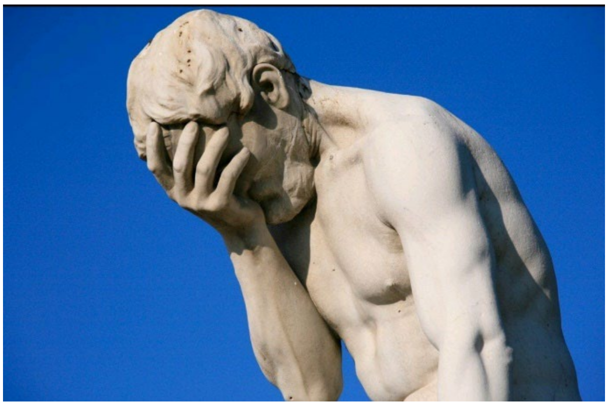
THE MAELSTREAM

The carta marina was drawn at the beginning of the 16th century. There, the maelstream was the end of many ships whose captains dared to discover new ways to explore the unknown. When Friedrich Schiller wrote his poem about the diver 'Which knight or esquire, which one will dare? …' did he also think of the maelstream? Is the maelstream an analogy of what we are going to live in 2050? Who knows?

Have we bet our chips on the right number in our roulette to reach the net zero scenario? Isn't the ship standing on our number on its way to the maelstream?

FACTS YOU WOULD NEVER HAVE IMAGINED BEFORE

The world is in the middle of a global energy crisis of unprecedented depth and complexity. This is having major implications for markets, policies, and economies worldwide. Europe is in the centre of this crisis. Here some facts and findings:



By 2040, **1200 million vehicles** will still be powered by fossil energy. Will the switch be possible and how is it going to happen?

By 2050, **95% of energy generation** is expected to come from renewable and nuclear energy sources. Dream of truth?

By 2040, the world must **add or replace 80 million km of grids**, equal to all grids globally today, to meet national climate targets and support energy security…

Recently the OECD steel committee expressed concerns about the deterioration in the global steel market as a result of increasing excess capacity, weakening demand in steel products and governmental interventions to protect local markets. It was stated that the global steel market, after a short-lived recovery at the beginning of the year collapsed due to a steel demand which was lower than expected.

Further the committee predicts an overcapacity in the coming years based on the actual new investments underway or in planning stage.

The decrease in capacity utilisation of the global steel industry forces manufacturers to find new markets. Producers are forced to make low-price offers for their unused capacities. These actions lead to disruptive effects on the global trade market. To protect the own market countries are considering raising levies and limiting the import which reduces the international trade volumes. As new capacities are coming into operation the wheel gets up speed. The nonadherence of the once planned capacities endangers the profitability and social stability of the companies. **The maelstream starts up**.

On the one hand the committee members of the OECD are talking about recession (degrowth) in various sectors among them also the steel industry. Recession or newly degrowth, is not a new scenario in the capitalistic world where only growth counts, but painful reality which is mostly accompanied by social disturbances. Yes, we will have to face recession in the coming years. In addition to the commercial and social consequences of a recession or degrowth, excess capacity is a serious problem. Rise of production was the tenor of the past decades, especially in the steel business. All processes had to be focussed on high and higher production, energy and resource input was in the second row. Now, excess capacity which goes along with the recession shows the real face of the **inefficiency of energy and resource use**.

ENERGY, THE DRIVING FORCE

The alarming news that the grid, the distribution net for electricity, is not strong enough to cope with the coming energy transition and must be renewed completely in the coming years to avoid black-outs, break downs and other unwanted events is frightening. Why is the grid, which is regularly maintained and serviced, suddenly unsecure and weak? Looking at the projected growth of the electricity consumption and the producing sources this news sounds reasonable. There is a strong growth of the renewables forecasted until 2050.

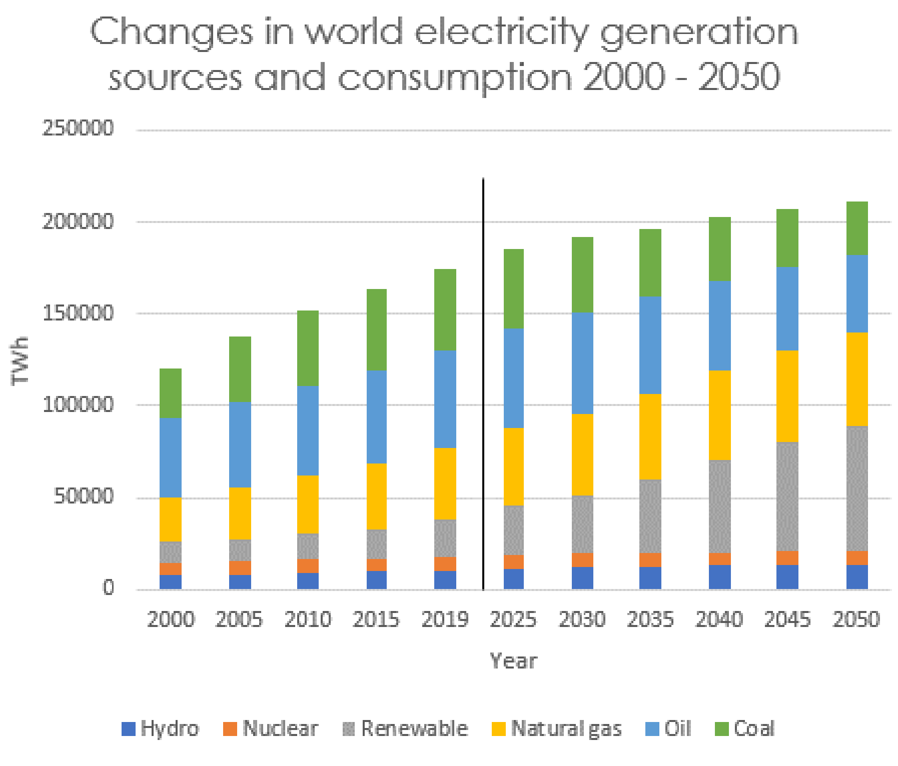


Fig. 1 / Changes in world electrical energy generation and consumption (Source: Statista 2023 (data base 3.2022))

The above graph shows the projected increase in the global energy consumption by 2050. Looking back to the past 20 years a constant growth of 1.5% was recorded, the forecasted growth for the coming 25 years (2025 to 2050) however is 0.4%. Honestly, I have some doubts about this projection. In this projection the worldwide energy consumption flattens in the coming years whereas more and more data are stored and processed which consumes an enormous amount of electricity, traffic is going to be electrified which will also boost the electric energy consumption. These two examples stand for many other consumers that will consume more energy. However, the increase of the renewables is remarkable, from presently 24000 TWh to 70000 TWh in 2050.

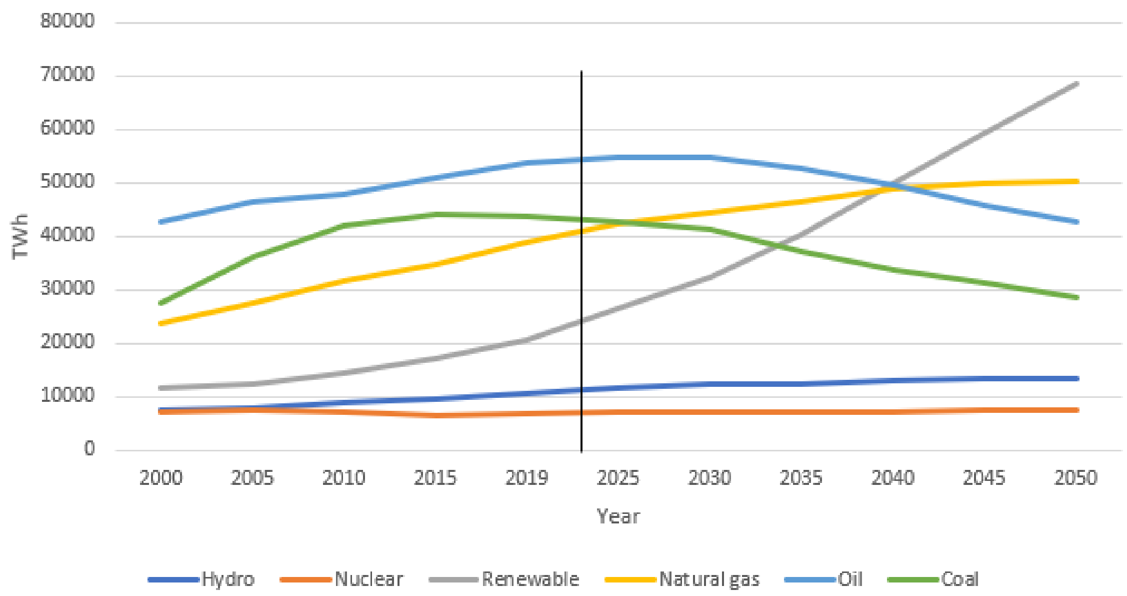


Fig. 2 / Changes in world electricity generation from 2000 to 2050 (Source: Statista 2023 (data base 3.2022))

Again, the remarkable growth of the combined renewable, which is shown in detail in the chart below (Figure 3). The tricky thing with the renewable is that they depend on various factors to generate electricity, factors such as sunlight for the PV, wind for the windmills, water flow for the hydropower plants, and so on. To stabilize the supply batteries, buffers, electrical compensators, etc. are needed.

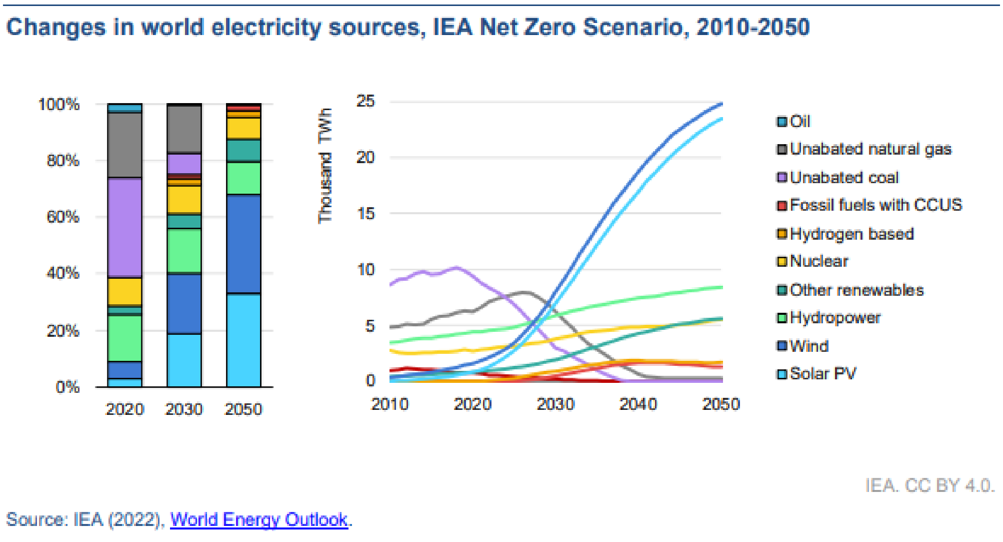


Fig. 3 / Renewable energy generation in detail

Now, on side of the medal we see the danger of a real recession in the steel industry, a recession triggered by false signals coming from governments, by dangerous policies of commercial protection, energy prices and nepotism, and driven by global overproduction due to an unexpected drop in demand. The other side of the coin predicts an enormous pull from the imminent need to build the electrical generation from renewable energy, the rebuilding of countries that have recently been devastated by war or natural disasters, the normal activities that go hand in hand with normal growth of the population, the migration of people towards centres, and a possible relocation of major cities if the projected rise of sea levels occurs.

The present situation can be summarized as follows: unhealthy growth, excessive resource use, emission levels that cause climate shift, and disproportionate income distribution have triggered a worldwide recession. And, the fight against the imminent rise of temperature boosts the economies in a way without precedent.

The decarbonization process initiated by the climate change as a consequence of global emissions requires a change in economic understanding. The new understanding is to be based on moderate and balanced growth, a respectful use of resources mainly the energy, the conversion of the industrial facilities to achieve environmental objectives, the reduction of production capacities, and a better proportional distribution of revenues since taxpayers will have to bear the burden of the huge investments caused by the development of renewable energy production.

Consequently, there is an imbalance between the rate of development and the rate of production. This will be a very big obstacle to achieving the NZS of 2050. Despite the enormous budgets, will it be possible to produce the thousands of windmills, build the thousands of photovoltaic parks, rehabilitate the grid, develop and build the large-scale storage facilities for electric energy, and all the associated facilities in the remaining time? All of this takes steel, concrete, labour, time, and money not mentioning all the precious metals, rare earths, and landscape.

Recession – growth – new technologies – transformation, these are issues that the economies have to deal with on a daily basis, **but what is new is all about saving and the conscious use of resources**.

SAVE ENERGY NOW, WHEREVER POSSIBLE!

Many of the contours of this new economic understanding are not yet fully defined, but there is no going back to the way things were.

This also applies to one of the most energy-intensive industries – the secondary or recycling steel industry. There most of the end-of-life scrap is recycled in the electric arc furnace. The traditional electric arc furnace, the heart of a steel mill, consumes roughly 700 kWh per tonne liquid steel, while the heat content of a ton liquid steel is about 385 kWh, depending on its temperature. That means that about 300 kWh per tonne is generated as process-related waste. Unfortunately, most of this process related waste ends up in form of heat to the environment. One part, the metallurgical slag, contains about 50 kWh per tonne. The rest is hot off gas, warm water, and radiation. The hot off gas is the main waste, more than 200kWh per tonne liquid metal. This energy is recuperable, at least a major part of it. There are several concepts to recuperate the energy of the hot off gas. The most-promising concept is the preheating of scrap. In the late 80ies of the last century the first shaft furnace was installed by Gerhard Fuchs and his crew. This concept which is based on the energy transfer of the hot off gas to the scrap was installed multiple times, but its success was damped by the environmental problems induced by the combustion of the impurities. The same problems arose with the incineration of municipal waste and in the production of cement. As the elimination of these combustion products demands a lot of energy the concept was abandoned by most of users. The concept only survived in countries where the act of clean air was not respected or not severely controlled. The cause of this problem was the off-gas velocity, since both in the incineration of waste and in the production of cement, the off-gas velocity is low, while in the traditional arc furnace the off-gas velocity is high. This is a important step in the development of the new scrap preheating concept.

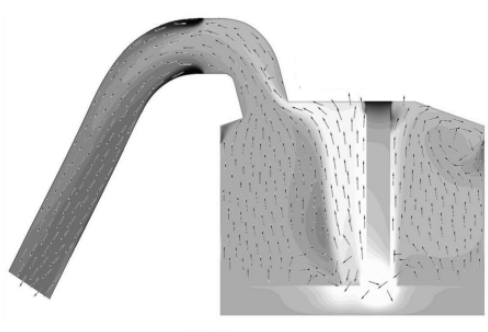


Fig. 4 / Model of the heat flow in the traditional arc furnace

But back to the furnace: the common concept of the arc furnace is that of an open chimney. All the energy generated in the area of the arcs is sucked through a channel along the electrodes towards the chimney, the hole in the cover, also called the 4th hole. The areas beside of this hot stream remain 'cold', the energy escapes!

Scrap Preheating a Paradigm Shift

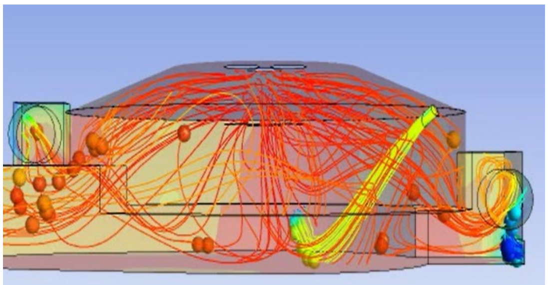


Fig. 5 / Model of the heat flow in the new concept

An all-new concept calls into question the off-gas flow of the open chimney. In fact, there is no compulsion to immediately drain the off gas out of the furnace before it has even done its job. With this new concept the off gas circulates within the furnace and preheats the scrap just before it melts. It is obvious that the energy required to melt the scrap is reduced by this circulation.

Another advantage of the concept is the homogenisation of the furnace atmosphere. There are no cold spots that need to be heated by additional burners, there is no cold EBT area and, in addition to these advantages the slag door changes from a passive to an active element, an area where the off gas forms a natural curtain for cold air to enter.

As if these arguments weren't enough, there are another two advantages: the furnace cover and the levelled off-gas temperature.

First the furnace cover: The weight of the off-gas duct has been taken off the cover and there is room for additional installations, such as a funnel for DRI addition. DRI, if available in reasonable quality, will be the butter on the scrap bread of the electric arc furnaces.

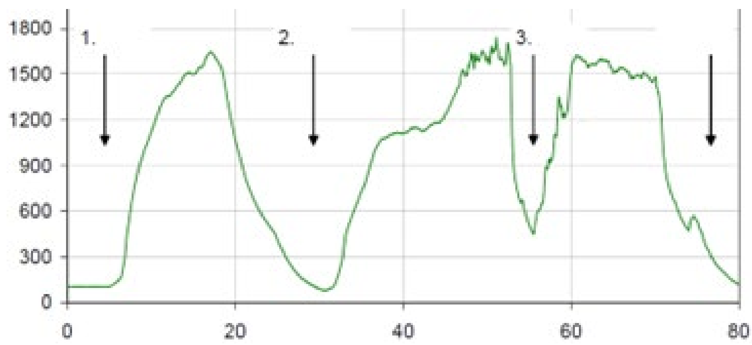


Fig. 6 / Typical temperature profile at the EAF

Then the levelled off-gas temperature: In the traditional furnace the off-gas temperature varies from some 600°C to 1800°C depending on the melting phase. Figure 5 shows a typical temperature profile of the off-gas temperature. The fluctuations and peaks at the new concept, let's call it torus furnace, are levelled during melting due to the pass through the scrap, enough to preheat the scrap in the following scrap preheating. There is no levelling during refining, so the full power of the off gas heats the scrap in the attached scrap preheating installation just before charging into the furnace. But one step after the other. The here described energy saving is in the order of 10% of the initially imported electrical energy.

SCRAP PREHEATING ENHANCED EFFICIENCY

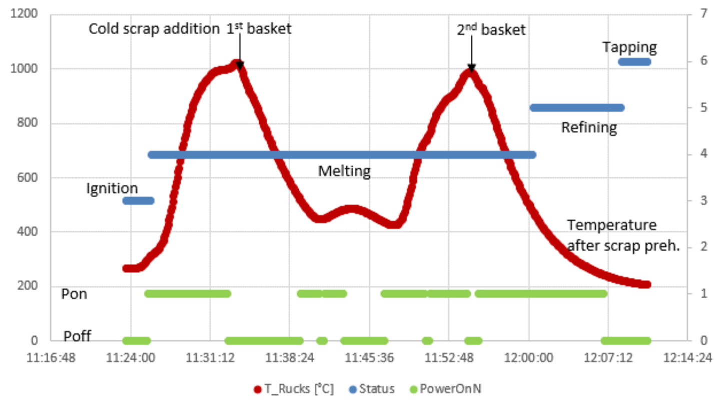


Fig. 8 / Temperature profile at a finger shaft furnace

When we are talking about energy saving, which we did for the part of the furnace, then we should also be talking about the remaining energy which is still in the off gas. Looking at the temperature profile of a shaft furnace (Fig. 6) we see a first hump with a peak temperature of about 1000°C; the shape is similar to the hump of the traditional furnace. The temperature difference of about 600°C is absorbed by the scrap. The temperature distribution in the scrap lying in the shaft is like the temperature distribution in a chimney, a hot zone in the middle and cold areas at the borders. So is the temperature profile in the scrap. The scrap is hold by water-cooled fingers. The gas speed between these fingers is very high as is the temperature (Fig. 7). It's there, where the scrap starts to melt and drops into the furnace. Back to the temperature profile after the scrap preheating. The first bucket is charged into the furnace right before the melting phase starts. After charging the scrap into the furnace, the fingers can't be closed. The melting starts and the scrap pile melts away. The fingers are closed as soon as the melting scrap has freed them. Now, the cold scrap is filled into the shaft. The temperature drops immediately as the cold scrap absorbs part of the energy. So far so good. But the efficiency of a finger shaft is rather poor due to the construction

Fig. 7 / Off gas flowing through fingers and the tilting of the fingers and due to the energy transfer. Well, the tilting fingers have been eliminated and replaced by retracting fingers which allow new cold scrap to be added once the preheated scrap has been released. Regarding heat transfer the shaft furnace is not ideal. The shaft furnace is nothing else than a chimney where the hot off gas is flowing fast. As seen in Fig. 7 the flow after the fingers is turbulent, fast in the centre and overheated (white flame). The high turbulence inhibits the post combustion within this area. Due to the high speed and the overheating, the centre of the scrap pile is melting, the borders are ‘cold’.

Changing concepts: The continuous horizontal scrap preheating is since years the best sold scrap preheating. Why? Because of its efficiency? No, the efficiency of this concept is even lower than the shaft furnace, but there are some advantages which are convincing. Continuous feed, no off-gas issues, and less dust.

Now, as promised a scrap preheating with enhanced efficiency. We have seen that the off-gas speed and its behaviour is an important factor for the heat transfer. Another not less important factor is the time of interaction between the members and the difference between the heating member, the off gas and the be-heated member, the scrap.

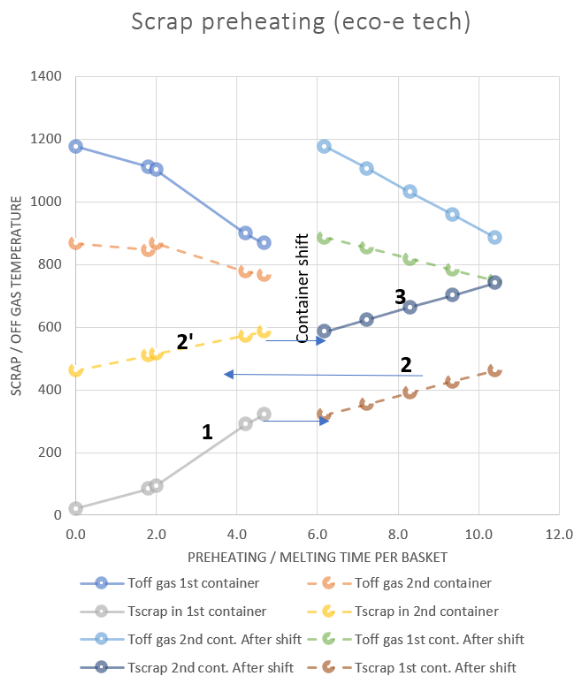


Fig. 9 / Enhanced efficiency with multiple container preheating

To reduce the off-gas speed the hydraulic cross section must be changed.

To optimize the time of interaction and to get the biggest possible difference in temperature the containers must be changed as soon as the heating member reaches a lower threshold temperature. On Fig. 9 the procedure is shown, on the horizontal the melting time of the content of one scrap basket, on the vertical the off-gas and scrap temperature. The blue line represents the off-gas temperature in the first container, the grey line shows the scrap temperature. The change in incline represents the internal burning of the pollutions which adds energy to the process. The off gas leaving the first container flows through the post combustion chamber where the combustion products of the pollutions are being neutralized. After that the off gas enters the second container. Here, the previously cleaned and preheated scrap is getting a temperature boost. The starting temperature difference between off gas and scrap is roughly 400°C (dotted orange and dotted yellow line (2’)). After about 4.6 minutes the containers are changed. The melting of the scrap which takes roughly 8 minutes continues. The hot off gas coming from the furnace (light blue line at the right) heats the scrap (dark blue line (3)) up to the point of oxidation (scaling) which is the limit of preheating. Corresponding to above, the off-gas flows through the post combustion chamber and reaches the second container (green dotted line) where the cleaned scrap lays (brown dotted line (2)).

The efficiency of this scrap preheating is around 60 to 65%, the enthalpy of the scrap at about 790°C is roughly 140 kWh/ton. The preheating is equal and gentle, no excess heat due to high off-gas speed, etc. The dust, which is still entrained, settles down in the two containers where it is brought back into the furnace and in the post combustion chamber where it is trapped in a sink.

The residual energy which is in the exiting off gas can be recuperated. The clean and dust-free off gas can be used via a heat exchanger for steam production or any other application for electricity generation. An interesting new storage application, the brine-battery allows a long and continuous heat flow to generate electricity through an OCR process.

Here, a short and concise summary of the three-step off-gas energy recuperation:

Step 1: Reduce thermal losses IN the furnace

Your advantage: Savings 6 to 10 % of the electric energy input and up to 20 % of the chemical energy input (NG/LPG) of your furnace, less refractory wear, less CO_2 production, an equilibration of the off-gas fluctuation, a preheating effect (faster melting of scrap) which shortens the melting time.

Step 2: Transfer most of the off-gas energy TO the scrap

Your advantage: energy recuperation of up to 75% of the off-gas energy (scrap preheating up the oxidation point (790°C)), no toxic of bad smelling exhaust, less dust, less refractory wear

Step 3: use of the residual energy IN the exiting off gas

Your advantage: residual energy recuperation (up to 30% of the off-gas energy) by various means.

Energy Saving NOW!

With these three steps we reach our target, the highest possible energy saving in melting of steel scrap.

The Bonus points

As a rule, such installations require new constructions, or at least major modifications such as raising the rails for the over-head cranes, increasing the building heights, large conveyor belts etc., which is not the case with the above system. This three-step modification is gradual and fits into most layouts without major transitions.

Gradual modifications mean step after step, a way to reduce risk and capital investment. Need to get more details? Write an e-mail with your name and company details and the keyword 'scrap preheating' to info@eco-eag.com

This new scrap preheating includes many more advantages.