# WASTE HEAT RECOVERY FOR EAF - INNOVATIVE CONCEPTS & INDUSTRIAL IMPLEMENTATION *

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**Abstract**

Over the last years, waste heat recovery in steel industry attracted more and more attention. Environmental regulations, public funding as well as required revamps of old dedusting systems lead steel plant operators to discuss and to evaluate possibilities of recovering waste heat.

The development of a waste heat recovery plant requires extensive knowledge as well as long experience of the entire plant, including water-steam cycle as well as EAF process, dedusting system and downstream waste heat consumers. Primetals provides innovative and reliable waste heat recovery solutions for EAF which are presented in this paper.

An innovative waste heat recovery plant is introduced which was installed at Arvedi / Italy. Waste heat is used to produce steam for two pickling lines, which are in a large distance to the EAF. The substitution of the existing gas fired boilers lead to a decisive reduction of operating costs of the steel plant.

A heat recovery plant was installed at steel plant Höganäs / Sweden, whereas hot water at high pressure is produced and utilized for the local district heating system.

The paper demonstrates economic opportunities for efficient waste heat recovery in EAF based steel plants and reasonable integration of the waste heat recovery system into the dedusting line.

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**Keywords:** EAF, waste heat recovery, dedusting, energy efficiency, off-gas cooling, gas cleaning

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## 1 INTRODUCTION

In the last decades the global steel production has increased continuously, driven by the big demand of growing markets and economic expansion. Nowadays, the steel demand has decreased and the global steel industry is dealing with an overproduction. Therefore steel plant operators are forced to reduce production costs and to optimize their steel making processes.
Furthermore, due to growing environmental consciousness and tightened emission control by authorities, environmental technologies and energy recovery become more and more in the focus of steel plant operators.
Energy is one of the most important cost factors for integrated iron and steel plants as well as for electric steel mills (cf. [1]). Especially the vast amount of electric energy in electric steel plants forces operators to improve the overall energy situation, in order to reduce the specific costs per ton steel and also to comply with legal requirements in terms of energy efficiency.
There are various opportunities along the steelmaking route for implementing energy efficiency measures. Smaller improvements can be implemented in terms of process optimization. Such measures can be done with a low or moderate effort.
However for a more decisive impact on the energy balance of a steel plant, bigger actions are required. By recovering waste heat a large amount of off gas energy can be utilized within the steel plant, leading to a significant reduction of energy costs. The largest amount of waste heat within electric steel mills can be found at electric arc furnaces, where approximately 30% of the total energy input is emitted to the off gas.
In the following two industrial implementations are introduced, in order to demonstrate efficient utilization of EAF waste heat. An innovative waste heat recovery system with internal heat utilization will be installed at Arvedi / Italy in 2017. Another waste heat recovery plant for external heat utilization (district heating) was installed and successfully commissioned at Höganäs / Sweden in 2016. Both systems will be presented in this paper.

## 2 DEVELOPMENT

### Basis of design for the waste heat recovery system

For the design of a heat recovery system it is crucial to have detailed information of the off gas parameter and the EAF operation. On the one hand, the maximum heat load is essential for the design of the waste heat boiler and its auxiliary equipment. On the other hand, the average heat load over one heat is relevant for the output of the system.

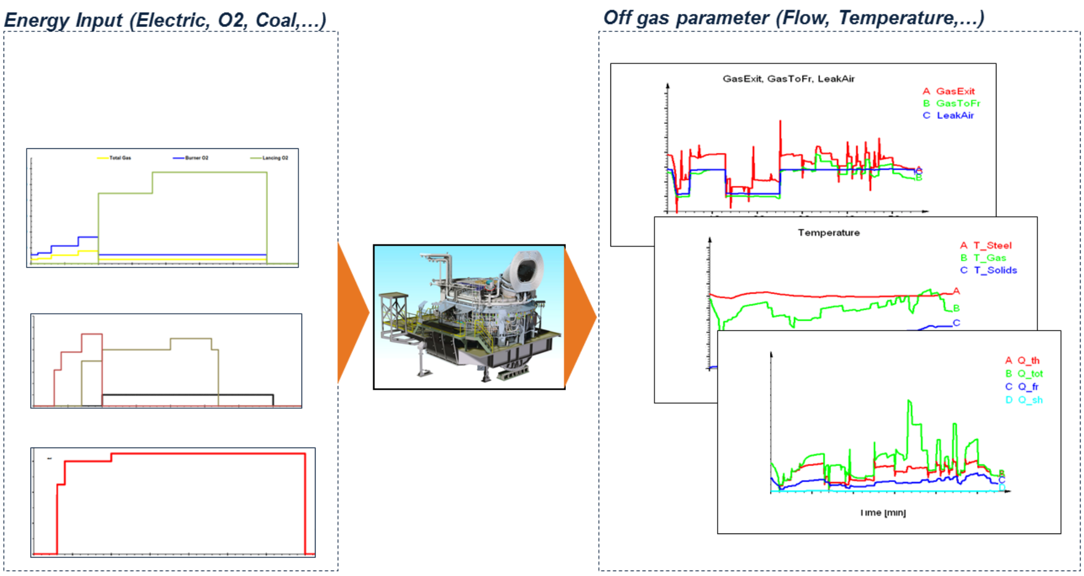


Fig 1: Dynamic calculation of off gas parameter

The dynamic off gas calculation is based on the input of raw materials and energy (e.g.: carbon injection, blowing oxygen, electric energy input) in the EAF. Therefore a special developed tool is used, which calculates all relevant furnace reactions, as well as energy and mass balances. Fig 1 shows the furnace operation on the left side (incl. raw materials, electrical and chemical energy input), and the off gas data on the right side. The calculated off gas data were used for further calculations of the dedusting, as well as the heat recovery system.

**Benefits beyond reduction of energy consumption**

Obviously, the main benefit of the waste heat recovery system is the reduction of overall energy consumption. Indeed, additionally there are several other benefits which may apply. Main benefits are listed below.

1. *Reduction of overall energy consumption*: With the newly installed system the waste heat is utilized for on-site steam production. The savings due to heat recovery helps the steel plant operator to reduce operational costs.
2. *CO2 Reduction*: Following the trend for industrial plants to reduce the carbon dioxide footprint, the heat recovery system help to reduce the demand for fossil energy.
3. *Dew point corrosion*: Higher tube wall temperatures in the cooling duct reduce the risk of sulfur corrosion, since the wall temperature is above the dew point of sulfur-oxides in the off gas.
4. *Inner corrosion*: Less inner corrosion in the water tubes occur above 200°C because of self-passivation of the tubes.
5. *Operational safety*: Heat recovery system is designed and operated under high pressure. Therefore, the design of the system must be according pressure vessel design code. This leads to the benefit that the design is according the high standard of the code and the risk of failures is minimized.
6. *Plant layout*: The footprint of the waste heat recovery system is similar to conventional dedusting cooling systems. An additional building is required for the equipment of the plant, such as pumps, tanks, heat exchangers, etc.

7. *Public funding*: Waste heat recovery technologies are in many cases funded by public authorities, since energy efficiency and environmental footprint is improved with such measures.

## Novel waste heat recovery systems for internal and external heat usage

Primetals Technologies has developed a novel solution for internal waste heat utilization within a mini mill based on an innovative waste heat recovery system. This new solution is installed at an Italian steel plant, whereas the heat is used for on-site steam production. With the newly installed system, almost the entire steam demand of the plant shall be covered. In Fig 2 a layout of the system can be found.

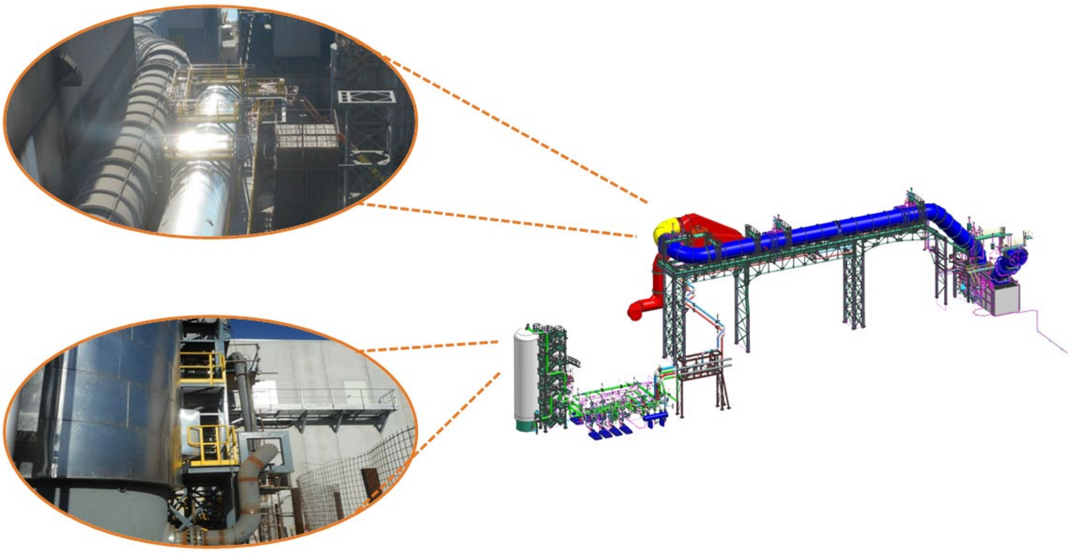

Fig 2: Waste heat recovery plant with steam generation

Furthermore a waste heat recovery system for external waste heat utilization was installed and successfully commissioned in 2016 at a steel plant in Sweden. The system is generating hot water, which is used for district heating of the nearby city. The layout of the plant can be found in Fig 3.

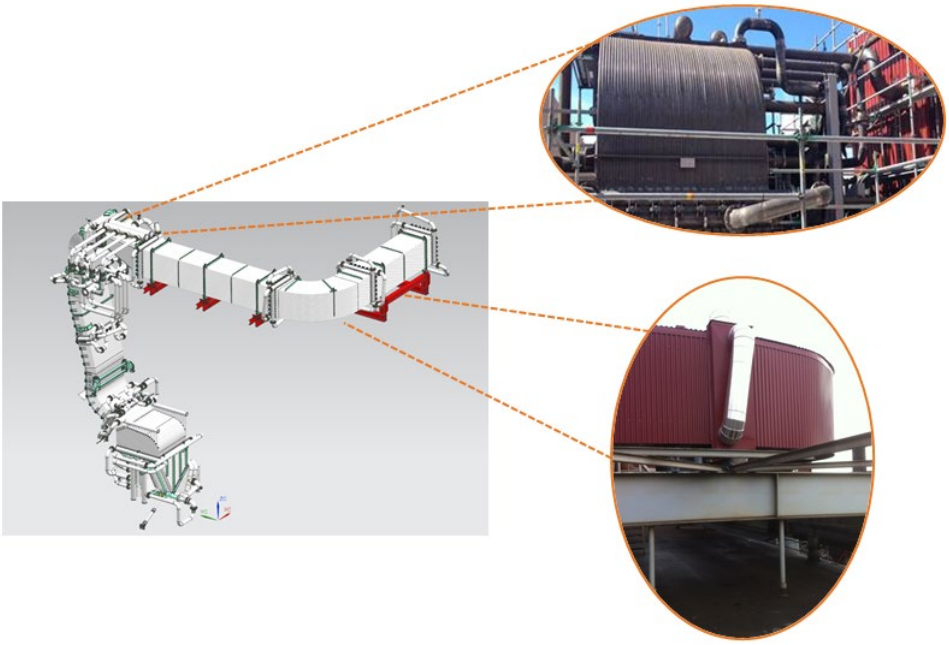

Fig 3: Waste heat recovery system with district heating applications

Both solutions demonstrate economic feasible opportunities for waste heat utilization. Primetals Technologies can provide strong support during project development and has also numerous references in waste heat recovery systems for basic oxygen furnaces. For more information regarding basic oxygen furnace cooling stack systems please refer to cf.[2].

## Utilizing recovered heat within the steel plant

The identification of possible utilization for the recovered heat is a key topic for developing a heat recovery plant, as it is strongly influencing the economic feasibility of the plant. Thus, this topic arises at a very early stage of the project development.

In contrast to integrated iron and steel plants, electric steel plants have only a limited demand for steam or heat, which makes the utilization of waste heat more challenging. Therefore electric steel plants often ask for a waste heat recovery system with power production. However, the installation of a power block requires an additional investment, which has a significant influence on the return on investment of such system. Typical consumer for waste heat recovery plants are listed below.

- Hot water production / district heating
- Chilled water production
- Electric power generation
- Steam generation for various consumers, such as…
    - Galvanizing and/or pickling lines
    - Steam ejectors for vacuum degassing plants (VD / VOD)
    - External steam consumer (e.g. sea water desalination, pulp and paper industry, other industries …)
    - Air separation plants

The respective consumers for the recovered energy have to be discussed and evaluated. For each steel plant an individual assessment of different consumers has to be done by consideration of various aspects, such as…

- Survey of on-site demand
- Economic considerations (cost-benefit calculation)
- Availability of governmental and public incentives
- Layout issues

For the innovative waste heat recovery solutions presented in the following, it turned out that hot water generation is the most efficient way of recovering the waste heat.
For the first example the hot water is turned into steam and the steam is used for both on-site pickling lines, whereas the existing gas fired boiler will bes substituted. The concept leads to a significant reduction of the overall gas consumption. The direct usage of steam without additional energy conversion unit (e.g. turbine) makes it economically attractive. Public funding for the savings of natural gas provides further economic benefits to the plant. A schematic process flow diagram with focus on the energy flows is given in Fig 4.

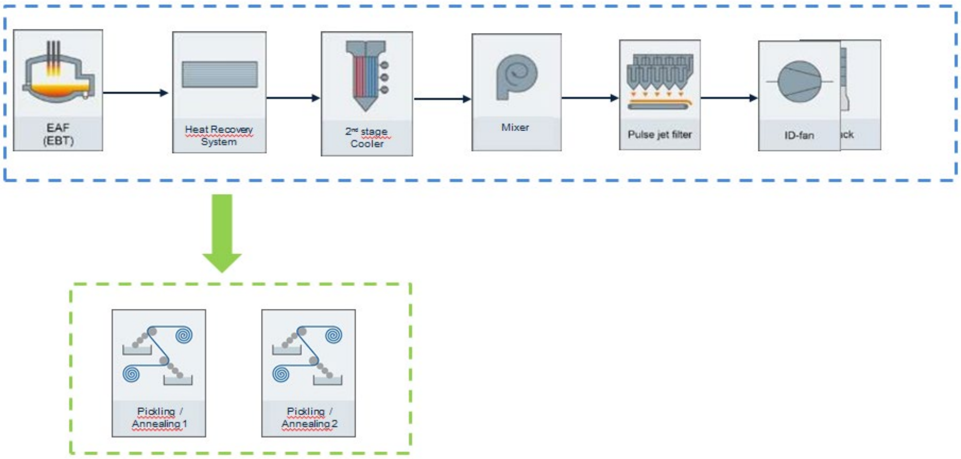


Fig 4: Steam generation for on-site pickling lines

In the other case a system was developed, were the recovered energy from the EAF off gas is used for district heating. Thus, hot pressurized water is fed to the district heating network of the neighbouring city. The hot water provided to the city gives an additional benefit for the steel plant operator.

**Innovative waste heat recovery systems based on hot water for efficient off gas cooling**

The water cooled hot gas line is operated at elevated pressure to avoid steaming of the cooling media. Thus, the entire cooling system is operated in liquid phase. This means that the off gas cooling is done in the same way as conventional hot gas lines, but at higher temperatures. In order to comply with pressure vessel design code, the entire system is designed accordingly.
A schematic overview of the system is given in Fig 5. In case of high heat supply of the EAF, water is fed to the storage tank and to the pickling lines. During EAF idle times, water is fed to the steam generator from the storage tank. In case of no steam consumption at the pickling lines, an additional heat exchanger is installed in order to ensure continuous EAF operation.

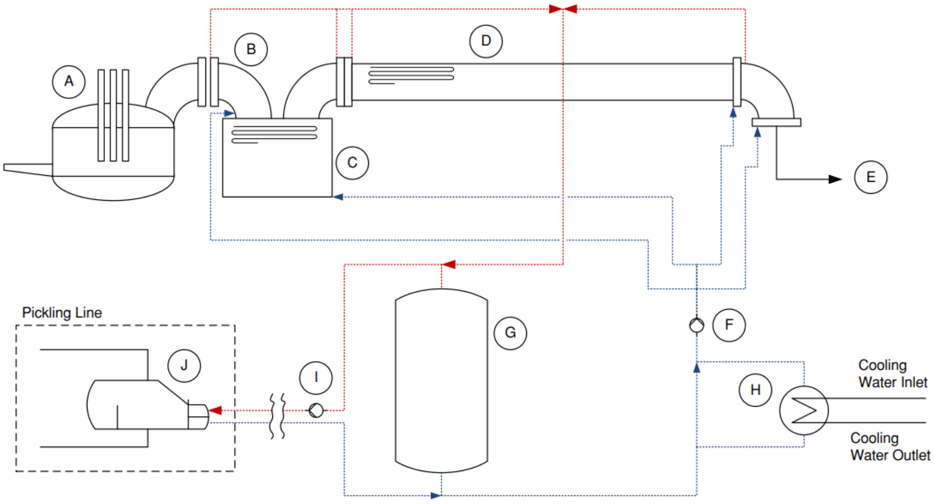


Fig 5: Schematic overview of the waste heat recovery system

Main advantage of the system is the simple duct routing, as well as similar layout compared to conventional cooling systems. The recovered heat can be transported in form of hot water to far-away consumer.

**Steam generation at pickling lines**

For the steel plant in Italy, the recovered energy is used for steam generation. Thus, the hot water is fed to two different pickling lines at a distance of 1,5 and 0,5 kilometre. The large distance between heat recovery system and consumer is covered by long piping throughout the entire steel plant. A layout of the pipeline system is given in Fig 6 and demonstrates that even long distances throughout the steel plant can be handled.

Steam generators are installed, which are heated by the hot water from the waste heat recovery system. Thus, feed water is fed to the steam generator and is evaporated. In parallel, hot water is cooled down by transferring heat to the water/steam side. The cooled water is fed back to the heat recovery system. The produced steam is enough to substitute the existing gas fired boilers.

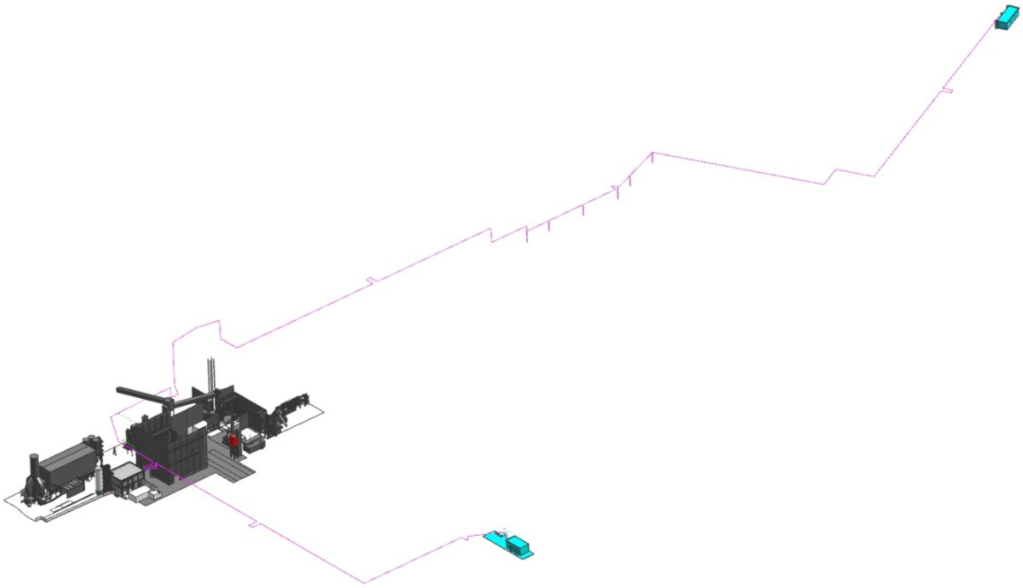

Fig 6: Heat supply to pickling lines

**Heat supply for district heating**

In the other case, hot water is used for district heating applications. Therefore the recovered energy from the hot water system is transferred to the district heating network via a heat exchanger. A buffer tank is used to compensate the fluctuations of the hot water production and to provide a continuous water supply to the district heating system. From the heat recovery system, hot water is fed to the district heating network via long pipelines.
District heating is an interesting option for steel plants which are situated close to a city where a district heating network is already installed. Since the supplied heat from the mini mill is typically low compared to the heat demand of larger cities, steel plants can provide the heat over the whole season and not only during winter times to provide the base load for hot water consumers. Furthermore, this utilization concept helps steel plant operators to strengthen their green reputation.

**From EAF batch process to continuous heat supply**

Electric arc furnaces are operated batch wise and the process is highly fluctuating. Furthermore, EAF off gas does not correspond directly to the energy input and the charged material in terms of flow, temperature and composition. Sudden occurring combustion of CO gas due to combustion of oil from a collapsing scrap bulk is causing further unexpected peaks.
On the other hand, downstream heat consumers require a more or less continuous input. Even though load changes can be handled in a certain range, the highly fluctuating and unexpected heat load from the EAF would make efficient heat recovery systems impossible.
Therefore a storage tank is foreseen to buffer the discontinuous heat supply. During high heat load from the EAF, hot water excess is fed to the storage tank. In idle times or low heat loads, hot water from the storage tank is fed to the consumer, in order to provide a continuous output.
The dynamic of the system through the EAF process plays an important role for the design of the system. Load changes, storage capacity and temperature gradients

were investigated intensively during the design phase. The dynamic behaviour of the system regarding process control was simulated with an advanced process simulation software. The simulation results were used to optimize the waste heat recovery system design, as well as process control strategy and fail-safe operation.
Results of the simulation, indicated in Fig 7, shall exemplary show particular plant areas which were investigated in detail. The dynamic behaviour of mass flows, temperatures and pressure were used to optimize the design and the control system of the plant, in order to meet the demands of an integrated waste heat recovery plant.

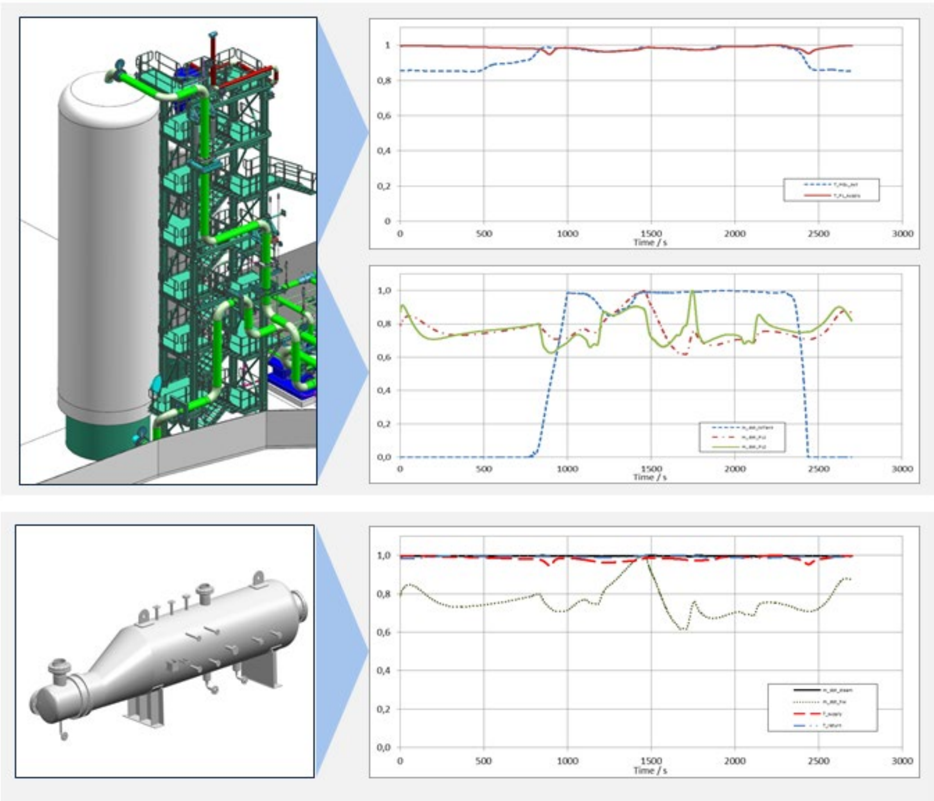


Fig 7: Dynamic simulation of waste heat recovery system

## 3 CONCLUSION

Waste heat recovery from EAF has a large potential to reduce the overall energy costs and to create additional benefits for steel plant operators. However, due to the characteristic of the EAF and the specific off gas conditions, as well as the plant situation and layout, a holistic plant view is required to develop a tailor-made solution for a waste heat recovery plant.
This paper shows that there are opportunities within EAF steel plants for turning waste heat into value. The present examples demonstrate reasonable possibilities for internal steam usage and therefore high economic efficiency. Furthermore, specific external waste heat consumers like district heating networks can make heat recovery attractive.
Waste heat recovery solutions can help steel plant operators to create an economic benefit out of their dedusting system.

## Acknowledgments

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