

**ECOPLANTS TECHNOLOGIES .**  
**REVOLUTIONARY CONTINUOUS S/EAF-PROCESS**  
**AND INNOVATIVE ENERGY RECOVERY SOLUTIONS**

BY

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SYNOPSIS:

Metallurgical processes generate either hot and / or combustible exhaust gases which can be used for **Energy Recovery**.

Along the process chain from steelmaking plants to processing lines we can find several process steps where heat is required and waste heat as well as combustible gases are also generated. Therefore SMS Siemag developed several technical solutions to recover the energy from

- hot off-gas (BOF, EAF, SAF) by evaporation cooled ducts or tailored waste heat boiler solutions
- hot slabs by innovative heat exchangers
- combustible exhaust gases by industrial power plant technologies

The revolutionary **ARCESS® steady EAF (S/EAF®)** is the combination of best practice EAF and SAF technologies and enables the continuous (!) operation of the electric arc furnace. This leads to a 30% higher productivity with lower energy consumption. By continuous charging virgin DRI (hot or cold) or pig iron high quality steel grades can be produced.

In addition we offer a holistic **Energy Management System** supporting plant managers to detect current potentials and maintain them in long term.

**Keywords:** Steel making, energy recovery, process gas, SAF, EAF, converter, steam boiler, energy efficiency, energy management, environment

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## 1. Energy Recovery from hot exhaust gases

Along the process chain from steelmaking plants to processing lines we can find several process steps where heat is required and waste heat is also generated.

For example up to 40 per cent of the energy spent in electric steelmaking leaves with the hot off-gas as sensible heat. Due to technical reasons, it is absolutely essential to cool down the primary off-gas from some 1,200°C to values below 250°C. By using our technologies, plant managers can recover up to 85 % of this wasted energy and improve their energy- and environmental balance instead of consuming electrical energy for the operation of cooling cycles. Similar proportions also apply to the processes in the SAF, CONARC and BOF or AOD converter. Compared to a BOF converter, the thermal off-gas energy of an EAF is more than two times higher related to the liquid steel quantity.

Conventional off-gas ducts are cooled by water that circulates through membrane walls. The cooling water itself flows through a heat exchanger . the thermal energy remains unused. In order to make use of this energy, SMS Siemag developed an energy recovery system that produces steam by means of an evaporation-cooled off-gas duct. The steam can be used for different technical purposes. Common applications are power generation in steam turbines, driving vacuum pumps, running a seawater desalination unit or feeding the steam into an existing network. The extent of economic benefit depends on the individual plant.

For BOF melt shops, evaporation-cooled off-gas ducts are well-known. For other metallurgical melting units, however, this is an innovative technology. Our customers have become aware of this opportunity to maximize energy utilization.

This is why ETI KROM, a ferrochrome producer from Turkey, ordered such an energy recovery plant that will be connected to two SAFs and supplies the steam to a 5-megawatt turbine. ETI KROM expects an amortization period of less than four years.

Fuxin Special Steel has placed an order with us for the engineering and supply of a steam generation plant that uses the off-gas heat at AOD converter and EAF . the world first installation of this kind.

Figure 1 shows the typical off-gas treatment setup of an EAF. The hot off-gas downstream the EAF can be used from approximately 1,200°C down to 700°C by constructing the swivel duct, the post-combustion chamber and off-gas duct as evaporation cooled system. By installing an additional waste heat boiler also the temperature from approx. 700° down to 250 °C can be used for steam generation.

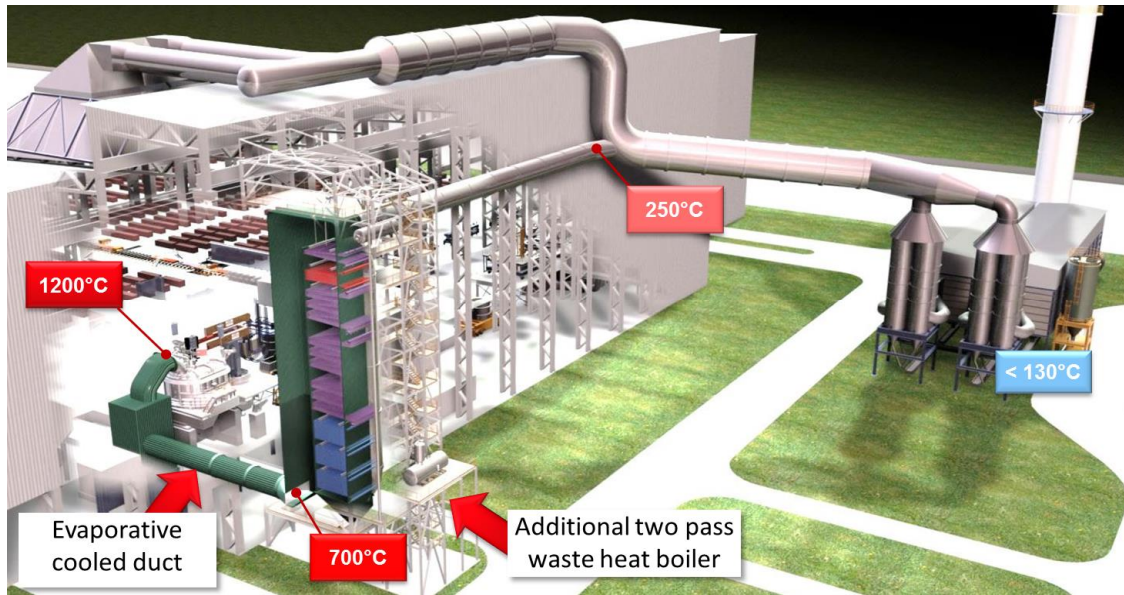


Figure 1: Typical temperatures in an EAF

In a low-pressure circuit the feed water is heated up to approx. 130 °C by cooling the movable off-gas elbow of the gas duct. This heat is used for deaerating the feed water. The pressurized water coming from the feed-water tank is pumped into the economizer, which is connected to the steam drum. The boiling water is circulated by pumps on natural circulation through the cooling surfaces of the off-gas system and partly evaporated.

This water-steam mixture is routed back to the steam drum and separated there. The discontinuous amount of steam generated in the EAF batch process is temporarily buffered in accumulators and delivered to the steam consumers. A typical 150 tons EAF will generate an average steam flow of approx. 40 tons per heat at a gauge pressure of 25 bar (charging material: 100% scrap). Steam generated in this way is always saturated steam. Due to rising energy costs, this proven technology depending on steam utilization, generates a low amortization time.

## 2. Energy Recovery from hot slabs

The continuous casting process is per se an energy elimination+process. Liquid steel is cooled down (figure 2) . first into solid phase and later mostly to room temperature (slab yard). The energy is extracted by cooling water or transferred to the environment via radiation or convection.

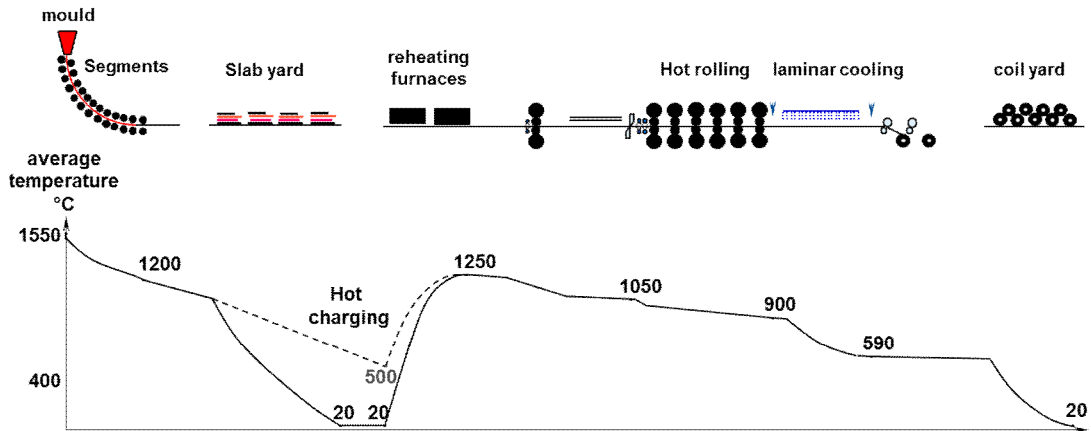


Figure 2: Characteristic steel temperatures during casting and hot rolling

Hot charging is of course the best way to save energy. The usage of isolated slab conveyers is a practicable solution for this purpose. Furthermore these boxes can avoid building of cracks especially for crack vulnerable steel grades.

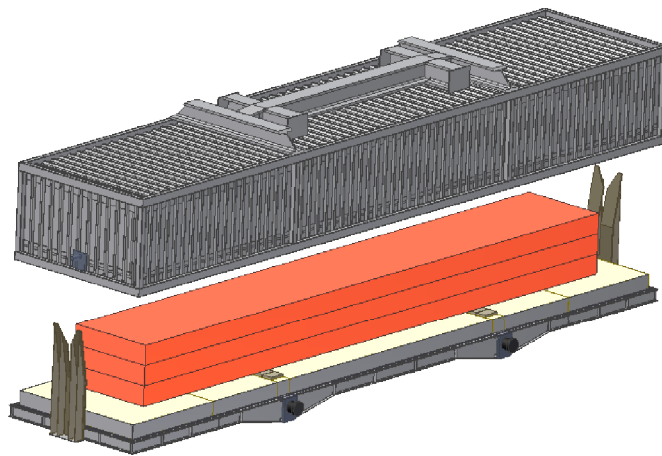


Figure 3: Isolated slab box for hot charging

Nevertheless hot charging cannot be realized in many plants. Therefore we developed and patented an innovative but simple, flexible and modular system to recover the energy.

After being cut the slabs are not moved to the slab yard crane as fast as possible but remain under heat exchangers as long as the next slab arrives. Within the new

setup, slabs stay on the roller table until the following slab arrives. The Energy Recovery System (figure 4) consists of heat exchangers which are installed above the roller table. They collect the thermal radiation of the approx. 800° - 900° hot slabs (surface temperature) and transfer it to a heat transfer medium. In this temperature window the slabs emit ca. 45 - 65 kW/m<sup>2</sup> energy.

In a first application one module will generate saturated steam with an energy content of nearly 2 MW<sub>th</sub> (8 gbar). This steam will be inducted via a check valve into the works network. Additional modules can be installed easily.

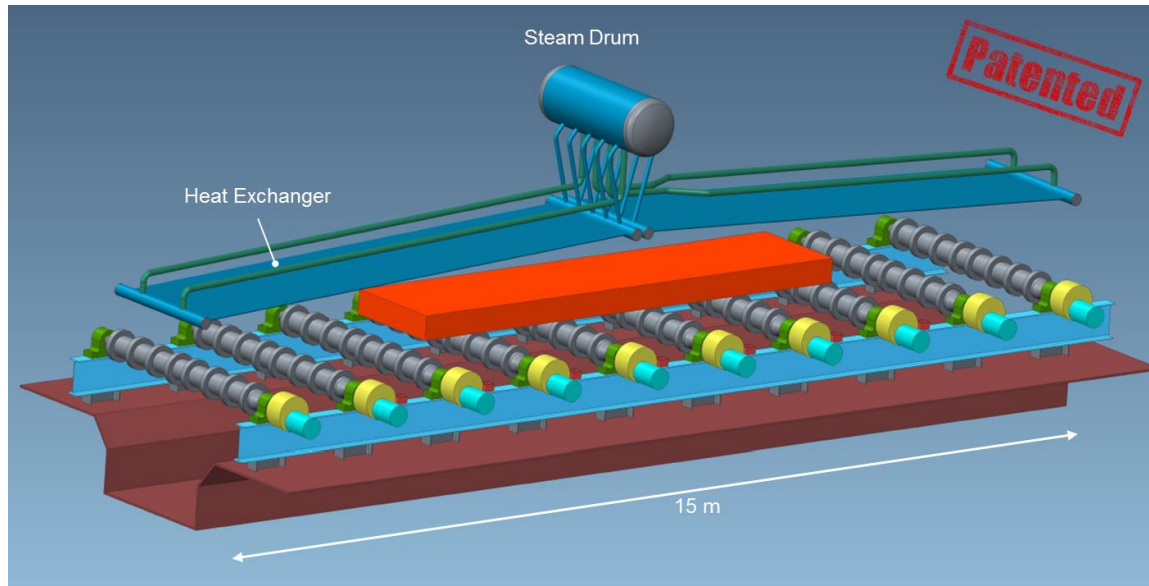


Figure 4: Patented design of the hot slab energy recovery system (1 module)

The major targets for the design of the whole system are:

- No negative influence of the steel production process
- High reliability (and nearly maintenance free design)
- Flexibility (modular design for easy extension)
- Cost effective design for high economic benefit

The amortization time highly depends on the utilization concepts of the steam (or other heat transfer media) but can reach 1 - 2 years.

### 3. Usage of exhaust gas

The large range of gaseous byproducts as blast furnace gas, coke oven gas and converter gas have a high energy content in terms of combustible components. Utilizing these gases as primary fuel in an industrial power plant contributes significantly to increased energy efficiency in steelworks and therefore reduces the overall steel manufacturing costs and saves CO<sub>2</sub> emissions (up to 55 kg per 1 ton steel).





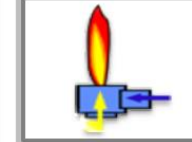
				
<b>Coke oven gas</b>	<b>FeMn SAF gas</b>	<b>Blast furnace gas</b>	<b>Converter gas</b>	<b>Natural gas</b>
LCV =16-18 MJ/m <sup>3</sup> 1.7-2m <sup>3</sup> COG replaces 1m <sup>3</sup> Natural gas L	LCV apr. 11.4 MJ/m <sup>3</sup> 2.7m <sup>3</sup> SAF gas replaces 1m <sup>3</sup> Natural gas L	LCV =2.5-3.3 MJ/m <sup>3</sup> 10-12m <sup>3</sup> BFG replaces 1m <sup>3</sup> Natural gas L	LCV =7-8.4 MJ/m <sup>3</sup> 3.5-4.5m <sup>3</sup> CG replaces 1m <sup>3</sup> Natural gas L	LCV = 31.4 MJ/m <sup>3</sup>
650-750 m <sup>3</sup> /hr COG per 1 MW <sub>el</sub>	Apr. 990 m <sup>3</sup> /hr SAF per 1 MW <sub>el</sub>	3,700-4,900 m <sup>3</sup> /hr BFG per 1 MW <sub>el</sub>	1,400-1,700 m <sup>3</sup> /hr CG per 1 MW <sub>el</sub>	

Figure 5: Specific values for different process gases

For the systematic utilization of these gases, e.g. to generate steam for production and/or to generate electricity in a complete power station process, SMS Siemag offers a wide range of part-standardized steam generators. In this context SMS Siemag focuses on taking into account the many demands that influence the choice of steam generator type. Examples for these requirements are:

- É Low Emissions
- É Wide range of fuels
- É Compact design
- É Fast starting capability
- É Flexibility
- É Variable and fixed-pressure mode
- É Daily start/stop
- É High availability
- É High cost-effectiveness

The SMS Siemag range comprises suspended or self-supporting natural-circulation steam generators with high to top outputs:

- Live steam pressures up to 160 bar
- Live steam temperatures up to 540°C
- Up to 150 MW<sub>el</sub>

We supply single or multi-pass types that can be adjusted to a wide variety of tasks . figure 6 shows the scheme of a typical two-pass steam generator.



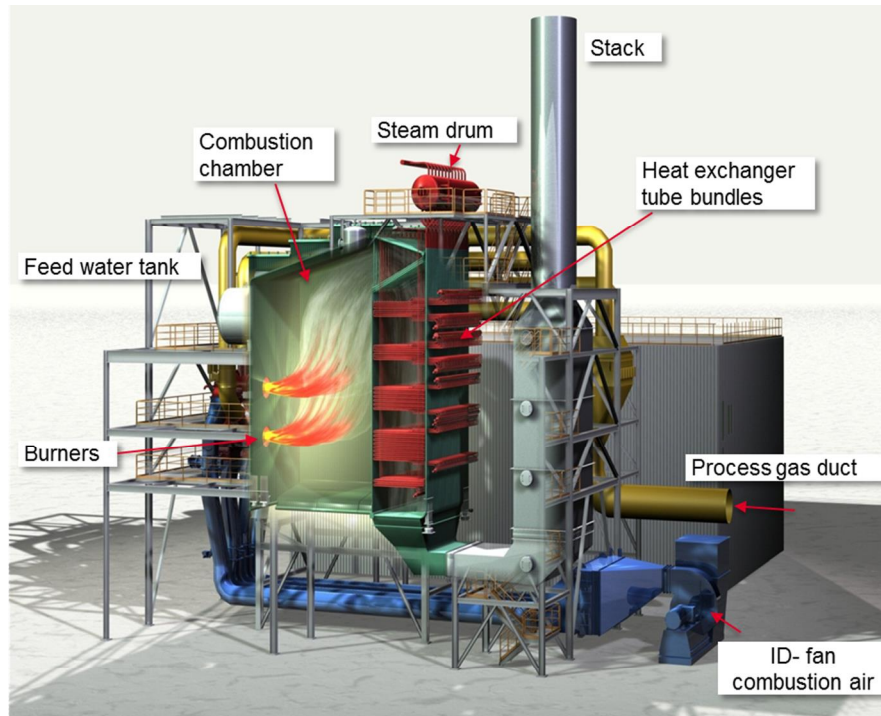


Figure 6: Typical two-pass steam generator

Existing plants have a high potential for the optimization of air- and fuel supply. Low calorific gas burners often operate with conservative combustion parameters that are highly prone to failures, which lead to fatal downtimes. Our experts have the required Know-how to optimize these burners and to ensure smooth operations.

Beside the installation of complete steam generators a lot of maintenance and services for boilers has to be done. SMS Siemag is specialized on the issues mentioned in figure 7.

Maintenance	Modification	Engineering
<ul style="list-style-type: none"> <li>▪ Maintenance</li> <li>▪ Inspection</li> <li>▪ Repair work</li> <li>▪ Revisions</li> <li>▪ Service-contracts</li> <li>▪ Replacement 1:1</li> <li>▪ Spare parts</li> </ul>	<ul style="list-style-type: none"> <li>▪ Plant upgrades/ Retrofit</li> <li>▪ Performance improvement</li> <li>▪ Emission reduction</li> <li>▪ Efficiency improvement</li> <li>▪ Firing system upgrades</li> <li>▪ Life time calculation</li> <li>▪ Plant behaviour</li> </ul>	<ul style="list-style-type: none"> <li>▪ Engineering( case studies, feasibilities)</li> <li>▪ Supervision</li> <li>▪ Commissioning</li> <li>▪ State Examinations</li> <li>▪ Measurement + Analysis</li> <li>▪ Monitoring-Systems (Level 1 &amp; 2)</li> </ul>
		

Figure 7: Portfolio of Boiler Services

#### 4. ARCESS<sup>®</sup> steady EAF (S/EAF<sup>®</sup>)

The electric arc furnace (EAF) is the core unit of an electric steelmaking plant and has a decisive impact on annual production and energy costs. A new development from SMS Siemag is the ARCESS<sup>®</sup> steady EAF (S/EAF<sup>®</sup>), which allows true continuous operation for up to one week (figure 8). The S/EAF has been newly developed from scratch and combines innovations with proven technology. This technology arises from SMS Siemag's long-standing experience in the fields of submerged-arc furnaces (SAF) with over 300 references, electric arc furnaces (EAF), with over 1,300 references and CONARC technology.

The result is a new type of electric arc furnace, yielding a 30 percent higher productivity with lower energy consumption thanks to its reliable continuous process. Depending on the raw material mix, the S/EAF is individually designed to cover a wide range with capacities known from standard EAFs up to several hundred tons.

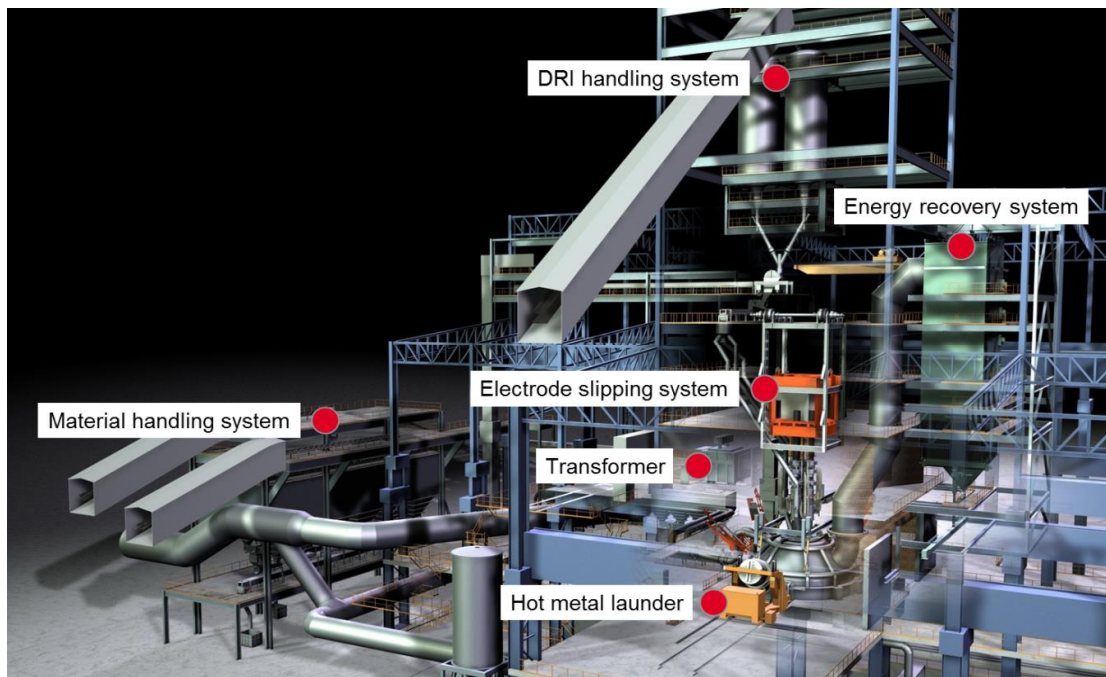


Figure 8: Illustration of the steady EAF (S/EAF) overall setup

##### **Plant technology for continuous operation**

In the evolution of EAF technology, various approaches for different charge materials have been made to realize a process that runs as continuous as possible. A continuous process sequence generally is advantageous in regard of economic reasons. For example, it reduces wear of refractories and makes it possible to save costs due to the uniform consumption of electric energy.



To produce high-quality steel for flat products, electric arc furnaces that are charged with direct-reduced iron (DRI) gain special importance. The charge mix can partly or completely consist of DRI. SMS Siemag developed a new type of electric arc furnace . the steady EAF (S/EAF) . that is most efficient for the continuous charging of DRI. With this solution, the idea of a continuously operated EAF turns into reality.

Due to the fact, that the S/EAF can be operated continuously, it is specifically suited for the direct charging of hot DRI with temperatures up to 600°C. Cold DRI and hot briquetted iron (HBI) can be charged as well in case the direct reduction plant is not in service. With optional equipment the S/EAF can also be charged continuously with shredded scrap or hot metal.

All components have been designed and rated to allow continuous operation for around one week with the power on. This steady and uniform operation under power-on sets new standards for the economic use of electric energy. It also prevents negative feedback on the electricity grid (for example flickers) due to the prevention of switching the power on and off.

Uninterrupted operating practice is made possible by a patented system derived from SAF technology, which allows the electrodes to be clamped and slipped continuously. Whenever an electrode has been used up, a fresh piece of electrode is joined on at its end. Both operations take place under power-on.

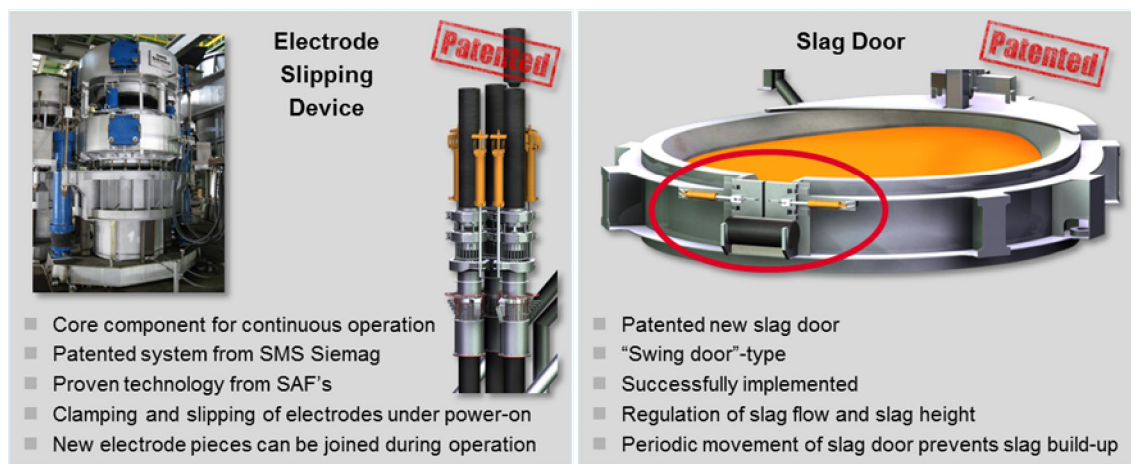


Figure 9: Patented technology . electrode slipping device and swinging slag door

The quantum leap towards the real continuous operation of an electric arc furnace is realized by the elimination of non-productive power-off times for tapping and electrode handling. Furthermore, the S/EAF is equipped with a patented tapping system that allows for slag-free tapping with the power on.

The refractory lining concept is adapted for continuous operation. It reduces maintenance times to a minimum.

The geometry of the new furnace shell has been optimized accordingly and comprises a flat lower shell and a conical furnace roof placed closely on top.

Water-cooled oxygen blowing lances are introduced through the furnace roof. This technology has been adopted from CONARC<sup>®</sup>, a furnace unit developed by SMS Siemag with the aim to rapidly decarburize melts with high carbon content. The O<sub>2</sub> lances are mounted on a slide mechanism that makes it possible to adjust the proper distance to the melt. This ensures an optimum distance of the de-Laval nozzles and efficient penetration of the supersonic oxygen jets. By these means high decarburization speeds can be realized and excessive splashing of steel or slag is prevented.

During de-slagging the slag flow can be controlled by a novel slag door that is designed as swinging door-type. The rigid movable leaves keep the slag door area free from the deposit of slag.

To ensure a high availability of the S/EAF furnace system, it is equipped with a vessel quick-exchange system. When a new refractory relining is required, the complete lower shell is driven to a maintenance stand and replaced by a freshly relined vessel. This procedure is realized by a vessel exchange car. Thereby, heavy-duty gantry cranes with elaborate building structures and foundations are not needed. Investment costs for this equipment can be reduced by 25 percent.

In contrast to conventional electric arc furnaces, the S/EAF high-voltage system is not realized with a three-phase transformer but with three single transformers that are star-connected in an angle of 120 degrees. This design allows an arrangement around the furnace that is advantageous in regard of a very good symmetry of the secondary electrical system. Furthermore, short distances of the high-voltage system can be realized.

### **Process sequence**

Figure 10 shows the process sequence of the S/EAF in comparison to a conventional electric arc furnace for a 100 percent hot DRI scenario. The S/EAF is operated with maximum input of electric energy for about 90 percent of the time. During this phase, hot DRI is continuously charged. Simultaneously, carbon and oxygen are injected to build up a good foamy slag layer. Only during the last minutes shortly before tapping, hot DRI feeding is interrupted to superheat the melt to the appropriate tapping temperature and to reliably adjust the proper carbon content.

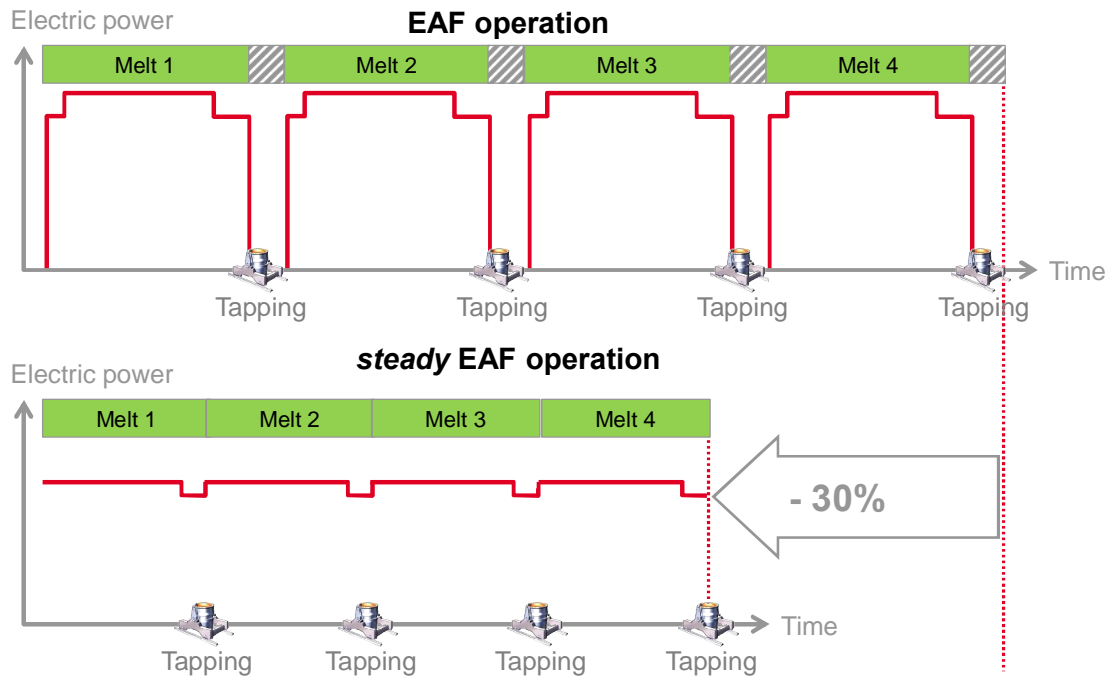


Figure 10: Process sequence of the S/EAF compared to a conventional EAF

At the end of this phase, slag-free tapping takes place under power-on with slightly reduced power input. As soon as the ladle is ready filled, DRI charging can be resumed into the hot heel with maximum power level.

### Energy recovery and furnace off-gas system

The whole off-gas system has been designed to meet the continuous process of the S/EAF and its steady-state operation. The process-related boundary conditions are very similar to the circumstances that can be found at submerged-arc furnaces. As far as volume flow rate and temperature conditions are concerned, the implementation of an energy recovery system is perfectly suited to make use of more than 50 percent of the thermal off-gas energy.

Due to continuous S/EAF operation, the off-gas temperature stays the same for a long period of time. This fact makes it possible to realize an off-gas system that features a continuous steam generation unit to recover the thermal energy of the hot fumes. These are routed through an energy recovery system (ERS) that generates superheated steam and serves for the necessary cooling of the off-gases from 1.200°C down to 200°C.

Superheated steam is a valuable medium that can be used for various applications within the steelmaking plant to improve overall energy efficiency. Possible applications . among others . are the propulsion of vacuum pumps for VD plants, air conditioning, serving a steam network or generating electric energy. The benefit depends on the individual plant configuration.

In an exemplary configuration, power generation via a turbine-generator unit makes it possible to drive a unit with an electrical output of 20 MW (for a 250-t S/EAF configuration). Other applications even yield higher recovery rates.

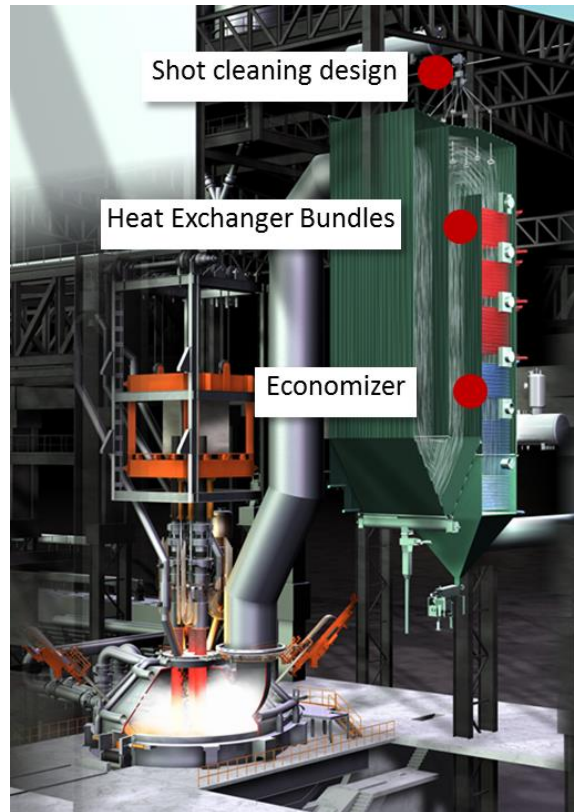


Figure 11: S/EAF energy recovery system

As the S/EAF can be connected to a primary gas cleaning system only, it can be targeted to the very special purpose of off-gas treatment independently from the secondary fume extraction system.

### **Influence on investment costs**

The permanently closed furnace makes it possible to abandon the canopy hood for secondary fume extraction. The primary off-gases are extracted directly from the furnace by means of a fume elbow. A furnace enclosure reduces noise and fugitive secondary fume emissions to a minimum. This results in a dramatically reduced off-gas volume. The downstream gas cleaning plant can be dimensioned for much smaller flow rates. Again, this fact reduces investment costs and marks a new level of environmental compliance. As mentioned before, cranes and civil structures can be designed a cost-saving way.

## Benefits from steady EAF technology

The performance figures of the S/EAF show a productivity that is up to 30 percent higher compared to a conventional electric arc furnace. To achieve the same annual production capacity, it is possible to realize a plant configuration that reduces investment and operational costs at the same time. The following table shows the essential design data for an S/EAF with a rated production of 2.2 million tpy in comparison to a conventional electric arc furnace with the same annual production capacity. Both cases represent 100 percent hot DRI as charge material. The elimination of non-productive times makes the decisive difference.

	Unit	EAF	S/EAF	Δ
Productivity	m. tpy	2.2	2.2	
Transformer Capacity	MVA	250	200	-20%
Tapping Weight	t/heat	200	180	-10%
Vessel Diameter	mm	10,500	8,700	-17%
Electrode Diameter	mm	750	610	-19%
Tap-To-Tap Time	min./heat	41	38	-7%
Electrical Energy Consumption	kWh/t	420	400*	-5%
Crane Capacity	t	450	190	-58%

\* Additional 100 kWh/t by using the energy recovery system for power generation

Figure 12: Comparison of EAF and S/EAF Process

Compared to the conventional EAF, the S/EAF allows to realize a transformer capacity that is 20 percent lower. With respect to the refractory wear index (RWI), the S/EAF can be designed with a vessel diameter that is almost 20 percent smaller. This solution enables the use of electrodes with smaller diameter and has major influence on operating costs. The minimization of process interruptions yields a reduced consumption of electric energy.



## 5. Energy Management

Rising energy costs, limited capabilities and political requirements call for an integrated Energy Management, to strengthen future competitive advantages and keep the production efficient and at minimum cost.

The X-Pact® Energy Advisor is a holistic Energy Management System and supports plant managers to detect current potentials and maintain them in long term. It is the essential tool for tackling this growing challenge and bringing the energy costs constantly down. Moreover, the X-Pact® Energy Advisor can be integrated easily in any corporate-structure and assists with the certification to DIN EN 16001 and DIN ISO 50001.

Further Advantages:

<b>Reduced energy costs</b>	due to continuous monitoring and utilization of savings potentials identified
<b>Competitive advantages</b>	due to increased efficiency and reduced energy input
<b>Enhanced cost-effectiveness</b>	due to simple calculation of efficiency measures
<b>Increased transparency</b>	due to a clear-cut presentation of all energy-relevant data in a single system
<b>Evaluation of energy efficiency</b>	due to analysis of variables and application of key figures
<b>Early warning system</b>	due to direct notification by email or text message
<b>Increased production stability</b>	due to early recognition of errors with the help of ratio figures
<b>Documentation and reports</b>	on energy-relevant procedures, for use in internal and external audits

Figure 13: Advantages of our X-Pact® Energy Advisor

Our competent Energy Consulting Team provides expert advices with regard to energy efficiency. Energy costs can be reduced in three steps:

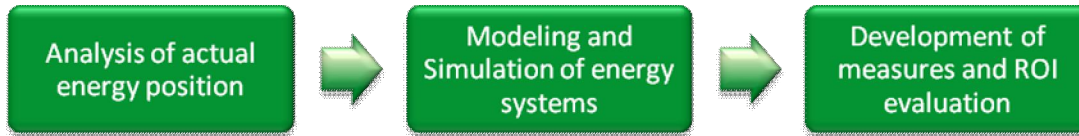


Figure 14: Reduction of energy costs

The creation of energy concepts for existing plants and Greenfield projects is another important subject of our consultancy expertise. Moreover we assist with the certification process to DIN EN-Standard 16001.



Figure 15: Our new **ecoplants** logo

The new **ecoplants** label is our new identification symbol for sustainable solutions by SMS Siemag. The connection of sustainability and economic growth is the result of our four **ecoplants**- criteria:

Significant reduction in the use of raw materials

Significant reduction in the use of energy and operating media

Significant reduction in emissions

Significant improvement in the recycling quota