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**COREX<sup>®</sup>**  
EFFICIENT AND ENVIRONMENTALLY  
FRIENDLY SMELTING REDUCTION

# ECONOMICALLY AND ECOLOGICALLY HOT METAL PRODUCTION

## YOUR CHALLENGE

The conventional blast furnace route is too costly and energy-intensive to keep pace with dynamic market changes, where even short- and medium-term fluctuations show their dramatic impact on iron production. The need to use coke and sinter makes it much more difficult to fulfill ever stricter environmental regulations and achieve economical competitiveness based on long-term sustainable growth. Rising energy demand, continuous price increases for natural gas and raw materials, and steadily decreasing quality of iron ore due to the global resource depletion are formidable challenges today. Radical changes are inevitable and are forcing operators to revamp their production routes and explore promising solutions to continue developing their iron making business successfully and responsibly.

## OUR SOLUTION

Corex is besides FINEX® the only reliable alternative to the conventional blast furnace route. It frees from the need to invest in the erection, operation and maintenance of coking and sinter plants because these additional facilities are not needed at all. Because it combines two decisive advantages, adaptable energy management/production and outstanding ecological compatibility, Corex provides you with the key technology for producing hot metal in an economically and ecologically sustainable manner. The ability to use a wider spectrum of raw materials with Corex will make you less dependent on price trends for raw materials. As an industrially and commercially proven solution, it already provides a number of plant operators worldwide with all the advantages to fulfill prospective requirements for the iron and steel industry. And how well prepared are you?

## ADVANTAGES OF COREX

- **Product quality** – hot metal quality suitable for all steel applications
- **Economic benefit** – low investment and operational costs due to the elimination of coking and sinter plants
- **Ecologic benefit** – lowest process-related emission rates
- **Resource preserving** – use of a wide variety of iron ores and especially non-coking coals
- **Beneficial by-products** – generation of a highly valuable export gas for various purposes (electric power generation, DRI production, or natural gas substitution)

COKING PLANT

SINTER PLANT

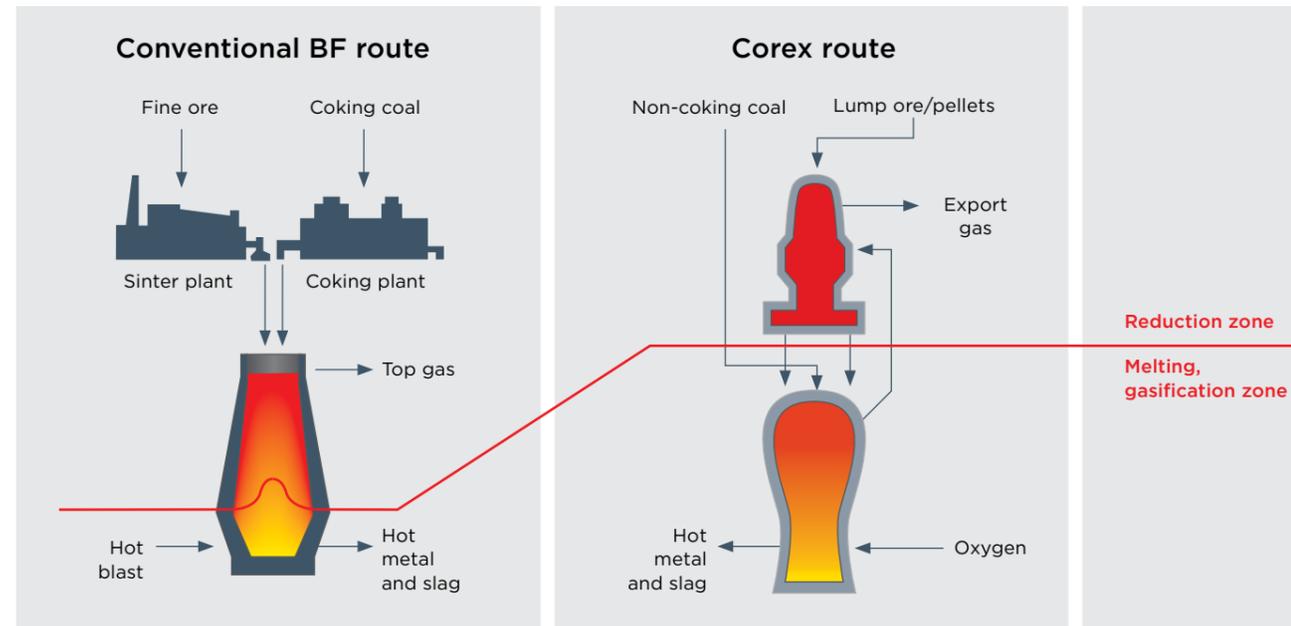
BLAST FURNACE

COREX

The Corex process combines coking plant, sinter plant and blast furnace into a single iron making unit.

# COREX

## THE ALTERNATIVE TO THE CONVENTIONAL BLAST FURNACE ROUTE



The reduction process of Corex

### MAIN DIFFERENCES FROM THE BLAST FURNACE ROUTE

The main differences between Corex and a conventional blast furnace route are:

- Non-coking coal can be used directly as a reducing agent and energy source
- Up to 80% of the iron oxide fraction can be lump ore; no sintering is required
- Pure oxygen instead of nitrogen-rich hot blast

### DIRECT USE OF NON-COKING COAL

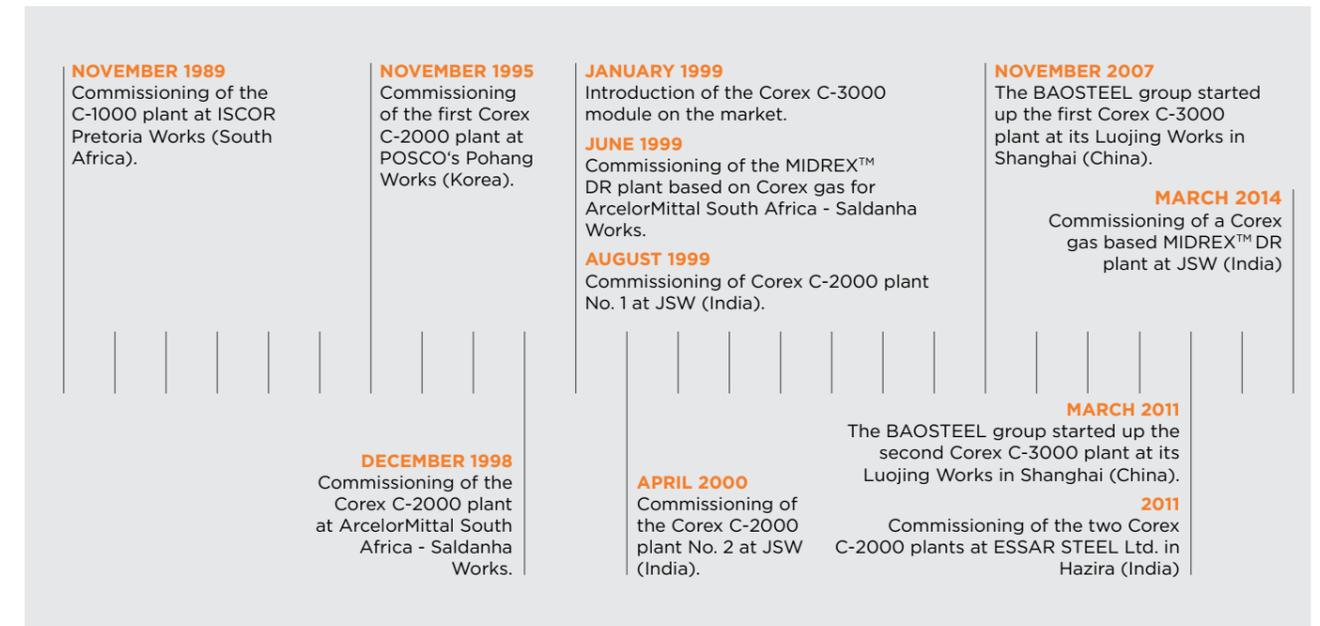
As the coal is charred inside the melter gasifier, even non-coking coal can be used, making a coking plant unnecessary. The high dome temperature exceeds 1,000°C, resulting in entire cracking of the coal's relieved hydrocarbons and avoiding the formation of tar.

### HIGH FRACTION OF LUMP ORE

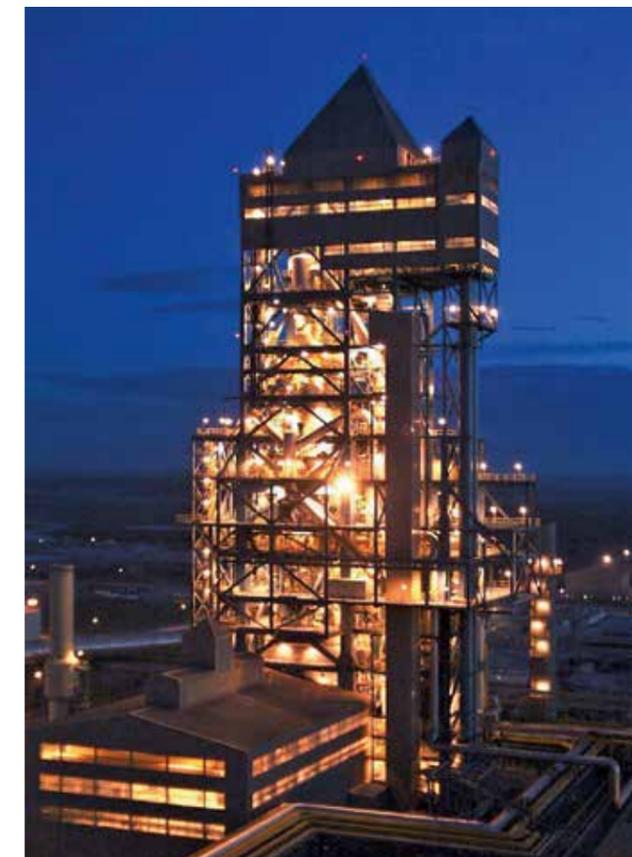
The typical iron oxide mix for Corex is 30% lump ore and 70% pellets. Operational results proved stable operations with a lump ore fraction up to 80%. In addition, no sinter – and therefore no sinter plant – is necessary for optimal operation.

### USE OF PURE OXYGEN

While blast furnace operators aim to enrich the hot blast with oxygen, Corex already uses high-purity oxygen, resulting in nearly nitrogen-free top gas. Due to its high calorific value, this gas can be recycled for reduction work or used for heat or energy generation. Depending on the steelworks demand, additional value can be created with the produced gas.

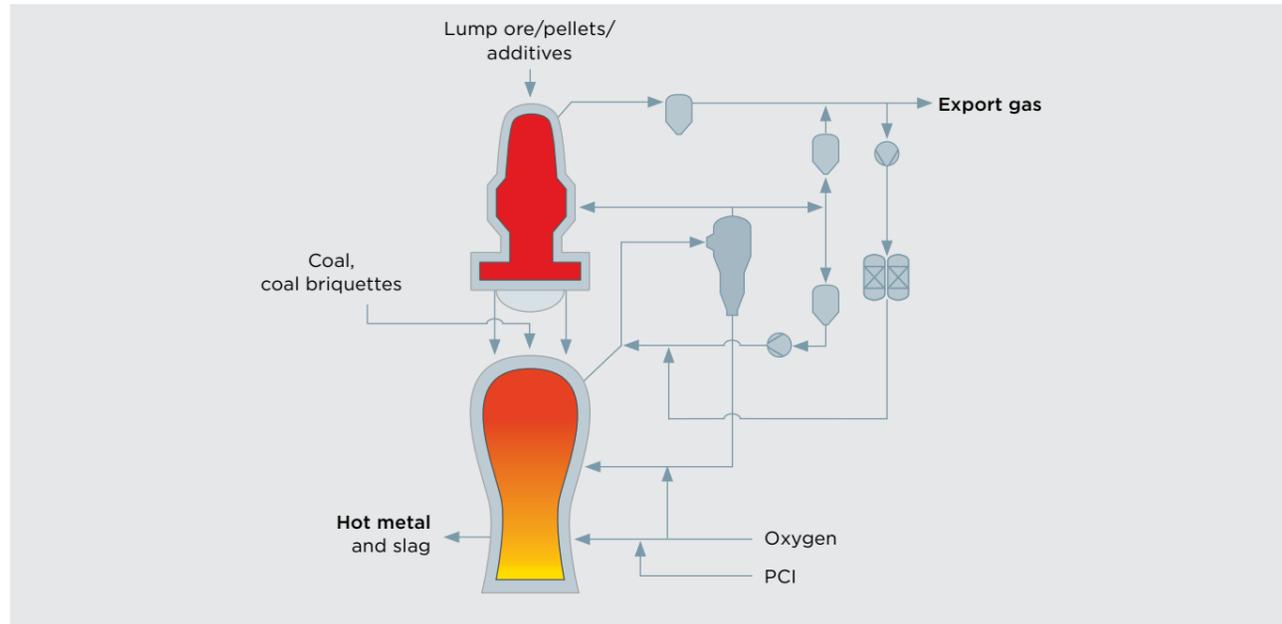


Milestones of Corex



Corex ArcelorMittal South Africa, Saldanha Works – profitable and environmental friendly iron making

# A LOOK INSIDE EFFICIENCY AT WORK



The Corex process

## PROCESS DESCRIPTION

With Corex, all metallurgical work is carried out in two separate process reactors – the reduction shaft and the melter gasifier. Iron ore (lump ore, pellets, or a mixture thereof) is charged into the reduction shaft, where it is reduced to direct reduced iron (DRI) by the reduction gas in counterflow. Discharge screws convey the DRI into the melter gasifier, where final reduction and melting take place in addition to all other metallurgical reactions. Hot metal and slag are tapped as in conventional blast furnace practice.

## DIRECT AND EFFICIENT

From the coal route perspective, coal is directly charged into the melter gasifier. It is gasified by injecting oxygen into the melter gasifier, resulting in the generation of a highly efficient reduction gas. This gas exits the melter gasifier and is cleaned, cooled, and then blown into the reduction shaft, reducing the iron ore to DRI in countercurrent flow as described above.

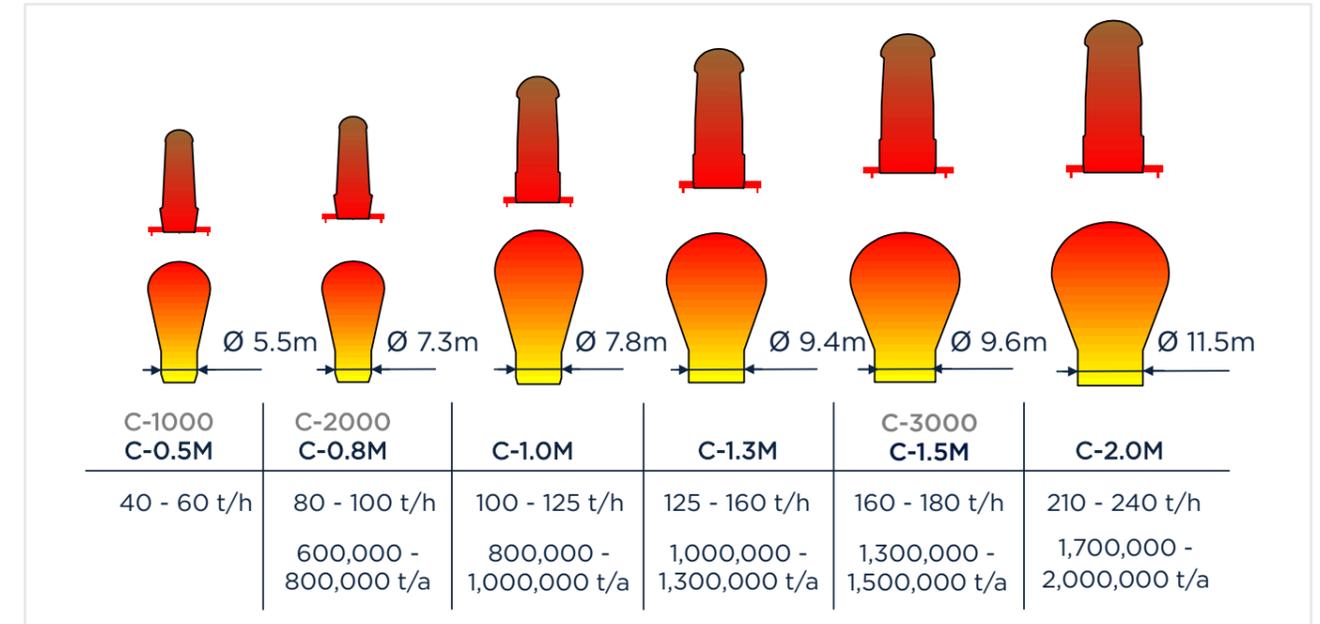
Due to the high temperatures prevailing in the dome of the melter gasifier (in excess of 1,000 °C), the higher hydrocarbons released from the coal during devolatilization are immediately dissociated to carbon monoxide and hydrogen. Undesirable by-products such as tars and phenols are destroyed and therefore cannot be released to the atmosphere.

## ECOLOGICAL AND PROFITABLE

The reduction gas exiting the melter gasifier mainly consists of CO and H<sub>2</sub> laden with fine coal, ash, and iron dust. This dust is largely removed from the gas stream in a hot gas cyclone and is then recycled to the process. Oxygen is injected into the melter gasifier when the coal is combusted, resulting in the generation of a highly efficient reduction gas. The top gas is subsequently cooled and cleaned in a scrubber, after which it is available as a highly valuable export gas with a net calorific value of approximately 8000 kJ/m<sup>3</sup> (STP) suitable for a wide range of applications (e.g., power generation, DRI production, natural gas substitution, and heating within the steel works).

## INCREASED GAS UTILIZATION

A recycling system consisting of a compressor station and CO<sub>2</sub> removal makes it possible to utilize more export gas for metallurgical work. This raises gas utilization to a higher level and makes the overall process even more economic and environmentally friendly.



Available Corex modules

## RECYCLING SAVES RESOURCES

Due to an increased gas utilization which is based on gas recycling, gas production in the melter gasifier can be significantly lowered, which is directly reflected in lower fuel and oxygen consumption. Slag production is subsequently reduced by more than 20%.

## TYPICAL CONSUMPTION FIGURES

	Standard	Recycle option	
Fuel <sub>dry</sub>	940	770	[kg/t <sub>HM</sub> ]
Additives	265	185	[kg/t <sub>HM</sub> ]
Oxygen	520	455	[m <sup>3</sup> /t <sub>HM</sub> ]

## TYPICAL CONSUMPTION FIGURES

	Standard	Recycle option	
Slag	340	265	[kg/t <sub>HM</sub> ]
Export gas	1,650 8,000	1,410 7,500	[m <sup>3</sup> /t <sub>HM</sub> ] [kJ/m <sup>3</sup> ]

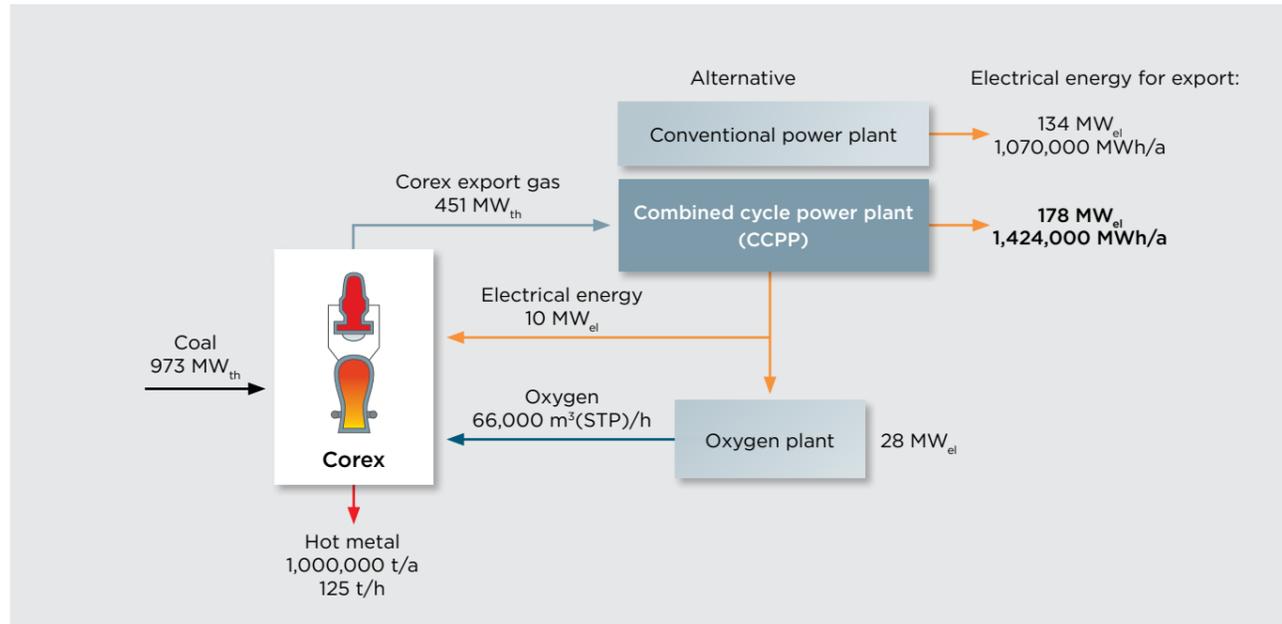
## EXTENDED RAW MATERIAL SPECTRUM

In terms of raw materials, the main advantage of Corex technology compared to the blast furnace route is the direct use of non-coking coal as the fuel/reducing agent and lump ore as the iron oxide feed. While the use of fine coal via pulverized coal injection is available for both technologies, coal briquetting is applicable to the Corex only. By coal briquetting it is possible to mix low-quality, low-cost coal fines with coals of higher grades. This results in lower coal cost and a substantially wider spectrum of coals to be utilized in Corex. This important economic advantage will counter limited raw material availability and prospective price increases in the future.

## CUSTOMIZED PLANT OPERATION

The implemented recycling circuit allows the operator to adjust the system according to on-site requirements – to minimize coal consumption or to maximize export gas generation – in order to respond to the steelworks demand. The reduced volume of export gas lowers the investment required for Corex export gas application, e.g., a downstream power plant.

# A LOOK INSIDE EFFICIENCY AT WORK



Production of electricity (Basis: e.g. Corex C-1.0M Plant)

## ADJUSTABLE EXPORT GAS GENERATION

Depending on the composition of coal and the decision whether gas recycling is applied or not, the amount and the composition of the export gas can vary within definite limits. The specific gas properties of the Corex export gas are compatible with natural gas, allowing for a wide variety of in-plant uses, including power generation by combined-cycle technology and DRI production. For the chemical industry, this gas can also serve as a feed stock for numerous applications.

## PRODUCTION OF ELECTRICAL ENERGY

Regardless of the recycling decision and plant setup, with its excellent calorific value the Corex export gas is excellent suited for power generation. When used in a combined-cycle power station, the export gas is converted to electrical energy with efficiencies up to 48%. Depending on particular site conditions, a tailor-made production route including power generation fulfills all requirements for optimized energy management. Beyond that, operators benefit from value created by surplus electricity, which can be used to supply public demand.

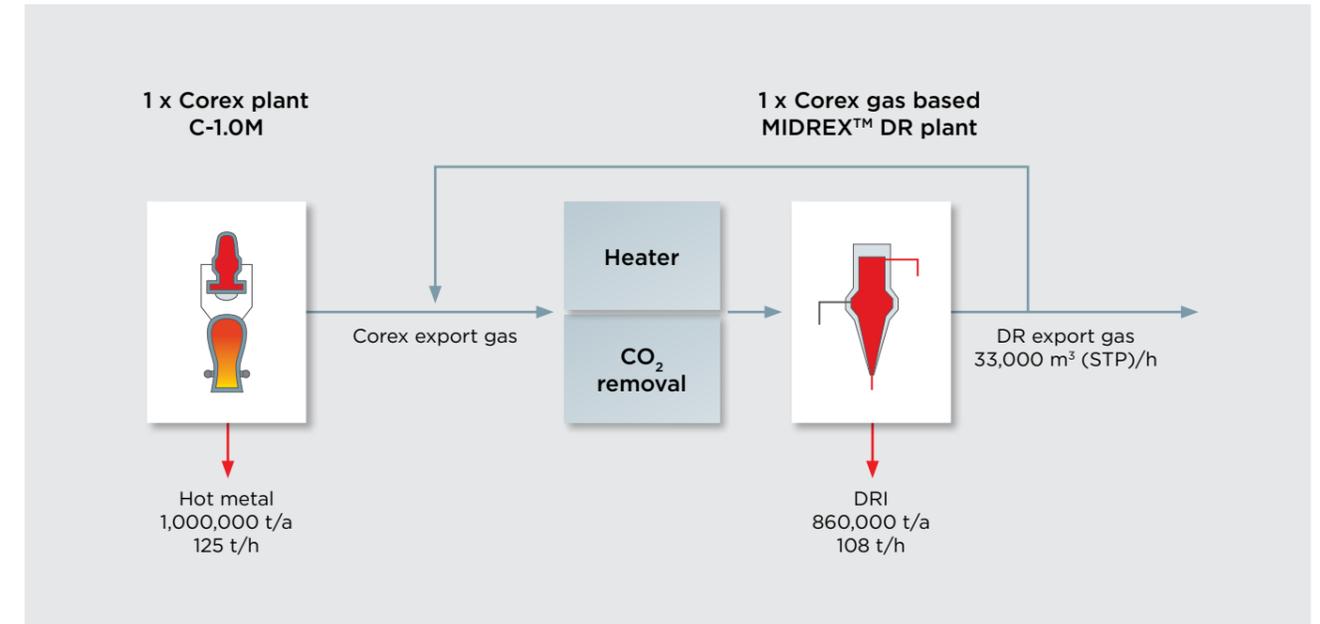
## TYPICAL THERMAL ENERGY BALANCE (FOR 1 MTPA HOT METAL)

Plant setup	Standard	Recycle option	
Energy input	973	790	[MW <sub>th</sub> ]
Energy consumption	522	450	[MW <sub>th</sub> ]
Energy output	451	340	[MW <sub>th</sub> ]

## TYPICAL ELECTRICAL ENERGY BALANCE\* (FOR 1 MTPA HOT METAL)

	Standard	Recycle option	
Power generation	216	155	[MW <sub>el</sub> ]
Internal power consumption and oxygen plant	38	45	[MW <sub>el</sub> ]
Power export	178	110	[MW <sub>el</sub> ]

\* Conversion ratio thermal energy:electricity 1:0.48



Production of DRI (Basis: Corex C-1.0 M Plant)

## PRODUCTION OF DRI

Another way to benefit from the surplus reduction potential is to reheat and utilize the export gas in a downstream direct reduction plant. According to the desired product mix, even more additional DRI can be produced compared to hot metal, thus raising the gas yield for iron making to a new level never imagined before.

## LOWEST SPECIFIC CONSUMPTION RATES

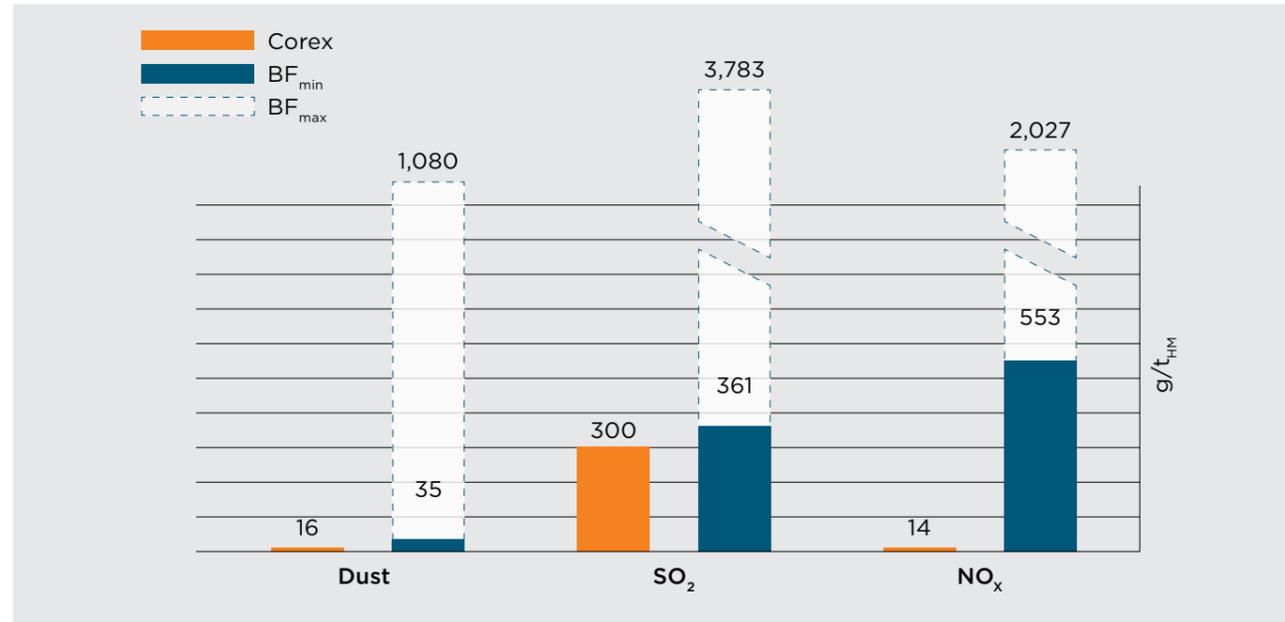
A decrease of 25% in the fuel rate and an increase of up to 20% in gas utilization compared to best-performing modern blast furnaces are decisive driving factors, especially when present and future mandatory CO<sub>2</sub> reductions for the iron and steel industry are taken into account. Even the calorific value of the direct reduction export gas is higher than blast furnace top gas and, similar to the Corex export gas, it can be utilized efficiently for various purposes.

## COREX/DR COMBINATION DRIVING FACTORS

DRI production	850	[kg/t <sub>HM</sub> ]
Fuel <sub>dry</sub>	530	[kg/t <sub>Iron</sub> ]
CO <sub>2</sub> emissions	< 1250	[kg/t <sub>Iron</sub> ]



# PROFITABLE AND ENVIRONMENTALLY FRIENDLY PREPARED FOR PRESENT AND FUTURE IRON MAKING CHALLENGES



Emission comparison - Blast furnace / Corex, (Source: BAT for the production of iron and steel - EU Joint Research Center)

## WHAT IS ENVIRONMENTALLY FRIENDLY?

Corex and the blast furnace route are coal-based processes reducing iron ore to sponge iron, which is subsequently melted into hot metal. In both processes, the same product is generated out of almost the same raw material. A question that arises – and not only from an economic point of view – is “how do these production routes deal with unwanted impurities?”

A certain amount of environmentally harmful substances are inevitable based on the raw material mix. Hence, the objective of a sustainable iron making process is to discharge these substances in an environmentally compatible condition, or destroy them in the process itself. Since the Corex Process captures most of the pollutants in an inert state in the slag and the released hydrocarbons are destroyed in the dome of the melter gasifier, no additional investment or operational costs are incurred for a complex gas or disproportional waste water conditioning plant.

## GREEN IS NOT ALWAYS EXPENSIVE

Minimizing the emission values for the blast furnace route requires the highest investment for environmental protection, disregarding all reasonable economic aspects. This can already be seen in the case of blast furnace dust emissions, where efficient but costly filter systems are installed in the sinter and coking plant. The Corex values are already far better than expected future standards. Moreover, the full development potential of Corex has not yet been realized with respect to a further reduction of emissions.

## GASEOUS EMISSIONS

Thanks to the in-situ coking of the coal in the melter gasifier, a large portion of sulfur is captured in the slag, dramatically decreasing emissions of gaseous SO<sub>2</sub> or H<sub>2</sub>S. Furthermore, pure oxygen is used instead of the hot air blast, significantly reducing nitrogen emissions in the form of NO<sub>x</sub> and providing the advantages already mentioned regarding dust emissions.



Corex Baosteel, Shanghai Baosteel Pudong Iron & Steel Shanghai, China

## LOWER PRODUCTION COSTS

Because coking and sinter plants are not needed with Corex, production and investment cost are reduced substantially. The extent of the savings depends, of course, on the local plant site and other specific conditions. Given the recent dramatic increase in cost for metallurgical coal and energy, the Corex can typically save operators up to 10% in hot metal production costs in comparison to the traditional blast furnace route.



Essar Steel, India

# COREX SUCCESS STORIES

## SELECTED REFERENCES



### COREX ESSAR

**Customer:** Essar Steel Ltd., Hazira, India

**The challenge:** Relocation of the two Corex plants from Asan Bay, Korea to Hazira, India and to successfully carry out a brownfield implementation into the existing steel plant infrastructure.

**Our solution:** 2 x Corex C-2000 plants with an annual production of 1.7 million tons of hot metal per year in blast furnace quality with highly valuable export gas for substituting natural gas for DR production.

### OUTLINE

In 2007 Essar Steel decided to relocate the Corex plant erected for HANBO STEEL, Korea to their existing steel works at Hazira, India. Beside production of high quality hot metal to be used in two new EAFs to improve the steel quality, one main target was to substitute natural gas at the existing Midrex™ DR plants. A special challenge was to integrate the Corex plants into the existing steel works due to very tight space availability.

### CUSTOMER BENEFIT

- Lower investment and operation costs compared to the conventional blast furnace route
- Economical and environmentally friendly production of hot metal
- Reduced DRI production cost in the adjacent Midrex™ plants due to substitution of high natural gas by Corex export gas
- Lower dependency on the local power and gas supply

### ENVIRONMENTAL BENEFIT

- Considerably reduced SO<sub>2</sub> and NO<sub>x</sub> emissions
- Reduced phenol, sulfide and ammonium contamination of waste water
- Resource preservation due to alternative raw material consumption



### COREX JSW

**Customer:** Jindal South West Steel Ltd. (JSW), Toranagallu, India

**The challenge:** Economical iron making basis for a new steelworks in an isolated area with limited access to fuel gas.

**Our solution:** Corex-DR combination consisting of two Corex C-2000 plants with a total annual output of 1.6 million tons of hot metal and a MIDREX™ DR plant with an annual output of 1.2 million tons of DRI

### OUTLINE

At Jindal South West Steel Ltd. (JSW), the two Corex C-2000 plants formed the iron making basis for steel production. As a special feature, plant wastes, such as Corex, limestone/dolomite fines, and LD slag, are recycled into the two Corex modules, either directly or indirectly through the pellet/sinter plants. The synergy of Corex and blast furnace helped JSW steel to maximize the utilization of solid waste and thereby reduced the cost of hot metal. In addition, Corex export gas is used for the production of DRI and as a backup in blast furnace stoves, boilers, and the sinter and pellet plant.

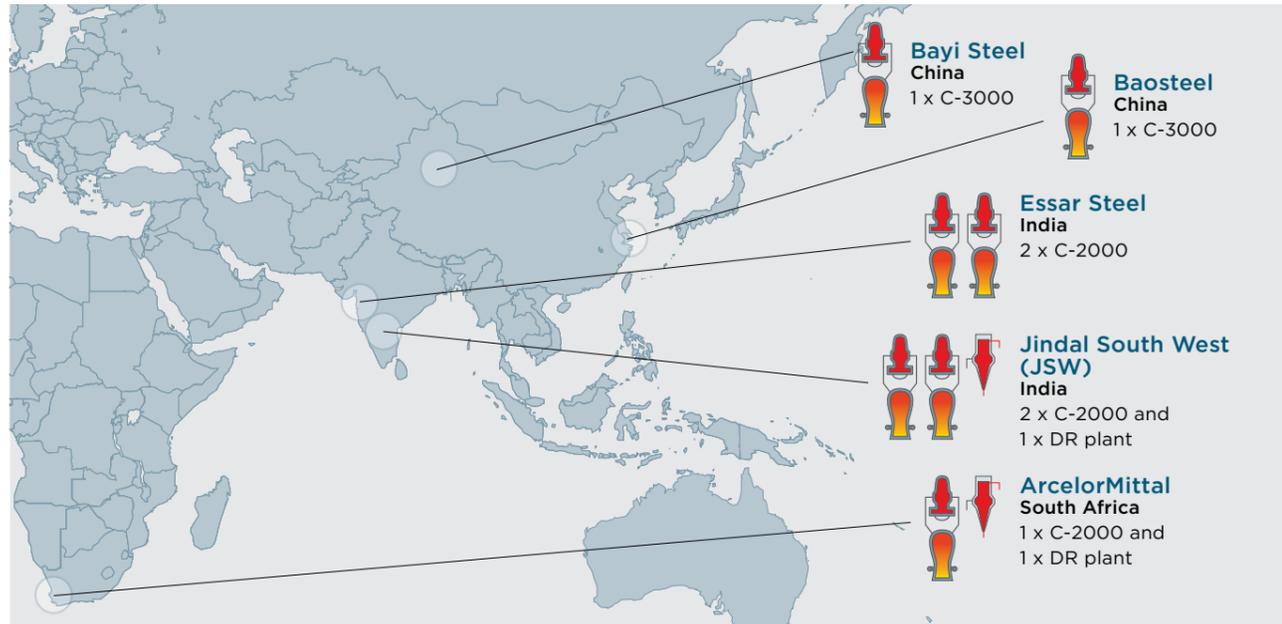
### CUSTOMER BENEFIT

- Lower production costs compared to JSW's benchmarking blast furnaces
- Synergistic combination of Corex and blast furnaces
- Stable operation and production of additional DRI in separate Midrex® plant

### ENVIRONMENTAL BENEFIT

- Efficient recycling of metallurgical waste material
- Production of valuable export gas for power generation

## WE TAKE THE RESPONSIBILITY ALWAYS AT YOUR SIDE



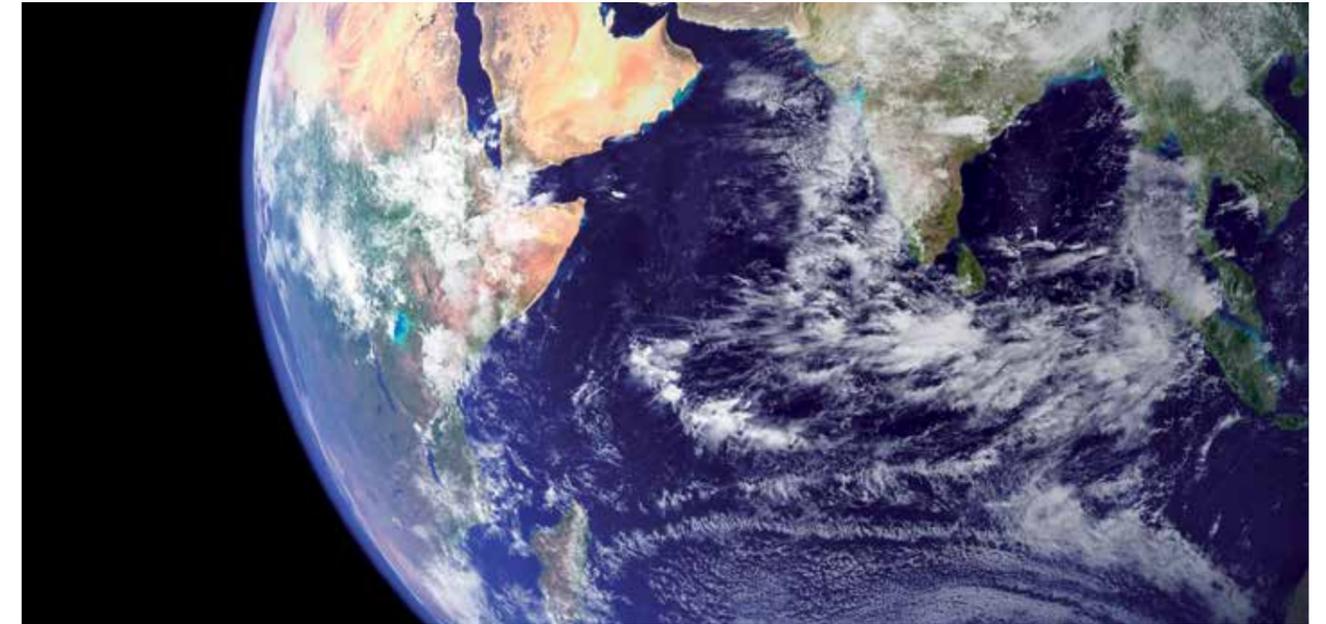
Corex plants in operation and under construction

### THERE IS ALWAYS A GOOD REASON FOR COREX

Corex fulfills all additional requirements beyond an economical and reliable iron making unit. Examples include JSW in India, where two Corex plants were erected for a steelworks in an isolated area with no access to natural gas or electricity; Baosteel in China, where a new steelworks was erected in a water protection area with a demand for electricity; and ArcelorMittal South Africa, where a Corex-DR combination forms the iron making basis for a steelworks in an environmentally restricted area with a zero-emission restriction specified by law. The expansion to a Corex-DR combination plant at JSW underlines the flexibility of Corex to respond to actual market demands in the iron and steel business.



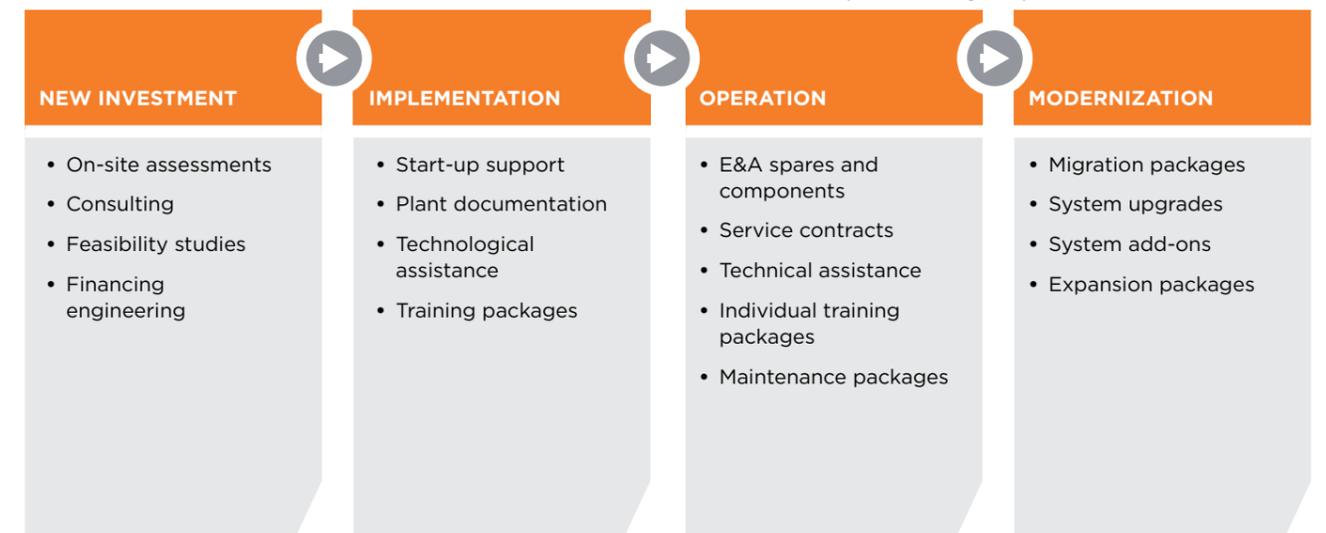
## LIFECYCLE MANAGEMENT ROUND THE CLOCK, ROUND THE GLOBE



### PRIMETALS TECHNOLOGIES LIFECYCLE SERVICES

As a plant operator, you have conflicting needs. On the one hand, your performance is measured each quarter against short-term profitability expectations. On the other hand, you have to think on a totally different timescale compared with the capital market. Depending on the lifetime of your plant, you have to take 15 years or more into account. At the very least, that's 60 full quarters.

But thanks to our comprehensive expertise and integrated approach to solutions, you benefit both in the short and long term from our lifecycle services. In the short term: Backed by our extensive experience with many reference plants, we provide you with the certainty of fast, dependable production start-up and shorter amortization periods. In the long term: Our master plan guarantees competitive performance for your plant in every phase of its lifecycle. Whether we're providing 24/7 technical support, optimizing maintenance, or making permanent plant improvements, we're always working to ensure the cost-effective operation of your plant.



**Primetals Technologies Austria GmbH**

A joint venture of Mitsubishi Heavy Industries and partners

Turmstrasse 44  
4031 Linz  
Austria

[primetals.com](http://primetals.com)

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