ENERGIRON HYL

DRI TECHNOLOGY BY TENOVA AND DANIELI

ENERGIRON HYL
THE SMART CHOICE


ENERGIRON

Energiron is as strong as the name suggests and the unique product of this technology is more than just Direct Reduced Iron it's Energy combined with Iron for the lowest cost and highest quality steelmaking applications.

Competitive CAPEX and OPEX solutions from Energiron:

_ Integration with EAF thanks to DRI hot charge via HYTEMP® system

_ Integration with BF shops for reduced carbon footprint or increased liquid steel production

_ Safe-to-transport high carbon DRI from stand alone plant

Energiron at a glance

Energiron is the result of a strategic alliance between Tenova HYL and Danieli to competitively serve the DR plant market. Under the alliance, the two companies have combined their know-how and technology for the design and construction of gas-based DR plants, offered worldwide under the Energiron trademark.

Since its establishment in February 2006, the Energiron alliance has brought to the market the most revolutionary technology which strongly contributed to change the DRI world scenario, as confirmed by the several Energiron DRP assigned.

The largest capacity DR plants in the world are now Energiron Zero-Reformer plants: Suez Steel in Egypt (2.0 Mtpy) and Nucor, USA (2.5 Mtpy). Moreover, since 2009 Emirates Steel in Abu Dhabi has been operating the two most efficient hot DRI Energiron units, each of which will reach a capacity of 2.0 Mtpy.

As a consequence, after six years of successful collaboration, Danieli and Tenova HYL reconfirmed their exclusive alliance for an additional 10 years. With this background and these long term prospectives, Danieli and Tenova HYL will continue to offer their combined experience to support the competitiveness of the steel producers and to enhance raw material quality and availability.

EAF steelmaking continues to grow in the production of higher quality steels, including specialty steel products. Energiron responds to the need for a premium raw material for competitive and quality clean steel production.

Steel production cost is a combination of raw material, energy and labor cost. There are areas where DRI production is naturally more convenient due to the availability of energy and iron ore at low prices. Energiron plant configurations can be designed to be competitive even in those areas where Natural Gas is not economically available, by using other sources of reducing gas, such as Coke Oven Gas (COG), Coal Gasification Gas (SYNGAS) and others.

Energiron DRI is a highly metallized product with controllable carbon content in the range of 1.5 to 4.0% which generates chemical energy in the EAF melting process.

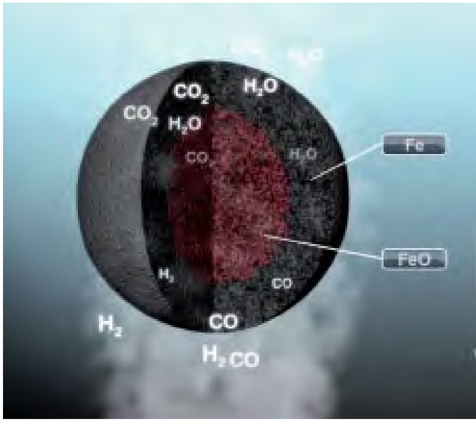
In DRI-based integrated minimills the use of the HYL HYTEMP® system allows the delivery of hot DRI directly to the EAF, thus further reducing electric energy consumption and tap-to-tap time.

The uniquely stable characteristic of Energiron DRI, makes it a product which can be safely and easily transported without briquetting, following standard IMO guidelines.

Proven layout and process integration for DRI production and electric steelmaking (DRI-based minimill concept). Emirates Steel minimills #1 and #2.

What makes Energiron unique:

_No raw materials limitation
_Best Carbon-Iron units mix
_Lowest OpEx in EAF melting



High process flexibility with proven technology

Energiron is the unique direct reduction technology that, with the same process scheme configuration, lets you choose the best energy source - natural gas, reformed gas, Syngas from a coal gasifier or even Coke Oven Gas without any modification.

High product flexibility

Controlled carbon content -0.8 to 4%- for best EAF steelmaking performances, comparable to hot metal practice.
HYTEMP® system for hot DRI charge into the EAF, providing additional energy savings.
Easy to transport passivated cold DRI due to high iron carbide (Fe_3C) content; no need to briquette.x

High project flexibility

To bring it all together, Energiron offers the flexibility of providing anything from the basic technology package to local equipment supply and erection up to full turnkey projects. Energiron team support runs from process technology through operations and maintenance training and technical assistance, not only in the DR plant but in the steel mill as well. Further, Danieli and Tenova can provide complete steel mill projects covering materials handling, direct reduction, EAF meltshop, casting and rolling and product finishing lines.

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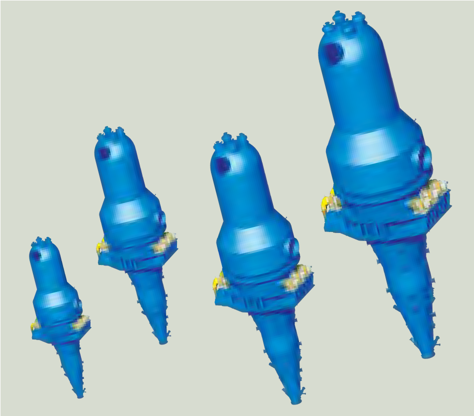
Sustainable production thanks to the lowest carbon footprint

Energiron plants are ecologically friendly and meet the most stringent environmental regulations; because of the unique features of this technology, it is the lowest carbon footprint of any ironmaking technology, with the further advantage that selectively removed CO_2 can be sold. Significant achievements have also been reached in the reduction of the air pollutants like NOx and SOx. Additionally the water by-product of the reduction reaction, easily condensated and removed from the gas stream, can be used as cooling water in a zero-water consumption circuit.



The widest range of plant capacities

Energiron plants are available in different modular sizes to meet the needs of the typical steel mill – either with the Micro-Module (200,000 tpy), or any sized plant up to 2.5 million tpy and larger.
No risk in technology change or scale-up will be present for any size.

Low maintenance and high plant avaibility

The possible elimination of the reformer and the use of standard equipment of smaller size throughout the plant significantly reduces the cost of maintenance. Further, Energiron plants are controlled by a highly automated system providing Level 2 automation, requiring minimal human intervention and providing high plant availability and reliability.

Emirates Steel, UAE. Energiron III (with external reformer) DR plants for production of 2+2 Mtpy of hot discharged DRI (94% metallization and 2.5% C). HYTEMP® system for directly feeding hot DRI to the EAF.


ENERGIRON

Pioneering achievements since 1957

HYL experience in DR technology dates back to the fifties and since then original continuous shaft reactor and zero reformer processes and the HYL HYTEMP® pneumatic trasportation system were developed.

2006 marked the establishment of the Energiron alliance: Tenova HYL and Danieli team up to promote and develop the new Energiron technology for direct reduction plants.

1957
Startup of the world's first commercially successful gas-based direct reduction plant, Hylsa 1M, using the HYL process.
Production of flat products via the EAF, based on the use of DRI.

1958
Batch charging of DRI to the EAF at 600 °C.

1965
Use of more than 30% DRI in an EAF charge, eventually increasing in stages up to 100% by 1972.

1968
Continuous feeding of DRI to the EAF. Computerize process control system put into use.

1969
Use of foamy slag practices.

1970
Design of pellets for direct reduction. First full scale testing and use of DRI as a BF-BOF feed.

1972
Production of extra-deep drawing steels in EAF using DRI.

1980
Start up of the HYL continuous shaft reactor process in Monterrey.

1984
First HYL pilot operation of a direct reduction plant without external gas reformer.

1988
Use of coating of pellet/lump ores for direct reduction.

1993
HYTEMP® pneumatic transportation system and hot DRI feeding to the EAF.

1993
First Zero kWh direct reduction plant begins operation at Vikram Ispat HYL III plant, India.

1994
HYL begins producing high carbon DRI with 3.0 to 5% carbon content.

1995
Production of ultra thin (< 1mm) hot rolled coils based on 100% DRI, with HYL plant and Hylsa CSP minimill.

1997
World's first dual-discharge (DRI and HBI) plant design put into operation, Vikram Ispat (now Welspun Maxsteel) HYL plant, India.

1998
Startup of first commercial scale HYL Zero Reformer Process plant, Hylsa 4M, Monterrey. Hot and cold DRI charging to the world's largest twin-cathode DC EAF.

1999
HYL III Plant with water producing option starts up at Hadeed, KSA.

2000
First plant to use 100% lump ore charge successfully on a routine basis (Usiba HYL plant, Brazil). Vikram Ispat becomes second in 2006.

2001
Successful economical design of Micro-Module (200,000 tpy) plants based on HYL ZR reformerless technology.

2003
Successful design of HYL ZR process plants based on coal gasification and COG.

2005
First coal gasification-based Energiron DRI plant for Jindal Steel, India. This 2 Mtpy module is the largest plant of this kind ever to be built in the world.

2006
First 1.6 Mtpy Energiron DR plant with HYTEMP® system order from Emirates Steel, UAE.

2006
First HYL Micro-Module plant built, GSPI, Abu Dhabi, UAE.

2008
Second 1.6 Mtpy Energiron DR plant with HYTEMP® system ordered by Emirates Steel, UAE.

2009
1.9 Mtpy Energiron plant for production of Cold DRI for Ezz Rolling Mill, Egypt.

2009
First new generation 1.95 Mtpy Zero Reformer Energiron plant for production of hot and cold DRI for Suez Steel, Egypt.

2010
The world biggest Energiron DR plant in a single module supplied for Nucor Steel with a 2.5 Mtpy design capacity.

2013
Excellent production ramp-up and learning curve at Emirates Steel DR plant #2 leading to full productivity during second year of operation.

Energiron products

Energiron plants efficiently reduce any iron pellet or lump into “energized” hot or cold Direct Reduced Iron or Hot Briquetted Iron with controlled metallization and carbon levels.

Our technology offers three product options from the same reduction process - DRI, HYTEMP® iron and HBI, each of which can be produced to different metallization and carbon levels.

DRI Direct Reduced Iron

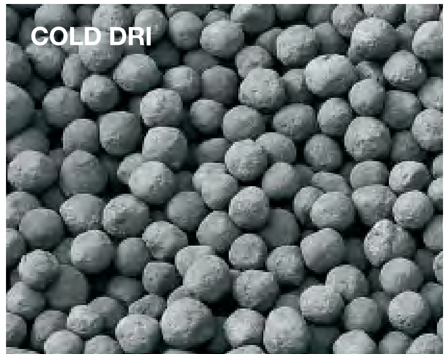
DRI is reduced iron pellet and/or lump, which is cooled and discharged at low (ambient) temperatures. The process characteristics allow for independent control of the DRI metallization and carbon levels. Metallization can be adjusted at will, typically around 94% and higher.
_ DRI carbon levels can be selected in the range of 1.5 - 4.0%, most of which is in the form of iron carbide.
_ The high iron carbide content provides the unique stability characteristic of this product. Energiron DRI is safe to transport and store under normal established procedures.

HYTEMP® Iron

Hot DRI is discharged continuously from the reactor at > 700 °C to a pneumatic transport system.
The product is transported by means of a carrier gas to surge bins located above the meltshop for controlled feeding to the electric arc furnace.
HYTEMP® iron, like cold DRI can be produced to high levels of metallization and carbon, in order to satisfy meltshop requirements for greater economy and efficiency.
The HYTEMP® system is the world’s first proven technology for continuous hot discharge, transport and feeding of quality DRI to the electric furnace shop. It is completely proven and reliable, with absolutely no downtime since its first implementation in 1998.

HBI Hot Briquetted Iron

Reduced pellet or lump is discharged at temperatures > 700 °C into hot briquetting presses located below the reactor discharge area. Briquettes are compressed, cut and cooled to make HBI, typically for merchant sale over long distances. As with DRI, HBI is produced in controlled metallization ranges around 94% and higher. HBI can be easily charged to an EAF as part of a standard scrap bucket charge to reduce scrap residual levels. It is additionally an excellent charge in integrated mills as a coolant to the basic oxygen furnace.
Carbon for HBI is typically 1.5%, higher than other HBI products that often have less than 1% carbon. Work is underway to develop HBI at even higher carbon levels.



Unique to Energiron DRI

High carbon DRI - iron carbide

A unique benefit of the ZR process is the DRI that it produces. As compared with DRI from other processes, his product typically has a metallization of 95% and a carbon content controlled in a range between 1.5 to 4% in the form of combined carbon. This type of product yields significant benefits in the electric furnace that no other process to date has been able to achieve.

Carbon in the DRI, mostly as iron carbide (Fe_3C) is derived mainly from methane (CH_4) and to a lesser extent from CO. The level of carbon is adjusted by controlling the reducing gas composition and/or oxygen injection.

DRI produced with the ZR scheme is characterized by higher stability than DRI typically obtained in other DR process schemes. The reason for this is the high cementite or Fe_3C content, which inhibits the re-oxidation of metallic iron in contact with air. For a carbon content of 4%, approximately 95% is present as Fe_3C. In general, every 1% of combined carbon corresponds to 13.5% of Fe_3C. Therefore, a DRI with 4% Carbon contains more than 50% of Fe_3C.

The high percentage of Fe_3C in the DRI makes the product very stable.

DRI stability

Extensive tests were conducted to determine whether the combined carbon in DRI was a factor in improving product stability over that of conventional DRI, whether produced by Energiron plants or other process technologies. In general, High-Carbon DRI is more stable than conventional DRI. This has been proven in specific tests that were performed for DRI being produced at the Ternium 3M5 plant, before and after its conversion to the ZR Process scheme. Since stability itself is not measured but rather reactivity of the product in three distinct environments, tests were conducted in the presence of air, air plus water and air plus salt water to determine which type of DRI is more stable. The test results indicate that reactivity to air, water and salt water is significantly less over time for DRI containing high percentages of carbon as iron carbide.

Currently, all or most direct reduction technologies carry out reduction reactions at very high temperatures – from 920 to 980 °C. The high reduction temperature is one of the factors determining the DRI stability.

Nevertheless a more significant factor is the carbon content of DRI. DRI, which has high levels of carbon in the form of iron carbide or cementite, forms a quality of DRI pellet which, while still requiring proper handling procedures, is much safer than ever before.

Energiron plants

Custom modules from
0.2 to 2.5 (3.0) Mtpy.
Compact plants
for several millions tpy
capacity, using different
gas sources.
No scale-up risk
for different plant sizes.

Micro-module
0.2 Mtpy

Mini-module
0.5 Mtpy

Custom modules
0.5 Mtpy / 2.5 Mtpy

Next challenge
3.0 Mtpy

Energiron plants are designed for maximum savings in both investment and operating costs. Multiple reduction reactors can share a common reducing gas source. Auxiliary systems and materials handling equipment can be common to several modules. With the ZR process configuration, further economies are obtained based on the smaller overall plant size and equipment requirement.

Micro-module

This basic plant design concept was developed specifically for markets where small volumes of DRI are needed, and where coal-based technologies have until now been the only option. The highly functional, no-frills version of the traditional plant provides the highest quality DRI available to companies requiring annual capacities in the range of 200,000 tpy.

Mini-module

This is the optimum sized DR plant for the typical steel mill producing quality products. It's a 500,000 tpy DR plant with the reliability and quality for which HYL is renowned.
A totally re-engineered DR module, designed with the latest technology such as reformerless (ZR) reduction and production of High Carbide Iron.
The Mini-Module takes advantage of modular design for a construction schedule that means shorter project implementation and a faster startup.

Custom modules

Energiron plants can be designed to incorporate a variety of technologies, depending on the particular needs of a client or project. Plant capacities can range anywhere up to 2.5 Mtpy in a single reactor, to multiple reactor plants of several million tons per year capacity.




Suez Steel, Egypt. Energiron ZR (without external reformer) DR plant for production of 1.95 Mtpy of hot and cold discharged DRI (94% metallization and 3.5% C). HYTEMP® system for directly feeding hot DRI to the EAF.

Plant and process economics

The overall smaller size of the equipment and land required, along with the possibility to use any gas and iron quality, optimum yield and minimum maintenance lead to the lowest market capital and operational expenses.

Both capital and operating expenses for Energiron plants are extremely low. For equivalent production capacity, a ZR plant requires barely half the land area needed for other processes. And because the process is pressurized, overall equipment sizes are smaller, for even greater savings.

Operating expenses are low as well, given the flexibility to use lower-cost ores, the inherent low gas and power requirements, and the best ore to-product yield of any DR process (1.38 t screened). These savings in energy requirements and also raw material consumption amount to a significant advantage for the Energiron technology of more than US$ 10 per ton in lower operating expenses. For a million ton per year plant, that means US$ 10 million savings every year.
The composition, final quality and cost of any DRI is dependent on the quality of the iron ores used for reduction.

Energiron plants offer the flexibility to operate with a wide variety of oxide pellets, lump ores or mixtures of both. This flexibility includes the possibility of using low grade iron ore feedstocks, an advantage in places such as China or India where huge amounts of iron ore are available, but with high percentages of silica and alumina.
There is no practical limitation regarding the chemical composition of the iron ore. In particular since gas is not recycled back to a reformer, the process is very flexible for using high sulfur iron ores.

Moreover, due to the lower gas velocities through the reactor, the use of hydrogen-rich gases and the mechanical system sealing devices, the use of friable lump ores can be maximized. Maintenance costs are also minimal.

Low maintenace costs
The HYTEMP® system has virtually no maintenance at all, unlike mechanical systems with lower availability.

By-product income
Energiron is the only technology that offers an additional revenue source beyond the DRI product. CO_2 capture and sale to off-takers is a lucrative business, providing millions of dollars in annual income to the DR plant operator.

Typical consumption figures

Item		Remark
Plant capacity (Mtpy)	0.2 - 2.5	world's smallest and largest capacities
Metallization (%)	≥ 93	adjustable to suit meltshop needs
Carbon (controlled) (%)	1.5 - 4	depending on extent of "in-situ" reforming

Inputs		Specific consumption
Iron ore (t/t)	1.38 - 1.40	depending on DRI carbon
Natural gas (Gcal/t)	2.24 - 2.60	depending on DRI carbon and temperature, extent of in-situ reforming and power co-generation
Electricity (kWh/t)	0 - 85	depending on power co-generation
Water m^3/t)	0 - 1.3	depending on the water recovery system
Labor (m-h/t)	0.11 - 0.17	depending on plant size
Maintenance (US$/t)	3.0 - 3.3	for cold-hot DRI

Technological characteristics

	Others	ENERGIRON ZR	ENERGIRON ZR advantages
CapEx	Large plant area, includes integrated reformer	No reformer	Less land required, more efficient plant design
	Non-pressurized system	Pressurized system	Smaller size equipment
OpEx	Requires top-grade DR pellet feed	Can use any pellet, lump or mix, even high sulfur	Lowest possible iron metallics cost per ton of product
	Higher fines loss to process off-gas	Lower velocity, lower fines loss	Higher yield per ton of ore
	Custom reformer catalyst	No reformer, no catalyst	No maintenance cost for replacing damaged catalyst
	CO_2 not recovered, fully released to atmosphere	CO_2 can be selectively captured and sold to off-takers	Lucrative additional revenue source

Energiron process

Energiron is the unique direct reduction technology that, with the same process scheme configuration, lets you choose the best energy source: natural gas, reformed gas, syngas from a coal gasifier or even coke oven gas, without any modification.

General process scheme

The Energiron Direct Reduction Process is designed to convert iron pellet/lump into metallic iron by the use of reducing gases in a solid-gas moving bed shaft furnace. Oxygen is removed from the iron ore by chemical reactions based on hydrogen (H_2) and carbon monoxide (CO), for the production of highly metallized DRI. The technology offers the flexibility to produce three different product forms, depending on the specific requirements of each user.

Reducing gases can be generated:
- directly, by in-situ reforming of natural gas inside the shaft furnace,
- in an external natural gas/steam reformer,
- from gasification of fossil fuels, biomass, etc., as Syngas
- from Coke Oven Gas (COG) sources.

In all the above cases, the process configuration corresponds to the same basic proven Zero Reformer (ZR) scheme, adjusting the relative sizes of equipment for the particular application. For both the in-situ and steam reforming schemes, natural gas analysis (heavy hydrocarbons content) is not a limiting factor.
One of the inherent characteristics of the Energiron process scheme and of high importance environmentally is the selective elimination of both by-products generated from the reduction process; water (H_2O) and carbon dioxide (CO_2), which are eliminated through top gas scrubbing and CO_2 removal systems, respectively.

Direct use of natural gas

The Energiron ZR process is a major step in decreasing the size and improving the efficiency of direct reduction plants. Reducing gases are generated in-situ in the reduction shaft, by feeding natural gas as make-up to the reducing gas circuit.

Since the reducing gases are generated in the reduction section, optimum reduction efficiency is attained, and thus an external reducing gas reformer is not required. Therefore, the overall energy efficiency of the ZR process is over 80%, optimized by the in-situ reforming inside the shaft furnace, since the product takes most of the energy supplied to the process, with minimum energy losses to the environment.

The impact on plant size of eliminating the external gas reformer is significant. For example, a plant of 1-Mtpy capacity requires only 60% of the area needed by other process plants for the same capacity. For additional capacity, the area required is proportionally smaller in comparison. This also facilitates locating the DR plant adjacent to the meltshop in existing operations. This plant configuration has been operated successfully since 1998 with the Ternium DR 4M plant, and also was incorporated in 2001 to the 3M5 plant, both at the Ternium steel facility in Monterrey, Mexico. The Energiron ZR plants in Egypt and in the USA are a further reference for this innovative technology.

A remarkable advantage of this process scheme is the wider flexibility for DRI carburization, which allows attaining carbon levels up to 5%. This is due to the improved carburizing potential of the gases inside the shaft, which allow for the production primarily of iron carbide.

Reformed gas, Syngas, COG

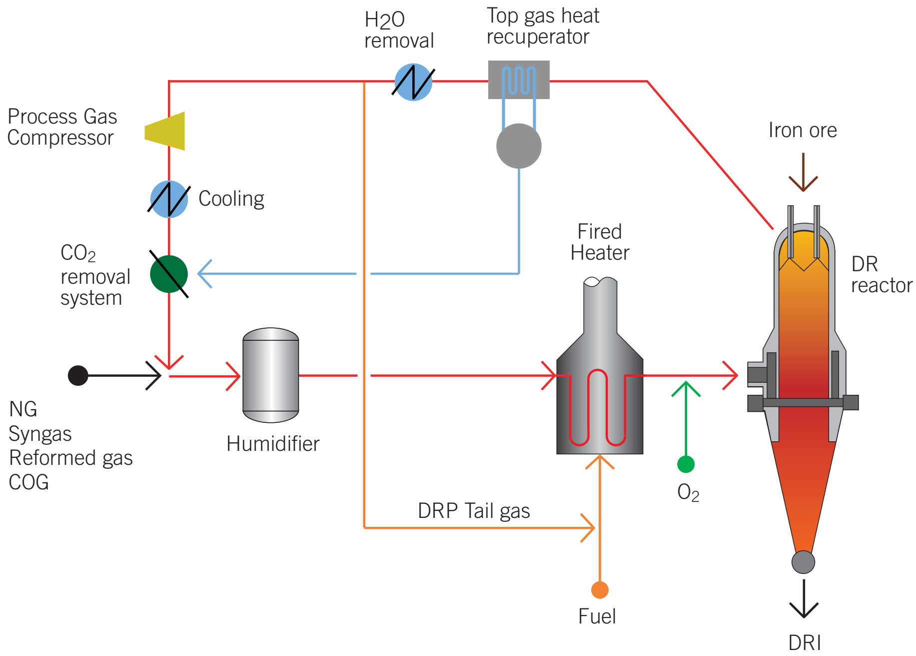
Energiron plants can also use the conventional steam-natural gas reforming equipment, which has long characterized the process. Other reducing agents such as hydrogen, gases from coal, pet coke and similar fossil fuels gasifications, and coke oven gas, among others, are also potential sources of reducing gas, depending on the particular situation and availability.

This flexibility is made possible precisely because the Energiron ZR Process is independent of the reducing gas source, with no requirement to recirculate gases back to a reformer to complete the process chemistry loop. Several projects are currently under development that will use coke oven gas as the reducing gas source, and projects using gas from coal gasification technology are also underway.

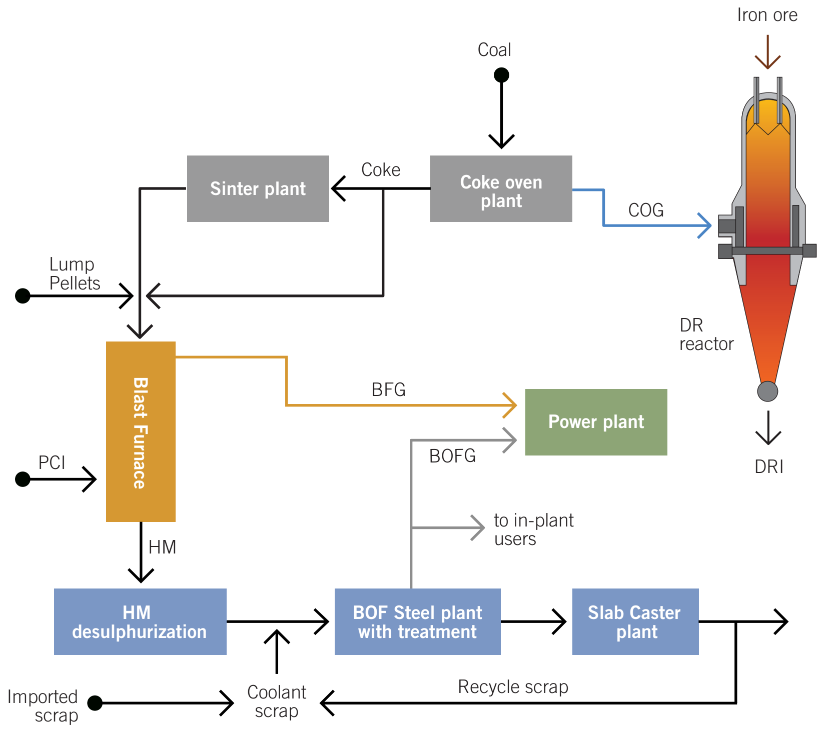
Reduction

Inside the shaft furnace vessel, hot reducing gas is fed to the reduction zone and flows upward counter-current to the iron ore moving bed.
The gas distribution is uniform and there is a high degree of direct contact between gas and solids.
The exhaust reducing gas (top gas) leaves the reactor at about 400 °C and passes through the top gas heat recuperator, where its energy is recovered to produce steam, or alternatively to preheat the reducing gas stream, and then through the quenching/ scrubbing system.

Standard ENERGIRON process flowsheet.



ENERGIRON DR plant flowsheet for integrated iron making plant.



In these units, water produced during the reduction process is condensed and removed from the gas stream and most of the dust carried with the gas is also separated. Scrubbed gas is then passed through the process gas recycle compressor, where its pressure is increased. Compressed gas, after being sent to the carbon dioxide removal unit, is mixed with the natural gas make-up, thus closing the reducing gas circuit.

The furnace operates at a pressure of around 7 bar absolute allowing a high reactor productivity of about 9 tph per m^2. This results in much higher production volumes, of more than 2.5 Mtpy in a single module when compared to ambient pressure systems. The pressurized operation also minimizes dust losses through top gas carry-over. This is reflected in low iron ore consumption, which keeps the operating cost low. Removal of oxygen from the iron ore is accomplished by the action of the hot reducing gases and then the product is carburized. A rotary valve, located at the bottom of the vessel, regulates the continuous gravity flow of the charge downward through the reduction furnace. DRI is discharged by automated mechanisms, consisting of pressurized bins and locks. Specially designed flow feeders insure the uniform flow of solids within the shaft. For cold DRI, a cooling gas is fed to the lower conical part of the furnace at about 40 °C, flowing upward countercurrent to the DRI moving bed. The gas distribution is uniform and there is a high degree of direct contact between the gas and solid, without physical restrictions to the flow of solids or gases inside the unit.
The cooling gas exits from the upper conical part, at about 460 °C, and is then quenched/scrubbed by means of cooling water. Scrubbed cooling gas passes through the cooling gas recycle compressor to be recycled to the furnace, after being made-up with natural gas. Natural gas is injected as make-up to the cooling gas circuit for optimum efficiency and control of the cooling and carburization processes.
For hot product discharge and use, the cooling circuit is eliminated and hot DRI is continuously discharged at > 700 °C.
For the HYTEMP® pneumatic transport system, the product is transported by means of a carrier gas to the surge bins located at the meltshop, for a controlled feeding to the electric arc furnace.
For production of HBI, hot DRI is continuously discharged at > 700 °C to the hot briquetting machines arranged below.
The HBI is cooled in vibrating cooling conveyors using cooling water and then discharged to the HBI transport conveyor.

The HYL HYTEMP® system

Virtually maintenance-free and with no fines nor metallization losses, the low OpEx HYTEMP® inert pneumatic charge system allows safe hot DRI feed and energy savings into the EAF.

An additional technology that, on its own provides significant benefits for steelmakers, is the HYTEMP® pneumatic transport system for sending hot DRI from the reduction reactor to the EAF shop. When combined with the Energiron ZR Process, the benefits increase substantially by bringing hot, high carbide iron to directly feed the melting furnaces. The HYTEMP® system involves an Energiron hot discharge direct reduction reactor connected to an adjacent electric furnace mill by means of a pneumatic transport system. HYTEMP® iron is DRI produced at high temperature (700 °C) and which is pneumatically transported from the reactor discharge to the meltshop for direct feeding to the EAF. In this manner, the energy value of the hot DRI is capitalized in the EAF.

This process scheme offers the most adequate arrangement for integrated steelmaking facilities due to the important benefits capitalized in the EAF. Hot DRI is sent to the meltshop, where it is temporarily stored in insulated inert storage bins for feeding to the furnace by continuous injection mechanisms which deposit the material directly in the metallic bath surface.

Currently the Ternium Monterrey 4M, Emirates Steel and Suez Steel DR plants produce hot-discharge DRI,

using the HYTEMP® system for hot DRI transport to the meltshop. Cold DRI is also produced via an external cooler if required.
The product is transported to the furnace by means of a carrier gas, via the interface bin where the carrier gas is separated from the hot DRI and where depressurization also takes place. Hot DRI is discharged to the EAF surge bin, which feeds the EAF.
The carrier gas is separated from the hot DRI in the pressurized interface bins, and it is passed through a quenching/scrubbing system for cooling and cleaning. Then, the carrier gas is recycled to the pneumatic transport circuit by means of the recycle compressor, thus closing the pneumatic transport loop.

According to the particular requirements of the steelmaking facilities, an off-line discharge for DRI cooling can be used during EAF downtime, or an external cooler can be incorporated for cold DRI production, or a briquetting machine can be installed in case that part of the production is being sent for export.
As the DR plant designed for HYTEMP® iron production is linked to steelmaking facilities, the reactor tower, pneumatic transport system and EAF feeding bins can be arranged in the most adequate layout to minimize distances and to match the continuous DRI output with the batch consumption of the meltshop.

The HYTEMP® system was not only the first successful continuous hot DRI charging system, having been in operation since 1998, but it is easily the most efficient and productive, with no fines losses from the system.
HYTEMP® is virtually maintenance-free with no recorded downtime in any of the plants using the system since it first started up over 15 years ago.

Energiron and steelmaking plant integration

Wide technology and field experience in DRI and electric steelmaking lead to the most efficient technical solutions for a competitive high quality liquid steel production.

Energiron improves steelmaking

The virtual absence of residual elements makes DRI the ideal complement to EAF scrap charges, as well as the recommended charge material for producing most high grades of steel. Additionally, DRI and HBI serve as quality metallic sources for blast furnace and BOF shops. DRI can be continuously charged for even greater advantages. The use of this quality feedstock in the EAF provides numerous advantages in steelmaking, including:

_ Greater uniformity and predictability;
_ Better slag foaming;
_ Increased efficiency and productivity, especially when using High-Carbide DRI;
_ Lower total steel cost.

The perfect integration between the direct reduction plant and the meltshop, achieved through the combination of the HYTEMP® system and a properly designed EAF, is presently a proven concept as previously indicated.

In particular, when DRI with a temperature of 600 °C is directly melted in the EAF, all the thermal energy of the DRI, discharged hot from the Direct Reduction Reactor, is completely recovered in the EAF. Immediate benefits are recorded at the melt-shop in terms of both electrical energy consumption and tap-to-tap time, if compared to the traditional solutions of charging only cold DRI. For example in Emirates Steel Industry Phase 1&2 plants, feeding the EAF their typical mix (90% hot +10% cold DRI), it is possible to save about 26 kWh/tls for every 100 °C increase in the DRI temperature.

Together with the savings in electricity, the EAF productivity increases with the DRI temperature. The tap-to-tap time decreases about 5% and the productivity increases accordingly per every 100 °C increase in the DRI temperature. For this reason, when DRI with a temperature of 600 °C is melted in the EAF, the savings in power consumption are up to 141 kWh/tLS with an increase in productivity of up to 22% for a practice of 90% hot+10% cold DRI.

Further benefits can be achieved by using high-carbon hot DRI in meltshop operations, as also widely demonstrated in the Ternium Monterrey EAF. The diagrams show the effect of DRI temperature inside the EAF, when using 100% DRI feed. Data are taken from industrial installation records, sorted by DRI average metallization, with a carbon content consistently in the range of 2.2 to 2.5%.

Effect of high carbon (as Fe3C)

Chemical energy contribution

The conversion of Fe_3C into iron and carbon is an exothermic reaction which improves the thermal efficiency in the EAF, by means of oxygen injection to the furnace.

Efficient use of carbon in EAF

The combined carbon is totally used, minimizing external carbon (graphite) additions, since it is a part of the DRI being fed.

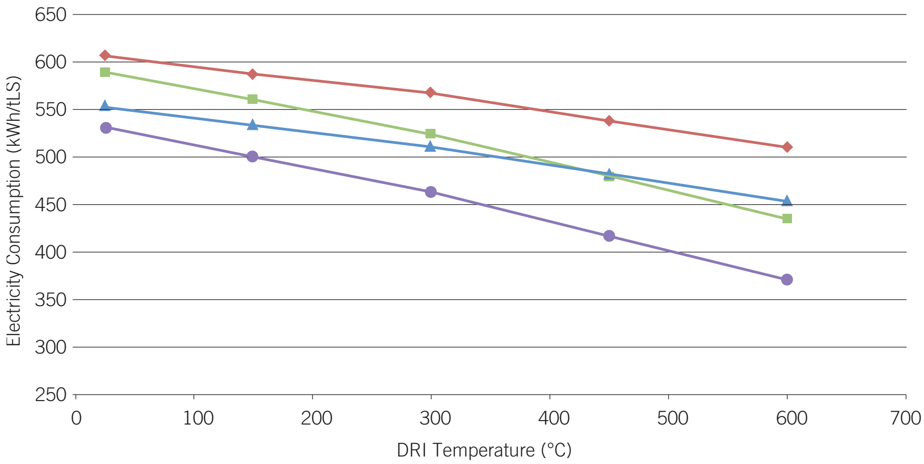
Higher stability during handling
Iron carbide is more stable and is safer to be stored and transported.

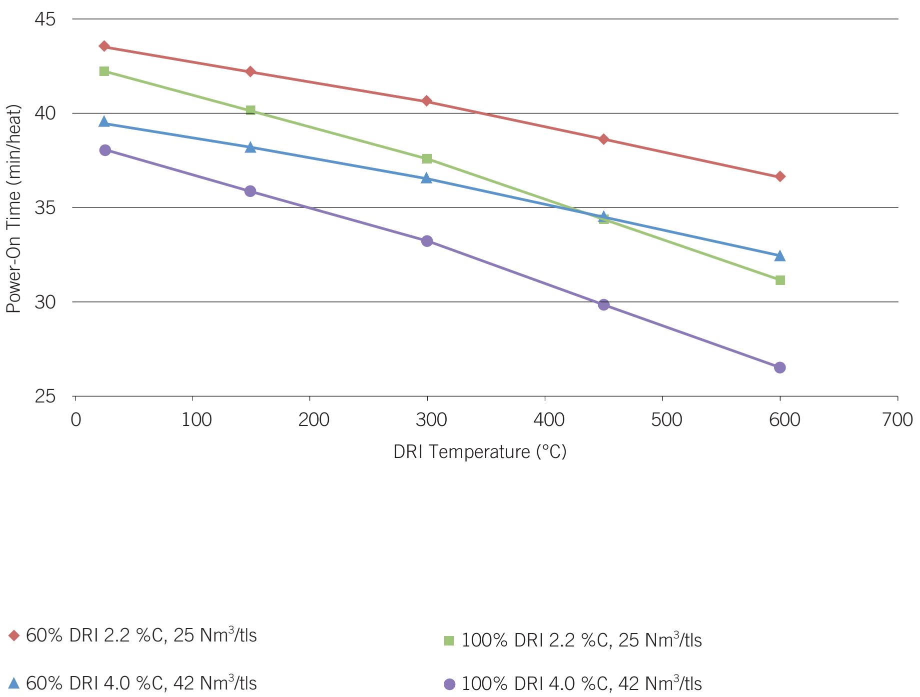
Easy foamy slag generation
As high carbon DRI enters in contact with free or combined oxygen.

The future of integrated steelmaking

Energiron direct reduction plants have reached a stage where they can conceivably compete with the traditional integrated steel mill in terms of size and production capacity. The conventional wisdom has been that for an integrated mill, capacities of blast furnace ironmaking need to be greater than 2 Mtpy of hot metal. Below that level, the capital cost associated with the BF/BOF installation would be too high on a per-ton of steel basis. While few new integrated mills have been built in the past decade or so, most have been in the range of 2 to 3 million tons per year of hot metal. Today's state-of-the-art EAF mill, with the use of oxygen lancing and carbon input (either from coal or graphite, or from high carbon DRI from Energiron plants) relies more and more on chemical energy as well as electrical energy. Using low residual metallic feedstocks, including DRI or HBI, allow EAF mills to produce the superior steel grades demanded by such users as automotive, special and tool steels that were previously only possible in integrated mills. So in terms of quality, the DR-EAF route is certainly not limited to producing simply commercial steel grades. Add to this the ability to now produce DRI in capacities exceeding 2.5 million tons per year, and coupling this type of plant with a modern EAF meltshop, we can easily see a new type of "integrated" mill for the near future: a high volume, integrated DR-EAF mill, capable of competing in both quality and cost.

The diagrams show the effect of DRI temperature inside the EAF, when using 100% DRI feed. Data are taken from industrial installation records, sorted by DRI average metallization, with a carbon content consistently in the range of 2.2 to 4.0%.






Suez Steel, Egypt. The high process flexibility provided by this Energiron ZR plant, designed for hot and cold DRI production, makes it possible to schedule the production according to any actual final user requirement.

Advanced automation systems

Energiron plants benefit from an advanced L2 production and quality control automation system developed over decades of process know how and research.

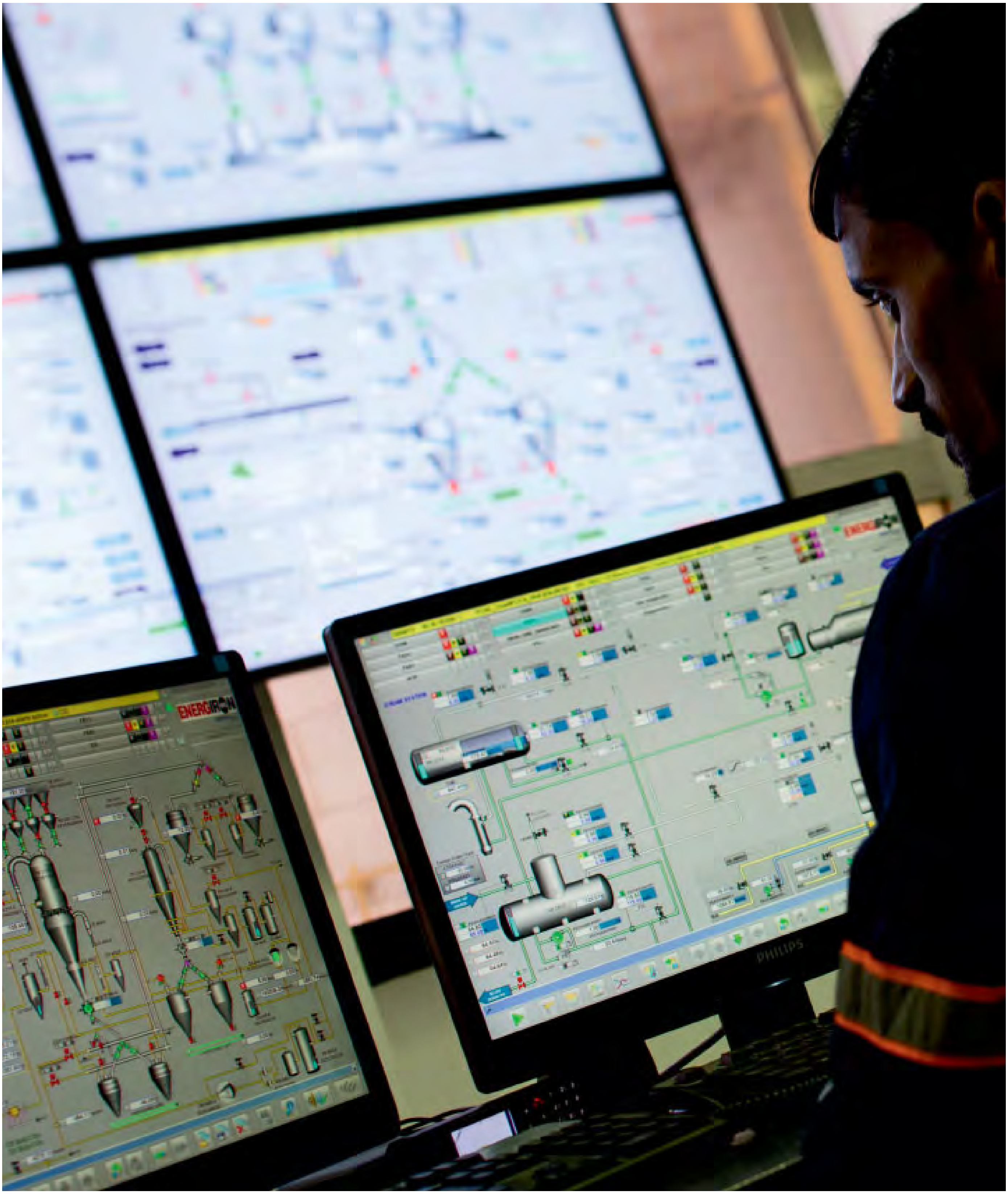
The Energiron Direct Reduction Process combines different and complex physico-chemical processes that have to be optimized to yield the desired set of chemical reactions and heat and mass exchanges among the variety of gaseous, liquid and solid phases. For this reason, a complete automation system is provided that uses the latest available technology in the field of process controllers, software diagnostics, high availability and fail-safe features.

The Energiron control system is based on an architecture consisting of a traditional Level 1 system for equipment control with a Distributed Control System, plus a new Level 2, not only for process supervision, data tracking and creation of production reports but also process optimization.

A “Process Reconstruction Model” (PRM) has been developed. It uses instrumentation signals coming from the PLC and physical equations in order to provide a full description of the plant status. In this way it is possible to calculate many normally unmeasurable items such as the top gas composition and relevant red/ox ratio.

Another target of this PRM is the Product Quality Prediction; starting from the gas composition measured by the mass spectrometer, we can predict with sufficient lead time (from 6 to 10 hours before the material is discharged) the characteristics of the product, such as metallization, carbon content and DRI temperature. As a consequence the process engineers have a consistent margin in terms of time to adjust the process parameters in order to reach the desired production both in terms of quality and quantity.

Further innovative Level 2 functionalities based on the Extended Kalman Filter Estimator and the Linear Quadratic Gaussian Regulator for calculation of the optimal Level 1 set points as a function of the Level 2 requested inputs will drive the future development of the advanced DR Process control.

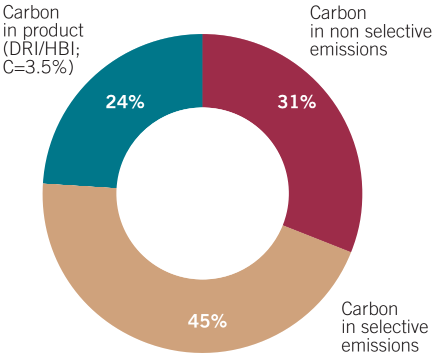


Energiron and the environment

Because of the unique features of this technology, significant achievements have been reached in terms of greenhouse gas emissions and in the reduction of air pollutants like NO_x and SO_2.

Energiron plant emissions are in accordance with the most stringent environmental regulations anywhere. This is achieved in large part due to the process itself; while other processes require heat recovery equipment that tends to increase the NO_x levels, Energiron technology is efficient by design due to its process configuration. Thus, while achieving high overall thermal efficiency in the plant, there is no significant need for preheating the combustion air to high temperatures in the reformer (when used) or in the heater, thus eliminating the possibility of high NO_x generation. The NO_x emission can be additionally reduced by adopting ultra-low NO_x burners; in this case, the NOx emission can be reduced to values below 25 ppmv (50 mg/Nm^3 as NO_2).
A further improvement can be obtained with the application of SCR technology, which can be easily installed in existing convective sections of the heater or reformer. The NO_x is reduced to N_2 by catalytic reaction with a commercial solution of NH_2. The evident benefit is the reduction of NO_x emission to values below 10 ppmv (20 mg/Nm^3 as NO_2).

Energiron is, without question, the cleanest DR technology available. Depending on the configuration, an Energiron plant can remove from 60 to 90% of total CO_2 emissions, which in



other technologies are flared or vented to the atmosphere. Energiron plants offer the unique option of selective recovery of CO_2, which can be cleaned and sold as a cash by-product.
The CO_2 absorption system not only captures the CO_2, but also the sulphur, whenever present in the process gas stream, reducing the overall SO_2 emission from the plant by around 99%.

The high operating pressure of the Energiron shaft and its low gas velocities, and thus low fluidization and dragging force, results in less fines carry-over by top gas (<1% losses in top gas). This low loss of iron ore fines from the reduction process means less particle emission, as fines normally have to be cleaned from the recycle gas stream.

Another advantage of the Energiron plant is the possibility to design the process for a zero make-up water requirement. This is possible mainly because water is a by-product of the reduction reaction and it is condensed and removed from the gas stream. As a consequence, adopting a closed-circuit water system, based on the use of sea/river water heat exchangers instead of conventional cooling towers, there is no need for fresh make-up water and actually a small stream of water is left available at battery limit. This feature is particularly attractive for locations where the water is expensive or not available at all.

Emissions

NO_x with Ultra Low NO_x burners	50 - 80	mg/Nm³
NO_x with Selective Catalytic Removal	10 - 50	mg/Nm³
CO	20 - 100	mg/Nm³
Dust from heater/reformer stack	1 - 5	mg/Nm³
Dust from material handling dedusting	5 - 20	mg/Nm³

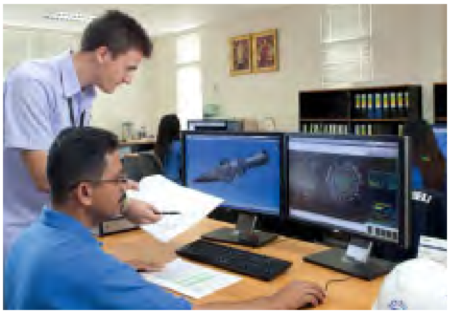
Nucor Steel (LA), USA. World's largest single DR module for 2.5 Mtpy cold DRI production (Energiron ZR - without external reformer). The plant reached 95% metallization and over 4% C in the first 24 hours of operation. Production rate was as expected since day #1.

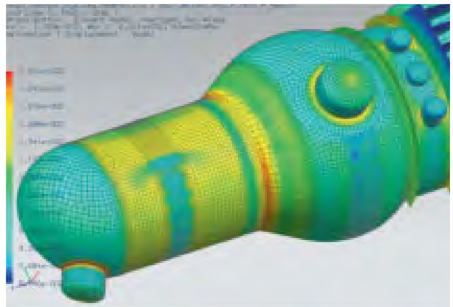

NUCOR

Global project execution

From basic design through manufacturing, project management and construction and through to plant startup and commissioning, the Energiron team assures a successful result in terms of time, quality and costs.

The Energiron alliance offers the unique flexibility of providing everything from a basic technology package to full turnkey projects. Our support runs from process technology through operations and maintenance training and technical assistance, not only in the DR plant but in the steel shop as well.
In addition to technology licensing and conceptual engineering, we provide maintenance and operations training, project and erection supervision, support during startup and commissioning, and a wide range of technical services after startup.
Our own qualified operations and maintenance personnel can even take charge of the operation of a DR facility on a contract basis, if requested.
Our technical staff has years of experience providing training and technical assistance for meltshop and steel mill personnel, with unequaled success in raising productivity levels in all areas, whether or not the steel mill is a DRI-based operation.
From mining, pelletizing and materials handling to steel mill operations and maintenance, computerized process controls, and even including administrative and commercial functions – we provide technologies and services for all areas of ironmaking and steelmaking.



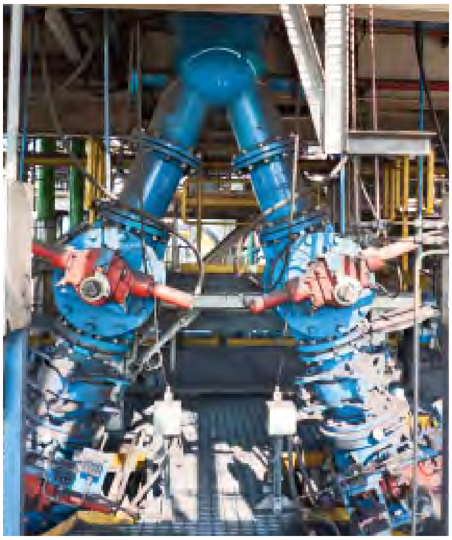


Quality manufacturing

The manufacturing capacity of the Energiron partners, Danieli and Tenova, assures quality and on-time delivery of the main technological equipment through in-house and controlled facilities.

Danieli and Tenova firmily believe manufacturing is a key factor for a winning project execution and assuring overall competitiveness.
Quality procedures and international certifications are the basis for the success in the production of the core equipment. Our workshops and assembly facilities in Europe, China, Thailand, India and the Americas allow us to optimize the sourcing of quality raw materials and to take advantage of the most competitive specific skills and manpower. The manufacturing capacity ranges from the core area equipment (reactor, process vessels, thermal equipment, flow feeders, rotary valve, expansion joints, and sealing valves) to steel structures and pipework.
To speed-up construction activities, complete material handling systems can be produced and pre-assembled in our workshops before delivery to the project sites. Select qualified external workshops cooperate in the successful execution of the jobs.

Employee involvement, quality belief and structured management form the basis of our manufacturing culture, which is widely recognized by the steel community.




PV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Construction capability

Energiron has the further advantage of an international construction capability within the alliance, allowing a constant know how transfer from engineering phase to construction and commissioning phase.

The worldwide presence with own handling and transportation equipment and through specialized and trained people covers full services from soil improvement, civil works, material and equipment handling, electromechanical installations, piping prefabrication, HVAC.

The gained experience proved to be a valuable asset in different socio-cultural environments and was developed during many decades of site activities carried out all over the world.

Ezz Steel, Egypt. Installation of a 700-t reactor in a 1.9-Mtpy DRP (Energiron III, with external reformer; cold discharged DRI: 93% metallization and 3% C) by means of the new Danieli TCR800 tower crane, an ideal flexible solution for on-site construction of heavy DRP or meltshop equipment.

Customer training and assistance

Partnership and customer service are at the basis of the services offered along with Energiron direct reduction plants. Personnel training, on-line/on-field assistance, original spare parts.

Energiron Technical Assistance and Services are jointly provided by Danieli and Tenova.
During the project execution phase, the assistance to the client is mainly devoted to Multilevel Theoretical and Practical Training, with classroom and hands-on activities both in similar Energiron plants and in the same plant under execution.
The future plant operators and managers are accompanied through a training course which covers a complete set of topics for each technical and managerial specialization to assure a deep knowledge of the Energiron technology and to develop the skills necessary to maximize the productivity and profitability of the DRI plant.
The range of after-sales activities covers Management Consulting, Remote Assistance Services, Production and Maintenance Service Agreements. Original Spares and Refurbishments are assured through the constant interaction between the plant management and the Energiron Service Team. Dedicated preventive and predictive maintenance tools and warehouse management software can be provided to plan efficiently the spares resources according to the different necessities of each Energiron plant.

Capacity enhancement and Equipment Technical Improvement analysis can be provided to the customers to let them exploit the latest technological state of the art.The success of the Customer is our pride.

Most recent projects

Emirates Steel - ES1 Integrated steel plant

2.0 Mtpy

_ Location: Abu Dhabi, UAE
_ Original design capacity: 1.6 Mtpy
_ Enhance capacity after revamping: 2.0 Mtpy
_ Energiron III (with external reformer)
_ Hot discharged DRI:
93% metallization and 2% C
_ HYTEMP® system for directly feeding
hot DRI to the EAF

Emirates Steel - ES2 Integrated steel plant

2.0 Mtpy

_ Location: Abu Dhabi, UAE
_ Original design capacity: 1.6 Mtpy
_ Enhance capacity after revamping: 2.0 Mtpy
_ Energiron III (with external reformer)
_ Hot discharged DRI:
93% metallization and 2% C
_ HYTEMP® system for directly feeding
hot DRI to the EAF

Al Ezz Rolling Mills - EZZ

1.9 Mtpy

_ Location: Ain Soukna, Egypt
_ Original design capacity: 1.9 Mtpy
_ Energiron III (with external reformer)
_ Cold discharged DRI:
93% metallization and 3% C

Suez Steel Company - SSC
Integrated steel plant

1.95 Mtpy

_ Location: Suez, Egypt
_ Original design capacity: 1.95 Mtpy
_ Energiron ZR (without external reformer)
_ Hot or cold discharged DRI:
94% metallization & 3.5% C
_ HYTEMP® system for directly feeding
hot DRI to the EAF

Nucor Steel

2.5 Mtpy

_ Location: Convent (LA), USA
_ Original design capacity: 2.5 Mtpy
_ Energiron ZR (without external reformer)
_ Cold discharged DRI:
96% metallization and 4.2% C

Jindal Steel and Power - JSPL
Integrated steel plant

2.5 Mtpy

_ Location: Angul, India
_ Original design capacity: 2.5 Mtpy
_ Energiron ZR (without external reformer)
with Syngas and COG
_ Hot discharged DRI:
_ 94% metallization and 1.5% C
_ HYTEMP® system for directly feeding
hot DRI to the EAF

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