

Alternative Energy Sources, CO₂ Recovery Technology and Clean Environment Compliance – Integral Components of Energiron Technology

By

Jorge Becerra, VP Commercial & Projects, HYL Technologies, S.A. de C.V.,
México

Alessandro Martinis, Exec. Mgr. Process Technology, Danieli & C., Italy

Abstract:

The alliance between HYL Technologies, Techint/Tenova and Danieli brings a new brand - ENERGIRON - to the forefront of the direct reduction industry. Current environmental regulations not only in the EU but worldwide bring more stringent demands to the design of industrial plant operations of all types. ENERGIRON technology is characterized by its flexible process configuration which is able to satisfy and exceed these requirements. In regions where either the high cost or low availability of natural gas work against this traditional energy source, the process is easily configured to operate using coke oven gas, syngas from coal synthesizers and other hydrocarbon sources. More importantly, the air and water effluents of the process are not only low but easily controlled.

Incorporation of selective CO₂ removal systems has been a key factor over the past decade in reducing significantly the emissions levels, providing an additional source of revenue for the plant operator via the captured CO₂. The high pressure operation and closed system of an ENERGIRON plant combined with the HYTEMP Pneumatic Transport System reduces dust emissions to both air and settling tanks, making the process more economical and environmentally friendly. This paper will review the design configuration and economic impact of these green technologies.

INTRODUCTION

The modern direct reduction industry began with HYL more than fifty years ago. Since then, HYL has always been at the forefront with technological innovations, geared towards improving the bottom line for steelmakers. To the end of 2006, HYL plants have produced close to two hundred million tons of high quality DRI/HBI.

HYL has now joined with Danieli & Co., forming an alliance along with HYL's parent company Tenova, for the development and supply of direct reduction technology and plants worldwide. This alliance, called ENERGIRON, combines the long technological experience of HYL with the DR experience and plant and equipment design and supply capabilities of Danieli, to offer the most competitive packages worldwide. ENERGIRON, the innovative HYL direct reduction technology jointly developed by Techint/Tenova and Danieli, reflects the strength of the product and technology which is already achieving successes in the market.

The ENERGIRON trademark is a concept derived from the unique quality of direct reduced iron produced by this technology, a combination of energy and iron for the steel shop that increases productivity and quality while reducing operating costs.

PROCESS FLEXIBILITY

General Process Scheme

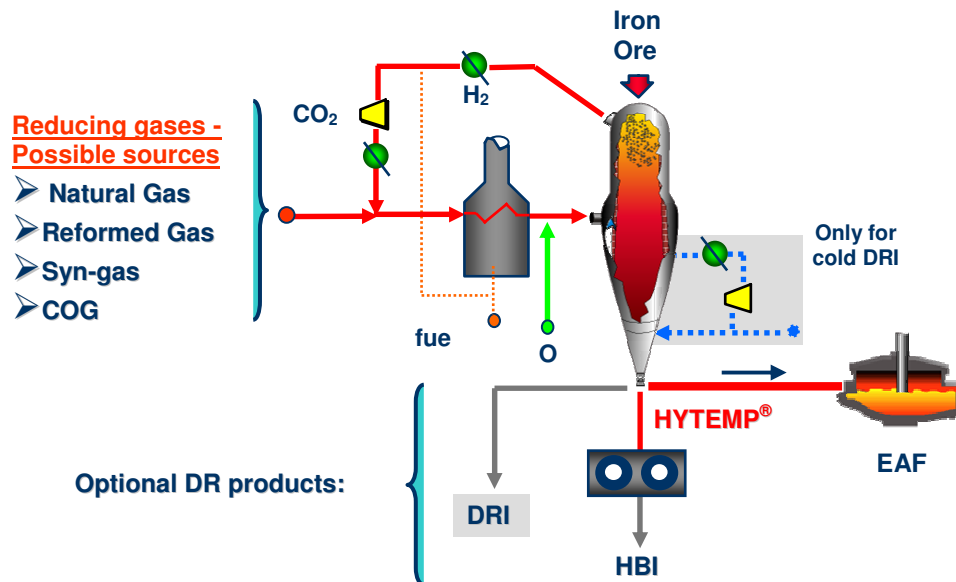
In an ENERGIRON plant the reducing gas source can be either Natural gas, Coke Oven gas, Syngas, or in general any gas containing in significant amounts Hydrocarbons, or directly Hydrogen and/or Carbon Monoxide as indicated in Figure 1. In all cases the process configuration is always the same. This is possible only due to the selective removal of the Reduction "products" Water (H_2O) and Carbon Dioxide (CO_2).

When the source for reducing gas is Natural gas, the reducing gas can be produced in two ways: in an external steam reformer, and/or directly in the shaft reactor by means of "in situ reforming" reactions.

The ratio between reforming and “in situ reforming” can be varied to balance production and investment costs exigencies. The process scheme can be based on 100% external reforming to 100% “in-situ” reforming (ZR) or any combination (small reformer + oxygen injection). This is a unique characteristic of the process flexibility. The most adequate scheme will depend on the local cost structure of energy and raw materials.

As an example, the scheme with external reformer consumes slightly more gas, but the power is minimized, while the ZR scheme minimizes the natural gas consumption but requires additional power (electricity + oxygen). Also, the product quality has to be considered: the scheme with 100% external reforming produces DRI with up to 2.4% carbon or up to 3.5% carbon if there is some oxygen injection, while the ZR scheme easily produces DRI with more than 4% carbon. The scheme is best selected based on a production cost analysis up to liquid steel, in order to consider all factors.

Figure 1
ENERGIRON Process Options

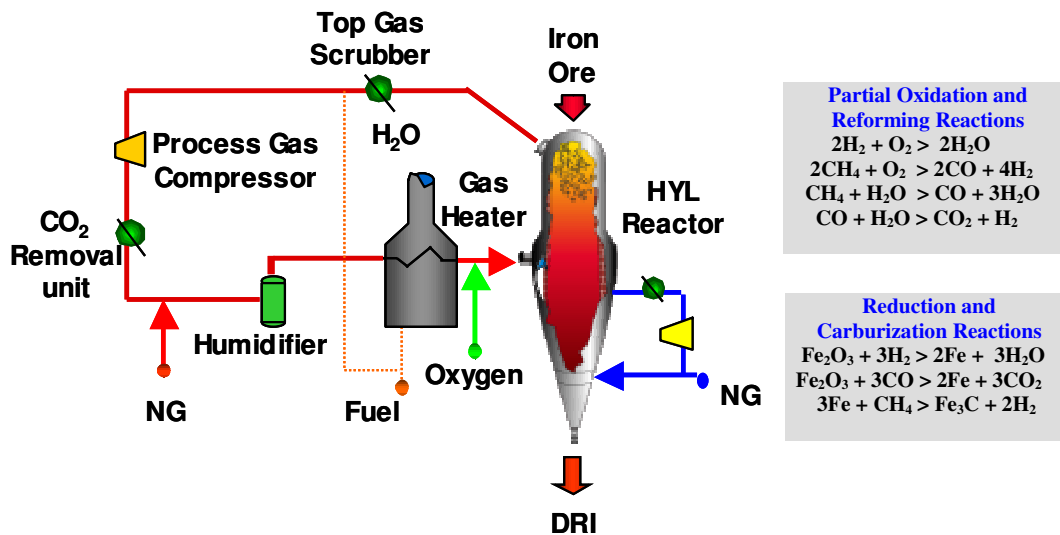


ZR Process Configuration

The ZR Process (Figure 2) is a major step in decreasing the size and improving the efficiency of direct reduction plants. Reducing gases are generated in-situ inside the reduction reactor, by feeding natural gas as make-up to the reducing gas circuit.

Since all reducing gases are generated in the reduction section, optimum reduction efficiency is attained, and thus an external reducing gas reformer is not required. Compared to a conventional DR plant including reformer, in addition to lower operating/maintenance costs and higher DRI quality, the total investment for a ZR plant is lower.

Figure 2
ZR Process Flow sheet



The overall energy efficiency of the ZR process is optimized by the integration of partial combustion to increase the , and “in-situ” reforming inside the reactor, as well as by a lower utilization of thermal equipment in the plant. Therefore, the product takes most of the energy supplied to the process, with minimum energy losses to the environment.

A remarkable advantage of this process scheme is the wider flexibility for DRI carburization, which allows attaining carbon levels up to 5.5%, due to the improved carburizing potential of the gases inside the reactor, which allow for the production primarily of iron carbide.

For the production of high quality DRI, (94% metallization, 4% carbon, discharged at 700°C), the energy consumption is 2.25 – 2.3 Gcal/ton DRI as natural gas and 60 – 80 kWh/ton DRI as electricity, with a low iron ore consumption of 1.35 – 1.40 t/t DRI, mainly due to high operating pressure.

The impact of eliminating the external gas reformer on plant size is significant. For example, a plant of 1-million tpy capacity requires only 60% of the area needed by other process plants for the same capacity. Also, due to the high operating pressure, the same reactor size diameter can be used for a 1 million or a 1.5 million tpy facility, while only the other related equipment would increase in size. This also facilitates locating the DR plant adjacent to the meltshop in existing operations.

The Zero Reformer plant configuration has been successfully operating since 1998 in the 4M DR plant and since 2001 in the 3M5 plant, both at the Ternium Hylsa steel facility in Monterrey, Mexico.

In the case of the Zero reformer process, other reducing agents such as gases from coal, pet coke and similar fossil fuels gasification or coke-oven gas, among others, are sources of reducing gas depending on the particular situation and availability. This flexibility is made possible precisely because the ZR Process is independent of the reducing gas source, with no requirement of recirculation of gases back to a reformer to complete the process chemistry loop. Several projects are currently under development which will use coke oven gas as the reducing gas source, and projects using gas from coal gasification technology are also underway.

In all cases, the reactor operates at elevated pressure (6 bar, absolute), allowing a high reactor productivity of about 10 t/h-m² and minimizing dust losses through top gas carry-over. This is reflected in low iron ore consumption, which reduces the cost for Iron ore, this is also due to the fact that the ZR process only requires

to screen out the fines -3mm from the Iron ore and not the fines -8mm as other processes.

One of the inherent characteristics of the process is the selective elimination of both by-products generated from the reduction process; water (H₂O) and carbon dioxide (CO₂), which are eliminated through top gas scrubbing and CO₂ removal systems, respectively. This will be mentioned again later.

ENERGIRON Plants – Flexibility for using alternative energy sources

Natural Gas

As was already mentioned, the basic reduction scheme (ZR) remains unchanged regardless of the source of reducing gases. For natural gas, the configuration can be based on either reformed gas or on the ZR scheme, depending on the local availability and/or cost of energy.

When an external Natural gas Reformer is used, steam is required in the reformer to adjust the steam/carbon ratio for reforming, and in the CO₂ removal system as sensible energy to release CO₂ from the absorbing solution. This Steam, can easily be generated at high pressure (40-60 BARg) so that it can be used to drive steam turbines prior to the final users or to generate either partially or totally the power required in the DR plant. In this way, electricity consumption is drastically reduced or even be ZERO.

There are DR plants, like Vikram Ispat in India, which not only zero power from the external grid, but even exports electricity to the adjacent village. Others like Perwaja Steel in Malaysia and Lebedinsky GOK in Russia have reduced the power consumption to around 30 KWH/ton by generating part of the power required using High Pressure Steam in a Turbo-generator.

In this regard, an ENERGIRON plant can be designed to achieve the most optimized DRI production cost, depending on local conditions.

Coke Oven Gas

In any integrated facility producing steel via BF/BOF there is a natural unbalance in energy. The energy contained in the gases generated by the COG, BF, and the BOF is always higher than the energy required as fuel inside the facility.

Typically, energy balances of integrated steel works show that most of the excess gaseous energies are mainly used for power generation or even flared.

An alternative use for the excess of COG is to produce DRI. The DRI produced can be used in several ways such as:

- Substitute of scrap in the BOF
- Metallic charge to the BF, to decrease the consumption of coke and/or powdered coal injection (PCI) or, to increase the production of hot metal
- For sale as a scrap substitute to other companies.

COG is a by-product of coke manufacture. It is produced during the carbonisation or destructive distillation of bituminous coal in the absence of air. As compared to BFG or BOF gas, the COG has a 5 – 6 times higher calorific value because it contains less N_2 and more CH_4 therefore it can be considered as a better source for energy. Nevertheless, the sulphur (as H_2S) present in untreated (not desulphurized) COG is a distinct disadvantage, particularly when heating certain grades of alloy steel for rolling. Its presence also requires the use of materials resistant to sulphur attack in pipelines, valves and burners.

For the carbonization process the coke oven furnaces require fuel for heating. In this regard, coke oven plants have a high flexibility for use of fuels from different sources, including BFG and their own generated COG.

Between the coke oven plant and the other plant systems of an integrated steel works based on HM and BOF, there is an energetic “interlink”.

The advantage of this interlinking gas system is mainly related to the use of the low calorific BFG as fuel in coke oven furnaces and hot stoves of the BF, while the high calorific coke oven gas can be used for other consumers like rolling mill and power plant.

Production of hot COG is approximately $420 \text{ Nm}^3/\text{t}$ of coking coal.

Even though the chemical compositions of COG and natural gas are quite different COG can be used directly in the ZR process, extensive Pilot plant investigation has been carried out on this respect and it has been found an

interesting fact, whether the make up to the Reduction circuit is COG or natural gas, the chemical composition of the reducing gas entering the Reactor is very similar, even better for the case of COG. The above fact, results in a minimum Technological risk involved in using COG instead of natural gas for the case of the HYL-ZR direct reducing process.

Typical requirement of COG for DRI production, based on the HYL-ZR scheme is about 9.5 GJ/t DRI, for a DRI of 94% metallization and 4.0% carbon.

*Figure 3. Comparative Gas Analysis:
COG vs. HYL-ZR (Nat. gas-based) Scheme*

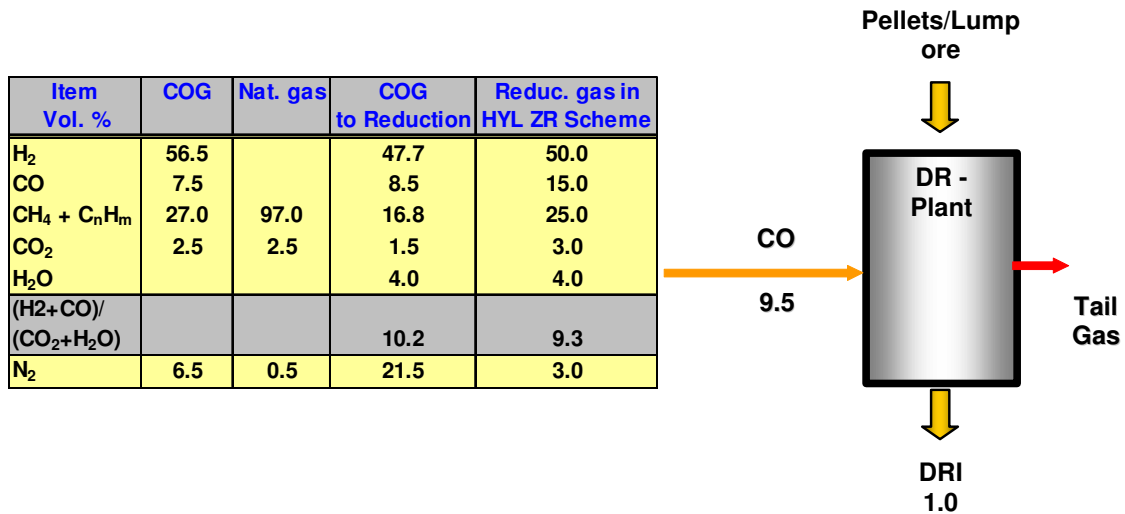


Figure 4 presents a simplified overview of the global energy scheme and CO₂ emission for a typical integrated steelworks for production of slabs. Corresponding figures of this example are presented in Table 1.

For this application, spent gases from the integrated steel mill are sent to the DR plant and split as follows:

- An amount of 2.26 Gj of COG/t HM is used as process gas for DRI production.
- Required amount of BFG is used as fuel for reducing gas heating and steam generation, which is needed for CO₂ absorption in the DR plant.

The diagram illustrates the energy flows and CO₂ emissions in a steel plant. The main components are:

- Coke oven** (Red box)
- Blast Furnace** (Grey box)
- BOF** (Blue box)
- Internal Use** (Light blue box)
- DR Plant** (Cyan dashed box)
- Power Plant** (Yellow box)
- Internal Use:** (Light blue box)
 - Coke oven plant
 - Sinter plant
 - Lime calcination
 - Reheat furnace
 - Others

The flows are as follows:

- Red flow:** From Coke oven to Internal Use and DR Plant.
- Green flow:** From Internal Use to DR Plant.
- Black flow:** From Blast Furnace to Power Plant.
- Blue flow:** From BOF to Internal Use.
- Black flow:** From Power Plant to Blast Furnace.
- Black flow:** From Power Plant to DR Plant.
- Black flow:** From DR Plant to Coke oven.

On the right side, two large yellow arrows indicate the outputs:

- CO₂ emissions** (Top arrow)
- Elec. Power** (Bottom arrow)

		Without DR-Plant	With DR-Plant
Power Generation	MW/t _{HM}	375	142
Export Power	MW/t _{HM}	194	0
Import Power	MW/t _{HM}	0	21
Total CO ₂ Emission	kg _{CO2} /t _{HM}	1,780	1,780
Range of selective CO ₂ removal	kg _{CO2} /t _{HM}	0	30 - 150
DRI Production	kg _{DRI} /t _{HM}	0	227
Note: Maximum potential DRI Production from a balanced/optimised-Integrated Steel Plant (using COG & BOFG for DRI)	kg _{DRI} /t _{HM}		380

Based on the results presented in the overall energy balance (Table 1), it can be observed that, as general rule, the same amount of COG can be used to produce either, 1.0 kg of DRI or 1.0 MW (227 kg DRI/t HM vs. 215 MW/t HM).

A simpler and direct result is also obtained if an efficiency of 35%, based on COG LHV, is considered. For comparison purposes, in both cases the same flow of COG of 38,100 Nm³/hr is considered, with this flow you can produce either 65 MW or 65 tonnes of DRI/hour (equivalent to 500,000 t DRI/year).

In both cases no capital cost is considered; only operational cost is used for this comparison.

As basis for calculation of the DRI production cost, the following has been taking into account:

- Imported pellets are used for the DRI production
- power and oxygen necessary for the production of DRI are at market prices

Based on the above, the DRI production cost estimate is presented in Table 2 below.

To compare both business alternatives, the following is assumed:

The production cost (COG at zero cost) is:

For power 0.01 US\$/kWh

For DRI 125 US\$/t

For comparative purposes, both, power and DRI are sold externally at market prices; 0.05 US\$/kWh and 220 US\$/ton of DRI.

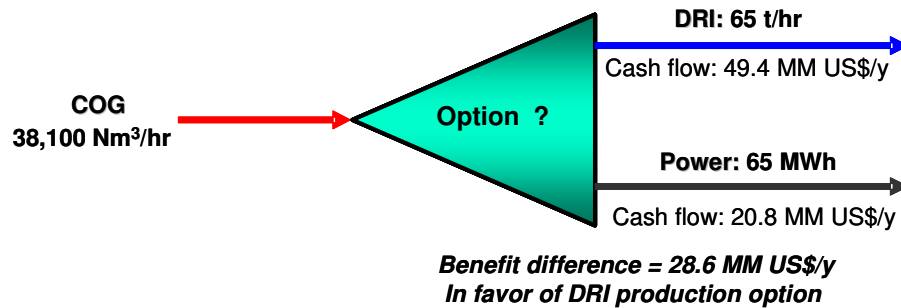
Table 2. DRI production Cost-based on COG

		Unit Cost	HYL MINI-MODULE 70% Pellets/30% Lump ore DRI: 94% Mtz, 4% C	
Concept	unit	US\$	consump/t	\$US/t
Pellets	t	90.0	0.97	86.94
Lump ore	t	70.0	0.41	28.98
Coke Oven gas	GJ	-	10	-
Electricity	kWh	0.05	80	4.00
Oxygen	Nm ³	0.05	11	0.55
Water	m ³	0.02	1.3	0.03
Other consumables	\$US			0.60
Maintenance	\$US			3.01
Personnel	m-h	5.00	0.17	0.85
G&A	\$US			1.00
Total DRI Production Cost	\$US			125.96

The results of the economical analysis for the use of COG to produce Power or DRI are presented in Figure 5 below.

Figure 5. Comparative analysis of DRI production vs. Power with COG

COG Utilization - Economical Comparison					
DRI cost (w/o COG)	US\$/tonne	125.00	Power gen. cost (w/o COG)	US\$/kWh	0.01
DRI price	US\$/tonne	220.00	Power price	US\$/kWh	0.05
DRI profit	US\$/tonne	95.00	Power profit	US\$/kWh	0.04
DRI Plant production	tonne DRI/hr	65.0	Power generation	kWh/hr	65,000
DRI benefits	MMUS\$/year	49.4	Power benefits	US\$/year	20.80



In addition to the economic benefits, for an integrated steel works, the following considerations are significant in terms of environmental aspects:

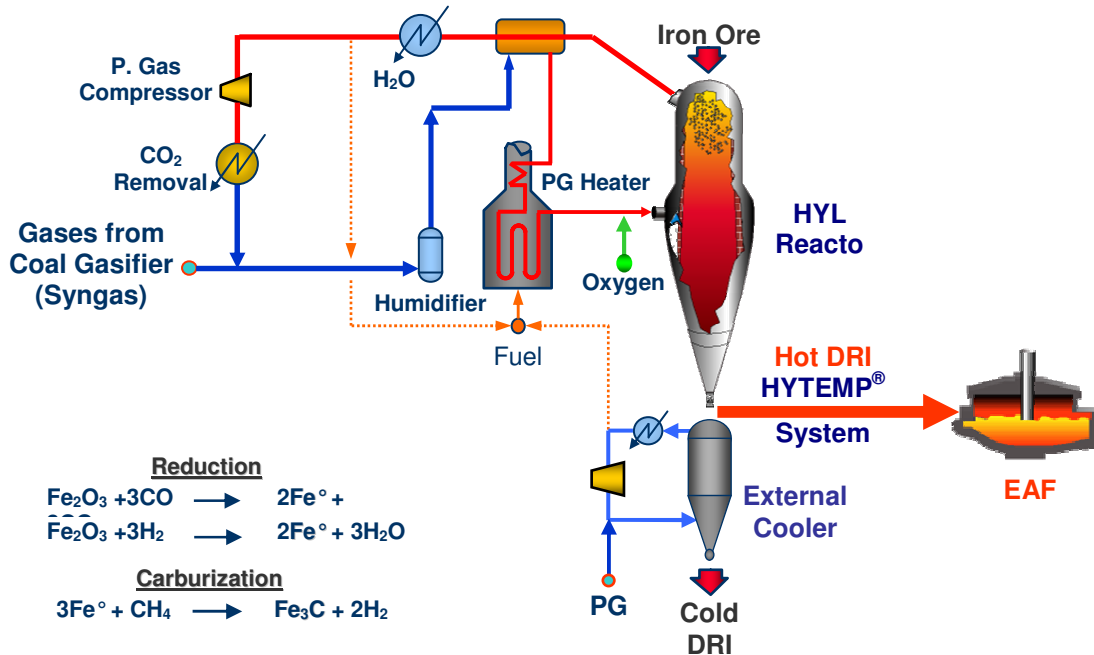
- Environmental restrictions related to CO₂ emissions, which could be of economical importance due to regulations/trading aspects envisioned in the Kyoto Protocol.
- By keeping the steelworks operating, there are some possibilities to overcome these issues. By modifying the current trend of using spent gases from the integrated facility for power generation, the alternative is to use these gases for more value-added DRI production while reducing fossil fuels consumption and decreasing CO₂ emissions. Potential decrease of non-selective CO₂ emissions is in the order of 23 – 34%.

Syngas from Coal Gasification

As presented in Figure 6 below, the syngas from the gasifier can be fed directly to the standard HYL ZR DR plant. The mixture of syngas make-up and recycle gas is preheated in a direct gas heater up to 930° C and fed to the reactor. After reduction of iron ores in the DR reactor, top exhaust gas is passed through a scrubbing unit for dust removal and cooling. The gas is then recycled by a compressor. To further decrease energy consumption, a top gas heat recuperator can be incorporated.

Specific requirements of syngas per tonne of DRI are only about 700 Nm³/t_{DRI}. Or about 9.5 GJ. In the case of an integrated steel mill, pneumatic transport of hot DRI (HYTEMP[®]) to the Electric Arc Furnace (EAF) has been incorporated as part of the basic plant arrangement in order to optimize the overall energy consumption and productivity.

Figure 6
HYL-ZR DR Plant with Syngas from Gasifier



As in the case of the COG, by comparing the reducing gas composition entering the Reactor, it can be seen that the gas composition is very similar, either when natural gas or when Syngas is used as make up for the reduction circuit, this is shown in Table 3 below and is the result of the selective removal of the reduction products. Because of the above, there is for all practical purposes no technological risk is for this application.

Table 3
Comparative Reducing Gas Analysis

Item Vol. %	Syngas Make-up	NG Make-up	Syngas to Reactor	ZR to Reactor
H ₂	55		54	55
CO	25		20	14
CH ₄ + C _n H _m	16	97	18	22
CO ₂	2	2	2	3
H ₂ O	0		4	5
(H ₂ +CO)/ (CO ₂ +H ₂ O)			13	9
N ₂	1	1	4	2

Depending on particular applications, optional schemes, which can be incorporated are:

- *In plant electrical generation*
This is achieved by installing a turbo expander in the treated syngas stream before being fed to the DR module. This allow potential power savings of about 3-6 MW (depending on gasifier technology) for typical plants of 1.2 MM tpy DRI by taking advantage of the gasifier high operating pressure.
- *Carbon dioxide (CO₂) recovery*
For sale as by-product.

Most suitable DR technology for using syngas from coal gasification

When comparing the basic HYL Process scheme to the one required for syngas from coal gasification, the following main aspects related to the HYL Process application can be easily noticed:

- *General process scheme*
No major changes and innovations are required in the basic process scheme. The reduction section is incorporated as it is in typical HYL ZR plants.
- *H₂-rich gases use in DR plants*
Syngas is conditioned through shifting and CO₂ removal to produce the H₂-rich gases which characterize the HYL Process.
- *Optimization of Process syngas consumption*
Recycling of reducing gases, through CO₂ removal, minimizes syngas make-up.
- *HYTEMP[®] Iron use*
Potential incorporation of the HYTEMP[®] System for use of hot DRI to the EAF leads to important economic benefits related to power savings and productivity increase. The HYTEMP[®] iron presents a unique option as alternate product for integrated steelmaking facilities based on the use of syngas from coal gasifiers.

Overall Plant Performance

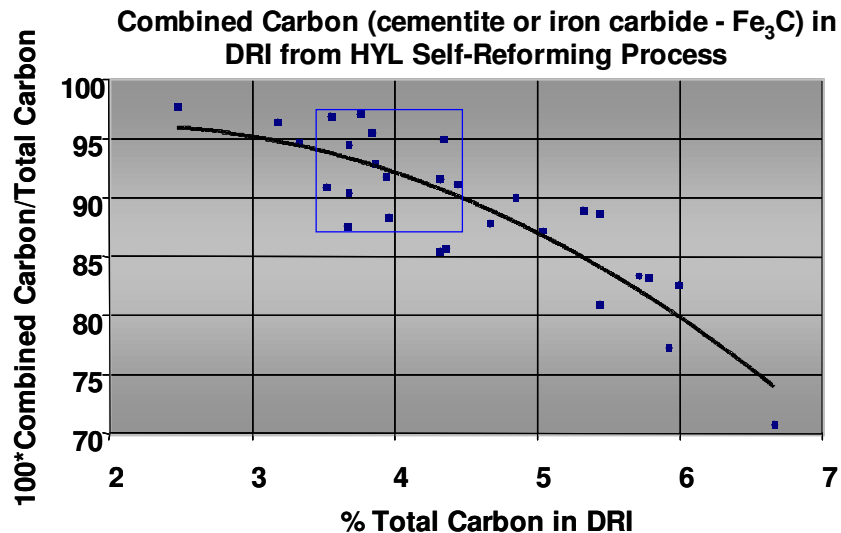
As compared to other existing and emerging coal-based DR technologies, this scheme offers the possibility to install a DR plant of any size up to 1.6 million tonnes/year of DRI in a single module. This approach is based on the incorporation of proven technologies: Gasifier unit and HYL DR plant.

High Carbide Iron

A unique benefit of the ZR Process is the DRI which it produces. This product, which we call High Carbide Iron or HCI, typically has a metallization of 95% and a carbon content of around 4% in the form of combined carbon. This type of product yields significant benefits in the electric furnace that to date, no other process 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. Most of the carbon in DRI currently being produced in the ZR scheme is in the form of Fe_3C (Figure 7).

Figure 7
High Carbide Iron (HCI)



DRI produced with the ZR scheme is characterized by its high stability, much higher than conventional DRI produced in other DR process. The reason for this high stability, 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 produced by a ZR plant makes the product very stable. This highly improved product has been registered as High Carbide Iron or HCI to distinguish it from typical reduced iron products.

The HYL® HYTEMP System

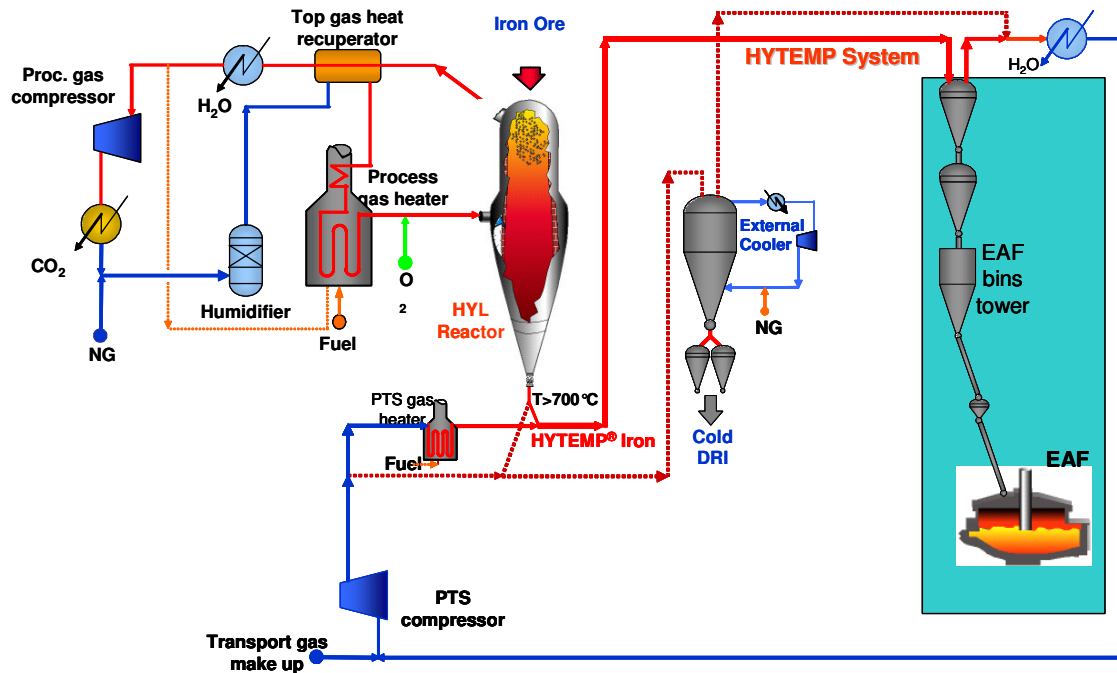
An additional technology which, on its own provides significant benefits for steelmakers is the HYL HYTEMP pneumatic transport system for sending hot DRI from the reduction reactor to the EAF shop. For an ENERGIRON plant combining the HYTEMP System with the ZR Process, the benefits increase substantially by bringing hot, high carbide iron to directly feed the melting furnaces.

A simplified process scheme of the HYTEMP system is presented in Figure 8. The HYTEMP System involves a 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) with metallization up to 95% and controlled carbon usually around 4%, 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.

The HYTEMP system also includes the means to continuously feed the Hot DRI to the EAF in a controlled and safe manner.

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.

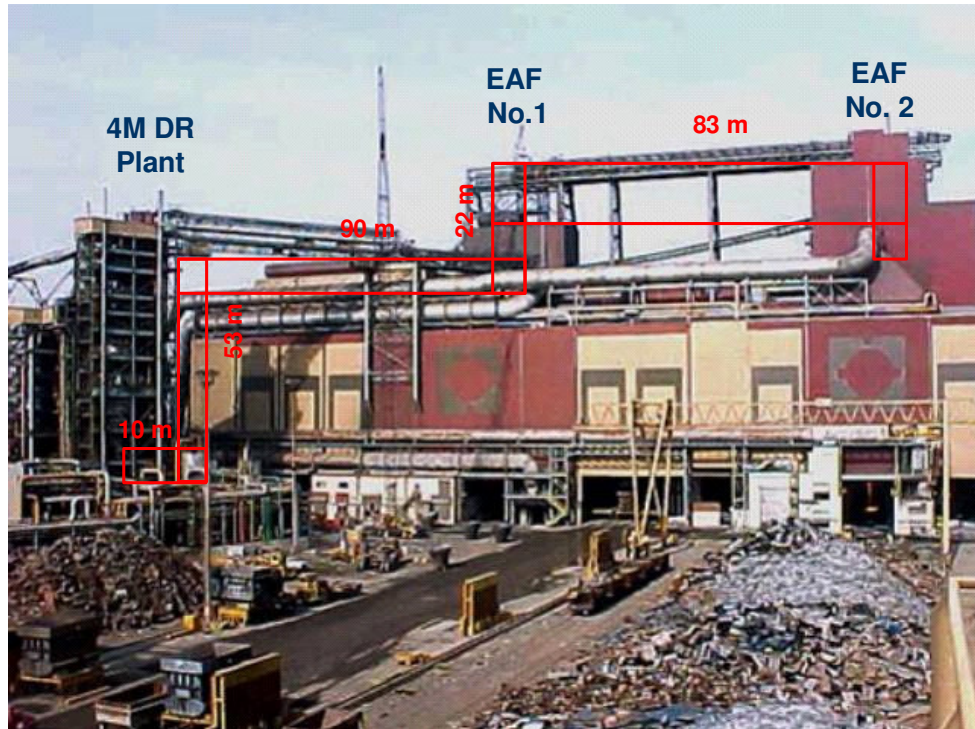
Figure 8
HYL® HYTEMP System



Combined Advantages of Hot, High Carbide Iron

The use of hot DRI is a proven concept in the Ternium Hylsa melt shop. In the 4M DR plant in Monterrey, the hot DRI is pneumatically transported to 2-EAF's. To date, this continues to be the only proven technology for hot DRI transport and charging to the meltshop. The system is presented in Figure 9. In this plant, hot DRI is transported through HYTEMP and fed to the DC-type EAF of Hylsa's meltshop. Over 6 million tons of DRI have been transported since initial start-up in 1998.

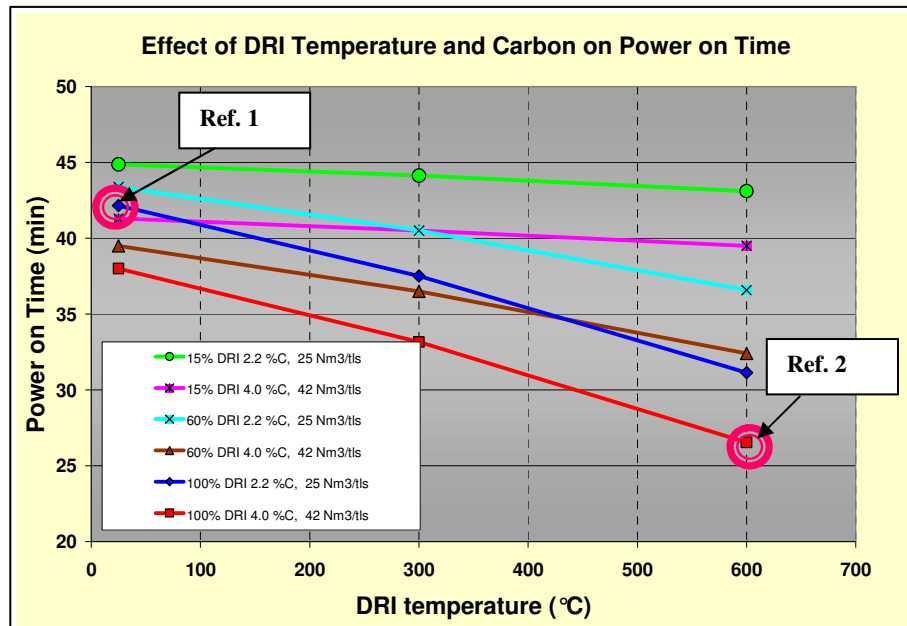
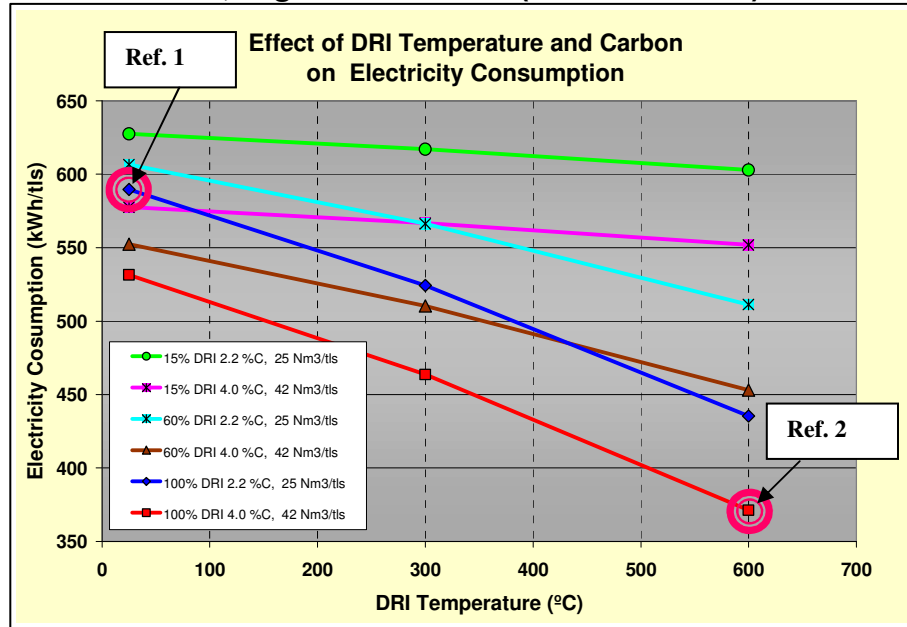
Figure 9
HYL HYTEMP System at Ternium Hylsa Monterrey Plant



The benefits of high-carbon hot DRI in meltshop operations have been widely demonstrated in Hylsa's EAF. Hot DRI feed provides additional sensible heat to the EAF, reducing power consumption and tap-to-tap time, which are reflected in productivity increase.

Direct feed of hot DRI in Hylsa's meltshop is carried out through the HYTEMP system. Comparative analysis, based on results of hot charging related to electricity consumption and to power on time are shown in Figure 10. Data for different percentages of DRI with 94% metallization and various carbon levels have been included. The differences between cold DRI with 2.2% C (Ref. 1) and hot DRI at 500°C with 4% C (Ref. 2) for 100% charge to the EAF are: a decrease of about 180 kWh/tLS and a reduction of about 12 min. on power on time, which may represent over 25% potential productivity increase.

Figure 10
Hot, High Carbide Iron (Actual Results)



Environmental Impact

ENERGIRON plant emissions are in accordance with the most stringent environmental regulations anywhere in large part due to the process design itself which recovers energy by Steam generation which is used in the CO₂ removal system, while In other processes it is necessary the use of heat recovery by preheating the combustion air and even the fuel resulting in very high emissions of NO_x.

CO₂ Removal

In addition to the removal of CO₂, the CO₂ removal system eliminates sulfur from the reducing gas stream (which has been acquired from the iron ore being reduced). In fact, sulfur coming from the ore, having been converted to H₂S in the reactor reduction zone, is eliminated in part in the reduction quenching/scrubbing unit, and to a greater extent in the CO₂ removal unit.

Waste effluents depend on the particular CO₂ removal process used. In amine based processes, a gaseous effluent is generated containing mainly CO₂ and H₂S with levels of the order of 60-400 ppmv.

Depending on demand, the CO₂ can be recovered and sold as a by product for other applications, so that it is not vented to the atmosphere. The environmental impact is decreased with this approach. The typical application for CO₂ recovery, used at the Ternium Hylsa plants in Monterrey and Puebla, Mexico, involves capturing and cleaning the CO₂, which is then sold to customers such as beverage industries, thus eliminating a similar volume of manufactured CO₂ while providing a significant source of revenue for the DR plant owner.

Dust Emissions

For integrated steel mini-mills there is an additional “green” factor known as the HYTEMP System. This first-of-a-kind technology has been in operation since 1998 and consists of the pneumatic transport of hot DRI from the reactor discharge area to the electric furnace shop. Since it is a completely enclosed system, the advantages are both economic and environmental.

Using the HYTEMP technology, HYL has been able to contain the entire direct reduction process – iron ore enters the top of the reduction tower and once inside, it doesn't see the light of day until it has been converted to liquid steel

Environmentally, the enclosed system eliminates the need for DRI screening and DRI handling system which require the use of dust collecting and scrubbing units which in any case at the end result in DRI fines as waste. The HYTEMP system, introduces the DRI fines into the EAF increasing the overall yield. The HYTEMP system includes the means to continuously feed the hot DRI to the EAF, then if 100% DRI is used, the EAF roof is never opened.

Conclusions

- **The HYL ZR technology, can use any kind of gas such as COG, Syngas, Corex off gas, Natural gas, etc maintaining always the same process configuration.**
- **The HYL ZR technology can produce a High Carbide Iron containing more than 50% of Fe_3C**
- **The technological risk involved in the use of other gas different from Natural gas for DRI production is minimized with the ZR process scheme.**
- **The use of COG to produce DRI in an integrated facility can help the optimization of production cost and reduce the CO_2 emissions.**
- **The use of High Carbon DRI in the EAF reduce the power consumption and increases the productivity**
- **The use of Hot DRI in the EAF reduce the power consumption and increases the productivity**
- **The use of the HYTEMP system reduces the dust emissions in a DR-metlshop installation.**
- **The use of the HYL ZR process reduces the emissions of NO_x to the atmosphere.**