ENERGIRON HYL

THE INNOVATIVE DIRECT REDUCTION TECHNOLOGY

High Carbon DRI - The Future for Both Captive and Merchant DR Plants

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Importance of DRI

- The Middle East region has become one of the highest growth areas for steelmaking via the direct reduction - EAF route.
- Natural gas availability and a strong growth in industrial and commercial development have increased steel demand significantly in the region.
- While the majority of new direct reduction facilities here are planned for onsite steel production, there is also merchant demand which can be satisfied.
- A key aspect of Energiron - the HYL DR technology from Danieli and Tenova HYL - is that it produces a reduced product with very high levels of iron carbide, unlike any other DR product. Energiron DRI, when charged hot to an adjacent EAF provides significant operating and cost advantages for steelmaking, and the product when discharged cold is a highly stable material which can easily be transported to satisfy merchant requirements.

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Importance of High Carbon DRI

- Energiron Technology
  - ✓ Process Highlights
  - ✓ Product Highlights
- Quality product
- Easy to transport and store
- Better productivity and yield in EAFs
- Better quality steel products
- Only from Energiron process:
  - ✓ Environmentally friendly
  - ✓ Fully proven hot charging system

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Energiron Technology

- The ENERGIRON Process based on the ZR scheme, is a major step in reducing the size and improving the efficiency of direct reduction plants. Reducing gases are generated by in-situ in the reduction reactor, feeding natural gas as make-up to the reducing gas circuit and injecting oxygen at the inlet of the reactor.
- Since all reducing gases are generated in the reduction section, taking advantage of the catalytic effect of the metallic iron inside the shaft furnace, optimum reduction efficiency is attained, and thus an external reducing gas reformer is not required.
- The basic ENERGIRON scheme permits the direct utilization of natural gas.

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Energiron Technology

- The basic scheme can also use the conventional steam-natural gas reforming equipment, which has long characterized the process. Other reducing agents such as hydrogen, gases from gasification of coal, petcoke and similar fossil fuels and coke-oven gas, among others, are also potential sources of reducing gas depending on the particular situation and availability.
- Additionally, the DR plant can be designed to produce High-carbon DRI, hot DRI, which can be directly fed to adjacent EAF through the HYTEMP System or to briquetting units to produced HBI or any combination of these products.

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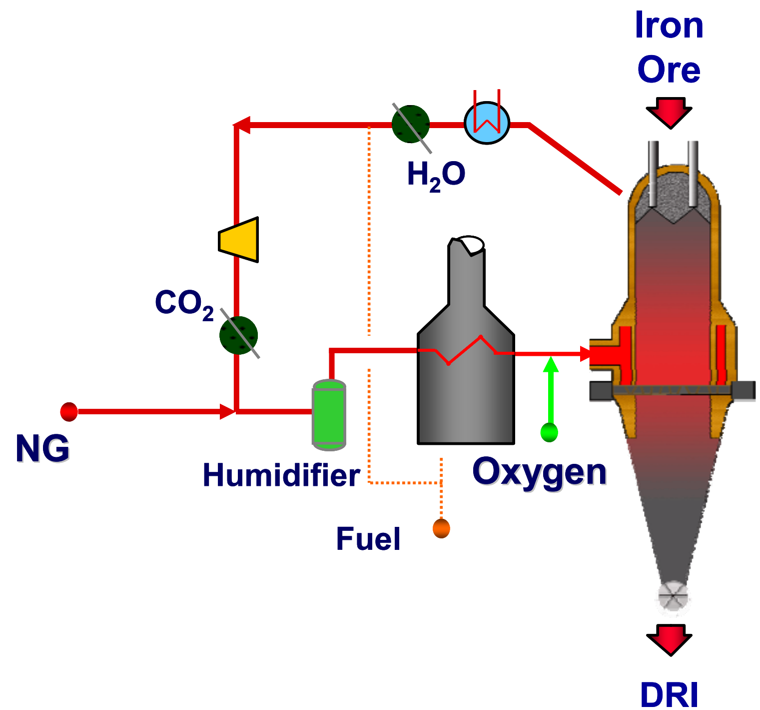
Process Highlights

- High reduction temp. (above 1050°C)
- In-situ reforming
- Low use of thermal equipment
  - ✓ Minimal energy losses
- High pressure operation
  - ✓ Minimal dust losses
  - ✓ Increased productivity/m^2
- Selective removal of by-products (H_2O and CO_2)
  - ✓ Clean & **Green**
  - ✓ CO_2 – merchant product



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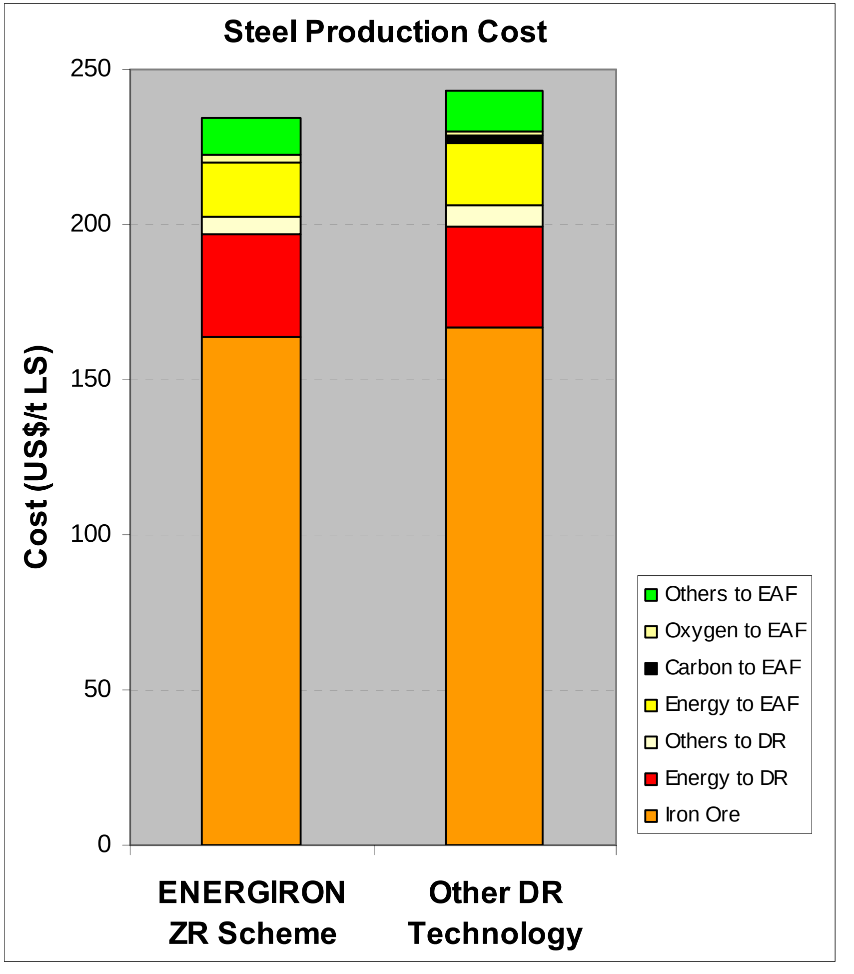
Process Economics

- As compared to other DR processes, the DRI and steel production costs through the ENERGIRON Technology is lower due to:
  - ✓ Lower consumption of iron ore
  - ✓ Lower total energy (thermal + electrical) consumption
  - ✓ High-carbon content in DRI, with significant costs and productivity benefits in EAF
  - ✓ Further reduction of production cost through use of low cost iron ores



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Process Economics

Basis, costs for:

Pellets	100 $/t
Natural gas	9.92 $/Gcal
Electricity	0.045 $/kWh
Oxygen	0.06 $/Nm^3
C addition to EAF	0.14 $/kg

Comparative Cost Analysis				
Scenario	DR-EAF: ZR High Carbon DRI vs. Other Technology DRI			
Scheme	**Other Cold DRI** 94% Mtz.; 2% C	**ZR Cold High-C DRI** 94% Mtz.; 3.7% C	**Other Hot DRI** 94% Mtz.; 1.5% C	**ZR Hot High-C DRI** 94% Mtz.; 3.7% C
Production cost estimate/t LS	106.9%	103.6%	103.6%	100%
Additional Operating cost for 1.4 m tpy LS (million $US/y)	**22.5**	**11.6**	**11.8**	Base: 225 $/t LS **0**
Comparative EAF Productivity	75.8%	80.4%	91.6%	100%

- Based on the benefits when using the high-C DRI, as compared to other DRI qualities/schemes, for a steel facility of 1.4 million tpy, savings can be as high as 12 million $/year.
- Additional benefits are related to higher EAF productivity by using high-carbon DRI.

Product Highlights

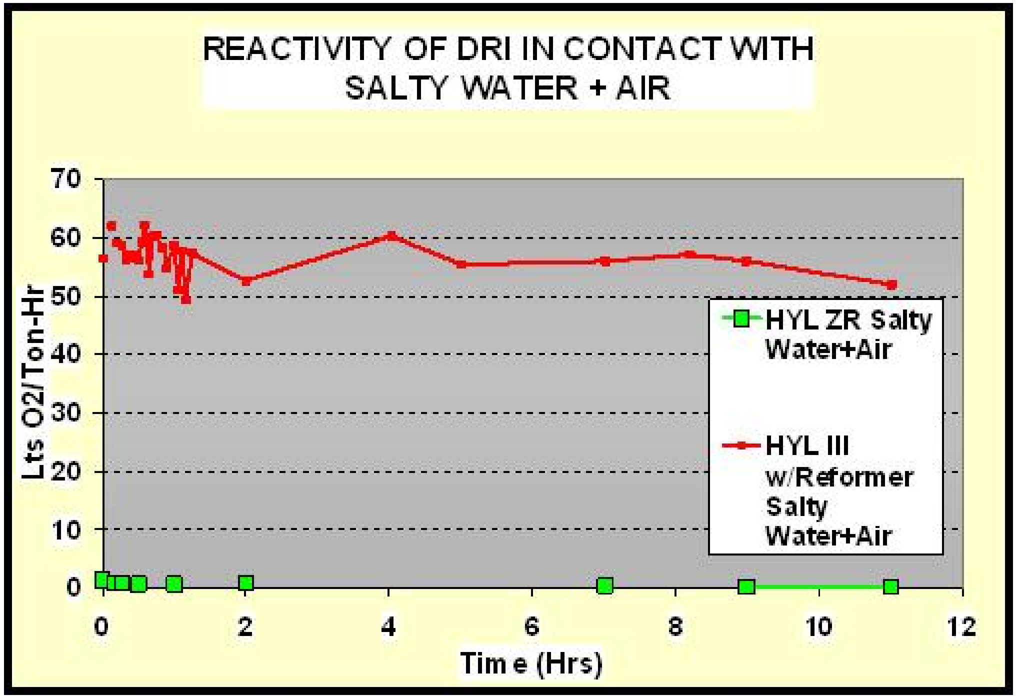
- Widest range of product carbon (2 – 5%), as iron carbide
- Carbon level is selective, not averaged
- Highly metallized, high carbon DRI brings energy to the EAF
- Lowest iron ore and gas requirements

ZR Scheme-Typical Consumption Figures

Item	Unit	
Plant capacity	t/a	**200,000 - 2,000,000**
Metallization		**≥ 94%**
Carbon (controlled)		**2% - 5%**
Inputs		**Specific Consumption**
Iron ore	t/t	**1.35 - 1.40**
Natural gas	Gcal/t	**2.3**
Electricity	kWh/t	**60-80**
Oxygen	Nm^3/t	**35**
Water	m^3	**1.2**
Labor	m-h/t	**0.11 - 0.17**
Maintenance	US$	**3 - 3.3**

High Carbon DRI Benefits - Safety

- Carbon is mostly as iron carbide in outermost part of pellets
- Carbide shell acts as inhibitor; improves stability



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High Carbon DRI Benefits - Economy

- Can be shipped without cost of briquetting
- Reduces need for carbon additions to the EAF
- Increases yield and productivity, especially when hot charged via HYTEMP System

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High Carbon DRI Benefits – in EAF

- Carbon is Energy and this energy is finally utilized at the EAF when the DRI is melted.
- The Carbon will yield energy by the following reactions:
  - ✓ 2C + O2 ------> CO + Heat
  - ✓ Fe3C ---> 3Fe + C + Heat
- The combination of the above reactions will yield more than 37 kWh/tls per each 1% Carbon in the DRI.
- Efficient use of carbon; as compared to other sources of carbon injection, while minimizing external carbon (graphite) additions, cementite in DRI is characterized by a higher recovery yield in the EAF.
- Easy foamy slag generation; as high carbon DRI enters in contact with free or combined oxygen.
- The same system controls the feeding rate of metallic charge and carbon additions.

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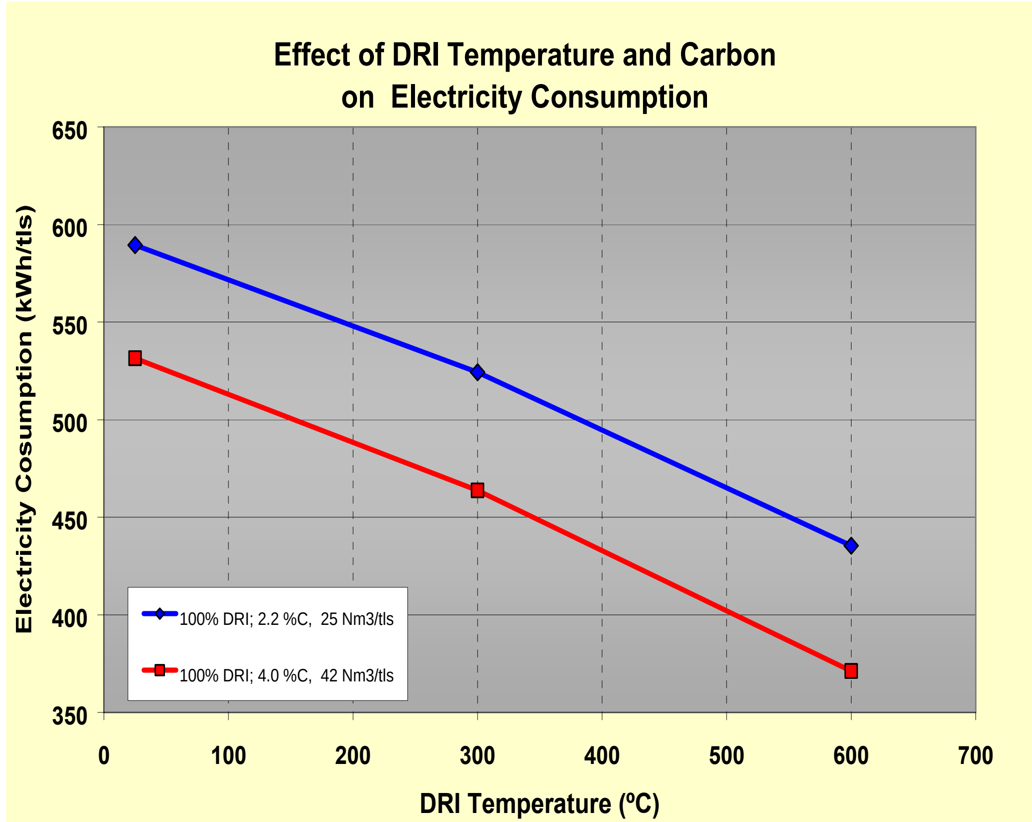
Impact of Carbon and Temperature

- Graphite injection is about 12 kg/tLS for DRI with 2.2% carbon and 0.5 kg/tLS for DRI with 4.0% carbon.
- For these operating conditions, the change from 2.2% to 4% carbon in cold DRI represents a decrease of 11-kg graphite and 58-kWh/tLS.
- This power saving is a result of the replacement of graphite by cementite related to yield and heat reaction.
- On the other hand, hot DRI feed provides additional sensible heat to the EAF, reducing power consumption and tap-to-tap time, which is additionally reflected in productivity increase. The overall effect of:
  - ✓ high-efficiency ZR scheme with minimum thermal and electricity consumption figures, and
  - ✓ use of hot and/or cold High-Carbon DRI in EAF,
- have an important impact on the overall energy demand for steel production, decreasing overall plant emissions and particularly CO2 release to atmosphere.



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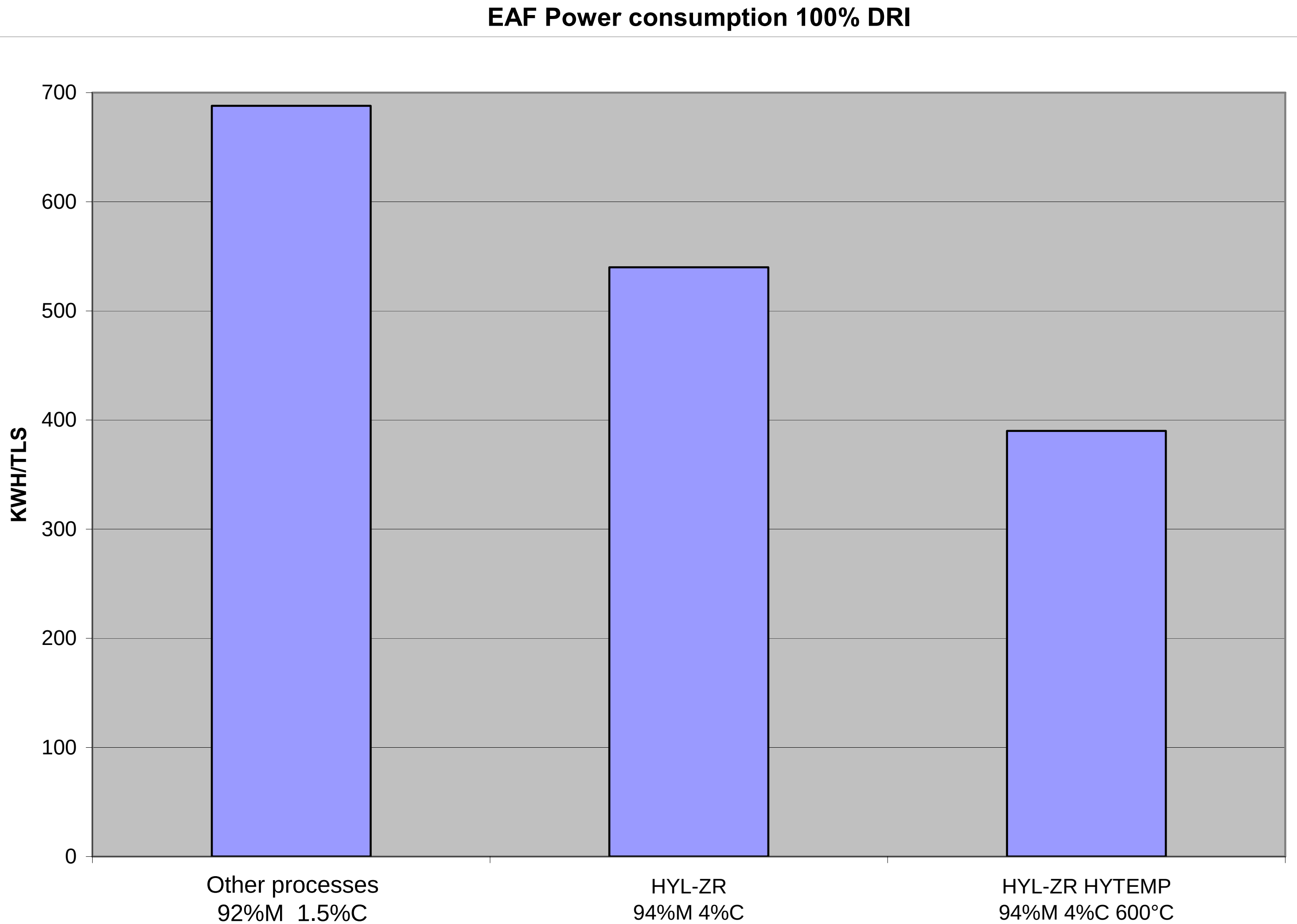

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Keeping it Clean – Keeping it Green

- For a DR plant, main gas and solids emissions are related to:
  - ✓ Iron ore particulates from material handling.
  - ✓ Iron ore and DRI particulates as sludge from process water system.
  - ✓ Gaseous effluents from thermal equipment and degassing stacks of water systems.
- Emissions from gaseous and aqueous effluents from a DR plant can be categorized in two main groups:
  - ✓ Pollutants, such as: NOx, SOx, VOC, particulates, etc., which limits are defined by the environmental regulations of local Governments.
  - ✓ Global Warming-Greenhouse emissions (GHG), which refer to gaseous compounds from natural and anthropogenic sources that absorb and re-emit infrared radiation, enhancing the greenhouse effect. GHG comprises: CO_2, CH_4, N_2O and HFCs, PFCs, SF_6.
- Compliance with the pollutants indicated in a) is mandatory to obtain governmental permits for the installation of the DR facility.

Energiron Plants and The Environment

- An ENERGIRON plant complies with the strictest environmental regulations worldwide without the need of specific process requirements and/or additional equipment for treatment of heavy hydrocarbons in natural gas, sulfur in iron ore and/or de-NOx systems.
- The amount of solids wastes is small because of the low gas velocities inside the shaft furnace due to the high operation pressure, which is reflected in low amount of carry-over particles in the gases.
- A ncritical pollutant, NOx emission in flue gases, is a result of high flame temperatures at the fuel combustion system. For the ENERGIRON plant, the NOx is below environmental limits due to the overall energy integration of the ZR DR plant, which is possible without the need of huge air preheating for energy recovery.

Energiron Emissions Compliance - Example

Specific Environmental requirements as compared with emissions of the ENERGIRON DR plant

Gaseous Pollutants	Minnesota, USA Environmental Regulation	Achieved value in ENERGIRON plant	Specific Method
Particulate	0.014 grains/dscf	0.01 grains/dscf	None
SO_2	15 lb/hr, 24-hour average.	14.1 lb/hr	None
NOx	96 ppmv @ 3% O_2 152 lb/hr, 24-hour average	85 ppmv (maximum) 75 lb/hr	Just use of low NOx burners.
CO	32 lb/hr, 24-hour average.	16.6 lb/hr	None
VOC	2 lb/hr, 24-hour average	0	None

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CO2 Emissions

CO_2 Emissions / tonne of Liquid Steel				
Scenario	DR-EAF: ZR High Carbon DRI vs. Other Technology DRI			
Location:	Power generation: 0,74 kg CO_2/kWh			
Scheme	**Other Cold DRI**	**ZR Cold High-C DRI**	**Other Hot DRI**	**ZR Hot High-C DRI**
	94% Mtz.; 2% C	94% Mtz.; 3.7% C	94% Mtz.; 1.5% C	94% Mtz.; 3.7% C
Item/unit	**kg CO_2/t LS**	**kg CO_2/t LS**	**kg CO_2/t LS**	**kg CO_2/t LS**
Iron ore (production)	132	129	132	129
CO_2 in flue gases + removal system	447	455	455	461
Electricity & O_2 to DR plant	89	78	97	83
Subtotal DR Plant	**668**	**661**	**683**	**673**
Power & O_2 requirements	441	412	337	302
Carbon addition	35	3	59	3
Subtotal EAF	**476**	**416**	**397**	**305**
Total DR-EAF route	**1144**	**1077**	**1080**	**978**
As %	-6%		-10%	

•The ENERGIRON ZR-based scheme reduces overall CO_2 emissions by 6% to 10% for cold and hot DRI, respectively, for liquid steel production.

•By the selective elimination of CO2 to optimize reuse of reducing gases in the Energiron plant, there is an important potential for further CO2 emissions reduction of an additional 30%.

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Latest Energiron Plants

Plant	Cap. (000)	Start
Ternium 4M, Monterrey, Mexico	0.90	1998
Ternium 3M5, Monterrey, Mexico	0.50	2001
Vikram Ispat-Grasim, India	0.60	2007
Mittal Steel Lazaro Cardenas, Mexico	0.50	2007
Ternium Sidor, Venezuela	0.80	2008
Al Nasser Industrial Enterprises, Abu Dhabi	0.25	2009
GHC, Abu Dhabi	1.70	2009
Minnesota Steel Industries, USA	1.70	2009

Final Remarks

- Energiron technology provides a UNIQUE product – High Carbon DRI (well above 2.5%)
- As iron carbide, it makes the DRI stable, safe to ship and allows higher yields for steelmaking
- The Energiron process does this all, while remaining the cleanest, most economical and reliable option available.

Final Remarks

- The benefits of producing High Carbon DRI are available to both captive and merchant producers
  - ✓ For captive plants, feeding hot High Carbon DRI to the EAF further increases benefits
  - ✓ For merchant plants following IMO guidelines, the product can be shipped safely while avoiding the cost of producing briquettes.