

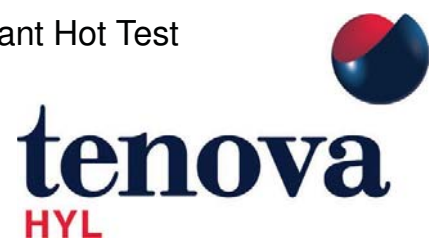
# HYL NEWS



DECEMBER 2015

## IN THIS ISSUE

- SPECIAL FEATURE: By-Products and Emissions in an Energiron DR Plant
- Participation in the AMM 3<sup>rd</sup> DRI & Minimills Conference 2015
- EZZ Rolling Mills Direct Reduction Plant Hot Test



## WE CARE ABOUT YOUR BUSINESS

Fifty eight years ago in December of 1957, the world's first commercially successful direct reduction plant started up in Monterrey, Mexico. At the time, the driving force behind the development of the early years of our direct reduction technology was the urgent need to secure quality iron units for what was a small EAF-based steel producer. So what is today's innovative and highly successful ENERGIIRON technology arose as a way to solve a problem and improve a steel company's overall business competitiveness.

This month of December of 2015 will be remembered for the COP21 commitment and this is the reason why in this number we focus on emissions and environmental issues, confirming the ENERGIIRON technology as the benchmark in the ironmaking and steelmaking business.

We are a dedicated team of highly skilled technology developers striving to improve our customers' bottom lines.

And because we grew out of, and are still a part of a highly successful and innovative steel company, we know steelmaking. We know what the market needs and we work to develop solutions that will benefit your company. Higher quality DRI, reliability, environment friendliness, more energy efficient process plants, more ways to increase productivity.

As this year comes to an end, we look forward to continue working with our customers – current and future – to help find new ways to grow stronger and more prosperous.

Best Wishes for 2016!



**Stefano Maggiolino**

President & CEO  
Tenova HYL

## VIEWPOINT

There is no doubt that this has been a trying year for the raw materials and iron and steel industries. Overcapacity, excess production and exportation of steel products, continued decline (plummeting might be a better word) in the prices of oil, gas, iron ore, coke, steel scrap and consequentially, of steel itself. Our own industry likewise suffers. Technology companies suffer whenever expansion plans are delayed or canceled.

What do we do? At Tenova HYL, we do what we've always done through down cycles in the industry – we work to improve operations and performance for our customers. Process improvements. Higher quality products for steelmaking. More economical, more efficient and environmentally friendly plants.

Recent comments by steel producers regarding the significant quality and operational benefits of using our High Carbon DRI over more conventional DRI products, provide a strong echo to what we have been saying in recent years.

Markets will recover. They eventually do. In the meanwhile, we continue to improve technology, improve DRI, promote knowledge in the industry and prepare for the future. This issue mentions our participation in industry events and technology committees toward that end, as well as providing process details regarding plant emissions.

We hope you find the articles in this issue to be informative and we welcome your comments and observations. You can always find additional information through our websites at [www.tenova.com](http://www.tenova.com) and [www.energiron.com](http://www.energiron.com).

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# BY-PRODUCTS AND EMISSIONS IN AN ENERGIRON DR PLANT

By Pablo Duarte and Jorge Martinez



number of by-products and pollutants that can have severe environmental impact and which require special attention, specifically for the BF-BOF route.

As of 2012 (Fig. 1), the integrated BF-BOF route represents about 71% of world steel production, compared to 24% from scrap recycling-EAF; 4% from gas-based DR-EAF and 1% via coal-based DR-EAF. However it represents 82% of energy consumption and 88% of CO<sub>2</sub> emissions. On the other hand, gas-based DR-EAF has an energy share of 4% and accounts for 3% of CO<sub>2</sub> emissions. Although the figures are from 2012, for a total steel production of 1.687 million tonnes in 2014, percentagewise remains the same.

The steelmaking industry is characterized by an intensive use of fossil fuels, which leads to a significant impact to the environment through Global Warming-Greenhouse Gases (GHG), mainly in the form of CO<sub>2</sub> emissions. For the integrated steelmaking process, the primary energy source for reduction of iron oxides is coal, while for the DR-EAF route the source of reducing gases can be not only NG but also coal itself through the use of gases from coal gasification (Syngas) or coke oven gas (COG). In general, just based on the use of coal in the BF-BOF route as compared with NG in the case of the DR-EAF route, by simple material balance, the DR-EAF route emits 40% - 60% less CO<sub>2</sub> (depending on plant location due to source of power generation) as compared to the BF-BOF route.

Besides GHG emissions, there are a

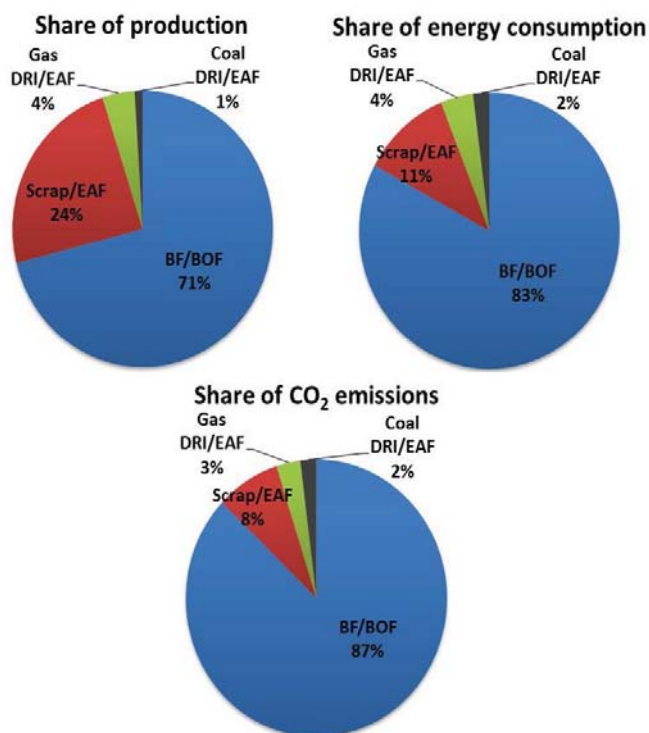


Figure 1. Steel production, energy consumption and CO<sub>2</sub> emissions share by steelmaking route (Source: Impacts of energy market developments on the steel industry. Laplace Conseil. July 2013)

As can be observed (Fig. 2), about 48% of steelmaking in Europe is EAF-based while NAFTA has shifted to EAF to reach 59%. Asian mills (OECD) represent only 29% via EAF. The Asian integrated mills however are the most modern. In general, in Europe and NAFTA there is a strong trend to shifting to EAF-based steelmaking.

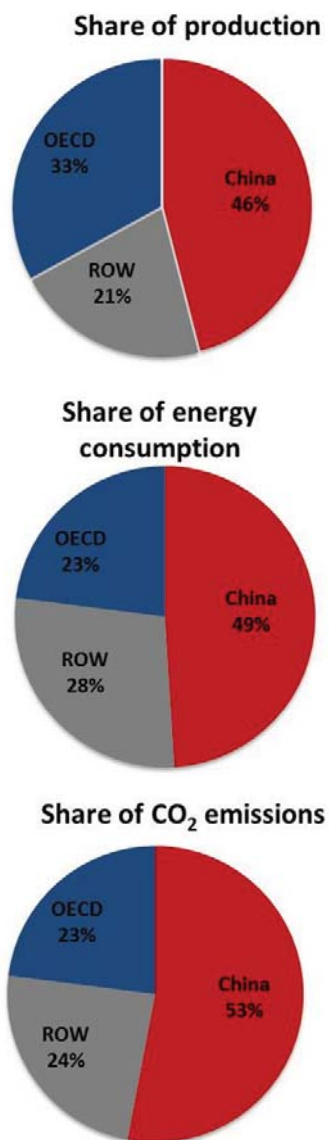


Figure 2. World steel production, energy share consumption and CO<sub>2</sub> emissions by region (Source: Impacts of energy market developments on the steel industry. Laplace Conseil. July 2013)

## BRIEF DESCRIPTION OF THE ENERGIRON DR PROCESS

The ENERGIRON Process (Fig. 3), 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 reforming within the reduction reactor, feeding natural gas as make-up to the reducing gas circuit and injecting oxygen at the inlet of the reactor.

The basic ZR scheme permits the direct use of natural gas. ENERGIRON plants can also use conventional steam-natural gas reforming equipment as an external source of reducing gases, which has long characterized the process. Other reducing agents such as hydrogen, syngas produced from coal gasification systems, pet coke and similar fossil fuels, and coke-oven gas, among others, are also potential sources of reducing gas, depending on the particular situation and availability. In any case, the same basic process scheme is used regardless of the reducing gas source.

The current configuration of this technology employs a continuous shaft furnace-based process, with both the product quality and process efficiency having been significantly optimized over the years. The ENERGIRON ZR technology is currently the most flexible option for producing DRI based on its uniquely simple process configuration and its wide flexibility for using different energy sources and available raw materials.

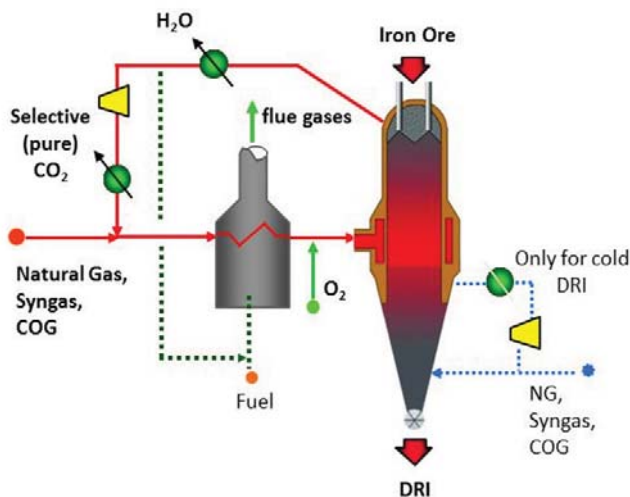


Figure 3. ENERGIIRON ZR Process Scheme

Operating conditions of the ZR process are characterized by high temperature ( $>1080^{\circ}\text{C}$ ) and high pressure (6-8 bar A at top gas). The elevated pressure allows a high productivity of about  $10\text{ t/h} \times \text{m}^2$  and low reducing gas velocities of about  $2\text{ m/sec}$ , as compared to lower operating pressure processes for which the gas velocities are  $>5\text{ m/sec}$ , thus minimizing dust losses through top gas carry-over. This lowers the overall iron ore consumption, which in turn lowers the overall operating costs. A distinct advantage of this process scheme without an integrated reformer is the wider flexibility for DRI carburization. DRI carbon levels up to 5% can be obtained, due to the prevailing conditions of high methane ( $\text{CH}_4$ ) concentration within  $\text{H}_2$ -CO and the high temperature of the bed ( $>860^{\circ}\text{C}$ ), which favors the diffusion of Carbon into the Iron matrix and the precipitation of Iron Carbide ( $\text{Fe}_3\text{C}$ ).

## GHG EMISSIONS

Regarding GHG emissions, the EU has committed to three targets for 2020. The first is to reduce emissions by 20% on 1990 levels. The second is to provide 20%

of its total energy from renewables. The third is to increase energy efficiency by 20% from 2007 levels.

In the USA, the EPA has addressed GHG emissions in a number of steps. Among them, in January 2011, the agency began requiring permits and the imposition of Best Available Control Technology on new stationary sources (and major modifications of existing sources) that emit more than a threshold amount of GHG's.

There are two ways to achieving the GHG emissions levels:

- national reduction measures in the various sectors of energy, industrial, transport, agriculture, etc., or
- through mechanisms consisting of: i) Emissions Trading, ii) Joint Implementation (JI) and/or iii) Clean Development Mechanism (CDM).

It is not the purpose of this paper to go into details of such mechanisms but the objective is to emphasize the importance of reducing the GHG emissions, basically because there are mechanisms which may be reflected in economic benefits and because of the responsibility of the industry to reduce the impact of the GHG effect for future generations.

## CO<sub>2</sub> EMISSIONS IN BF-BOF VS. DR-EAF

The scenario is based on the comparison between the DR/EAF and the BF/BOF routes for manufacturing of Hot Roll Coils (HRC). The selected integrated steel work comprises a coke oven plant, sinter plant and blast furnace for generation of HM and a BOF steel plant with ladle furnace and thin slab caster or compact strip plant (CSP) for the production of hot rolled coils (HRC).

Fig. 4a shows the schematic energy distribution of this facility.

The major gaseous fuel by-products, which are recovered in integrated steel works, are: blast furnace gases (BFG), coke oven gases (COG) and basic oxygen furnace gases (BOFG). Energy balances of integrated steel works show that most of the gaseous energies are mainly used for power generation or even flared. Since only a minor part of the electrical power that could be generated from these gases can be used in the steelworks for its own requirements, most of the electrical power has to be exported.

As it can be noted, the optimized utilization of primary fossil energy also has the effect of significantly reducing the specific CO<sub>2</sub> emissions per tonne of steel. For this optimized scheme, the specific CO<sub>2</sub> emission in flue gases via the conventional BF/BOF route is about 1,8 tonnes of CO<sub>2</sub>/t of liquid steel.

The DR/EAF route is presented in Fig. 4b. The ENERGIRON ZR-based DR plant was selected as reference, for high-C DRI production as 100% feed to the EAF.

Main observations are related to the fact that while the integrated steel plant is a net exporter of electricity, the DR-EAF mill is a net importer. By using the ZR scheme, more than half of the gaseous CO<sub>2</sub> is selectively removed; this provides a strong potential for alternate disposal of this CO<sub>2</sub>, thus significantly reducing the GHG emissions.

Electricity generation has an impact on CO<sub>2</sub> emissions depending on the location of the steel plant. Electricity generation is a composite of sourcing from natural gas, coal, hydraulic, eolic, nuclear, biomass, and depending on the particular location, the CO<sub>2</sub> emission is a reflection of the overall combination. There are countries like Venezuela where the power generation is based on 0,3 kg CO<sub>2</sub>/kWh and others like India, where it is 0,9 kg CO<sub>2</sub>/kWh.

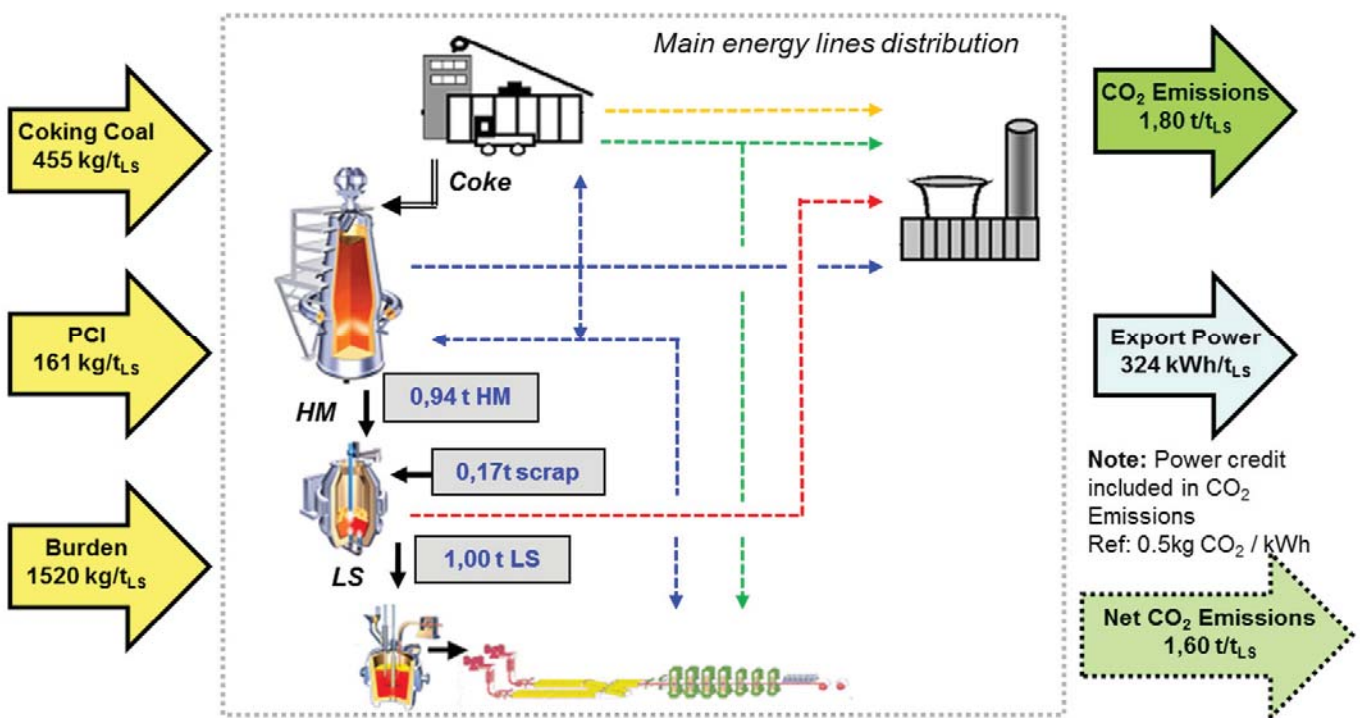


Figure 4a. Energy Distribution in Integrated Steelworks

On the other hand, a steel plant based on DR-EAF using basically natural gas for DRI production is unlikely to be located in countries where coal is the main energy source, just as an integrated steel plant is unlikely to be located in countries with significant natural gas resources. However, there are countries which actually are using both energy sources for steel production.

The difference between BF-BOF vs. DR-EAF in terms of CO<sub>2</sub> emissions is clear when analyzing the conversion of CH<sub>4</sub> → CO + 2H<sub>2</sub>. Reduction of ores through DR drastically reduces CO<sub>2</sub> emissions as compared to coal, for which all reductants are coming from C.

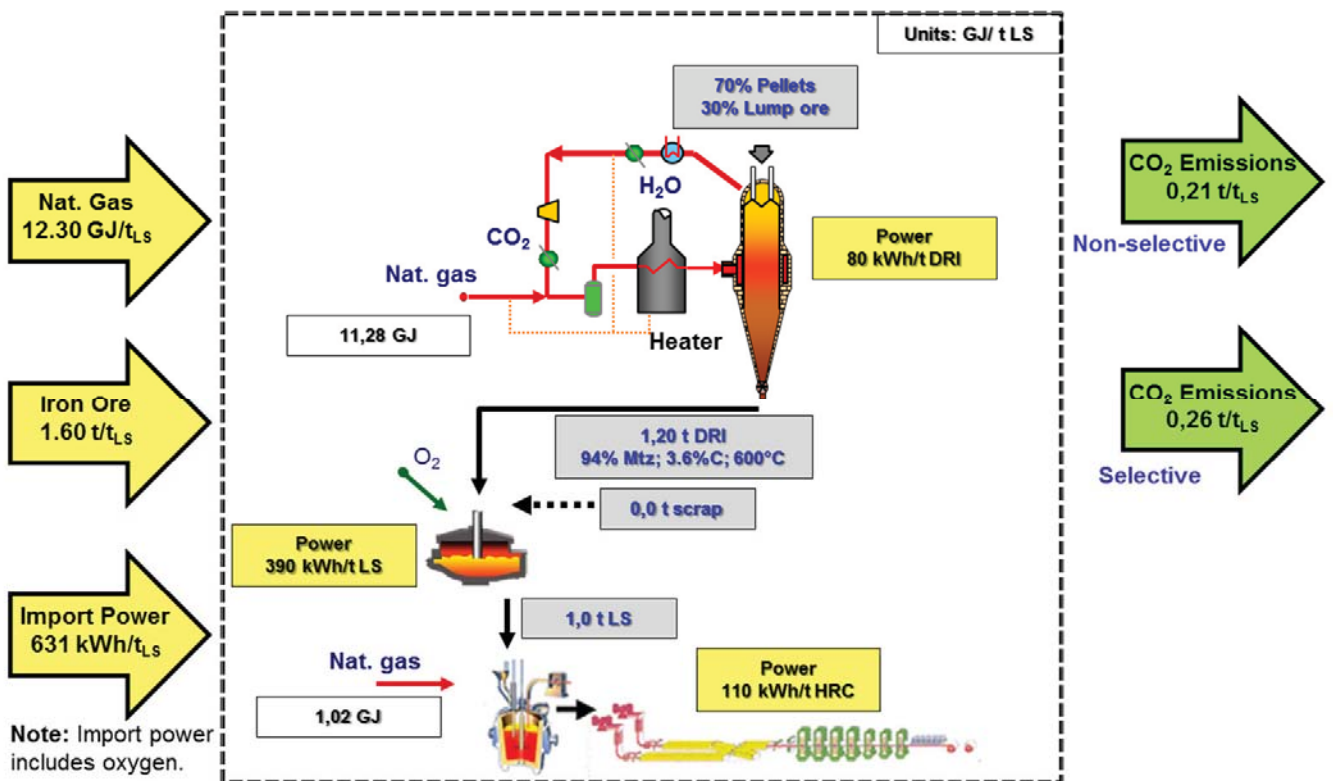


Figure 4b. Energy Distribution in DR-EAF mill route



## CO<sub>2</sub> EMISSIONS IN AN ENERGIIRON DR PLANT

GHG emissions may be significantly different as well when comparing the two leading technologies for production of DRI. Regardless of whether using natural gas (CH<sub>4</sub>), syngas from coal gasifiers, or COG, the make-up of reducing gases to a DRP contains Carbon, either in the form of hydrocarbons and/or carbonaceous compounds –CO, CO<sub>2</sub>. Also, regardless of the DR process configuration, from the total Carbon in the make-up, only 15-40% (depending on the Carbon content in the DRI) exits the process as combined Carbon in the DRI. By the principle of mass conservation, the balance of the Carbon must exit the process, and for the case of a DR process, this takes place in the gaseous form as CO<sub>2</sub>.

Because the ENERGIIRON ZR process takes advantage of the catalytic effect of metallic Fe in the DRI, combining carbon in the form of Fe<sub>3</sub>C, higher levels of carbon are included in the product and thus less carbon is removed in the form of CO<sub>2</sub>. This higher carbon level in DRI, as has been well documented in various papers, is beneficial in the steelmaking process by providing chemical energy to the furnace, and for making the steelmaking process more efficient.

The difference can be seen when a DR scheme configuration with an external catalytic reformer integrated to a DR shaft is used as the reducing gas make up source. From total process natural gas make-up, containing 140 kg C/t DRI, about 25 kg C/t DRI (17%) exits the system as part of the DRI and the balance is released as flue gases from the reformer (Fig. 5).

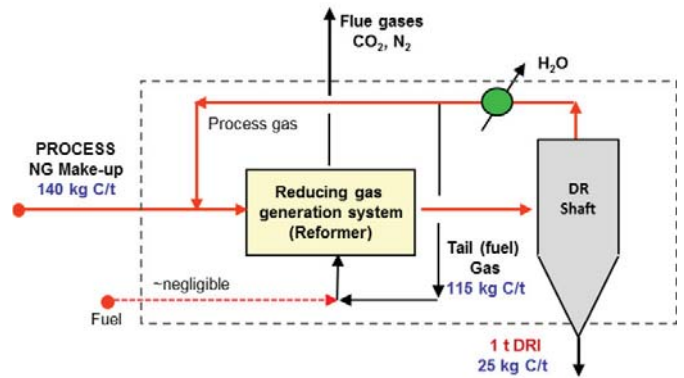


Figure 5: Carbon balance for a DR plant with integrated reformer

Whereas in the ENERGIIRON ZR process (Fig. 6), the process natural gas make-up is lower, with about 110 kg/t DRI, from which 40 kg C/t DRI (36%) is in the DRI produced. Additionally, from the remaining 70 Kg C/t DRI, 65 Kg C/t DRI are selectively removed as pure CO<sub>2</sub> which can be used for other applications or sequestered. The elimination of both by-products generated from the reduction process water (H<sub>2</sub>O) and carbon dioxide (CO<sub>2</sub>) - improves the gas utilization in the process to more than 95%.

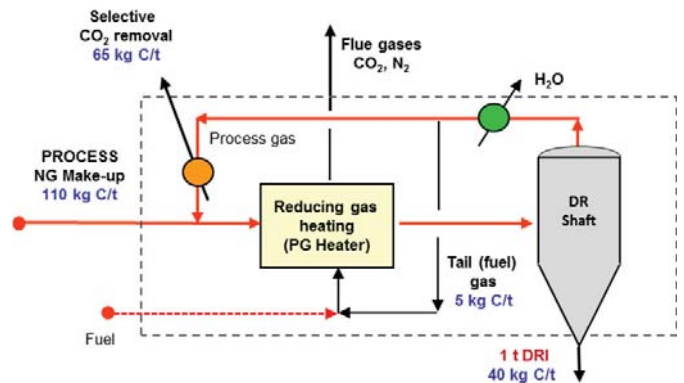


Figure 6: Carbon balance for a DR plant based on the ENERGIIRON ZR process

The result of the ENERGIIRON scheme configuration is the inherent selective elimination of about 65% of total carbon input as CO<sub>2</sub> (about 240 kg CO<sub>2</sub>/t DRI), which when commercialized, significantly reduces CO<sub>2</sub> emissions. This is a clear advantage of this configuration when compared to competing DR technology.

## OVERALL ANALYSIS FOR CO<sub>2</sub> EMISSIONS

The overall analysis for the BF-BOF route, as compared to DR-EAF configurations for the ENERGIRON ZR scheme (with and without CO<sub>2</sub> commercialization and/or sequestration) and to the competing DR technology, is shown in Fig. 7. The analysis refers to a location producing 0,54 kg CO<sub>2</sub>/kWh (typical of that prevailing in some states in USA).

In general, the DR-EAF route is characterized by about 50% of the CO<sub>2</sub> emissions of the BF-BOF route and, specifically, the ENERGIRON ZR scheme route is 10-45% lower than the competing DR technology, depending on the possibility of using the removed CO<sub>2</sub> for other applications.

## COMMERCIALIZATION OF CO<sub>2</sub> FROM HYL/ENERGIRON DR PLANTS

Since 1998, CO<sub>2</sub> gas from the CO<sub>2</sub> absorption system of HYL/ENERGIRON plants has been used as by-product by different off-takers. It is important to note that this is dependent on the iron ore composition, natural gas analysis and the absorbing solution used in the CO<sub>2</sub> absorption system. In the case of amines absorbing solutions, both CO<sub>2</sub> and H<sub>2</sub>S are removed and thus the CO<sub>2</sub> stream from the DR plant may contain some H<sub>2</sub>S in the range of 200 ppm's. For H<sub>2</sub>S removal, there are some possibilities:

Passing the CO<sub>2</sub> stream through an incinerator for conversion of H<sub>2</sub>S to SO<sub>2</sub>, for which case the CO<sub>2</sub> will have no further use, delivering the CO<sub>2</sub> stream as it is, as valuable by-product to gas companies for further treatment and commercialization, or

passing the CO<sub>2</sub> stream through a sulfur removal system, like Sulferox<sup>®</sup> for CO<sub>2</sub> purification and immediate commercialization as a more valuable by-product.

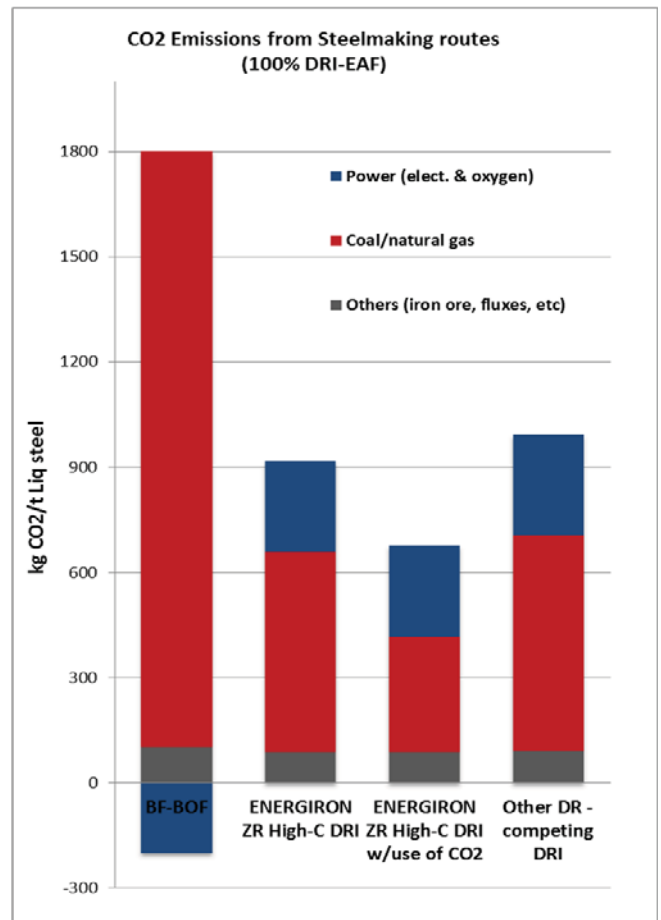


Figure 7. CO<sub>2</sub> emissions from BF-BOF and DR-EAF steelmaking routes/process.

The current scenario of CO<sub>2</sub> from HYL/ENERGIRON DR plants is as follows:

Ternium DRI plants at Monterrey, Mexico  
 ZR plants of 0,7 M t/a cold DRI and 1,0 M t/a hot DRI - since late 1990's sells the raw CO<sub>2</sub> output to Praxair, which after further cleaning, distributes the gas for food and beverage industries.

### Ternium DRI plant at Puebla, Mexico

DR module of 0,7 M t/a cold DRI, who's clean CO<sub>2</sub> is being sold to Infra for further use in beverages.

### PTKS DRI plant in Indonesia

Two modules of 0,75 M t/a cold DRI each (in idle conditions since 2013 due to lack of NG) provided the CO<sub>2</sub> to Janator, for final use in the food industry.

### PSSB DRI plant in Malaysia

Two modules of 0,60 M t/a cold DRI each (in idle conditions since 2012 due to lack of NG), used to sell the CO<sub>2</sub> to Air Liquid/MOQ for further cleaning and application in the food industry.

### JSW-Salav in India

Module of 0,75 M t/a DRI HBI/DRI plant used to provide CO<sub>2</sub> to Air Liquid for production of dry ice.

### Emirates Steel in Abu Dhabi

For the two ENERGIRON plants, each of 2,0 M t/y of hot DRI plus the Micromodule of 0,2 M t/a cold DRI, there is a project for a CO<sub>2</sub> capture facility as part of the collaboration between Masdar, ADNOC AND Emirates Steel to explore feasibility of joint projects to reduce the carbon footprint of the Emirate and make CO<sub>2</sub> available for enhanced oil recovery (EOR) operations.

### Nucor Steel Louisiana in USA

The largest DR ZR module ever built in the world of 2,5 M t/a DRI, includes a Sulferox<sup>®</sup> system for desulfurization of the CO<sub>2</sub> stream, yielding pure CO<sub>2</sub>, which will be commercialized as a valuable by-product of the DR plant.

The previous facts indicate the current trend in steelmaking for decreasing CO<sub>2</sub> emissions, by using the CO<sub>2</sub> from DR plants as by-product for diverse applications, the sources of which would

otherwise come from other fossil fuel combustion systems. It should be mentioned that what for many is an environmental problem, for this type of plant is a lucrative source of added income.



*Figure 8. Nucor Steel Louisiana DR plant with CO<sub>2</sub> absorption and sulphur removal system*

## **WASTES AND BY-PRODUCTS**

Iron ore based steelmaking accounts for about 75% of world steel production, with the balance being from scrap recycling. The main inputs are: iron ore, coal, and limestone, among others. The main by-products are slag (about 90%), sludge and dusts.

On average (Fig. 9), in the BF-BOF route the amount of these by-products exceeds 400 kg/t crude steel while for the DR-EAF route it is less than 200 kg/t crude steel. Slag is made up of mixtures of silica, calcium and magnesium oxides, and aluminum and iron oxides, as by-products coming from slagging and fluxes being used during the steelmaking process.

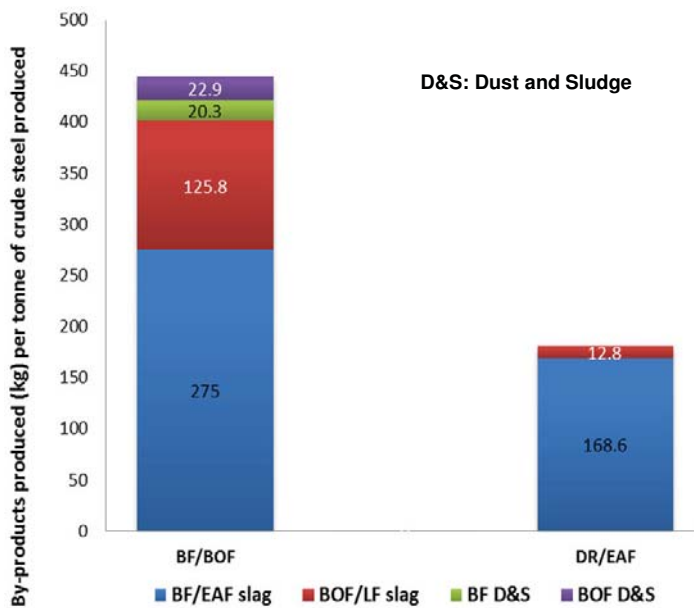


Figure 9. Main by-products by steelmaking routes (Source: World Steel Association. *Steel Industry By-products*. Feb. 2012)

On the other hand, additional effluents from the BF-BOF route are related to the use of coal as the primary energy source: BTX (light oil vapor), Tar vapors, naphthalene vapor, ammonia gas, hydrogen sulfide gas and hydrogen cyanide gas; all of which require specific and special treatment. The COG is

normally used as fuel at the coking battery and steel works; flushing liquor is recirculated to the coke oven plant, waste water is discharged to treatment plant; ammonia/ammonia sulfate is sold as by-product and light oil (if recovered) is also sold as by-product and sulfur/sulfuric acid (if gas is desulfurized), is sold as by-product. All these make the emissions treatment a very intensive and expensive system of the integrated steelmaking plant and which ultimately is reflected in higher CAPEX and OPEX requirements.

The summary of emissions from BF-BOF vs DR-EAF route has been reported as per Table 1. The main impact in terms of NO<sub>x</sub> and SO<sub>2</sub> emissions are an order of magnitude higher for the BF-BOF route, as well as the higher metals emissions from the integrated route. Actual figures for the ENERGIIRON DRP are indicated in Table 2. (Note: in the table, no credit due to electricity co-generation from the integrated route is reflected in CO<sub>2</sub> emissions).

|   | BF/BOF                 | EAF                    | DRI                    |
|---|------------------------|------------------------|------------------------|
| Energy consumption (GJ/t)                             | 22                     | 5.8                    | 10                     |
| CO <sub>2</sub> eq emissions (t CO <sub>2</sub> eq/t) | 2.1                    | 0.7                    | 0.4                    |
| Water consumption (m <sup>3</sup> /t)                 | 2.6                    | 0.6                    | 0.8                    |
| Land use (m <sup>2</sup> /t)                          | 1.7                    | 0.5                    | 0.4                    |
| Emissions to air (kg/t)                               |                        |                        |                        |
| NO <sub>x</sub>                                       | 1                      | 0.04                   | 0.2                    |
| SO <sub>2</sub>                                       | 1                      | 7.4 x 10 <sup>-4</sup> |                        |
| CO  | 56                     | 9.8                    |                        |
| PM <sub>10</sub>                                      | 0.15                   | 0.14                   | 0.13                   |
| PM <sub>2.5</sub>                                     | 1.4 x 10 <sup>-2</sup> | 0.3 x 10 <sup>-2</sup> | 7.7 x 10 <sup>-2</sup> |
| Pb  | 2.6 x 10 <sup>-4</sup> | 1.4 x 10 <sup>-4</sup> |                        |
| Hg  | 9.8 x 10 <sup>-6</sup> | 0.1 x 10 <sup>-6</sup> |                        |
| As  | 6.2 x 10 <sup>-6</sup> | 6.6 x 10 <sup>-6</sup> |                        |
| Cr <sup>6+</sup>                                      | 4.5 x 10 <sup>-6</sup> |                        |                        |
| Ni  | 3.5 x 10 <sup>-5</sup> | 1.6 x 10 <sup>-5</sup> |                        |
| Cd  | 8.1 x 10 <sup>-6</sup> | 0.5 x 10 <sup>-6</sup> |                        |

Table 1. Main emissions by steelmaking routes (Source: *Defining sustainability indicators of iron and steel production*. V. Strevoz, A. Evans, T. Evans)

## EMISSIONS IN AN ENERGIIRON DRP

Emissions, effluents and by-products in an ENERGIIRON DR plant can be summarized as follows:

DRI fines: are normally cold briquetted in most plants and used/delivered as DRI briquettes product.

Iron ore fines: iron ore fines from screening and sludge are normally disposed as by-

| SOLIDS                           |  |
|----------------------------------|--|
| Emissions                        | Source   |
| Iron ore fines/TSP $\mu$         | fugitive emissions in MH transfer points, coating area   |
| By-products                      |  |
| Iron ore fines -5 mm             | screening before DR shaft feeding  |
| Iron ore & semi-metallized fines | sludge from de-dusting systems in MH and scrubbing systems in DR plant   |
| DRI fines -6 mm                  | screening of cold DRI before shipping  |
| GASES                            |  |
| Emissions                        |  |
| NO <sub>x</sub>                  | PG heater (flue gases), incinerator for CO <sub>2</sub> stream, package boiler                                       |
| SO <sub>2</sub>                  | PG heater (flue gases), incinerator for CO <sub>2</sub> stream, package boiler                                       |
| CO                               | PG heater (flue gases), incinerator for CO <sub>2</sub> stream, package boiler, BD stack (QCW), BD de-gasifier (PCW) |
| By-products                      |  |
| CO <sub>2</sub>                  | CO <sub>2</sub> from selective removal (absorption) system   |
| Sulfur <sup>(1)</sup>            | From CO <sub>2</sub> stream from selective removal system  |
| AQUEOUS EFFLUENTS                |  |
| Effluents                        |  |
| Bleed-off                        | Clarifier/settling pond or filtering system  |

*Note (1): In case of CO<sub>2</sub> cleaning through Sulferox® technology, SO<sub>2</sub> is converted to elementary sulfur as slurry by-product.*

Typical emissions points from an ENERGIIRON plant, including material handling, core plant, water systems and utilities, are indicated in layout as per Fig. 10.

An important observation is that most of the outputs from the ENERGIIRON plant may be considered as by-products, due to their further recovery and use, which differentiate this technology from others.

product; however, Tenova HYL is involved in a developing project for the recycling of these fines, which will significantly increase the overall yield of the ENERGIIRON DRP.

CO<sub>2</sub>: as indicated above, an important and valuable product from an ENERGIIRON DR plant is the CO<sub>2</sub>, which can be commercialized and used for various applications.



On the limitation of emissions of certain pollutants into the air from large combustion plants (the "LCP directive"). Emission limit values are defined for SO<sub>2</sub>, NO<sub>x</sub> and dust.

For the USA, emission limit values related to combustion plants are given in Title 40 (Protection of Environment), Part 60 (Standards of Performance for New Stationary Sources). In 2010, the EPA revised the primary SO<sub>2</sub> NAAQS by establishing a new 1-hour standard at a level of 75 parts per billion (ppb).

In general there are no hazardous elements in emissions and effluents from a DR plant, with the exceptional cases of using water for direct and indirect cooling, already containing some elements (metals, salts), which will be concentrated and purged in the bleed off stream from the

plant. In such cases, additional treatment will be required.

An ENERGIRON plant for hot DRI charging to an adjacent EAF is normally designed for about 95% hot DRI production for direct charging to the EAF, pneumatically transported by the HYTEMP system, and about 5% of cold DRI, which is produced whenever the EAF is not receiving hot DRI. Typical environmental data for such plant are included in Table 2. From these data, the following can be observed:

The amount of total solids wastes is very low because of the low gas velocities inside the shaft furnace. This is due to the high operation pressure, which is reflected in low amount of carry-over particles in the gases.

#### 1. Emissions factors of gaseous streams from DR Plant:

| Gaseous emissions | Source (units: kg/t DRI) |   |                |
|-------------------|--------------------------|---|----------------|
|                   | Process gas heater       | Incinerator of CO <sub>2</sub> effluent | Package boiler |
| CO                | 0.0299                   | 0.0010                                  | 0.0032         |
| NO <sub>x</sub>   | 0.0550                   | 0.0081                                  | 0.0107         |
| SO <sub>2</sub>   | 0.0027                   | 0.0803                                  | 0.0000         |
| TSP               | 0.0000                   | 0.0000                                  | 0.0000         |

| Gaseous emissions | Blow down stack (QCW) | Blow down degasifier (PCW) |
|-------------------|-----------------------|----------------------------|
| CO                | 0.0118                | 0.0017                     |

| Gaseous pollutant | Source (units: kg/t DRI) |              |                           |              |
|-------------------|--------------------------|--------------|---------------------------|--------------|
|                   | Fugitive Emissions       |              | With controlled emissions |              |
|                   | Iron ore/pellet          | Coating area | Iron ore/pellet           | Coating area |
| TSP               | 2.75                     | 0.00159      | 0.0027                    | 0.00001      |

#### 2. Emissions factors of aqueous streams from DR Plant:

| Aqueous effluents | Source (units: kg/t DRI) |                           |
|-------------------|--------------------------|---------------------------|
|                   | Settling Ponds           | CO <sub>2</sub> Scrubbing |
| Solids fines      | 19.5                     | 0.1                       |

Table 2: Typical Emissions figures of an ENERGIRON DR plant

A nowadays critical pollutant, NO<sub>x</sub> emission in flue gases, is a result of high flame temperatures at the fuel combustion system. For the ENERGIRON plant, the NO<sub>x</sub> is below environmental limits due to the overall energy integration of the ZR process scheme, which is possible without the need of huge air preheating equipment for energy recovery.

SO<sub>2</sub> can be further minimized since most of the sulfur, in the form of H<sub>2</sub>S is captured in the CO<sub>2</sub> absorption system and removed as elemental sulfur through systems like Sulferox®, while producing

clean, pure CO<sub>2</sub>.

An ENERGIRON DR 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-NO<sub>x</sub> systems.

To illustrate specific compliance with strict environmental regulations, actual data are indicated in Table 3. It can be noted that no particular methods and/or additional equipment is necessary to fulfill the local regulations.

Table 3: Specific Environmental requirements as compared with emissions of the ENERGIRON DR plant in USA

| Gaseous Pollutants | Minnesota Environmental regulation                          | Achieved value in ENERGIRON plant | Specific Method                          |
|--------------------|---|-----------------------------------|--|
| Particulate        | 0.014 grains/dscf   | 0.01 grains/dscf                  | None                                     |
| SO <sub>2</sub>    | 15 lb./hr., 24-hour average.                                | 14.1 lb./hr.                      | None                                     |
| NO <sub>x</sub>    | 96 ppmv @ 3% O <sub>2</sub><br>152 lb./hr., 24-hour average | 85 ppmv (maximum)<br>75 lb./hr.   | Just use of low NO <sub>x</sub> burners. |
| CO                 | 32 lb./hr., 24-hour average.                                | 16.6 lb./hr.                      | None                                     |
| VOC                | 2 lb./hr., 24-hour average                                  | 0                                 | None                                     |

Table 4 lists the conventional methods for controlling emissions in an ENERGIRON DRP.

Table 4: Emission Control methods used in the ENERGIRON DR plant

|        | Pollutant                   | Method   |
|--------|-----------------------------|--|
| Solids | Iron ore fines              | Use of dry bags as dust collectors   |
|        | DRI fines                   | Use of wet scrubbing system.<br><i>Note: Dry bags may be used with proper nitrogen inertization.</i>   |
| Gases  | NO <sub>x</sub>             | Use of Ultra-Low NO <sub>x</sub> burners.<br><i>Note: NO<sub>x</sub> emission can be further reduced (~8ppmV) by using the SCR system in the PGH flue gases.</i> |
|        | SO <sub>2</sub>             | Sulfur removal in the CO <sub>2</sub> absorption System.<br><i>Note: SO<sub>2</sub> can be reduced to the minimum by using the Sulferox® Technology.</i>         |
|        | CO                          | None   |
|        | CO <sub>2</sub> (selective) | Selectively removed by chemical absorption based on Amines (α-MDEA)  |



## CONCLUSIONS

The ENERGIRON Process is the most feasible DR technology, already designed and prepared for maximum CO<sub>2</sub> emissions reduction in steelmaking while processing virgin metallic units.

The ENERGIRON DR plant, due to its inherent characteristics, complies with the strictest environmental regulations worldwide, while disposing of some effluents and emissions as valuable by-products.

## REFERENCES

- [1] *Technical and economic aspects of production and use of DRI in integrated steel works*. PE Duarte, K Knop, E Zendejas. *Millennium Steel 2004*
- [2] *High-carbon DRI with Energiron DR technology*. P. Duarte, J. Becerra. *Stahl und Eisen (2015) No 11*
- [3] *Decrease of GHG emissions through the Carbon Free Emissions ENERGIRON DR Scheme in Integrated Mills*. P. Duarte, J. Becerra. *METEC and INSTEELCON® 2011*

# PARTICIPATION IN THE 3<sup>rd</sup> AMM DRI & MINI MILLS CONFERENCE 2015



Chicago, USA, November 2015 – Tenova HYL participated in the 3<sup>rd</sup> DRI & Mini-mill/9<sup>th</sup> Steel Scrap conference organized by AMM in Chicago last Nov. 11-12.

During the panel related to the way technology providers can help steelmakers navigate current difficult market conditions, use of DRI and potential replacement of pig iron or scrap, Pablo Duarte (Commercial VP Tenova HYL – shown in above picture), pointed on improvements of raw material consumption, wastes recovery and energy optimization, while emphasizing on the ZR scheme flexibility and the benefits of the high-Carbon DRI. “DRI will certainly keeping supplementing scrap and/or pig iron for production of high-end quality steel, based on availability and price”.

Potential replacement of BF will be driven by reduction of carbon footprint through DRI and/or DR-EAF”. By this approach, CO2 emissions can be decreased in about

50% and additional 20% reduction of CO2 emissions is possible through the ENERGIRON ZR technology.

Angelo Manenti, (Commercial VP NA) during his presentation focused on DRI economics in NA, indicated the feasibility of iron ore owners for production of DRI during the depressed metallic pricing conditions

Another point discussed was the use of High Carbon DRI which is a premium quality product; that allows improvements the overall energy balance of the melting process on an EAF.

Related to this, during the conference in Chicago, the following statement was made by a prominent steel producer and DRI user:

*“In the furnace, 2.5% carbon DRI is more challenging to work with than high-carbon DRI, as the latter boosts a furnace’s efficiency more readily”*

[Source: Steelfirst Daily Nov. 16, 2015]

With the above mentioned characteristics and benefits of our Technology we remain committed to bringing solutions for our clients. High Carbon DRI continues to gain ground as more EAF’s operate with this material and steelmakers become aware of the great benefits brought by it.

# EZZ ROLLING MILLS DIRECT REDUCTION PLANT HOT TEST

The 1.9 million ton/year Energiron plant supplied by Danieli and Tenova HYL for Ezz Steel in Suez, Ain Sukhna, Egypt has successfully started up and passed the Provisional Acceptance Test conditions in record time this past November.

The test conditions were achieved only two

weeks after initial plant startup, operating for 48 consecutive hours with production above 92% metallization and 2% carbon.

The plant is currently in stable operation above 240 tph with product consistently at or above 93% metallization and 3% Carbon. We will provide more detailed information on EZZ start up in our next HYL NEWS.

## AIST FORMS DRI TECHNOLOGY COMMITTEE

The Association for Iron & Steel Technology (AIST) recently formed its 30th Technology Committee by approving the formation of the DRI Technology Committee. Specific tasks of the committee include:

- Organize conferences and seminars relevant to DRI production, transportation, storage and use.
- Solicit papers and chair sessions pertaining to this topic at AIST's annual AISTech conference.
- Produce a DRI plant roundup that covers comprehensive steel production processes for publication in Iron & Steel Technology, AIST's monthly technical journal.
- Schedule meetings and encourage involvement of DRI producers, technology suppliers and users.

Tenova HYL has long been a participant in AIST committees, including ironmaking

and technology, and the first chairman of this new committee is Angelo Manenti of Tenova.



*AIST DRI Technology Committee visit to Nucor Energiron DR plant in Louisiana.*

# CALENDAR OF EVENTS

DECEMBER 2015 – JUNE 2016

Look for Tenova HYL at the following events:

**December 14 - 16**

Metal Bulletin - 19th Middle East Iron & Steel Conference  
Atlantis, The Palm  
Dubai, UAE

**March 14 - 17**

CONAC 2016  
Cintermex  
Monterrey, México

**March 14-15**

12th Annual Steel Markets North America CONFERENCE  
Ritz-Carlton Chicago  
Chicago, IL - USA

**April 30**

Metal Bulletin – World DRI & Pellets Congress  
Dubai, U.A.E.

**May 16 - 19**

AISTech 2016  
Pittsburgh, PA - USA

**June 13 - 15**

Annual Steel Success Strategies Conference  
New York, NY - USA



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