

# DIRECT FROM MIDREX

2ND QUARTER 2018



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## COMMENTARY

## TECHNOLOGY, FLEXIBILITY, AND PEOPLE

By K.C. Woody

*Vice President-Sales & Marketing  
Midrex Technologies, Inc.*



**At Midrex**, technology is the foundation, flexibility is essential, and people make it happen. We have built our business on a “renewable technology” concept, a self-sustaining cycle that blends science, engineering, and “real world” experience to constantly renew and improve the body of MIDREX® technology.

Midrex engineers, technicians, and designers have developed some of the direct reduction industry’s most impressive processes, systems, and equipment over the last 50 years. Our suppliers and construction partners have helped us build MIDREX® Plants, start them up, and attain rated capacity quickly. The MIDREX family of plant owners and operators are

the best in the industry, pushing the boundaries of performance and developing innovative operating practices.

Among the recent technology innovations introduced by Midrex are combination plants and on-demand adjustable product carbon, which provide operators flexibility in DRI product forms and carbon content; larger plant capacities (up to 2.5 million tons/year) and advanced process monitoring and control systems for improved operating economics; the use of pure hydrogen as the reductant to reduce the plant’s CO<sub>2</sub> footprint; and higher briquetting temperatures to enhance product quality and minimize fines generation...to name a few. And many of these innovations can be implemented at existing plants, as well as included in new plant designs. In addition, we are aggressively enhancing our aftermarket service offerings, including “big data” products and operations assistance.

Engineers appreciate equations, so we like to represent **the MIDREX experience** as:

**Annual Availability + High Performance = Production Profits**  
**Production Profits + Flexible, Sustainable Operation = Investment VALUE**

Regardless of how it is described, you can count on MIDREX® technology and those who develop, test, design, supply, and service it...Midrex people.

A MIDREX® plant manager once observed, “Ironmaking isn’t only about how many tons you make in an hour; it’s also about how many hours you make tons.” There is a lot of truth in that statement, so much so that we consider **availability** along with **performance** and **flexibility** as the keys to operational success.

Plant production capacity is based on a sustainable hourly tonnage multiplied by an industry standard of 8,000 hours per year. For HBI plants, that number is 7,800 hours to compensate for additional maintenance of briquetting operations. In simplest terms, plant capacity is positively affected by increasing either one or both of these parameters: hourly tonnage and/or operating hours.

DRI plant performance is defined not only by how it performs in peak market conditions but also by how well the plant copes with the inevitable valleys of the global steel industry. MIDREX® Plants have an excellent record of operating well beyond the industry standard by limiting downtime and increasing availability through superior operating practice and excellent maintenance. In 2017, 16 MIDREX® Plants established new annual production records and at least 16 plants established new monthly production records. Twenty MIDREX® Modules operated more than 8,000 hours and 7 exceeded 8,300 hours. Likewise, MIDREX® Plants can operate efficiently at 1/3 of annual capacity to provide the best economics for overall operations in a down market.

At Midrex, our focus is on relentless innovation in products and services to enhance plant performance and value. Critical to this effort is attracting outstanding talent and providing them the tools and training they need to excel. The “Midrex family,” including team members, plant owners and operators, suppliers, and construction partners, are essential to continued progress. Therefore, we see a bright future based on technology, flexibility and people...the perfect combination for success. ■





## HOT BRIQUETTED IRON

# Steel's Most Versatile Metallic

## PART 2

By Robert Hunter,  
Consultant - DRI Economics & Applications

**EDITOR'S NOTE:**

This article is the second in a series that will appear in DFM throughout 2018. In Part 1, we went back to the basics and described what is hot briquetted iron (HBI), what makes it such a useful source of steelmaking metallics, how it became part of MIDREX® direct reduction technology and where HBI plants are located. Part 2 in the series will look at where HBI can be sourced today and considerations for where additional capacity could be built in the future.

**PART 2 – SOURCING MERCHANT HBI****INTRODUCTION**

**M**erchant HBI allows those who do not own and operate their own plant to purchase material in the open market. The motivation for obtaining HBI from a merchant source can be

**that local prices for the primary inputs for producing it – iron ore and natural gas – are prohibitive and the steelmaker wants the flexibility to purchase HBI in specific quantities on an as-needed basis.**

Which locations are best suited for producing and selling HBI as a merchant product? There are three primary considerations related to merchant HBI: iron ore, natural gas, and steelmaking. Since iron ore and natural gas are the primary inputs for manufacturing HBI, we need to look at where they are produced in relation to the steelmaking plants that could use the product.



| Region         | Usable iron ore production<br>(million metric tons) |
|----------------|---|
| European Union | 27.5  |
| Other Europe   | 11.4  |
| C.I.S.         | 195.3   |
| North America  | 103.5   |
| South America  | 454.2   |
| Africa         | 82.3  |
| Middle East    | 39.4  |
| Asia           | 278.4   |
| Oceania        | 814.4   |
| <b>TOTAL</b>   | <b>2,006.4</b>                                      |

**TABLE I. Regional production of iron ore (year: 2016)**

Source: Steel Statistical Yearbook 2017,  
World Steel Association

## IRON ORE

Riding on the back of the phenomenal boom in steelmaking within China, world iron ore production surpassed 2 billion tons per year (B t/y) earlier this decade, which is up by more than 2-to-1 since 2000.<sup>1</sup> (see TABLE I). Since passing the 2B t/y mark, growth has slowed and output has remained relatively level, as demand is now being satisfied. TABLE II shows the major iron ore producers in 2015.

Roughly 80% of all iron ore – about 1.6B t/y – is traded internationally, and approximately 90% of this trade is carried in ocean-going vessels. Of this seaborne trade, more than three-fourths originates in Australia, Brazil or India.

Due to China's extreme scarcity of good quality iron ore, massive amounts are imported, today exceeding 1B t/y. The producers of the ore from the huge reserves of Australia's Pilbara, which are the closest high-grade ores that occur in large quantity, have benefitted from China's demand, growing in output by more than 400% since 2000. Australia now exports over 800 million tons per year of ore, mostly to China, making it by far the world's number one producer and number one exporter of iron ore.

| Ranking | Country      | Usable iron ore production<br>(million metric tons) |
|---------|--------------|---|
| 1       | Australia    | 817.0   |
| 2       | Brazil       | 397.0   |
| 3       | China        | 375.0 (est)   |
| 4       | India        | 156.0   |
| 5       | Russia       | 101.0   |
| 6       | South Africa | 73.0  |
| 7       | Ukraine      | 67.0  |
| 8       | USA          | 46.0  |
| 9       | Canada       | 46.0  |
| 10      | Iran         | 27.0  |

**TABLE II. Top 10 countries producing iron ore (year: 2015)**

Source: CIA World Fact Book, 2017



Brazil, the second largest iron ore producer, also has experienced significant growth. Brazil currently produces about 450M t/y of ore, of which about 85% is exported. To provide an historical perspective, the entire world never produced over 400M t/y tons of iron ore until sometime in the 1950s.

After Australia, Brazil and China, India is the next largest producer of iron ore, but a strong clampdown on illegally (unpermitted) production and transport curtailed production in recent years and has enormously decreased exports.

**Footnote**<sup>[1]</sup> – A correction has been made to equate Chinese iron ore to the typical world standard. Even though China produces about 60% of the world's iron, the country has almost no reserves of good quality ore. In fact, the quality of this ore is so low that it yields only about 25% as much iron as most of the ore produced and traded in the rest of the world. More recently, as mining/processing capacity for higher quality ores has come on line in Australia, most of China's mines have been closed in favor of the lower cost Australian ores.



The ports shown on the map in Figure 1 represent where 98.5% of the world's total iron ore seaborne trade originates.

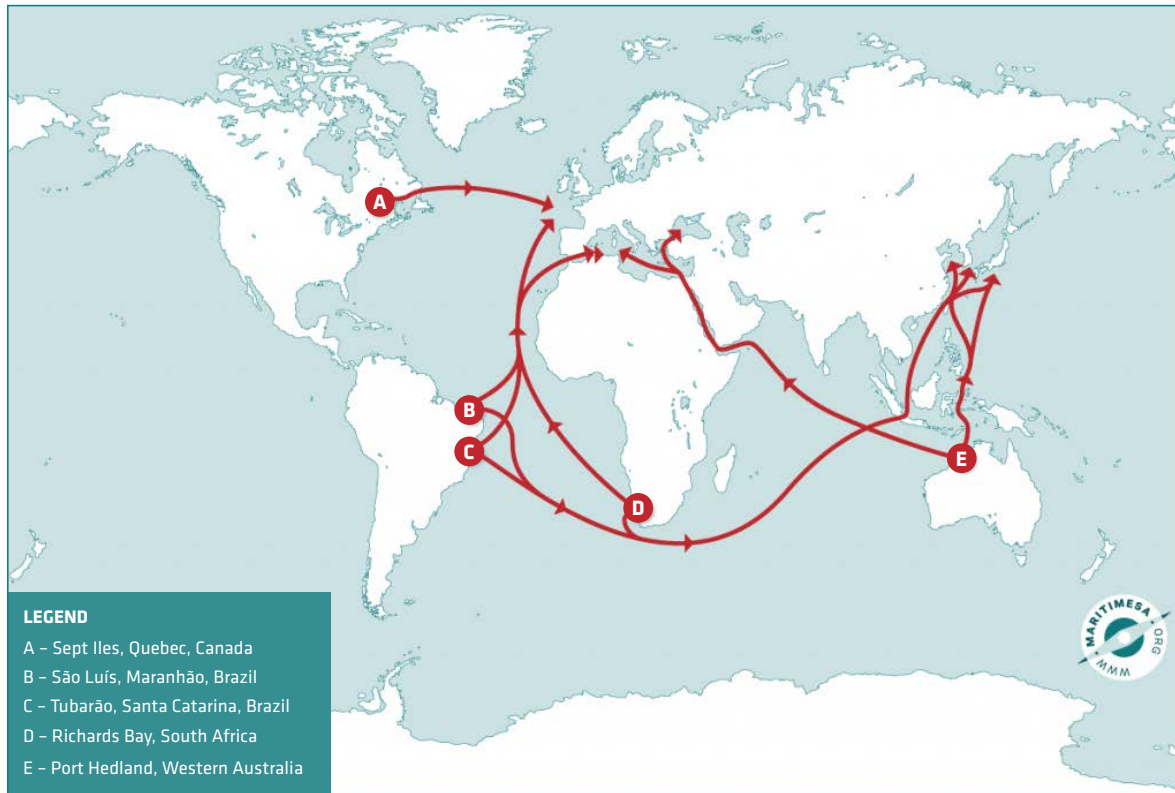


FIGURE 1. Major seaborne iron ore trade routes (Source: [www.Maritimesa.org](http://www.Maritimesa.org))

As Figure 1 shows, the great majority of the seaborne iron ore originates in the southern hemisphere, primarily Australia and Brazil, and is consumed in the northern hemisphere, primarily by China, Japan, South Korea, and Europe.

## NATURAL GAS

When we consider natural gas, the ranking of countries is not so straight-forward, shifting somewhat on whether we are evaluating production, reserves or supply fields.

TABLE III shows the top 10 natural gas producing countries in 2015 (except China, which is 2016).

| Ranking                 | Country      | NG Production (billion m <sup>3</sup> ) |
|-------------------------|--------------|---|
| 1                       | USA          | 766.2                                   |
| 2                       | Russia       | 598.6                                   |
| 3                       | Iran         | 184.8                                   |
| 4                       | Qatar        | 164.0                                   |
| 5                       | Canada       | 149.9                                   |
| 6                       | China*       | 138.4                                   |
| 7                       | EU           | 120.0                                   |
| 8                       | Norway       | 117.2                                   |
| 9                       | Saudi Arabia | 102.3                                   |
| 10                      | Turkmenistan | 83.7                                    |
| * 2016 (all other 2015) |              |   |

TABLE III. Top 10 natural gas producing countries (years: 2015, 2016)

Source: CIA World Fact Book, 2017





The top 10 ranking of natural gas reserves is shown below in *TABLE IV*. To complete the natural gas trifecta, *TABLE V* shows the 10 largest non-associated natural gas fields, six of which are in Russia/CIS.

| Ranking | Country      | NG Reserves<br>(trillion m <sup>3</sup> ) |
|---------|--------------|---|
| 1       | Russia       | 47.8                                      |
| 2       | Iran         | 34.0                                      |
| 3       | Qatar        | 24.5                                      |
| 4       | USA          | 9.7                                       |
| 5       | Saudi Arabia | 8.5                                       |
| 6       | Turkmenistan | 7.5                                       |
| 7       | UAE          | 6.1                                       |
| 8       | Venezuela    | 5.6                                       |
| 9       | Nigeria      | 5.1                                       |
| 10      | Algeria      | 4.5                                       |

**TABLE IV. Top 10 natural gas reserves by country**  
(years: 2015, 2016) Source: CIA World Fact Book, 2017

How does all this data relate to locations for producing HBI? It can best be used to identify countries with natural gas currently available (production) for HBI production and those with resources that could be developed (reserves) and those with undeveloped fields (possible).

Countries with the largest current natural gas production would be considered the leading loca-

| Ranking | Field name  | Country        | Recoverable reserves<br>(million m <sup>3</sup> ) |
|---------|-------------|----------------|---|
| 1       | South Pars  | Iran and Qatar | 35,000  |
| 2       | Urengoy     | Russia         | 6.3   |
| 3       | Yamburg     | Russia         | 3.9   |
| 4       | Hassi R'Mel | Algeria        | 3.5   |
| 5       | Shtokman    | Russia         | 3.1   |
| 6       | Galkynysh   | Turkmenistan   | 2.8   |
| 7       | Zapolyaroye | Russia         | 2.7   |
| 8       | Hugoton     | USA            | 2.3   |
| 9       | Groningen   | Netherlands    | 2.1   |
| 10      | Bovanenkovo | Russia         | 2.0   |

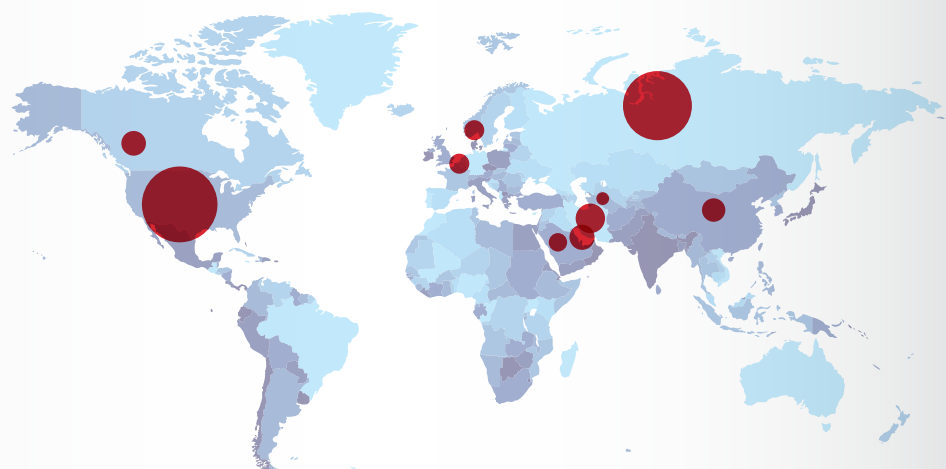
**TABLE V. Largest non-associated natural gas fields (1,000K m<sup>3</sup> and more)**  
Source: "Global Natural Gas Reserves – A Heuristic Viewpoint," IPC Petroleum Consultants, 2017

tions for a merchant HBI plant. In fact, the top five – USA, Russia, Iran, Qatar and Canada – all have direct reduction plants, and merchant HBI plants already are operational in USA and Russia. However, several other countries in Middle East/North Africa (MENA) and the Commonwealth of Independent States (CIS), as well as Australia, Azerbaijan, China, India, Indonesia, Mexico, Nigeria, Norway, Bolivia, Brazil and Venezuela are significant natural gas producers. *Figure 2* shows the major natural gas production countries in 2015-16.

**FIGURE 2.**

### Where natural gas is produced - by country

Source: CIA World Fact Book, 2017  
SEE TABLE III for production figures





## STEEL PRODUCTION

The third consideration when determining the best location for merchant HBI plants is where steel is produced, as HBI is a raw material that can be used in electric arc furnaces (EAFs), blast furnaces (BFs) and basic oxygen furnaces (BOFs). *TABLE VI* shows global steel production in 2017 by process and the map in *Figure 3* indicates where steel is produced by region.

### EAF

EAF steelmaking and DRI have been closely associated for half a century. You might say they have grown up together...from producing low cost, carbon steel long products to making high quality flat products that meet the most exacting specifications. Today, almost 99% of all DRI is used in EAFs.

DRI is still used primarily to make long products in the developing world where scrap supplies are limited and costly to import. The products include reinforcing bars and light structural steel. In the industrialized world, scrap is abundant and steels with low metallic residuals are required to produce high quality flat products and low nitrogen steels. In those cases,

the chemical purity of DRI dilutes the copper and other undesirable metals content in the charge, while the DRI-carbon reaction with oxygen enhances foamy slag, which purges nitrogen from the steel bath.

### BF/BOF

Due to both its physical properties and resistance to oxidation, HBI is the preferred form of DRI for blast furnace use. It can increase hot metal production and lower coke consumption and can be used at up to 30% of the BF charge with no significant equipment or process changes.

The addition of HBI increases hot metal production by boosting the BF burden metallization rate. Up to 8% more production can be realized when burden metallization is increased 10%, which means 24% more hot metal when 30% HBI is added to the charge.

HBI also is the form of DRI best suited for use in the BOF because of its bulk density and physical strength. It performs well as up to 1/3 of the cold charge and is excellent alternative to scrap.

| Region         | PROCESS                         |            |          | Total        | PROCESS                        |           |          |
|----------------|---------------------------------|------------|----------|--------------|--------------------------------|-----------|----------|
|                | BF/BOF<br>(million metric tons) | EF         | OHF      |              | BF/BOF<br>(% total production) | EF        | OHF      |
| European Union | 101                             | 67         |          | 168          | 60                             | 40        |          |
| Europe (Other) | 14                              | 28         |          | 42           | 33                             | 67        |          |
| Russia/CIS     | 68                              | 27         | 6        | 101          | 67                             | 27        | 6        |
| North America  | 38                              | 77         |          | 115          | 33                             | 67        |          |
| South America  | 30                              | 14         |          | 44           | 69                             | 31        |          |
| Africa         | 5                               | 10         |          | 15           | 33                             | 67        |          |
| Middle East    | 2                               | 33         |          | 35           | 6                              | 94        |          |
| Asia           | 964                             | 198        |          | 1,162        | 83                             | 17        |          |
| Oceania        | 5                               | 1          |          | 6            | 77                             | 23        |          |
| <b>TOTAL</b>   | <b>1,227</b>                    | <b>455</b> | <b>6</b> | <b>1,688</b> | <b>71</b>                      | <b>28</b> | <b>1</b> |

**TABLE VI. Crude Steel Production by Process (Year: 2017)**

Source: *World Steel in Figures 2018*, World Steel Association

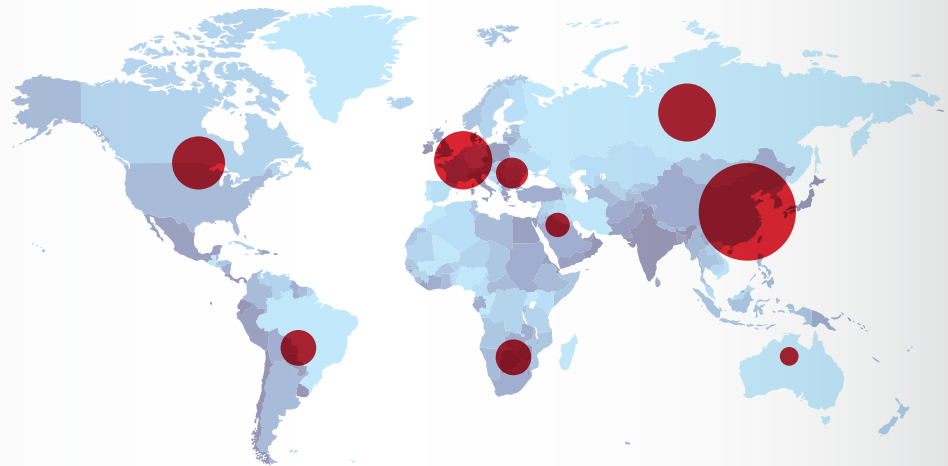


FIGURE 3.

### Where steel is produced - by region

Source: *World Steel in Figures 2018*,  
World Steel Association

SEE TABLE VI for production figures



### BEST CONDITIONS FOR MERCHANT HBI

Looking at *Figures 1-3*, we can see that there are several locations where iron ore, while in transit from mine to steelworks, could be converted into HBI at coastal plants using the natural gas-based MIDREX® NG Process. Among these sites are the southern coast of Brazil, the Caribbean Sea/Gulf of Mexico basin (Venezuela, Trinidad & Tobago, and US Gulf Coast), West Africa (Nigeria south to Angola), North Africa (Algeria to Egypt), the Arabian Sea, Western Australia, and the Malay-Indonesian archipelago. Other possible locations are the North Sea gas fields for ores moving to Western Europe, and even though

landlocked, the Siberian gas fields are quite convenient to the Russo-Ukrainian ore deposits.

Clearly, many of these locations correspond to existing HBI plants: Libya, Malaysia, Russia, Venezuela and the USA (see *Figure 4*). The best scenario is when sufficient quantities of competitively priced natural gas and iron ore are available in reasonable proximity to an ocean port. However, countries with natural gas that are along the seaborne trade routes for iron ore are possible locations to economically implement a merchant HBI operation.

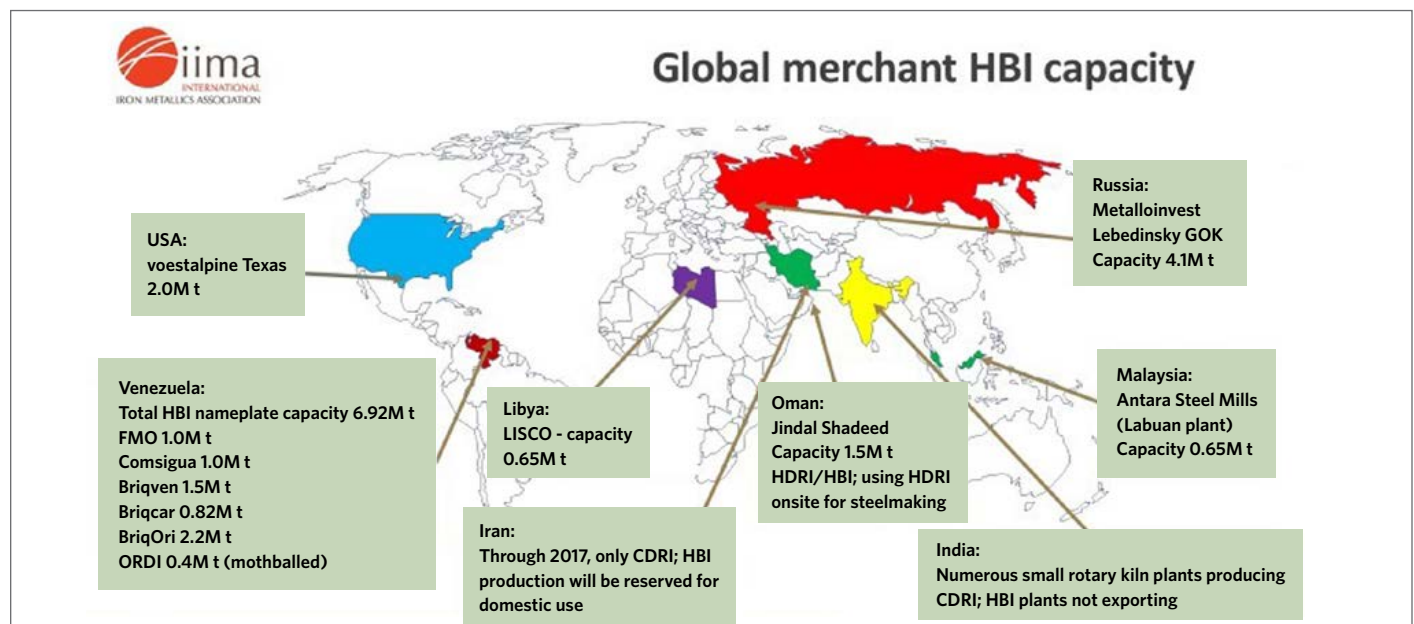


FIGURE 4. Global merchant HBI capacity





## COMMISSIONED HBI CAPACITY VS. PRODUCTION

There are more than 25M t/y of HBI capacity installed or under construction worldwide; 18 plants using MIDREX® technology, 3 HYL/ENERGIRON®, and one each FINMET®, CIRCORED® and FIOR®. However, much of that capacity is not available as merchant HBI, either because of owner decision (in the case of dual product plants), operational issues (natural gas price/availability, oxide pellet shortage, etc.) or geopolitical situations that restrict some or all of production. See *TABLE VII*.

To make a more accurate accounting of how much installed HBI capacity currently is available for merchant trade, we must start by accounting for the dedicated HBI plants (i.e., those whose sole product is HBI) that were idle/limited in 2017:

- **MIDREX® HBI plants** in Venezuela (FMO, COMSIGUA and Briqcar), with a total installed capacity of 2.82M t/y, are severely limited due to the general economic collapse in the country. Their output last year only averaged 21% of capacity.
- LISCO 3 (0.65M t/y) is operating occasionally in the wake of the civil war in Libya.
- Briqven, BriqOri, Circored, and Operaciones RDI, which represent 4.6M t/y of installed capacity, were either limited or idle in 2017. The first two operated at an average of about 12% of capacity and the latter two have not operated in over 20 years.
- Iranian steel authorities have reserved HBI production for domestic steelmaking.

Then, we must include currently installed plants that have HBI capacity but only utilize it for merchant trade when the adjacent steel mill does not require iron units:

- Essar Steel made the decision to switch entirely to HDRI production (3.82M t/y) to feed their steelmaking furnaces.
- Qatar Steel has increased internal usage of CDRI (2.5M t/y) and rarely makes HBI.
- Jindal Shadeed (1.5M t/y) is using its HDRI onsite now that its steel mill is operational.
- Lion DRI (1.54M t/y) is closed.





| Plant                         | Location                       | Rated Capacity (Mt/y) | Product(s) | Status | Recent Shipments (Mt/y) |
|-------------------------------|--------------------------------|-----------------------|------------|--------|-------------------------|
| <b>MIDREX® PROCESS</b>        |                                |                       |            |        |                         |
| Antara Steel Mills            | Labuan Island, Malaysia        | 0.65                  | HBI        | O      |                         |
| Essar Steel I & II            | Hazira, India                  | 0.88                  | HBI/HDRI   | L      |                         |
| FMO                           | Puerto Ordaz, Venezuela        | 1.00                  | HBI        | L      |                         |
| Briqcar                       | Matanzas, Venezuela            | 0.82                  | HBI        | L      |                         |
| Essar Steel III               | Hazira, India                  | 0.44                  | HBI/HDRI   | L      |                         |
| LISCO 3                       | Misurata, Libya                | 0.65                  | HBI        | L      |                         |
| COMSIGUA                      | Matanzas, Venezuela            | 1.00                  | HBI        | L      |                         |
| Essar Steel IV                | Hazira, India                  | 1.00                  | HBI/HDRI   | O      |                         |
| Essar Steel V                 | Hazira, India                  | 1.50                  | HBI/HDRI   | O      |                         |
| LGOK HBI-2                    | Gubkin, Russia                 | 1.40                  | HBI        | O      |                         |
| Qatar Steel II                | Mesaieed, Qatar                | 1.50                  | HBI/CDRI   | O      |                         |
| Lion DRI                      | Banting, Malaysia              | 1.54                  | HBI/HDRI   | I      |                         |
| Jindal Shadeed                | Sohar, Oman                    | 1.50                  | HBI/HDRI   | O      |                         |
| voestalpine Texas             | Corpus Christi, TX, USA        | 2.00                  | HBI        | O      |                         |
| LGOK HBI-3                    | Gubkin, Russia                 | 1.80                  | HBI        | O      |                         |
| Persian Gulf Saba             | Bandar Abbas, Iran             | 1.50                  | HBI        | C      |                         |
| Makran                        | Chabahar, Iran                 | 1.60                  | HBI        | C      |                         |
| Cleveland Cliffs              | Toledo, Ohio, USA              | 1.60                  | HBI        | C      |                         |
| <b>MIDREX Total</b>           |                                | <b>22.38</b>          |            |        | <b>&lt; 7.0</b>         |
| <b>HYL/ENERGIRON® Process</b> |                                |                       |            |        |                         |
| JSW Steel                     | Raigad, India                  | 0.75                  | HBI/CDRI   | O      |                         |
| LGOK HBI-1                    | Gubkin, Russia                 | 0.90                  | HBI        | O      |                         |
| Briqven                       | Matanzas, Venezuela            | 1.50                  | HBI        | L      |                         |
| <b>HYL/ENERGIRON Total</b>    |                                | <b>3.15</b>           |            |        | <b>≈ 1.0</b>            |
| <b>FINMET® Process</b>        |                                |                       |            |        |                         |
| BriqOri                       | Matanzas, Venezuela            | <b>2.20</b>           | HBI        | L      | <b>≈ 0.3</b>            |
| <b>CIRCORED® Process</b>      |                                |                       |            |        |                         |
| Mittal-ISC Trinidad           | Point Lisas, Trinidad & Tobago | <b>0.50</b>           | HBI        | I      | <b>≈ 0.0</b>            |
| <b>FIOR® Process</b>          |                                |                       |            |        |                         |
| Operaciones RDI               | Matanzas, Venezuela            | <b>0.40</b>           | HBI        | I      | <b>≈ 0.0</b>            |
| <b>Total HBI Capacity</b>     |                                | <b>28.14</b>          |            |        | <b>≈ 8.3</b>            |

Status Codes: O – Operating    I – Idle    C – Construction    L – Limited Operation

**TABLE VII.** *Installed HBI capacity by process (primary or secondary product) and recent shipments*





## CONCLUSION

The amount of HBI available to the merchant market is extremely limited. Therefore, as shown in *TABLE VII*, almost 20M t/y of HBI capacity either installed or under construction, currently are not available for merchant sale. So arguably that leaves the world with not quite 8.5M t/y of reliable merchant HBI capacity, which ironically is less than the market forecast in 1984 by Midrex (9.63M t/y).

To meet even a conservative estimate of potential demand, additional HBI plants need to be built. Therefore, investing in natural gas-based direct reduction plants, either directly or through long-term supply contracts, in strategically located sites around the globe is now feasible. For instance, the plant owned and operated by voestalpine Texas LLC is located at a coastal site on the Gulf of Mexico, and uses regionally available natural gas and iron ore from the regular Brazil-USA trade route to make HBI primarily for voestalpine's steelmaking operations in Austria.

Midrex has been the leading supplier of HBI technology since the mid-1980s, and recently added 3.8M t/y of HBI capacity (voestalpine Texas, 2.0M t/y; and LGOK HBI-3, 1.8M t/y). Cleveland-Cliffs, Inc. broke ground for a 1.6M t/y MIDREX® HBI Plant earlier in 2018. The location of the brownfield site at the Port of Toledo (Toledo, Ohio, USA) is in proximity to several future customers and has logistics advantages including local gas availability, access to the Minnesota Iron Range ore, and service by multiple rail carriers.

As worldwide merchant demand for high quality metalics continues to grow, HBI production must keep pace. Midrex will continue its leadership through innovation, improvement and implementation of reliable technology solutions for the global steel industry. ■

### EDITOR'S NOTE:

*In the next issue of DFM, we will look at what defines HBI quality and how it is determined.*







## MIDREX® Direct Reduction Plants OPERATIONS SUMMARY

**M**IDREX® Plants produced 56.5 million tons in 2017, almost 19% more than the updated total of 47.6 million tons produced in 2016. The production for 2017 includes both the tonnage confirmed by MIDREX® Plants located outside Iran and those within Iran. Over 5.8 million tons of hot DRI (HDRI) were produced by MIDREX® Plants and consumed in nearby steel shops, assisting these steel shops to reduce their energy consumption per ton produced and increase their productivity.

MIDREX® Plants continued to account for approximately 80% of worldwide production of direct reduced iron (DRI) by shaft furnaces. Sixteen plants established new annual production records and at least 16 plants established new monthly production records. Thirteen additional MIDREX® Modules came within 10% of their record annual production and 20 MIDREX® Modules operated more than 8000 hours.

Production of DRI and hot briquetted iron (HBI) dramatically increased, as world pricing for iron and steel products rose to profitable levels in almost all

nations. Total DRI output exceeded 87 million tons. DRI production growth was strongest in Iran and India. In Iran, the commissioning of new plants caused output to be 28% greater than the prior year, according to WSA numbers. Exports of steel from China, though large, were much less than in previous years, and the decline is continuing into 2018, as efforts to control pollution combined with a growing domestic demand for steel are bringing balance to the market.

The price of iron ore remained volatile. The bellwether price of 62% sinter fines, delivered to Qingdao, China, approximately doubled in 2016, from around \$40/t up to nearly \$80/t. In 2017, it peaked at \$92/t in March and then plummeted to less than \$55/t within only three months, then recovered to \$74/t by the end of the year.

Since direct reduction plants use very high grades of ore, it is also important to look at the premium charged for "DR Grade," which rose from \$53/t mid-year 2017 to \$63 at the beginning of January 2018, where it has remained since. Especially high premiums for high grade ore were possible due to the tightness of supply



caused by a combination of demand growth and supply constraint. The Samarco mine, a major portion of the world capacity for high grade pellets, remained closed throughout the year.

The high prices for iron ore were sustainable due to the strong demand for iron metalics. Using the US market as a guide, the price for premium scrap steel and DRI/HBI rose in 2016 from as low as \$160/t to over \$280/t by the beginning of 2017. In 2017, prices continued to rise, albeit with volatility, so they were at the \$370-390/t level by the end of the year and have continued into 2018.

One new MIDREX® Module producing HBI was started up in March 2017: LGOK HBI-3 located in Gubkin, Russia, belonging to the Metalloinvest group. Two additional modules started up recently in Iran: an 800,000 t/y cold DRI (CDRI) MIDREX® Plant belonging to the Sefid-Dasht Steel Complex at Sefid-dasht, Chaharmahal-Bakhtiari, in October 2016; and a 1,500,000 t/y HBI MIDREX® Plant belonging to Persian Gulf Saba Steel Co. near Bandar Abbas, in March 2017.

MIDREX® Plants have produced a total of 967 million tons of DRI/HBI through the end of 2017.

## 2017 PLANT HIGHLIGHTS

### ACINDAR

ACINDAR's MIDREX® Plant operated an increased number of hours in 2017 (30% more than in 2016) despite the typical winter natural gas curtailments in July and August and market constraints. In 39 years of operation to date, ACINDAR's MIDREX® Plant has produced almost 30 million tons.

### ANTARA STEEL MILLS

The first MIDREX® Plant designed to make HBI surpassed the 20 million-ton production milestone in 2017, although the plant averaged 87% of annual rated capacity during the year due to market constraints. Total iron in the HBI product was the highest of all MIDREX® plants, averaging 93.67% for the year. All HBI produced was shipped to third parties by water.

### ARCELORMITTAL HAMBURG

In its 46th year of existence, AM Hamburg's MIDREX® Plant, comfortably exceeded annual rated capacity, averaging over 77 t/h, and set a new annual production record of 635,000 tons with a record 8,196 hours of operation in the year. Despite product quality of 94.66% metallization, AM Hamburg's natural gas consumption was below 2.40 netGcal/t and its electricity energy consumption at 72 kWh/t was the lowest of any MIDREX® Plant.



ACINDAR



Antara Steel Mills



ArcelorMittal Hamburg





### ARCELORMITTAL LAZARO CARDENAS

AMLC produced 11% over its rated capacity of 1.2 million tons. In 2017, its 20th year in operation, AMLC surpassed the 30 million-ton production mark despite downturns in 2001-2002 and 2009. Its 30.3 million tons produced is the most by a single **MIDREX® Module** to date, surpassing the previous record-holder, the smaller ACINDAR module.

### ARCELORMITTAL MONTREAL

With 8,107 hours of operation in the year, Module 1 set a new monthly production record in March, as well as a new annual production record, 4.8% higher than the previous record set in 2010, and surpassed the 10 million-ton milestone. In its 40th anniversary year, Module 2 set a new annual production record of 980 thousand tons with 8,097 hours of operation, eclipsing the previous record set in 2014. Production from both modules exceeded 1.6 million tons.

### ARCELORMITTAL POINT LISAS

All three **MIDREX® Modules** in Trinidad and Tobago remained shut down throughout the year.

### ARCELORMITTAL SOUTH AFRICA (SALDANHA WORKS)

The **COREX®** export gas-based **MXCOL® Plant** operated the whole year but was limited by the availability of gas from the **COREX® Plant**. The **MXCOL® Plant** averaged using more than 66% South African lump ore for the year

### COMSIGUA

COMSIGUA operated at reduced capacity for about 1,000 hours over a 3-month period in the year due to the limited supply of locally produced pellets.

### DELTA STEEL

The two **MIDREX® Modules** in Nigeria did not operate in 2017.

### DRIC

In their 10th anniversary year, DRIC's two **MIDREX® Modules** in Dammam, Saudi Arabia, operated well despite being limited by the demand of the neighboring Al-Tuwairqi steel shops. Module 1 operated a record 8,231 hours in 2017, within 10% of its annual production record; and Module 2 operated a record 8,333 hours, within 4% of its annual production record.

### ESISCO

Due to the high price and reduced availability of natural gas in Egypt, as well as the competition of foreign steel products, ESISCO did not operate.



*ArcelorMittal Lazaro Cardenas*



*ArcelorMittal Montreal*



*ArcelorMittal South Africa*



*Comsigua*





## ESSAR STEEL

Essar's HDRI/HBI modules (Modules 2 through 5) operated at less than maximum capacity, producing mostly HDRI, whereas Module 6 (producing CDRI) operated at maximum capacity, breaking its previous annual production record set in 2012, as well as its monthly production record in January. Modules 5 and 6 operated using off-gas from Essar's COREX® Plant as part of their energy input. Module 1 remained shut down the whole year. Total DRI production for the complex was 4.0 million tons in 2017.

## EZDK

Less limited by natural gas availability in Egypt than in recent years, production from EZDK's MIDREX® Modules increased to just under 2.5 million tons, which is about 81% of their maximum capacity. Twenty years since initial startup, EZDK's Mod 2, rated for 800,000 t/y, has produced 17.8 million tons despite a slowdown the last few years due to the limited availability of natural gas. EZDK again focused on maximizing production of DRI with the natural gas available and on maximizing operating time (8,362 hours in Module 1 and 8,346 hours in Module 2).

## FERROMINERA ORINOCO

Ferrominera Orinoco's MIDREX® HBI Plant in Puerto Ordaz operated at reduced capacity most of the year, producing approximately 25% of its total annual rated capacity due to limited availability of locally produced oxide pellets in Venezuela.

## HADEED

Hadeed exceeded rated capacity for the 33rd consecutive year in Modules A and B and for the 25th consecutive year in Module C. In its 10th anniversary year, Module E produced 1.88 million tons, exceeding its rated capacity of 1.76 million tons, and averaging 237 t/h and 7,950 hours of operation in the year. Hadeed's four MIDREX® Modules have produced 86 million tons of DRI to date.

## JINDAL SHADEED

In 2017, Jindal Shadeed established a new annual production record by operating a record-breaking 8,642 hours, despite being limited by the availability of natural gas. This MIDREX® Plant is designed to produce mainly HDRI, with HBI as a secondary product stream. A major portion of its production (88%) was consumed as HDRI by Jindal Shadeed's own steel shop adjacent to the DR plant.



*Essar Steel*



*EZDK*



*Hadeed Module E*



*Jindal Shadeed*



### JSPL (ANGUL)

Jindal Steel and Power Ltd.'s (JSPL) combination HDRI/CDRI plant in Angul, Odisha State, India, operated at reduced capacity during the first half of 2017, with 76% of production being fed hot to their steel shop. The plant remained shut down the second half of the year upon the start-up of JSPL's new blast furnace, and is expected to restart operations in the second half of 2018. This is the first MXCOL® DRI plant using synthesis gas from coal gasifiers to produce HDRI and CDRI for an adjacent steel shop.

### JSW STEEL (DOLVI)

JSW Steel's MIDREX® Plant, which produces CDRI, set a new annual production record for the second year in a row, operating 8,186 hours in 2017 at increased production rates, exceeding their previous record by 8.6%. Unscheduled shutdown time was limited to only 5.6 hours. The plant also set a new monthly production record in December after breaking the previous monthly record twice earlier in the year. The system installed at the end of 2014 to reduce natural gas consumption by adding coke oven gas (COG) from JSW Steel's coke oven batteries to the MIDREX® Shaft Furnace operated throughout the year. The plant has operated over 8,000 hours per year on average since its start-up in September 1994.

### JSW STEEL (TORANAGALLU)

JSW Steel's hot/cold DRI plant using COREX® export gas in Toranagallu, Karnataka State, India, set a new annual production record for the third straight year through increased hourly productivity and a record 8,094 hours of operation in 2017. JSW also set a new monthly production record in March 2017. This is the second plant of its kind, the first one being ArcelorMittal's COREX®/MIDREX® Plant at Saldanha, South Africa.

### LEBEDINSKY GOK

A new MIDREX® HBI Module, LGOK HBI-3, located in Gubkin, Russia, and belonging to the Metalloinvest group, was started up in March 2017, and rapidly met expectations. LGOK's other MIDREX® HBI Module, HBI-2 produced over its rated capacity, operating 8,087 hours and producing only 2.7% less than their production record set in 2015.

### LION DRI

The Lion DRI plant located near Kuala Lumpur, Malaysia, continued to be shut down throughout 2017 due to insufficient market demand for locally produced steel products.

### LISCO

Twenty years after the startup of Module 3, the production at LISCO's three MIDREX® Modules in Misurata, Libya, decreased 19% compared to 2016 totals due to restricted natural gas supply and recovery from the civil war.



JSPL (Angul)



JSW Steel (Dolvi)



JSW (Toranagallu)



LGOK HBI-2 and HBI-3





## NU-IRON

In its 11th year in operation, Nucor's MIDREX® Plant in Trinidad and Tobago established a new annual production record and broke its monthly production record twice in 2017. Average DRI metallization for the year was the highest of all MIDREX® Plants at 96.29%, with 2.70% carbon in the DRI.

## OEMK

Thirty years after the start-up of Modules 3 and 4, OEMK produced just under 3 million tons in 2017, with Modules 1 and 2 setting new monthly production records in July and December, respectively. Module 2 underwent a revamp in August-September to increase production, whereas Modules 1, 3 and 4 operated 8,254, 8,362 and 8,417 hours, respectively in 2017. Modules 1, 2 and 4 came within 2-3% of their annual production records, whereas Module 3 came within 7.5% of its annual production record. OEMK's four modules have produced over 66 million tons since start-up of the first module in December 1983.

## QATAR STEEL

In its 10th full year of operation, Qatar Steel's dual product (CDRI and HBI) Module 2 operated 19% over its rated annual capacity of 1.5 million t/y, and came within 5% of its annual production record and within 1% of its monthly production record. The entire production from Module 2 was CDRI, with metallization averaging 94.8% for the year. Operating over 8,100 hours in the year, the production of Module 1 was only 3.4% below its record annual production and within 1% of its monthly production record. With the 25.4 million tons from Module 1 and the 16.1 million tons from Module 2, Qatar Steel has produced more than 41 million tons of DRI to date.

## SIDOR

Production from all four of Sidor's MIDREX® Modules was 620,000 tons in 2017, limited by oxide pellet and natural gas availability. Module 2C continued to be shut down the whole year and Module 2B was shut down in January for the remainder of the year.

## SULB

SULB's 1.5 million tons/year combo (simultaneous CDRI and HDRI production) MIDREX® Plant in Bahrain was limited by market demand in its fourth full year of operation. HDRI sent directly to the steel mill accounted for 76% of DR plant production.



*Nu-Iron Trinidad and Tobago*



*OEMK*



*Qatar Steel*



*SULB*





### TENARISIDERCA

TenarisSiderca operated well below maximum capacity and was down all the month of January and from June through August due to limited DRI demand by the steel shop and natural gas curtailment during the winter months.

### TUWAIQI STEEL MILLS

The Tuwairqi Steel Mills 1.28 million tons/year combo (simultaneous CDRI and HDRI production) MIDREX® Plant, located near Karachi, Pakistan, did not operate in 2017 due to market conditions.

### VENPRECAR

VENPRECAR's HBI production was restricted by the limited availability of iron ore pellets in Venezuela.

### voestalpine TEXAS

The 2.0 million tons per year voestalpine Texas MIDREX® HBI Plant, located near Corpus Christi, Texas, USA, ramped up production in 2017, setting a new annual production record and various monthly production records during the year. A majority of the HBI produced was shipped to the steel mills of its parent company, voestalpine AG, in Austria.

### EDITOR'S NOTE:

At the time of printing, only limited information had been received from MIDREX® Plants in Iran.



TenarisSiderca



Tuwairqi Steel Mills



VENPRECAR



voestalpine Texas



## MIDREX News & Views

### McClaskey Receives Prestigious AIST Award



**F**ormer Midrex President & CEO, Jim McClaskey, was recognized for his 43 years of service to the global iron and steel industry by the Association for Iron & Steel Technology (AIST) at the **2018 AISTech Conference in Philadelphia, PA on May 8**. McClaskey was one of four recipients of the AIST Distinguished Member and Fellow Award.

McClaskey was cited for exhibiting the drive, determination and leadership ability that personifies the vision of AIST in establishing the MIDREX brand and expanding the technical and commercial influence of Midrex in the worldwide direct reduction industry. He led Midrex through several industry cycles, including the most successful years in the company's history.

McClaskey championed the evolution of the purchasing function at Midrex into a



procurement and technical services business and led several strategically important Midrex Group companies. His vision was the driving force for establishing offices in Europe, Asia and India and in designing and equipping a world-class research and development center. He regularly represented Midrex throughout the world, meeting with heads of state and conducting business with many of the leading figures in the international steel industry.

Lourenco Goncalves, Chairman, President and Chief Executive Officer of Cleveland-Cliffs, Inc., said in his endorsement of McClaskey, "I have been impressed by his can-do attitude and willingness to seek a mutually beneficial solution to technical and commercial issues." Goncalves went on to say, "He is an advocate of publishing

and presenting information to prepare current and future steel producers for success in our rapidly evolving global industry."

McClaskey is a member of AIST and serves as chairman-of-the-board for a non-profit organization dedicated to recognizing the contributions of first responders in the Greater Charlotte area. ■

**"I HAVE BEEN IMPRESSED BY HIS CAN-DO ATTITUDE AND WILLINGNESS TO SEEK A MUTUALLY BENEFICIAL SOLUTION TO TECHNICAL AND COMMERCIAL ISSUES."**

LOURENCO GONCALVES, CHAIRMAN,  
PRESIDENT AND CEO OF CLEVELAND-CLIFFS, INC





## MIDREX News & Views

# Cleveland-Cliffs Breaks Ground For Great Lakes Region HBI Plant



### steelmakers in the Great Lakes region.

Lourenco Goncalves, Chairman, President and Chief Executive Officer of Cleveland-Cliffs, said, "Today we are launching a new era for the iron and steel industry in the United States. As Cleveland-Cliffs begins the construction of the first hot-briquetted iron (HBI) production plant in the Great Lakes region, we are taking the initial steps to enable EAF steelmakers to produce the specs associated with high margin steels for sophisticated end markets, such as automotive and others."

Mr. Goncalves added: "For several decades, Cleveland-Cliffs

*Pictured L-R: Clifford Smith, Executive Vice President, Business Development, Cleveland-Cliffs Inc.; Dean Monske, President and CEO, Regional Growth Partnership; Paul Toth, President and CEO, Toledo-Lucas County Port Authority; Congresswoman Marcy Kaptur, U.S. House of Representatives (OH-09); Lourenco Goncalves, Chairman, President & CEO, Cleveland-Cliffs Inc.; Mayor Wade Kapszukiewicz - City of Toledo; Peter Ujvagi, Toledo City Councilman; and Alex Johnson, CEO & President, Midwest Terminals. (Photo: Business Wire)*

**S**tate and local leaders joined Cleveland-Cliffs executives on April 5, 2018, to celebrate the groundbreaking for construction of its hot briquetted iron (HBI) plant in Toledo, Ohio, USA. The 1.6 million metric tons/year plant, based on MIDREX® NG Process technology, will be one of the world's most modern and efficient ironmaking production facility when it begins operation in summer 2020. It will provide a domestic source of high quality ore-based metallics for electric arc furnace

has been supplying the American steelmakers in the Great Lakes with customized pellets to feed their blast furnaces. With the growth in participation of EAFs, it was just a matter of time for Cliffs to become a supplier of these important steelmakers. Our HBI will be for the EAFs the same great feedstock our taconite pellets are, and will continue to be, for our blast furnace clients."

The announcement of the HBI project by Cleveland-Cliffs in 3rd quarter 2017, was applauded by Ohio Governor John R. Kasich, who said, "We're excited that Cleveland-Cliffs is expanding their presence in Ohio by building the very first hot-briquetted iron plant in the Great Lakes region." He went on to say, "The great work of JobsOhio, their local partners and the Company's trust in the Toledo workforce will create hundreds of new jobs





## News & Views *(cont'd.)*

and greater economic opportunities for families throughout this region.”

JobsOhio President and Chief Investment Officer John Minor greeted the project by saying, “JobsOhio, along with our regional partner RGP, the Toledo-Lucas County Port Authority and the City of Toledo are looking forward to supporting Cliffs as they construct this landmark facility that will create 130 permanent jobs and more than 1,200 construction jobs over the next two years.” ■



*Pictured L-R: Craig Filizetti, General Manager, HBI – Toledo, Cleveland-Cliffs; Sami Achkar, VP - Metals & Manufacturing Sector Director, ch2m Jacobs; K.C. Woody, VP - Sales & Marketing, Midrex Technologies, Inc.; Steven Montague, President & CEO, Midrex Technologies, Inc.; James McClaskey, former President & CEO, Midrex Technologies, Inc.; and Clifford Smith, Executive VP, Business Development, Cleveland-Cliffs*

## Midrex Relocates to New Quarters

**M**idrex Technologies, Inc. has moved its corporate headquarters to another location in Charlotte, near the previous office. The new address is 3735 Glen Lake Drive, Charlotte, NC 28208. It is very convenient to Charlotte Douglas International Airport, and there are several hotels nearby.

The new Midrex office space was designed for a collaborative work environment, with an open floor plan and numerous meeting rooms and areas for discussion. The work space is organized so that Midrex teammates can change locations as project teams evolve. Another feature is enhanced collaboration work spaces, where teams can review the latest information in AVEVA Engage, which brings together project documents, data, and 3D visualization. The office also includes a dedicated Remote Professional Services (RPS) center that uses secure technologies to help clients analyze



*Pictured: The new corporate headquarters of Midrex Technologies, Inc.*

operations and achieve a higher level of performance. All these features will enable Midrex to better serve its clients with new and improved products and services. ■



## MIDREX News & Views

### Chris Hayes Named Vice President – Operations



Midrex has promoted Chris Hayes to Vice President Operations, effective March 31, 2018. Most recently, Hayes served as Chief – Mechanical Engineering.

In announcing the promotion, Stephen C. Montague, Midrex President and CEO, said, “Chris has served Midrex in a variety of roles, building a solid foundation for this new opportunity. He has developed strong relationships with plant operators and key vendors, which will serve him well in facilitating a seamless transition of plant needs into practical solutions.”

Hayes spent most of his first 10 years with Midrex designing and optimizing equipment and systems to boost the performance of existing MIDREX® Plants. With a mechanical engineering degree and knowledge of civil engineering, Hayes has served as project engineer, project manager or mechanical lead on 13 greenfield and brownfield Midrex projects in 12 countries.

His experience in new plant design and commissioning & start-up teams, as well as in a broad range of engineering assignments for Global Solutions, the field and technical services arm of Midrex, has prepared Hayes to transform situations into opportunities for the mutual benefit of Midrex and its Process Licensees.

“Working shoulder-to-shoulder builds respect and confidence,” Hayes observed. “It’s what we do with the earned respect and confidence that produces value.” ■

#### CHRIS HAYES VICE PRESIDENT – OPERATIONS

##### POSITIONS/ROLES

Project Engineer/Manager & Auditor  
Lead Mechanical/Project Engineer  
Lead Mechanical/Project Engineer & Mechanical Engineer  
Commissioning & Start-up/Upgrades & Additions Project Manager  
Project Manager  
Project Engineer/Manager  
Project Manager  
Lead Mechanical/Project Engineer  
Lead Mechanical Engineer & Project Manager  
Lead Mechanical Engineer & Start-up/  
Field Service/Engineering Support  
Project Engineer  
Project Manager  
Lead Mechanical/Project Engineer  
Project Engineer  
Project Manager  
Project Manager – Commissioning & Start-up  
Chief – Mechanical Engineering

##### PROJECT (MIDREX NG™ unless noted)

Antara Steel Mills  
COMSIGUA NG Pre-Heat System  
Hadeed A, B, C Studies, Upgrades & Additions  
Hadeed E  
Shadeed Iron & Steel LLC\* (HOTLINK®)

JSW Dolvi Works COG Study  
LISCO 1, 2, 3 Studies, Upgrades & Additions  
Lion DRI Dust Collection Engineering  
Qatar Steel I Upgrades & Additions  
Qatar Steel II Upgrades & Additions  
OEMK I, II, III Upgrades & Additions

Tenaris Siderca Production Upgrade  
Tenaris Siderca Water System Study  
ArcelorMittal Lázaro Cárdenas Upgrade  
Nu-Iron Study & Expansion  
Nu-Iron Furnace Reline  
Tuwairiqi Steel Mills  
Midrex Corporate

\* now Jindal Shadeed

##### LOCATION

Labuan, FT, Malaysia  
Matanzas, Venezuela  
Al-Jubail, Saudi Arabia  
Al-Jubail, Saudi Arabia  
Sohar, Oman

Raigad, India  
Misurata, Libya  
Banting, Malaysia  
Mesaieed, Qatar  
Mesaieed, Qatar  
Gubkin, Russia

Campana, Argentina  
Campana, Argentina  
Lázaro Cárdenas, Mexico  
Point Lisas, Trinidad & Tobago  
Point Lisas, Trinidad & Tobago  
Karachi, Pakistan  
Charlotte, NC, USA



## Technology should be...

- designed to fit your needs
- designed to work reliably
- designed to make life easier

DRI Technology **is** designed  
by Midrex to work for **you.**

John Kopfle: Editor

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**MIDREX**