MIDREX

DIRECT FROM MIDREX

1ST QUARTER 2026

What Does The Next Generation Of **MIDREX Plants** Look Like?

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DIRECT INJECTION OF DRI FINES IN ELECTRIC ARC FURNACES:
The AM Hamburg Experience

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COMMENTARY

Shaping the next era of low-carbon ironmaking: **MIDREX'S PATH FORWARD IN 2026**

By KC WOODY
President and Chief Executive Officer

As 2026 begins, the steel industry is in a turbulent period. The industry is under pressure to remain competitive while trying to decarbonize. Costs remain high. Energy availability remains uneven. Raw materials and workforce capability continue to constrain decisions. Government subsidies or policies impact investment decisions throughout the world.

These pressures are now clearly shaping how the market is responding.

The market perspective is clear. It is not a question of whether steel decarbonizes. It is a question of how quickly and which pathways scale in the real world. At the current pace of decarbonization, demand for DRI is expected to grow by about 80-85 Mt to reach around 224 Mt by 2035. This growth is linked to expanding EAF capacity, tighter scrap availability, and regulatory frameworks such as the EU's CBAM. This growth, however, is not evenly distributed across regions.

The Middle East and North Africa (MENA) region remains the leader for both consumption and exports of DRI/HBI. India continues to provide the greatest absolute demand, although production remains focused on coal-based reductants. Europe shows the sharpest growth as it continues to prepare for government regulatory frameworks. North America is expected to roughly double its requirements as flat-rolled EAF steelmaking capacity expands. China remains the wildcard, since even modest growth would materially affect seaborne HBI flows. Against this backdrop, attention is increasingly turning to how decarbonization will actually be achieved in a highly competitive market.

We see hydrogen-based steelmaking progressing, but many forecasts remain overly ambitious and underestimate the complexity of deployment. Several steelmakers and newcomers continue to advance lighthouse projects, but many "H2 now" plans are being delayed or scaled back. Renewable infrastructure remains limited, and policy frameworks are still evolving. Capital costs and supply constraints remain high. Taken together, these factors are reshaping near-term decision-making across the industry.

The bottom line is straightforward. Hydrogen is only competitive in a few geographical areas or where government intervention is done, and more cost-effective near-term options are gaining attention. A focus on solutions that can make a meaningful step in lowering carbon emissions through use of natural gas can be made now and transition to

COMMENTARY

hydrogen as it becomes available at a more competitive price. For more than 50 years, Midrex has delivered technology that helped our clients deliver a world-class product in an economically competitive manner. Today, that means providing flexible technical solutions, strong service, and support that helps steelmakers make confident decisions that allow them to be competitive today and in the future.

INNOVATION, DIGITALIZATION, AND CONTINUOUS IMPROVEMENT

Innovation at Midrex is deliberate and practical. Each improvement must support safe and reliable operations while improving performance in some way.

Increasingly, opportunity comes not only from equipment, but optimizing performance through the use of plant data. Digitalization is becoming much more critical to operating a world class ironmaking facility.

Steelmakers face narrower operating windows, greater raw material variability, and stringent customer demands. They are under pressure to optimize assets in real time while maintaining the highest product quality. That requires a continuous, data-driven view of what is happening in the plant, why it is happening, and how to intervene before an issue escalates into downtime, inefficiency, or loss of process control.

Midrex is focused on leveraging our 50 years of know-how, large repository of data, and practical experience to deliver solutions that combine strong engineering with actionable digital insight. We strive to support our family of licensees to continuously improve performance and establish new industry leading benchmarks for safety, product quality, and availability. Delivering on these goals depends as much on people as on technology.

A GROWING FAMILY

As demands on DRI plants continue to intensify, the company continues to invest in our global team leveraging a talented global workforce while maintaining the culture of the company that has been leading the Direct Reduction Market for over 50 years.

LOOKING AHEAD

As we look to the future, we see that the market drivers for Direct Reduction remain strong. Traditional drivers of the market, like EAF Steelmaking, continue to grow, while decarbonization begins to accelerate demand in certain regions. All of these forces point to the fact that DRI demand will continue to grow. As we are wrapping up the first quarter of 2026, the team at Midrex is excited about the opportunities and remains focused on delivering world class products and services that will support our customers now and in the future.

→

This issue of *Direct From Midrex* features an article examining the technological advancements shaping next-generation MIDREX Plants, along with a look at ArcelorMittal Hamburg's experience with direct injection of DRI fines in EAFs. The News & Views section highlights recent Midrex awards, a world record achievement, and MIDREX Plants celebrating first-quarter anniversaries.

WHAT DOES THE NEXT GENERATION OF **MIDREX PLANTS** LOOK LIKE?

Dillingen MIDREX Flex Plant Rendering
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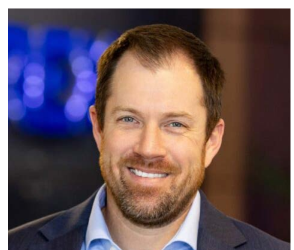

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INTRODUCTION

The direct reduced iron (DRI) industry is undergoing a period of transformation. DRI is positioned to become one of the fastest-growing commodities in the steel value chain, driven by steel industry decarbonization, the need for low-carbon feedstock alternatives to scrap for electric arc furnaces, and increasingly stringent environmental regulations.

The transition from natural gas to hydrogen is underway, offering significant reductions in long-term carbon emissions in steelmaking. However, the industry also requires practical solutions in the near term: plants that can operate profitably with today's natural gas while building in flexibility for tomorrow's hydrogen economy; systems that maximize material recovery, minimize waste, and reduce water consumption; and digital tools that optimize operations in real time. The next generation of MIDREX® Direct Reduction (DR) Plants must deliver on all these fronts.

At Primetals Technologies, innovation has been a key part of its approach for decades. The company has worked with Midrex Technologies to build more than 20 MIDREX Plants worldwide, playing a significant role in various innovations implemented in these plants. This article explores the technological advances that define next-generation MIDREX Plants, including process innovations, energy-efficiency solutions, water-treatment technologies, and digital solutions that optimize operations in real time.

PROCESS INNOVATIONS: MAXIMIZING EFFICIENCY & MATERIAL RECOVERY

Hot Fines Recycling System

One of the most significant recent developments in MIDREX Plant efficiency is the robust hot fines recycling (HFR) system, designed for high pressure to handle potential DRI combustion, which addresses a persistent challenge in hot briquetted iron (HBI) production: the generation of fine particles downstream of the briquetting process.

Traditionally, HBI fines < 6.3mm discharged downstream of the cooling conveyor represented approximately 3-4% of production. This fine material poses safety, material-handling, and process challenges in downstream steelmaking. It also results in material losses. The HFR system reduces the fine content to below 1.5%, effectively recovering valuable material that would otherwise require separate handling or be lost. The system has been successfully implemented at reference plants including AM Texas and Cleveland Cliffs and is included in all new HBI plants under construction or in development.

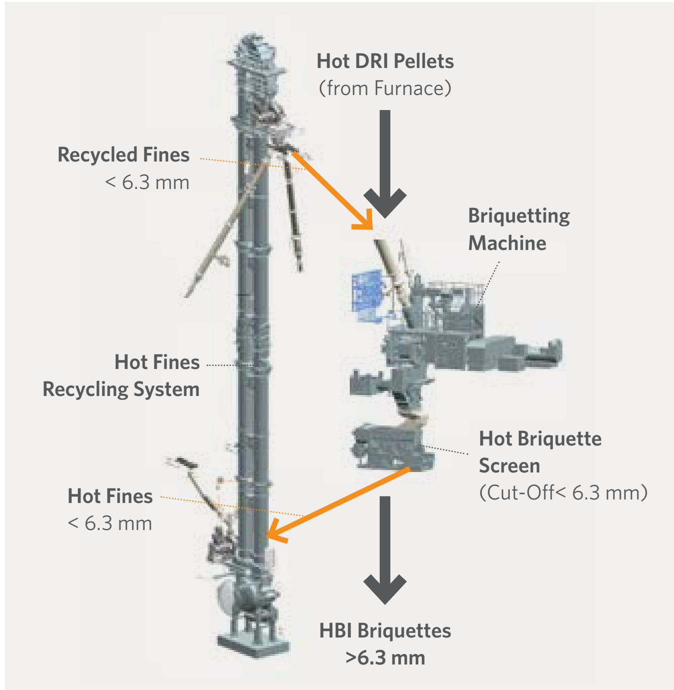


FIGURE 1. *Hot fines recycling system*

> 2% less fines after the cooling conveyor results in an additional 40,000 tons of HBI per year for a 2.0 MTPY plant. Assuming a profit of $100 per ton, this generates approximately $4 million in additional annual profit

ENERGY EFFICIENCY: CAPTURING WASTE HEAT

Modern MIDREX Plants generate substantial heat at various points in the process. Next-generation designs incorporate additional heat recovery systems to recover and reuse this heat, generating energy for various purposes. This improves the energy efficiency of the MIDREX Process, reducing energy inputs and costs, as well as any associated carbon emissions.

The most prominent additional waste heat recovery opportunities in a modern DR plant are top gas heat recovery, reformer flue gas recovery, and seal gas recovery *(Figure 2, top of next page)*:

1. Top gas heat recovery:
Top gas has a typical temperature of 350˚C to 400˚C. Dust-laden, hot gas is routed to a waste heat boiler, where it is used to generate about 40-70 tons per hour of steam. The cooled gas is then returned to the top gas scrubber. Coarser dust is removed at the bottom of the waste heat boiler, while a soot blower system can be installed to clean the heat exchange bundles.

2. Reformer flue gas heat recovery:
Even downstream of the standard heat recovery system, flue gas can reach about 325˚C. By installing additional heat recovery bundles, further heat can be extracted from the flue gas, reducing the outlet temperature to about 220˚C. As example for a MIDREX Plant producing 2.5 MTPY, this can recover an additional 18 MW of thermal heat, generating about 22 tph of steam.

3. Seal gas heat recovery:
A portion of the reformer flue gas is used as seal gas in the MIDREX Process. This seal gas is about 1,150˚C before cooling in a direct contact cooler. However, this heat can also be recovered, which reduces the seal gas temperature to about 220˚C, generating about 16 MW of thermal heat, which is equivalent to 19 tons per hour of steam.

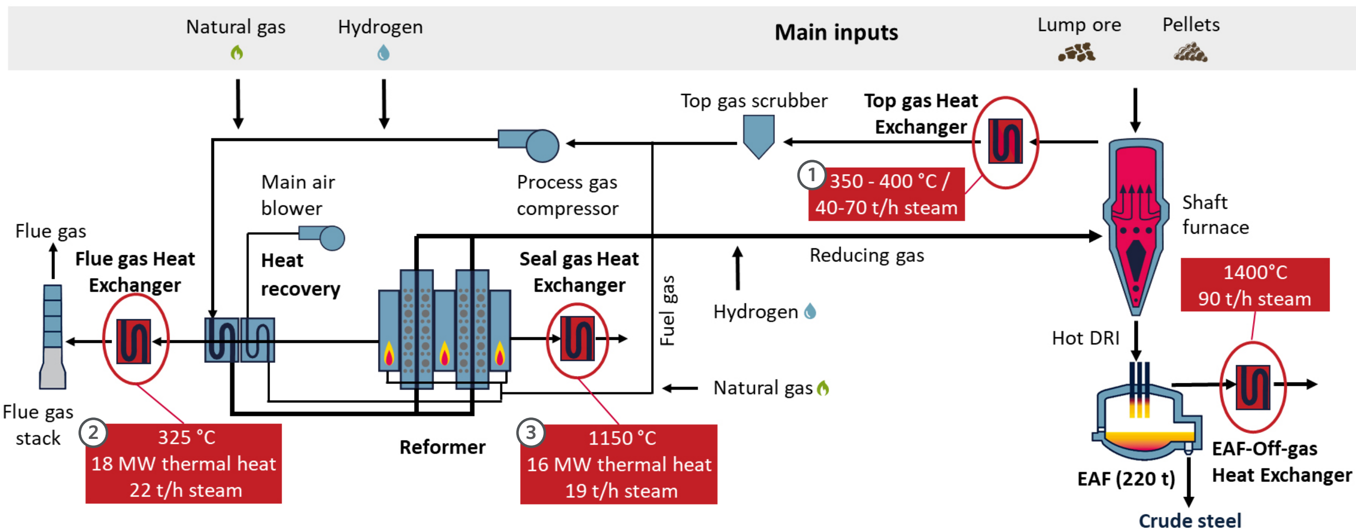


FIGURE 2. *Heat integration opportunities in a MIDREX Plant.*

Combined, these systems can produce more than 80 tons per hour of low or medium pressure steam for use in theclient's steam network, which can be used for many things including steam heat tracing for cold climates. The modular nature of modern plant design means that if considered in the initial plant design waste heat recovery systems can be installed during initial construction or retrofitted later as economic conditions warrant. Alternatively, these additional waste heat recovery systems can be utilized to pre-heat other process streams or utilized in a CO_2 removal system.

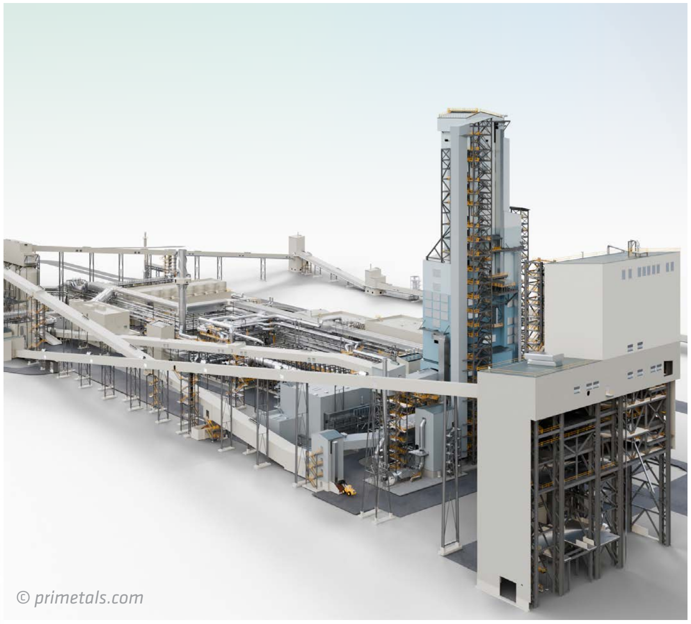
When the MIDREX plant is integrated with electric arc furnace (EAF) operations, the EAF off-gas provides an additional opportunity for heat recovery. Off-gas temperatures of 1400°C can be reduced to just 300°C, generating approx. 90 tons per hour of steam.

> The return of investment strongly depends on the utilization of the steam and the energy prices available at that side, but typically is in the range of a few years.

WATER TREATMENT SOLUTIONS: RESPONDING TO SCARCITY

Water scarcity affects many regions where MIDREX Plants operate, making water conservation a critical consideration in next-generation plant design. Primetals Technologies has developed comprehensive water-saving concepts that address this challenge through multiple approaches.

Water losses are mainly caused by evaporation, by slurry/sludge handling or as blow down, therefore water saving measures target these three points.



Dillingen MIDREX Flex Plant Rendering

1. Evaporation

For example, the common water-based circuit cooling can be partially executed by air cooled equipment. The hot water return will be cooled in the first step by fin air coolers.

These systems use axial fans to draw air through evaporative cooling pads, which lower the temperature of incoming process fluids contained in dry-finned coils.

In the second step the water will be further cooled by water heat exchanger to achieve the required cold water temperature within the circuit. The heat exchanger can be re-cooled by a fresh water or sea water cooling tower system, depending on plant location.

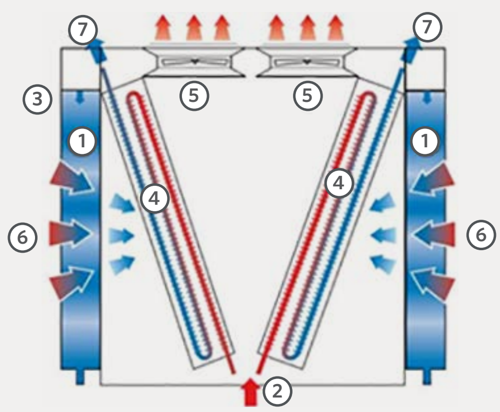
2. Slurry/sludge handling

Slurry containing water and solids from the process water loop will be dried via filter a press to recover a high percentage of the water.

3. Blow down

Another water-saving opportunity is to reuse blowdown water. Rather than treating this water as waste, it can be used in adjacent operations, such as pelletizing plants, supporting closed-loop water management. In processes that require maximum water conservation, Minimal Liquid Discharge (MLD) and Zero Liquid Discharge (ZLD) systems combine evaporation and centrifugal separation to produce a concentrated solid product and high-quality condensate water suitable for reuse as make-up water.

> Depending on the local condition and the chosen concept, fresh water savings of 50% or even more compared to conventional freshwater cooling towers and without blow down water treatment could be realized.



1. Adiabatic pre-coolers
2. Hot process fluid
3. Water flows
4. Dry-finned coil
5. Axial fans
6. Air flows
7. Cooled process fluid

FIGURE 3. *Fin air cooler*

Wastewater Treatment Excellence: The Dillingen Example

The wastewater treatment plant under execution at Dillingen, Germany, demonstrates the sophistication of modern water management systems. The facility handles a maximum flow rate of 480 m³/h from both EAF and DRI operations within space-constrained dimensions of 70 m x 20 m.

The multi-stage treatment process includes metal and solids removal, biological nitrification and denitrification for complete nitrogen removal, lamella clarification, final polishing, and centrifuge-based sludge dewatering. The treated water meets quality parameters and complies with stringent German environmental standards.

Dillingen MIDREX Flex Plant Rendering

DIGITALIZATION SOLUTIONS: THE SMART MIDREX PLANT

Perhaps no area of innovation promises more transformative impact than digitalization. Next-generation MIDREX Plants incorporate digital technologies throughout the production process, from network infrastructure to operator training systems. These digital systems employ a unified digital architecture that spans four layers:

- **Plant Automation:** Industry-standard hardware with integrated process safety, designed for high availability and backed by long-term lifecycle support.
- **Plant Improvement:** Equipment modernization and improvements such as better/redundant instruments, sensors, devices, cameras, etc.
- **Plant Optimization:** Featuring value-added solutions and optional enhancements designed to improve operational efficiency for customers
- **Plant Digitalization:** Integrate equipment with cloud-based infrastructure to enable faster issue resolution and real-time monitoring.

Central Operation Cockpit

The central operation cockpit ***(Figure 4)*** represents a reimagining of the operator interface. Rather than forcing operators to monitor dozens of separate screens and systems, the cockpit integrates camera streams, classic HMI elements, and digital assistants into an ergonomically optimized design. Key features include automatic switching of camera streams based on operational status and events, intelligent augmentation of camera images with overlays that provide tracking data and guidance, and seamless integration of plant overview data with detailed process operating elements.

Operator Training Simulation (OTS)

One of the most innovative digitalization approaches is the operator training simulation (OTS):based on digital twin technology is proving to be a pivotal advancement. These systems are not just about training; they are about optimizing plant operations, enhancing safety, and driving efficiency. OTS aims to enhance their skills, improve their decision-making abilities, and ensure they are well-prepared to handle various operational scenarios.

1. **Training centre for operators:** New operators can be trained on the plant before it is built; existing operators can maintain high skill levels through simulation; and training can occur without disrupting production.
2. **Test and engineering environment:** Providing a non-production environment for software commissioning, testing, and lifecycle management.

1. Plant overview
2. Camera streams for required process view
3. SCADA level for process control
4. Operating elements for manual process intervention (conventional and touch elements).

FIGURE 4. *Central operation cockpit, featuring an optimized ergonomic design.*

DRIpax and DRIpax Expert System

The DRIpax suite of digital tools includes multiple integrated systems:

- **Process information and data management:** Consolidating laboratory data, product data, and process events.
- **Product quality prediction:** Providing forecasts of product metallization, carbon content, and discharge temperature.
- **Expert system:** Offering process diagnoses and corrective actions to achieve standardized operation and stable product quality.

CASE STUDY: DILLINGEN 2.0 MTPY MIDREX FLEX PLANT

The Dillingen plant in Germany exemplifies the next-generation MIDREX Plant. This 2.0 MTPY facility incorporates virtually every innovation discussed in this article, making it an ideal case study for understanding how these technologies integrate in practice. The plant features a MIDREX Flex design with hydrogen utilization, feeding a new EAF melt shop that replaced older BOF operations. Key design parameters include the following:

- **Capacity:** 2.0 million tons per year.
- **Product types:** both hot and cold DRI.
- **Reduction module:** MIDREX Megamod.
- **Furnace:** 7.15m internal diameter MIDREX reduction furnace.
- **Reformer:** 19 bay, 6-row design with MA-1 11-inch reformer tubes.
- **Hourly production:** 250 tons rated capacity.
- **Annual operation:** 8,000 hours of continuous operation.
- **Product specification:** 94.0% metallization, 2.5% carbon with 100% natural gas operation.

The plant can process pellets (including low- and DR-grades) and lump ore, providing operational flexibility. For hot DRI applications, a hot transport conveyor system delivers material to the EAF via two 400-ton HDRI bins. For cold DRI production, six storage bins with a capacity of 8,000 tons each provide substantial inventory and integrated train-loading facilities.

Innovations Implemented at Dillingen

The Dillingen facility incorporates numerous next-generation features ***(Table 1)***.

Given the plant's proximity to residential areas, extensive noise-reduction measures were also incorporated into the design. These included the following:

- Fully clad reduction tower.
- Encapsulation of process gas compressors.
- Silencers for compressors, blowers, and flue gas stack.
- Concrete buildings housing major noise-generating equipment.
- All conveyors enclosed within insulated galleries.
- Enclosed screening stations with soundproof elements.
- Noise insulation on valves and pipelines.
- Low-noise design for stacker, reclaimer, cooling towers, and dedusting units.

Contract effectiveness was in October 2024 and civil works for the DR plant started in autumn 2025 with the mechanical erection to start a year later and the first product expected for Mid 2029.

CONCLUSION: DEFINING THE NEXT GENERATION

The next generation of MIDREX Plants represents a holistic evolution in DR technology. Process innovations recover materials previously lost to waste streams. Energy efficiency measures capture heat that would otherwise be wasted. Water treatment solutions enable operations in water-scarce regions. Digitalization transforms plant operations from reactive to predictive, from manual to automatic and optimized. As the Dillingen example demonstrates, modern DR plants also address critical community concerns, such as noise reduction.

As the steel industry navigates the energy transition, next-generation MIDREX Plants provide a pathway forward to maintain the technology's operational excellence, while meeting the environmental, economic, and social expectations of sustainable steelmaking.

PROCESS INNOVATIONS	ENVIRONMENTAL FEATURES	DIGITALIZATION
• MIDREX Flex for flexible hydrogen utilization. • Three-stage process gas compressors for improved efficiency. • Hot DRI transport system for direct EAF feeding. • Pre-screening station prepared for low-quality pellets. • CDRI storage and train loading infrastructure. • Variable frequency drives to reduce energy use.	• Blowdown water treatment system. • Future-ready design for waste heat recovery installation (flue gas and seal gas). • Dedusting units designed for 10 mg /Nm³ emissions, retrofittable to 5 mg/Nm³.	• A complete digitalization package as described earlier in this article, supporting start-up, operation, operator training and maintenance.

TABLE 1. *Next-generation MIDREX Plant innovations at the Dillingen facility, Germany.*

Direct Injection of DRI Fines in Electric Arc Furnaces:

The ArcelorMittal Hamburg Experience

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INTRODUCTION

Direct reduction (DR) of iron ore pellets in MIDREX® Plants generates fine particulate material, which must be captured to reduce material loss rates and associated safety risks. Standard practice is to compact these fines into briquettes. However, at facilities where the MIDREX Plant is in close to electric arc furnace (EAF) operations, direct pneumatic injection of DRI fines may offer an attractive alternative approach.

SOURCES AND CHARACTERISTICS OF DRI FINES

DRI fines originate from two primary sources:

- 1. **Dry dedusting systems:** The baghouse or cyclone systems that capture particulate emissions from the reduction shaft and product discharge areas and transfer points, generating the fines fraction of material. This dust is the main source of fines that requires management.
- 2. **Product screening operations:** Material handling systems incorporate screening stations to remove undersize particles from the product stream. This screening occurs both after furnace discharge for fresh production and during subsequent conveying of passivated material reclaimed from silo to the steelmaking facility.

A typical particle size distribution (PSD) of DRI fines recovered from a dry dedusting system is presented in ***Table 1***. This distribution shows a median particle size falling in the fine silt range with a significant tail of coarser particles extending into the sand fraction. The submillimeter PSD creates dusting potential during handling and requires positive containment to prevent fugitive emissions. The undersized material from screening operations exhibits a distinctly coarser distribution, with particles up to 3.5 mm.

D10%	D50%	D90%
5.2 µm	49.6 µm	687.6 µm

TABLE 1. *Typical grain size distribution of fines from dry dedusting, ArcelorMittal Hamburg.*

The chemical composition of DRI fines differs significantly from that of product DRI, particularly in carbon content; DRI fines typically contain 4-6% carbon compared to about 2% in product DRI. This elevated carbon level requires consideration during EAF charge balancing, as it can impact slag chemistry and foaming behaviour.

In addition, DRI fines are marked by their reactivity and abrasiveness. The highly metallized iron in DRI fines exhibits significant chemical reactivity, particularly toward oxygen and moisture. Exposure to air can result in exothermic oxidation reactions, while contact with water produces hydrogen gas, both of which pose potential safety risks. Meanwhile, the fines' angular particle morphology and hardness can cause accelerated wear of conveying equipment, particularly at impact points and changes in flow direction.

ARCELORMITTAL HAMBURG: OPERATING DIRECT INJECTION OF DRI FINES IN EAF

ArcelorMittal Hamburg operates as an integrated mini-mill facility with an installed capacity of:

- 700,000 tons per year of DRI production via an onsite MIDREX Plant.
- 1.1 million tons per year of billet production.
- 800,000 tons per year of high-quality wire rod.

Iron ore pellets are delivered to the ore yard and processed through the MIDREX Plant before melting in the EAF, with supplemental scrap, and refining through dual ladle furnaces. These ladles feed a continuous caster that produces billets for final rolling into finished wire rods. The MIDREX Plant is situated within 250-300 meters of the melt shop. As will be discussed in more detail below, this distance is critical as it allows for pneumatic conveying of DRI fines directly to the melt shop.

FIGURE 1. *ArcelorMittal Hamburg*

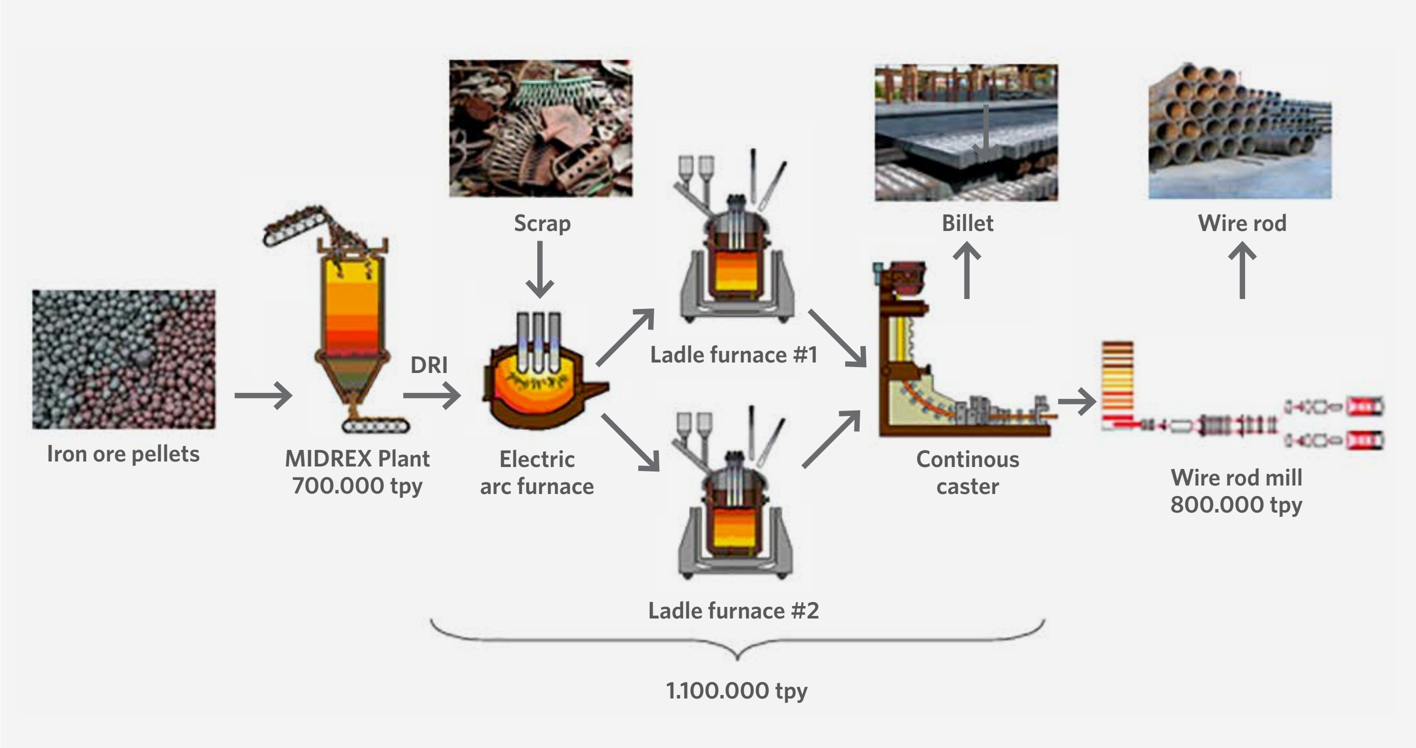

FIGURE 2. *Production flow at ArcelorMittal Hamburg.*

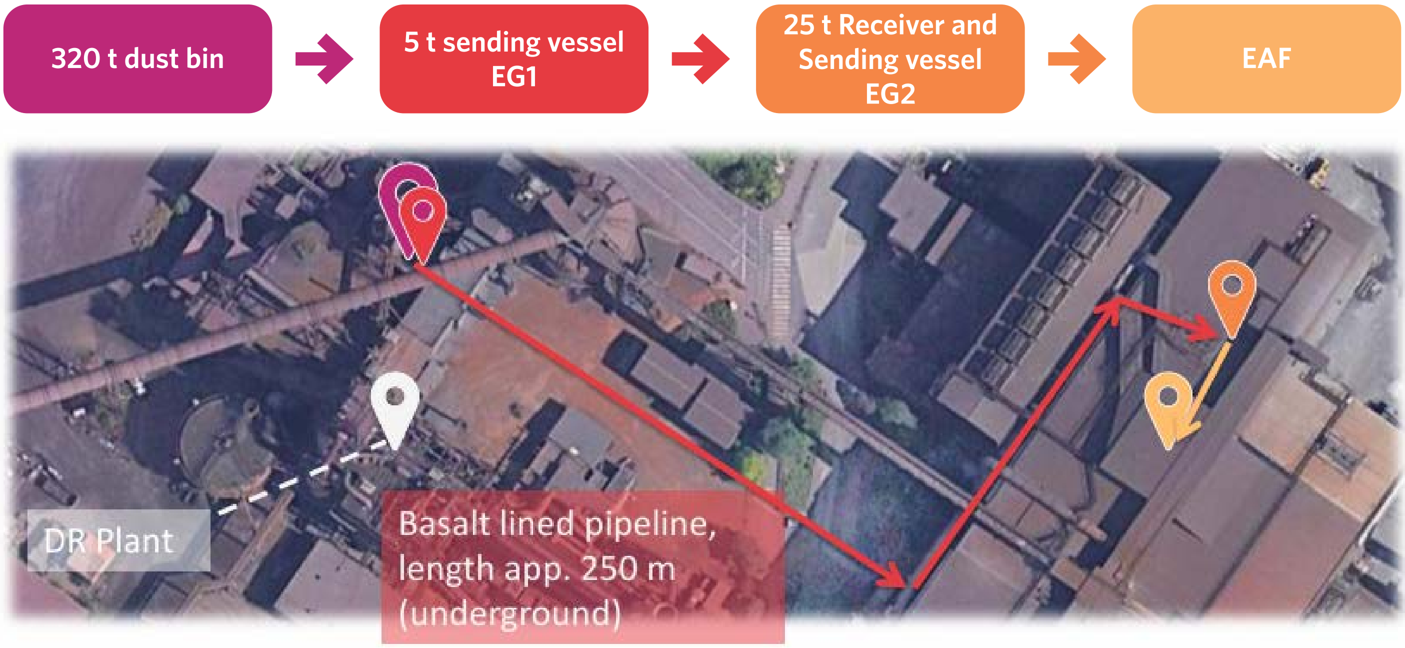

FIGURE 3. *Hamburg DRI dust injection system layout.*

DRI Dust Injection System Design

The injection system was designed in collaboration with Stein Injection Technologies and comprises four main components: storage, intermediate handling, transport, and injection. A 320-ton bin at the MIDREX Plant serves as primary storage for the DRI fines. An adjacent 5-ton sending vessel serves as the pressure vessel for initiating pneumatic transport via a 250-meter, underground basalt-lined pipeline. The selection of basalt lining addresses the severe abrasion that would rapidly degrade conventional steel piping. At the melt shop, a 25-ton receiver/sending vessel provides buffer storage and feeding capability to the EAF. The injection lance assembly allows the introduction of DRI dust into the molten bath.

The system is fully automatic, controlled from the central control room. DRI dust flows by gravity from the 320-ton storage bin into the first sending vessel. Level sensors automatically stop charging when 5 tons of material have accumulated; the vessel is then pressurized using feed gas, typically to a pressure of 4.5 to 5.0 bar. The basalt-lined pipeline is prepared simultaneously by filling it with feed gas and adjusting the oxygen concentration through the addition of nitrogen.

Pneumatic conveying initiates when sufficient differential pressure develops between the sending vessel and the receiving cyclone. DRI dust travels through the underground pipeline to the cyclone positioned above the receiving vessel at the melt shop. The cyclone connects to both the steel plant's dedusting system, which captures the feed gas, and to the receiving vessel, where the DRI dust is collected. Following material transfer, the system undergoes depressurization to ambient conditions. The same pneumatic transfer method conveys material from the receiving vessel to the EAF when injection is required. A moveable consumable lance introduces the DRI fines into the EAF.

Safety Systems

The reactive nature of DRI dust, particularly its potential to generate hydrogen gas and undergo spontaneous heating, requires comprehensive safety monitoring and control systems:

- **Hydrogen monitoring** in the dust bin, receiver vessel, and sending vessel. Hydrogen generation signals potential moisture ingress or exothermic reactions requiring immediate attention.
- **Oxygen monitoring** in the pipeline. Automatic nitrogen injection occurs when the oxygen concentration exceeds 16%, preventing conditions that could support combustion or accelerate oxidation reactions.
- **Temperature monitoring:** Thermocouples positioned along the pipeline provide continuous temperature surveillance. If the temperature exceeds 120°C, indicating

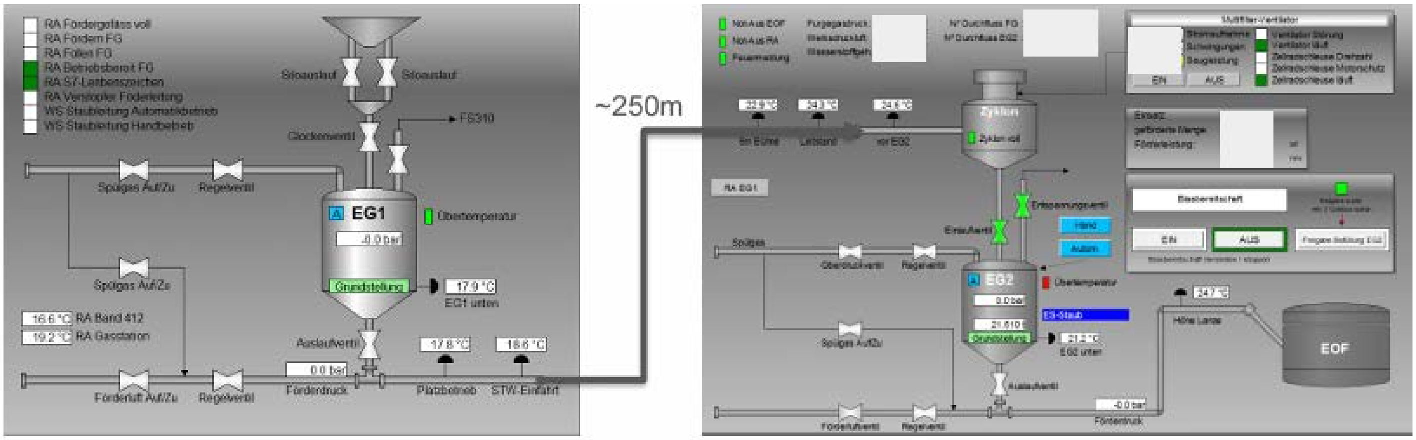

FIGURE 4. *Fully automated injection system.*

a potential exothermic reaction, the system automatically shuts down.

- **Inert gas blanketing:** The system maintains a 100% inert gas atmosphere (nitrogen or spent process gas) in the sending vessel and dust bin, preventing oxygen and moisture ingress.

All monitoring systems report to the central control room, where operating personnel maintain continuous observation, allowing manual intervention if necessary.

OPERATIONAL EXPERIENCE

Injection practice

DRI fines injection occurs through the consumable injection lance below the slag level, typically during flat bath operation. Submerged injection of the fines minimizes the reoxidation of metallic iron, thereby improving yield compared to top charging. The fine particle size enables rapid dissolution into the molten metal. Lance consumption (up to 15 heats per lance) represents a cost that must be balanced against the benefits of high-yield injection. Lance design must also accommodate the abrasivity of the DRI fines while providing reliable material flow control. The movable lance assembly enables positioning adjustments during heating to optimize the injection location as bath conditions change.

The injection rate and total quantity per heat must be coordinated with the overall charge balance to ensure a stable system. Excessive injections of DRI fines can lower the bath temperature, while insufficient injections fail to maximize the use of the available fine material. Operating experience at Hamburg has established protocols for integrating fine injections with scrap charging, DRI product addition, and auxiliary material feeding to achieve the target bath composition and temperature.

Slag Management

The high carbon content of the injected dust has a significant impact on the behavior of the slag. Carbon dissolution into the slag promotes foam formation, providing thermal insulation that reduces refractory wear, minimizes nitrogen pickup from the atmosphere, and improves electrical efficiency by stabilizing the arc. However, excessive foaming can lead to operational challenges, including slag overflow, furnace pressure fluctuations, and difficulties maintaining proper slag chemistry.

The PSD also affects formation kinetics differently than lump DRI or scrap. The rapid dissolution and distribution of the fines promote uniform foaming rather than localized reaction zones. This generally produces more stable and controllable slag conditions compared to discontinuous carbon injection or the addition of lumpy material. The ash content of the carbon in the DRI fines, along with any gangue constituents from the original ore, also contributes to slag volume and composition. Although these contributions typically remain minor compared to the additions required for flux optimization, they should be considered in the overall mass balance.

Yield Considerations

Closed pneumatic transportation of the DRI fines eliminates material losses and emissions, while injection below the slag level prevents reoxidation losses and entrainment in the off-gas stream.

ECONOMIC ANALYSIS

Operating Costs

The operating cost analysis for the injection system at Arcelor Mittal Hamburg indicates low specific costs of DRI dust processed. This encompasses several cost components:

- Labor costs
- Spare parts, primarily for pipeline maintenance and lance replacement
- Purge gas compressor operation and associated electrical energy
- Plant compressed air consumption for pneumatic controls
- Consumable lance replacement
- Rubber hoses and connection components

Capital Investment

Capital costs include storage bins, sending and receiving vessels, pneumatic conveying pipelines, safety monitoring equipment, control system integration, and a lance injection assembly. While specific capital figures remain proprietary, the investment must be evaluated against the alternative of briquetting (see the following section).

The MIDREX Plant's proximity to the melt shop at ArcelorMittal Hamburg (about 250-300 meters) proves crucial to economic viability. Transport distances exceeding about 300 meters would require intermediate support stations or alternative conveying methods, which would significantly increase both capital and operating costs. The Hamburg installation operates near the practical distance limit for single-stage pneumatic conveying of DRI dust.

Value Considerations

Any economic evaluation of DRI fines injection must consider the value of the recovered iron in the injected fines. The improved EAF performance resulting from beneficial slag formation also provides an indirect economic benefit. Enhanced slag foaming reduces electrical energy consumption, improves refractory life, and can increase productivity through faster heat times. While difficult to quantify precisely, these operational improvements contribute to the overall economic case for injection.

COMPARISON WITH BRIQUETTING

Briquetting Process Overview

Briquetting represents an alternative approach for utilizing DRI fines. The process employs hydraulic presses, roller presses, or press chamber equipment to compact DRI dust into solid briquettes under high pressure. Binding agents, such as bentonite or organic substances, are typically added to enhance the strength and handling characteristics of the formed briquettes.

The briquetting process addresses the handling challenges of loose fines by creating a stable, non-dusting product that can be stored, transported, and charged to the EAF through conventional methods (cold DRI briquettes) or recycled as part of the MIDREX Plant feed material (oxide fines briquettes). The volume reduction achieved through densification facilitates storage and transportation, while the reduced surface area decreases oxidation rates during storage and transportation.

Injection Versus Briquetting

Direct injection provides several advantages over briquetting in appropriate applications:

- **Yield:** Closed transportation and submerged injection maximize iron recovery with minimal losses. Briquetting introduces handling steps and surface oxidation that reduce yield.
- **Labor:** The fully automated injection system operates with minimal labor requirements, contrasting with the operator-intensive nature of briquetting operations, including material preparation, press operation, and briquette handling.
- **Maintenance:** The ceramic-lined pipeline system has low maintenance requirements, despite the abrasivity of DRI fines. Conversely, briquetting is more maintenance-intensive, with multiple wear components, including rolls, dies, and hydraulic systems.
- **Environment:** The closed injection system operates without dust emissions or environmental releases. Briquetting operations generate dust during material handling, press feeding, and briquette discharge, necessitating the installation of additional dust collection and handling systems.
- **EAF metallurgy:** Fine particle sizes promote rapid dissolution and uniform slag foaming, improving furnace performance. Briquettes dissolve more slowly and may contain binder materials that adversely affect slag chemistry, requiring additional flux additions and increasing energy requirements.
- **Operational simplicity:** The automated injection system operates continuously without the complexity of press

operation, binder preparation and addition, briquette quality control, and storage management that briquetting entails. For example, despite binder additions, briquettes are prone to breakage during handling, generating dust and fine material that requires reprocessing. Extended storage can also lead to briquette degradation through oxidation and moisture ingress.

However, when the distance between the MIDREX Plant and the EAF exceeds the practical limits for single-stage pneumatic conveying (approximately 300 meters), briquetting may prove to be the preferred option, as briquettes are easier to transport longer distances. In addition:

- Briquetting decouples fines utilization from the EAF operating schedule and charge practice. The briquettes can be produced continuously and stored for use when convenient, whereas direct injection requires coordination with EAF scheduling.
- Briquettes represent a saleable product that can generate revenue if on-site utilization capacity is insufficient or if market conditions favor external sales. Direct injections preclude this option as the fines must be consumed in the integrated facility's EAF.
- Briquetting operations can combine DRI fines with other fine-grained residues from steel production, including sludges, oxide fines, and scale. This co-processing capability provides a utilization pathway for multiple waste streams simultaneously. The injection system handles only DRI dust and screened undersize.
- Briquettes charge through conventional methods and can be incorporated across a wide range of scrap ratios in the EAF charge. Injection during flat bath operation may be constrained by furnace conditions that depend on the scrap/DRI ratio.

CONCLUSION

The ArcelorMittal Hamburg installation demonstrates that direct pneumatic injection of DRI fines to the EAF can provide an effective solution in appropriate operating and site conditions. The system achieves high yield through loss-free transport and submerged injection, operates with minimal labor requirements, maintains low maintenance costs, and provides metallurgical benefits through enhanced slag foaming. The total operating cost of approximately €6 per ton compares favorably with alternative approaches.

However, direct injection will not be appropriate for all sites. The choice between direct injection and briquetting depends on facility-specific factors that should be systematically evaluated. For example, facilities should consider direct injection as the preferred solution when:

- The MIDREX Plant and steelmaking facility are located within about 300 meters, enabling economical pneumatic conveying.
- The EAF operates with a charge practice that accommodates dust injection during flat bath periods.
- All produced fines can be utilized in the integrated facility's steelmaking operations.
- Minimizing labor requirements and operating costs is prioritized.
- Environmental performance and elimination of handling emissions are essential.
- Capital investment availability favors the lower-cost injection system.

In contrast, briquetting becomes the appropriate choice when:

- Transport distances exceed the practical limit for pneumatic conveying.
- The facility produces more fines than the on-site EAF can utilize.
- Flexibility to sell excess production as a product is desired.
- Multiple fine-grained residue streams can be co-processed.
- Storage capacity for inventory management is required.
- The EAF charge practice or scrap ratio constraints limit injection opportunities.

References:

1. Lohmeier, S., et al. "Briquetting of Fine-Grained Residues from Iron and Steel Production Using Organic and Inorganic Binders." ***Steel Research International***, 2020.
2. Lohmeier, S., et al. "Use of Bentonite and Organic Binders in the Briquetting of Particulate Residues from the Midrex Process for Improving the Thermal Stability and Reducibility of the Briquettes." ***Steel Research International***, 2021.

Midrex News & Views

The full news articles are available on **www.midrex.com**

MIDREX Plant with 1st Quarter Anniversary

We are proud to celebrate this significant milestone with our customer - 5 years since start-up for Algerian Qatari Steel (AQS)!

ALGERIAN QATARI STEEL (AQS)

LOCATION:
Bellara industrial zone, El-Milia, Jijel, Algeria

START-UP:
February 2021

PRODUCTS:
CDRI/HDRI

RATED CAPACITY:
2.5 Mt/y

Algerian-Qatari Steel (AQS) was established in December 2013, as a joint venture between Qatar Steel International (49%), SIDER Investment Group (46%), and the Algerian National Investment Fund (5%). The steel complex occupies a total area of 216 hectares (> 553 acres) and includes:

- MIDREX Direct Reduction Plant – production capacity of 2.5 Mt/y hot and cold direct reduced iron (HDRI and CDRI)
- Two 120-ton electric arc furnaces (EAFs) – total production capacity of 2.2 Mt/y
- Three rolling mills – total production capacity of 2 Mt/y of reinforcing bars and wire rods

First direct reduced iron (DRI) was produced in February 2021, and HDRI was initially charged to the EAF in March 2021.

Since first DRI production in February 2021, the MIDREX Plant has produced high-quality HDRI and CDRI and established multiple operational records. The plant received four awards at the 2025 International MIDREX Conference, with further performance milestones achieved during the same year.

Read more about **Algerian Qatari Steel** at:
https://aqs.dz

Midrex News & Views

The full news articles are available on **www.midrex.com**

TOSYALI Algerie Sets New World DRI Production Record in 2025 with Second Module

TOSYALI Algerie A.Ş. has established a new world record for annual direct reduced iron (DRI) production by a single direct reduction (DR) module. In 2025, TOSYALI Algerie's Module 2 produced 2.43 million tons, setting a new global benchmark during its first year of operation, demonstrating an exceptional achievement.

In addition to this achievement, TOSYALI Algerie's first DRI module also delivered an outstanding performance in 2025, ranking third globally in annual DRI production, further underlining Tosyali's leadership and scale in direct reduction ironmaking.

Honoring Achievement and Excellence in 2025

The Midrex Iditarod Award

Presented annually in honor of former Midrex executive Dan Sanford, the Iditarod Award recognizes an employee who demonstrates integrity, dependability, initiative, teamwork, accountability, respect, organization, and decisiveness.

The 2025 Iditarod Award was presented to **Carly Russ**, a key member of the Procurement team and a trusted partner to Project Managers across the organization. Known for her attention to detail, strong expediting skills, and organized approach, she helps keep projects moving forward while fostering respectful and productive vendor relationships.

CARLY RUSS,
Junior Buyer & Expeditor wins 2025 Iditarod Award

Runners-Up

Will Riney was recognized for his steady presence during major project challenges and for keeping critical commitments on track. **Supratim Bhattacharya** was honored for consistently pursuing sound engineering solutions and for earning the trust of teammates and leadership alike.

PATENT RECOGNITION

Midrex engineers **Mickie Michishita** and **Katsuma Fujiwara** were awarded a patent for Hot Metal Production from DRI with Electric Arc Heating. Their work represents an important advancement in process technology and reflects the practical innovation that continues to strengthen Midrex solutions worldwide.

2025 PROCESS DESIGN TRAINING PROGRAM

From January through December, participants completed more than 12 modules featuring structured technical instruction, formal assessments, competency evaluations, and progress reviews. Their participation demonstrates a strong commitment to continued professional growth and engineering excellence.

Midrex proudly congratulates the 2025 graduates:

Allison Sellers
Andrew Gallagher
Eddie Cochell
James Jacobs
Micah Deneen
Richard Barrington
Sara Chacra

2025 STEPHEN C. MONTAGUE INNOVATOR OF THE YEAR AWARD

Midrex is proud to recognize **Paul Kazalski** as the recipient of the 2025 Stephen C. Montague Innovator of the Year Award, honoring his outstanding contributions to innovation, engineering progress, and collaborative leadership across the organization.

→ Aashima Vadhera promoted to Managing Director of Midrex India

AASHIMA VADHERA
Managing Director,
Midrex India

Aashima has been with Midrex for almost 14 years and is a member of the Midrex Executive Staff. She brings extensive experience in leadership, business strategy, finance, tax advisory, corporate governance, and regulatory matters. Her knowledge and strategic mindset will be instrumental as Midrex India continues to scale. In her new role, she will have oversight of all functions, including India Engineering.

Lauren Lorraine: Editor

DIRECT FROM MIDREX is published quarterly by
Midrex Technologies, Inc.,
3735 Glen Lake Drive, Suite 400, Charlotte,
North Carolina 28208 U.S.A.
Phone: (704) 373-1600 Fax: (704) 373-1611,
Web Site: www.midrex.com under agreement
with Midrex Technologies, Inc.

All references to tons are metric unless otherwise stated.

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