MIDREX

Ironmaking technology
for a sustainable
steel industry

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ABOUT MIDREX

At Midrex, we believe two things to be true: our world needs steel, and the steel industry cannot survive unless we develop a way to produce high-grade steel while minimizing greenhouse gases.

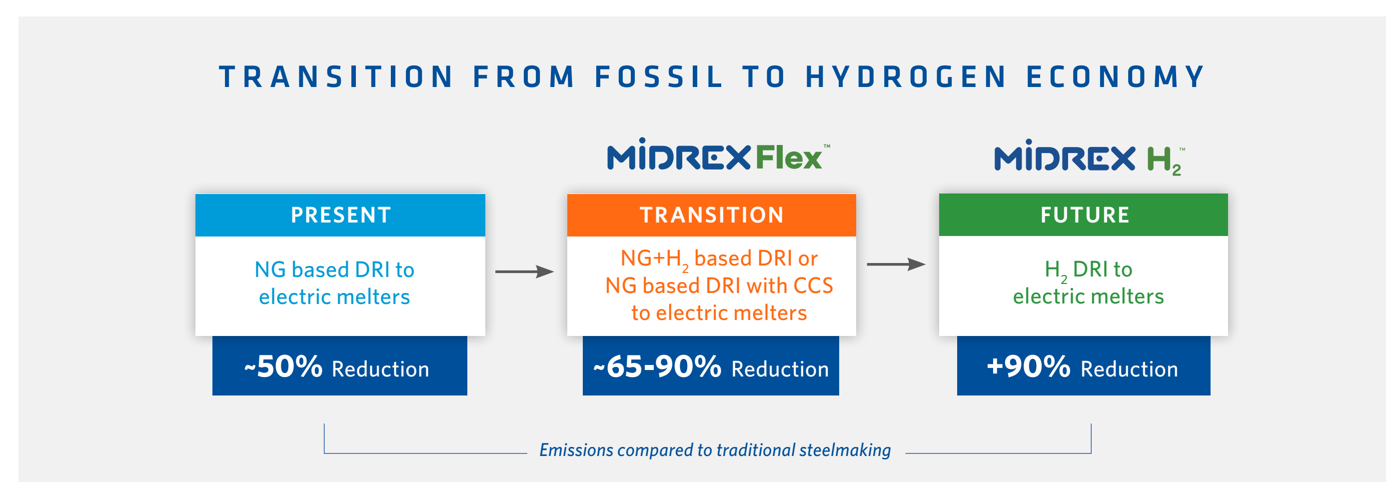
Steel is used in every aspect of our lives. To make steel, you need iron. Our solution is the MIDREX® Direct Reduction Process, a method for producing direct reduced iron (DRI), a high-quality and sustainable metallic iron. By using hydrogen in place of natural gas or other hydrocarbon energy sources, the MIDREX Process can reduce CO_2 emissions to nearly zero.

Steelmaking Decarbonization Starts Here

Whatever your particular circumstances, plans, or ambitions might be, **Midrex has a reliable process technology solution for you.**

Decarbonization is key to the sustainability of the steel industry, and direct reduction is the only proven way to lower carbon monoxide (CO_2) emissions in the vital ironmaking step. The use of green hydrogen is the ideal solution for reducing CO_2 emissions, but when it will be available in sufficient amounts and at a competitive price is uncertain. We need ironmaking technology that can adapt to a changing energy landscape.

MIDREX® Direct Reduction Process solutions are available to allow steelmakers to adapt to the Hydrogen Economy at their pace. Clean-burning natural gas (NG) can be used immediately in a MIDREX Flex™ plant (50% or more of the reformed reducing gas composition is hydrogen, H_2). As sufficient quantities of hydrogen become available at competitive prices to other energy sources, a MIDREX Flex plant can be easily modified to operate with higher percentages of H_2 up to 100% NG replacement. For those committed to H_2 operation from the start, MIDREX H_2™ is available.



Setting the Standard for Direct Reduction Ironmaking

What began as an idea for a new way to use a pelletizing furnace design and heat-treating expertise has developed over the last 50 years into the world's most productive direct reduction technology—the MIDREX® Process.

MIDREX Plants have produced more than 1 billion metric tons (tons) of DRI since the first fully commercial plants began operations in the early 1970s—and one of those, ArcelorMittal Hamburg, continues to supply low residual, highly metallized iron units today.

What is the secret?

PROCESS BASICS

The patented MIDREX Reformer (**Figure 1**) makes reducing gas by mixing recycled gas from the reduction furnace with fresh NG (CH_4) and catalytically reforming the mixture to create an H_2 and CO-rich reducing gas. The reduction by-products, CO_2 and H_2O, along with untreated H_2 and CO are recycled to minimize energy consumption and produce additional reducing gas. The MIDREX Reformer also provides the energy needed for the reduction reactions within the MIDREX Shaft Furnace.

Iron oxide pellets and lump iron ores are metallized in the upper portion of the MIDREX Shaft Furnace (**Figure 2**) as the material descends while reacting with ascending reducing gas. Carbon is added by a controlled flow of NG as the DRI bed continues to descend. A cooling zone is included in a cold discharge furnace where the DRI (CDRI) is brought to almost ambient temperature by a flow of gas similar to that used for carbon addition.

Hot discharge furnaces allow the production of hot DRI (HDRI) for direct charging into an electric arc furnace (EAF) via a system knows as HOTLINK®, transfer to an EAF by insulated conveyor or transport vehicles, or compaction into hot briquetted iron (HBI). Combination plants allow simultaneous discharge of CDRI and HDRI from the same reduction furnace.

CARBON CAPTURE

CO_2 removal is not necessary in a MIDREX Flex plant because the CO_2 is recycled back into the reformer and converted into CO. However, Midrex has designed and engineered CO_2 removal systems for plants in India based on coal gasification.

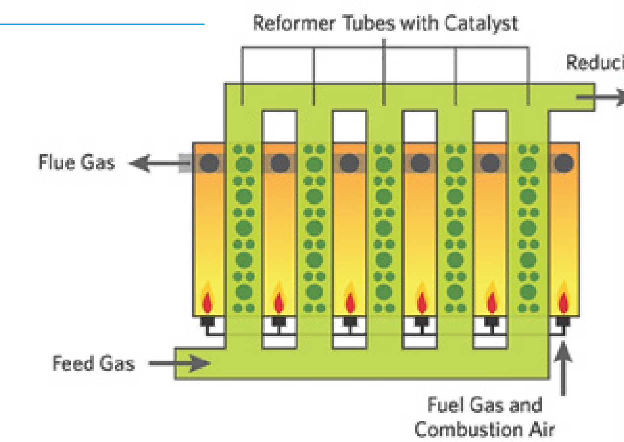
Any MIDREX Flex plant can be designed with CO_2 removal or with provisions to install CO_2 removal at a later date if it is economical (e.g. carbon tax credits) and if there is a means to store or utilize the CO_2.

There are two options to separate CO_2 and capture it. Option 1 (by itself) removes half. Option 2 (by itself) removes almost everything (near zero).

(**Figure 2, Option 1**) Remove CO_2 from the top gas fuel, which is used in the reformer for heating. CO_2 emissions can be reduced (up to 500,000 t/y of CO_2) .

(**Figure 2, Option 2**) Remove CO_2 from the flue gas of the reformer, after heat recovery. CO_2 emissions can be reduced by ~0.5 t/t DRI (up to 1,000,000 t/y of CO_2).

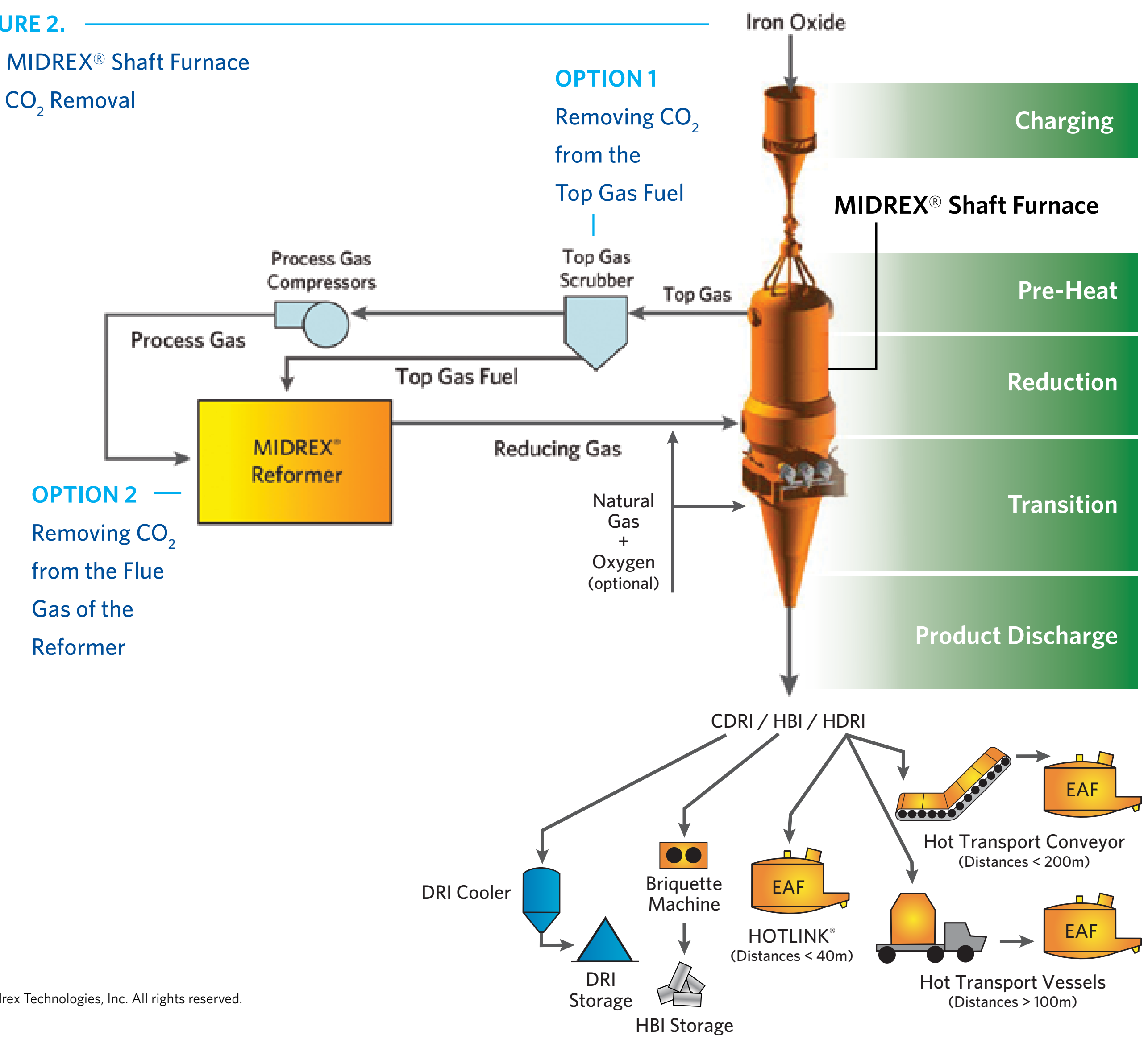
FIGURE 1.
The MIDREX® Reformer



TYPICAL COMPOSITION

	INLET	OUTLET
H_2	35	55
CO	19	35
CO_2	15	2
H_2O	13	6
CH_4	17	1
N_2	1	1
Temp. (°C)	580	980

FIGURE 2.
The MIDREX® Shaft Furnace and CO_2 Removal



Freedom from Market Uncertainties

MIDREX Flex™

MIDREX Flex allows for the replacement of any percentage of the natural gas (NG) feedstock with H_2 based on the plant's operating goals (**Figure 3**). This provides the flexibility the plant needs to respond to ever changing market needs and feedstock availability. Therefore, a MIDREX Flex plant can be built now and operated with NG until sufficient quantities of H_2 are available at competitive prices, when it can be converted to operate on up to 100% H_2.

INJECTION POINTS

In a MIDREX Flex plant, H_2 is injected downstream of the reformer without preheating. Up to 75% of NG can be replaced by H_2 in this manner, which facilitates optimum reformer operation while maximizing the reducing gas quality to the reduction furnace. When NG replacement reaches ~75%, H_2 is added to the reformer burners to maintain the DRI product carbon as far into the replacement as possible and still continue to reduce the carbon footprint. Between ~85-100% replacement, H_2 injection is introduced upstream of the reformer to maintain reducing gas quality and enhance energy efficiency in the process. The three injection points are shown in **Figure 3A**.

FIGURE 3.
The MIDREX Flex™
Natural Gas to Hydrogen

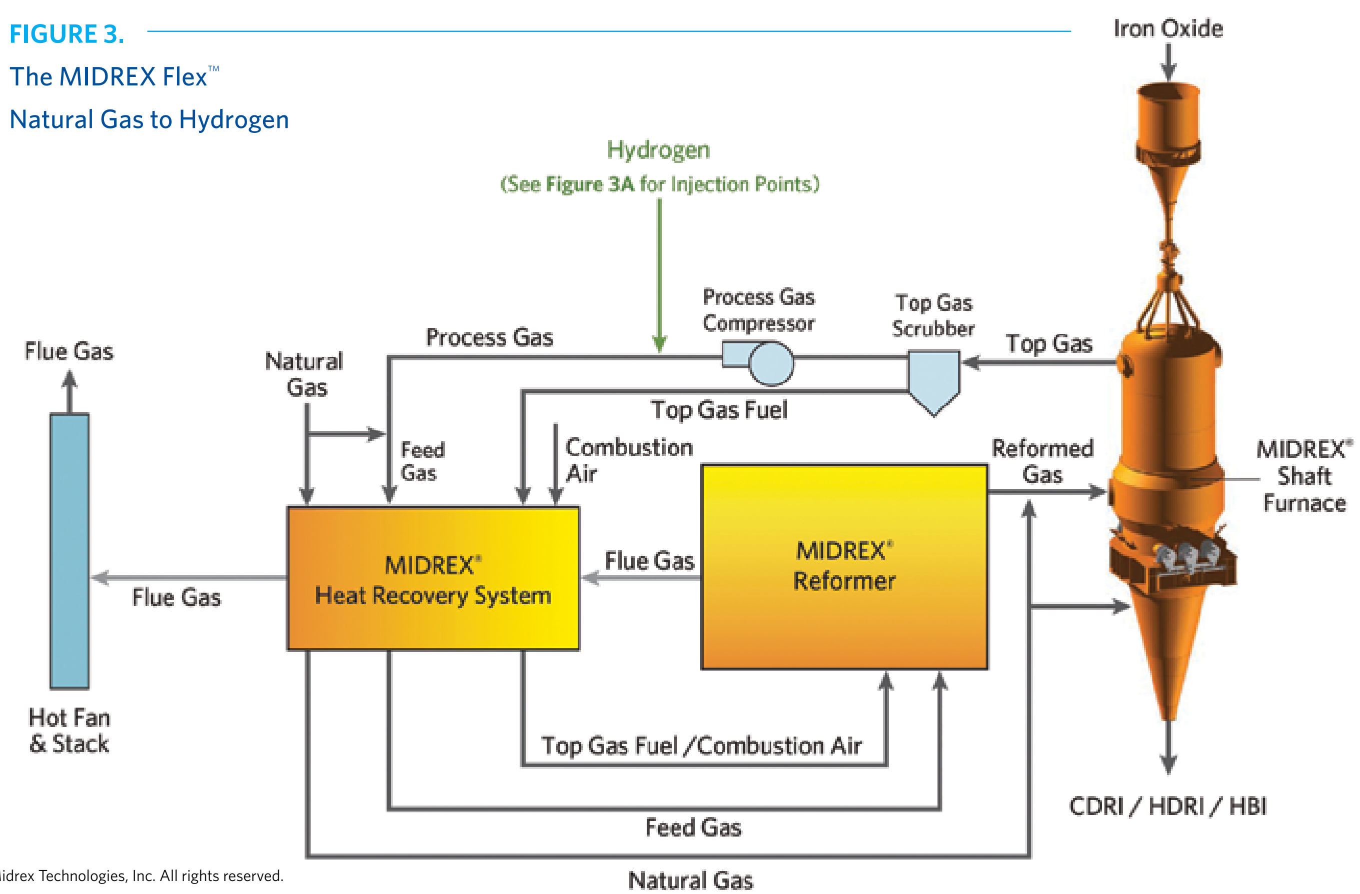
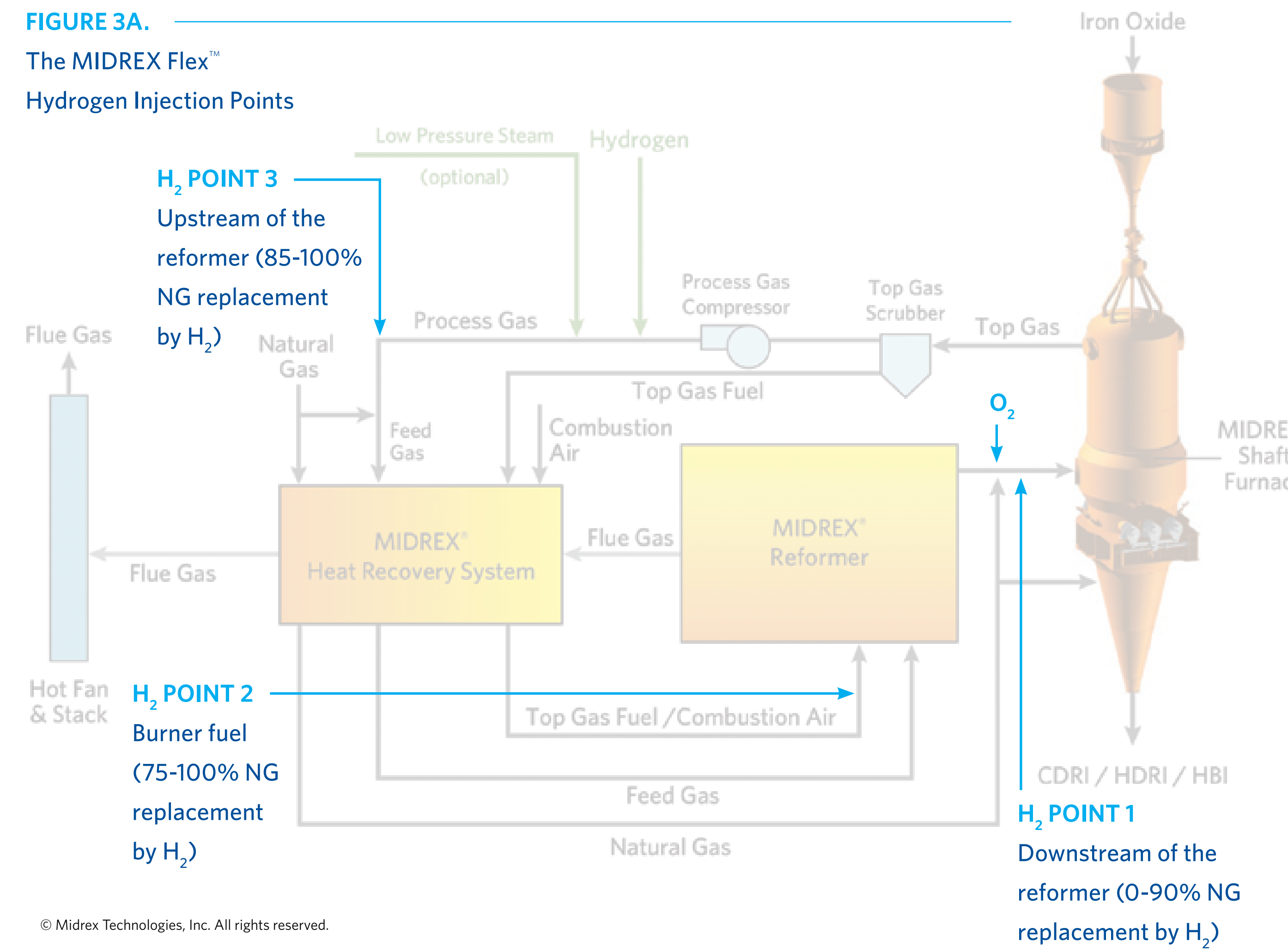


FIGURE 3A.
The MIDREX Flex™
Hydrogen Injection Points



CONVERSION TO MIDREX FLEX | PHILOSOPHY

- Maintain full plant capacity across the full transition range.
- Maximize DRI carbon across the full transition range.
- Maintain optimum reducing gas quality to the reduction furnace (H_2 addition downstream of the reformer up to 80% natural gas replacement, H_2 addition at the feed gas side of the reformer above 80% natural gas replacement).
- Use standard type centrifugal compressors with an additional third stage of compression (for natural gas replacement >30%).
- Maintain the required amount of thermal mass flow to support the higher endothermic reduction load in the furnace (H_2/CO ratio increases as H_2 addition increases requiring a larger thermal mass flow at the bustle).
- Minimize equipment modifications or the addition of new equipment.

The Future of Ironmaking

MIDREX H_2™

The ultimate method for reducing the steel industry's CO_2 footprint is the use of green hydrogen produced from renewable energy to make DRI in a MIDREX Shaft Furnace for use as either in combination with steel scrap or as the primary metallic feed to an EAF. This innovative direct reduction technology is known as MIDREX H_2™.

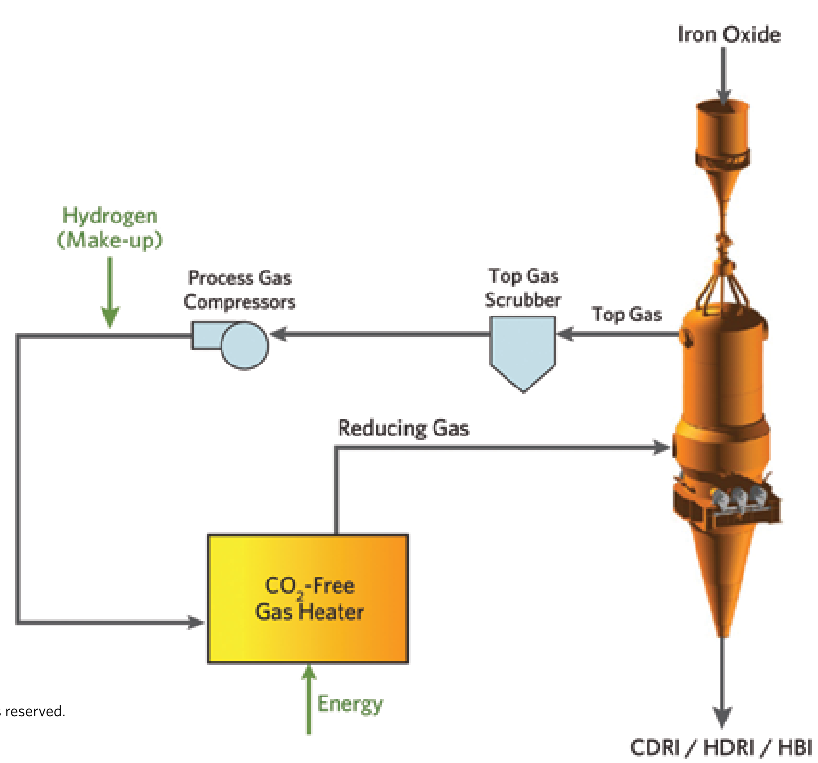
MIDREX NG already uses significant percentages of H_2 in its reducing gas (55% H_2 and 36% CO). So, MIDREX H_2 can be considered an "evolutionary innovation." Operation of a MIDREX Shaft Furnace with high levels of hydrogen has been proven at the FMO plant in Venezuela, where the hydrogen-to-CO (H_2/CO) ratio has varied from 3.3 to 3.8.

Hydrogen input gas can be generated externally to the process or integrated within the process. There is no need for a gas reformer—only a gas heater is needed to bring the gas to the required temperature.

The hydrogen consumption for reduction purposes is approximately 550-650 Nm^3/t DRI. Additionally, up to 300 Nm^3/t DRI of H_2 or another environmentally friendly heat source, such as waste heat, electricity, and natural gas is required as fuel for the gas heater.

With MIDREX H_2, CO_2 emissions can be reduced up to 90% versus the BF/BOF steelmaking route.

FIGURE 4.
The MIDREX H_2™
Hydrogen to DRI



INDUSTRY "LIGHTHOUSE" H2 PROJECT H2 GREEN STEEL

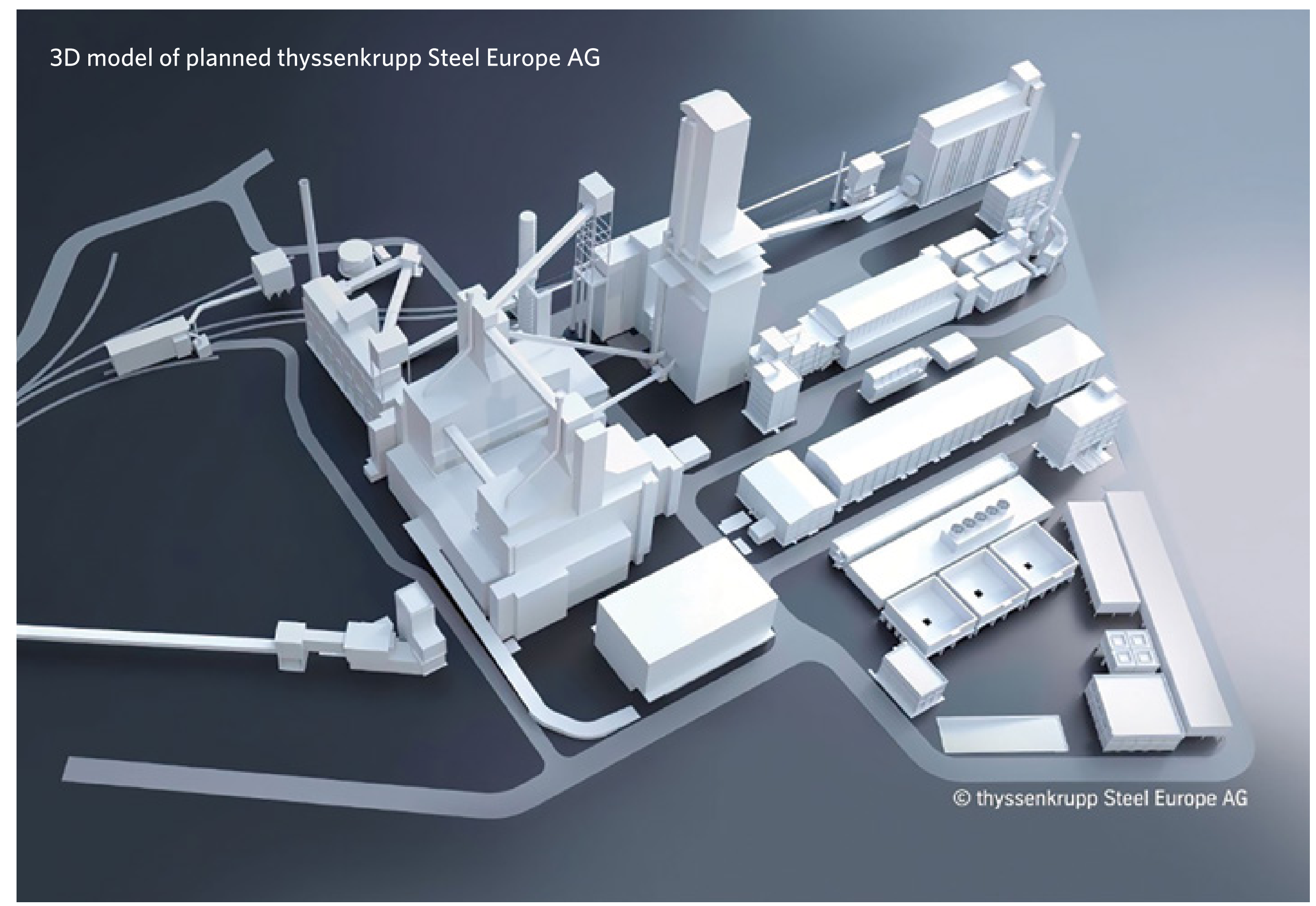
Midrex and Paul Wurth have been selected to supply the world's first greenfield steel mill based on totally green technology for H2 Green Steel in Boden, Sweden.

MIDREX H_2 technology will be used to produce 2.1 million tons/year of HDRI and HBI. The MIDREX Plant is expected to begin production in 2025 and ramp up during 2026.

THYSSENKRUPP STEEL

Midrex and Paul Wurth will engineer, supply, and construct a 2.5 million tons/year MIDREX Flex plant for thyssenkrupp Steel Europe AG at its Duisburg, Germany site. The plant will initially operate on reformed natural gas until sufficient H_2 is available, at which time it will be transitioned to 100% H_2 operation.

Start-up of the MIDREX Plant is planned for the end of 2026.



3D model of planned thyssenkrupp Steel Europe AG

H2 Green Steel in Bowden, Sweden

> *"Green Steel must be produced from a combination of a significant amount of green virgin iron and scrap in a production process which uses electricity from renewable energy sources.*
>
> *The total emissions in such a process must be more than 90% lower than that of traditional steelmaking [using] a blast furnace [for the ironmaking step]."*
>
> *– H2 Green Steel*

LEARN MORE ONLINE AT
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