ENERGIRON HYL

DRI TECHNOLOGY BY TENOVA AND DANIELI

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ENERGIRON is an innovative and sustainable direct reduction (DR) technology jointly developed by Tenova and Danieli.

Ever since it was developed, it has been consistently improving steel production efficiency and quality, making it the most sustainable and cleanest DR technology available on the market.

ENERGIRON converts iron ore (pellets or lump) into metallic iron using reducing gases in a moving bed shaft furnace.

ENERGIRON is a unique direct reduction technology that lets you choose the best energy source with the same process scheme configuration and without any modification: **from natural gas, reformed gas, syngas to coke oven gas and even hydrogen.**

ENERGIRON is characterized by its versatility.

The continuous development, optimization, and reliability of the **ENERGIRON direct reduction process** offers the flexibility of tailor-made solutions for each user.

What makes **ENERGIRON unique**

GREEN TECHNOLOGY

ENERGIRON plants are ecologically friendly and meet the most stringent environmental regulations. Thanks to ENERGIRON's unique features, it offers:

- **Lowest Carbon Footprint**: It has the lowest CO_2 emissions among ironmaking technologies.
- **CO_2 Removal**: It selectively removes ~62% of the total CO_2 generated, with the further advantage that the high purity captured CO_2 can be commercialized for other applications.
- **Hydrogen-Ready**: It is over 80% hydrogen-compatible without major process changes.
- **Efficiency Boost:** Hydrogen enables faster reduction kinetics – up to 5x faster than carbon-based technologies.

COST OPTIMIZATION

ENERGIRON plants optimize energy efficiency, decreasing OPEX:

- IOP/DRI yield ≤ 1.4.
- Natural Gas Consumption of 2.4 Gcal/Ton of DRI.

OPERATIONAL FLEXIBILITY

The ENERGIRON process offers unparalleled flexibility to its clients:

- **Ore Flexibility**: It handles a wide range of iron ore qualities, including low grade iron oxide pellets.
- **Fuel Versatility**: It uses various reducing gases – natural gas, reformed gas, syngas, coke oven gas, and hydrogen.
- **Adjustable Carbon Content**: It allows carbon levels between 1.5% and 4.5%, without affecting the high metallization level.
- **Hydrogen Flexibility**: The process can switch from 100% natural gas to high hydrogen usage. Plants are designed to operate from 100%NG to high H_2 usage in any proportion, including back-and-forth mode.

ENERGIRON
Sustainability

Decarbonization is one of the most pressing industrial challenges of the 21st century. By utilizing innovative direct reduction iron (DRI) processes, **ENERGIRON is at the forefront of sustainable steel production, reducing carbon emissions by up to 80%** compared to traditional steelmaking methods. Moreover, this pioneering technology significantly lowers energy consumption, contributing to more efficient processes. **Using ENERGIRON** doesn't just mean investing in better steel - it **means aligning with global initiatives to combat climate change**.

OUR COMMITMENT

We are wholeheartedly committed to shaping a sustainable future for the iron and steel industry. With ENERGIRON, **we strive to significantly reduce the environmental impact of steel production,** to enhance safety in the workplace, and to support customers in achieving high production standards while minimizing their environmental footprint. **With our ENERGIRON technology, we are determined to drive positive change** and create a greener, more responsible steel industry for generations to come.

ENVIRONMENTAL & SOCIAL BENEFITS

Our ENERGIRON technology is a **leader in sustainable steel production**, meeting the highest global environmental standards. Its innovative design minimizes gaseous and water effluents, ensuring they are the lowest and easiest to manage in the industry, making it the "go-to" technology worldwide.

Over the past decade, we have made significant strides with the introduction of **selective CO_2 removal systems**, which not only significantly reduce emissions but also generate an additional revenue stream for our customers through captured CO_2.

By utilizing hydrogen and other available industrial gases as a reducing gas, **ENERGIRON further cuts global CO_2 emissions**, making a substantial impact on mitigating climate change.

We are also deeply committed to improving plant safety, ensuring our customers benefit from secure operations. This focus on safety not only boosts operational efficiency but also supports our broader mission of fostering sustainability in the industry. By prioritizing a safe work environment, we aim to promote the long-term well-being of our clients and the planet alike, creating a healthier future for all.

ENERGIRON
Products

ENERGIRON plants efficiently reduce iron ore pellets or lumps into “energized” hot or cold Direct Reduced Iron (DRI) or Hot Briquetted Iron, with high carbon content providing additional chemical energy in the downstream operations.

COLD DRI

Cold DRI (CDRI) Solid reduced iron pellets with **high porosity and bulk density (1.6–1.8 t/m³)**. Must be stored dry and inert due to reoxidation risk. Easier and faster to melt than Hot Briquetted Iron (HBI).

HOT DRI

Delivered directly **from the reactor to the EAF at ~600°C using the HYTEMP system**. This retains thermal energy, saving ~150 kWh/tLS and reducing power on time by 30%.

HBI

DRI compressed at >680°C into dense, carbon-rich briquettes. Lower reactivity, higher bulk density, and safer handling—can be stored and transported like scrap.

ENERGIRON and Steelmaking Plants

Wide technology and field experience in DRI and electric steelmaking lead to the most efficient technical solutions for competitive high quality liquid steel production.

ENERGIRON IMPROVES STEELMAKING

The virtual absence of residual elements makes **DRI the ideal complement to EAF scrap charges**, as well as the recommended charge material for producing the highest grades of steel.

The perfect integration between the DR plant and the melt shop, achieved through the combination of the HYTEMP system and a properly designed EAF, is widely used by the industry and allows several advantages: **when DRI with a temperature of 600°C is directly melted in the EAF, all the thermal energy of the DRI, discharged hot from the DR Reactor, is completely recovered in the EAF.** Immediate benefits are recorded at the melt-shop in terms of both electrical energy consumption and power on time when compared to the traditional solutions of only charging cold DRI.

Together with savings in electricity, the productivity of the EAF increases with the increase in DRI temperature. The power on time decreases by about 5% and the productivity increases accordingly per every 100 °C increase in the DRI temperature.

Further benefits can be achieved by using high-carbon hot DRI in melt shop operations.

- Chemical energy contribution.
- Efficient use of carbon in EAF.
- Higher stability during handling.
- Easy foamy slag generation.

Additionally, DRI and HBI serve as quality metallics sources for blast furnace and BOF shops.

DRI CAN BE CONTINUOUSLY CHARGED FOR EVEN GREATER ADVANTAGES, INCLUDING:

- Greater **uniformity** and **predictability.**
- Increased **efficiency and productivity,** especially when using high-carbide DRI.
- Lower **total steel cost.**

THE FUTURE OF INTEGRATED STEELMAKING

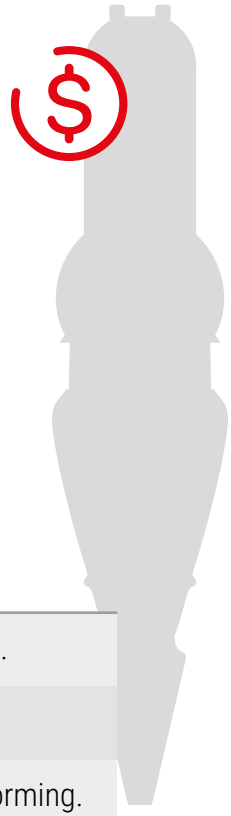
ENERGIRON direct reduction plants have been consolidated as **strong competitors to traditional integrated steel mills**, not just in abstract but in real-world performance. Today, these advanced DR plants not only match but in many cases surpass integrated mills in both production capacity and operational efficiency. Historically, integrated steelmaking relied on blast furnaces with capacities exceeding 2 million tons of hot metal (Mtpy) per year to remain economically viable. Thankfully, the landscape has shifted.

Modern EAF mills, especially when paired with ENERGIRON's high-carbon DRI, now **leverage a powerful combination of chemical and electrical energy.** With tools like oxygen lancing and optimized carbon input, these EAFs can achieve metallurgical performance once thought exclusive to blast furnaces. Moreover, by utilizing low-residual metallic feedstocks such as DRI and HBI, they consistently produce **premium steel grades**—meeting the stringent demands of industry sectors like automotive.

What was once a vision of the future is now a reality: **a new generation of high-capacity, integrated DR-EAF mills is here**. These plants not only compete with traditional integrated mills in terms of quality and cost but also offer a more **sustainable, flexible, and scalable** path forward for global steel production.

ENERGIRON IS NOT JUST PLAYING A PART IN THE **FUTURE OF STEELMAKING, IT IS LEADING IT.**

Plant and Process
Economics



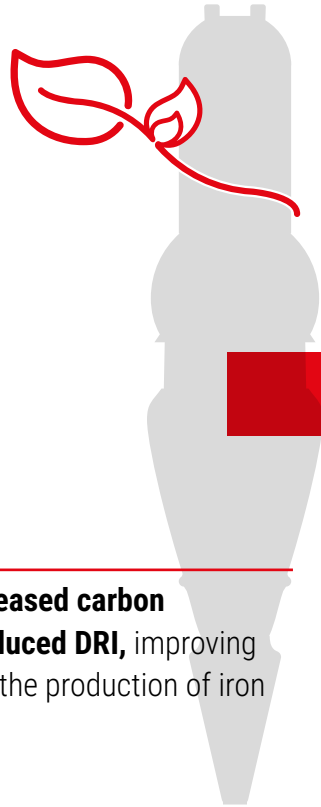
ENERGIRON plants are highly cost-effective, both in terms of capital and operating expenses. They require less land and smaller equipment due to their pressurized processes. Operating costs are reduced by using lower-cost ores, with low gas and power requirements, and achieving the **best ore-to-product yield among DR processes (1.38t screened).**

ENERGIRON plants can use a wide variety of iron ores, including low-grade ores with high silica and alumina content, and high sulfur ores. The process is flexible and efficient, with low maintenance costs, especially with the HYTEMP system. Additionally, **ENERGIRON technology offers an extra revenue stream through CO_2 capture and sale**, providing significant additional income.

TYPICAL CONSUMPTION FIGURES

Item		Remark
Plant capacity (Mtpy)	0.2 - 2.5	World's smallest and largest capacities.
Metallization (%)	> 94%	Adjustable to suit melt shop needs.
Carbon (adjustable) (%)	1.5 - 4.5	Depeding on used gas and "in-situ" reforming.
Inputs		**Specific consumption**
Iron ore (t/t)	1.36 - 1.42	Depending on DRI carbon and FeT.
Natural gas (Gcal/t)	2.30 - 2.45	Depending on DRI carbon and temperature.
Electricity (kWh/t)	70 - 85	Depending on the type of product.
Water (m^3/t)	1.2 - 1.6	Depending on the water recovery system.
Labor (m-h/t)	0.11 - 0.17	Depending on the plant size.
Maintenance (US$/t)	3.0 - 3.3	For cold-hot DRI.

ENERGIRON
Key Features



VERSATILITY

It can be tailored to meet its customers' needs and market demand. **ENERGIRON plants** have the widest range of capacities reactors, **from 0,2 up to 2,5 million tpy** using different gas sources.

ADAPTABILITY TO DIFFERENT REDUCING GASES

The process allows the use of reformed gas, syngas, and coke oven gas (COG) and up to 100% Hydrogen, **making it adaptable to different energy sources.** No process scheme modifications are needed for high hydrogen.

HIGHER FLEXIBILITY IN DRI PRODUCTION

The process allows an **increased carbon content of up to 4.5% in produced DRI,** improving carburization and facilitating the production of iron carbide.

DIRECT USE OF NATURAL GAS

The **ENERGIRON ZR** process enhances efficiency by generating reducing gases directly in the shaft furnace, eliminating the need for an external reformer. This **increases energy efficiency and reduces energy losses** and minimizes footprint requirements.

ENVIRONMENTAL BENEFITS

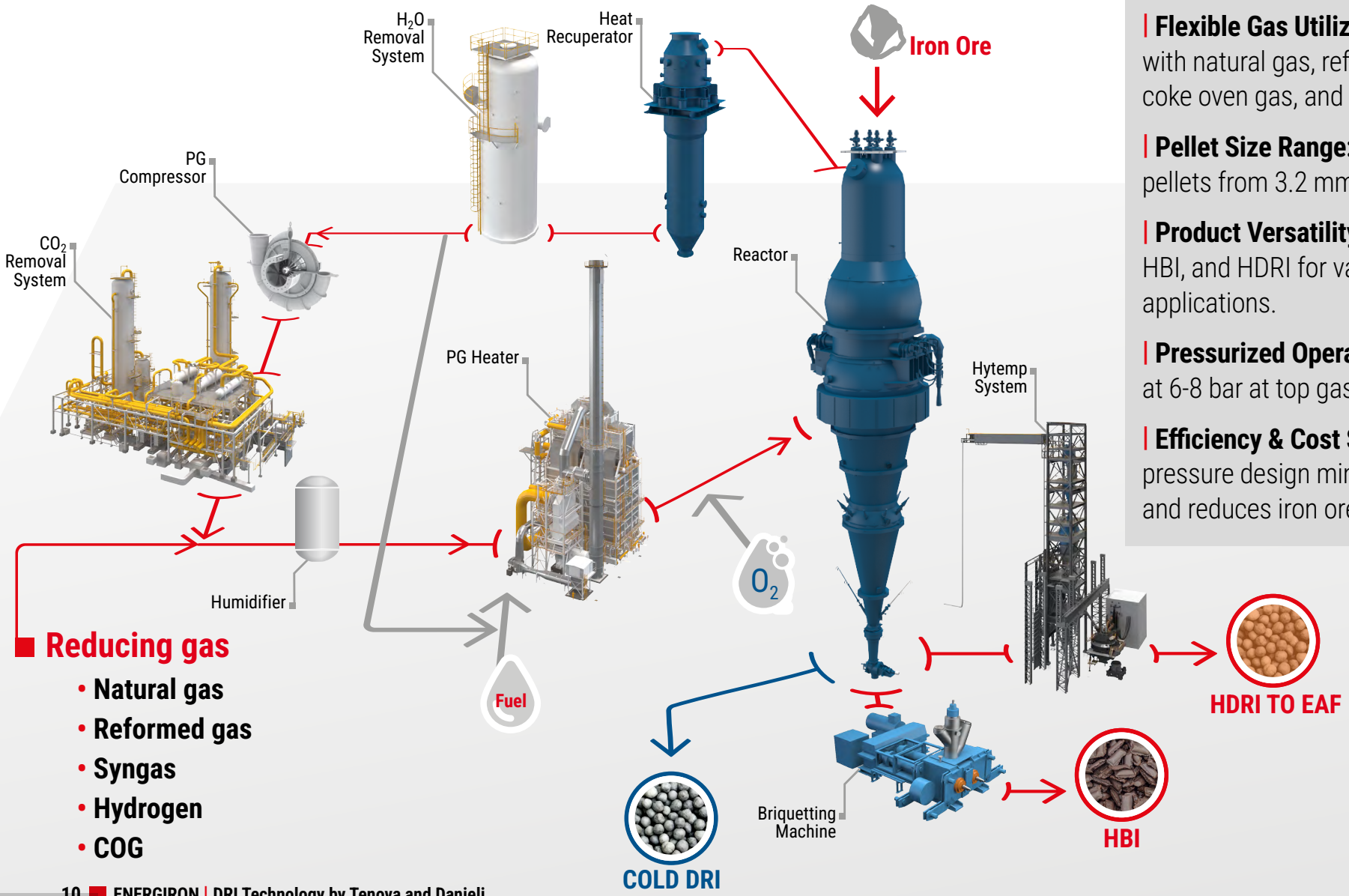
By-products such as water (H_2O) and carbon dioxide (CO_2) are efficiently removed through gas scrubbing and CO_2 removal systems. The sealing of the process equipment drives the fugitive emissions to zero, thanks to mechanical sealing of the reactor.

EFFICIENT REDUCTION PROCESS

The shaft furnace operates on an upward counter-current flow, ensuring **uniform gas distribution** and optimal contact between gas and solids.

The top gas heat recuperator recovers energy, producing steam or preheating reducing gases, further improving efficiency.

ENERGIRON
Process Overview



Reducing gas

- Natural gas
- Reformed gas
- Syngas
- Hydrogen
- COG

Flexible Gas Utilization: Compatible with natural gas, reformed gas, syngas, coke oven gas, and hydrogen.

Pellet Size Range: Handles iron ore pellets from 3.2 mm to 18 mm.

Product Versatility: Produces CDRI, HBI, and HDRI for various downstream applications.

Pressurized Operation: Furnace runs at 6-8 bar at top gas.

Efficiency & Cost Savings: High-pressure design minimizes dust loss and reduces iron ore consumption.

Integrated **Features**

CO_2 REMOVAL SYSTEM

ENERGIRON's process includes **built-in CO_2 capture**, making it ideal for **Carbon Capture and Use (CCU) or Storage (CCS)**. It reduces CO_2 emissions by over 60% per ton of steel compared to traditional steel mills, supporting both environmental sustainability and production efficiency.

HYDROGEN-READY SOLUTION

ENERGIRON is designed to use hydrogen as a primary reducing gas without major modifications. Operating with a **typical H_2:CO ratio of 3:5, it achieves reduction rates.** This not only boosts efficiency but also minimizes CO_2 emissions producing water instead of CO_2. The result is a **cost-effective, sustainable path to high-grade steel production.**

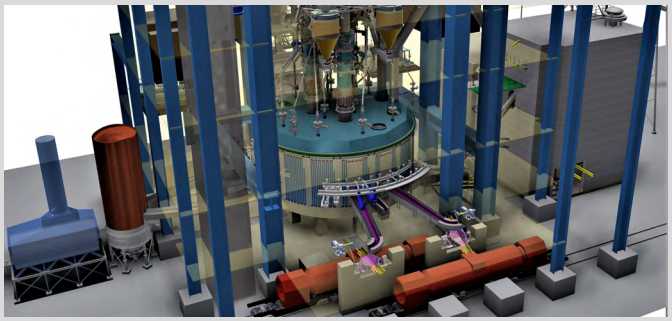
HYTEMP SYSTEM

The HYTEMP system pneumatically transfers Hot DRI at ~600°C directly to the EAF or OSBF, preserving thermal energy for the EAF and reducing cooling needs. In use since 1998, it's the **first and most efficient continuous HDRI charging system,** with minimum DRI fines loss, virtually no maintenance, and zero downtime reported in over 25 years of operation. It significantly boosts plant efficiency by feeding high-energy DRI directly into the furnace.

HOT METAL PRODUCTION

ENERGIRON's direct reduction process can be combined with a dedicated electric steel smelter to produce **Hot Metal with very low CO_2 intensity.** As a byproduct, the process generates an inert slag that serves, once granulated, as a raw material for the cement and rockwool industries.

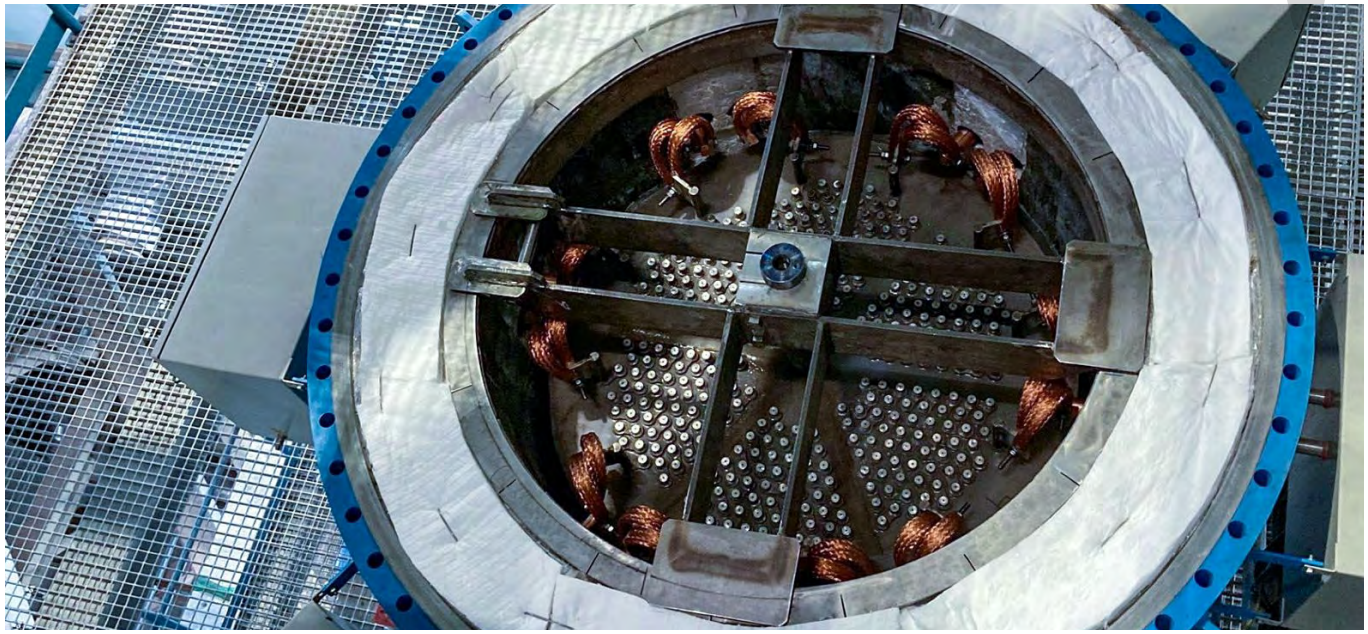
The key feature of this solution is the **capacity to operate with pellets containing high percentages of acidic gangue and enable usage of BF-like iron ore.** The stream of Hot Metal produced can be merged with the product of existing Blast Furnaces to feed Basic Oxygen Furnaces (BOF), or solidified to produce High Purity Pig Iron (HPPI). The CO-rich smelter off-gases can be collected to feed power plants or heaters.



ELECTRICAL PROCESS GAS HEATER (E-PGH)

The Electrical Process Gas Heater **(E-PGH) is a high-efficiency alternative** to traditional fuel-fired heaters (F-PGH), using electric resistive elements instead of combustion. It achieves up to **95% efficiency** (vs. 89–91% for F-PGH) and enables net-zero emissions when powered by renewable energy.

ENERGIRON plants can operate in full electric, full gas, or hybrid mode, with modular E-PGH units added over time to shift thermal duty as needed. This **flexibility supports a smooth transition to sustainable steelmaking while maintaining high performance and reliability.**



ADVANCED AUTOMATION SYSTEMS

ENERGIRON plants feature a sophisticated **two-level automation system** built on decades of process expertise.

- **Level 1:** manages equipment through a distributed control system.
- **Level 2:** oversees process optimization, production tracking, and reporting.
  It uses advanced control techniques that learn from plant behavior to fine-tune parameters like DRI carbon content and energy use, improving efficiency and reducing EAF consumption.

A standout feature is the **Process Reconstruction Model (PRM)**, which combines sensor data and physical models to predict product quality (e.g., metallization, carbon content, temperature) 6–10 hours in advance. This allows proactive adjustments for better results.

The system **enhances reliability, reduces human error, and lowers operational costs** by minimizing manual intervention and adapting to real-time conditions.

ENERGIRON
Services

At the heart of our **ENERGIRON technology** is a commitment to exceptional technical support and services. ENERGIRON prioritizes its **customers' operational efficiency**, **safety, and reliability**, ensuring that their Direct Reduction Plant runs smoothly. ENERGIRON's **proactive approach** helps prevent costly downtime and unexpected breakdowns, allowing customers to focus on what matters most. ENERGIRON values **working collaboratively** to address every customer need, delivering innovative solutions that enhance performance and productivity.

TURNKEY PLANT

ENERGIRON's turnkey project offers the **convenience of a fully operational production facility,** encompassing everything from the direct reduction plant to the melt shop and rolling mills. It handles every aspect of the project, ensuring a seamless experience from design and engineering all the way through construction, installation, and commissioning of all plant units. **The goal is to simplify the process**, so customers focus on what matters most: confidently achieving their production goals.

TECHNOLOGICAL SUPPLY

Our comprehensive supply services include cutting-edge engineering standards, advanced equipment, and proprietary technology tailored to specific operative and productive process needs. The goal is to provide our customers with a top-notch technological supply package that empowers their projects and helps realize innovative direct reduction plant possibilities.

COMPLETE SUPPLY

ENERGIRON offers a **comprehensive and complete range of supply services designed to meet all DRI production requirements.** This solution includes essential technological equipment, support systems, engineering expertise, and seamless integration services. ENERGIRON is committed to ensuring customers have everything they need for successful production, tailored to their unique requirements.

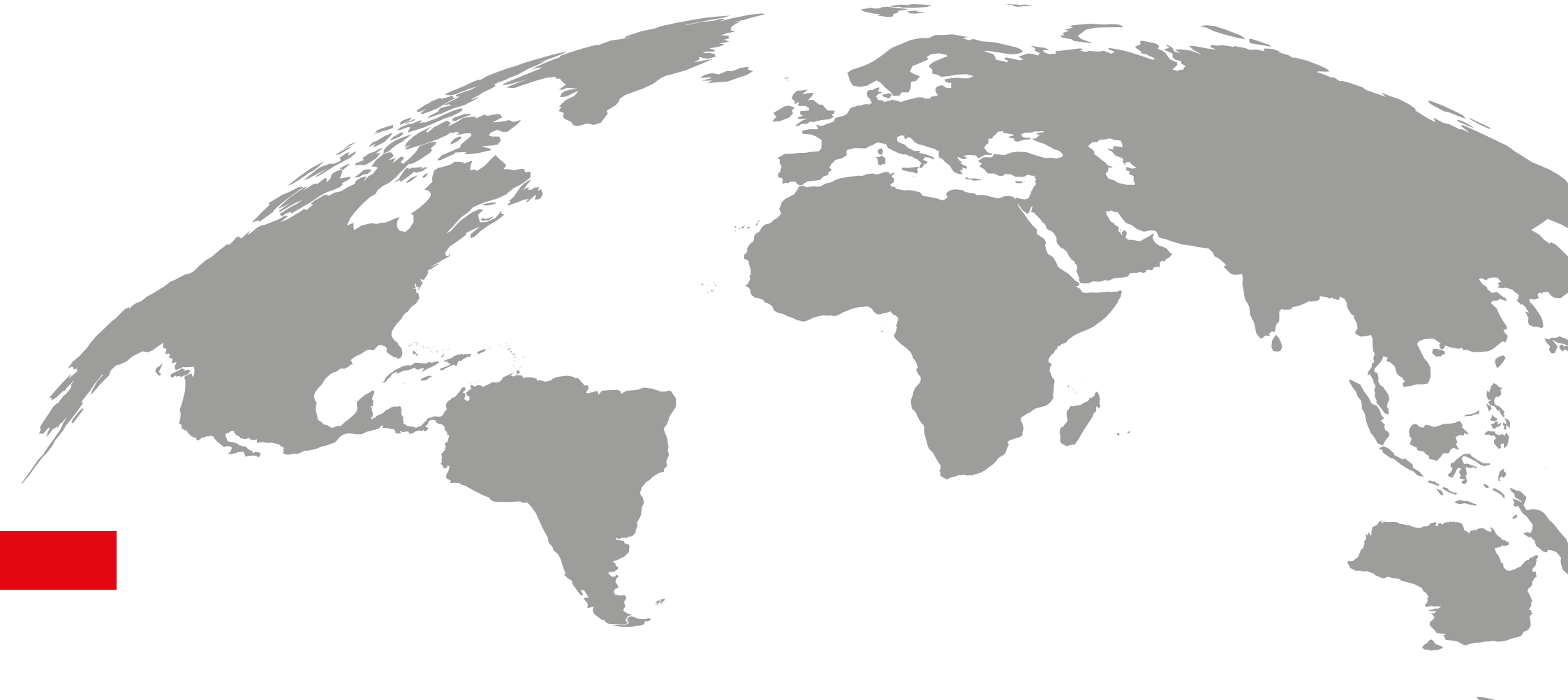
TECHNICAL SERVICE

ENERGIRON technical services provide **ongoing support after the installation and commissioning of an ENERGIRON plant.** Offering a diverse range of tailored services, including plant assessments, technical assistance (i.e., training programs), conceptual studies, spare parts, modernization, and revamping. Our commitment is to ensure that our customers' operations maintain the highest levels of safety, availability, reliability, and productivity.

ENERGIRON

Reference List

You can view the **complete and updated references list** and obtain more information about each plant at www.energiron.com/solutions



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