Enhancing the Value-in-Use of Direct Reduced Iron in Electric Steelmaking

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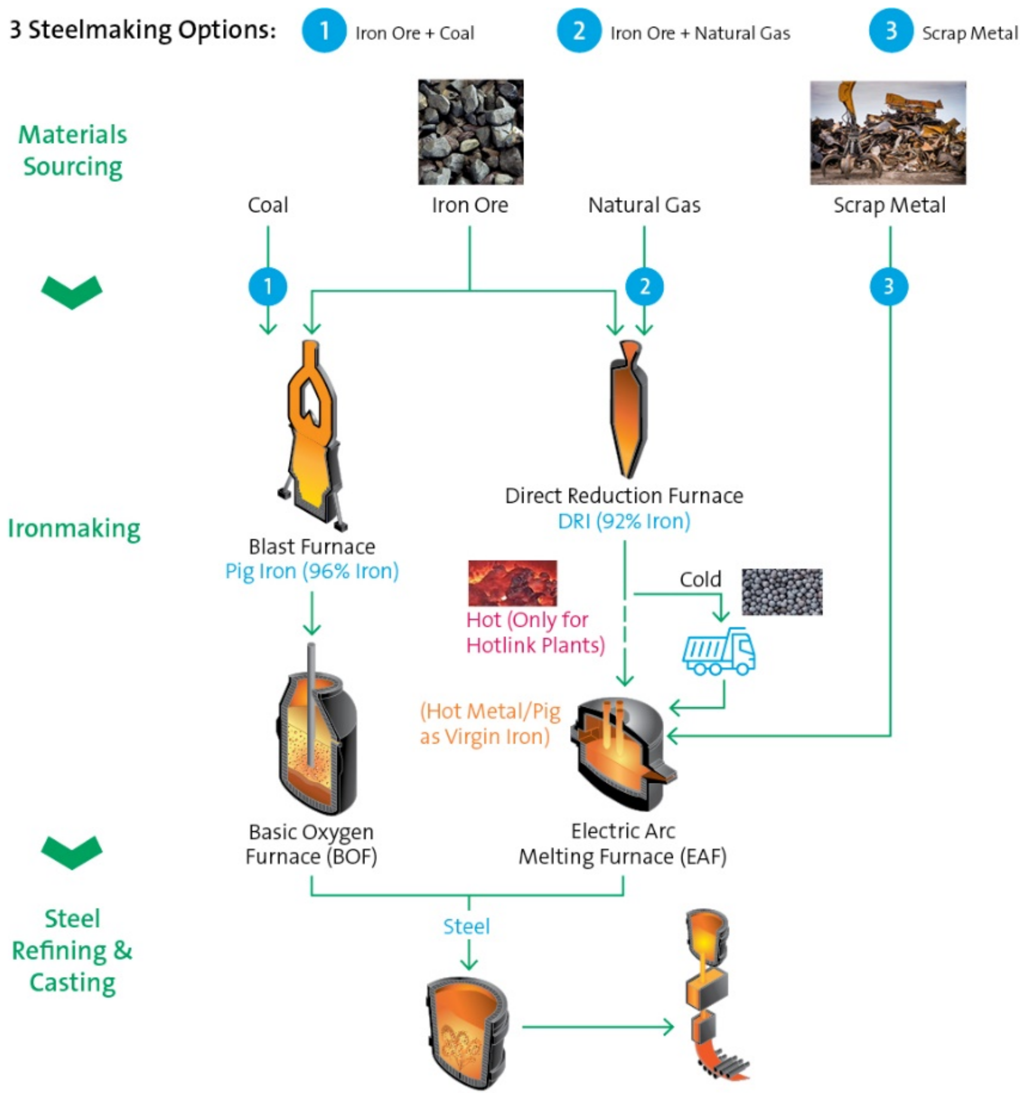
Steelmaking Synopsis

- **Blast furnace route**
  - Majority of steel produced in the world by this route
  - In the US, integrated mills hold their niche for automotive steel
  - Account for over 95% CO_2 emission from steelmaking
- **Shaft furnace and scrap route**
  - Majority of steel produced in NA is by EAFs and gaining popularity in RoW
  - EAF operations need to use ore based metallics to:
    - Lower impurities
    - Produce advanced grade steels by controlling alloy chemistry
- **Ore Based Metallics (Pure iron units)**
  - Pig iron/ hot metal
  - Direct Reduced Iron (DRI)
  - Hot Briquetted Iron (HBI)



OBMs – How Do They Compare?

Pig Iron/ Hot Metal

DRI

~96%	Total Iron	~92%
<1%	Iron Oxide	~7%
~1%	Gangue + Impurities	~5 %
High/ Low	Density/ Porosity	Low/ High
> 4%	Carbon	2 to 4%
Easy	Material Handling	Challenging (Pyrophoric and fines)
~1250 C	Melting temperature	~>1300 C (?)
~<50 $/ton of liq steel	Cost to melt in EAF	~108 $/ton of liq steel
~350 $/ton	Price on merchant market	~250 $/ton

How are OBMs Made?

Blast Furnace

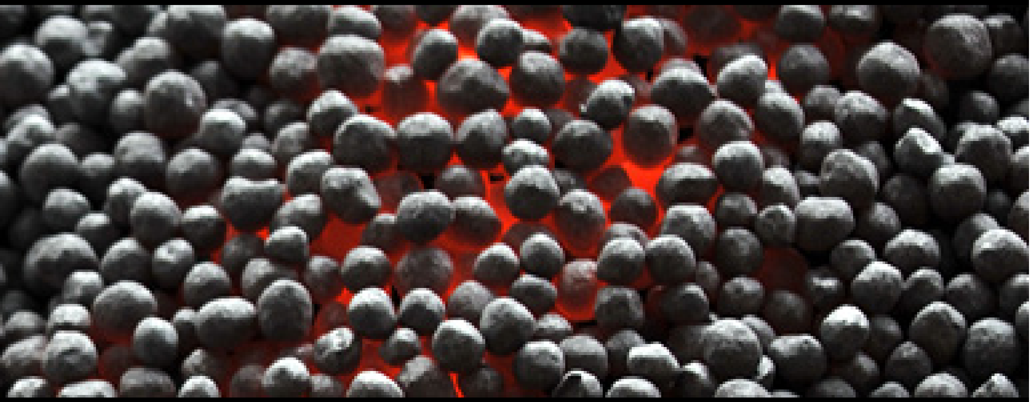
DRI Process

Yes	Melting of Iron	No
Mainly CO	Reducing gases	CO, and/or H2
Coal	Primary fuel	Natural Gas
Pig iron/ Hot Metal	Final Product	DRI / HBI
~1.83	**CO_2 (mt/mt)**	**~0.7**

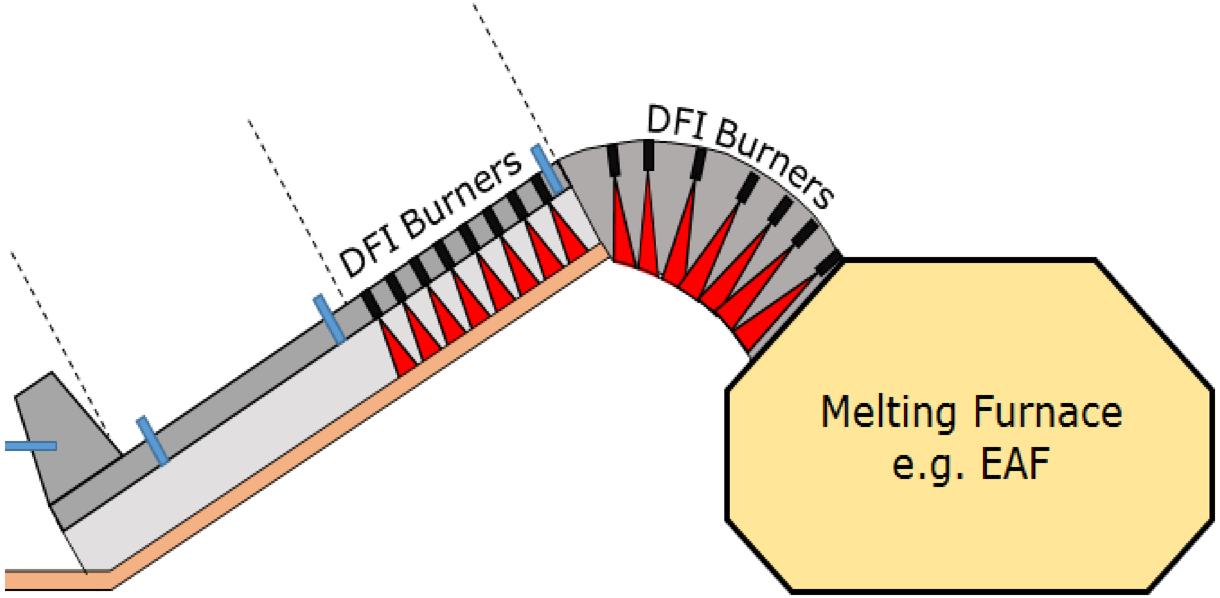
So Why Enhance DRI?

- Pig iron or hot metal are preferred OBMs over DRI, HBI
- Blast furnaces that produce pig iron may dwindle in future due to their big carbon footprint, whereas the DRI process has significantly lower carbon footprint
- **How do we enhance DRI, bringing it closer to pig iron, without increasing the carbon footprint ?**

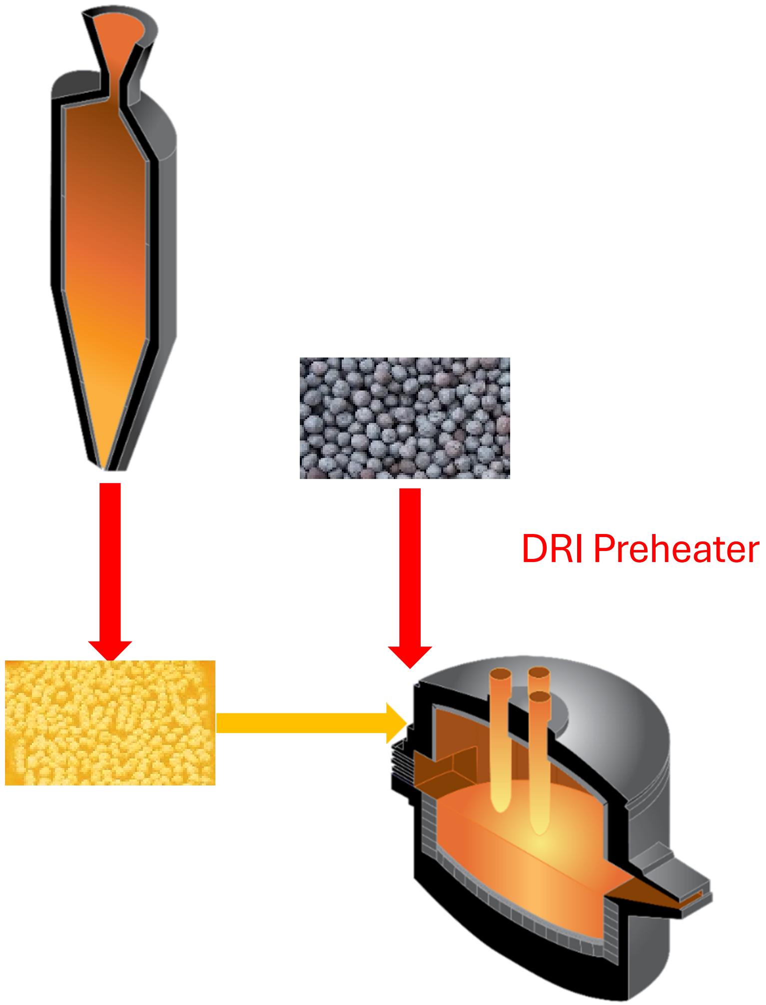
DRI Preheating



DRI Preheating
- Use combustion to preheat DRI charge



Preheating the DRI



- Feeding the DRI "hot" into the EAF has documented advantages:
  - Better melting efficiency (reduced kWh)
  - Reduction in heat time = increased production rate
- How can EAF ... RI
  operation get
- Preheating th ... on
  - Use oxy-fue

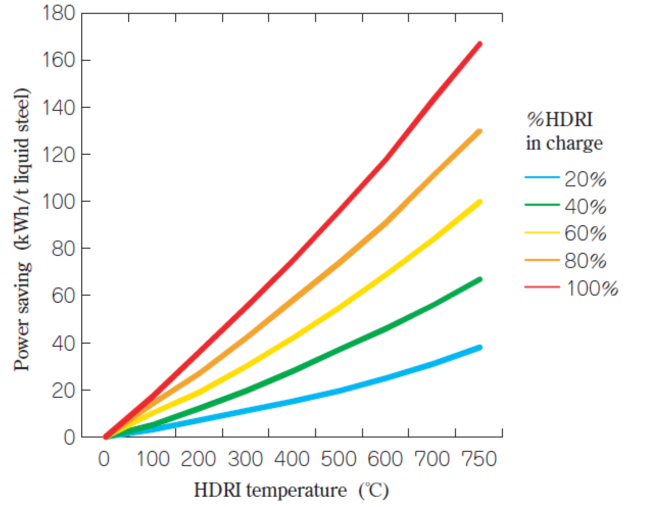
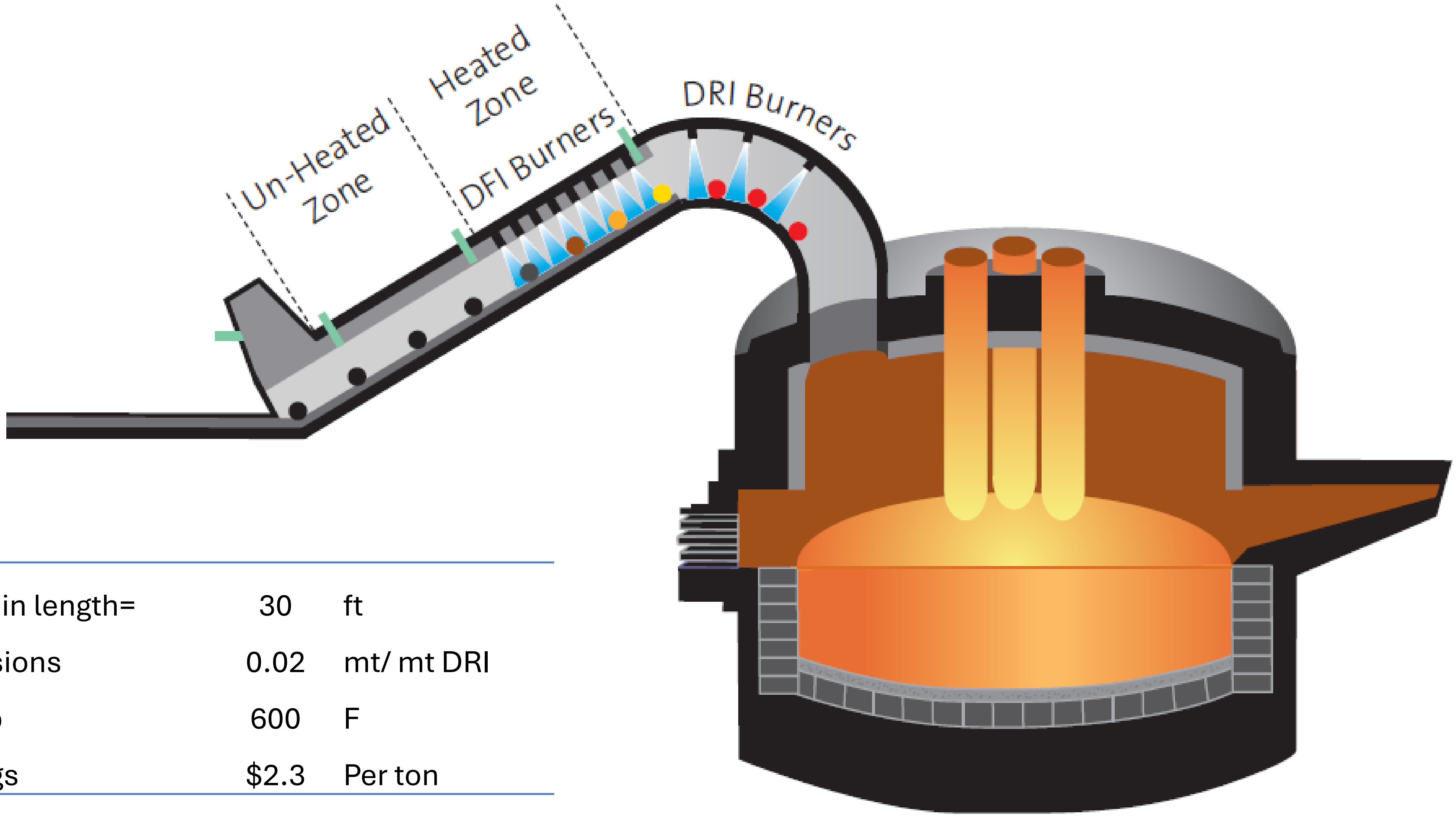


Fig.16 Correlation between HDRI temperature and power savings at EAF

Reference: MIDREX Processes: Masaaki ATSUSHI, Hiroshi UEMURA, Takashi SAKAGUCHI, Plant Engineering Department, Iron Unit Division, Natural Resources & Engineering Business

Preheating of DRI*



BURNERS in length=	30	ft
CO_2 emissions	0.02	mt/ mt DRI
Final temp	600	F
Net Savings	$2.3	Per ton

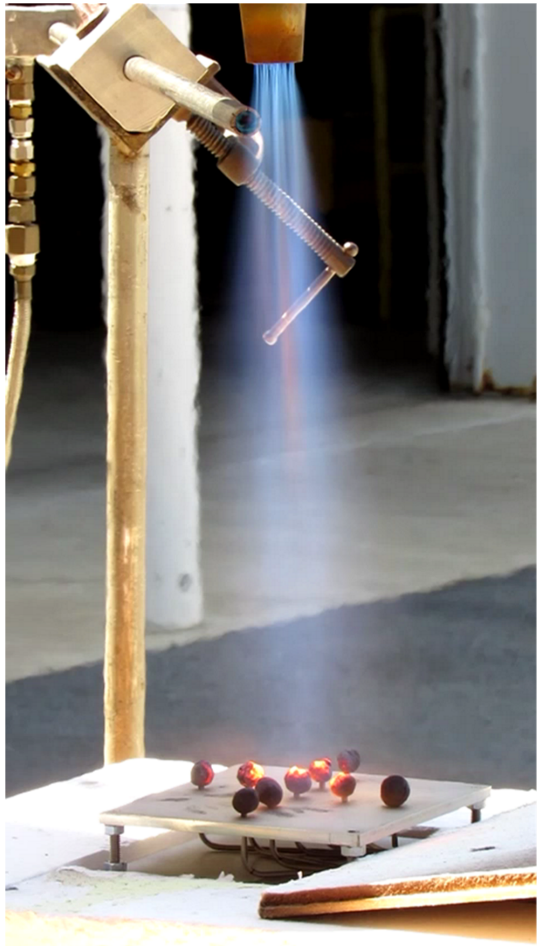
*Patented

Economics for an EAF with Preheated DRI

EAF Charge Weight	**180**	tons
% of Charge as DRI	**25%**	%
Target temp of preheating	**600**	F
Total burner firing rate	**35**	MMBtu/hr
TAP-TAP time =	**50**	min
Operating days/yr	**300**	days
Net Savings per ton	**$ 2.20 - $ 2.50**	Savings /ton

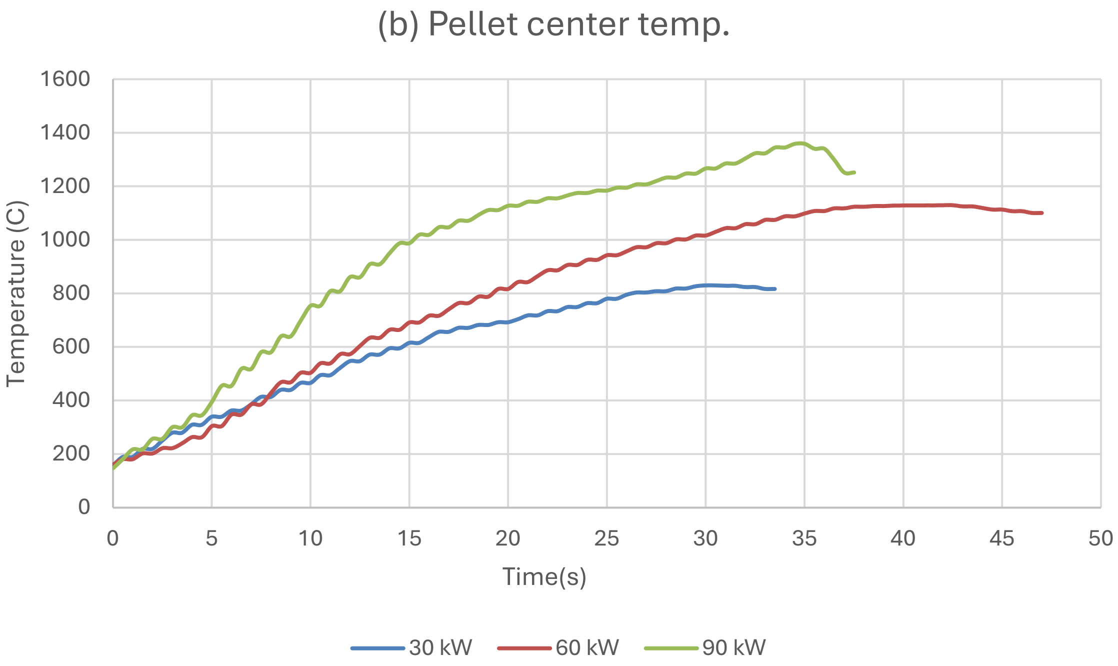
Assumption: Hot charging lowers energy (20 kWh/100 ^{0}C realized) and increases productivity (2 mins/100 ^{0}C)

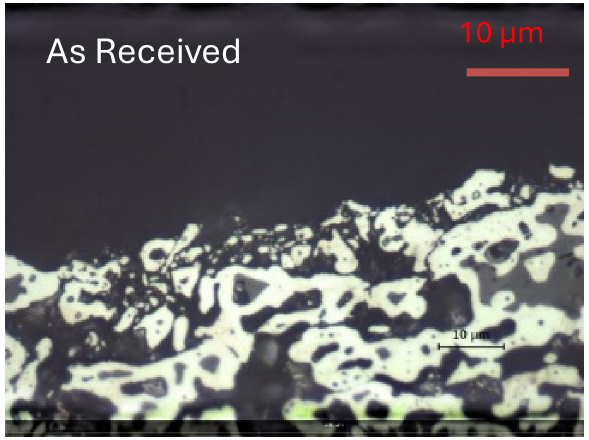
Lab Scale Experiments at Air Products

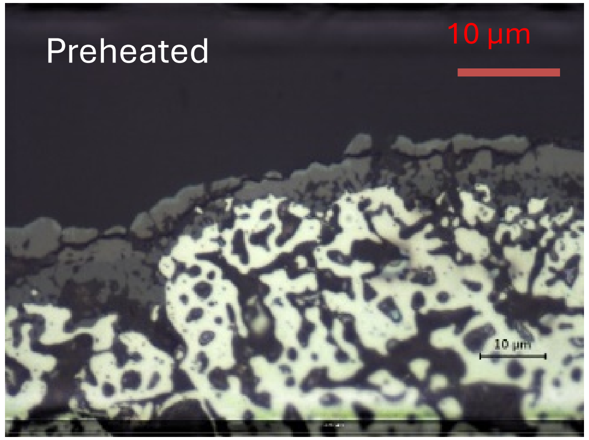


Individual pellet preheating

Lab Scale Experiments at Air Products

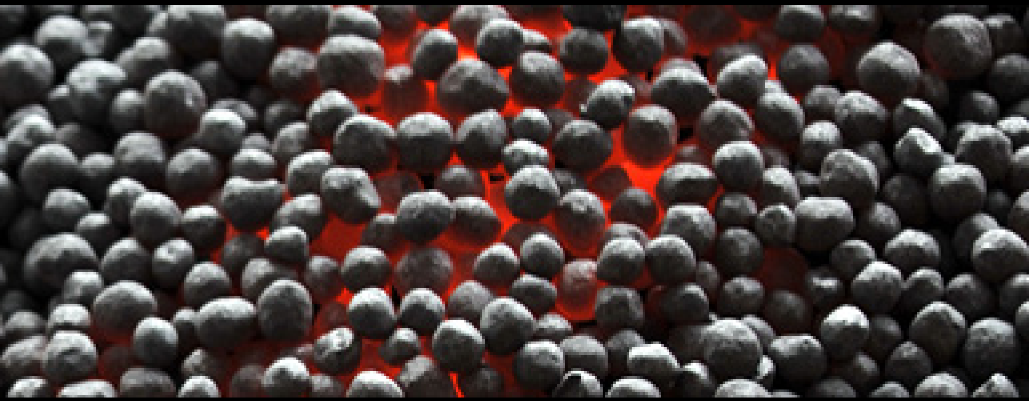




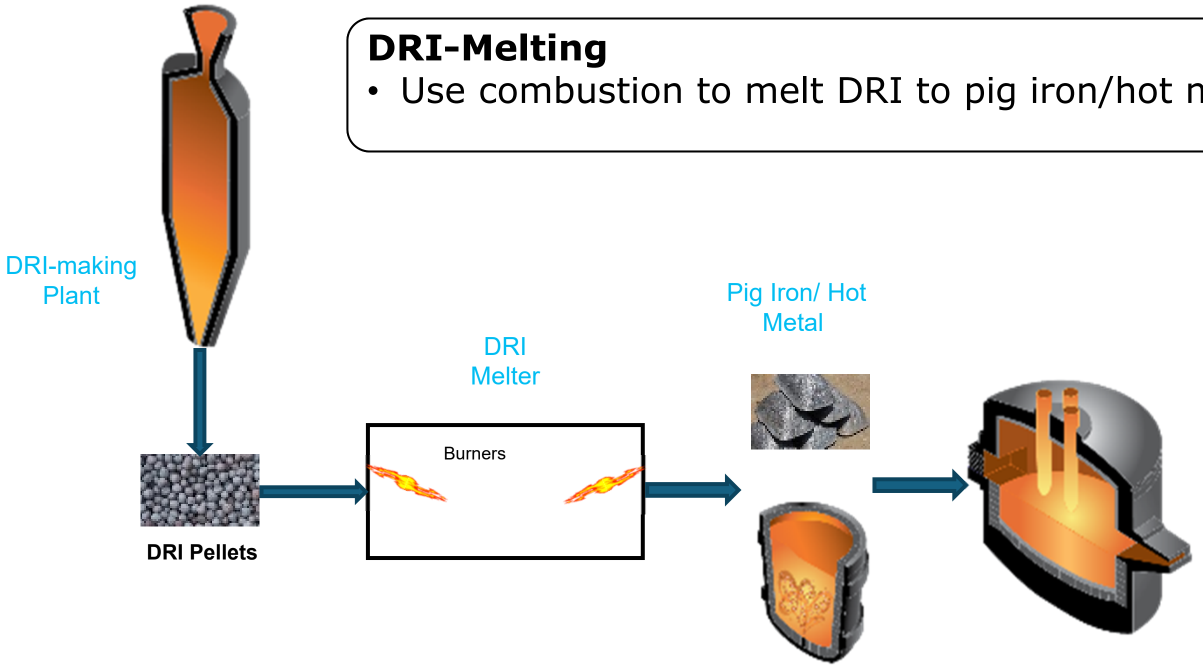


- Minimal slag layer formation on the pellet as a result of preheating
- Change in C and Fe concentration is not significant

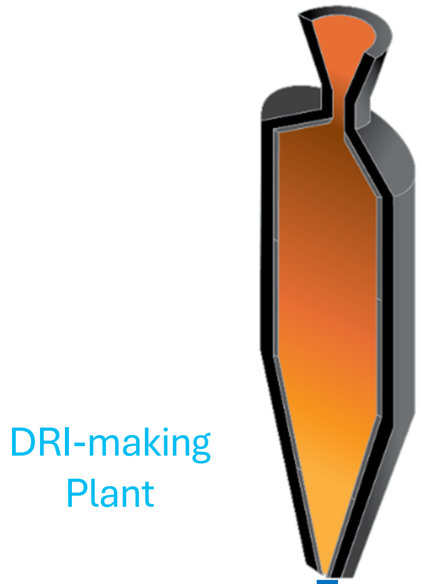
DRI Melting



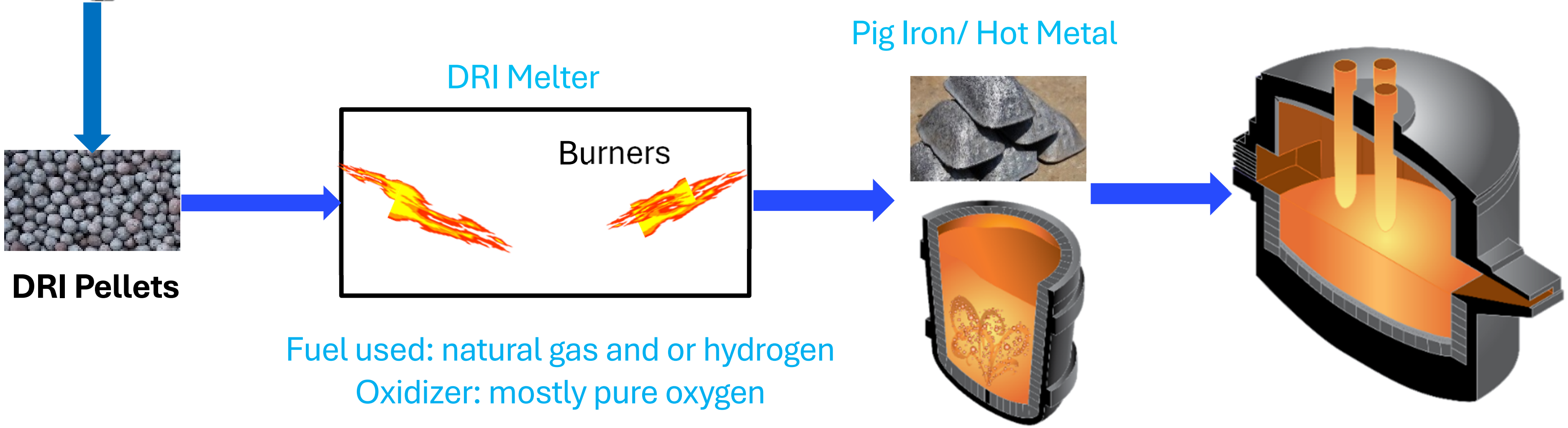
DRI-Melting
- Use combustion to melt DRI to pig iron/hot metal



DRI Melting



Energy needed (per ton of DRI)	**1.9, 550**	MMBtu, kwh
Additional CO_2 generated	**0.12**	mt/ mt of DRI
Total CO_2 generated (DRI process + conversion)	**0.85**	mt/ mt
Cost of conversion (capital + operating)	**~$50**	Per ton DRI
Production furnace size	**50**	tph
Cost savings compared to electric conversion (SAF/ EAF)	**~$20**	Per ton DRI

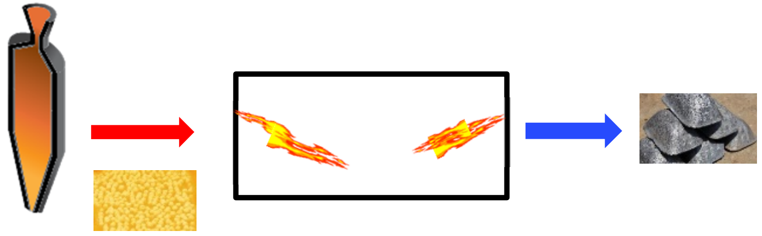


Fuel used: natural gas and or hydrogen
Oxidizer: mostly pure oxygen

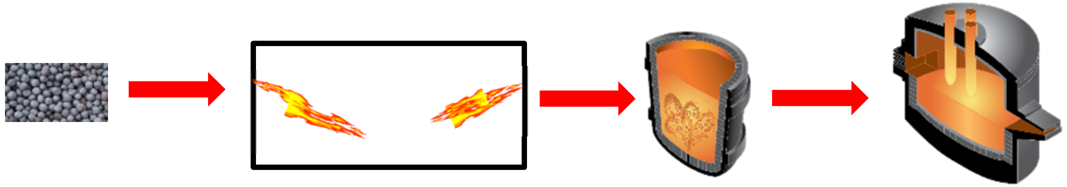
DRI Melting Applications

- Downstream of DRI-making plant – direct conversion to pig iron before transport
  - Use the "hot transport" mode to use the preheat of DRI
  - Handling of fines on the site – conversion to useful product
- Upstream of the EAF in a mini mill – direct hot metal charge into the EAF
  - Improve productivity of EAF
  - Lower electric power consumption
  - Lower electrode consumption
- Upstream of the BOF in an integrated mill
  - Offset BF with DRI Shaft + DRI Melter
  - Reduce CO_2 footprint of integrated mill by 50%

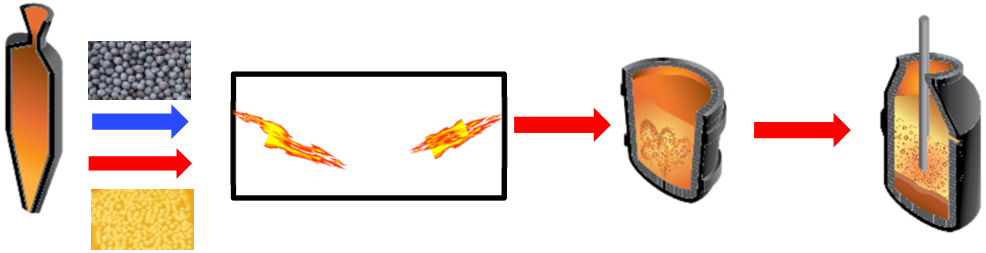
DRI to pig iron conversion with hot connect



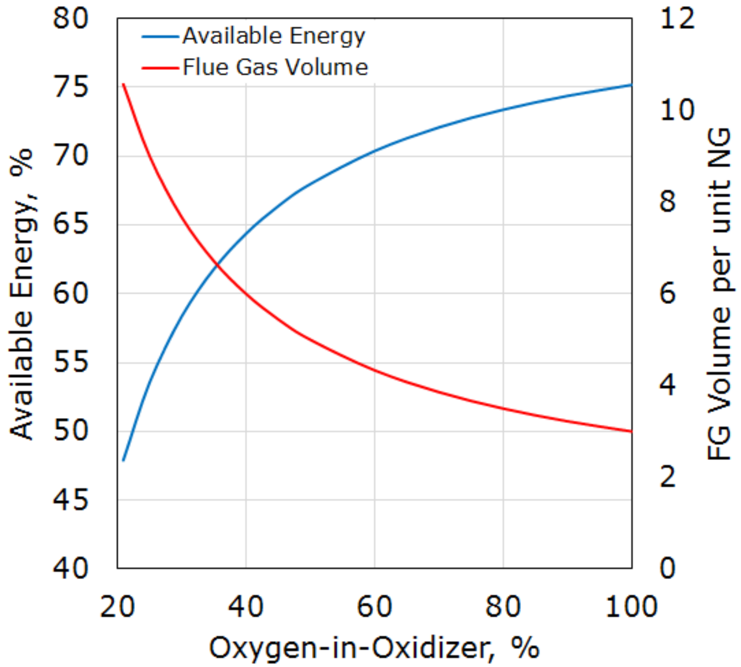
Cold DRI to hot metal conversion

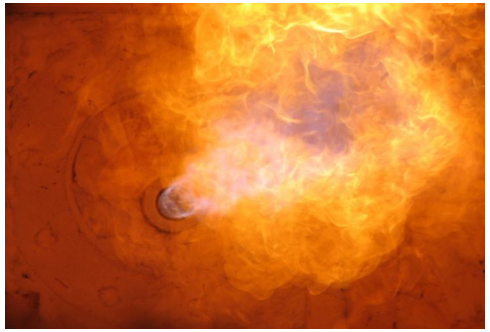


Integrated Mill using DRI Melter



Why Oxy-fuel Combustion?

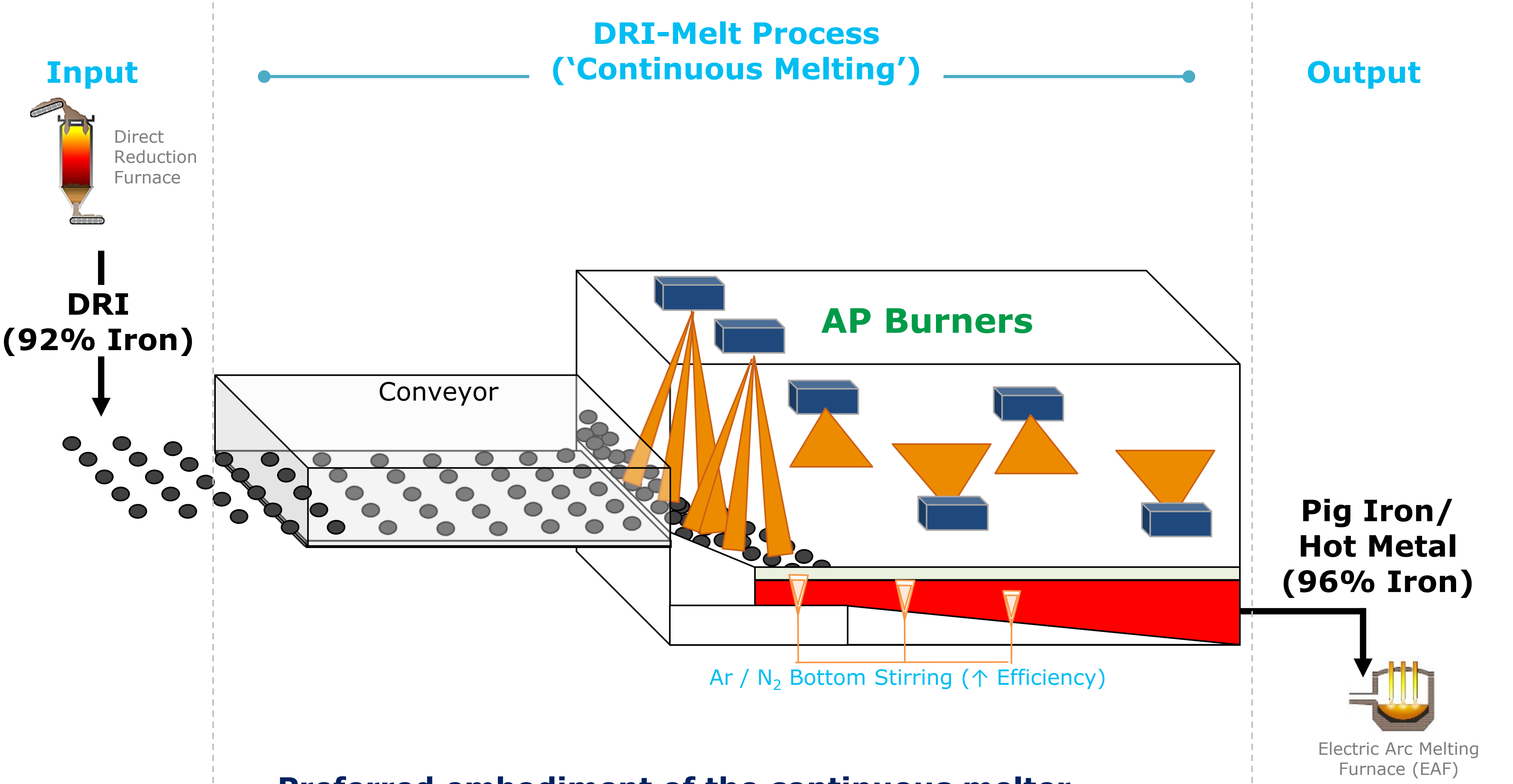




- More available energy, so higher efficiency
- Smaller furnace size for given throughput
- *Flue gases from melter ready for CO_2 capture*

- Better flame stability
- Better “control of the flame”
- Faster melting

DRI Melting Process*



Preferred embodiment of the continuous melter

*Patented

Summary

- DRI Preheating
  - *Productivity and efficiency increase for EAFs*
  - *Low CO_2 footprint*
  - *Existing feed system can be adapted*
- DRI Melting
  - *Can replace BF route to produce pig iron at ½ the CO_2 footprint*
  - *Enable EAFs to use pig iron more readily*
  - *Supplement DRI process for more widespread use*
- Next Steps
  - *Move from lab scale to prototype/mini pilot scale*
  - *Customer and OEM partnerships for scale up*

Thank you
Questions?

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