# Potential for CO2 emissions reduction in MIDREX direct reduction process

**Presented by**

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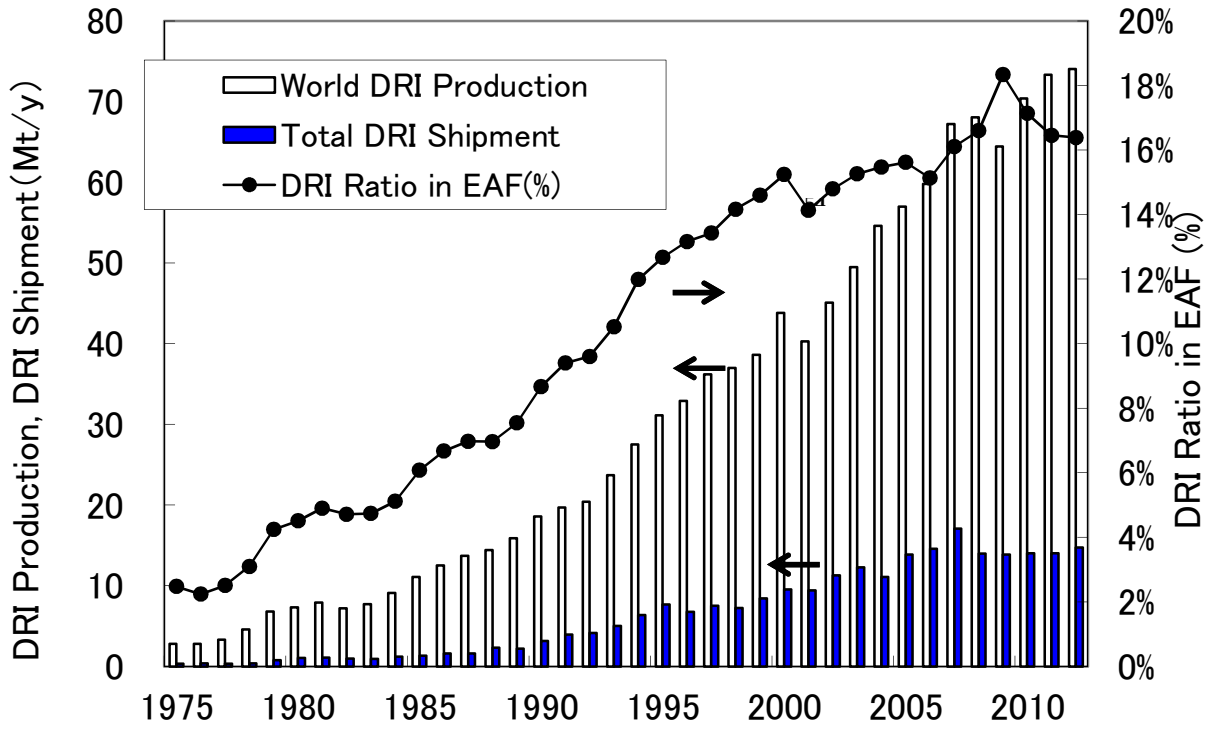
# World DRI Production

**DRI (Direct Reduced Iron)**

Direct Reduction: The removal of oxygen from iron ore without melting

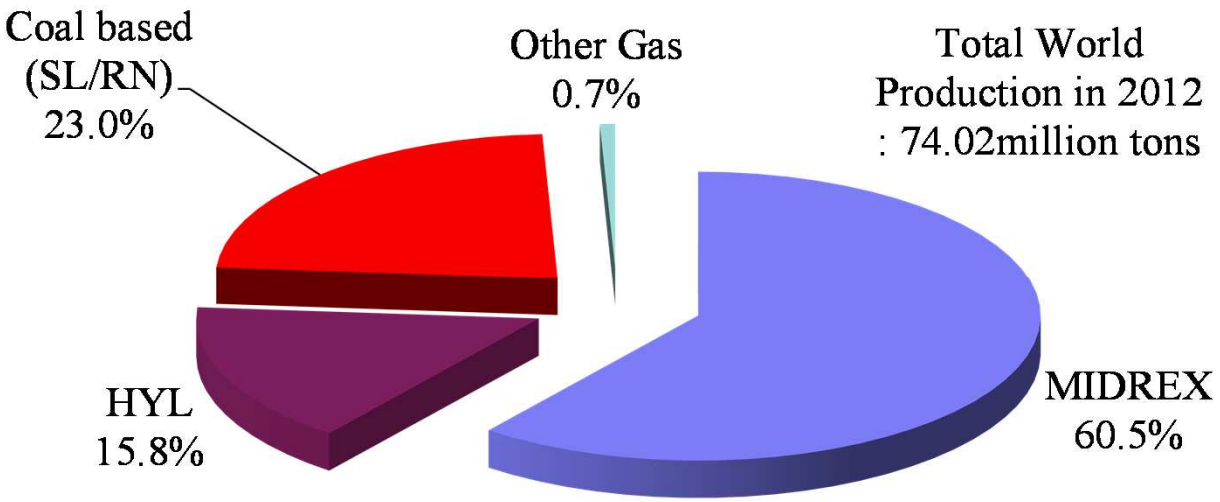
TFe%:90-94, MFe%:83-89, Met%:92-95, Carbon%:1.0-3.5, Gang%:2.8-6.0

# World DRI Production & Shipment




- World DRI production was 74 million tons in 2012
- World DRI shipment increase gradually due to strong demands of DRI in advanced country.
- Total DRI shipment was 14.8 million tons in 2012.
- DRI ratio in EAF becomes 16% of total EAF charging materials.

# World DRI Production by Process




- MIDREX is a wholly owned subsidiary company of Kobe Steel
- Kobe Steel is a leading company of this DRI production field

# Why MIDREX ?

- Of the 67 MIDREX Plants built and started-up since 1969, only 3 have been dismantled and taken completely out of service (Fig.1)
- 33 MIDREX Plants have been operating more than 20 years (Fig.2)
- The reason why MIDREX process covers 60% of world DRI production is due to high performance of stable and simple operation.(Fig.3)

Fig.1 **Where are they now?**

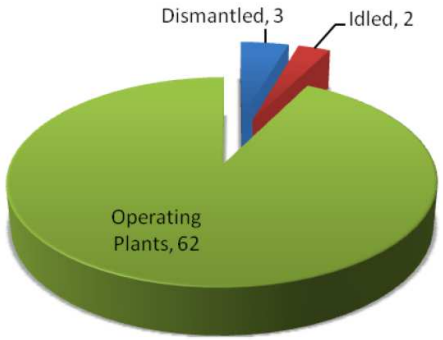



Fig.2 **Operating MIDREX® Plants**

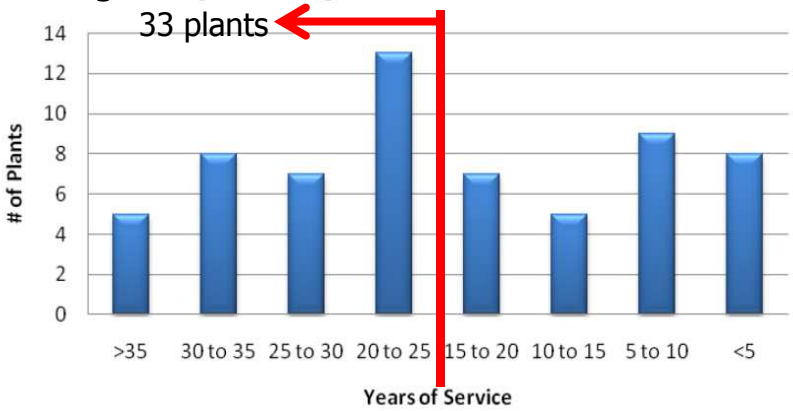
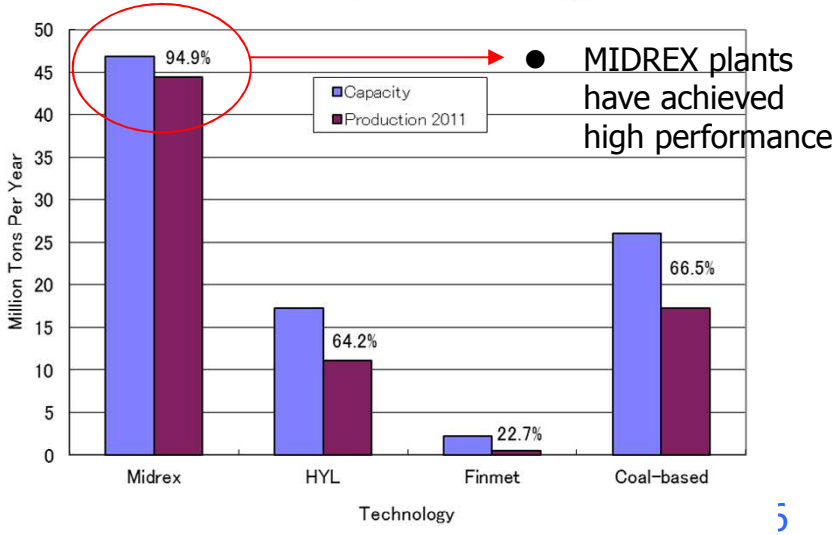



Fig.3 World Direct Reduction Capacity and Production per technology in 2011



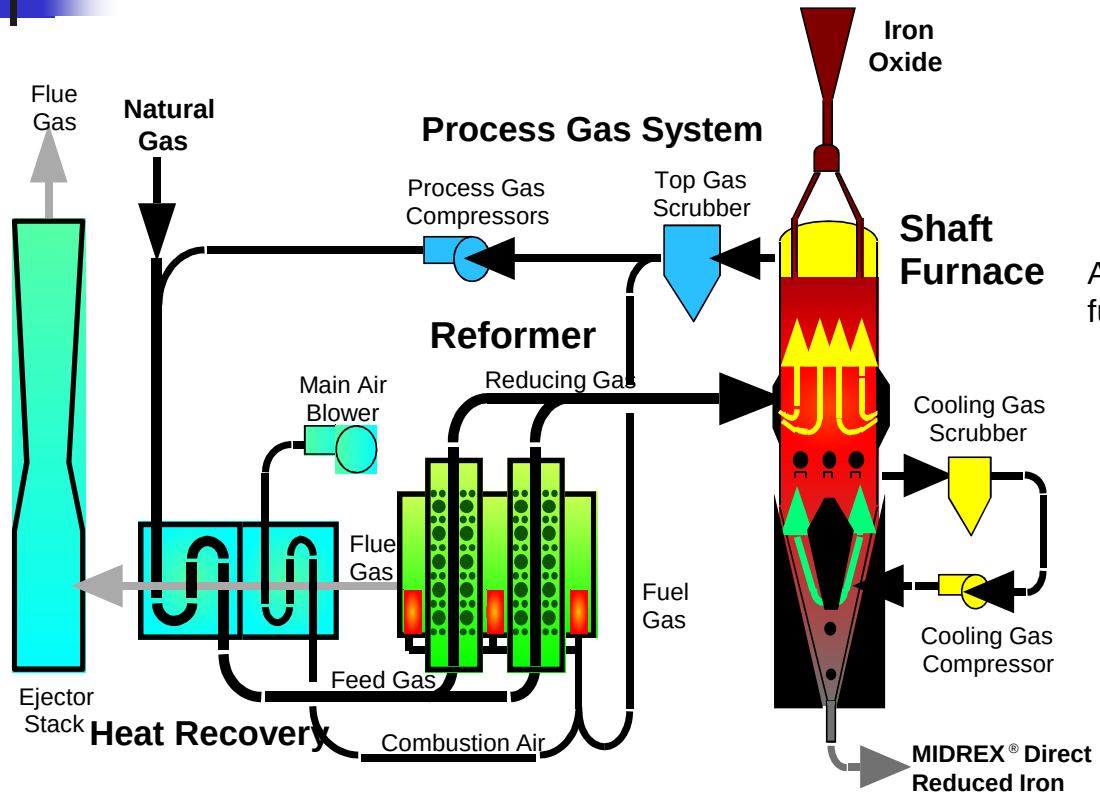

- MIDREX plants have achieved high performance

# Natural Gas Based DR Process (MIDREX)

**MIDREX® DR Plant**
**Qatar Steel (II)**

Country : Qatar
Start-Up : Dec., 2007
Capacity : 1,500,000 t/y

# Standard Process Flow of MIDREX® Process




## Shaft Furnace

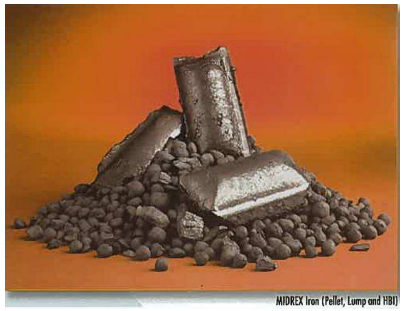
$$Fe_2O_3 + 3H_2 \rightarrow 2Fe + 3H_2O$$
$$Fe_2O_3 + CO \rightarrow 2Fe + 3CO_2$$

As the iron oxide descends through the furnace, the iron oxide is heated and reduced

- **Natural Gas is used as a reductant.**
- **Coke is not required.** (Pellets/Lump Ore are reduced to produce DRI without being melt in the shaft furnace.)
- **DRI is fed to EAF to produce steel.**

## Reformer

$$CH_4 + H_2O \rightarrow 3H_2 + CO$$
$$CH_4 + CO_2 \rightarrow 2H_2 + 2CO$$




DRI/HBI

# Reason why MIDREX is less CO2 Emission

- As Fuel

Table shows the CO2 emission rates for combusting methane versus two types of coal.

As the table shows, natural gas emits only about one-half the CO2 per unit of energy as does coal.

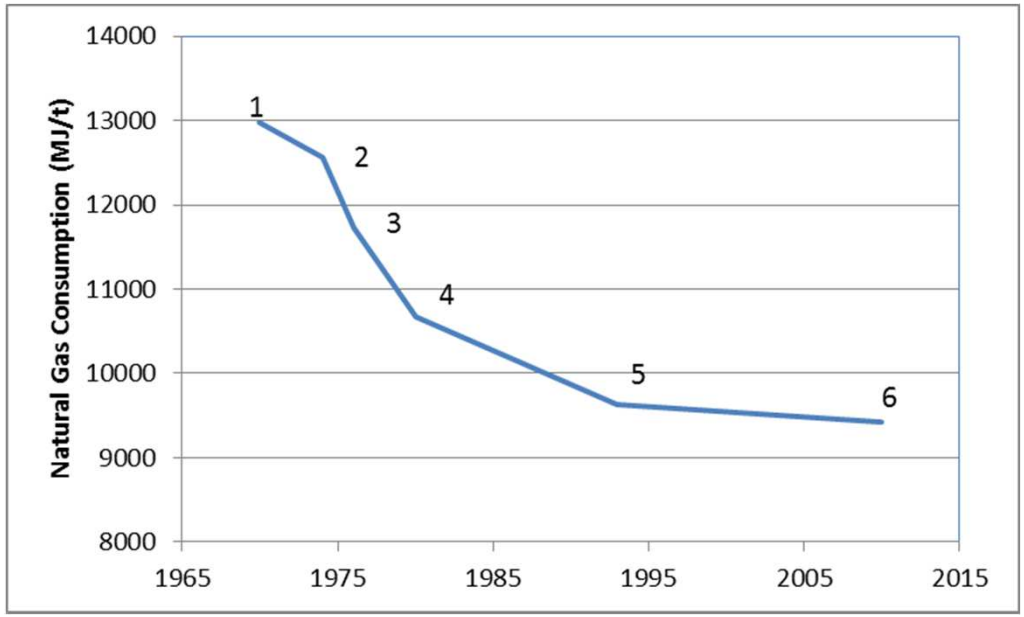
| Energy Source | CO2 Emissions (kg/GJ) |
|---|---|
| Natural gas (CH4) | 49 |
| Bituminous metallurgical coal | 90 |
| Bituminous steam coal | 94 |

- As Reductant

- $C + O_2 \rightarrow CO_2$ :Carbon can remove one mole O2 and produce one mole CO2
- $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$ :Methane can remove two mole O2 and produce one mole CO2

These characteristics make natural gas an ideal energy source for ironmaking.

# Decrease in natural gas consumption with MIDREX Process development




- Energy usage in direct reduction shaft furnaces has decreased by about 30% over the past forty years.
- This has occurred gradually over the years in the course of overall process development.

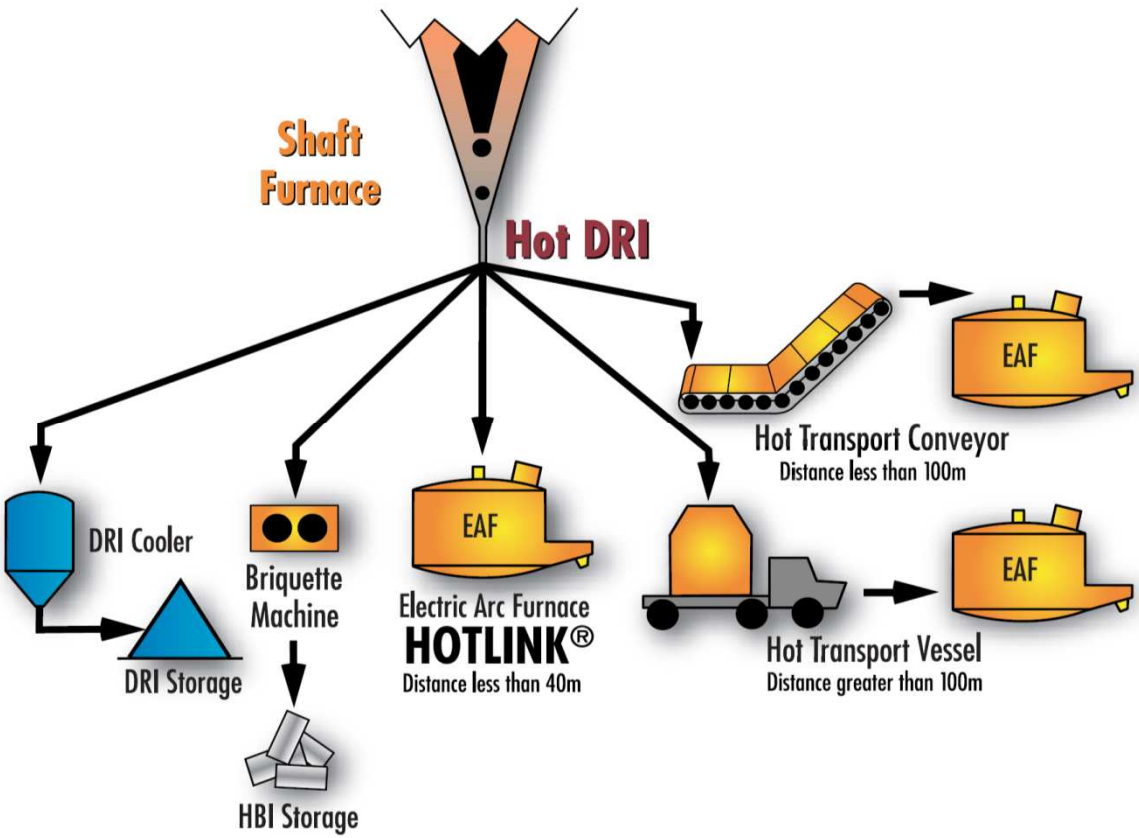
- Six stages of natural gas reduction are indicated, which equate to the following process upgrades:

1: 480° C combustion air preheat
2: in situ reforming
3: 540° C combustion air preheat and 400° C process gas preheat
4: 650° C combustion air preheat and 540° C process gas preheat
5: Top gas fuel preheat
6: Preheat of natural gas used for transition zone and enrichment



DIRECT FROM MIDREX 2nd QUARTER 2004

# Hot Charging DRI to the EAF Options

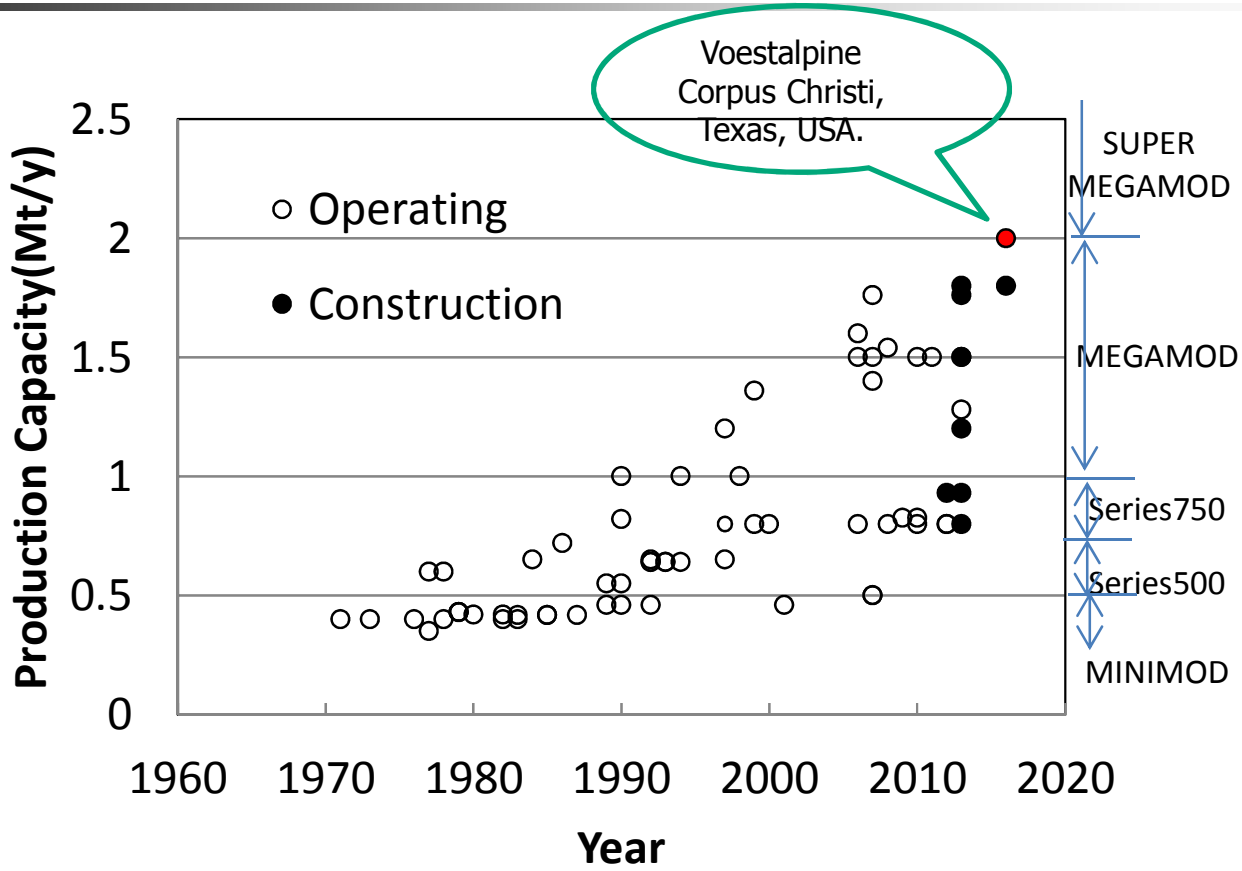



- Traditionally, MIDREX Plants have cooled the DRI and stored it for later charging to the EAF.

GET IT WHILE IT'S HOT

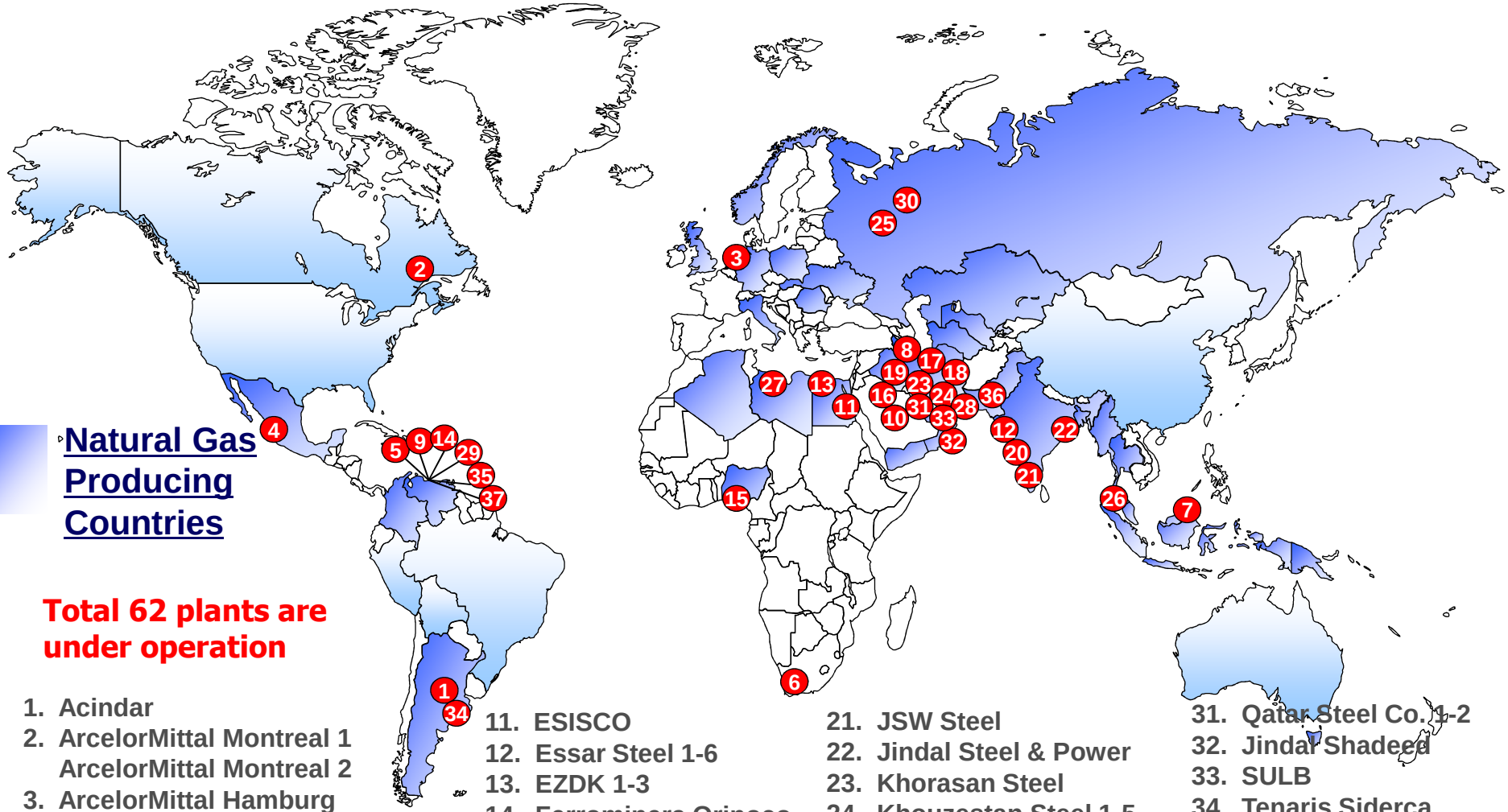
- Carbon emissions can be further reduced by hot charging the DRI to the EAF
- MIDREX has developed three methods for discharging the DRI at elevated temperature, transporting it hot to the meltshop, and charging it to the EAF at 600-700° C
- These methods lower the electricity required per ton of steel produced, which also reduces CO2 emissions from the power plant.
- Electricity consumption can be reduced about 20 kWh/t liquid steel for each 100° C increase in DRI charging temperature.
- Thus, the savings when charging at over 600° C are 120 kWh/t or more.

# MIDREX Plant Rated Capacities by Year




- Production capacity of MIDREX plant has been increased year by year.
- New MIDREX "SUPER MEGAMOD" DR plant is designed for an annual capacity of 2 million tons of HBI. It will be the largest single HBI producing module in the world.

# Locations of MIDREX® DR Plants




**Total 62 plants are under operation**

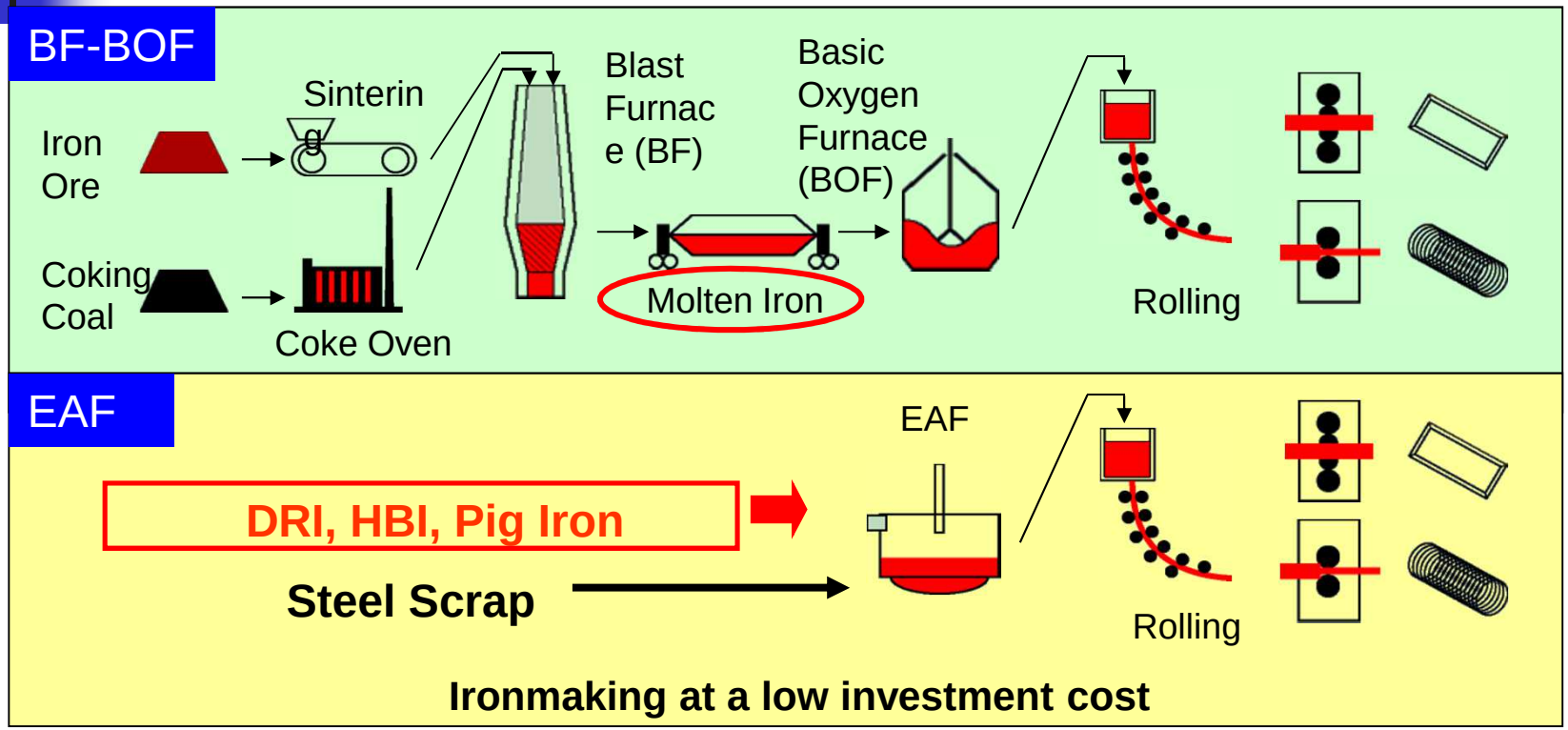
1. Acindar
2. ArcelorMittal Montreal 1
   ArcelorMittal Montreal 2
3. ArcelorMittal Hamburg
4. ArcelorMittal Lazaro Cardenas
5. ArcelorMittal Pt. Lisas 1-3
6. ArcelorMittal South Africa
7. Antara Steel Mills
8. Arfa Steel
9. Comsigua
10. DRIC 1-2
11. ESISCO
12. Essar Steel 1-6
13. EZDK 1-3
14. Ferrominera Orinoco
15. Global Steel Holdings
16. Hadeed A - E
17. HOSCO 1-2
18. IGISCO
19. IMPADCO
20. JSW Ispat Steel
21. JSW Steel
22. Jindal Steel & Power
23. Khorasan Steel
24. Khouzestan Steel 1-5
25. LGOK 2, 3
26. Lion DRI
27. LISCO 1-3
28. Mobarakeh Steel A - F
29. Nu-Iron
30. OEMK 1-4
31. Qatar Steel Co. 1-2
32. Jindal Shadeed
33. SULB
34. Tenaris Siderca
35. Sidor 1
    Sidor 2 A - C
36. Tuwairqi Steel Mills
37. Venprecar

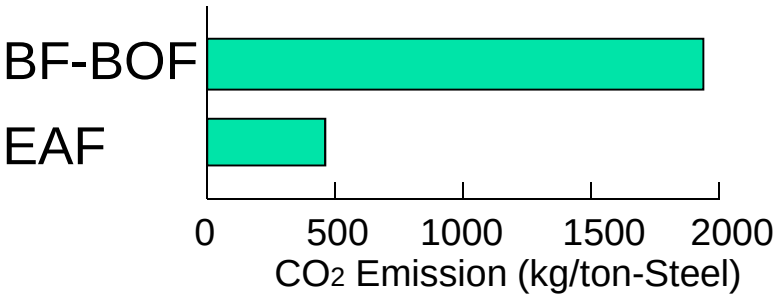
# Potential for CO2 emissions reduction by using DRI/HBI

(1) **In EAF Steelmaking Process**

(2) **In BF/BOF Steelmaking Process**

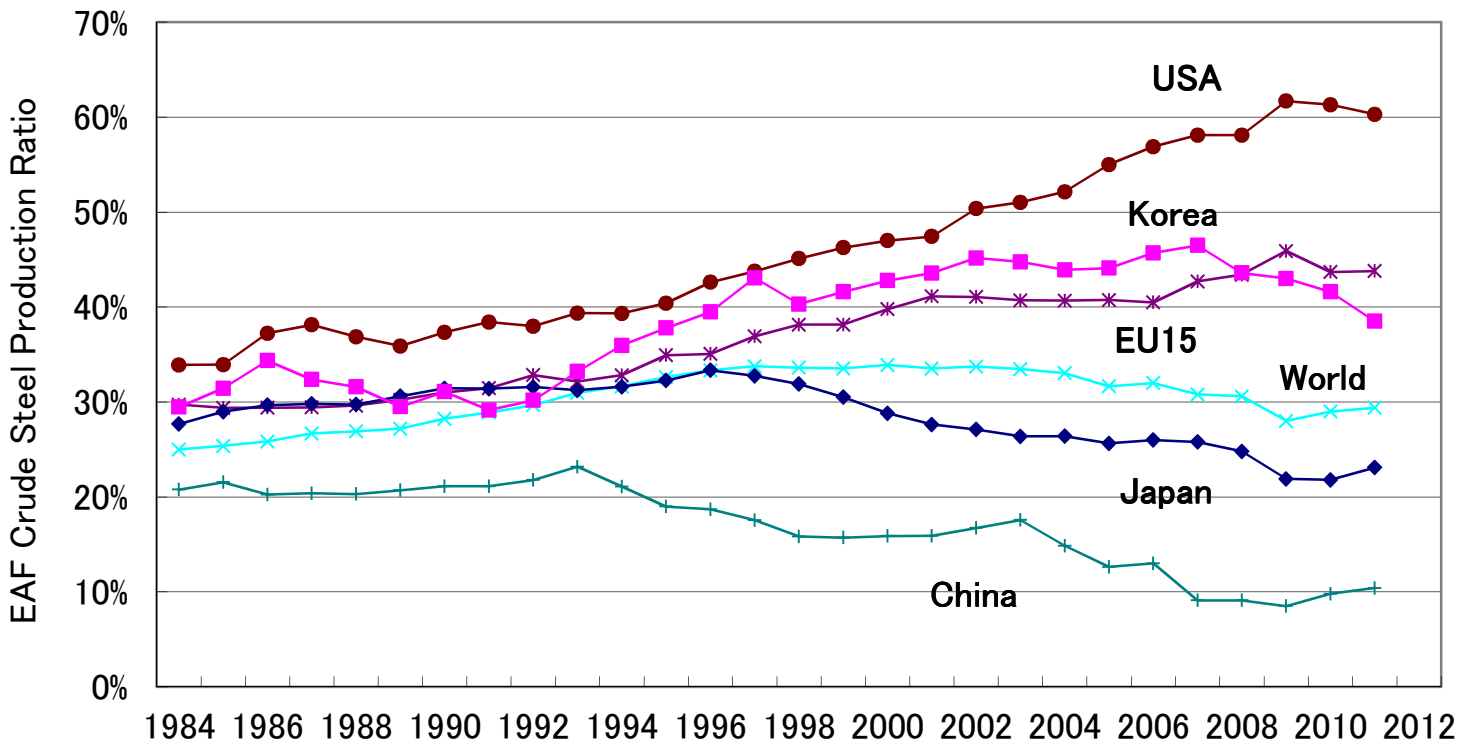
# Difference between BF-BOF steelmaking process and EAF steelmaking process



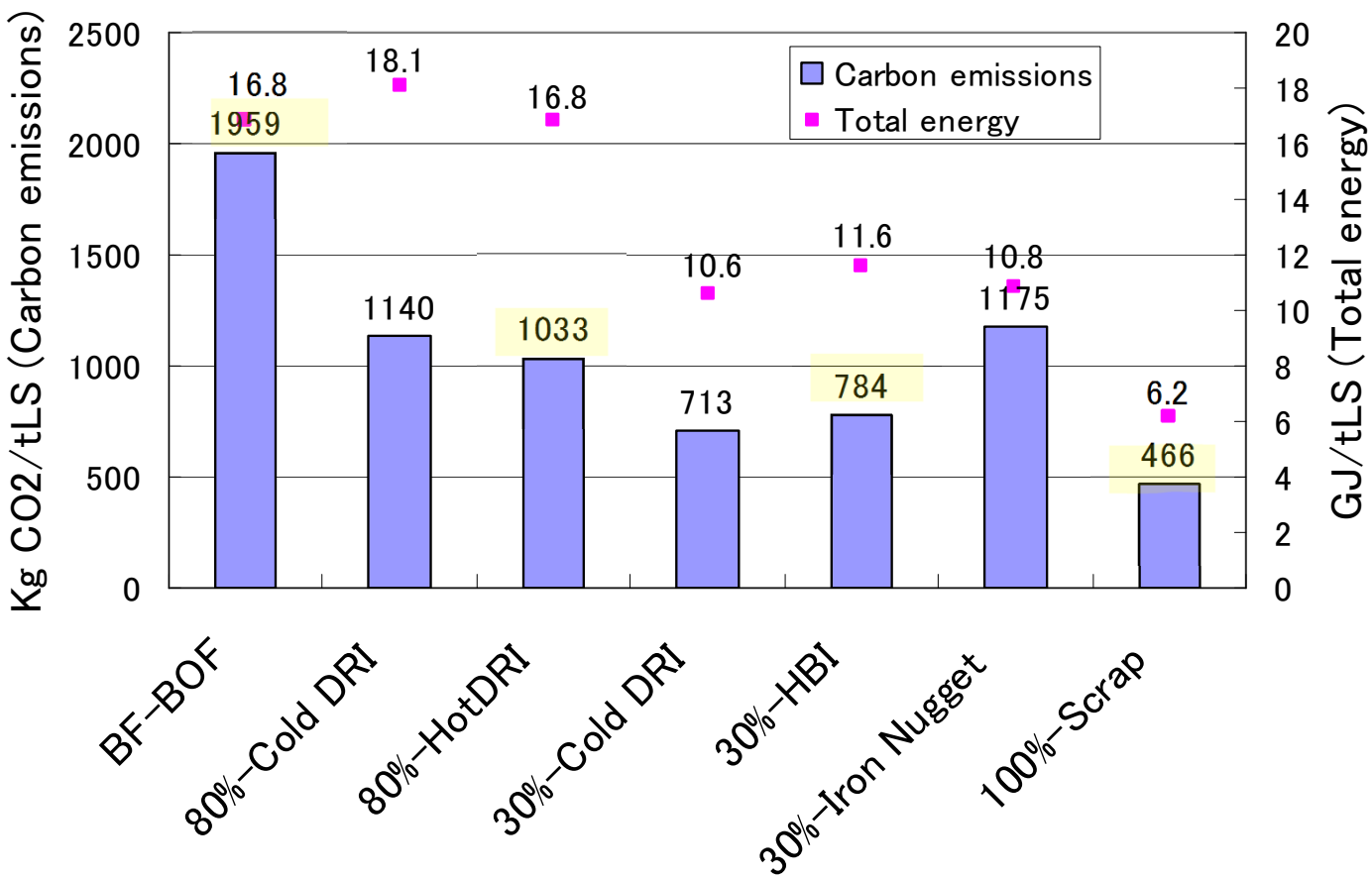

- **CO2 Emission for EAF is approximately 25% of that for blast furnace.**
- **The steel scrap normally contains impurities such as Cu, Sn, Pb, etc. which often limit its usage to satisfy the product quality**

# EAF Crude Steel Production Ratio




・EAF steelmaking is rising due to more scrap in advanced countries.

# Energy Requirements and Carbon Emissions for Steelmaking Routes




- Steelmaking by feeding either the DRI or the HBI to the EAF together with the scrap can significantly decrease the CO2 emissions while satisfying the steel quality by diluting the impurities containing in the scrap.

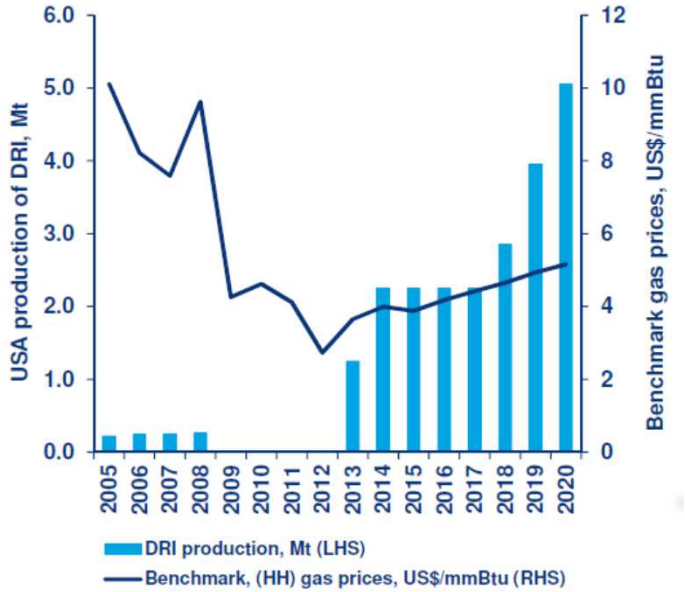
Reference : MILLENNIUM STEEL 2007

# Potential for CO2 emissions reduction by using DRI/HBI

(1) **EAF Steelmaking Process**

(2) **BF/BOF Steelmaking Process**

# US DRI Projects Status

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- Falling gas prices a boon to DRI production in the U.S.A.
- There are two movements

(1) BF substitute

(2) HBI utilization in BF

| Company | Location | Capacity(kt) | Status | Start-up |
|---|---|---|---|---|
| Nucor | Lousiana | 2,500 | Confirmed | 2013 |
| Nucor | Lousiana | 2,500 | Permitted- not approved | 2015+ |
| voestalpine | Texas | 2,000 | Confirmed- needs permitting | 2016 |
| Bluescope | Ohio | 1,000 | Under consideration | 2016+ |
| Essar Steel | Minnesota | 2,500 | Permitted - not approved | 2016+ |
| Severstal NA | Mississippi & Trinidad | n/a | 1.5m tpy project rejected | |
| US Steel | Minnesota | n/a | Under consideration | 2016+ |

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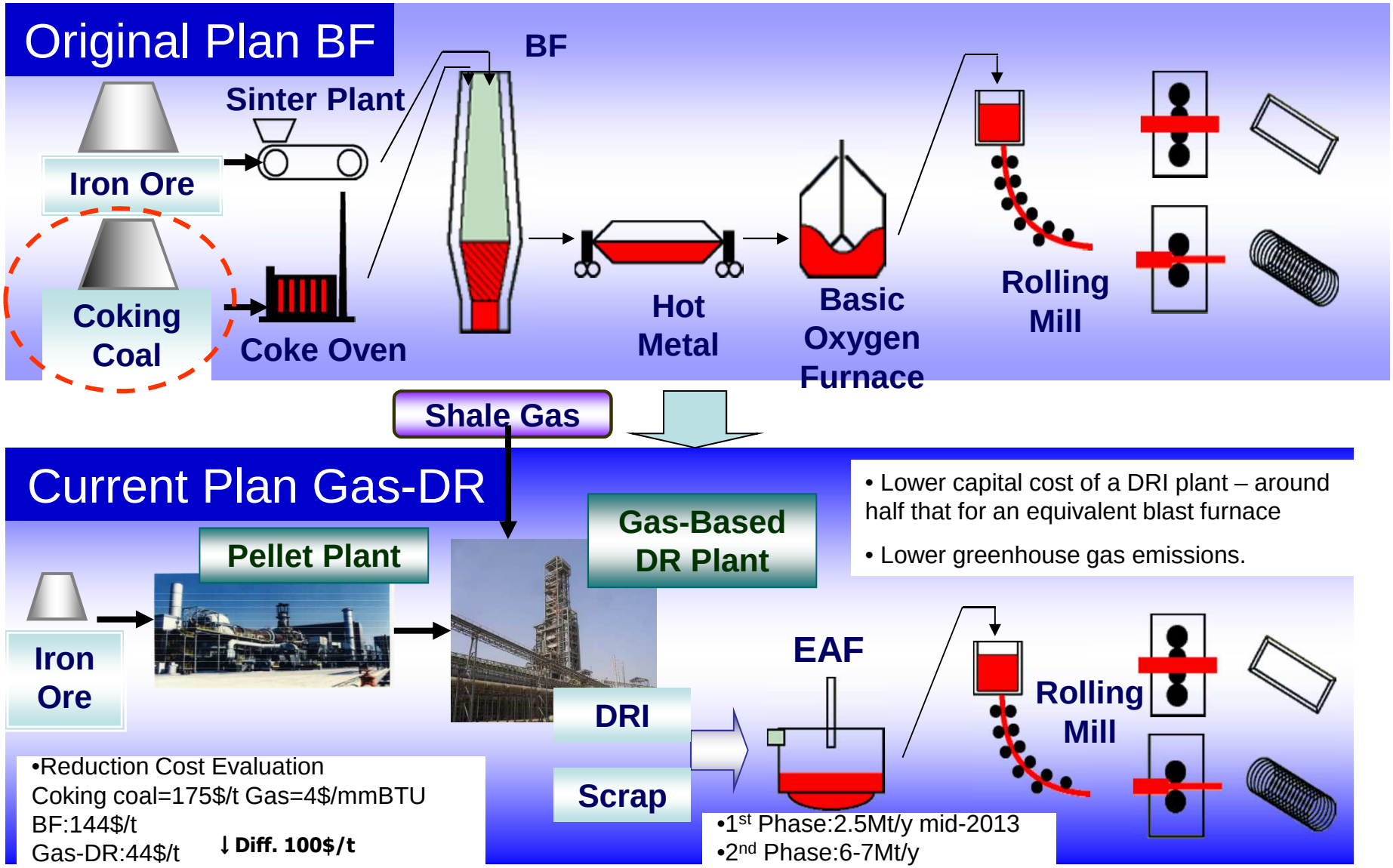
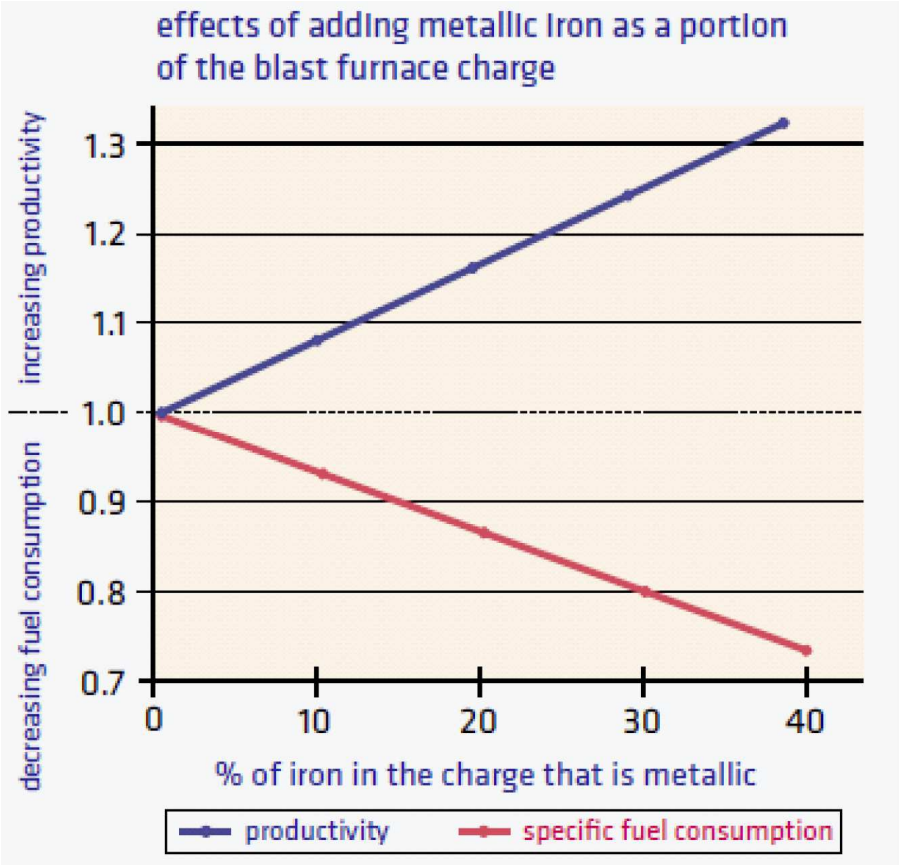
# Nucor Louisiana Project in the U.S.A. (2.5Mt/y)




- With the cheap shale gas, construction of the large-sized gas DR plant was started in the U.S. instead of construction of the BF

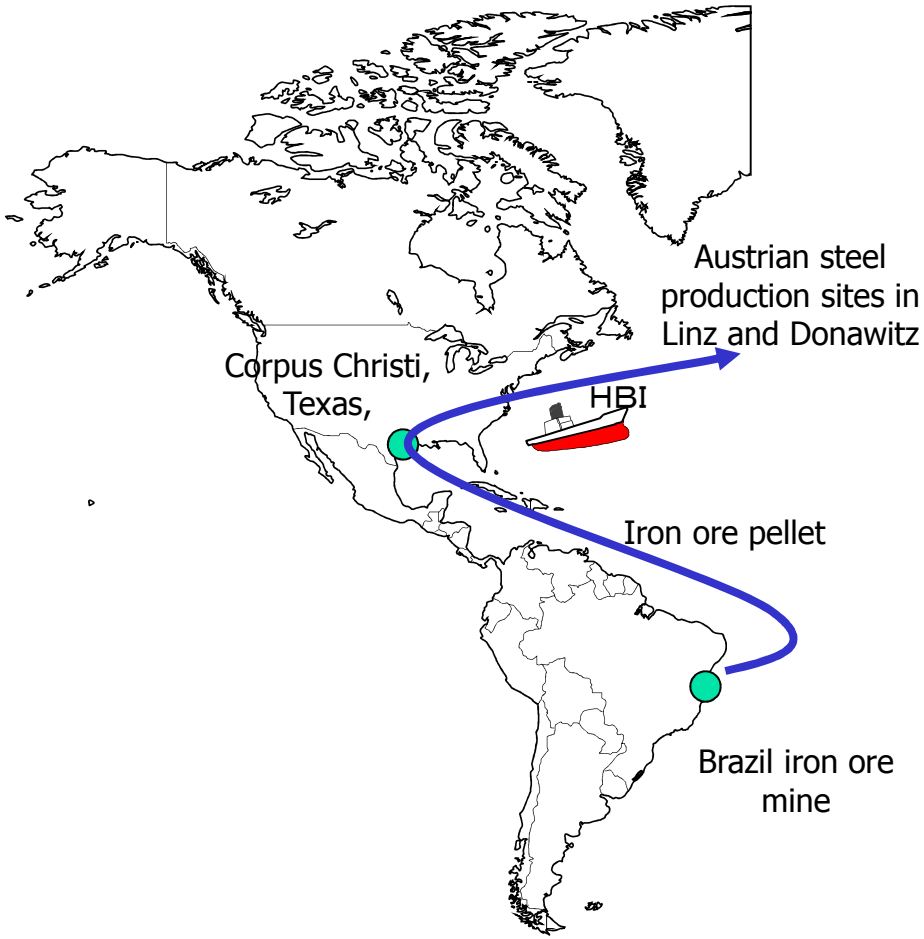
# HBI utilized in BF

- The use of HBI in Blast Furnaces is not new
- AK Steel began using HBI in their Middletown blast furnace in 1989
- Blast furnaces in Canada, Western Europe and Japan have also begun using HBI
- HBI is typically less than 30% of the charge
- HBI is often used when additional hot metal is required
- For each ten percent (10%) of the iron charged into the blast furnace as metallic iron:
  (1) Productivity is increased by 8%
  (2) Fuel rate is decreased by 7%
- HBI also lowers the CO2 emissions perton of hot metal produced

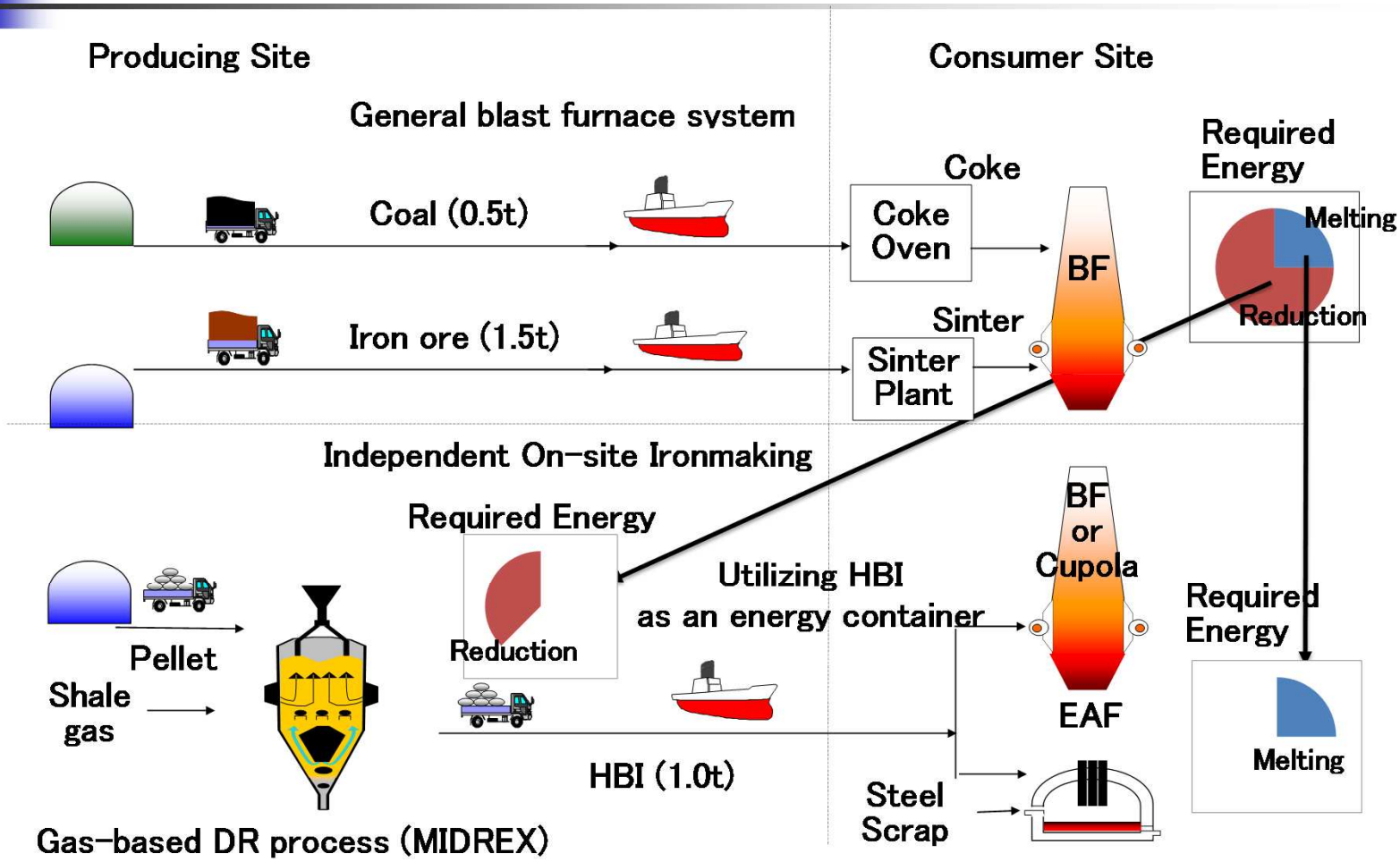


# Voestalpine constructing MIDREX direct reduction plant in Texas, USA

- The decision on the construction of the Voestalpine direct reduction plant in North America has been made.
- The plant will be constructed on just outside the city of Corpus Christi, Texas, USA.
- The planned facilities are designed for an annual capacity of around 2 million tons of HBI and DRI.
- The investment volume is around EUR 550 million.
- The plant is due to begin operations in early 2016.
- This will provide the Austrian steel production sites in Linz and Donawitz with access to cost-efficient and environmentally-friendly HBI and DRI pre-materials, ensuring their competitiveness over the long-term.



# Future ironmaking Model




- Overseas shift of the reduction energy and utilization of HBI as energy container can realize significant $CO_2$ reduction in the consumer site.
- Transportation weight and related $CO_2$ emission becomes half.

# Conclusions

1. MIDREX gas-based DR technologies is the process to produce iron units which are advantageous in terms of the CO2 emissions. Because this process can use natural gas as a reductant and a fuel source.
2. Considering the increase of the scrap supply to the steel market, feed of the scrap in the EAF with the DRI/HBI is expected to be effective and practical solutions in terms of the CO2 emissions.
3. With the cheap shale gas, construction of the large-sized gas DR plant was started in the U.S. instead of construction of the BF
4. Future ironmakingh model will be to produce the direct reduced iron near the energy competitive sites and transfer these products as an energy container to consumer sites.

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