Innovative uses of Hydrogen in Steelmaking

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H2@SCALE WORKSHOP
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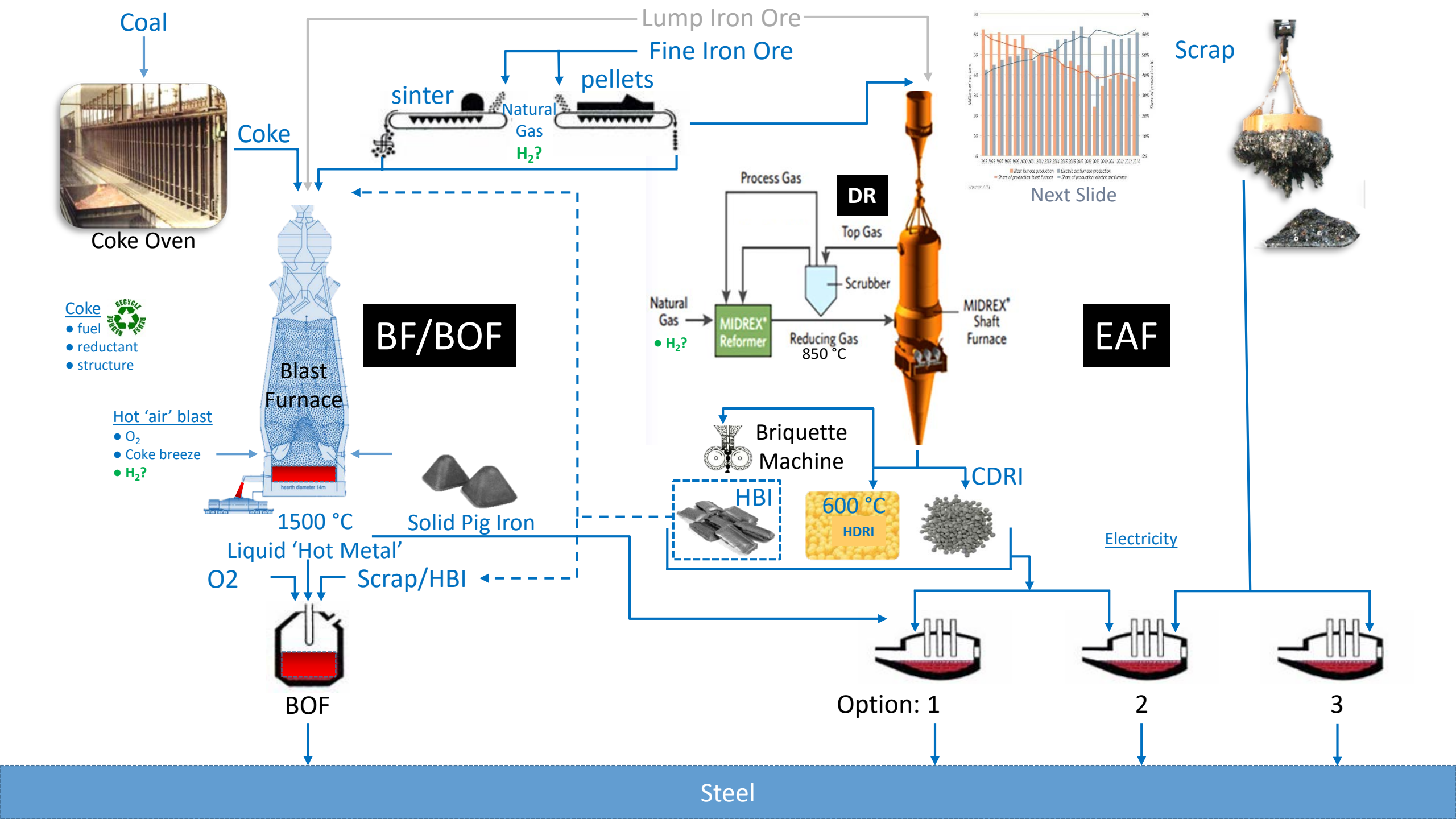
Outline

I. The 2 Routes to Steelmaking
   I. Blast Furnace -> Basic Oxygen Furnace (BF/BOF)
   II. Electric Arc Furnace (EAF)
      I. Scrap
      II. Scrap Supplements
         I. Pig Iron, Direct Reduced Iron (DRI)

II. RD&D Needs for H_2 Steelmaking
   I. Emerging Routes
   II. Existing Routes: BF or EAF


Coal
Lump Iron Ore
Fine Iron Ore
pellets
sinter
Natural Gas
H_2?
Coke
Coke Oven
Scrap
Next Slide
Process Gas
DR
Top Gas
Scrubber
Natural Gas
H_2?
MIDREX® Reformer
Reducing Gas 850 °C
MIDREX® Shaft Furnace
Coke
• fuel
• reductant
• structure
BF/BOF
EAF
Blast Furnace
Hot 'air' blast
• O_2
• Coke breeze
• H_2?
Briquette Machine
HBI
600 °C HDRI
CDRI
1500 °C
Solid Pig Iron
Liquid 'Hot Metal'
O2
Scrap/HBI
Electricity
BOF
Option: 1
2
3
Steel

DRI, HBI, & Pig

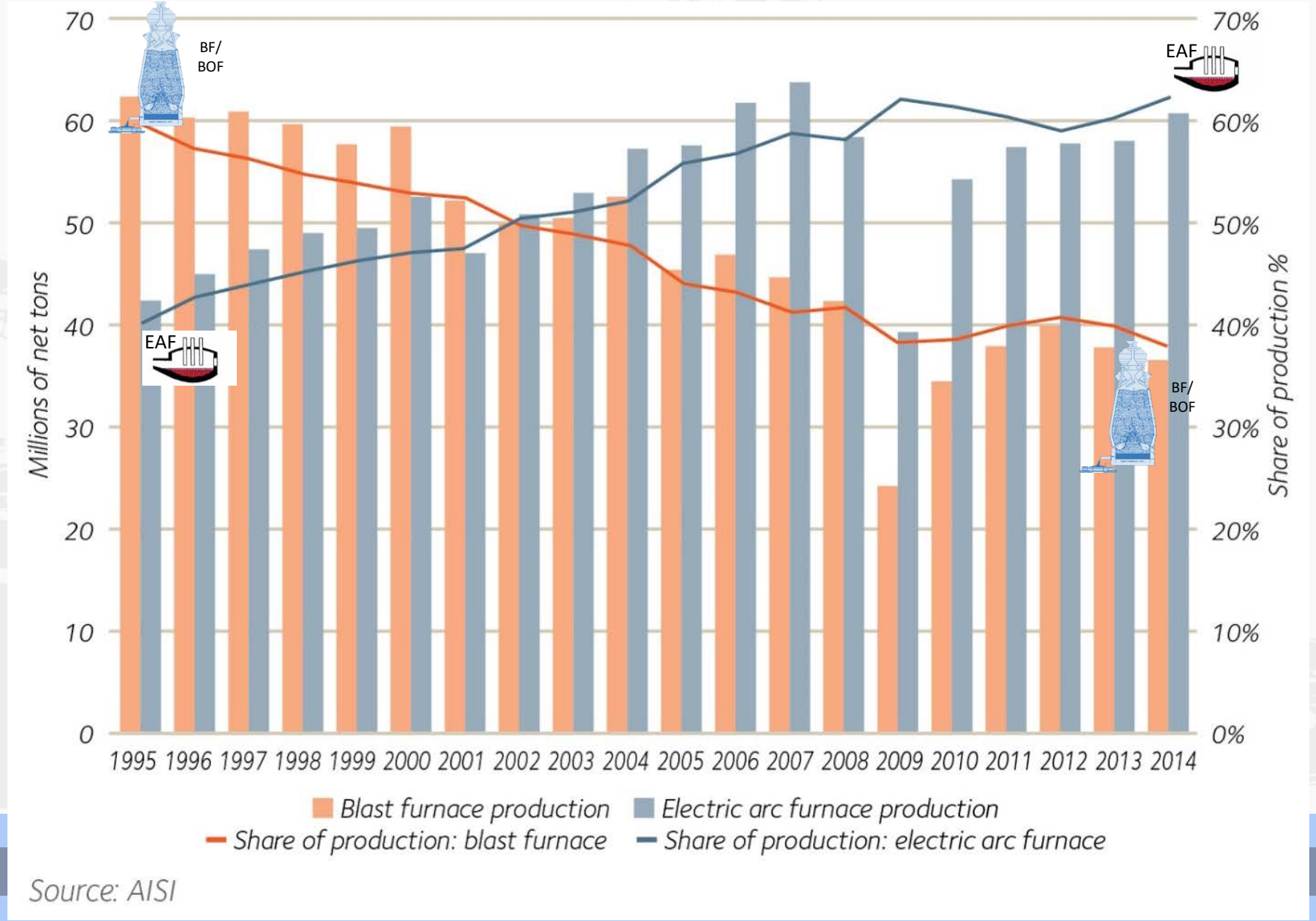
Direct Reduced Iron: DRI is typically produced in pellet form and can be loaded directly into an EAF, Blast Furnace, or Basic Oxygen Furnace. It contains a very high iron content (typically >90%). DRI exits the DRI module at a high temperature, and can be fed directly into furnaces as a means to reduce energy costs.

Hot Briquetted Iron: HBI is a compressed form of DRI that facilitates easier transportation and handling. HBI is formed as DRI exits the module, and it compressed while still hot. DRI reacts more easily with water and requires tighter standards for shipment; HBI is less reactive and ships easier.

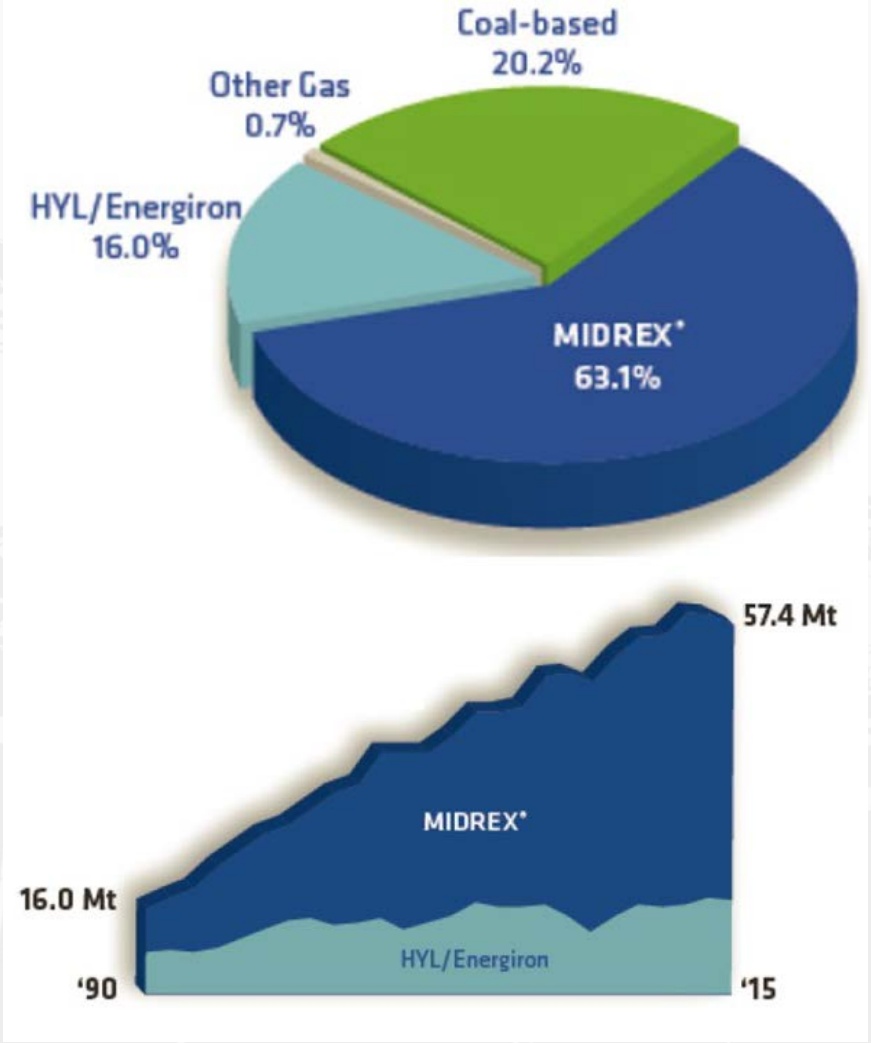
Merchant Pig Iron: MPI is produced in a blast furnace and cast into small "pigs" suitable for transportation. MPI has a higher iron content (around 96%) and less slag elements than DRI or HBI, and will typically sell at a premium. That said, MPI, HBI, and DRI are all substitutes for one another.

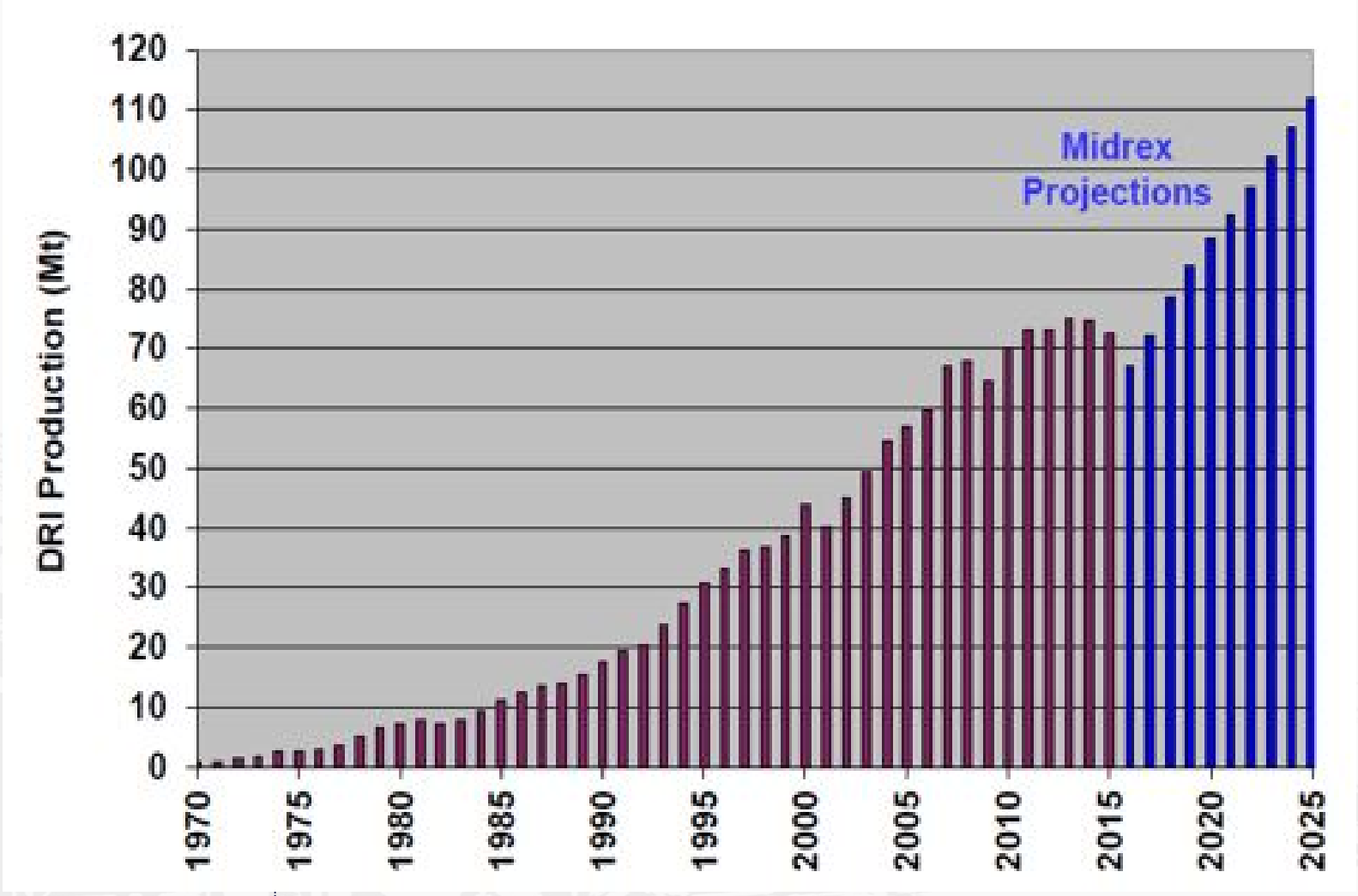
Source: Midrex

U.S. Shifting from BF/BOF to EAF/DRI Steelmaking

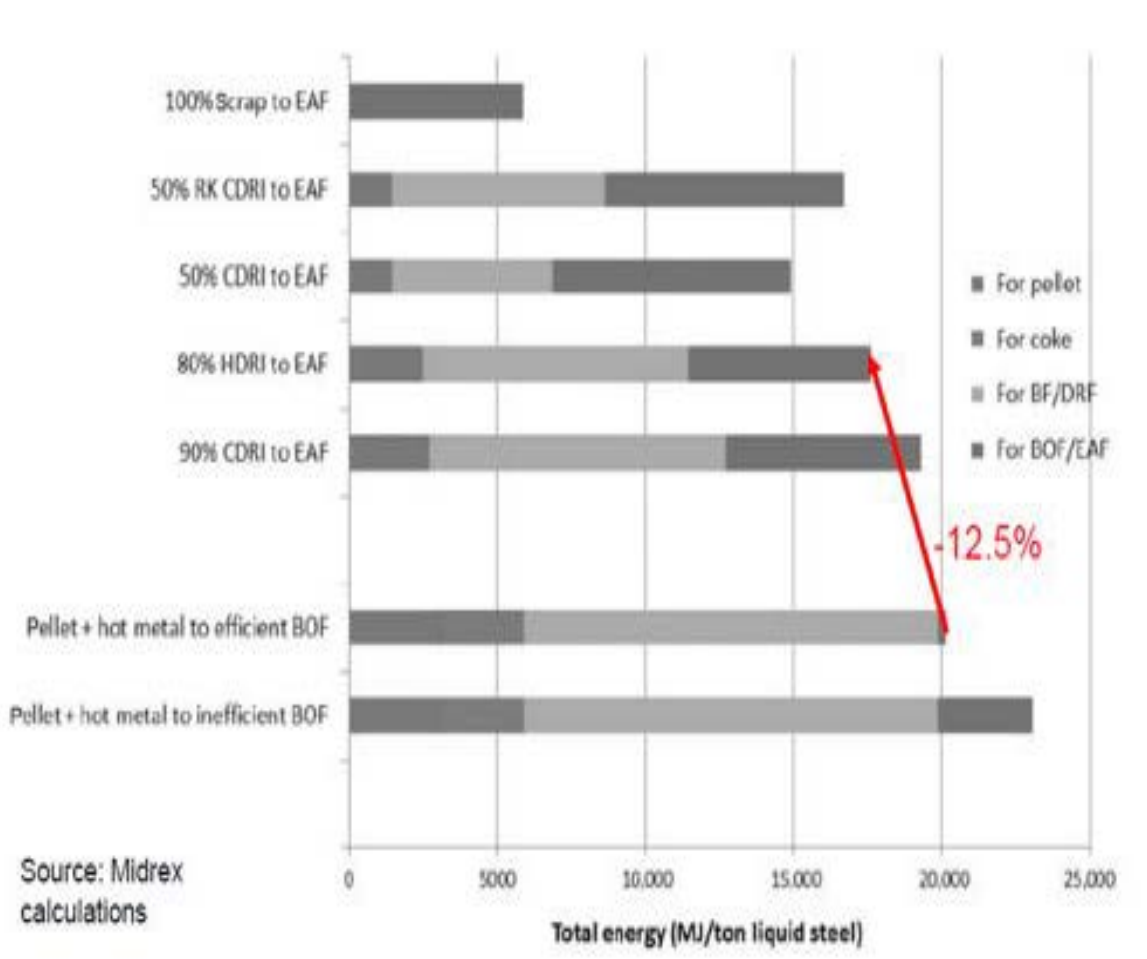


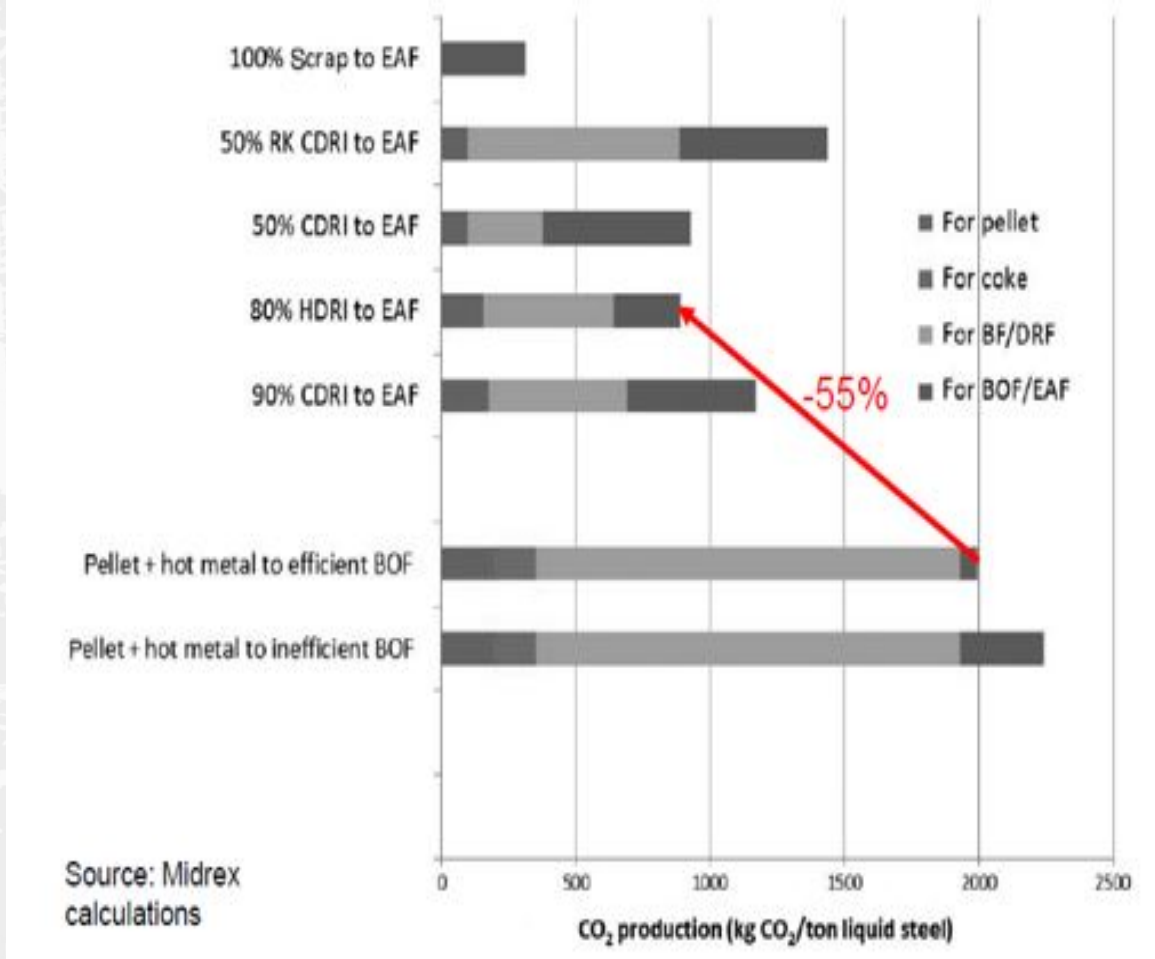
DRI: Current & Projected Production





Energy Efficiency & Emissions
EAF/DRI vs. BF/BOF





voestalpine's MIDREX NG® DR plant: Corpus Christie, TX

RD&D Needs for H_2 Steelmaking
Emerging Routes / Low CO2 Steelmaking

- Hybrit (LKAB and SSAB)
- va PEM
- FIT (Sohn) - AISI
- ULCOS - Ultra-Low CO2 Steelmaking – 45 Europe, 48 groups/15 countries; aim: 50%↓ CO2.
  - HIsarna (Coal, sub bio or H2)
  - ULCORED (DR w/Pox)
  - ULCOWIN (electrolysis of Fe_xO_y)
- MEFOS
- Steelanol (PRI, AM)
  - recycle CO2 into bioethanol
- Carbon2chem
- CDA
- Salzgitter
- China Steel
- Baowu
- Course50
- POSCO (nr 2009)
- CIRCORED (historical, not emerging)

RD&D Needs for H_2 in Steelmaking
Existing Routes: BF or EAF

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EAF

- H_2 for iron ore pelletizing?
  - S, Q, E, R, CAPEX/OPEX, equipment
- H_2 replace/supplement R-$NG_{(CO+H2)}$
  - DRI/HBI product Quality
    - Physical: H_2 embrittlement, CCS, tumble, fines, sticking/cluster
    - Metallurgical: reducibility, metallization, carbon
  - Mass & Energy Balance
    - Flowsheet
    - Energy Efficiency
    - Production Rate
  - CAPEX/OPEX
  - Equipment (embrittlement)

BF/BOF

- H_2 for iron ore pelletizing?
  - Any Δ S, Q, E, R in BF/BOF vs. EAF?
- Supplement coke by H_2
  - Fuel, reductant, ~~structure~~
  - Steel Quality
- Mass & Energy Balance
  - Flowsheet
  - Energy Efficiency
  - Production Rate
- CAPEX/OPEX
- Equipment (embrittlement)

S = Safety, Q = Quality, E = Efficiency, R = Rate (throughput)

Thank You