Hot Briquetted Iron - beyond the electric arc furnace

SEASI CONFERENCE & EXHIBITION - JUNE 2018

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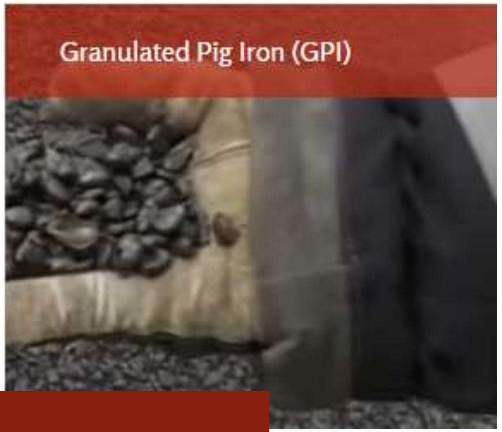
Presentation overview

- IIMA's credentials
- Background to HBI
- HBI as blast furnace feedstock
- HBI in the basic oxygen furnace
- Sources of HBI

What is IIMA?

Created in 2011 as the unified voice of the Ore-Based Metallics industry



Communication

Getting the right messages to our stakeholders

Product & Market Support

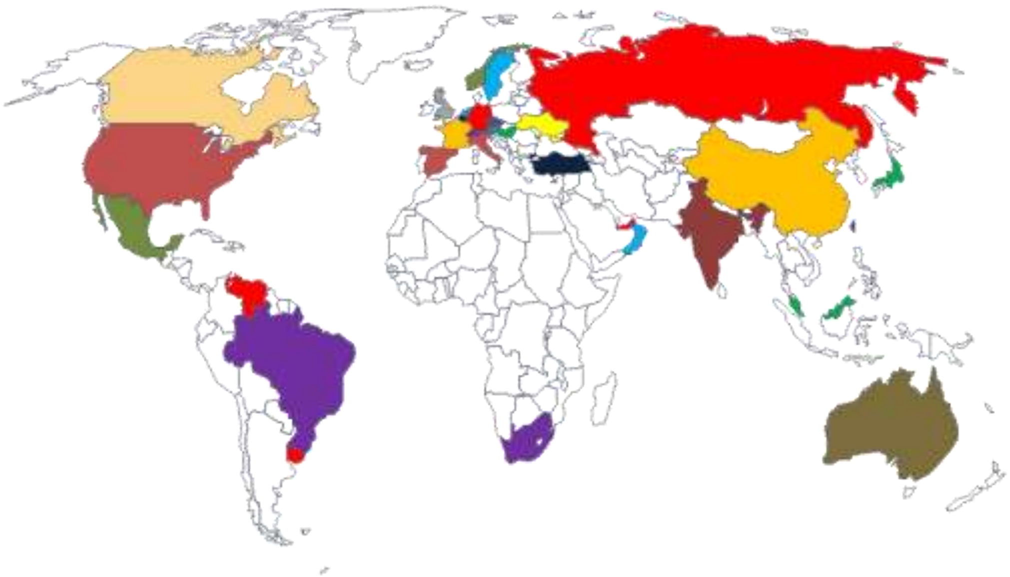
Product information & guides
Value-in-use model
Educational workshops & webinars

Regulatory Support

Chemical industry regulation (e.g. REACH)
Maritime regulation
Product stewardship

IIMA's membership

- iron ore producers
- pig iron, HBI and DRI producers
- traders and distributors
- OBM consumers
- technology suppliers
- plant and equipment suppliers
- shipping and logistics providers
- sampling and inspection providers
- project developers



... spanning the global supply chain ...

Beyond the electric arc furnace….

- **HBI has for long been perceived, primarily and correctly, as a metallic feedstock material for the EAF.**
- **However, HBI offers potential for use as a blast furnace burden material *under certain conditions*, a potential that has been evaluated and exploited by various steel mills around the world.**
- **HBI has also found application as a trim coolant in the basic oxygen furnace**

Background to Hot Briquetted Iron

- **HBI was developed as a product in order to enable Direct Reduced Iron to be handled, transported and stored safely.**
- **The high reactivity of DRI, i.e. the tendency to re-oxidise exothermically back to iron oxide, gave rise to**
  - the risk of self-heating in the presence of oxygen (air) - if not controlled, the temperature of the material could increase to the point of ignition
  - the risk of evolution of hydrogen through the aqueous corrosion of iron
- **By compacting the DRI through briquetting at elevated temperature (> 650°C) after it exits the furnace, its porosity (and thus its reactivity) is reduced such that the self-heating and gas evolution hazards are reduced to a level where the resultant HBI can be transported and handled safely with much less stringent precautions.**

HBI production process

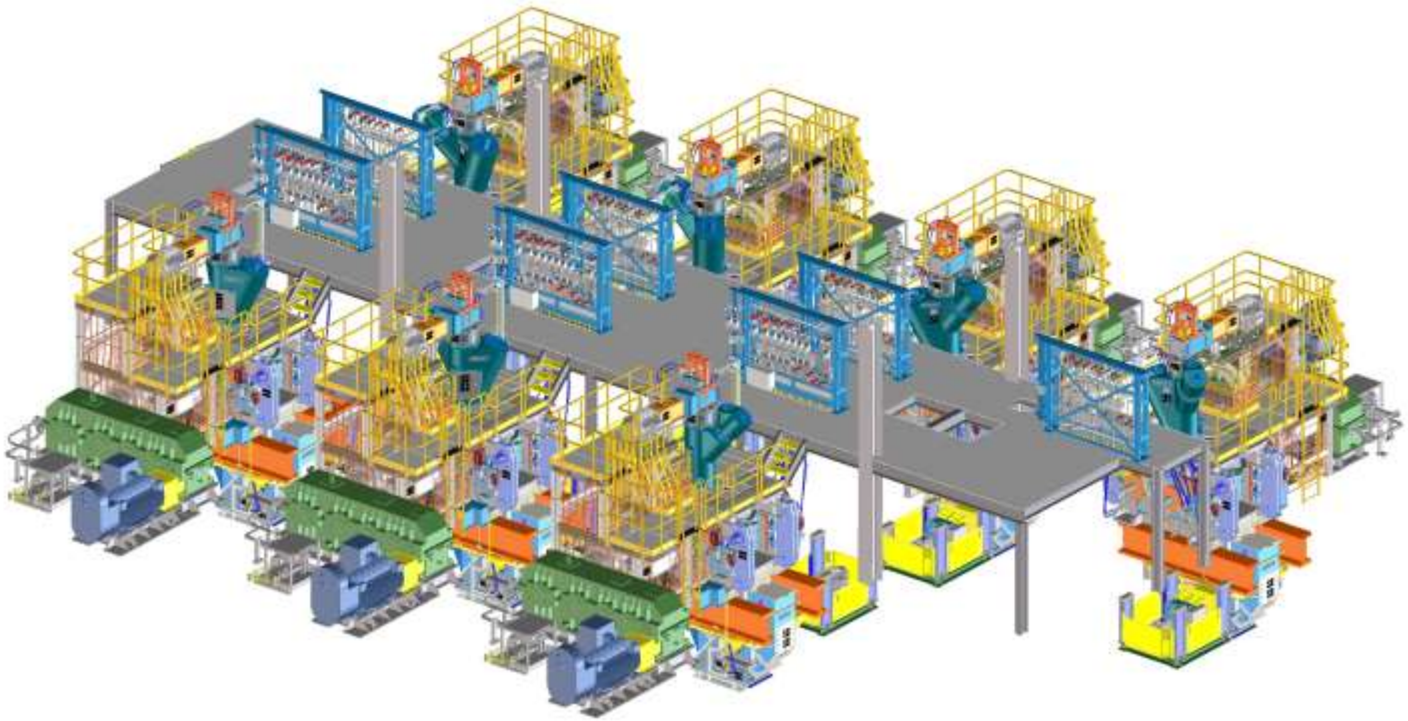


Image and video courtesy of Maschinenfabrik Köppern

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General Specifications for HBI (Ranges % by Weight)

(based on 65.5 — 68.0% Fe Iron Ore)

Metallization	94.0%
Fe (Total)	88.3 - 94.0%
Fe (Metallic)	83.0 - 88.4%
C	0.5 - 1.6
S	0.001 - 0.03%
P_2O_5	0.005 - 0.09%
Gangue*	3.9 - 8.6%
Mn, Cu, Ni, Cr, Mo, Sn, Pb, Zn	Traces
Size (typical)	(90 - 140) x (48 - 58) x (32 - 34) mm
Fines & chips	≤ 5.0%
Apparent Density	> 5.0 t/m^3
Bulk Density	2.5 - 3.3 t/m^3

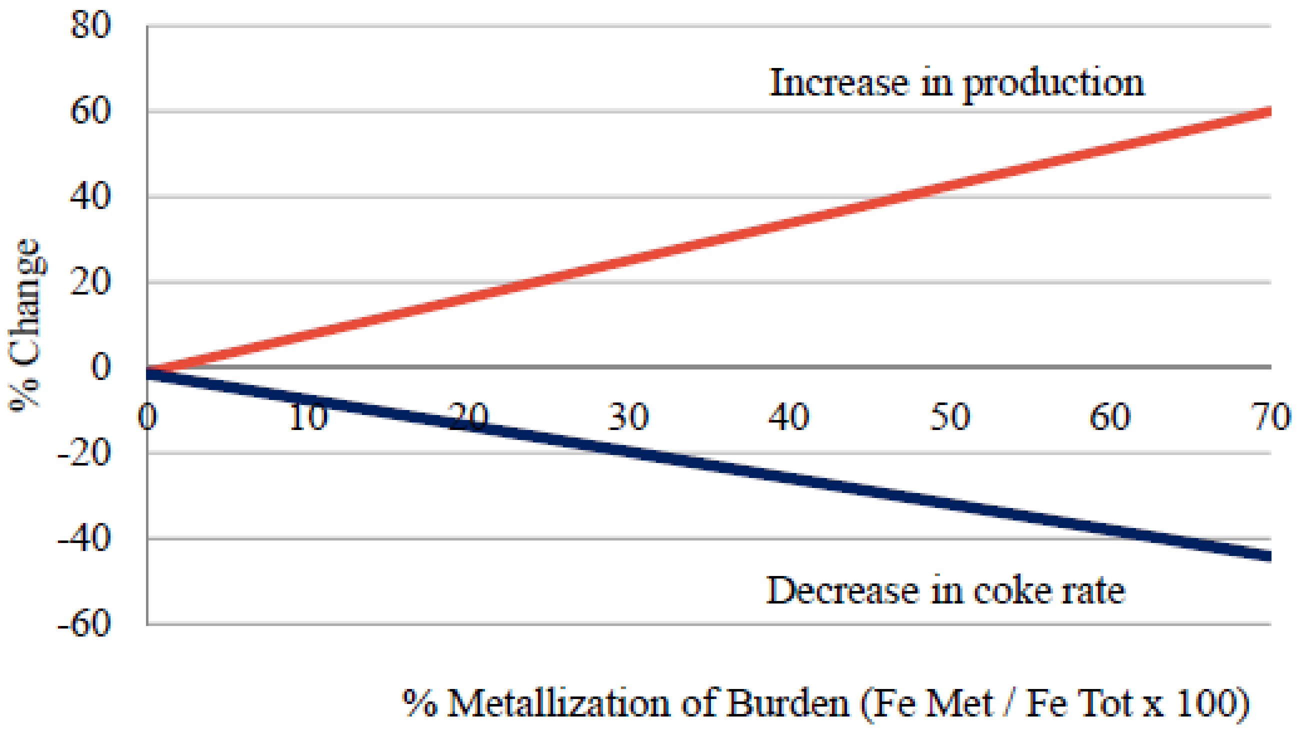
* residual unreduced oxides, mainly SiO_2 and Al_2O_3,, but also CaO, MgO, MnO, etc.

Why are benefits of using HBI in the BF?

- Use of HBI allows greater flexibility in BF production rates, allowing output to be increased during periods of increased hot metal demand or when the BF is the bottle neck in the steel production chain.
- Reduction of coke rates may ease/eliminate the pressure to purchase external coke.
- HBI is easier to use than scrap in the BF material handling system.
- Reduction of coke rate results in reduced CO_2 emissions.

Rules of thumb

- **increased blast furnace productivity (increase of about 8% for each 10% increase in burden metallisation)**
- **reduced coke rate (decrease of about 7% for each 10% increase in burden metallisation)**



Ostrowski (1999) in the ISS book "Direct Reduced Iron Technology and Economics of Production and Use"

When does it make sense to use HBI?

- **Longer term - permanent solution:**
  - **the bottleneck scenario - where BF hot metal capacity is insufficient to meet demands of downstream steelmaking operations and all the usual productivity enhancement measures have been exhausted (oxygen / natural gas injection, increased blast temperature, etc.): hot metal capacity can be increased with HBI additions;**
  - **where there is an imbalance between the required tonnage of hot metal and BF capacity, e.g. the plant operates three BF’s when the hot metal output of somewhere between two and three BF’s would be sufficient: it may be economical to operate two BF’s at slightly higher hot metal cost in order to optimize profitable production of downstream facilities;**
  - **where coke production capacity is limited, capital expenditure on coke ovens is not viable and/or purchased coke is too expensive: use of some HBI will reduce specific coke consumption.**

When does it make sense to use HBI?

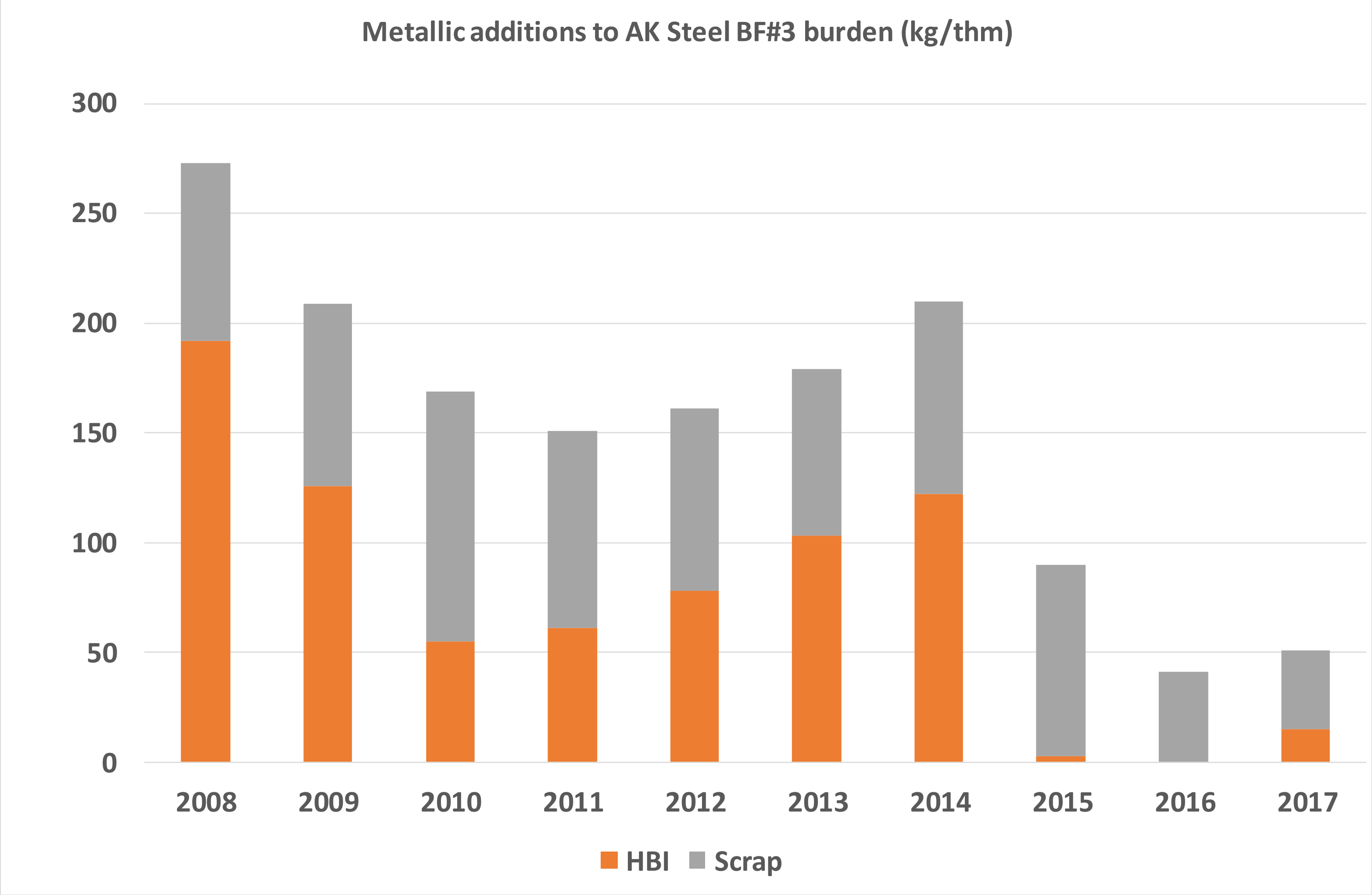
Short term - temporary solution:

- **where one of several BFs is out of operation, e.g. for reline, maximum hot metal production is required from the remaining BF's to satisfy downstream steel plant requirements: BF productivity can be increased through HBI addition;**
- **where the mix of raw material prices is such that there is an economic case for including some HBI in the BF burden, e.g. through reduction in coke rates if the cost of purchased coke increases to the point where the higher cost of HBI can be more than offset, or where there is a shortage of other raw materials, e.g. iron ore.**

Example of the longer term solution

- In the mid-1980s, AK Steel's Middletown, OH BOF shop relied on hot metal from the on-site #3 BF and from the Hamilton BFs 30 km away.   AK had to decide on a BF modernisation programme and decided to close the Hamilton BF's and to modernise and boost production at the Middletown BF and also to supplement slab supply from its Ashland works and with imports.
- The strategy of maximising BF production at Middletown included maximising injection of natural gas and oxygen enrichment and by charging up to 250 kg HBI and/or prepared scrap per tonne hot metal.
- This practice ceased a few years ago, due in part to the non-availability of the preferred HBI supply from Venezuela.

AK Steel data



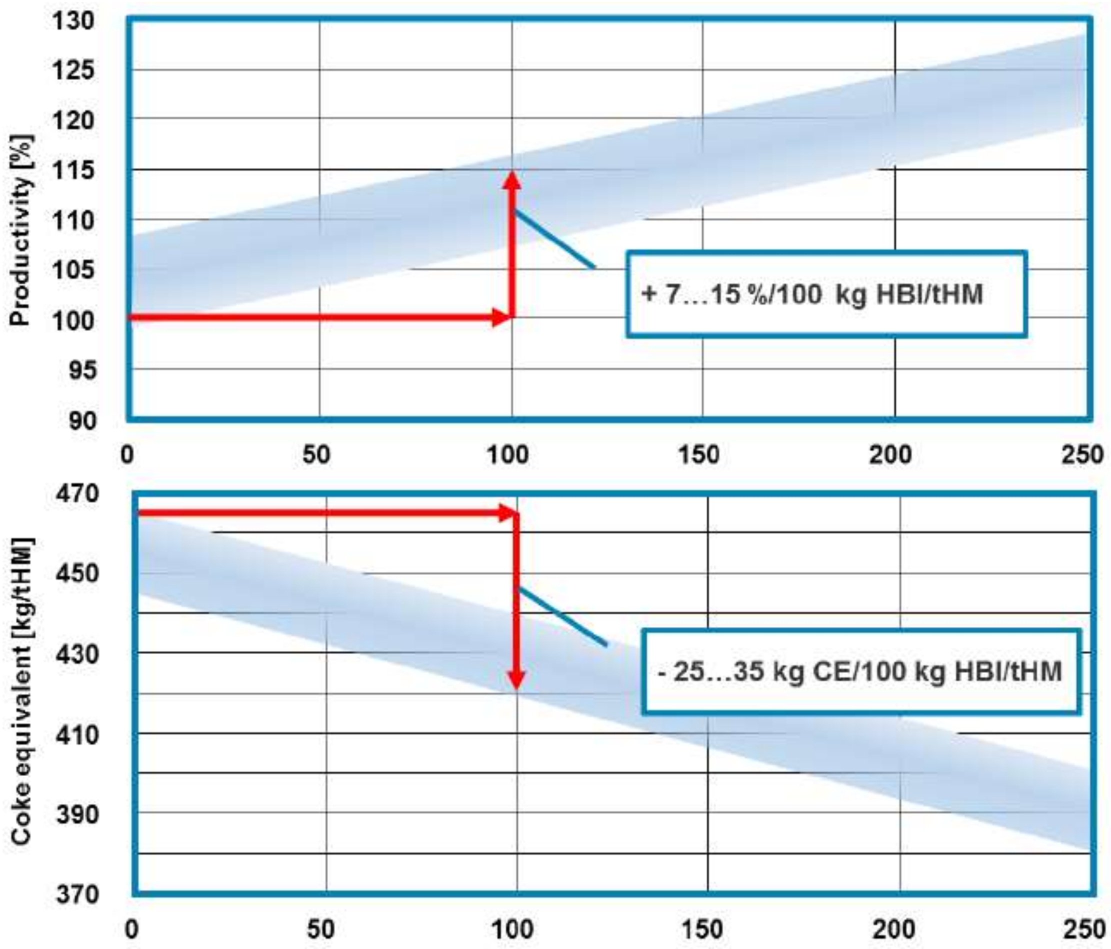
Data source: AIST Process Benchmarker

Example of the shorter term solution

- voestalpine commissioned its 2 mt HBI plant at Corpus Christi, TX in October 2016 with the eventual intention to ship about 40% of production to its BF plants at Linz and Donawitz in Austria, with the rest being sold to external customers.
- BF "A" at Linz is being relined in 2018 - during the period of the reline BF's 5 and 6 will include about 150 kg/t HM HBI in their burden at 3,000 t HM/d and reductant consumption of 415 kg/t HM (coke equivalent).

voestalpine data

Source: presentation at IIMA meeting, 2016



HBI kg/tonne hot metal

HBI stock in front of BF at Linz works

Evaluation of economic impact of HBI use in BF

Costs item	Cost $/tonne	
	2016	2018
Coke	**160**	**375**
Pellets	**80**	**120**
Flux	**15**	**15**
HBI	**220**	**275-345**

- Evaluation model is sensitive to many parameters.
- BF practice varies from furnace to furnace.
- Input material costs are often volatile.
- In the 2016 analysis (presented at an IIMA conference that year), the "incremental steel contribution" was partially offset by the higher net feedstock cost.
- In the 2018 analysis, with the high cost of pellets and coke relative to the HBI, at the lower end of the HBI price range there can be an economic benefit even without the increased steel production.

Use of HBI as coolant in the BOF

HBI provides an optimal BOF charge due to:

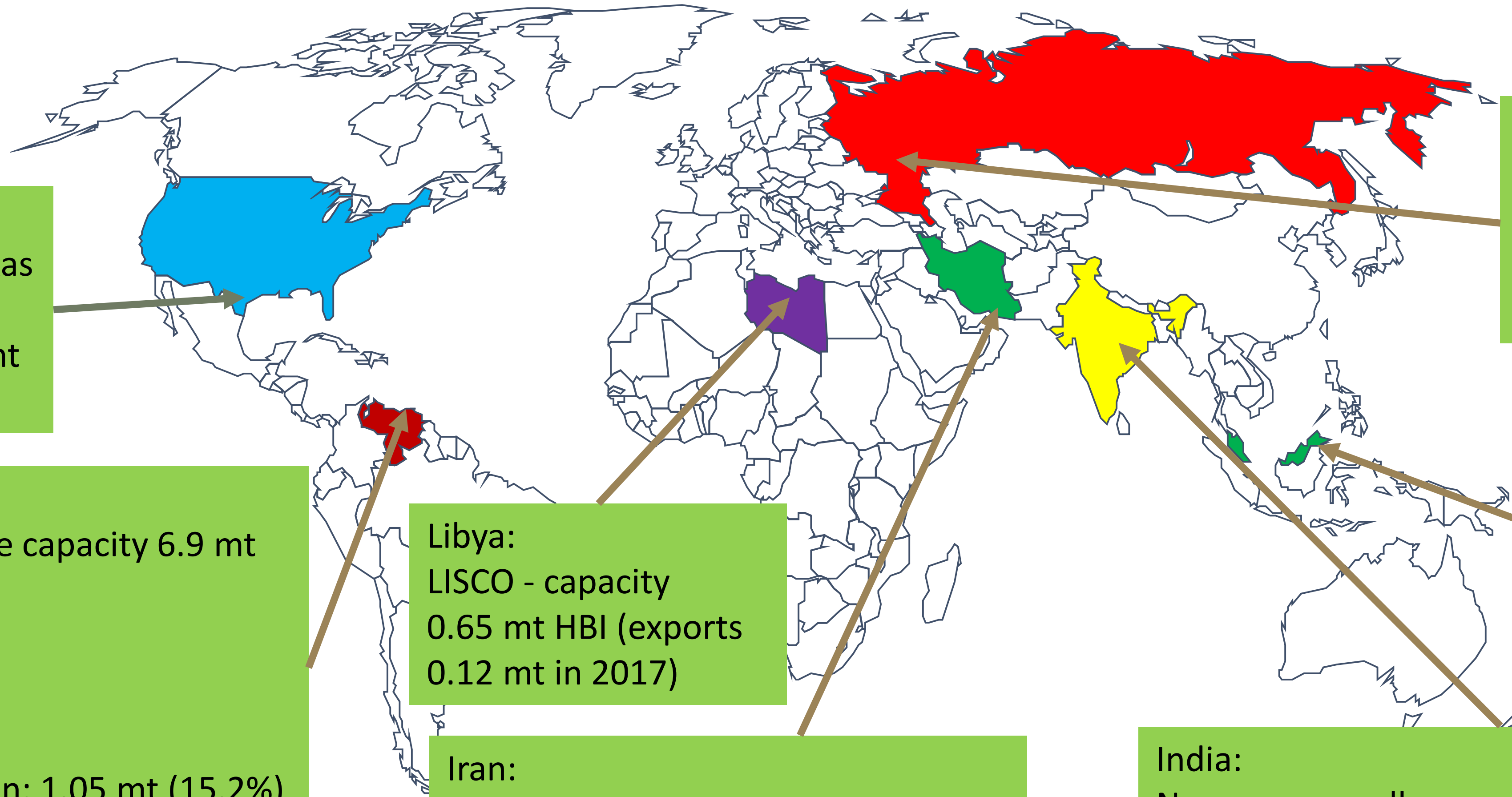
- well defined physical and chemical properties - low levels of residual elements
- bulk density of ~2.8 t/m^3 - higher than scrap
- higher yield and increased productivity than with conventional coolants - same metallic yield as hot metal
- more predictable mass and heat balances
- free-flowing and easily charged from overhead bins
- maintains steel bath composition
- rapid penetration of slag
- reduces slag volume when used instead of fluxes

Use of HBI as coolant in the BOF

The use of HBI as a part of the solid charge mix is recommended for the following situations:

- **when the proportion of hot metal and scrap used results in overheating at the end of the blowing process (using HBI as a coolant produces the desired temperature without a cooling process)**
- **when iron ore is used as cooling agent due to scarcity of scrap (which reduces productivity)**
- **when scrap availability is an issue**
- **when lower sulphur content of the charge material is required**
- **when lower residual content is required, e.g. for certain grades of steel**

Global merchant DRI/HBI supply



USA:
voestalpine Texas
2.0 mt HBI
(exports ±1.0 mt
in 2017)

Venezuela:
Total HBI nameplate capacity 6.9 mt
FMO 1.0 mt
Comsigua 1.3 mt
Briqven 1.5 mt
Bricar 0.9 mt
Bricor 2.2 mt
2017 HBI production: 1.05 mt (15.2%)
2017 DRI production 0.44 mt (9.2%)

Libya:
LISCO - capacity
0.65 mt HBI (exports
0.12 mt in 2017)

Iran:
Various steel mills exporting surplus DRI /HBI to regional markets (0.6 mt In 2017)

Russia:
Metalloinvest
Lebedinsky GOK
Capacity 4.5 mt HBI
(2017 exports 2.8 mt)

Malaysia:
Antara Steel Mills
(Labuan plant)
Capacity 0.7 mt HBI
2017 exports ±0.55 mt

India:
Numerous small sponge iron plants small volume exports to nearby markets (0.55 mt in 2017)

Mt = million tonnes

IIMA Fact Sheets

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The Use of Hot Briquetted Iron (HBI) in the Blast Furnace (BF) for Hot Metal Production

HBI can be used as blast furnace burden material with the following environmental, productivity and cost benefits:

- lower carbon dioxide emissions
- increased blast furnace productivity (increase of about 8% for each 10% increase in burden metallisation)
- reduced coke rate (decrease of about 7% for each 10% increase in burden metallisation)

Hot Briquetted Iron

Reasons for HBI Charging into the Blast Furnace

Various circumstances under which including HBI in the BF burden could have a positive economic effect:

- Output limit of a BF based on pellets and sinter has been reached and the downstream steel mill has excess capability. Increase of hot metal production can be achieved without additional investment.
- Coke production capacity is limited and capital expenditure on coke ovens is not viable. Therefore, the plant needs to reduce specific coke consumption.
- Purchased coke is used, but the price is sufficiently high to enable a reduced coke consumption to offset higher cost when adding HBI to the BF burden.
- Out of several BF's, one BF must be relined, so increased hot metal production is required from the remaining BF's to minimize downstream production losses.
- There is an imbalance between the required tonnage of hot metal and BF capacity: the plant operates three BF's when the hot metal output of somewhere between two and three BF's would be sufficient. Therefore, it can be economical to operate two BF's at slightly higher hot metal cost in order to optimize production of downstream facilities.

Under these circumstances, some increase in hot metal feedstock cost due to addition of HBI to the BF burden can be justified on the basis of increased steel production, higher BF productivity, reduced coke consumption, etc. HBI specifications for BF use can be less stringent than for EAF steelmaking since higher levels of silica, iron oxides and sulphur and lower metallization can be tolerated in the BF.

www.metalllics.org | IIMA Fact Sheet #4 (2017) | info@metallics.org

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The Use of Hot Briquetted Iron (HBI) in the Basic Oxygen Furnace (BOF) for Steelmaking

The use of HBI as a part of the solid charge mix is recommended for the following situations:

- When the proportion of hot metal and scrap used results in overheating at the end of the blowing process (using HBI as a coolant produces the desired temperature without a cooling process)
- When iron ore is used as cooling agent due to scarcity of scrap (which reduces productivity)
- When scrap availability is an issue
- When lower sulphur content of the charge material is required
- When lower residual content is required

The Benefits of HBI in the BOF

HBI provides an optimal BOF charge due to

- Low levels of residual elements
- Bulk density of ~2.8 t/m^3 - higher than scrap
- Same metallic yield as hot metal
- More predictable mass and heat balances

HBI is an excellent trim coolant due to the following characteristics

- Free-flowing from overhead bins
- Well defined physical and chemical properties
- Maintains steel bath composition
- Easily charged from overhead bins
- Rapid penetration of slag
- Reduces slag volume when used instead of fluxes
- Higher yield and increased productivity than with conventional coolants

www.metallics.org | IIMA Fact Sheet #3 (2017) | info@metallics.org

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HBI!

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