Electric Smelting Furnace-based Flowsheets for Sustainable Iron and Steel Production

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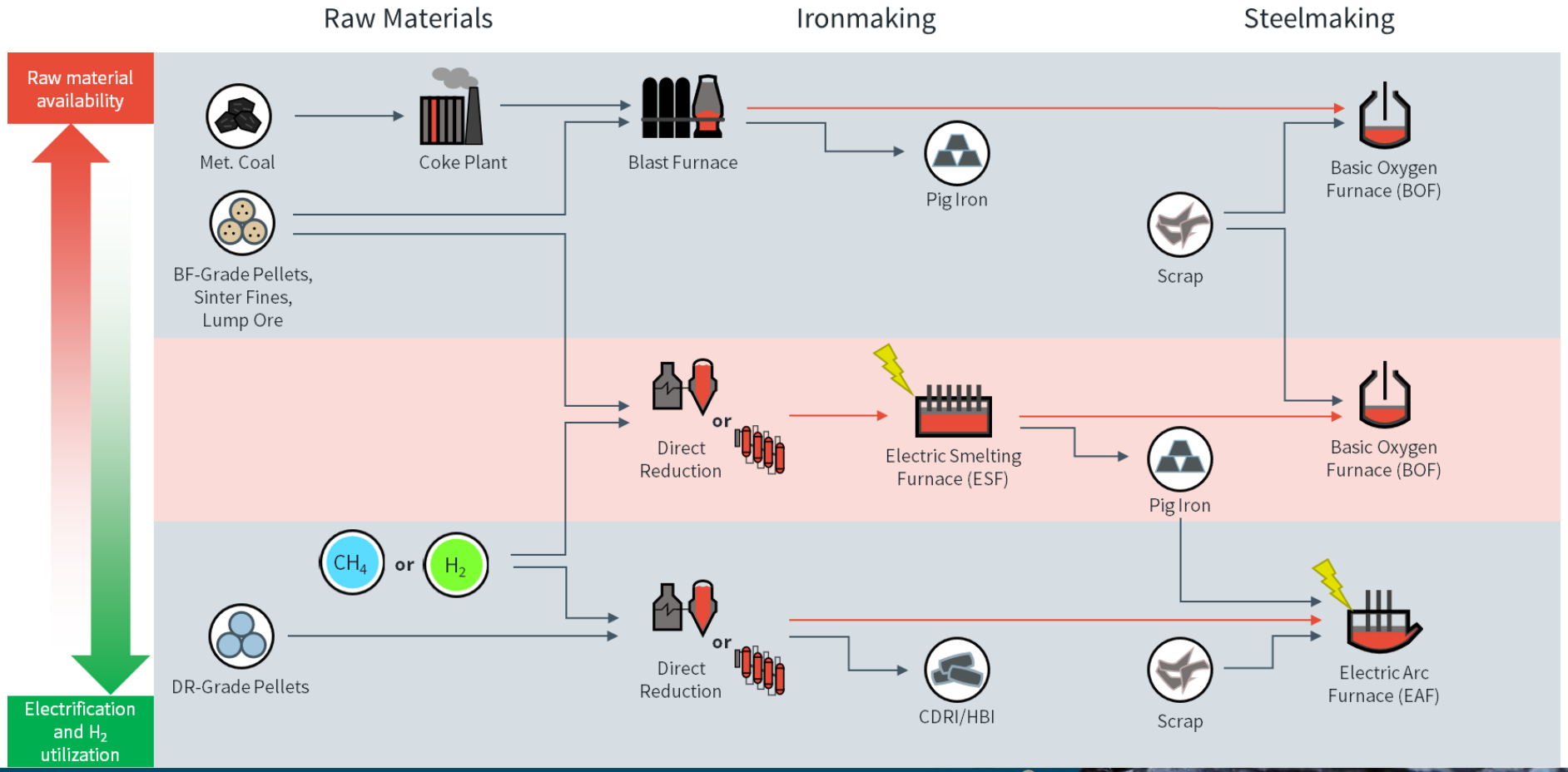
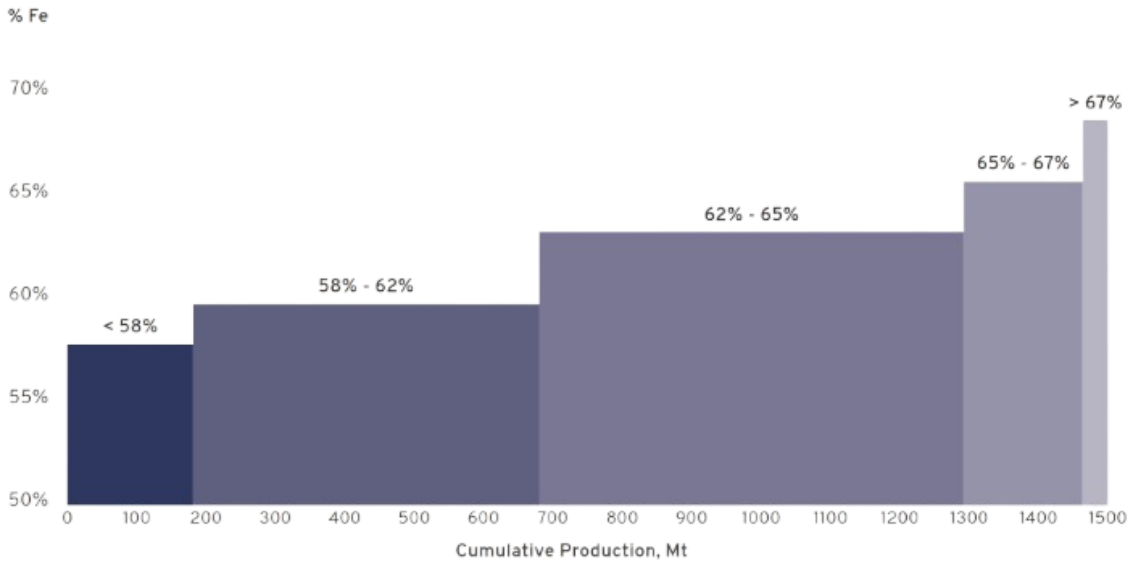
The Green Steel Trilemma: Emissions, Raw Material, and CAPEX

The ESF enable the efficient use of **abundant iron ore** resources in **low-emissions flowsheet**, while **limiting the CAPEX and disruption** of the transition



Iron Ore Supply and Gangue Rejection in Iron and Steel Making



Beneficiation

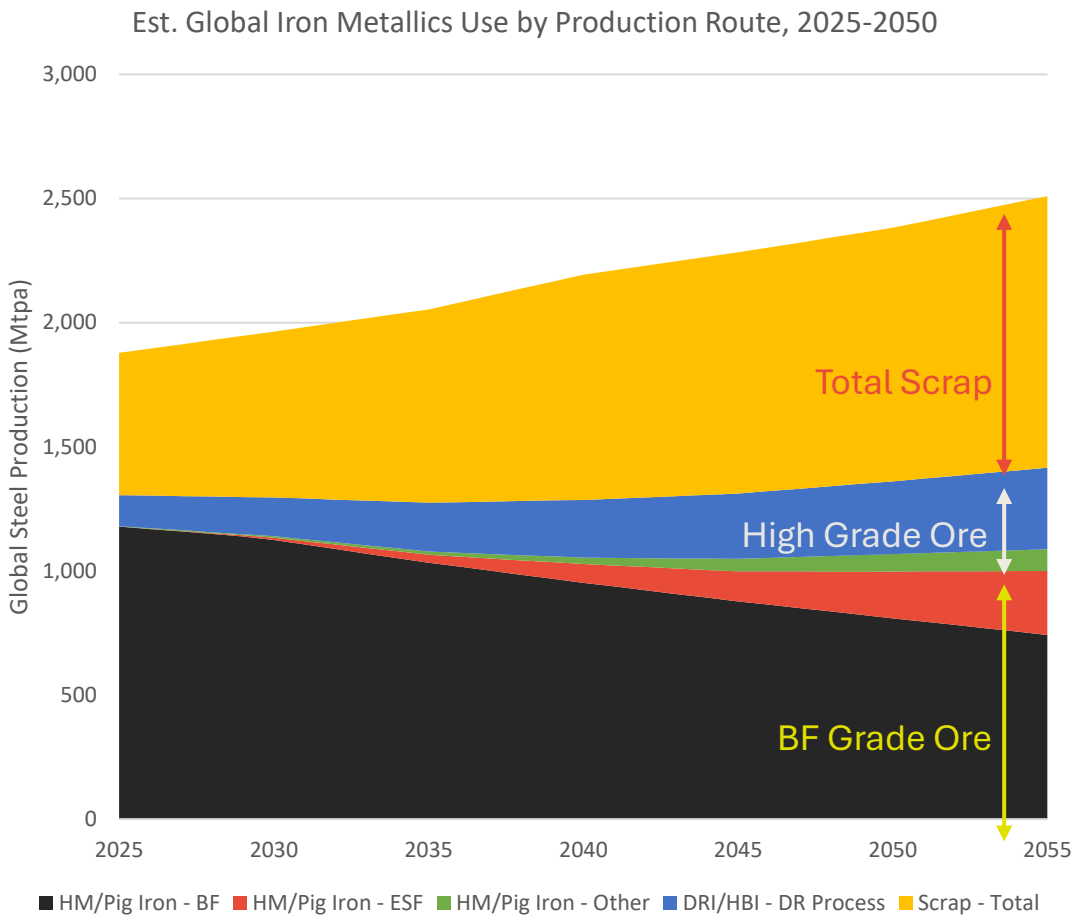
+ Gangue rejected as tailings.
+ **High Fe loss** in beneficiation.
+ Must reach DR-garde to allow efficient EAF steelmaking.

Ironmaking

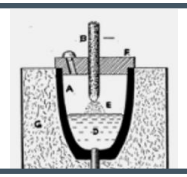
+ Reject gangue as low-FeO slag
+ **Low Fe loss and valorized**
+ DR reduces GHG but does not reject gangue.

Steelmaking

+ Unrejected gangue becomes high-FeO slag.
+ **Hurts EAF performance**
+ Low value use / solid waste



History of Ferrous Electric Smelting Furnaces



Pre-1930

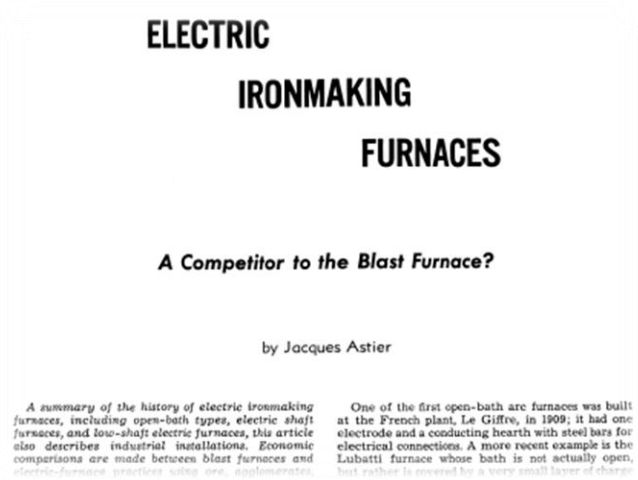
- 1879: Electric scrap melting 1st demonstrated
- c.1900: Heroult EAF; CaC_2, phosphorus, ferroalloy ESF

~1930-1950

- Tysland-Hole IM ESF
- Elkem FeNi RKEF
- Norsk Jernverk IM ESF

~1950-1960

- NZ Steel IM ESF Trials
- Highveld Steel IM ESF
- Strategic-Udy DRI-ESF
- QIT (now RTIT) IM ESFs



ELECTRIC

IRONMAKING

FURNACES

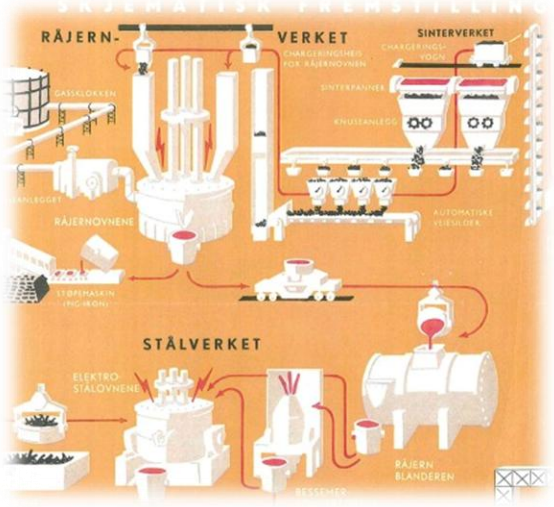
A Competitor to the Blast Furnace?

by Jacques Astier

A summary of the history of electric ironmaking furnaces, including open-bath types, electric shaft furnaces, and low-shaft electric furnaces, this article also describes industrial installations. Economic comparisons are made between blast furnaces and

One of the first open-bath arc furnaces was built at the French plant, Le Giffre, in 1909; it had one electrode and a conducting hearth with steel bars for electrical connections. A more recent example is the Lubatti furnace whose bath is not actually open,

Journal of Metals, 1963



Norsk Jernverk, 1955 Flowsheet

~1960-2000

- Richards Bay Min. IM ESFs
- Falcondo FeNi ESFs
- Rapid scale-up of high intensity ferroalloy ESFs

~2000-2010

- NZ Steel IM ESFs Upgrade
- Highveld IM ESFs Upgrade
- Iron Dynamics IM ESF
- ~100MW FeNi ESFs

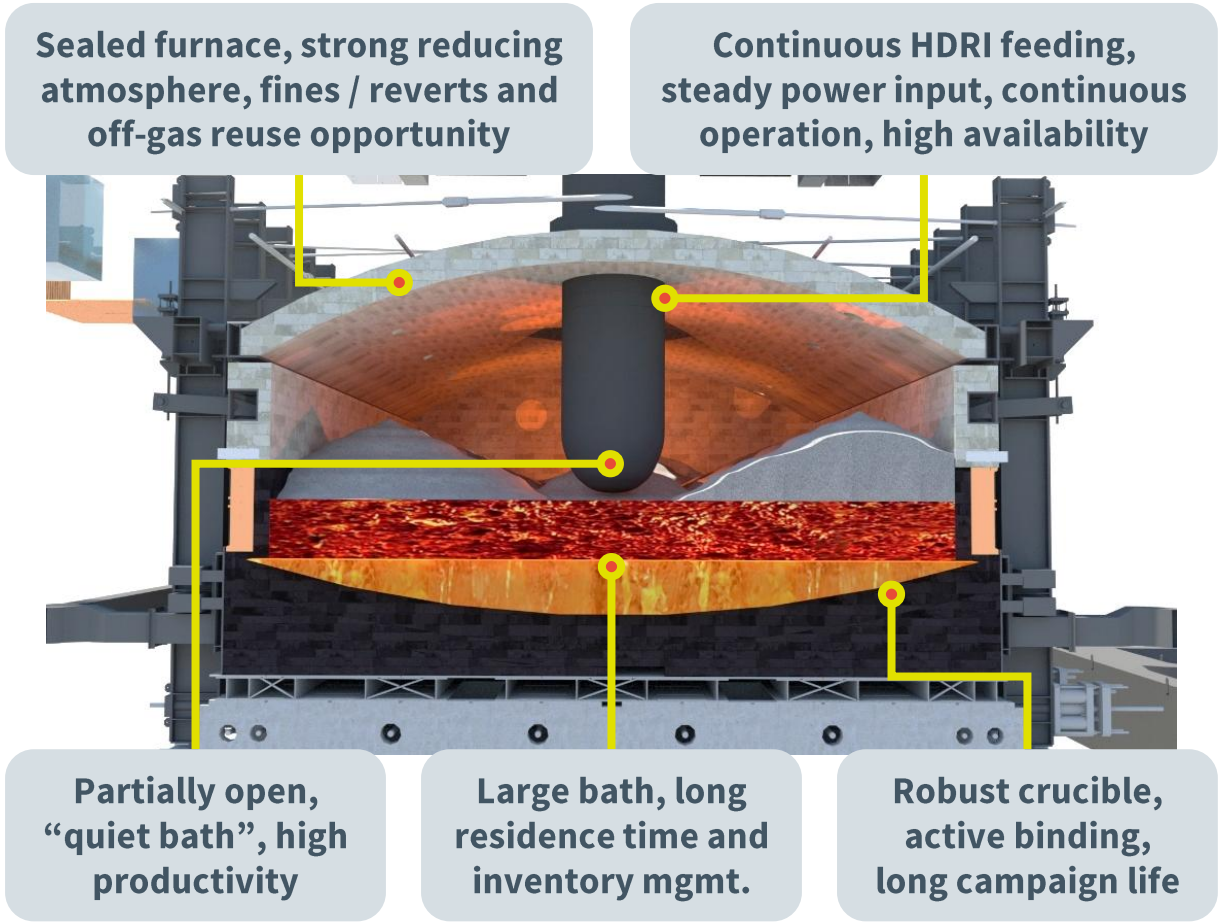
~2010-Present

- NeoSmelt IM ESF Program
- Modern DRI-ESF
- CRISP Steelmaking ESF and more…

*Hatch Technology / Design

ESF Technology for DRI Melting – CRISP+

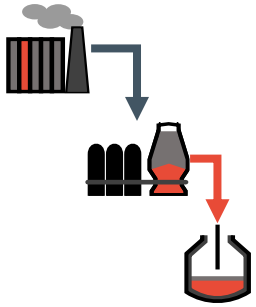
+ Developed for melting and slag removal of DRI
+ **Complete smelter solution** including feed delivery, off-gas processing and reuse, slag processing, and hot metal treatment
+ **Large, high power, stationary furnace**
  - To match scale needed for iron and steel industry
  - ~120 MW, up to 160 MW (>1.5 Mtpa hot metal)
  - Over 400 m^2 hearth area (~12 × 35m)
+ **Proven technology with decades of experience**
  - Rectangular design with 6 Soderberg electrodes
  - Continuous feeding and operation, with low power-off time and high availability
  - Operation and slag tailored for performance, yield and cost efficiency based on raw material and slag sale opportunity



Hatch Ferrous ESF References

Client	Furnace Geometry	# of Furnaces	Power	Application
Rio Tinto	Rectangular	13	60 – 80 MW	Iron + TiO_2 Slag
Vale Onça Puma	Rectangular	2	96 MW	FeNi
Anglo Barro Alto	Rectangular	2	85 MW	FeNi
SNNC	Circular	1	90 MW	FeNi
Pronico	Circular	1	90 MW	FeNi
Koniambo	Circular	2	85 MW	FeNi
Cerro Matoso	Circular	2	75 MW	FeNi
PT Vale	Circular	4	60 – 85 MW	FeNi
Falcondo	Rectangular	2	65 MW	FeNi
New Zealand Steel	Rectangular	2	42 MW	Iron
Highveld Steel	Circular	4	36 MW	Iron

ESF Flowsheet Flexibility

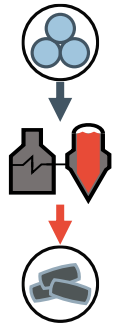


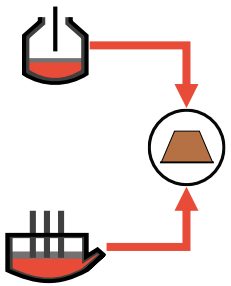
+ Minimum disruption to BF-BOF flowsheet to reduce ~50% of emissions
+ Maintains high quality BOF products, retain existing assets, and lower transition risks

DRI-ESF Blast Furnace Replacement

DRI-ESF Metallics Production

+ Turn BF-grade ore into high quality, low emissions pig iron and low-FeO slag for sale
+ Reject gangue as ESF slag before shipping
+ Reduce the need for beneficiation / DR-grade



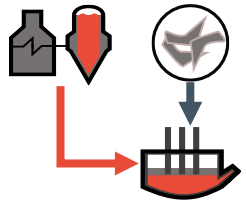


+ Valorize high FeO slags and other plant wastes
+ Supplies BF-grade slag to cement makers and HM to steelmaking
+ "Waste Hub" concept for centralized treatment

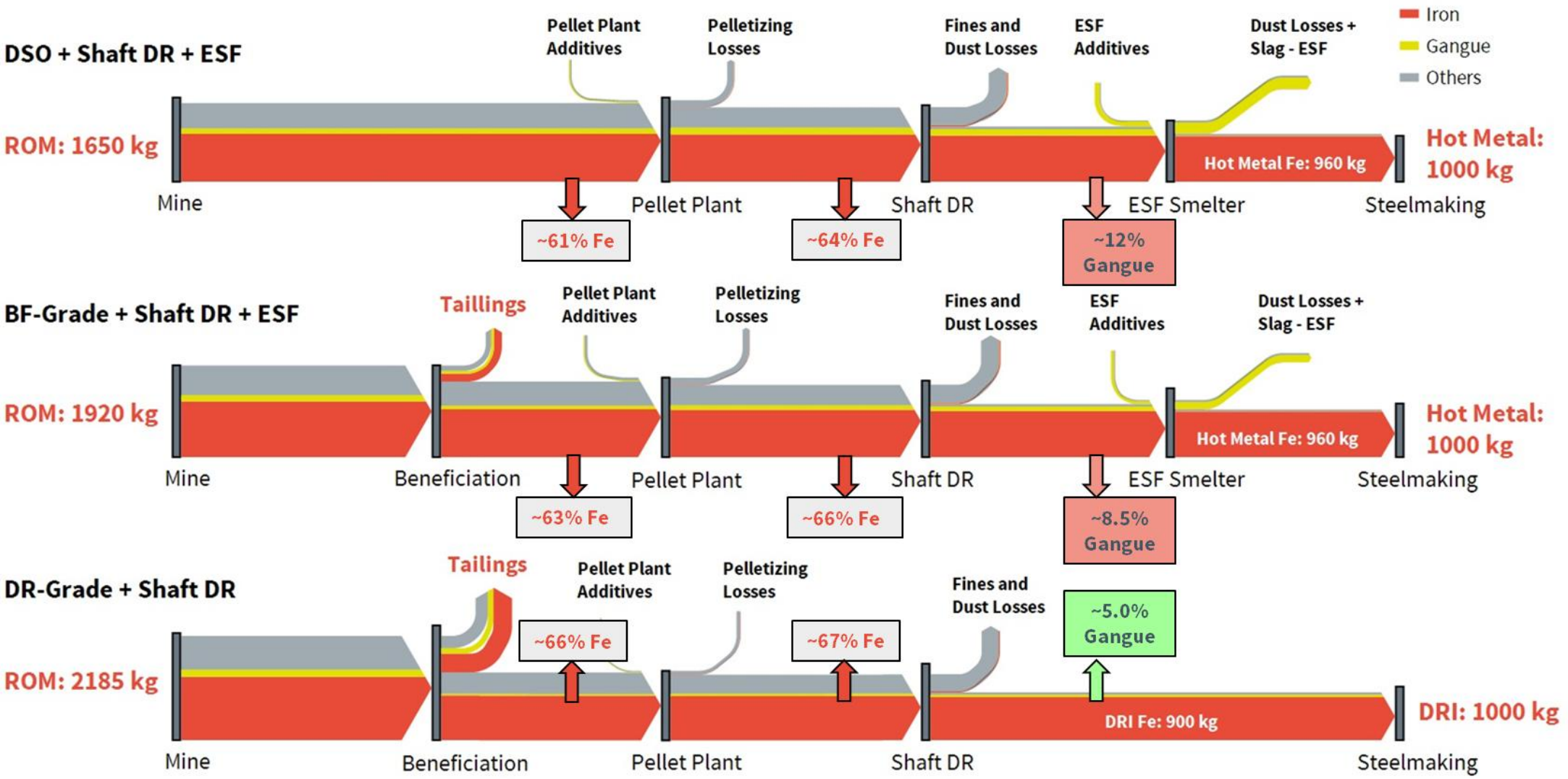
Waste Valorization

ESF Steelmaking

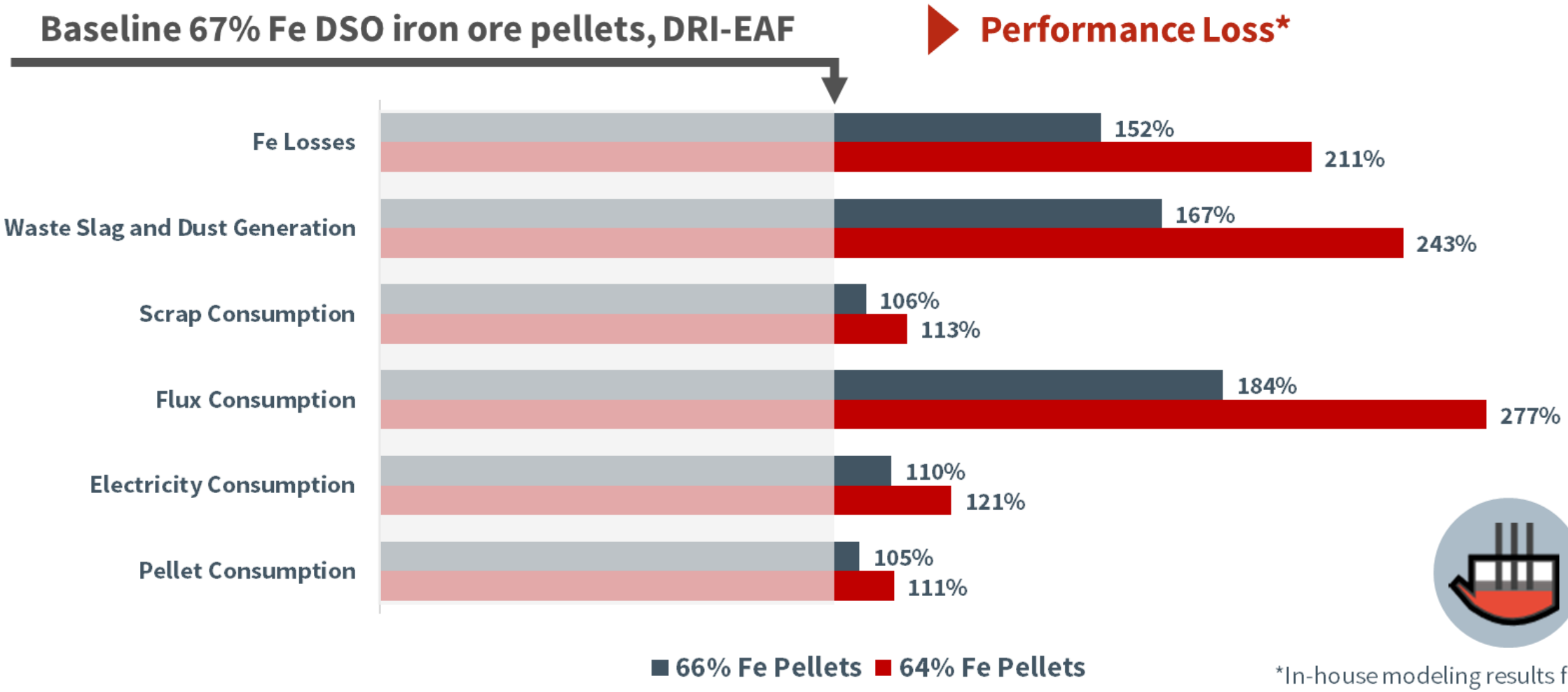
+ True continuously operated steelmaking
+ BOF quality steel from an electrical process using DRI and scrap
+ High yield and energy efficiency vs. EAF



Case Study: Fe Yield in DRI-based Flowsheets

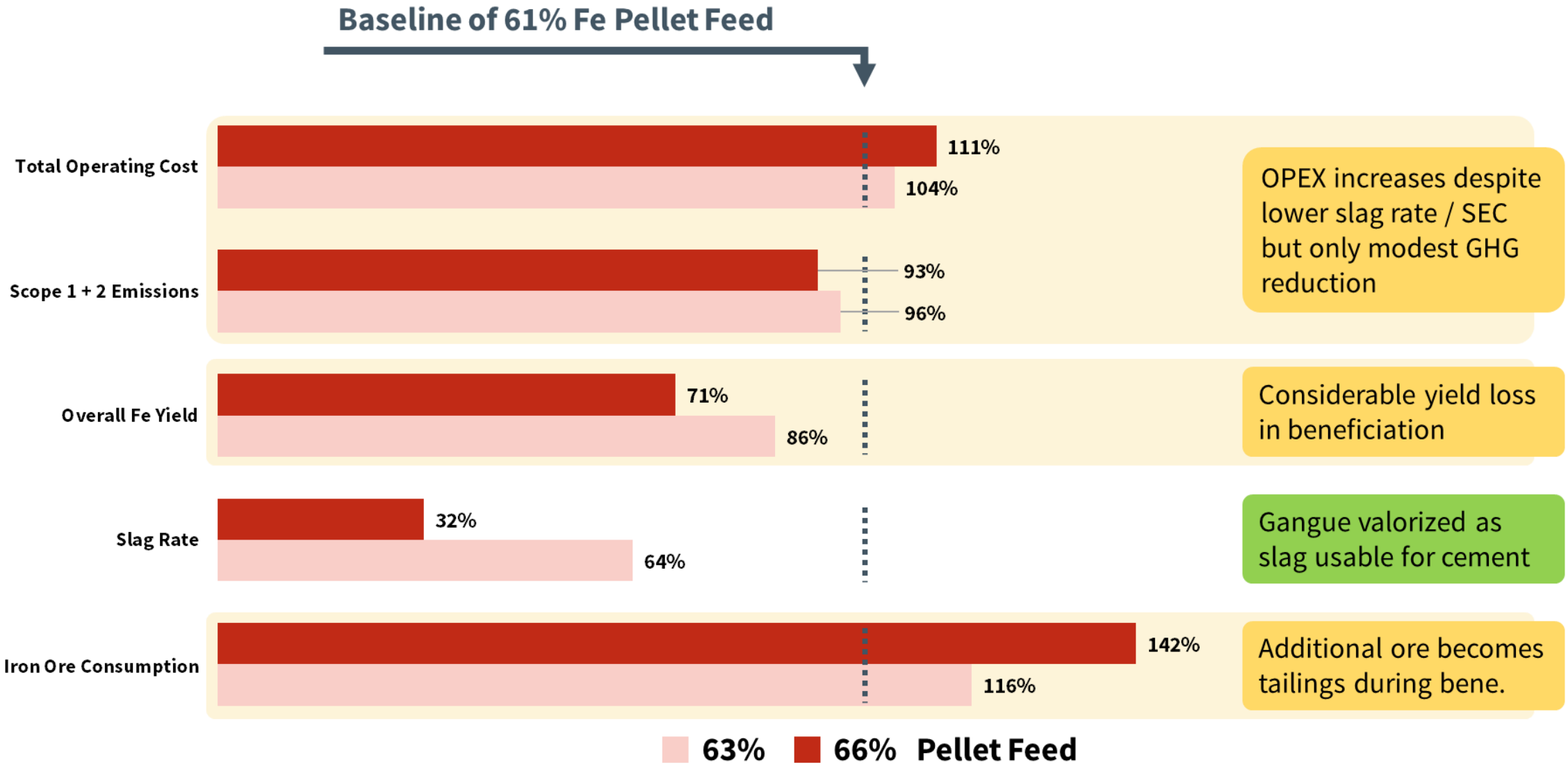


Beneficiate to DR-grade to Optimize EAF Steelmaking



*In-house modeling results for 85% DRI-EAF

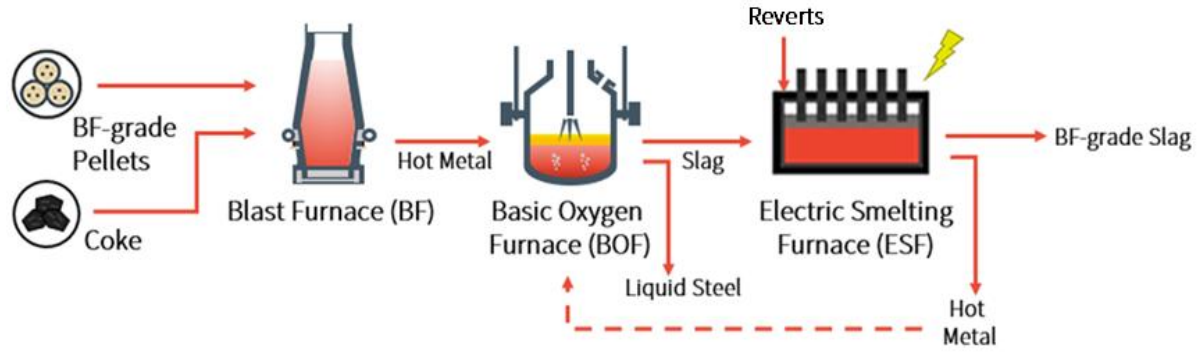
Impact of Beneficiation of DRI-ESF Flowsheets



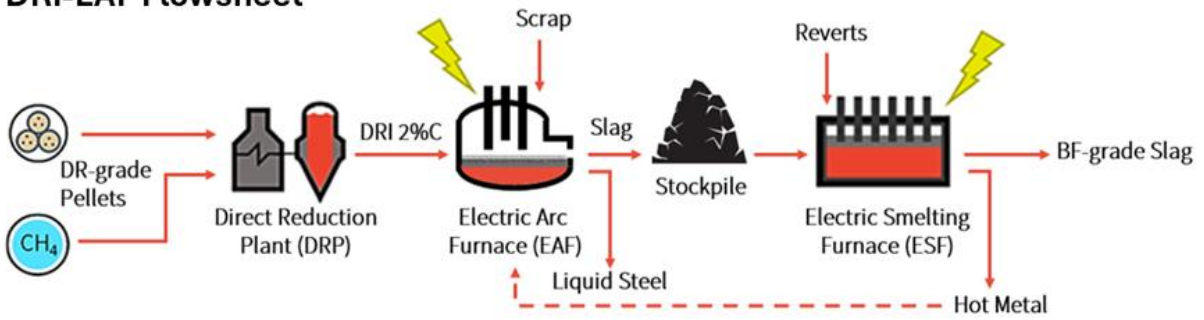
ESF for Steelmaking Slag Valorization

+ Converts steelmaking slag and solid wastes into hot metal, ironmaking slag, and CO-rich off gas
  - **For both BOF and EAF steelmaking**, using molten, air-granulated, or legacy slags
  - Able to recycle BF dust, mill scale, pellet fines, DRI fines, etc. to replace sinter plant
+ Up to $450 per tonne net return of input SM slag, driven by iron yield and hot metal sales
  - Significant avoided waste disposal cost and ESF slag sale depending on location
  - **Environmental sustainability beyond just GHG**
+ The **"Waste-Hub"** concept
  - Central collection and processing of SM wastes
  - EAFs + ESF improves yield, productivity, material efficiency, and tolerance for lower-grade ore
  - Outlet for legacy solid waste from integrated mills
  - Supports decarbonization of cement industry

Traditional BF-BOF Flowsheet



DRI-EAF Flowsheet



ESF Products from Slag Valorization

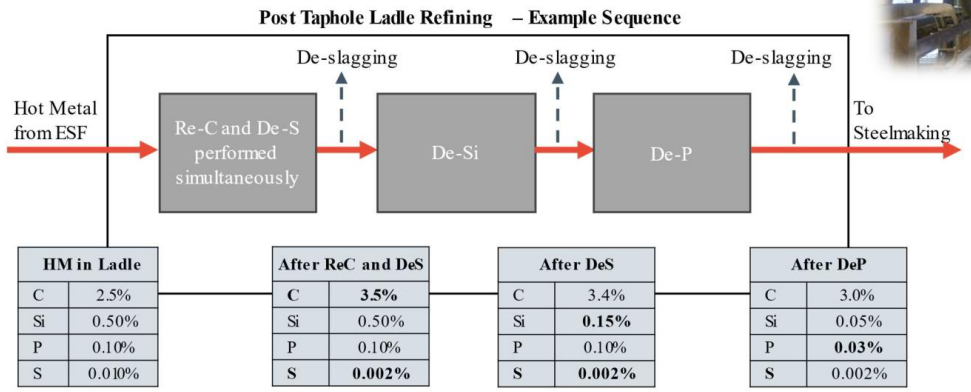
- Dry or water granulation of slag to produce high quality product for cement makers
  - Customizable composition
  - Heat / energy recovery
- Optional HM pretreatment to control impurities (S, P) and chemistry (Si, C) and increase value-in-use
- CO-rich, continuous off-gas stream for reuse within steel plant

ESF Slag Composition		
B2	-	> 1.0
Al_2O_3	wt%	< 15
MgO	wt%	< 14
FeO	wt%	< 10
P_2O_5	wt%	<1.8
Hot Metal Composition		
Fe	wt%	Balance
C	wt%	~2.0 (+)
Si	wt%	~1.0 (+/-)
P	wt%	< 0.05
S	wt%	< 0.05

Select Complementary Technologies for ESF

Hot Metal Pretreatment

+ Multiple refining processes in a single ladle station after ESF tapping
+ De-S, De-Si, De-P, and/or Re-C
+ Tailored HM chemistry to user / sale



Air Slag Granulation

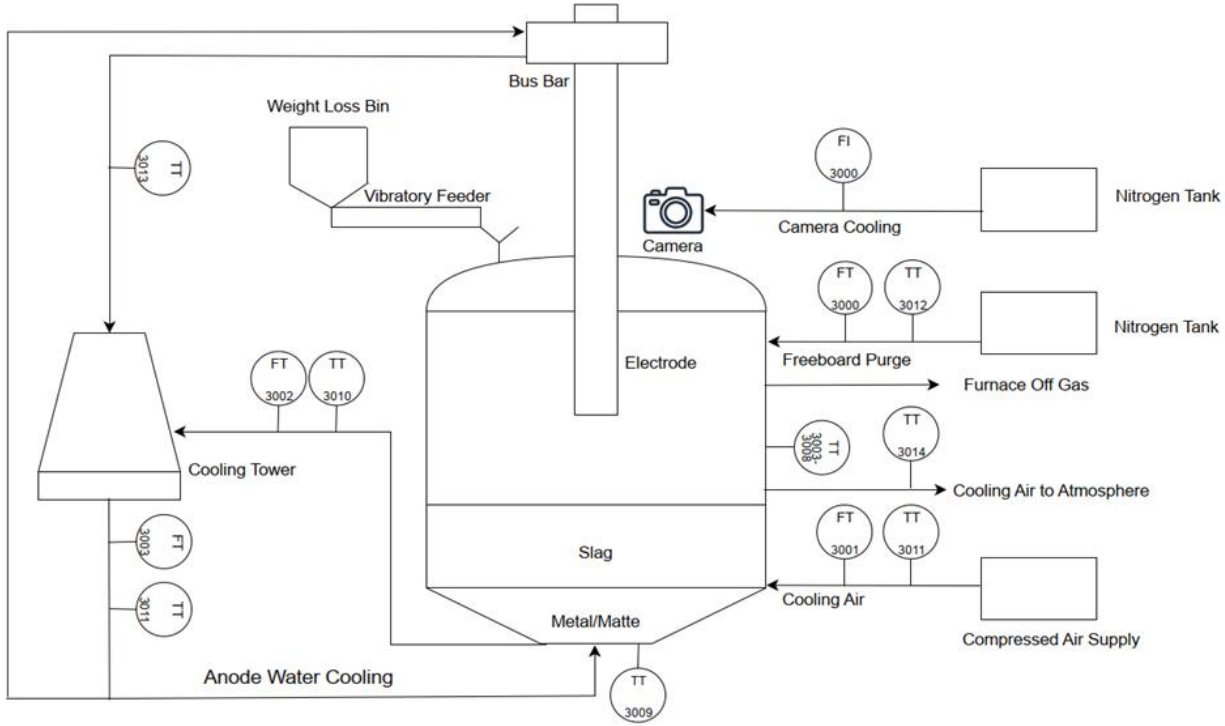
+ Water-less granulation process
+ Energy recovery from granulation off-gas and cooling hot granules
+ Feeding of hot granulated slag to ESF

ESF Ramp-up Optimization through Pilot-scale Tests

+ Proven technology foundation built on large electric ironmaking and FeNi operations.
+ **Pilot-scale ESF to optimize process** for different feed materials, accelerate ramp-up, and fine-tune improvements.

Piloting runs were completed for:

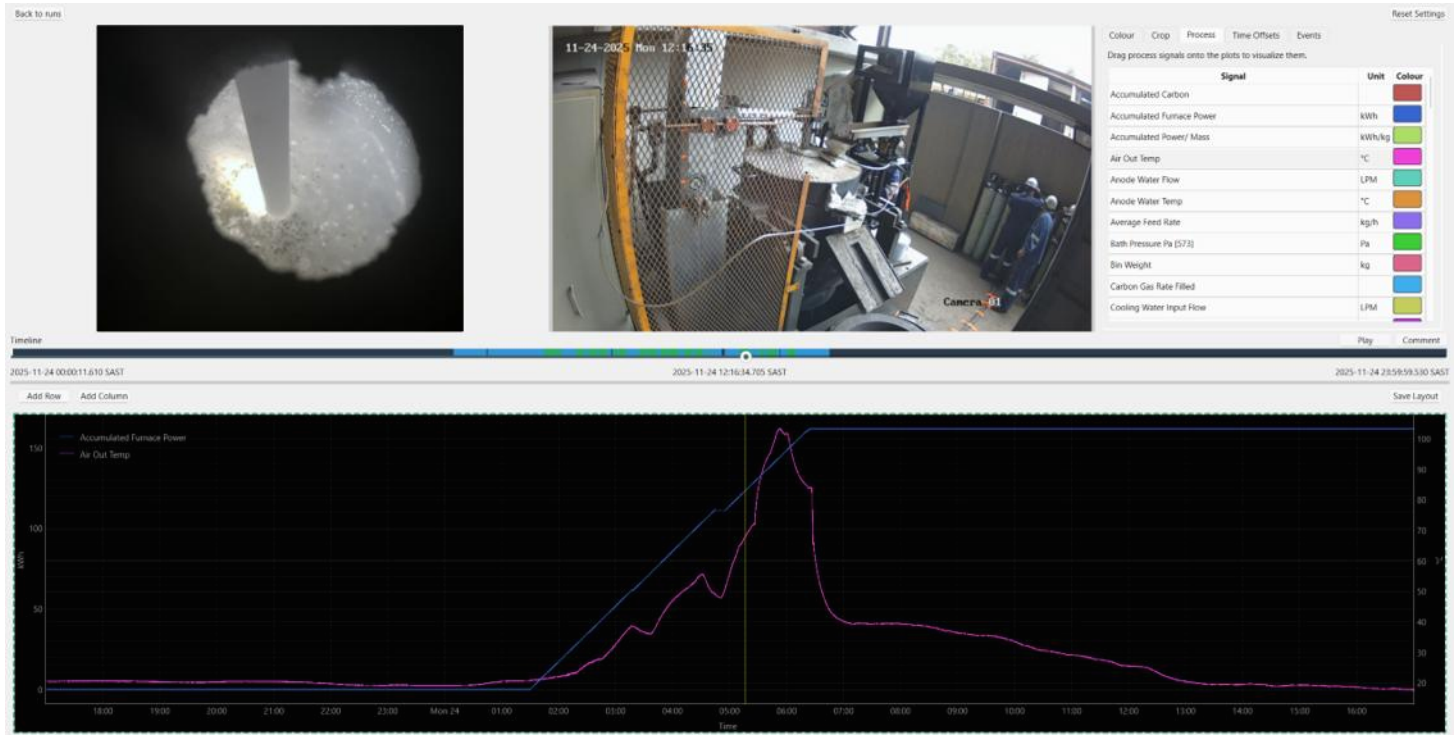
+ **DRI Smelting** – evaluate HM quality and carburization for a variety of feed materials and furnace operating conditions
+ **EAF Slag Valorization** – optimize degree of reduction and elemental partitioning
+ **Evaluating new materials with speed, robustness, and agility**

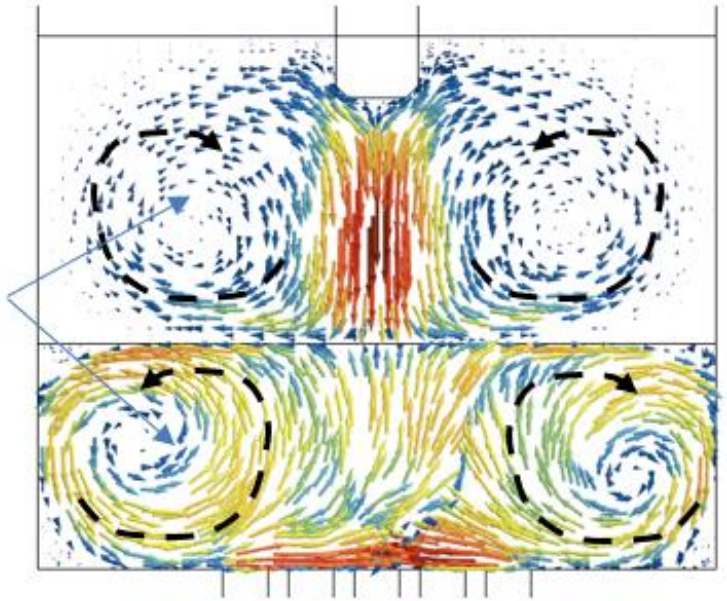


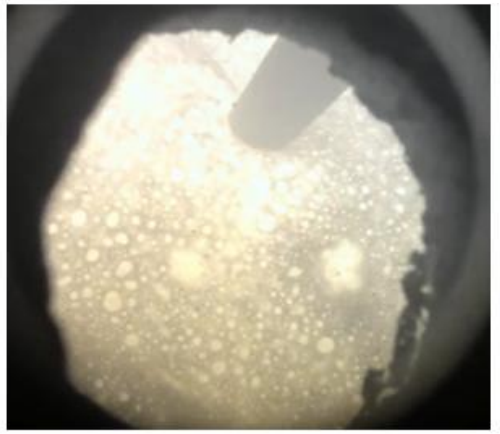
- Rigorous feed preparation
- Purpose-built pilot furnace replicates different modes of operation
- Active off-gas management.
- High-resolution monitoring tools.
- Structured digital data systems.

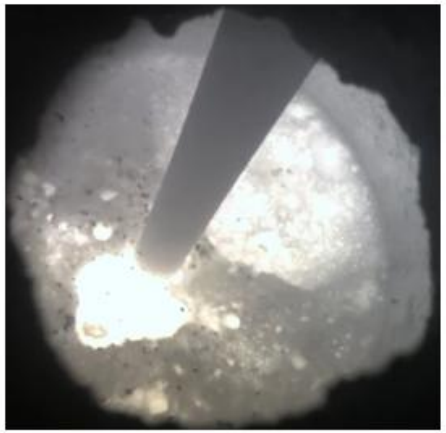
CFD, Monitoring, & Data Visualization

- Advanced monitoring and measurement couples with CFD and data visualization









Pilot-scale ESF Testing Results

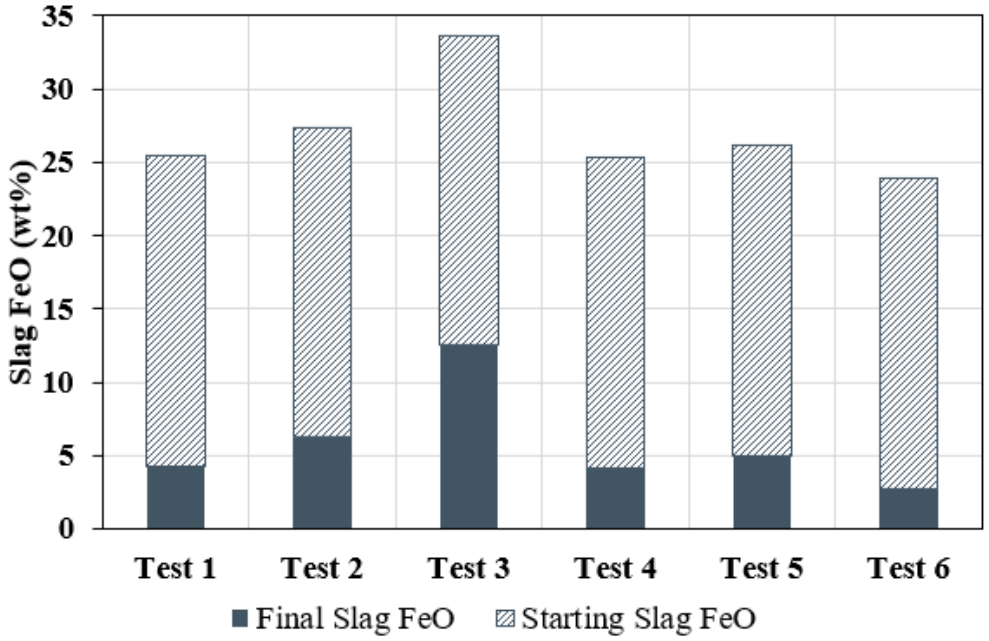
+ DRI Smelting

- Hatch proprietary hybrid feeding technology greatly improves HM carburization.
- Effective carburization for C-free DRI
- HM carbon were well within the range needed for most BOF operations.
- Other proprietary technologies for further carburization

+ EAF Slag Valorization

- Consistently achieved targeted degree of reduction (2.5 – 12% FeO)
- HM and processed slag quality confirmed

Feed Type	Max. HM %C	Avg. HM %C	Notes
Conventional Feeding	1.6%	1.6%	Poor carburization
Hybrid Feeding with C-free DRI	4%+	3.4%	Very good carburization
Hybrid Feeding with High Gangue, NG-DRI (~1.6% C)	4%+	3.6%	Performance aligns with commercial benchmark



Recent News in ESF Ironmaking

NEOSMELT™

BHP

Rio Tinto

BlueScope

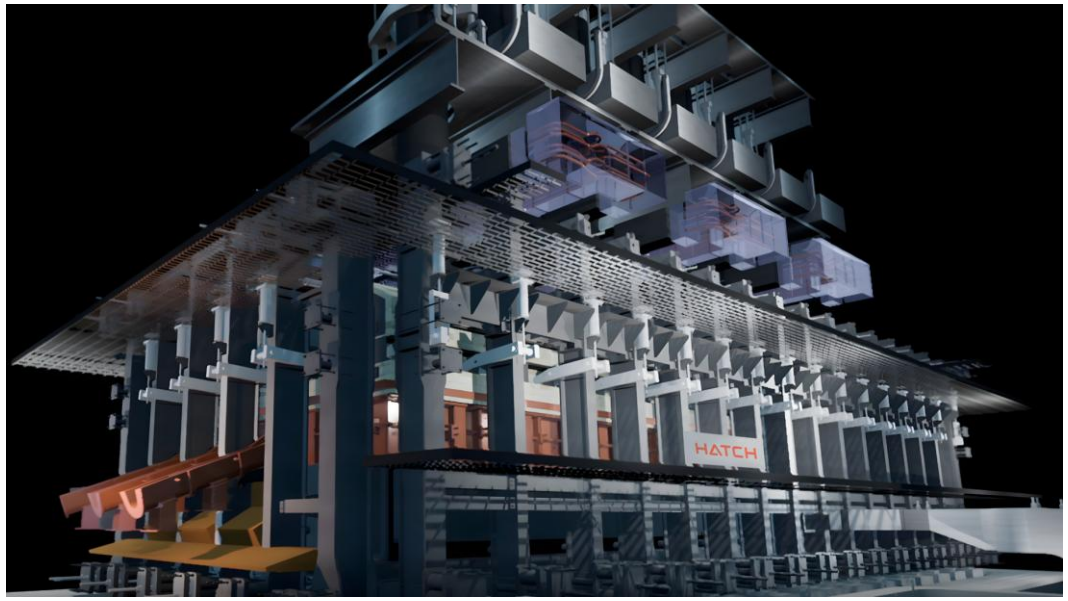
Woodside Energy

MITSUI&CO.

NeoSmelt consortium selects Hatch to design Australia's largest ironmaking electric smelting furnace

Hatch will provide electric smelting furnace technology, complemented by project management and engineering services, for the NeoSmelt project

July 10, 2025



Hatch has been working collaboratively with the NeoSmelt consortium since the initial pilot furnace design was completed in 2023. This work leverages over 70 years of Hatch's capability and experience in smelting furnace technology across multiple industries. We are delighted to bring our smelting technology to accelerate decarbonization of the iron and steel industry, The pilot will seek to demonstrate the viability of a lower carbon intensity technology ironmaking route using Pilbara iron ore in the difficult to abate iron and steel industry. We are extremely excited to be part of this extraordinary project.

John Bianchini, chair and CEO, Hatch

Conclusions

- ESF is a **proven commercial technology** with decades of successful operation
- ESF is a versatile technology that can be used in various flowsheets to improve **economic, environmental, and emissions performance**
- Hatch's CRISP+ for DRI smelting offers a **low emissions, low cost, low waste and low disruption transition** option for BF-BOF steelmaking
- ESF slag valorization allows **profitable conversion** of steelmaking slags and reverts into valuable cement-usable slag and hot metal
- ESF slag valorization couples effectively with both EAF and BOF and can be implemented as a **"Waste Hub"** to further improve business case
- Hatch continues to conduct **pilot-scale ESF optimization campaigns** to optimize business case with a variety of commercial / emerging materials

Thank You

For more information,
please visit www.hatch.com

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