TATA STEEL

Update to the Developments of Hisarna
An Ulcos alternative ironmaking process

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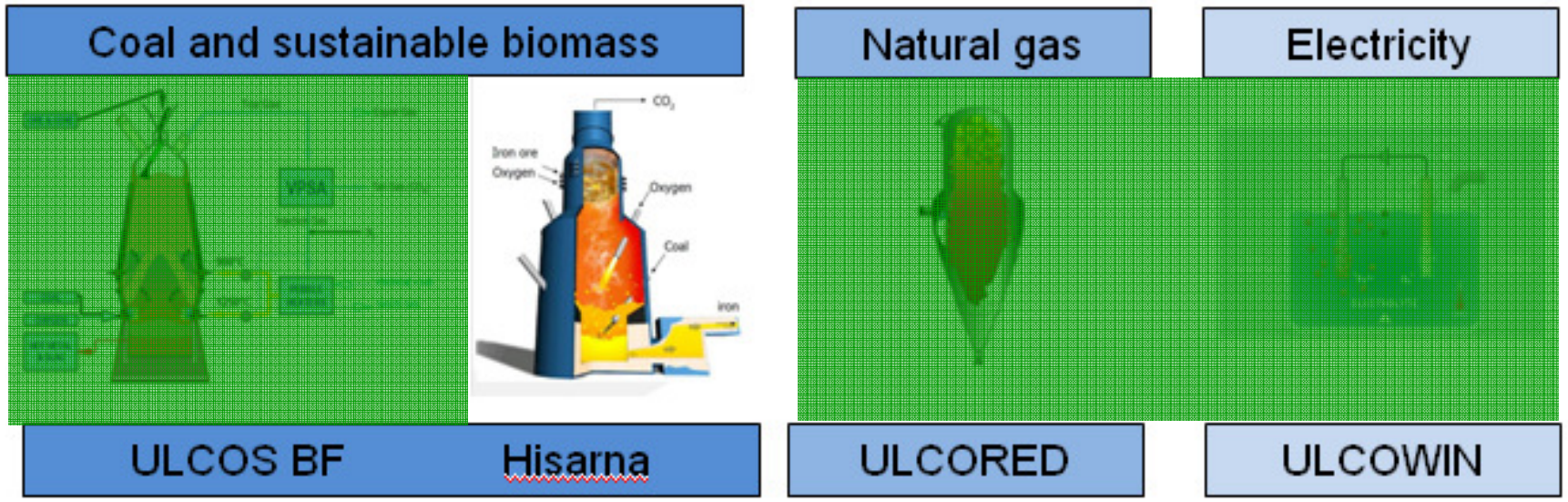
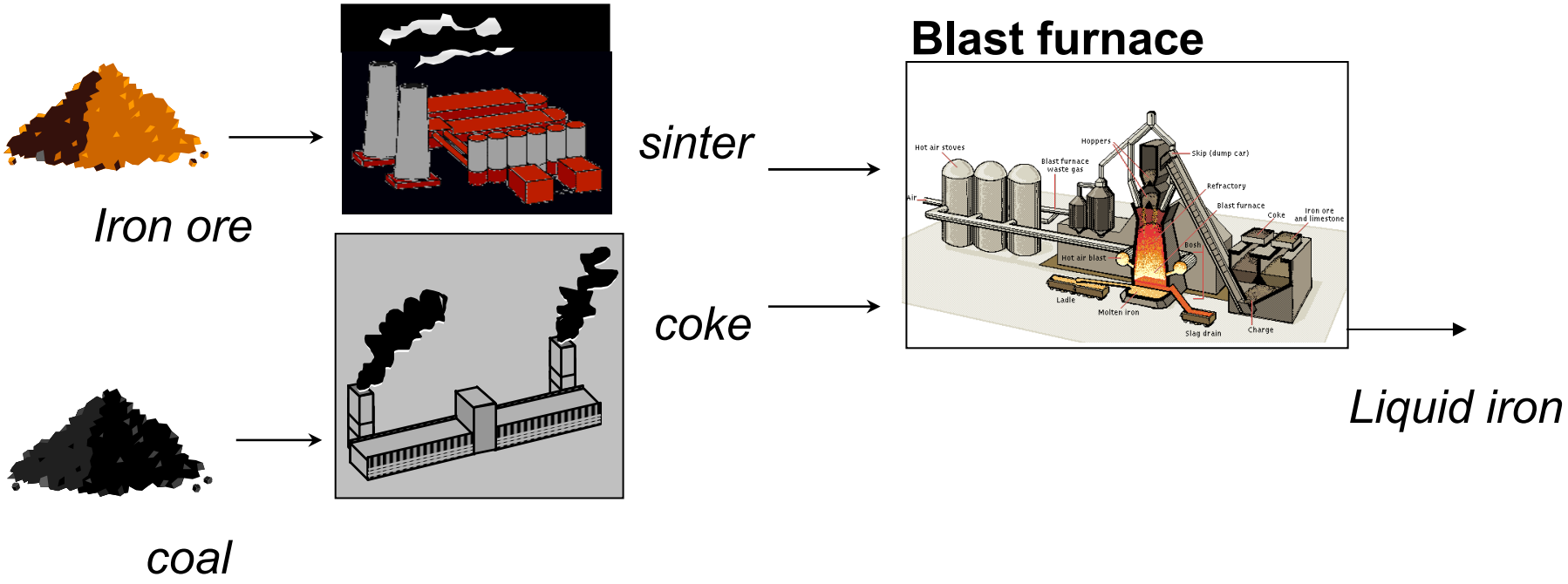
Ulcos


Coal and sustainable biomass
Natural gas
Electricity
Iron ore
Oxygen
Oxygen
Coal
Iron
ULCOS BF
Hisarna
ULCORED
ULCOWIN

1. HIsarna technology

Comparison with the BF route



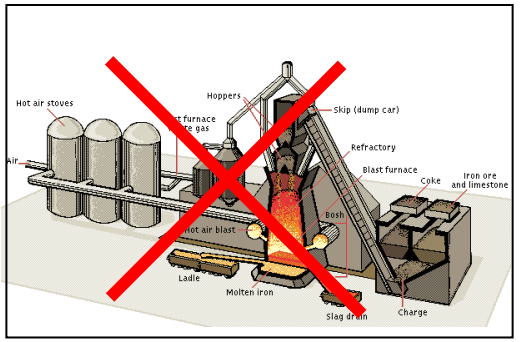
1. HIsarna technology

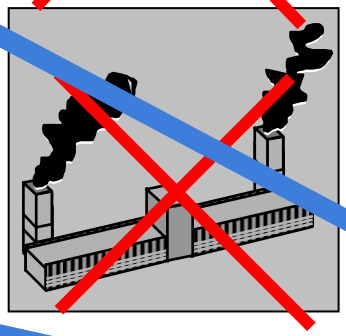
Comparison with the BF route

Iron ore

sinter

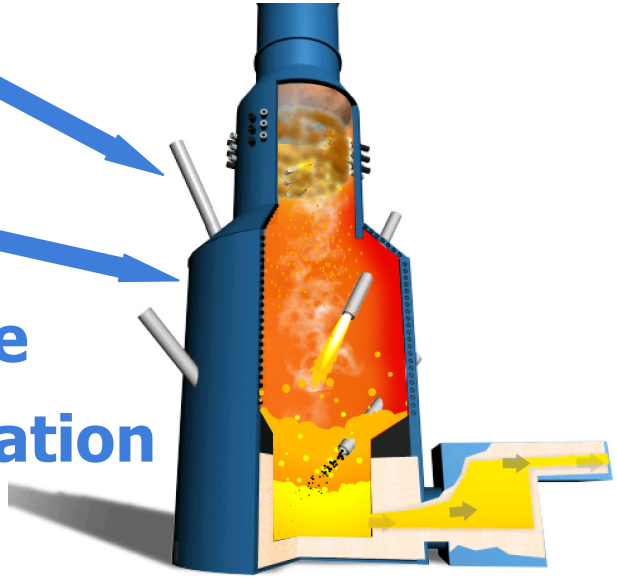
Blast furnace





coke

coal

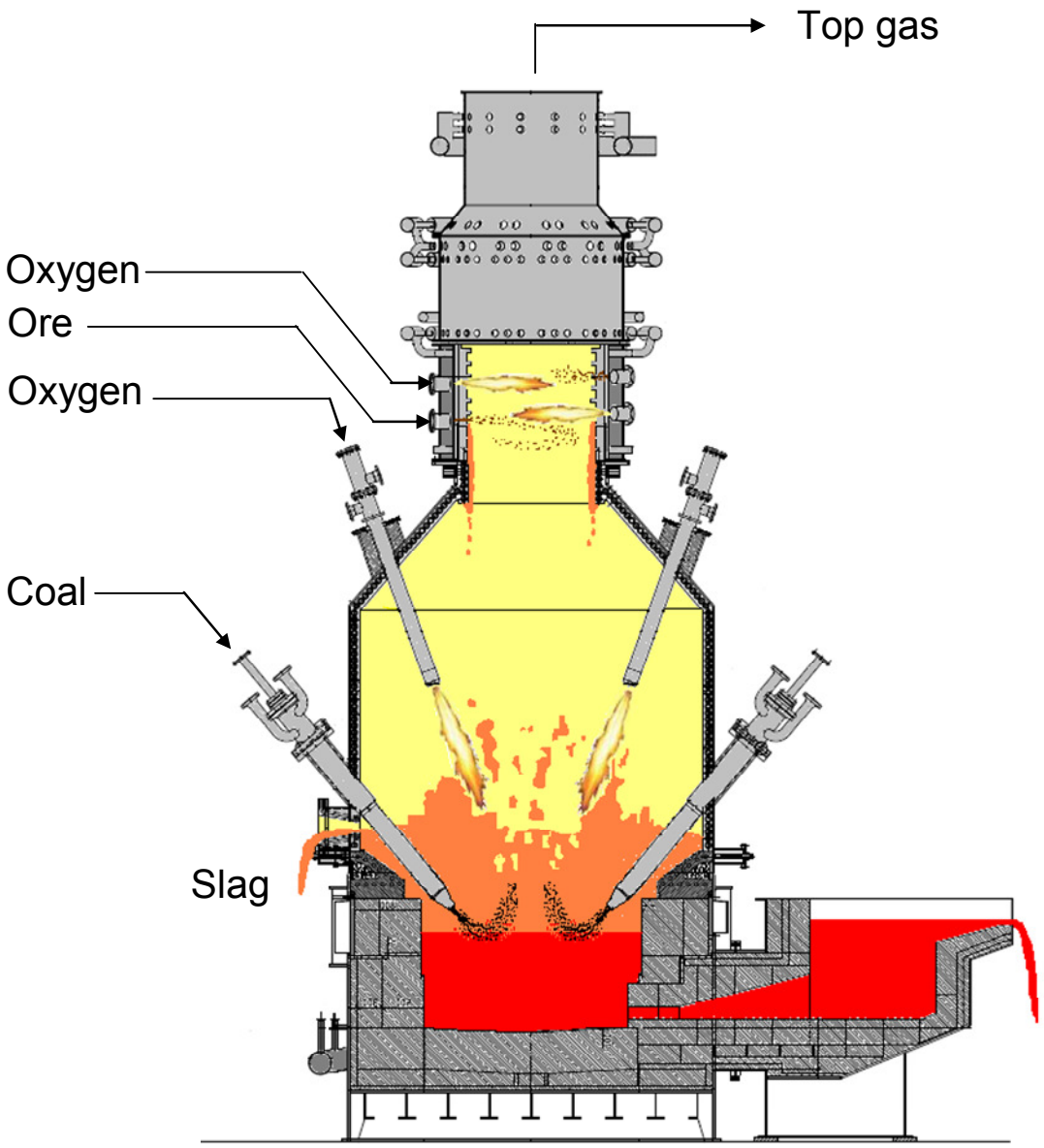


Liquid iron

Direct use of coal and ore

No coking and agglomeration

1. HIsarna technology

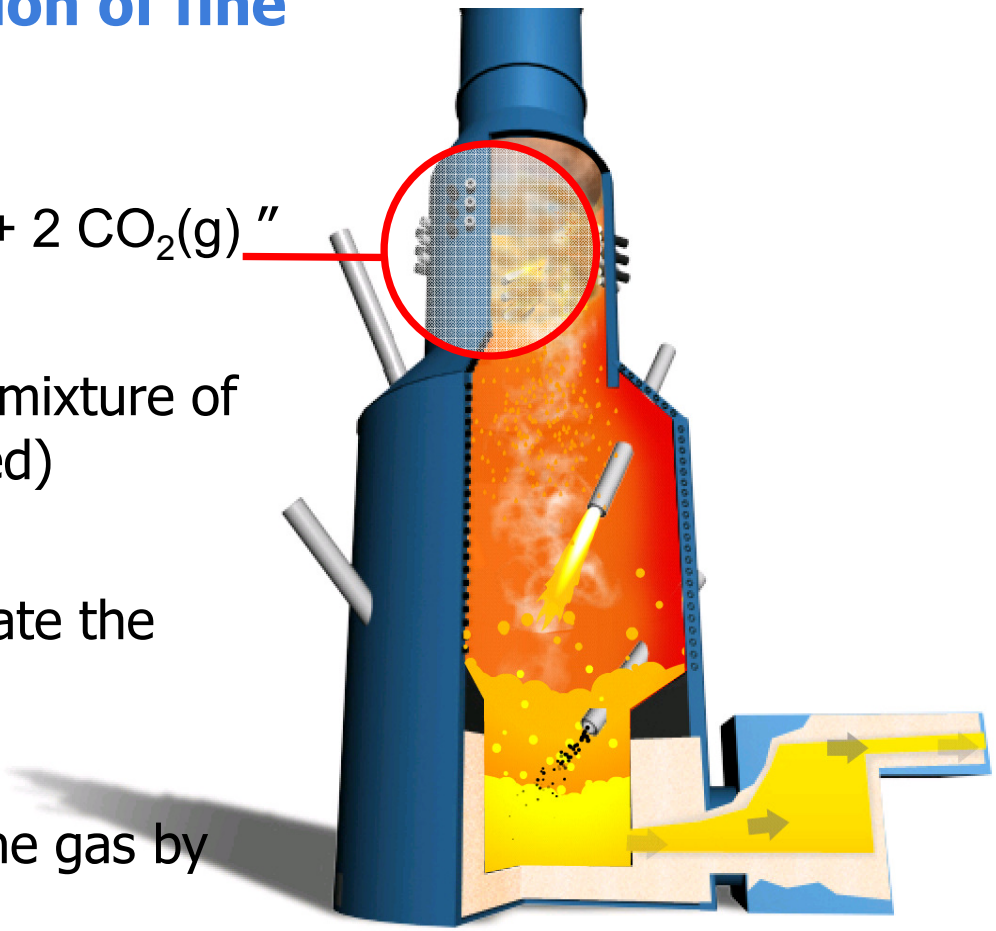


1.1. HIsarna technology
Melting cyclone technology

Melting and partial reduction of fine iron ores

"$2\ Fe_2O_3(s) + 2\ CO(g) \rightarrow 4\ FeO(l) + 2\ CO_2(g)$"

- The cyclone product is a molten mixture of **Fe_3O_4 and FeO** (~ 20 % reduced)
- Pure oxygen is injected to generate the required **melting** temperature
- The fines are **separated** from the gas by centrifugal flow of the gas

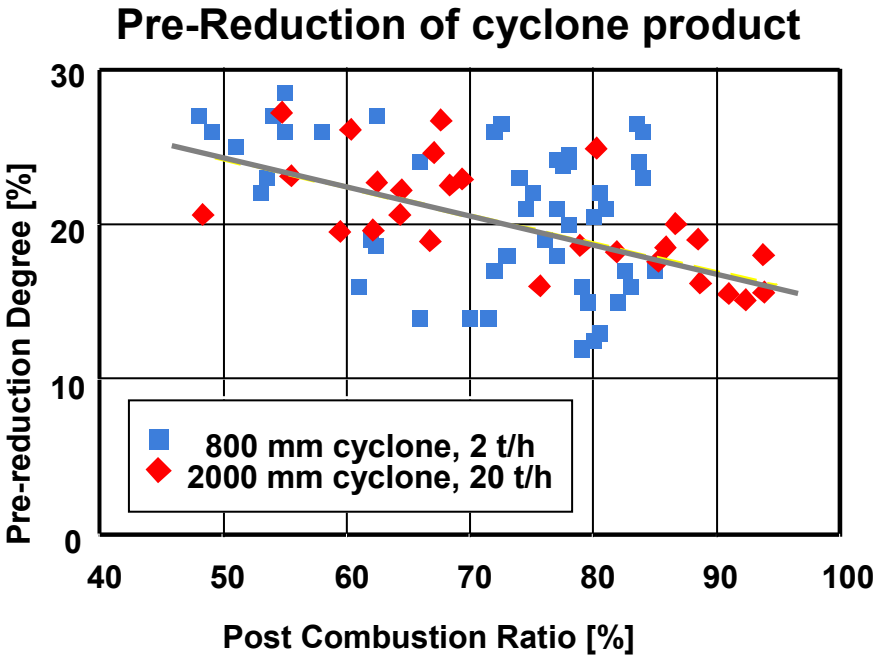


1.1. HIsarna technology

Melting cyclone technology

Experimental results CCF trials 1994 – 1998

Cyclone tests at 20 t-ore/h

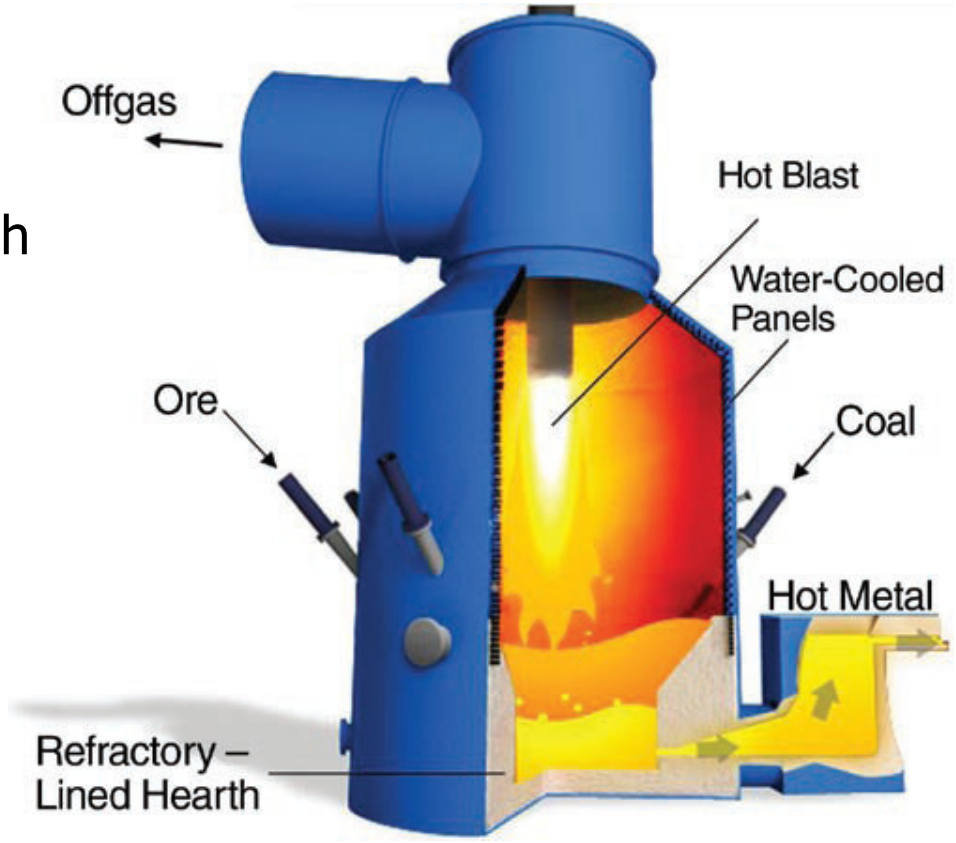


Experimental plant (1994-1998)

1.2 Hisarna HIsmelt technology

Smelter technology

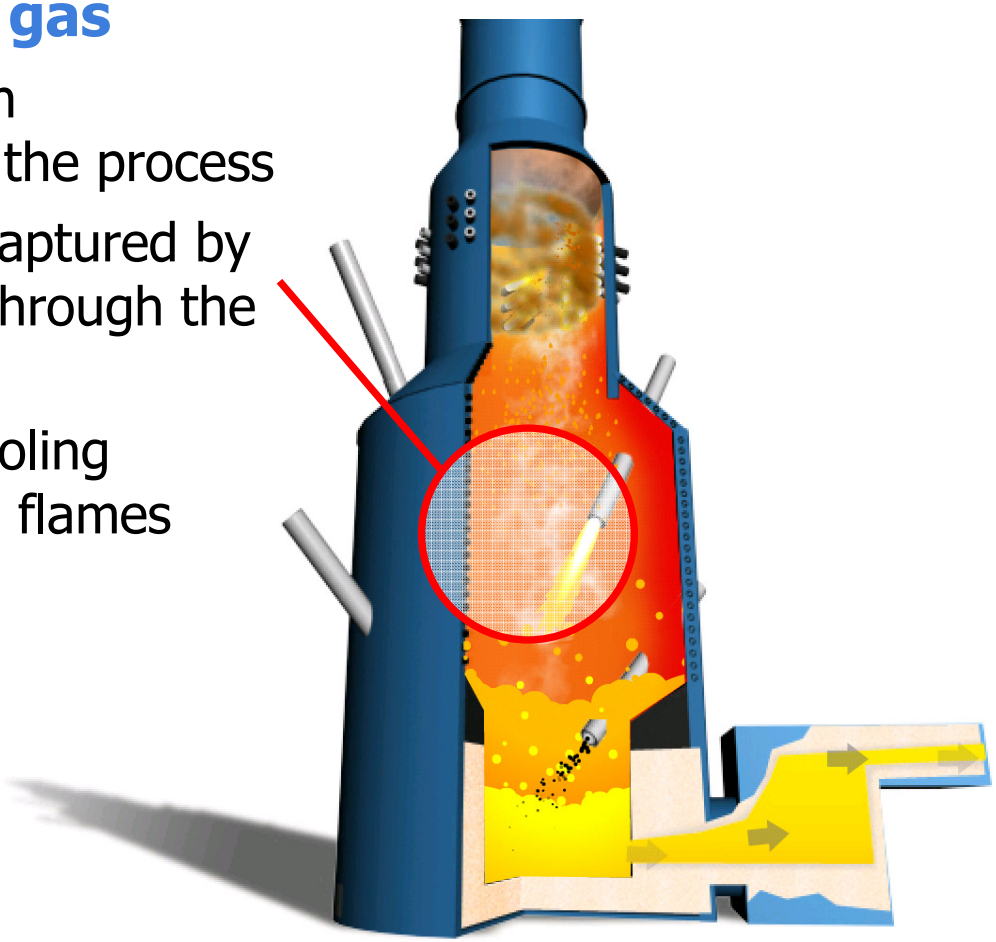
- HIsmelt is owned by Rio Tinto
- Large scale demonstration plant was constructed and operated in Kwinana, Australia
- Technology demonstrated at 80 t/h
- The Kwinana plant was idled in 2009 because off too high operating costs



1.2. HIsarna technology
Smelter technology

Post combustion of smelter gas

- Utilisation of the post combustion ($CO \rightarrow CO_2$) heat is essential for the process
- The heat of post combustion is captured by the **slag splash** that circulates through the freeboard
- This splash also **protects** the cooling panels from the post combustion flames



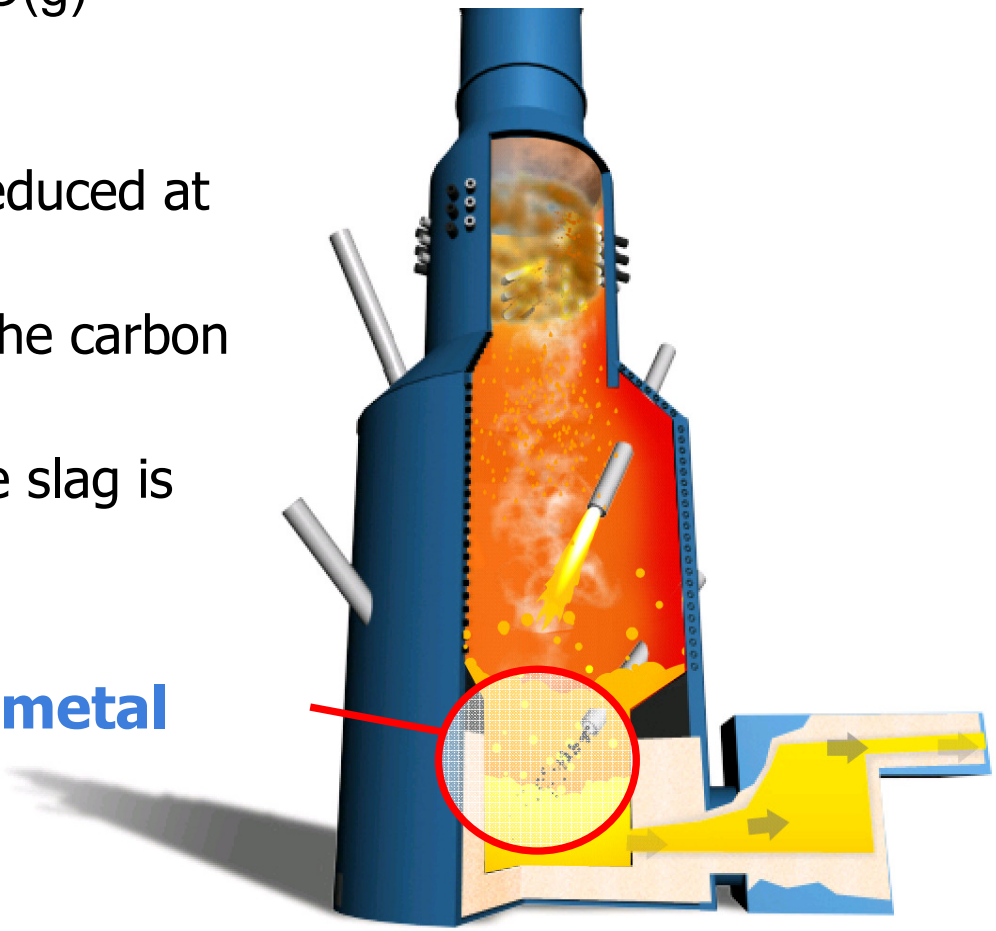
1.2. HIsarna technology

Smelter technology

"2 FeO(l) + 2 C(s) → 2 Fe(l) + 2 CO(g) "

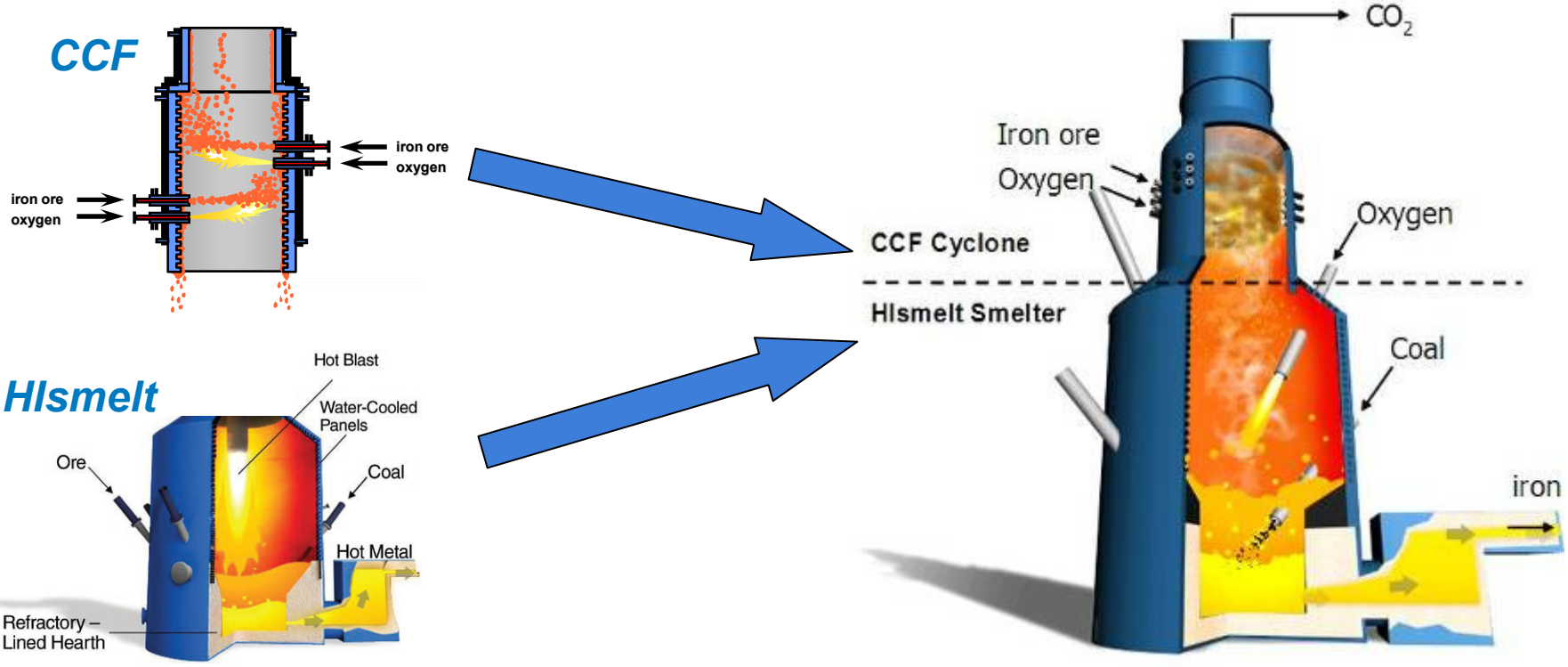
- The iron oxides in the slag are reduced at the slag/metal interface
- Granular coal injection supplies the carbon and creates intense mixing
- Due to this mixing the FeO in the slag is relatively low

Final reduction on slag/metal interface



1.3. Combined technology

- The HIsarna technology combines CCF pre-reduction and melting technology with HIsmelt final reduction technology



1.4. The benefits of HIsarna

The HIsarna ironmaking process for continuous production of liquid hot metal has a unique combination of **environmental** and **economical** benefits:

Economic benefits:

- Reduced OPEX and CAPEX compared to Greenfield blast furnace route
- Wider range of raw material qualities (Ore: P, Zn, S, Ti or alkali)
- Use of plant waste oxides (BOF, BF dust or mining reverts)

Environmental benefits:

- 20 % lower energy usage and CO_2 emissions per ton
- 80 % lower CO_2 emission with CO_2 capture & storage (CCS)
- Reduction of other emissions (e.g., NOx, SOx, dust and CO)

2. HIsarna and CCS

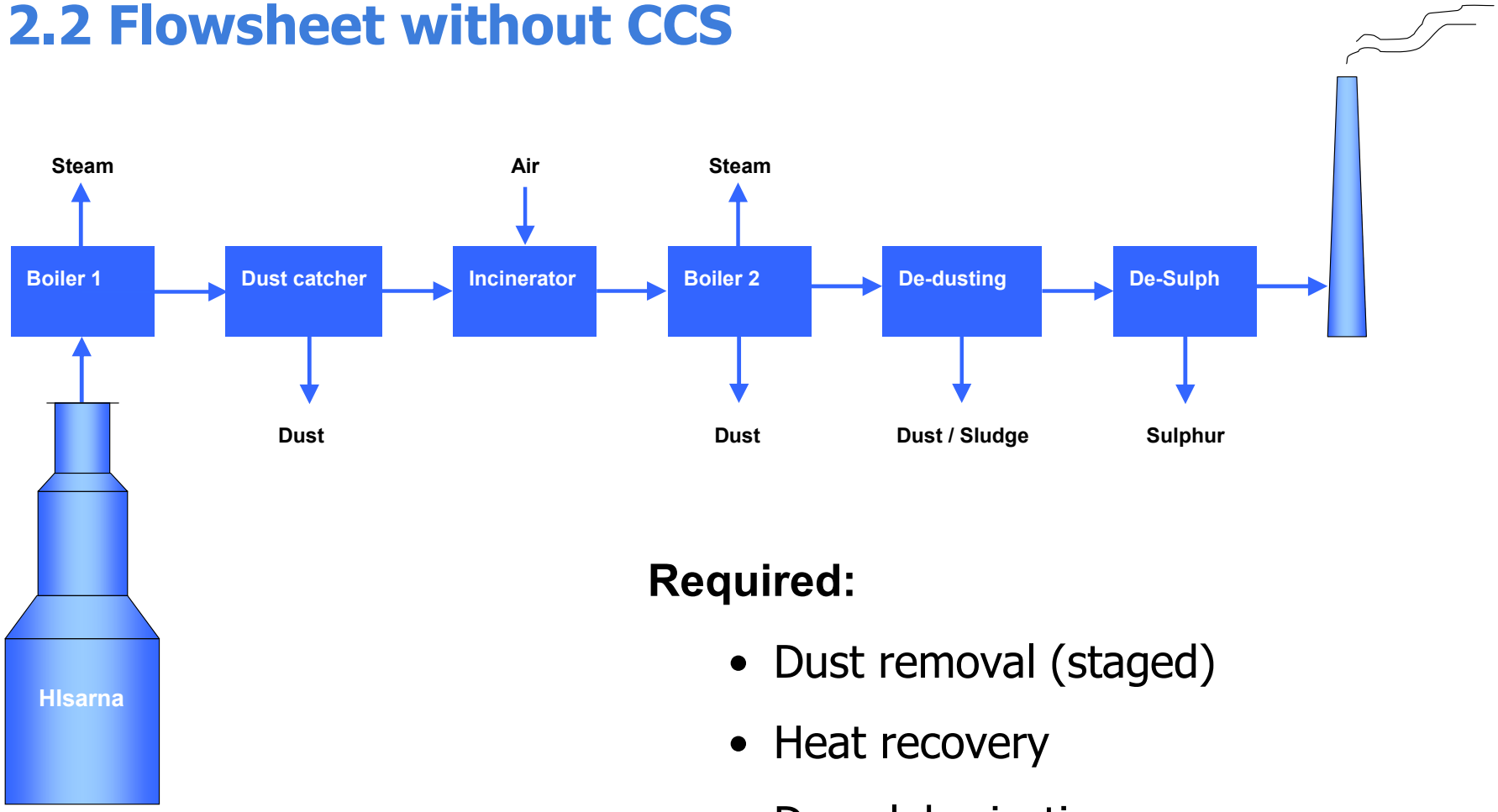
2.1. Why an attractive combination?

HIsarna flue gas:

- Oxygen based process with Nitrogen free flue gas;
- All ironmaking flue gases at a single stack (85 % of CO_2 from integrated site);
- Fully utilised gas, (almost) no remaining calorific value;

2. HIsarna and CCS

2.2 Flowsheet without CCS

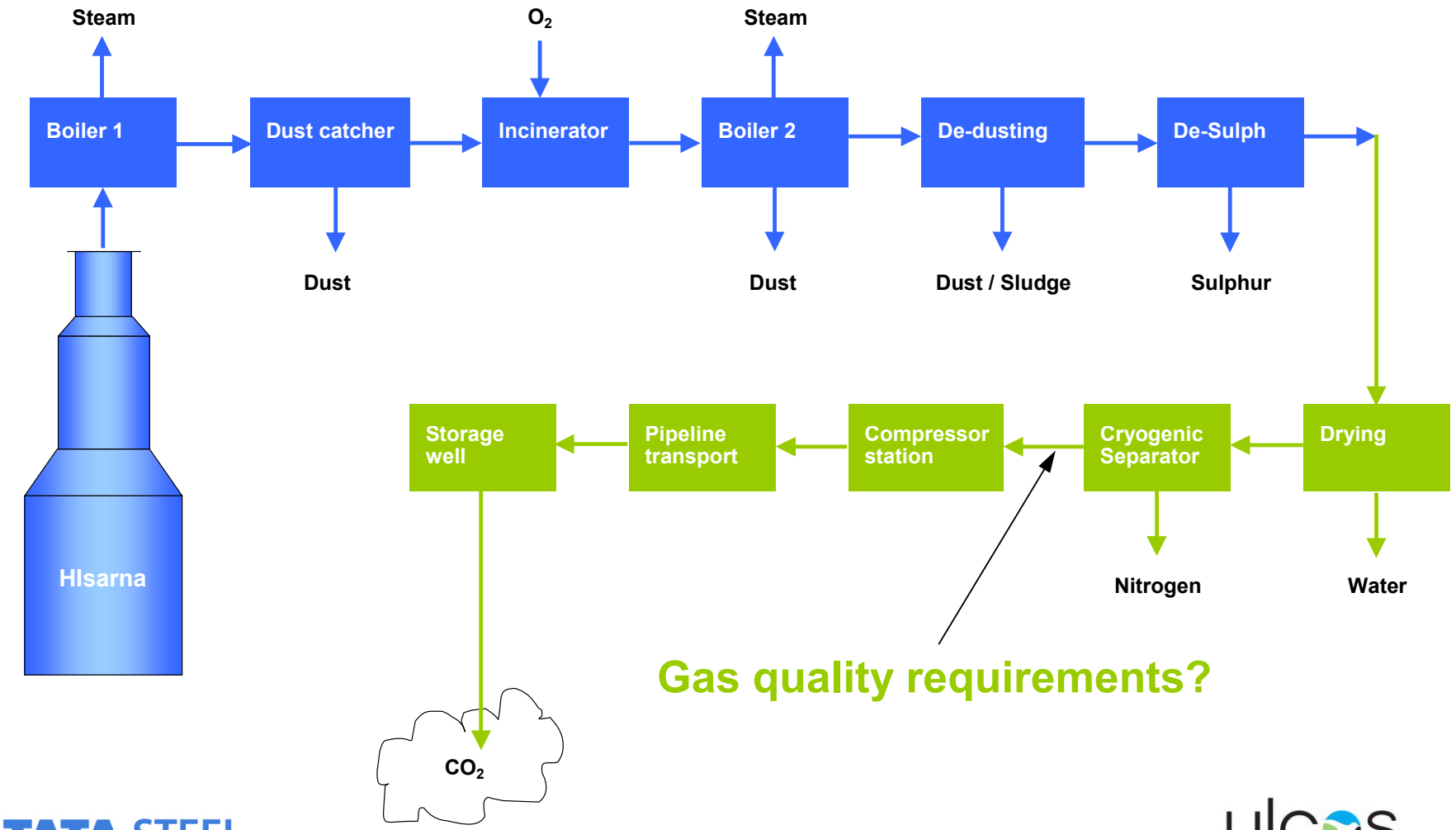


Required:

- Dust removal (staged)
- Heat recovery
- De-sulphurisation

2. HIsarna and CCS

2.3. Flowsheet with CCS

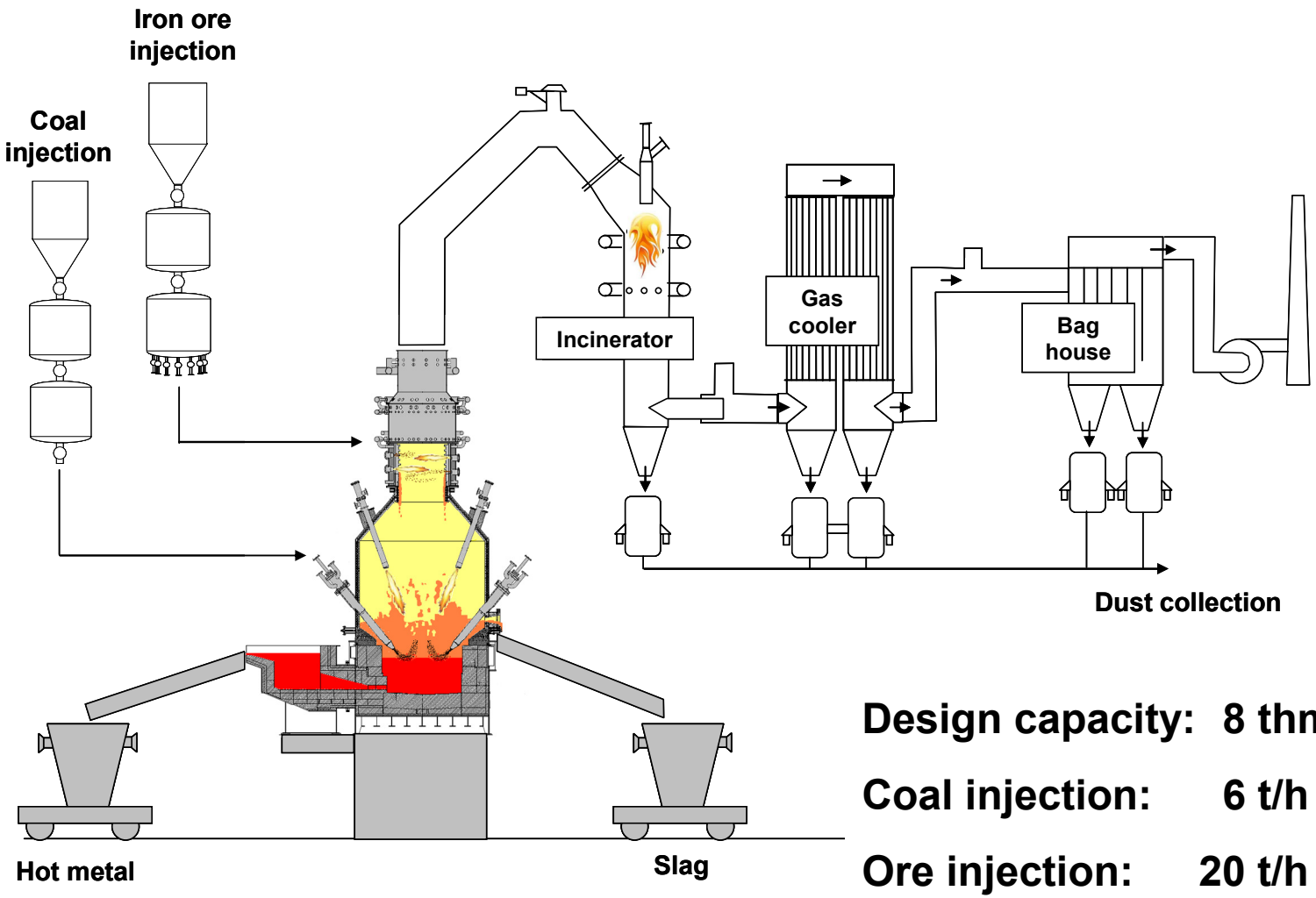


2. HIsarna and CCS

2.4. Gas quality requirements

- Technical requirements
  - Corrosion
  - Hydrate formation
  - Compression energy
- Legal requirements
  - European directive: "*Overwhelmingly CO_2*"
  - Dynamis recommendation: CO_2 > 95.5 %
- ***For HIsarna a slightly less strict CO_2 concentration would be very beneficial. According to the directive there is room for negotiation.***

3. The HIsarna pilot plant

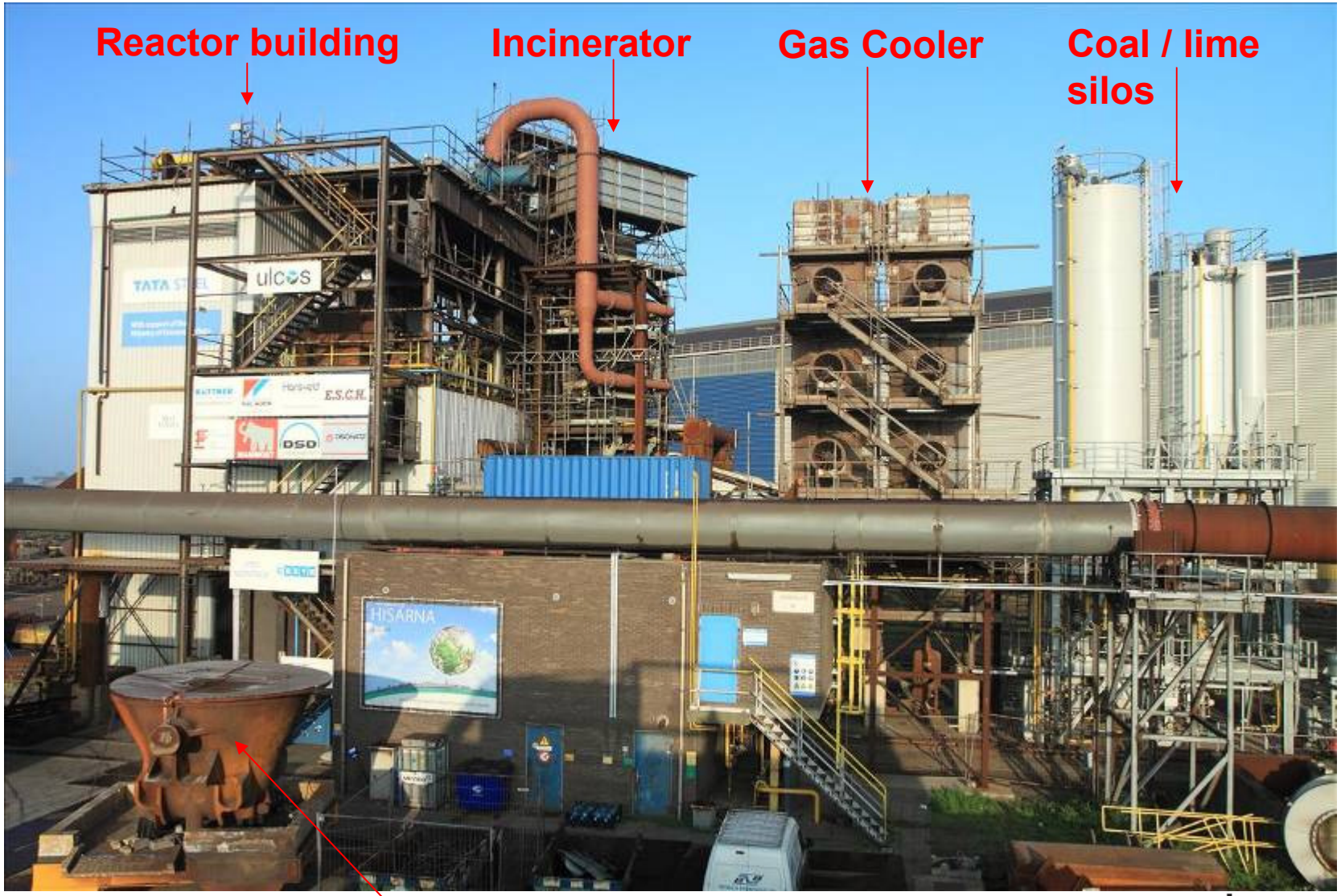


Design capacity: 8 thm/h

Coal injection: 6 t/h

Ore injection: 20 t/h

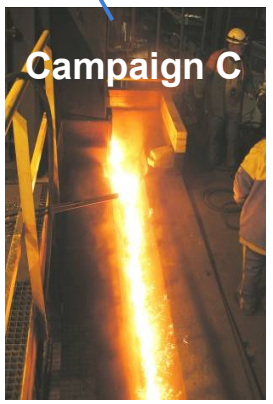
3. The HIsarna pilot plant



3.1. Pilot plant development

The HIsarna process has developed from conceptual design to the first experiments in the pilot plant.

In May 2011 the first metal was tapped.



2004

2007

2009

2010

2011

2012

2015

Preparations

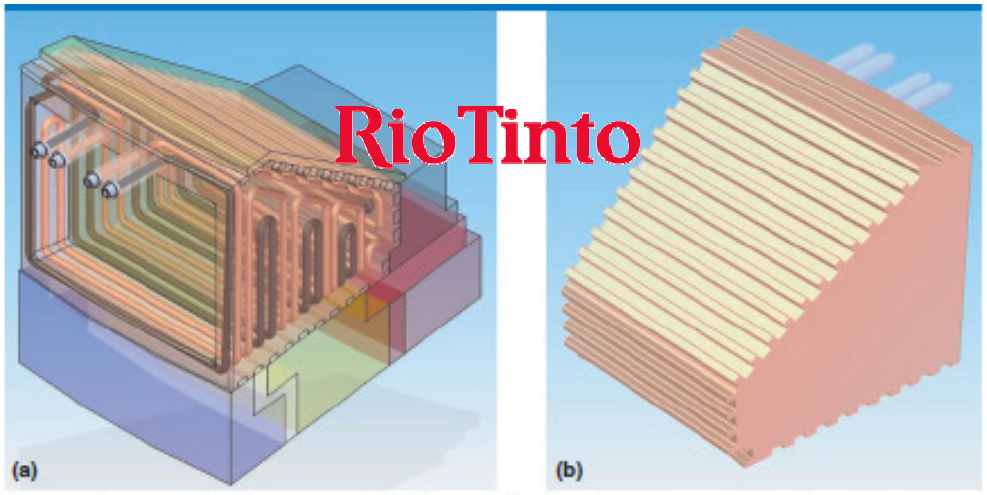
Industrial Demo

3.2. Design and Construction

3.2. Design and Construction

Refractory

- Lifetime of refractory has been a concern for the HIsmelt technology
  - Refractory lining only in lower part of the SRV
  - Critical area is the top layer of the lining in the "hot slag" zone
  - Specially designed Kwinana slag zone coolers were installed to protect this area
  - The experience so far has been good



Cooler with water-cooled copper panels for improved stadium life: (a) cross-section view of the interior, and (b) view of the exterior.

AIST, March 2009

3.3. Site construction

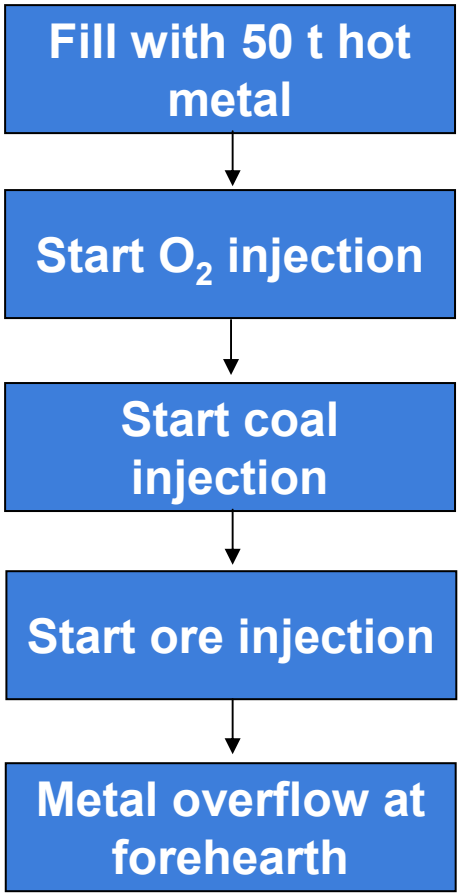
- Suitable location (former de-S plant) at Tata Steel IJmuiden
- Project execution:
  - Tata Steel Engineering
  - Tata Steel Research
  - European steelmakers
  - European equipment suppliers
  - Rio Tinto

4. Pilot plant operation

- The team:
  - Tata Steel Operations
  - Tata Steel Research
  - ULCOS partners
  - Rio Tinto

4. Pilot plant operation

Start-up procedure



Hot metal tapped from blast furnace

Secure ignition of the O_2 at bath surface

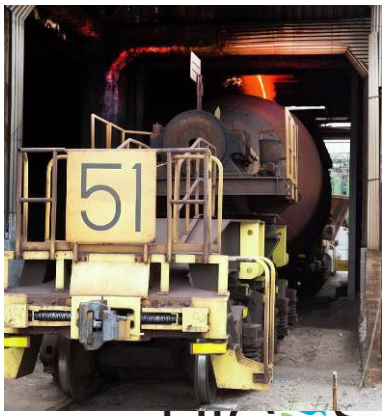
After start of coal injection the coal and O2 are ramped up stepwise

After building of a first slag layer the ore injection can start

Metal production must be achieved within 8 hours after filling

4.1. Milestones of 3 campaigns

2010	Completion of pilot plant	
2011	Campaign A	Feasibility of new process
		First tap May 2011
2012	Campaign B	First long operating period
		Standard raw materials
		65 % of design capacity reached
2013	Campaign C	First use of steam coal
		First use of low grade ore
		First metal delivered to BOF
		Good plant availability



4.2. Impressions from campaigns

Hot metal tap (continuous)

Slag tap (periodic)

5. Forward plan

New project is planned to start in 2014

Partners: Tata Steel, TKS, ArcelorMittal, voestalpine, Paul Wurth

2 additional HIsarna pilot plant campaigns are foreseen:

2014: Campaign D of 6 weeks

2015: Campaign E of 6 months

5. Forward plan
5.1. Objectives

- Campaign D (short duration):
  - Testing wider range of raw materials
  - Increasing productivity (finding upper limit)
- Campaign E (long duration):
  - Demonstrating refractory life under stable operating conditions
  - Final check for design flaws before scale up

6. Conclusions

- With the ULCOS and HIsarna project the European steel industry is proactively approaching the Climate Change issue
- In the HIsarna project knowledge end experience of steelmakers and equipment suppliers from all over Europe is brought together
- HIsarna is a high risk/high reward innovation that can potentially have a strong **environmental** and **economical** impact on the steel industry
- Environmental impact:
  without CCS **20 %** CO_2 reduction
  with CCS **80 %** CO_2 reduction
- Economical impact: Low cost ores (Zn, P) and (non-coking) coals
- No quick fix possible: Earliest industrialization 2020

Acknowledgement

The HIsarna project is made possible with the support of:

- 9 steelmakers
- Leading equipment Engineers and Suppliers
- Rio Tinto/HIsmelt
- EU FP6
- RFCS
- Dutch Ministry of Economic Affairs
- The people from Tata Steel R&D

HIsarna pilot plant


Thank you for your attention