TATA STEEL

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The HIsarna Ironmaking Process

Together we make the difference

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1. Introduction

- In 2004 several European steelmakers proactively started the ULCOS project with the objective to achieve 50 % reduction of the CO_2 emissions of steelmaking
- HIsarna is one of the four process development that originate from the ULCOS project.
- Since 2007 Tata Steel, Rio Tinto and ULCOS have been active developing this coal-based smelting reduction process.
- The HIsarna process offers a combination of **environmental** and **economical** benefits.

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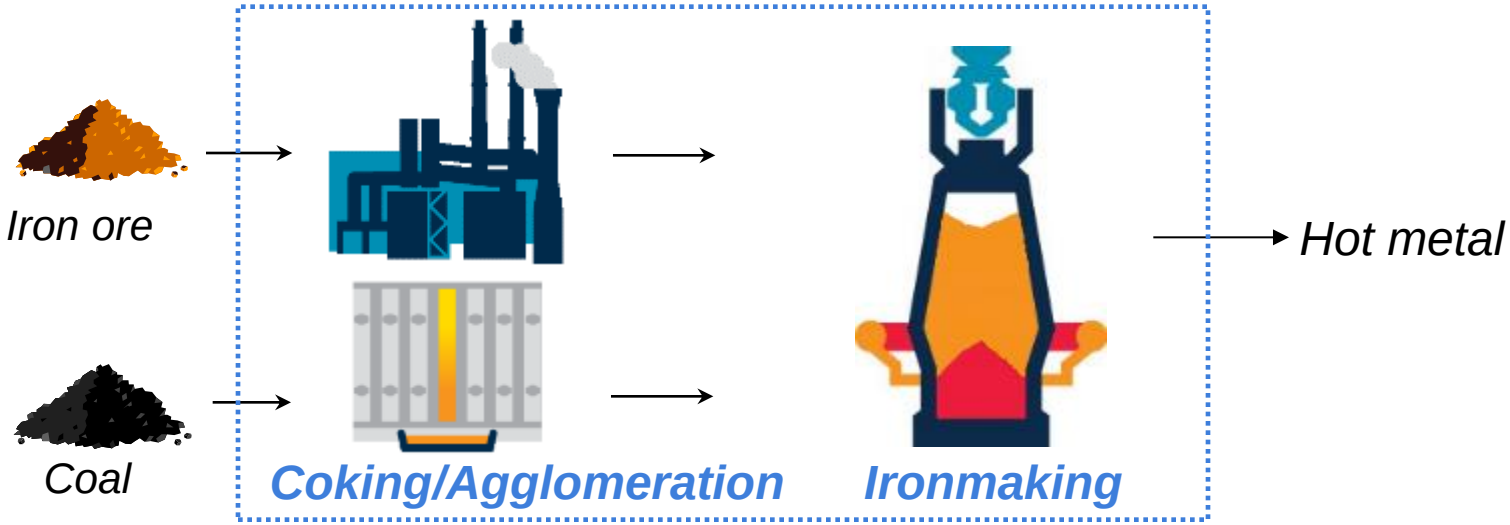
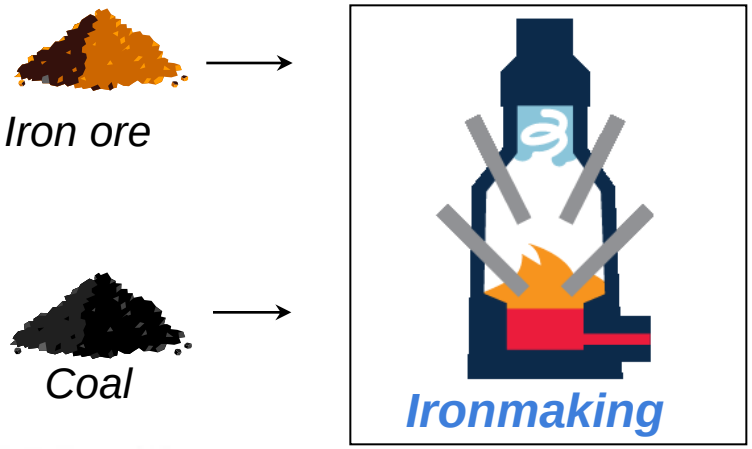
2. The benefits of HIsarna

Comparison BF route - HIsarna





Direct use of fine ores and coal (no agglomeration and coking)

2. The benefits of HIsarna

HIsarna offers a combination of **environmental** and **economic** benefits

Economic benefits

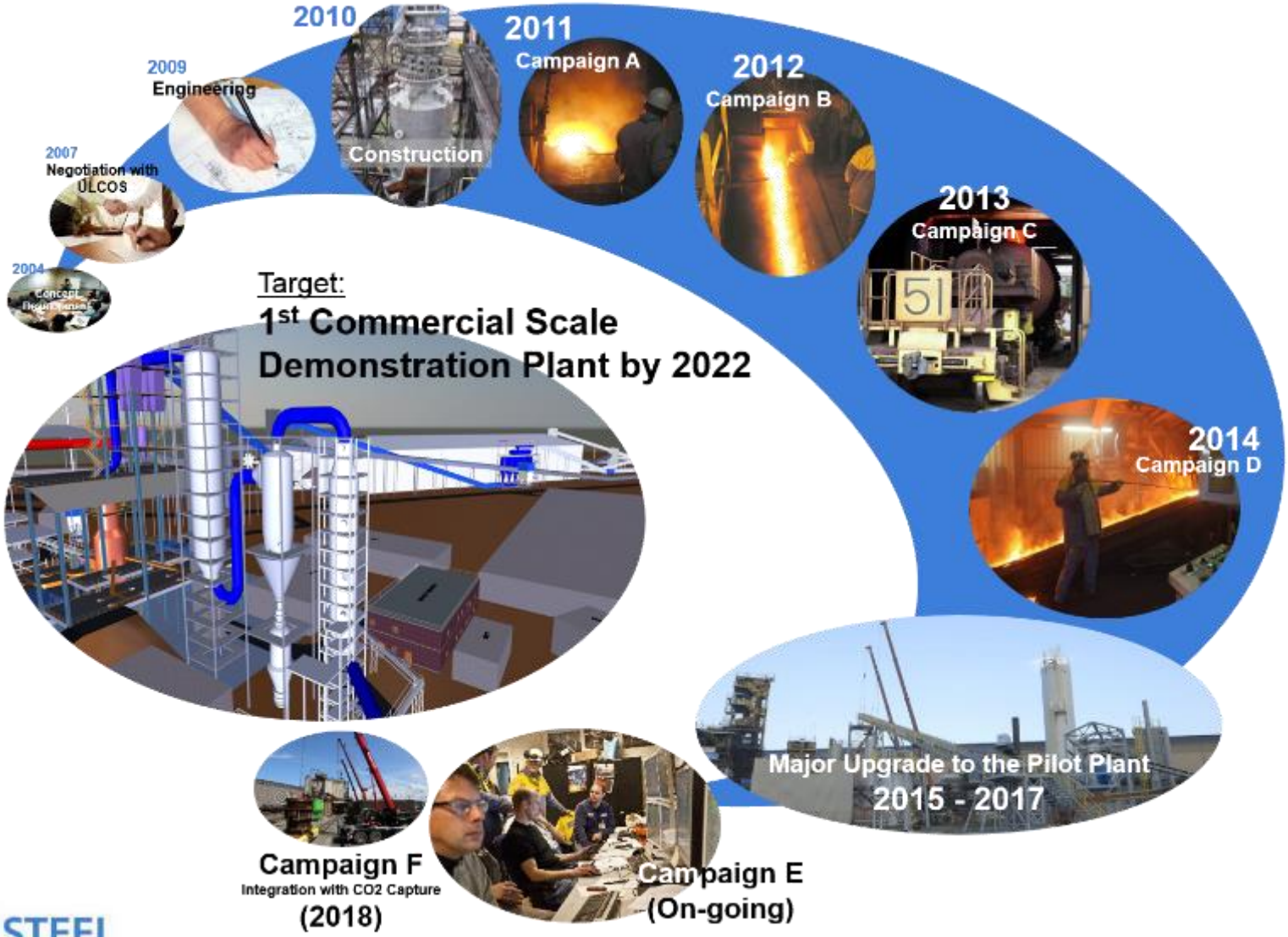
- Ironmaking with low cost raw materials, non-coking coals and low grade ores
- Recycling of waste oxides, slags and galvanised scrap
- Higher energy efficiency
- Lower steelmaking costs because of low Si, P in hot metal
- Greenfield developments with much lower CAPEX

Environmental benefits

- CO_2 emission reduction 20 % without CCS
- CO_2 emission reduction 80 % with CCS
- Lower emissions SO_X, NO_X, dioxines and fine dust
- Avoidance of dumping slags and dusts

3. HIsarna Pilot Plant

Over 10 Years of Development



3. HIsarna pilot plant

Achievements

2011
- First metal tap

2012
- First long operating period

2013
- High energy efficiency
- First metal delivered to BOS plant

2014
- Recycling of high Zn waste oxides
- Recycling of scrap

2015 - 2017
- Major plant expansion (20 M€ investment)
- CO_2 reduction target of 35 %
- Long duration testing of process and equipment
- Financial support from EU Horizon2020
- Dutch Government DEI (Demonstratie Energie Innovatie)

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Hlsarna Pilotplant

1. Alternative raw materials storage silos
2. Off-gas duct
3. Gas cooler
4. Coal and lime storage silos
5. Cooling towers
6. Bag filter
7. Secondary dedusting
8. Smelting cyclone
9. Smelting reduction vessel
10. Fore hearth
11. Control room
12. Coal grinding, drying and screening
13. Ore drying and screening
14. Raw materials storage
15. Offices
16. Workshop

Raw materials preparation

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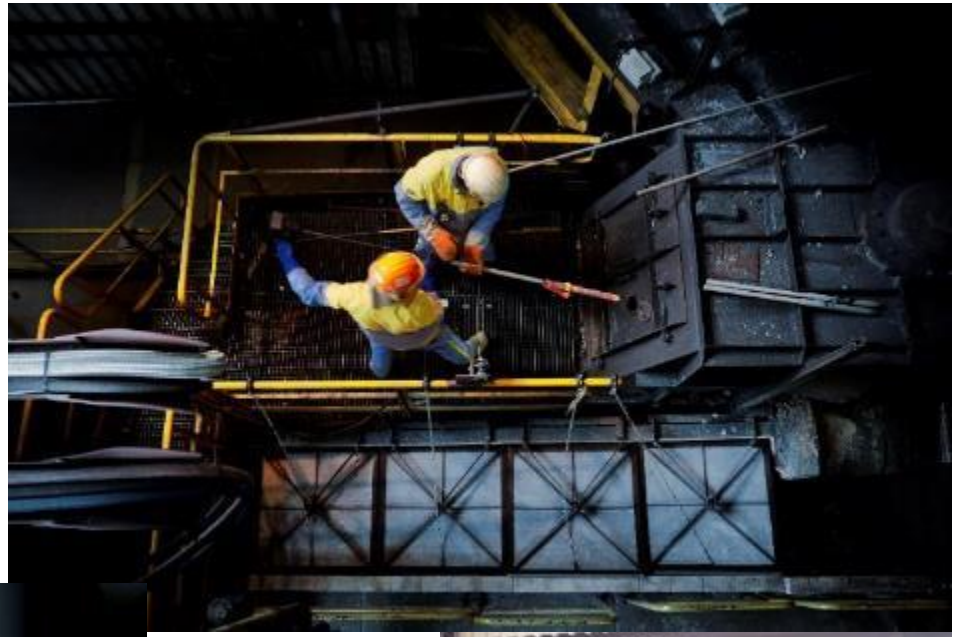
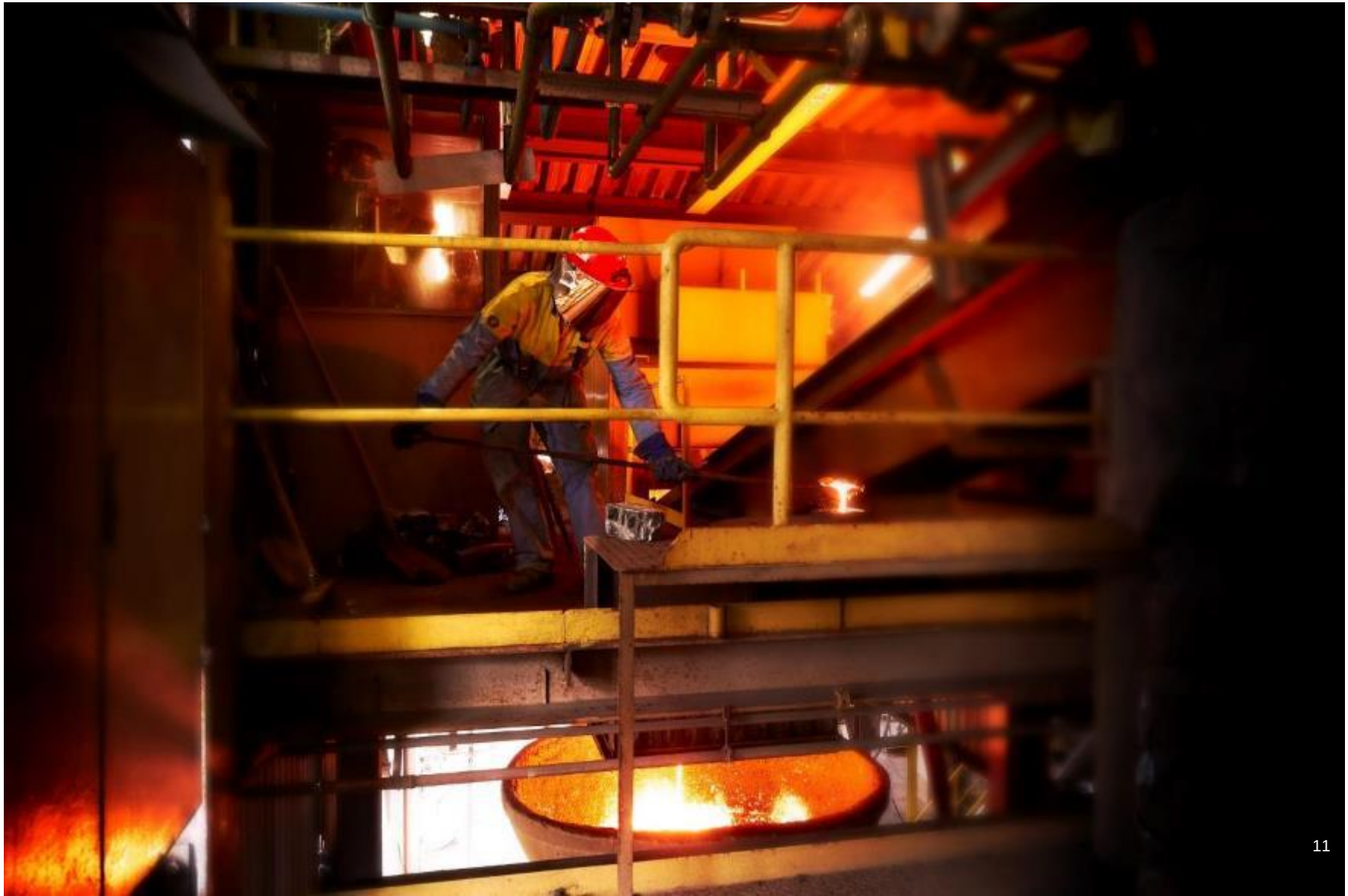
Hot metal production



Regular slag tap and slag sampling

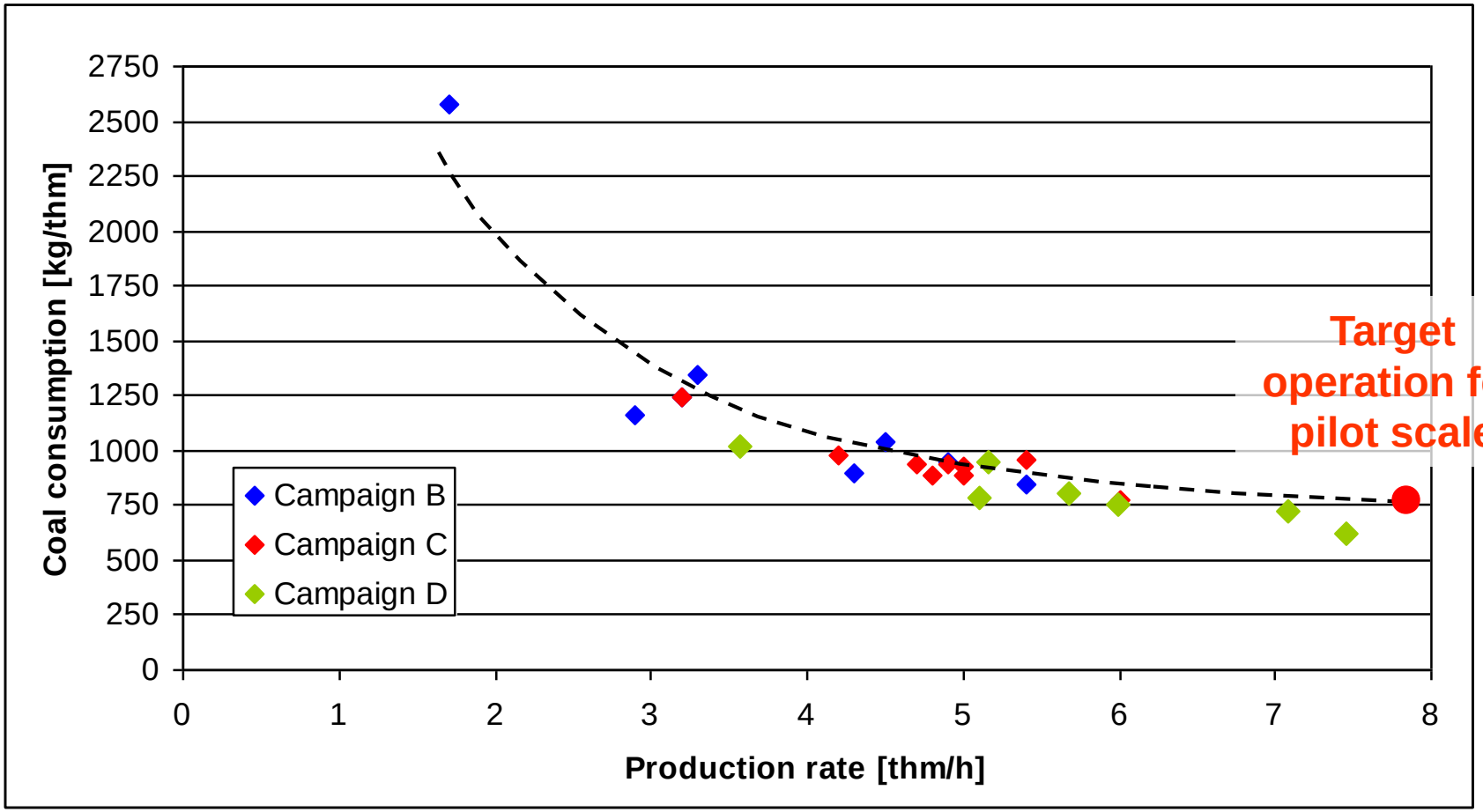


3.1 Campaign C & D: Raw Materials

- Standard Ore:
  - Campaign C: high quality hematite (65% Fe), finer granulometry
  - Campaign D: high quality hematite (63% Fe), coarser granulometry
- Alternative Ores:
  - Ironstone: Low quality (33% Fe)
- Coal Types:
  - Standard: Low-volatile 8% VM
  - Alternative 1: Mid-volatile coal 22% VM
  - Alternative 2: High-volatile coal 39% VM
- Fluxes
  - Lime
  - BOF sludge (high lime content)

3.2 Coal requirement

Coal rate achieved during the 4 campaigns



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3.3 Overall results Campaign C & D

- Stable operation at ~ 90 % nameplate capacity (~ 7 tHM/h)
- Successful operation with hematite ores, low-vol, mid-vol and high-vol coals
- Cyclone capture efficiency and pre-reduction in line with earlier experience
- Coal rates reached expectation (design 750 kg/tHM at pilot scale)
- Post Combustion Ratios > 90% achieved for long stable periods
- Successful tapping into torpedo ladle cars, subsequently used for steel making at BOS plant

4. Further development

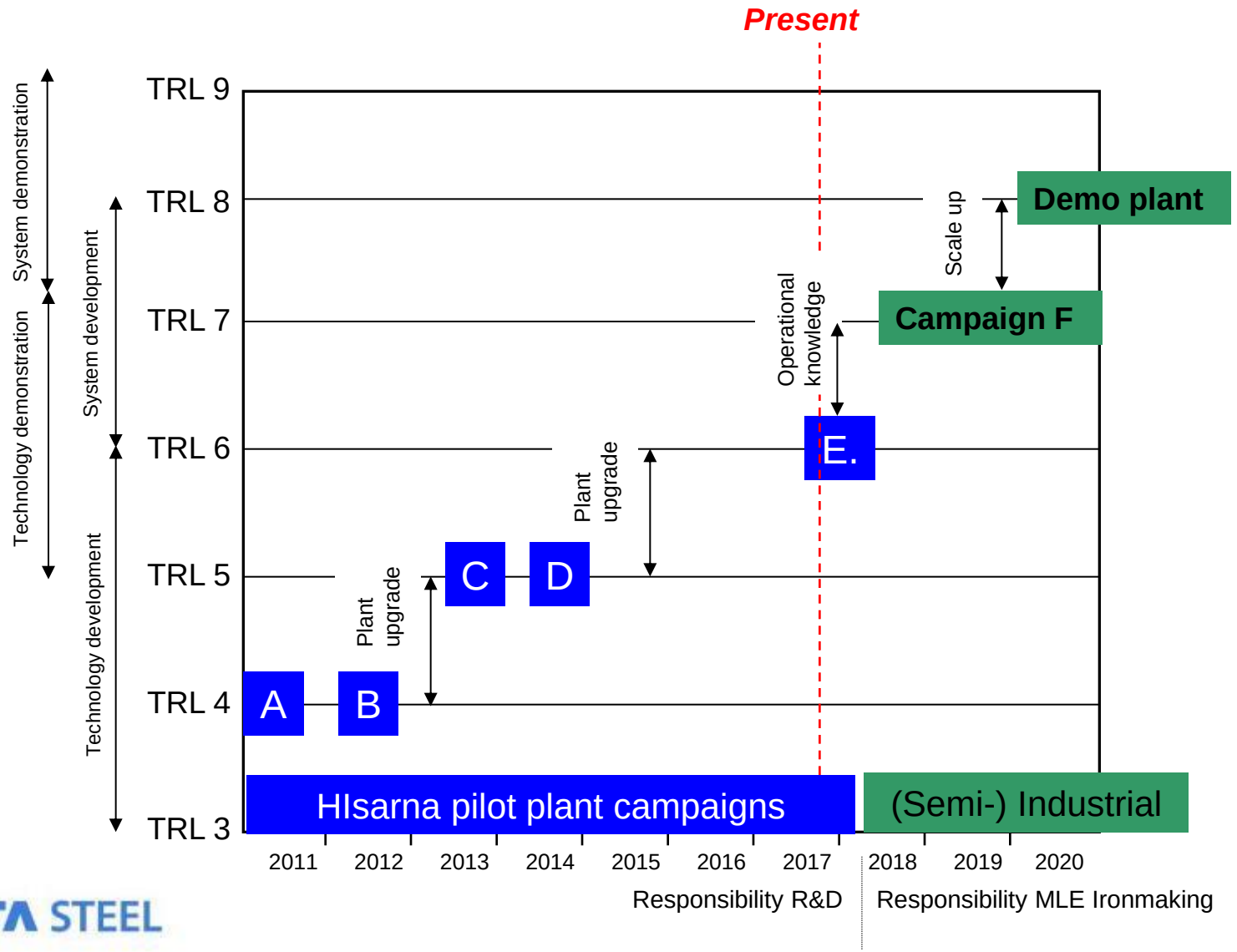
Demo plant preparation:

- Scale up
- Demo plant engineering study

Further technology development at the pilot plant:

- CO_2 capture at the pilot plant
- Recycling of galvanised steel scrap
- Zn recovery from steel plant waste oxides
- Partial replacement of coal by natural gas and/or biomass

4. Further development
4.1. Towards the Demo plant

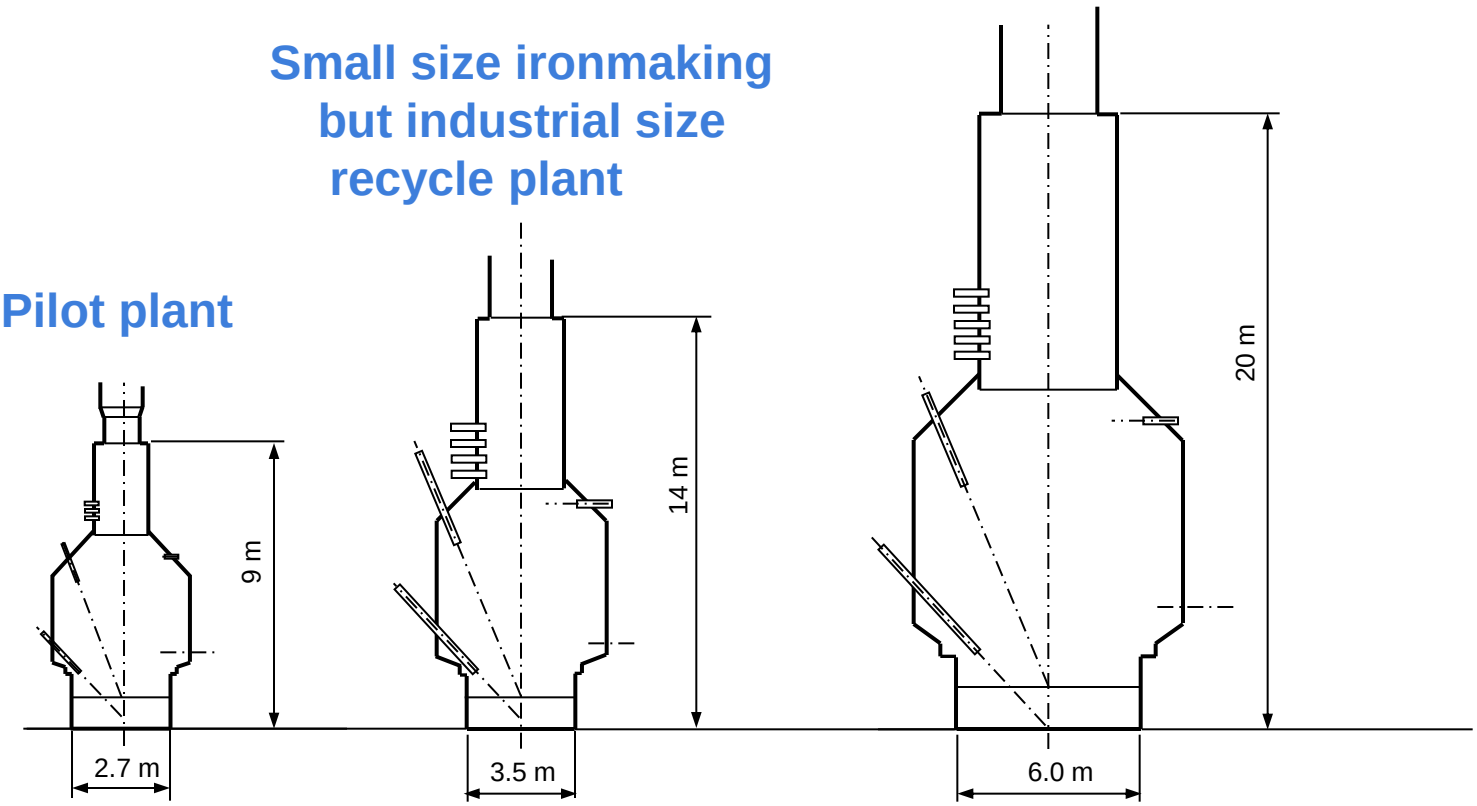


4.2 Scale up

Pilot plant

Small size ironmaking but industrial size recycle plant

Industrial size ironmaking



60,000 thm/year

Atmospheric

1.0 bar abs

400,000 thm/year

Pressurised

1.8 bar abs

1,000,000 thm/year

Pressurised

1.8 bar abs

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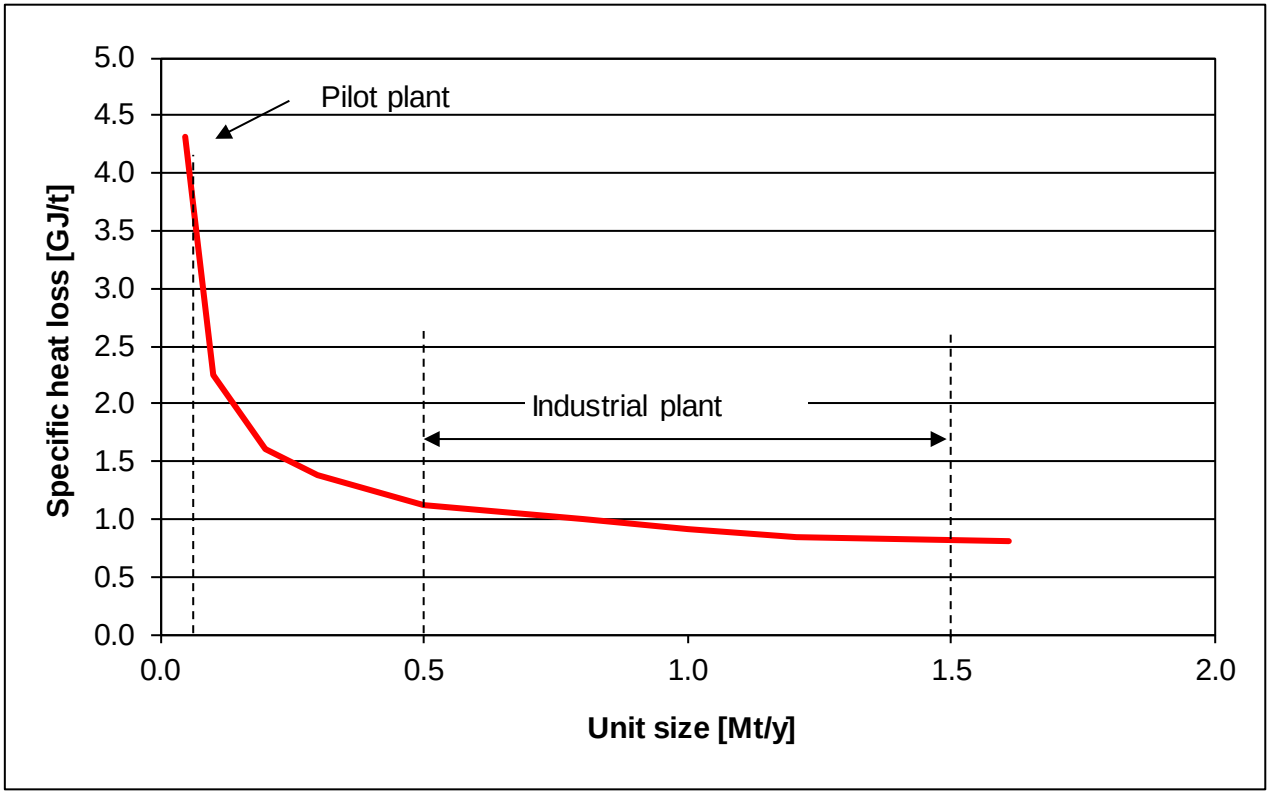
Bigger plants are more efficient

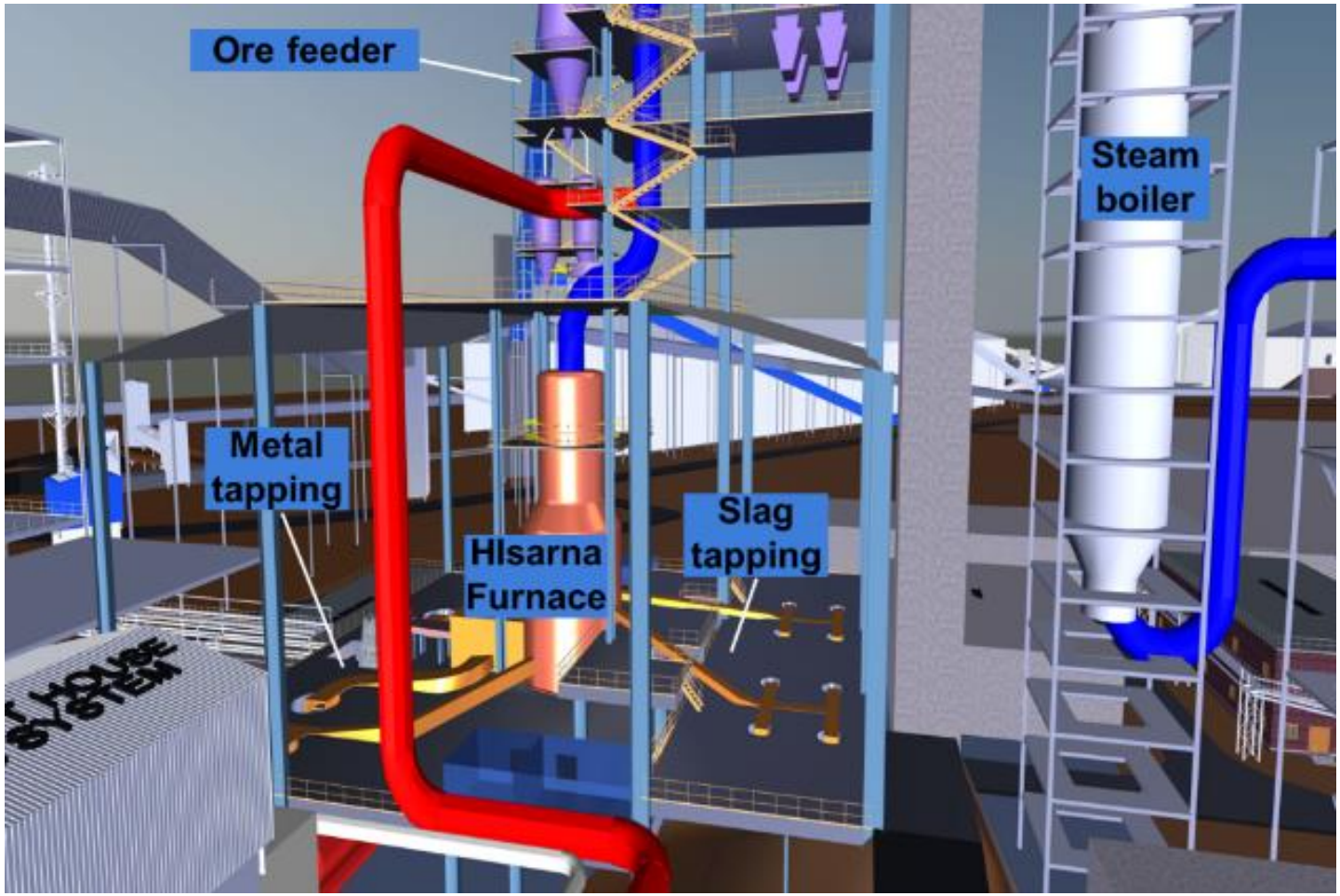


4.3 Industrial scale HIsmelt

- A HIsmelt furnace with a hearth diameter of 6.5 m operated in Kwinana, Australia and now in Molong, China.
- En engineering package (12,000 documents) of this facility is owned by Rio Tinto

4.4 Engineering study

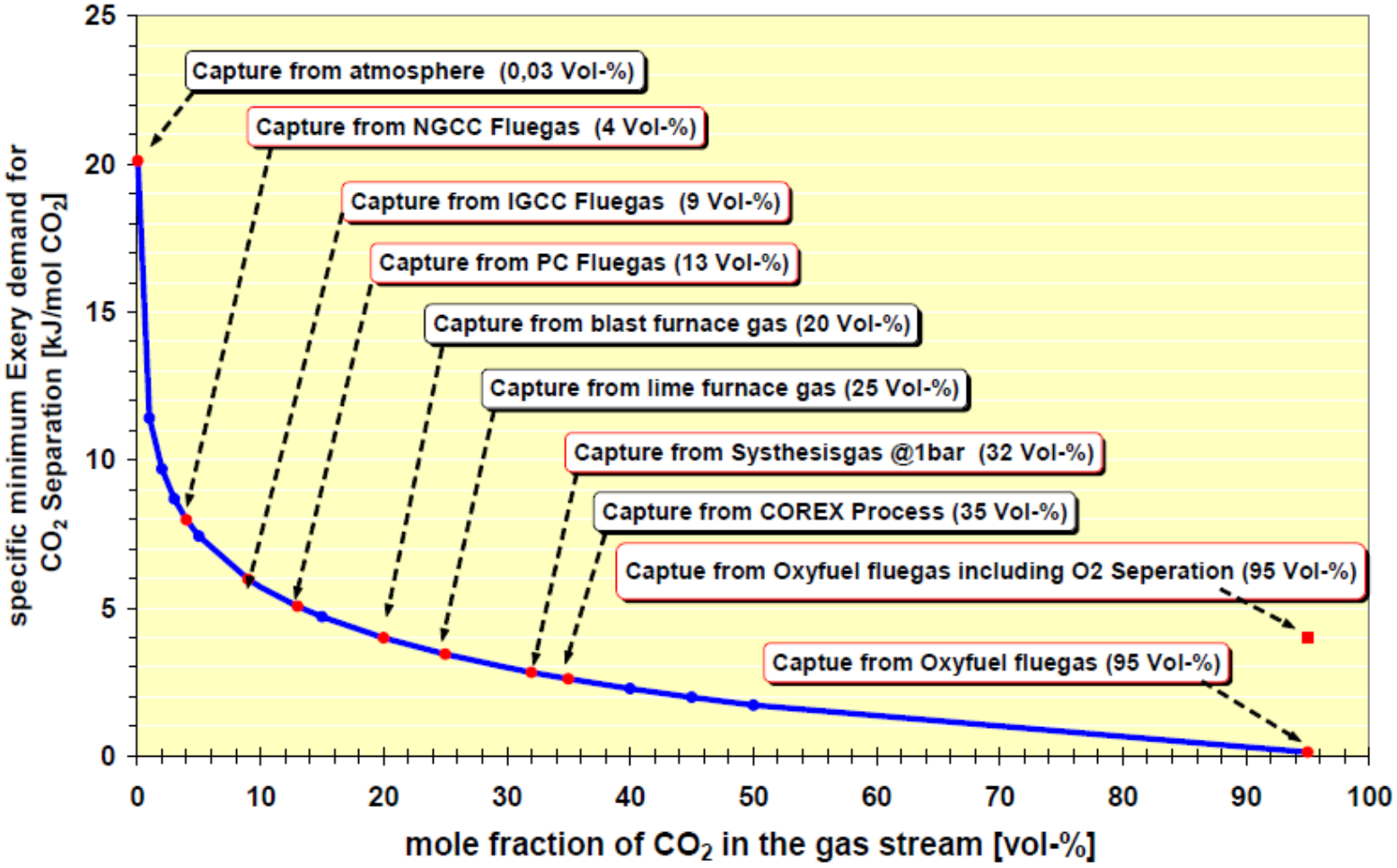
- Study made for 1 Mt/y HIsarna plant at Tata Steel IJmuiden site



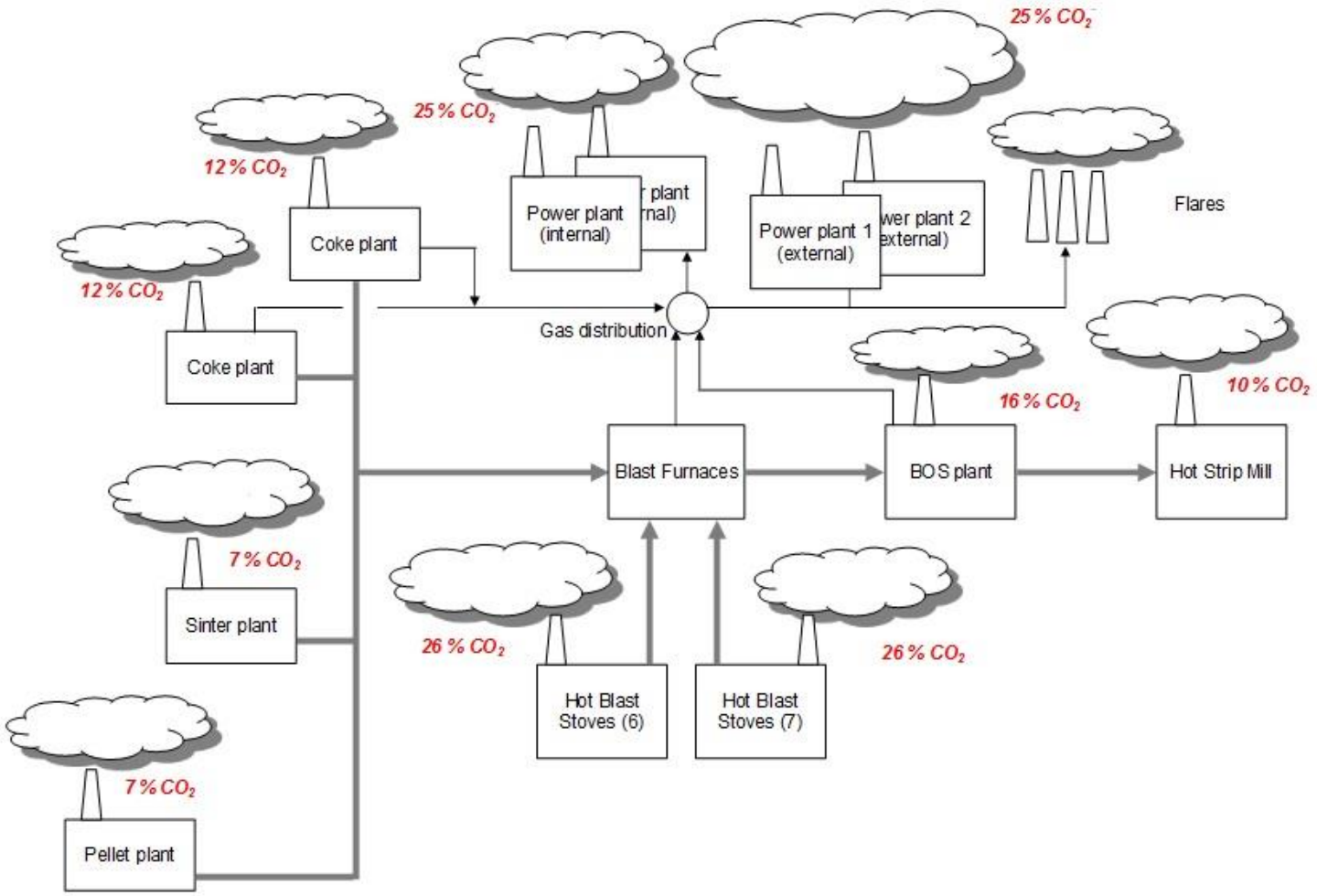
4.5 CCU or CCS

The HIsarna process is very suited for a combination CCS or with CCU because:

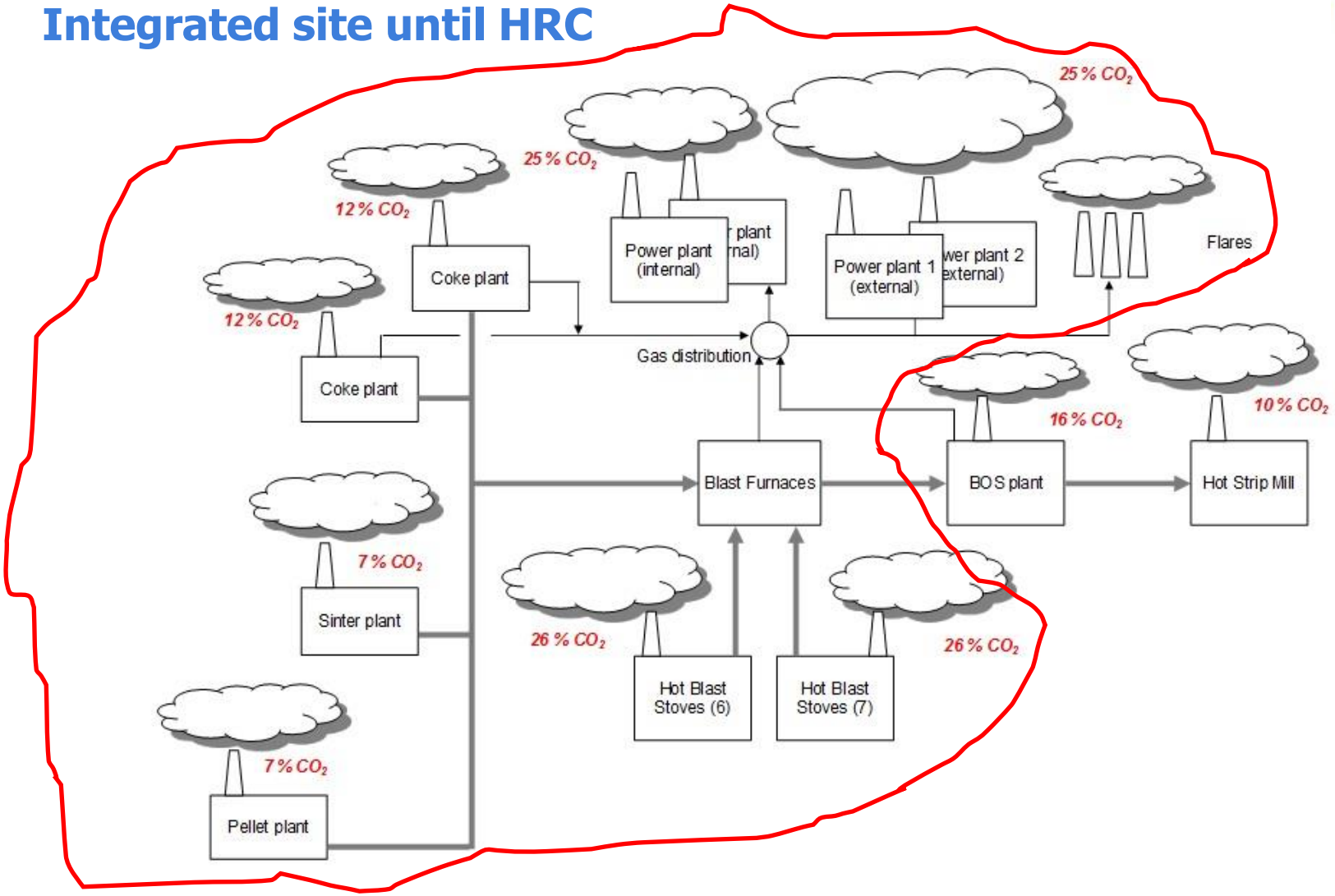
- The CO_2 concentration in the HIsarna off gas is > 85 %
- With the HIsarna process the emissions are concentrated at a single stack


specific minimum Exery demand for CO_2 Separation [kJ/mol CO_2]
mole fraction of CO_2 in the gas stream [vol-%]
Capture from atmosphere (0,03 Vol-%)
Capture from NGCC Fluegas (4 Vol-%)
Capture from IGCC Fluegas (9 Vol-%)
Capture from PC Fluegas (13 Vol-%)
Capture from blast furnace gas (20 Vol-%)
Capture from lime furnace gas (25 Vol-%)
Capture from Systhesisgas @1bar (32 Vol-%)
Capture from COREX Process (35 Vol-%)
Captue from Oxyfuel fluegas including O2 Seperation (95 Vol-%)
Captue from Oxyfuel fluegas (95 Vol-%)
0
5
10
15
20
25
0
10
20
30
40
50
60
70
80
90
100

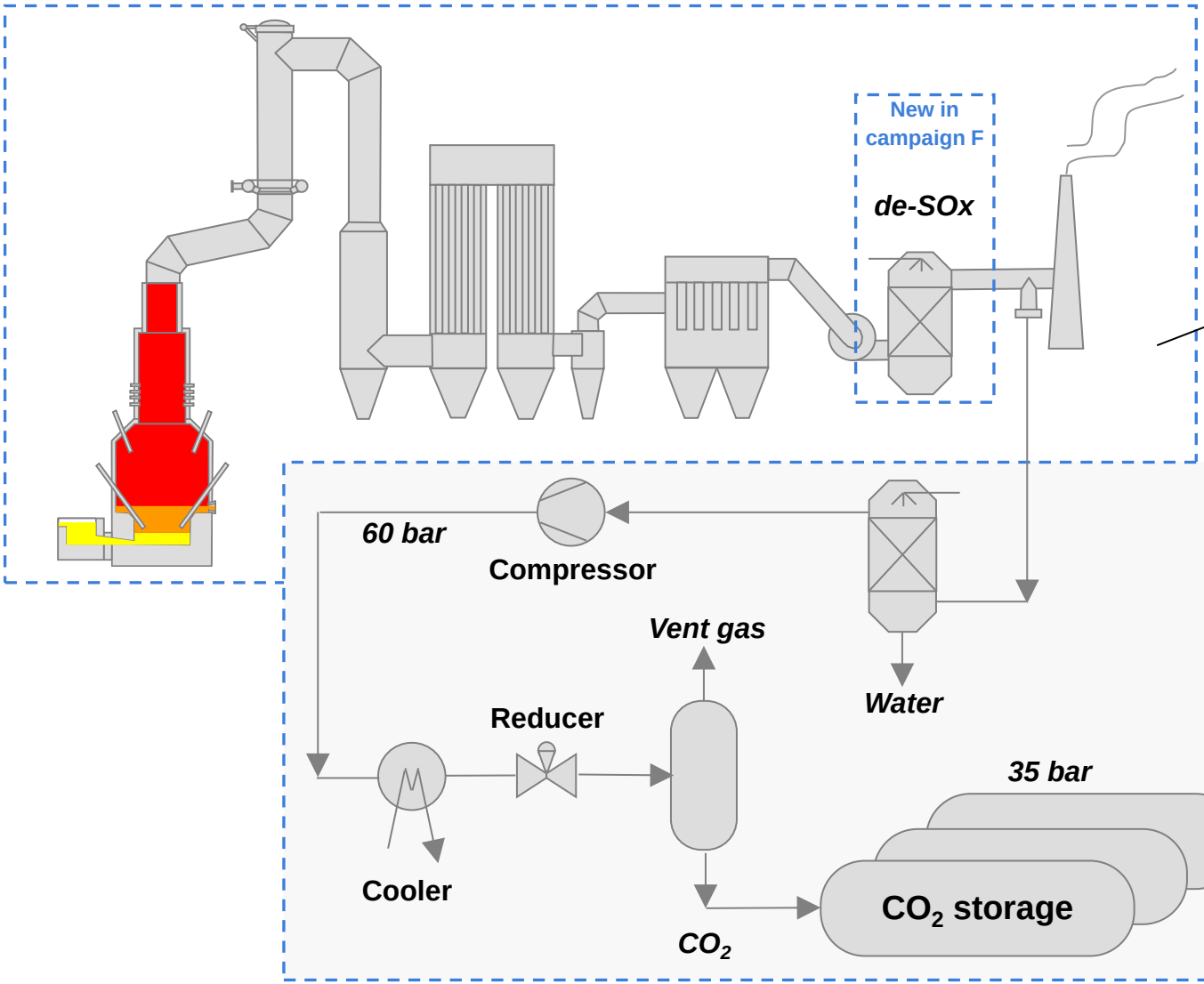
Integrated site until HRC



Integrated site until HRC



4.6 HIsarna pilot plant with CO_2 capture unit



100 kt-CO_2/y to greenhouses

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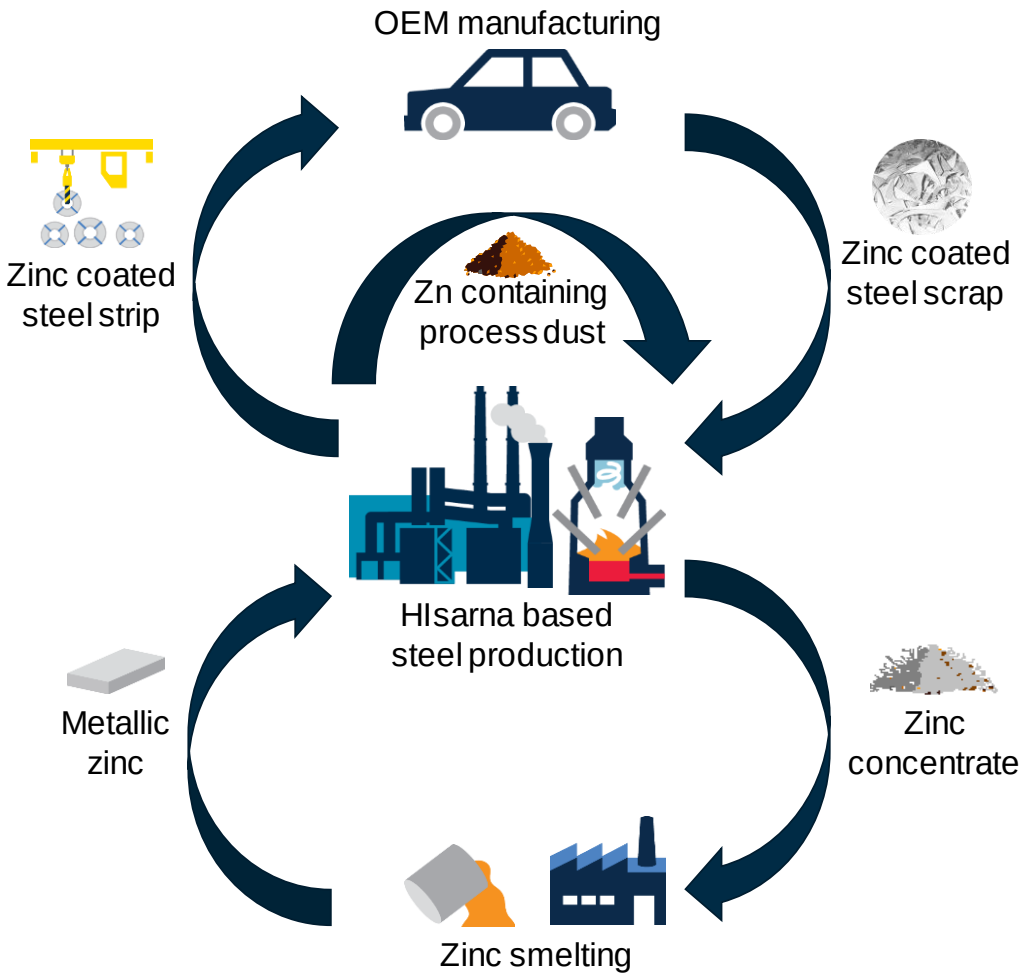
4.7 By-product recycling

HIsarna can use Fe rich process dusts and sludges from other process as a raw material.

These include BOF sludge and BF dust, also those with a high Zn fraction. This was succesfully done for the first time in campaign D (2014)

The objective is to reach sufficient Zn rich dusts for use in Zn smelters



5. Conclusions

- HIsarna is a new coal-based ironmaking process offering both economical and environmental benefits
- The environmental benefits include a 20 % reduction of CO_2 emissions without CCS/CCU
- 80 – 90 % CO_2 reduction with CCS/CCU
- Experimental results of the plant in IJmuiden have confirmed the:
  - High energy efficiency
  - Raw material flexibility
  - Good start/stop abilities of the process
- Conceptual engineering for the first industrial scale plant, 0.5 to 1.0 M t/y, has started