TATA STEEL

TATA

Development of the HIsarna process

Alternative Ironmaking technology with CO_2 capture potential

Koen Meijer
Christiaan Zeilstra
Tata Steel Research, Development & Technology

Industry CCS Workshop, VDEh, Düsseldorf
8 - 9 November 2011

Content

1. Sustainability
2. The ULCOS project
3. HIsarna technology
4. HIsarna and CCS
5. HIsarna development
6. First Campaign
7. Preliminary results
8. Conclusions

1. Sustainability

Steel industry strives for continuous improvement of their environmental performance and sustainability

- Steel is **100 %** recyclable
- New steel qualities improve sustainability of our costumers products
- Steel industry is committed to ongoing energy saving and reduction of CO_2 emission
- Steel accounts for **5 % of man-made CO_2**

1. Sustainability

1.1. Challenge

Growth

World steel consumption will double in 2050

Sustainability

Ambition to cut CO_2 emissions by 50 % in 2050

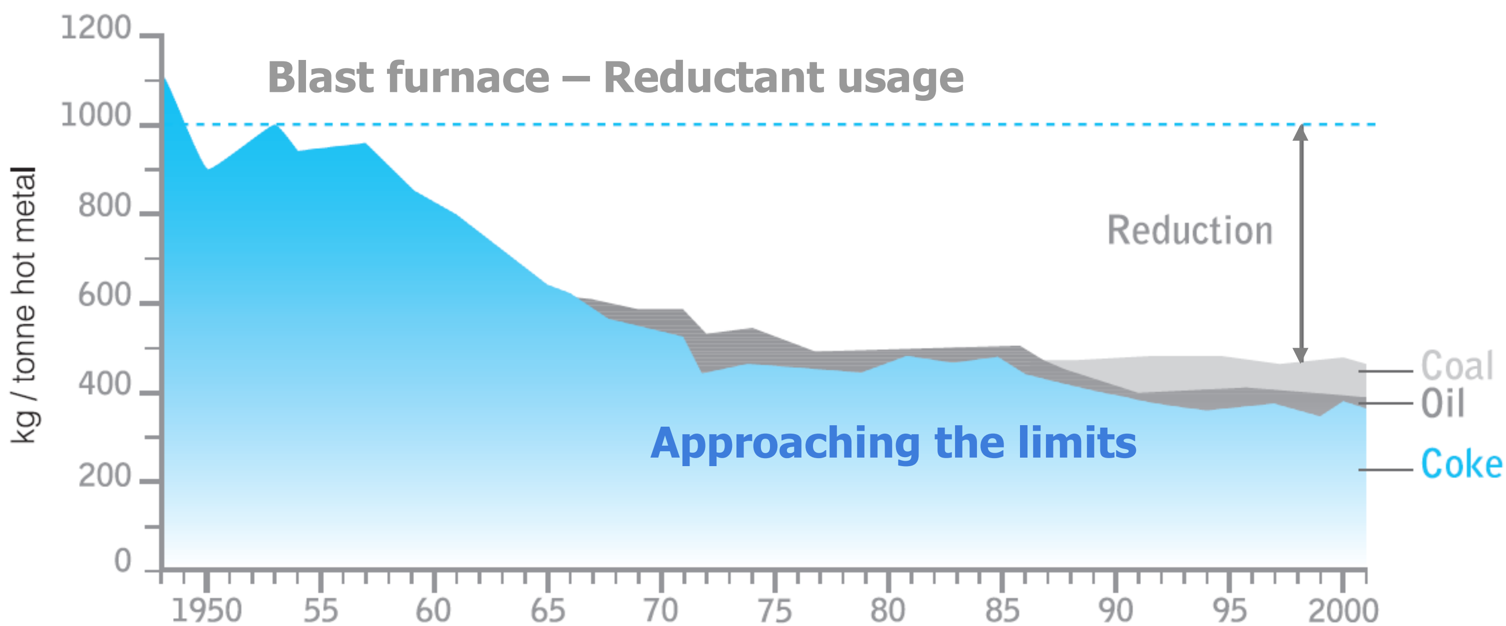
1. Sustainability

1.2. Need for breakthrough developments

- Focus on Ironmaking (80 – 90 % of CO_2)
- Present operation close to "Best Practice"

→ Further energy saving will **not** deliver long term target

→ **Breakthrough** development needed



2. The ULCOS project

Objective:

50% reduction in CO_2 emissions per ton of steel from iron ore based steel production by 2050

- Globally the largest Steel Industry project on Climate Change
- Core partners: ArcelorMittal, Tata Steel, ThyssenKrupp, Ilva, Voestalpine, LKAB, Dillingen/Saarstahl, SSAB, Rautaruukki
- Co-partners: over 40 Institutes, Universities, Engineering companies, etc

- Budget: **70 M€**
- Duration phase I: **2004 - 2010**

2. The ULCOS project

2.1. ULCOS subjects

1. Efficiency of carbon use

   New and improved processes

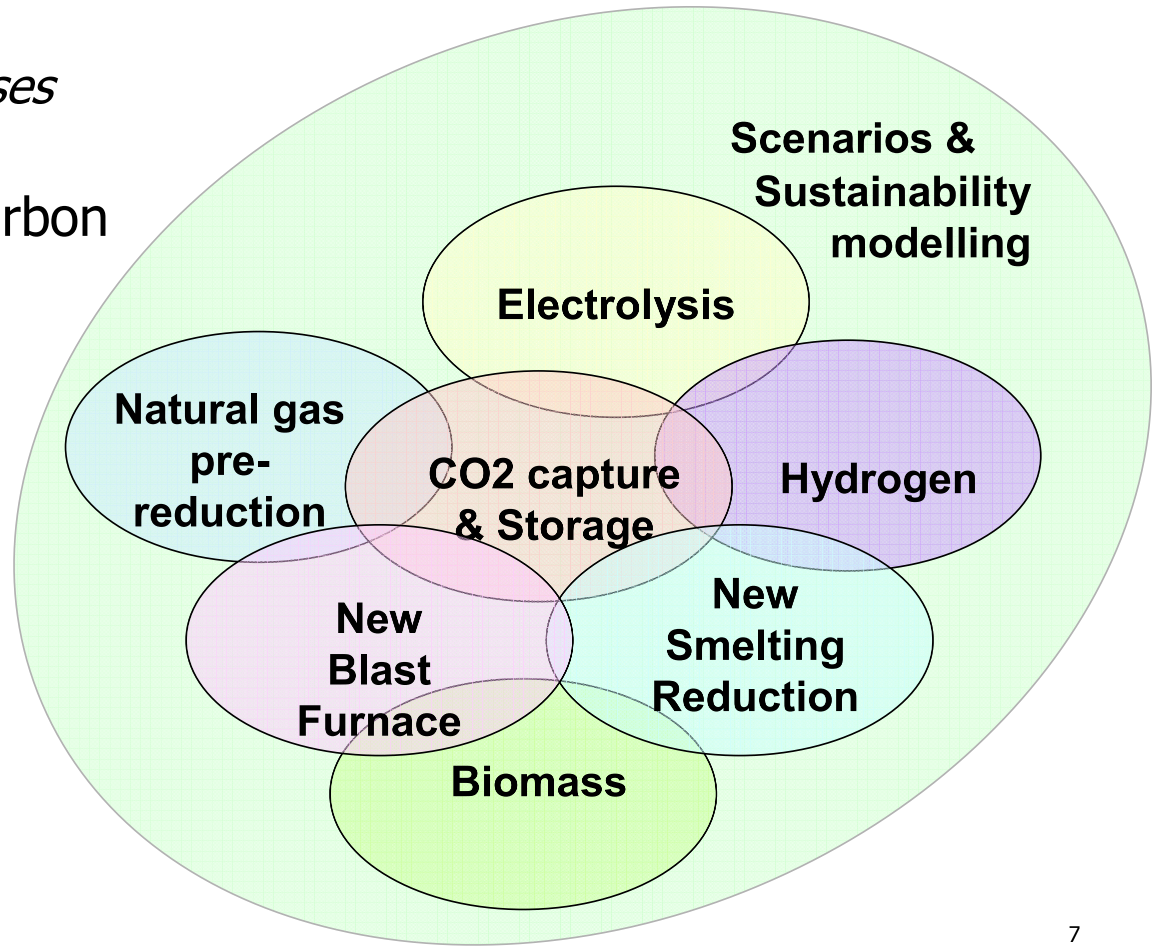
2. Replacement of fossil carbon

   Biomass

   Hydrogen

   Electricity

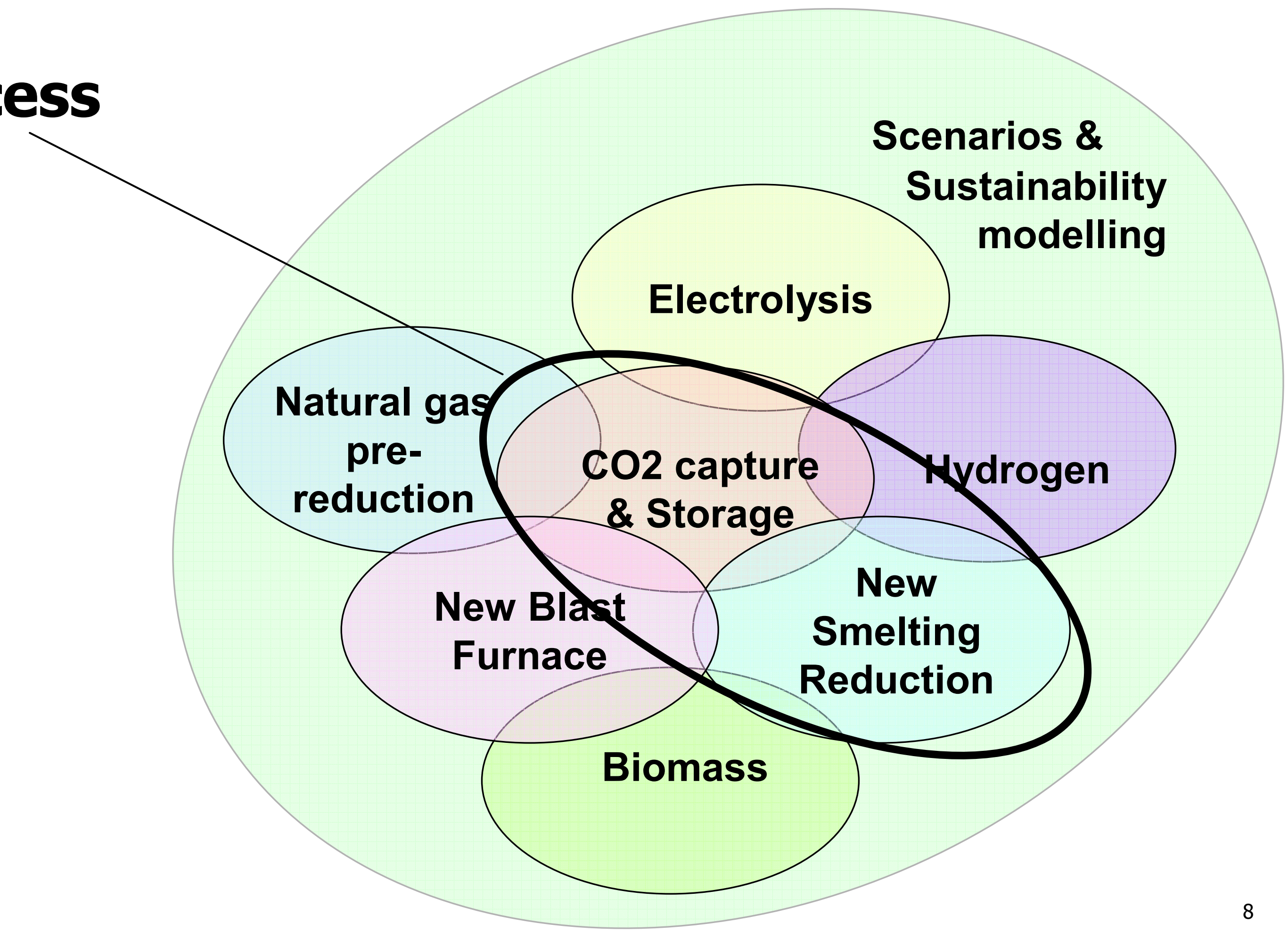
3. Capture



2. The ULCOS project

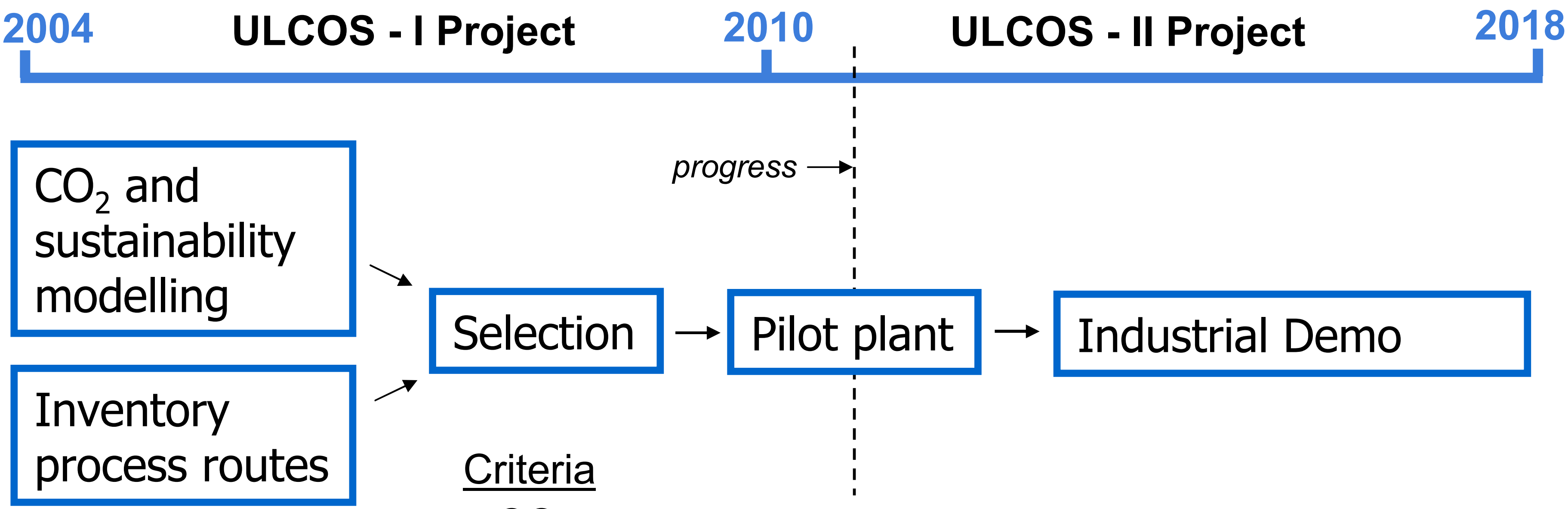
2.1. ULCOS subjects

HIsarna process



2. The ULCOS project

2.2. Ironmaking process selection



<u>Criteria</u>

- CO_2
- Economical
- Technical maturity
- Social
- Other environmental aspects
- Fit with existing configuration

2. The ULCOS project

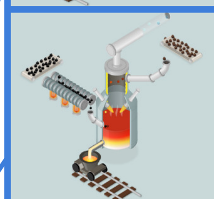
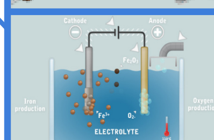
2.2. Ironmaking process selection

2004 **ULCOS - I Project** **2010** **ULCOS - II Project** **2018**

CO_2 and sustainability modelling

Inventory process routes

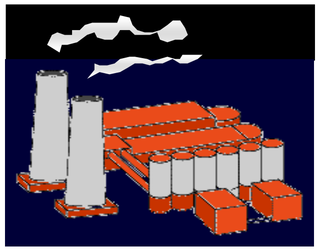
Selection

4 processes selected	
	*Top Gas recycling BF*
	*HIsarna*
	*Gas based reduction*
	*Electrolysis of iron ore*

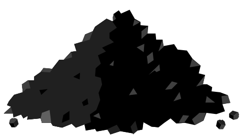
3. HIsarna technology

3.1. Comparison with the BF route

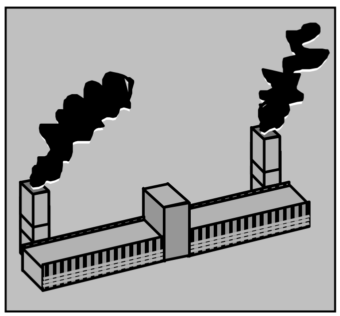
Iron ore



sinter

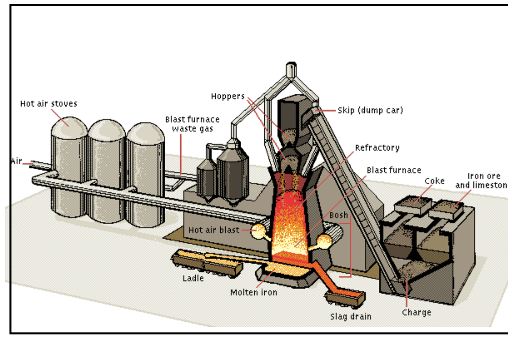


coal



coke

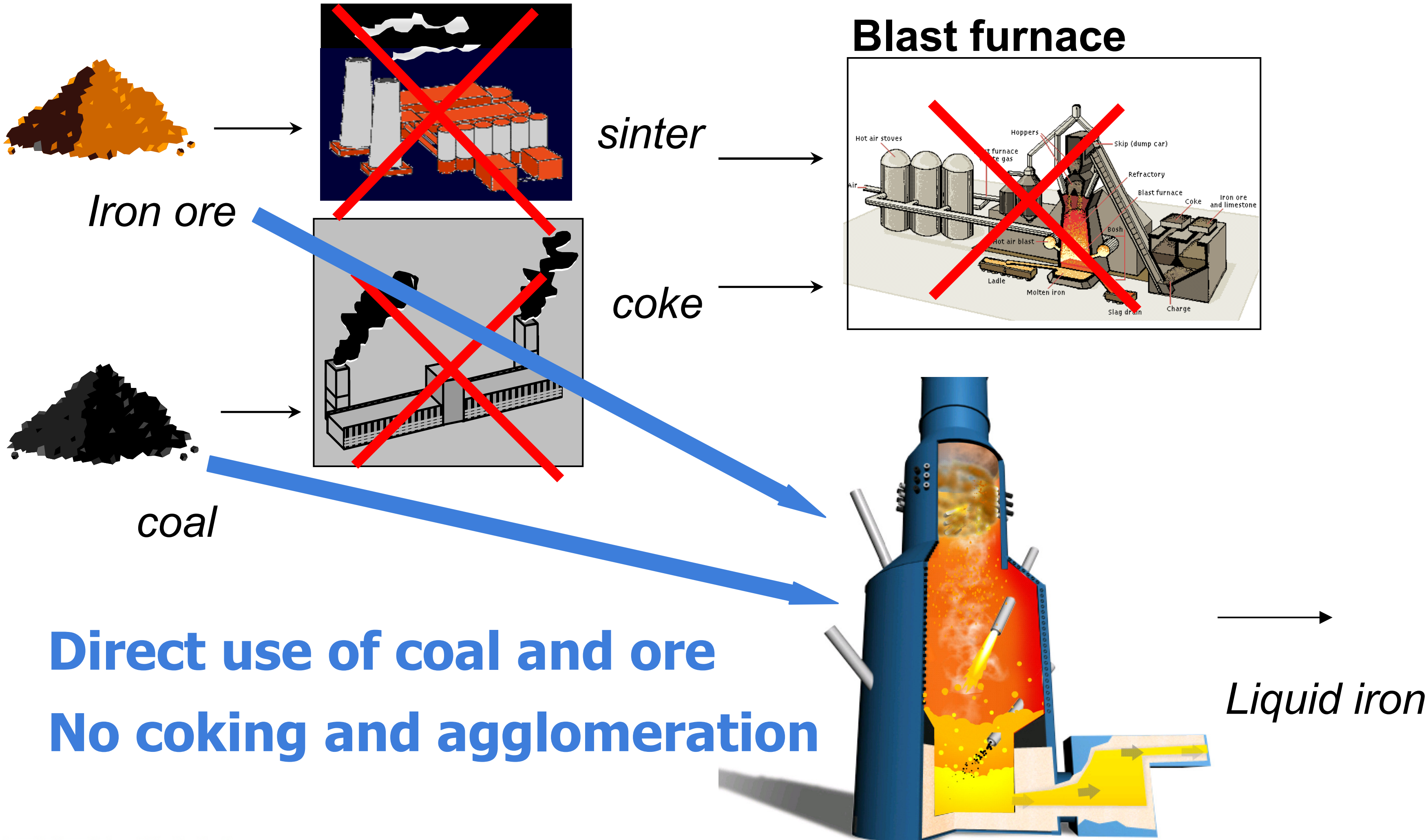
Blast furnace



Liquid iron

3. HIsarna technology

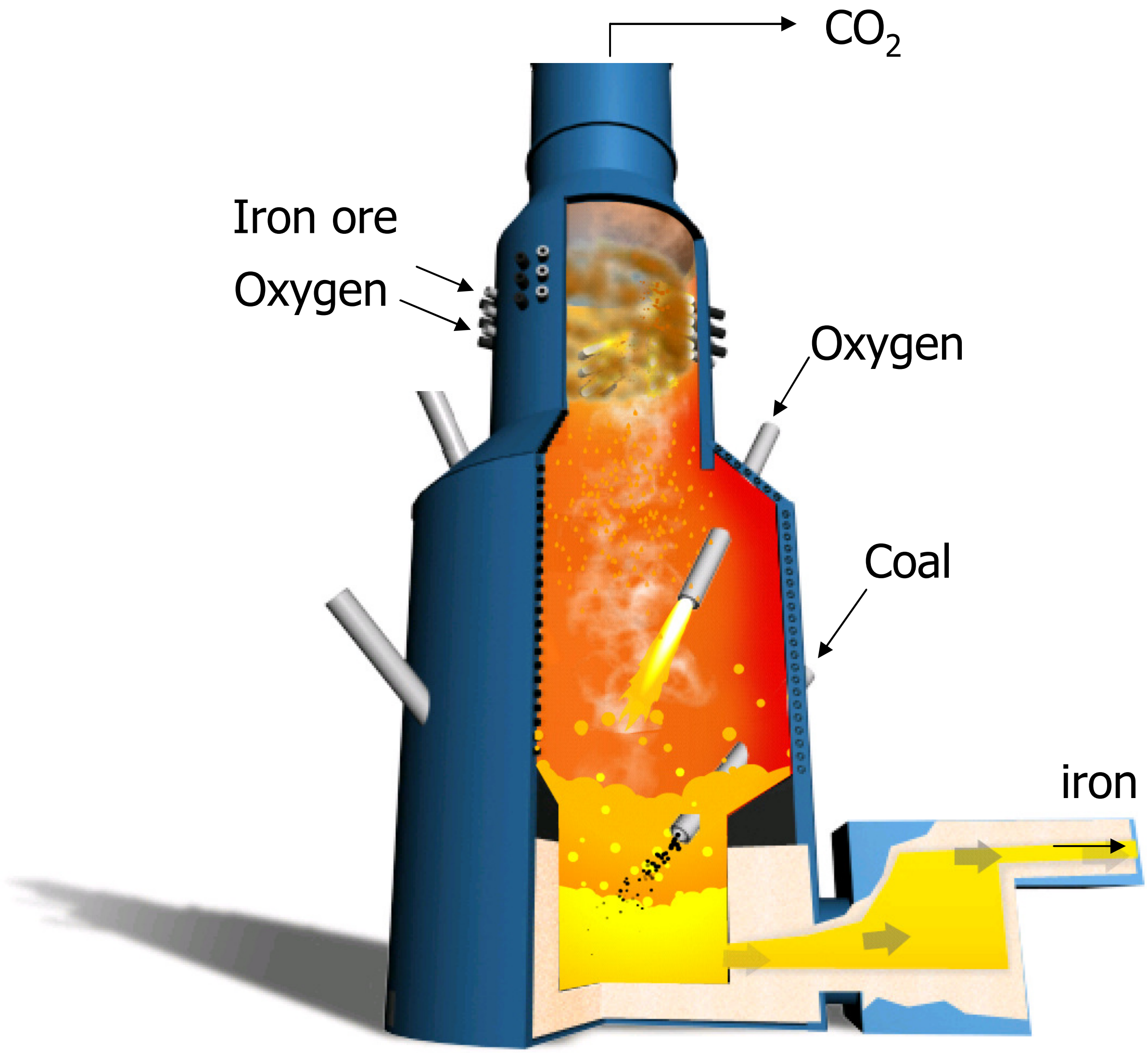
3.1. Comparison with the BF route



Direct use of coal and ore

No coking and agglomeration

3. HIsarna technology



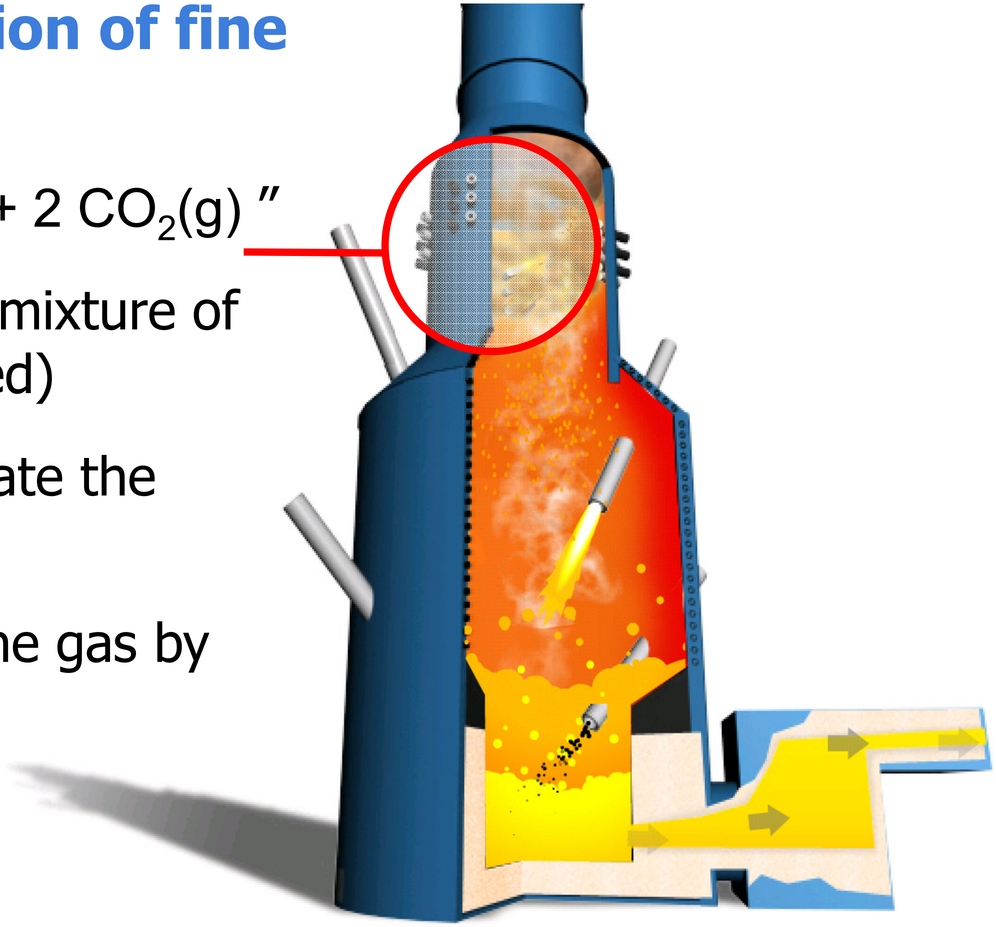
3. HIsarna technology

Melting cyclone technology

Melting and partial reduction of fine iron ores

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

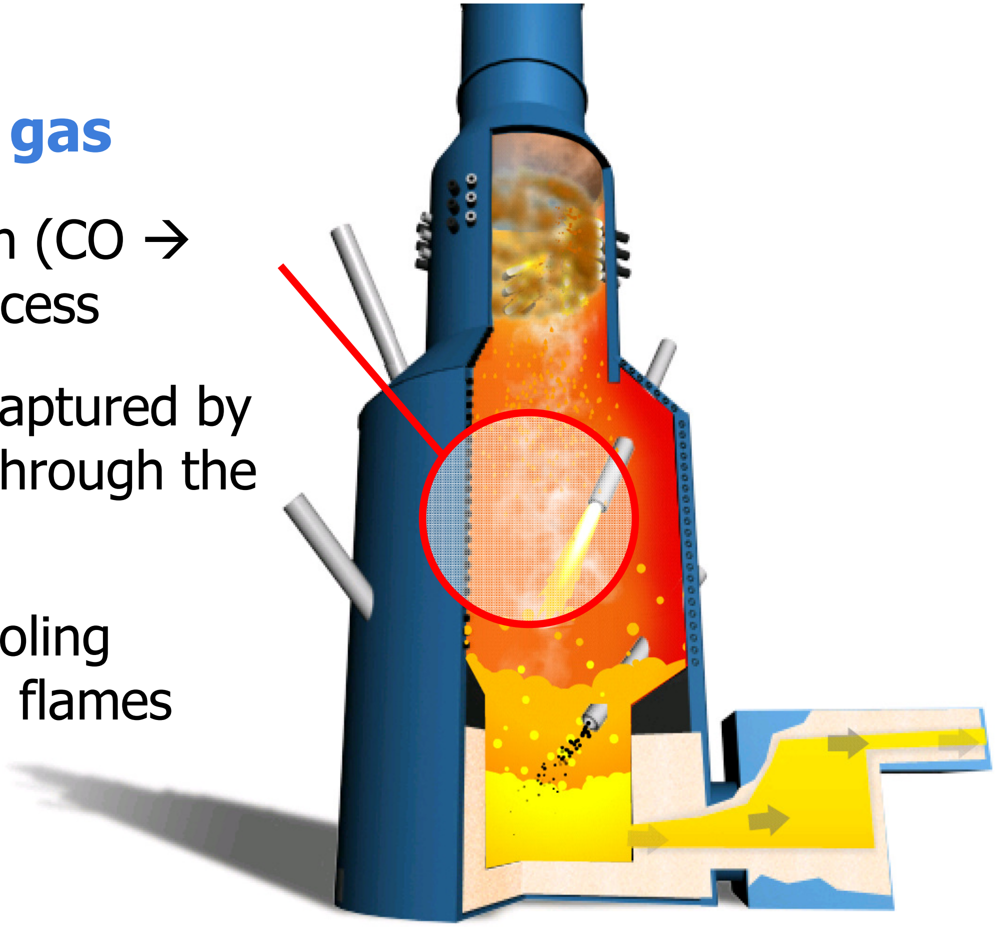
- The cyclone product is a molten mixture of **Fe_3O_4 and FeO** (~ 20 % reduced)
- Pure oxygen is injected to generate the required **melting** temperature
- The fines are **separated** from the gas by centrifugal flow of the gas



3. 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



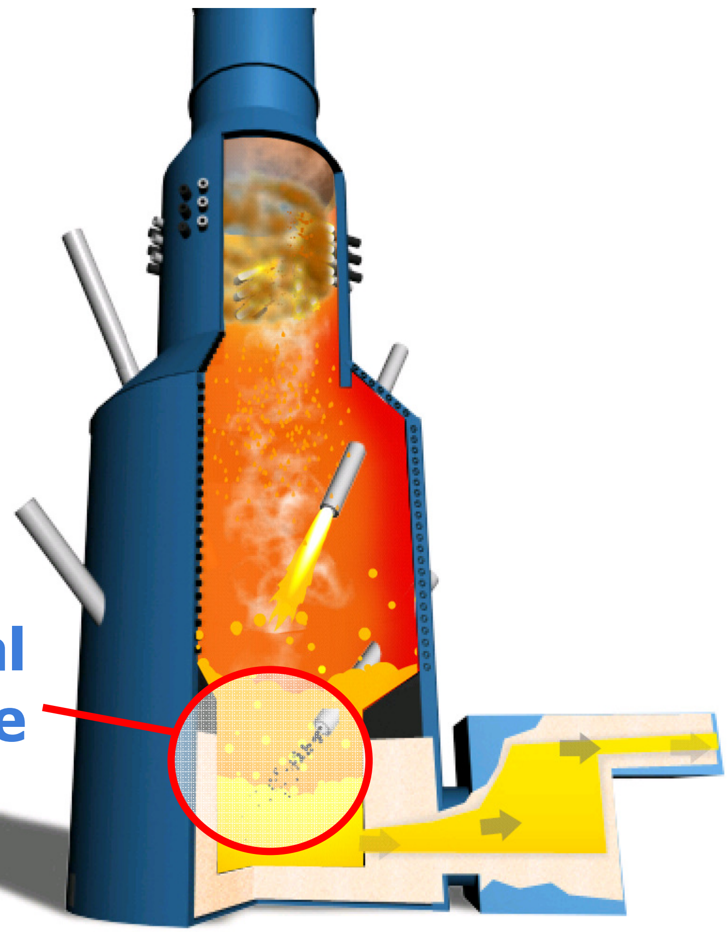
3. HIsarna technology

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



3. HIsarna technology
Benefits of the HIsarna process

Environmental:

- 20 % reduction of CO_2 per ton steel product
- Well suited for CO_2 storage (nitrogen free off gas)
- 80 % reduction with CO_2 storage
- Substantial reduction of other emissions (dust, NOx, SOx, CO)

Economical:

- Low cost raw material
- Reduced CAPEX

4. HIsarna and CCS

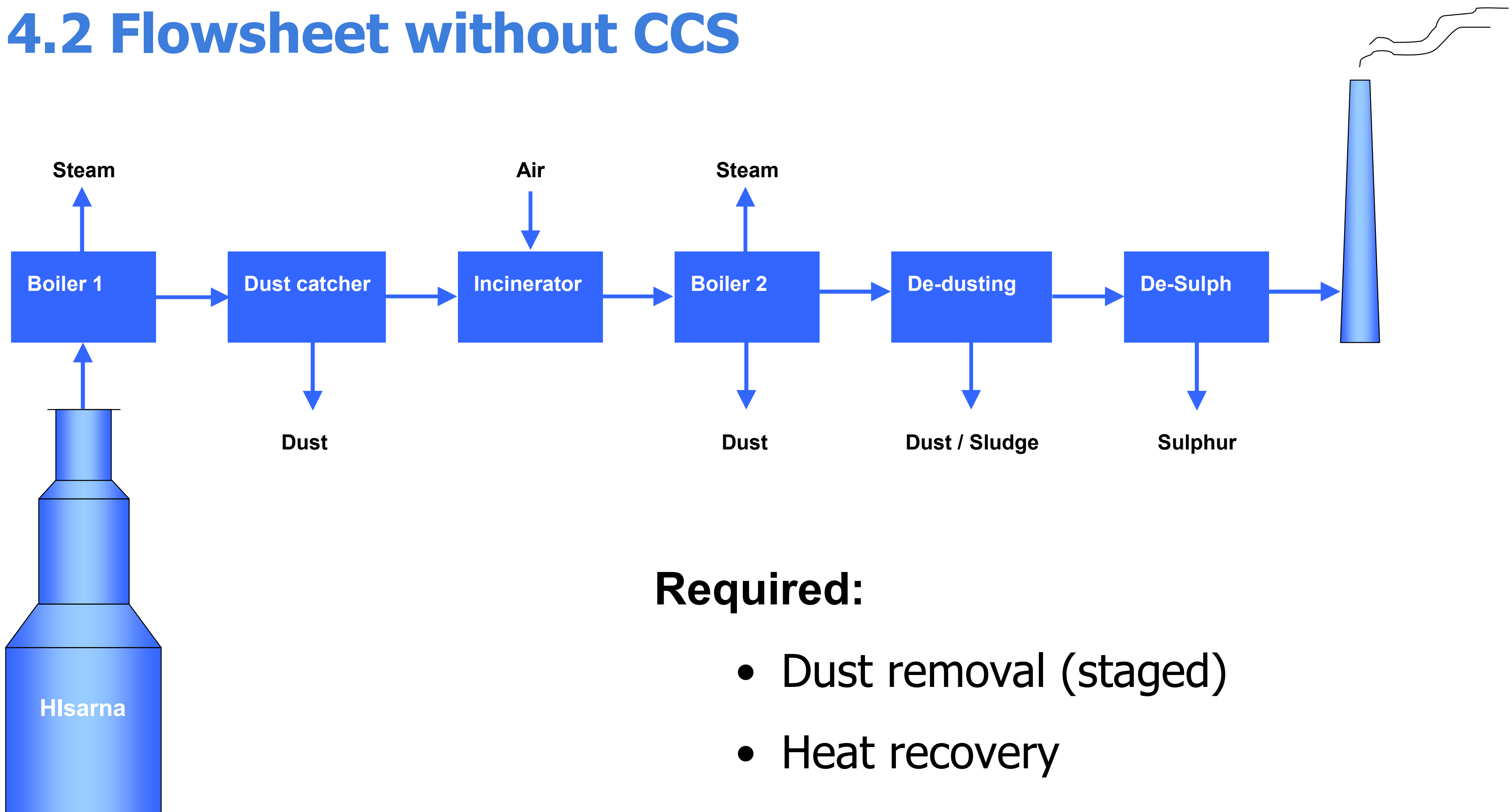
4.1. Why an attractive combination?

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

4. HIsarna and CCS

4.2 Flowsheet without CCS

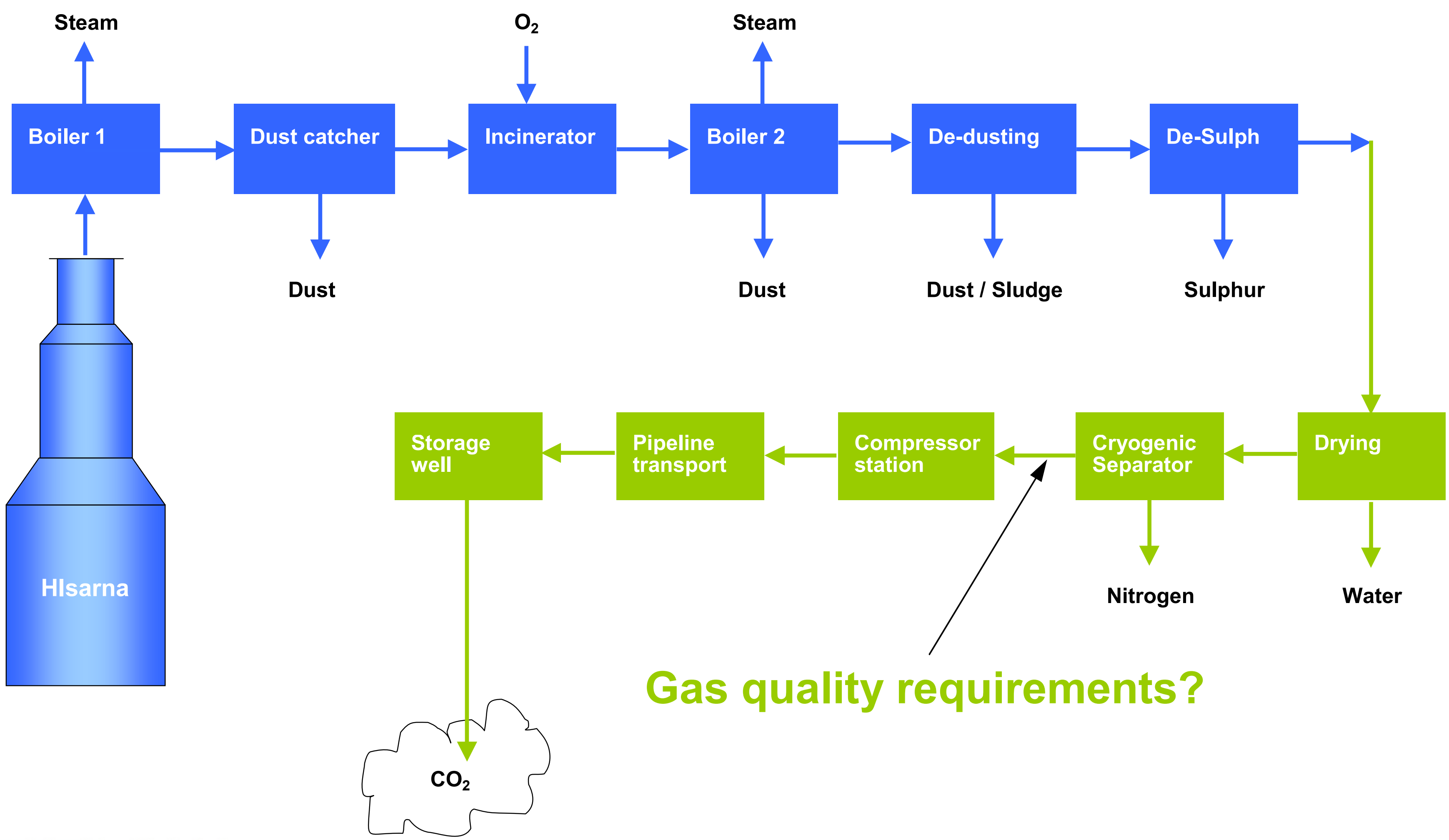


Required:

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

4. HIsarna and CCS

4.3. Flowsheet with CCS



4. HIsarna and CCS

4.4. 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.***

4. HIsarna and CCS

4.5. Dynamis recommendation

Component	Concentration	Limitation
H_2O	**500 ppm**	Technical: below solubility limit of H_2O in CO_2. No significant cross effect of H_2O and H_2S, cross effect of H_2O and CH_4 is significant but within limits for water solubility.
H_2S	**200 ppm**	Health & safety considerations
CO	**2000 ppm**	Health & safety considerations
O_2[2]	Aquifer < 4 vol%, **EOR 100 – 1000 ppm**	Technical: range for EOR, because lack of practical experiments on effects of O_2 underground.
CH_4[2]	Aquifer < 4 vol%, EOR < 2 vol%	As proposed in ENCAP project
N_2[2]	< 4 vol % (all non condensable gasses)	As proposed in ENCAP project
Ar[2]	< 4 vol % (all non condensable gasses)	As proposed in ENCAP project
H_2[2]	< 4 vol % (all non condensable gasses)	Further reduction of H_2 is recommended because of its energy content
SO_x	**100 ppm**	Health & safety considerations
NO_x	**100 ppm**	Health & safety considerations
CO_2	>95.5%	Balanced with other compounds in CO_2

5. Development

2004

2007

2009

2010

2011

2012

7 years of preparation before the first experiments

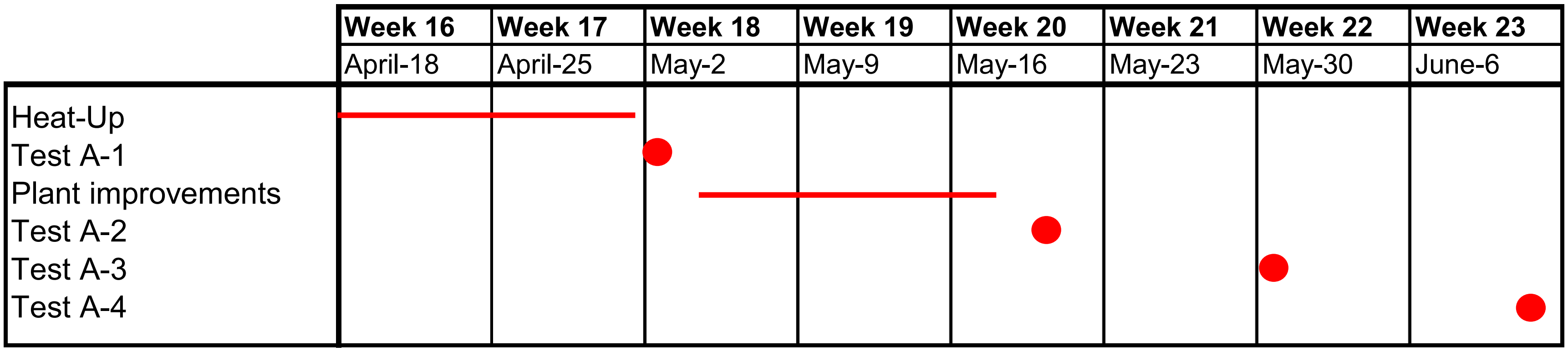
5.1. Site construction

- 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

6. The first campaign (A.)

- The plant was operated from April 18 to June 11
- The team:
    - Tata Steel Operations
    - Tata Steel Research
    - ULCOS partners
    - Rio Tinto
- 4 start-ups took place

6. The first campaign (A.)

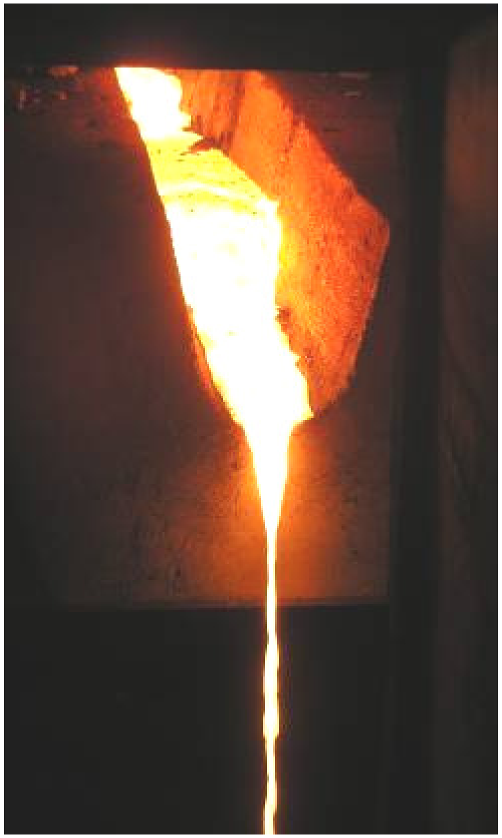


- First start-up failed
- Various improvements required
- 3 successfull start-ups followed

First metal tap at May 20th (test A-2)

7. Results first HIsarna campaign

- After many “teething problems” the plant and all it’s support systems were finally operational
- 3 successfull start-ups were carried out
- 60 % of the design capacity was achieved
- Available data indicates that process works as expected but more operating hours are needed to prove this
- The number of operating hours was below expectation



7.1. HIsarna and CCS likely?

Test results relevant for CCS:

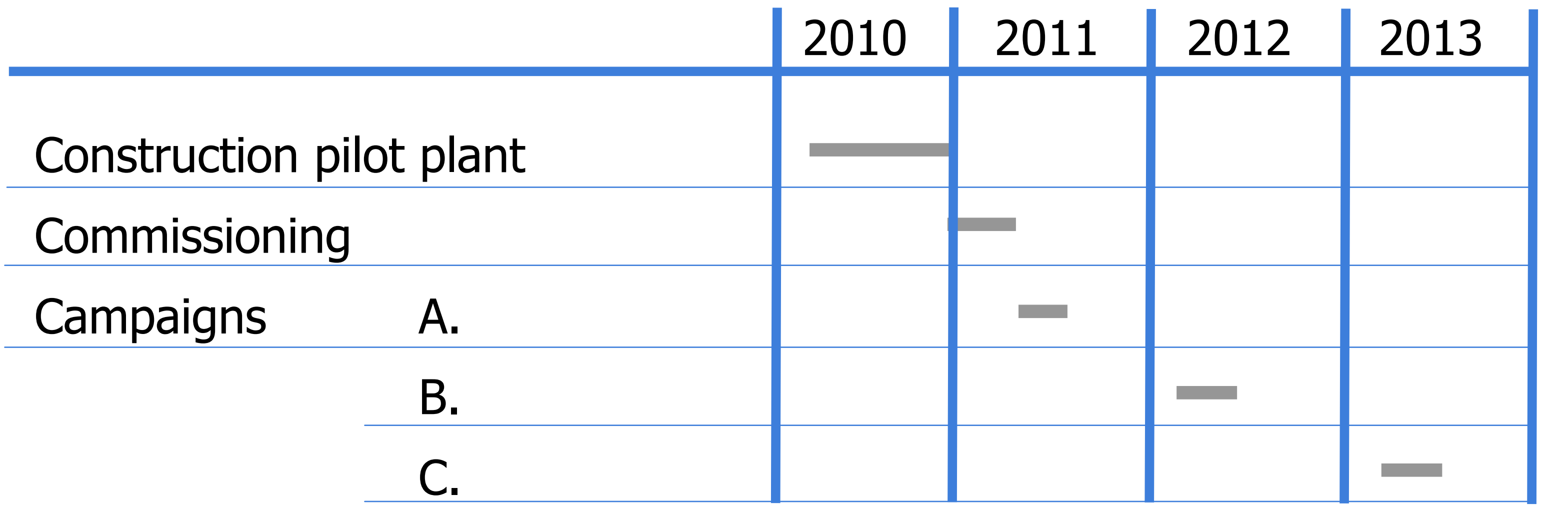
- Use of 100 % oxygen successful
- High gas utilisation partly achieved
  - Achieved: 78 % post combustion at top of cyclone
  - Target: > 85 % post combustion

- Nitrogen in off gas during tests was 17 % in dry gas
  - Nitrogen used for coal and lime injection (35 % of N_2)
  - Air used for iron ore injection (60 % of N_2)
  - Camera purge etc. (5 % of N_2)

- For industrial applications alternative iron ore carrier gas considered
- **Test results indicate that combination with CCS is attractive**

8. Further campaigns

Pilot plant experiments



Industrial scale demonstration **2014 - 2018**

Industrial implementation **2020 - …….**

9. Conclusions

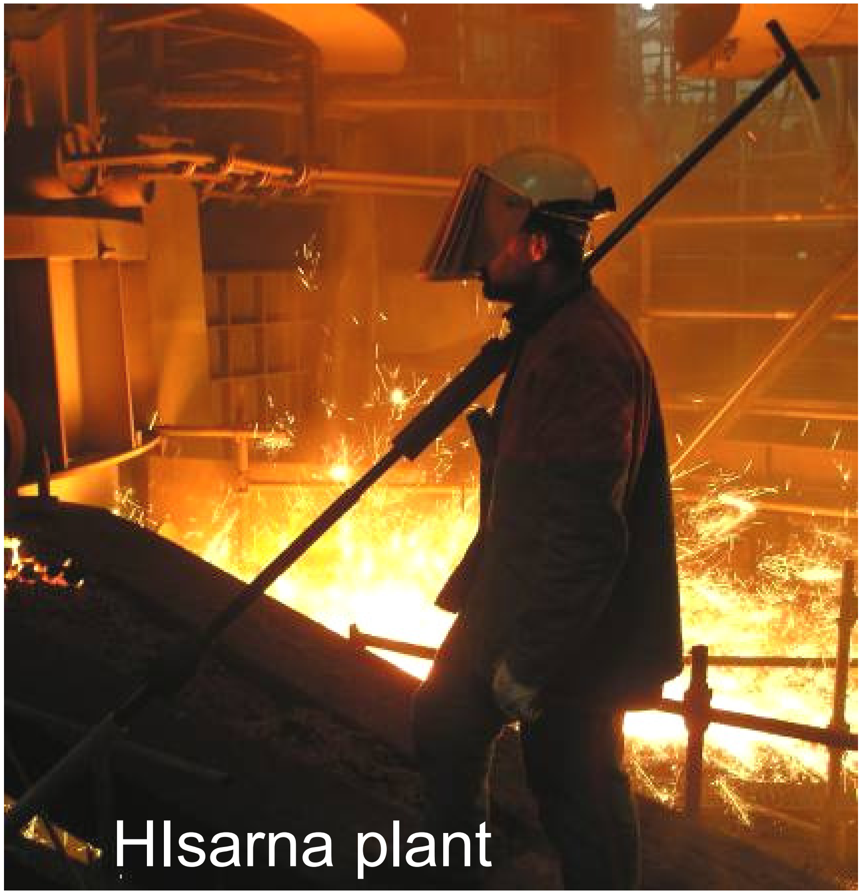
- With the ULCOS and HIsarna project the European steel industry is proactively approaching the Climate Change issue
- In the HIsarna project knowledge end experience of steelmakers and equipment suppliers from all over Europe is brought together
- HIsarna is a high risk/high reward innovation that can potentially have a strong **environmental** and **economical** impact on the steel industry
- Environmental impact:
  - Without CO_2 capture and storage **20 %** reduction
  - With CO_2 capture and storage **80 %** reduction
  - Strong reduction of other emission (dust, CO, NOx, SOx)
- No quick fix: HIsarna not ready for industrial implementation before 2020

  CCS available before 2020?

Aknowledgement

The HIsarna project is made possibly with the support of:

- 9 steelmakers
- Leading equipment Engineers and Suppliers
- Rio Tinto/HIsmelt
- EU FP6
- RFCS
- Dutch Ministery of Economic Affairs



TATA STEEL