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Experimental validation of coke breeze oxy-combustion for H_2-rich syngas production in integrated steelmaking

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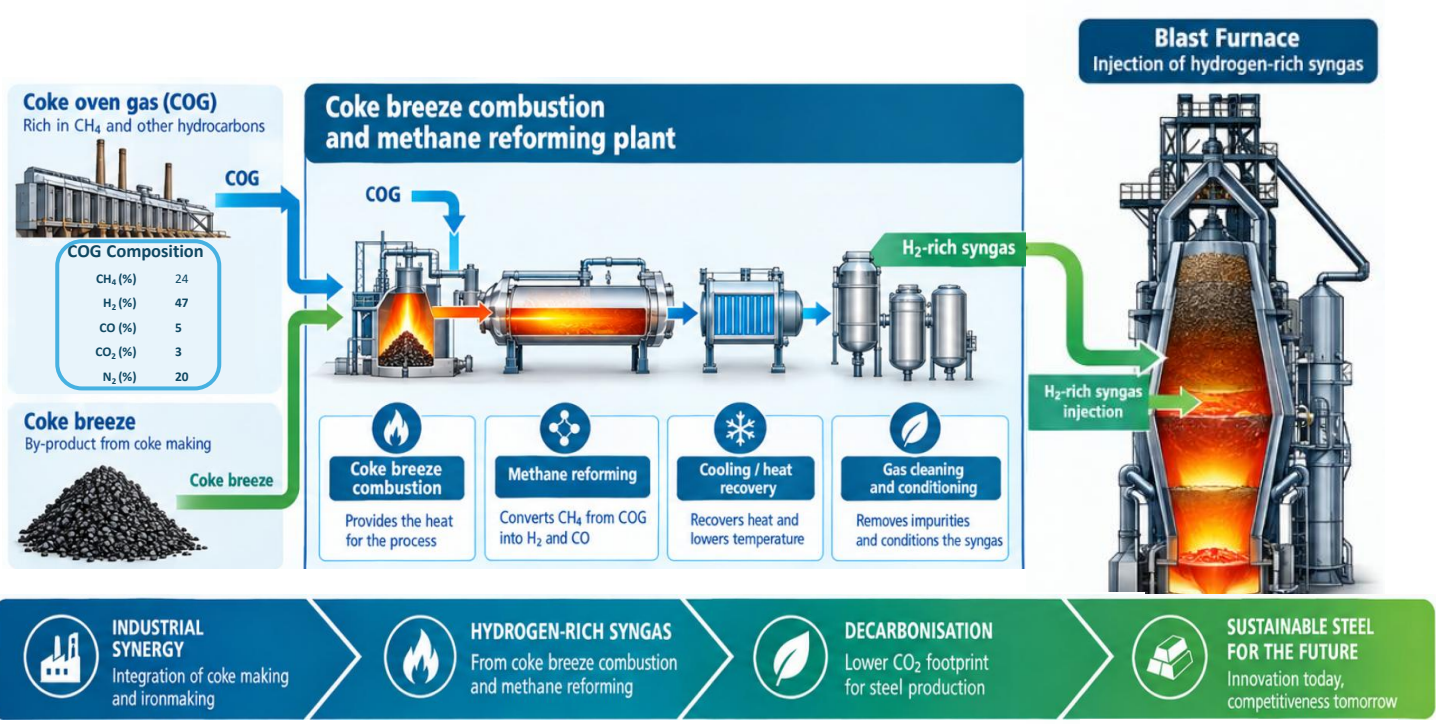
THE PROJECT

Reseach Fund for Coal and Steel (RFCS)

Grant Agreement N° 101057965

Due Date Dec. 2026

Hot hydrogen-rich syngas for injection in the blast furnace and CO_2 mitigation



Project objective

Reduce blast furnace coke consumption by injecting **H_2-rich syngas** produced by reforming the **natural gas in coke oven gas (COG)**, using the heat recovered from **coke breeze** flue gases in an adapted industrial pilot plant. The potential use of alternative carbon materials will also be assessed

TARGET OUTCOME

LESS COKE
Reduced fossil ductant demand

MORE H_2
Higher hydrogen contribution

WASTE-HEAT RECOVERY
Valorisation of process heat

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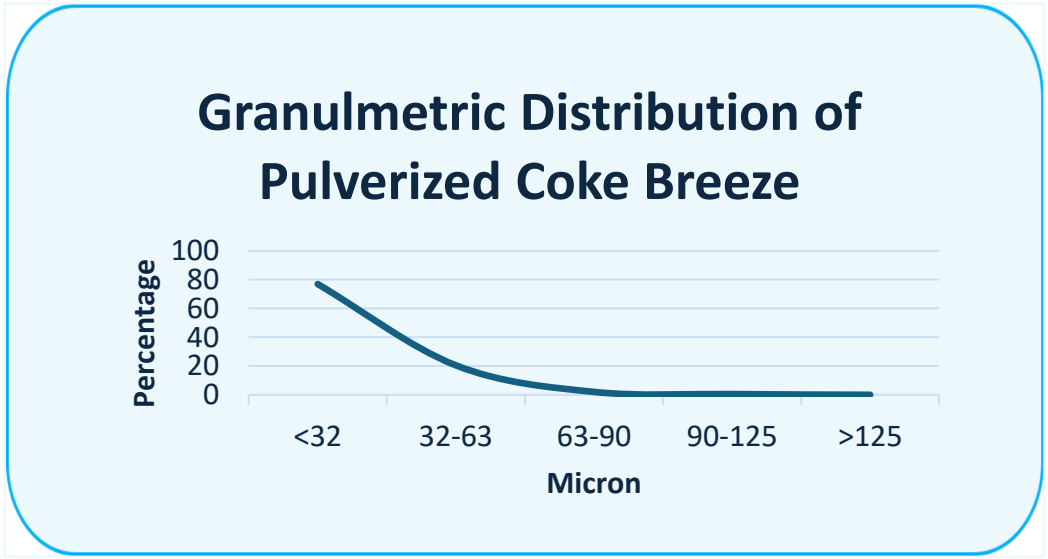
Coke breeze preparation

Value	Coke breeze
Proximate analysis	
Moisture (%)	0.8
VM(% db)	12.2
Ash (% db)	11.8
Fixed Carbon(%db)	86.0
Ultimate analysis	
Carbon (%)	85.5
Hydrogen (%)	0.3
Nitrogen (%)	1.3
Sulphur (%)	0.0





~500 kg of pulverized coke breeze was consumed during the experimental trials.





ProSynteg

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The experimental platform of Dalmine









Fuel handling | Oxygen supply | Thermal monitoring | Cooling circuit | Gas analysis

Burner power of the PW burner 1MW

Temperature of the combustion chamber 1600°C

Integrated reactor, cooling, flue gas treatment and instrumentation.

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Dalmine site arrangement

Combustion chamber

Burns coke breeze with oxygen, providing the heat for the reforming process.

Electric generator

Produces electricity from excess energy

Cooling system

Maintains the required temperature of the equipment and ensures safe operation and durability.

Compressor and fuel tank

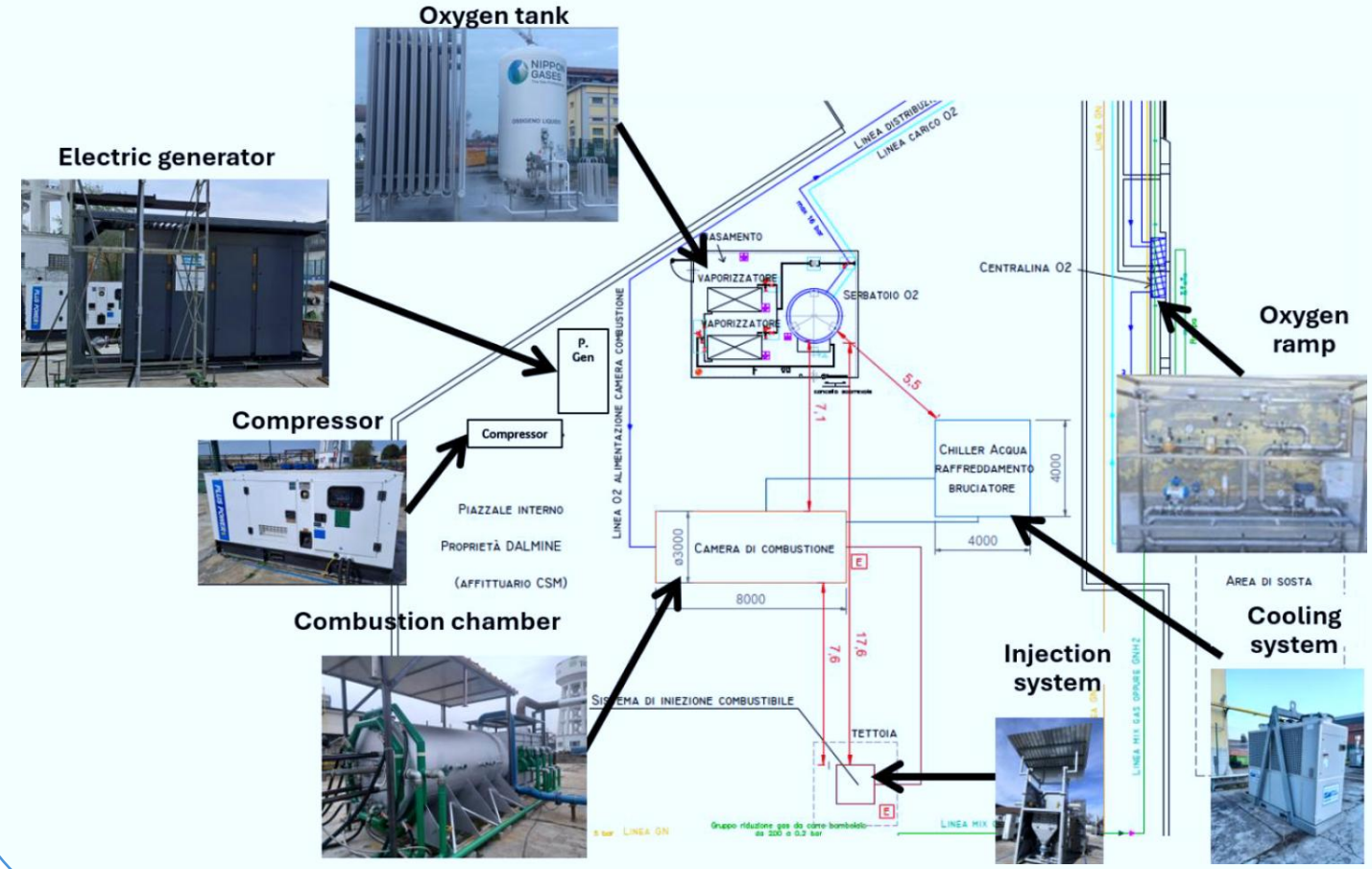
Compresses and stores

Coke breeze injection system

Feeds the coke breeze into the combustion chamber at a controlled rate.

O_2 Oxygen tank

Supplies high-purity oxygen for the combustion chamber.



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Safety & Risk Management

HAZID

Identified hazards and mitigations across the complete facility.

HAZOP

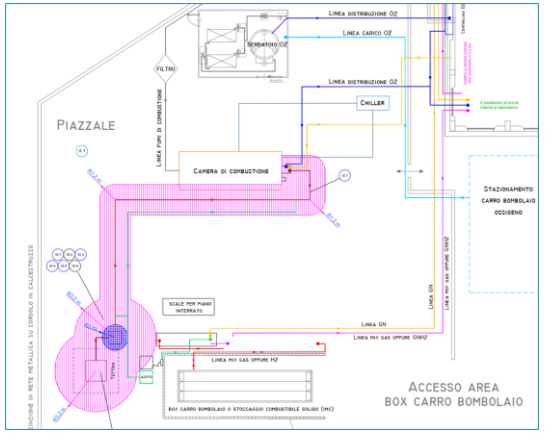
Reviewed deviations in flow, pressure, temperature, composition and direction.

ATEX

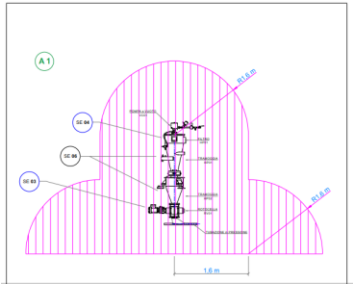
Classified areas where combustible coke dust could form explosive atmospheres.

Area	Emission Source	Flammable Substance	Emission Source Description	Zone Type	Hazardous Distances
OUTDOOR YARD	Coke dust big bag	Shot-blasting Dust	SE 01 Big bag	**Zone 22**	Sphere - Height = 1.6 m Layers = 1.6 m
	Joint or connection under vacuum		SE 02 Discontinuity	**Zone 22 NE**	-
	Rotary valve / Rotocel		SE 03 Rotocel	**Zone 22**	Sphere - Height = 1.6 m Layers= Negligible
	Filter under vacuum		SE 04 Filter	**Zone 22**	Sphere - Height = 1.6 m Layers = 1.6 m
	Safety valve		SE 05 Safety valve	**Zone 21** **Zone 22**	Sphere - Height "a" = 1.0 m Layers "ds" = 1.0 m - "as" = 1.6 m
	Hopper under vacuum		SE 06 Hopper	**Zone 22 NE**	-
	Joint or connection under pressure		SE 07 Discontinuity	**Zone 22**	Sphere - Height "a" = 1.2 m Layers= Negligible

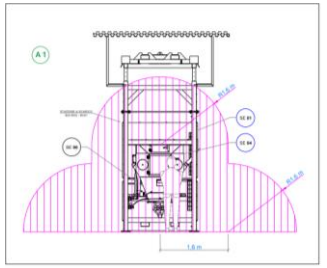
Classification of areas with explosion hazard



Vacuum Skid (side view)



Big Bag discharging system (side view)



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Temperature evolution

GENERAL TREND

A correlation exists between the coke breeze flow rate and the combustion chamber temperature.

As the coke breeze flow rate increases, the heat released during combustion increases, resulting in higher temperature throughout the combustion chamber

20 kg/h
Stable combustion
~1,200°C
(max. temperature)

Temperature reached is well below the limit temperature of the refractory. It permits to increase the coke breeze.

50 kg/h
Transient instability
~1,300°C
(max. temperature)

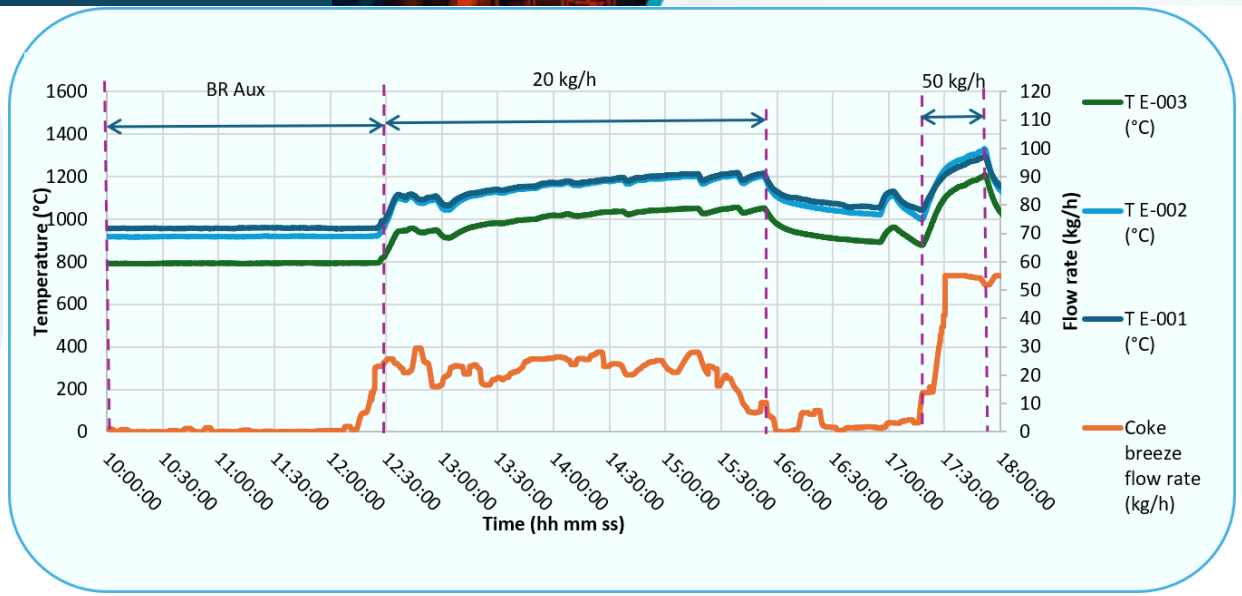
Temperature changes

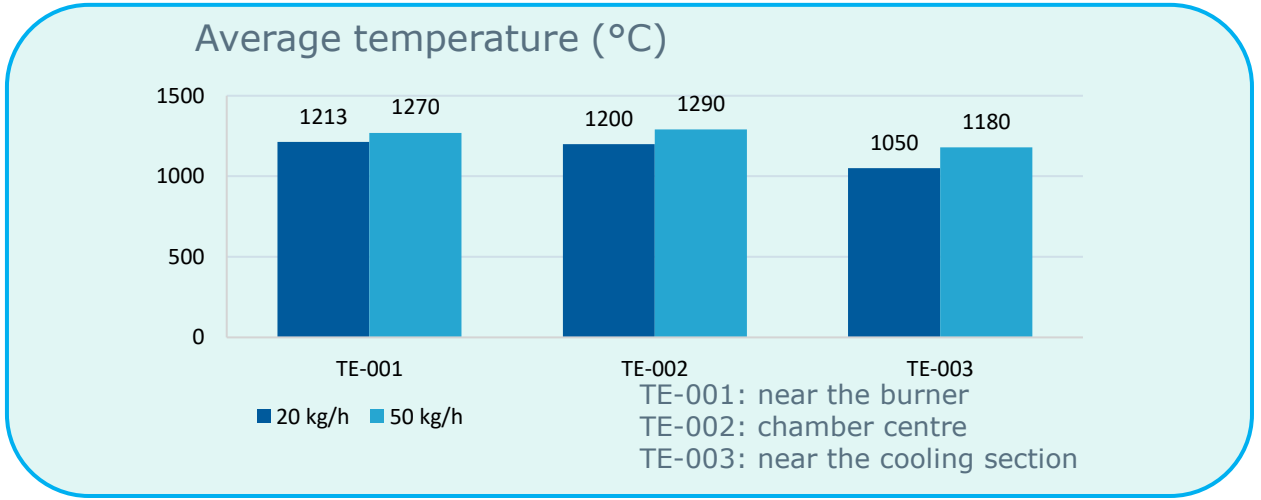
- Higher temperature in the combustion chamber
- Peak temperature at the middle (TE-002)
- shifting the peak heat release toward the rear section of the combustion chamber.

80 kg/h
Test interrupted
~1,580°C
(max. temperature)

Refractory temperature approaches the limit value of 1600°C very quickly.

The coke flow rate has been reduced at 50 kg/h





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Gas emissions

CO

39–48 ppm
(20–50 kg/h)

The relatively low CO concentration indicates an efficient combustion process and no evidence of significant incomplete combustion

NO_x

450 → 1,050 ppm
(20 → 50 kg/h)

At 20 kg/h of coke breeze injection NOx 450 ppm
At 50 kg/h there is an increase of NOx up to 1000 ppm

CO_2

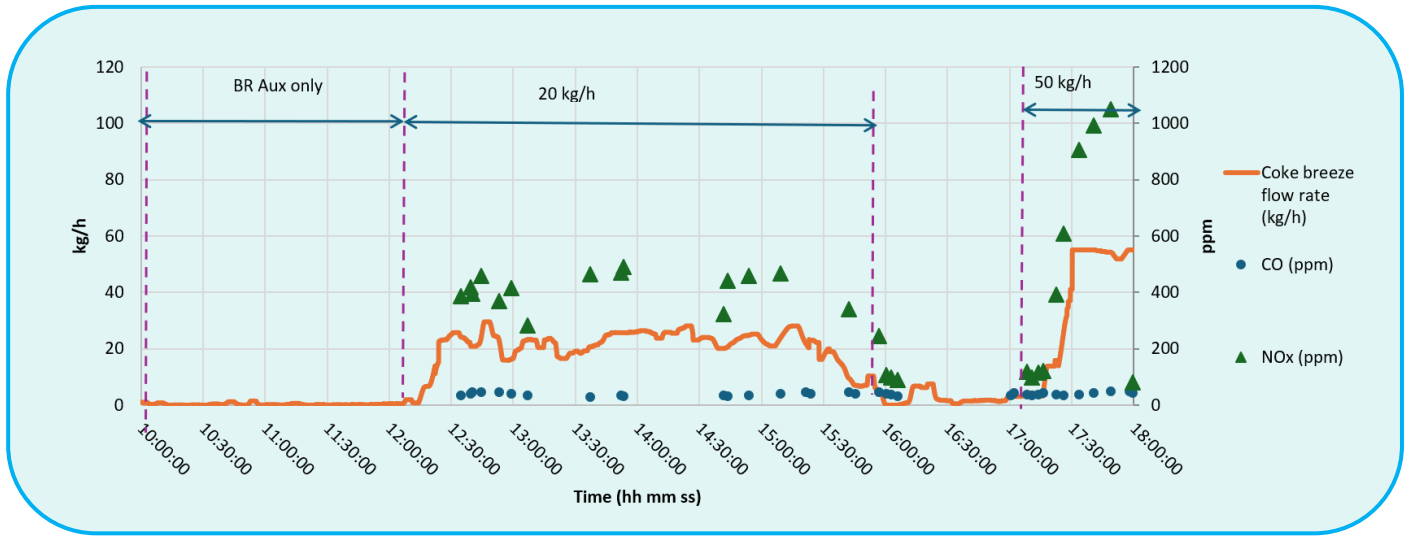
~70 vol%
(at 20 kg/h)
Not reliable at 50 kg/h

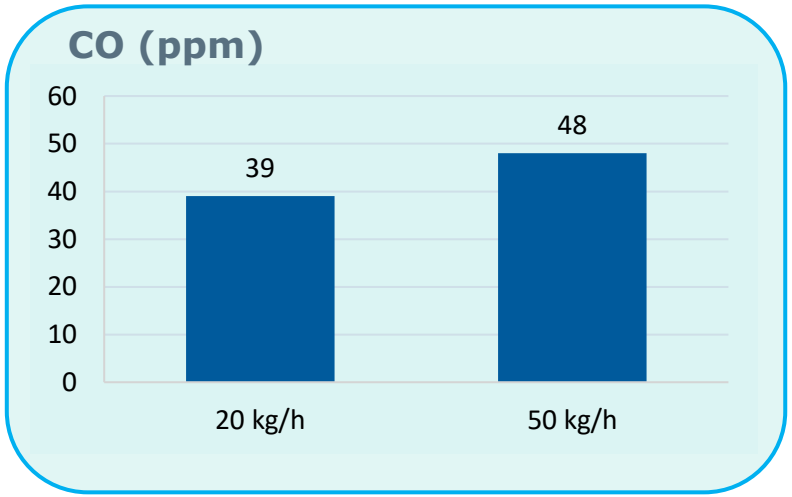
CO_2 concentration is ~70% and it remains quite stable for all period indicating a stable combustion process

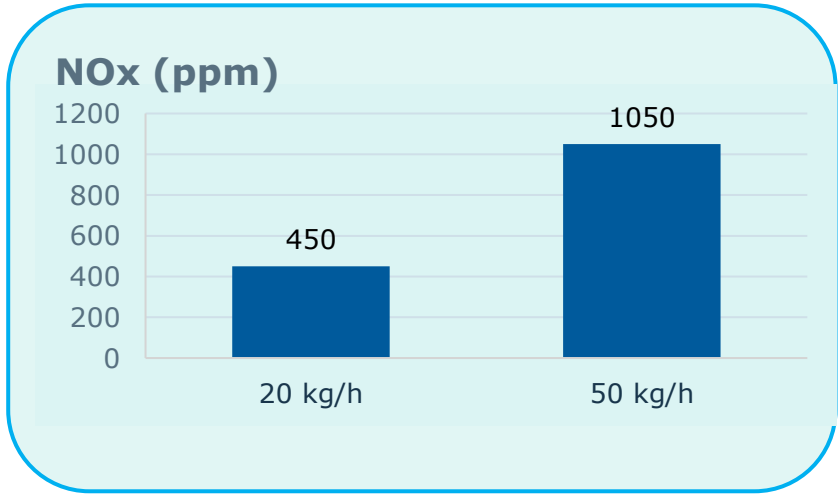
O_2

9.7–10 vol%
(20–50 kg/h)

Complete combustion of the coke and to minimize the release of unburned carbonaceous compounds.







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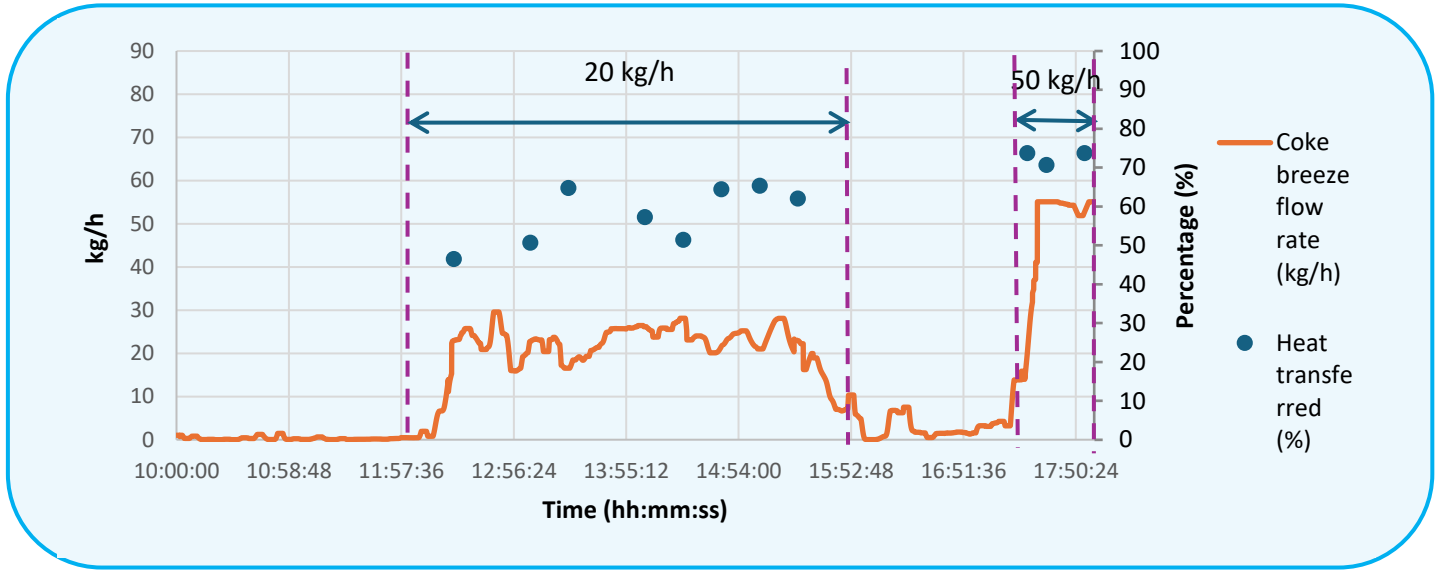
Heat Tranfer to cooling water



The thermal behavior of the reactor highlighted the progressive increase in the fraction of heat removed by the cooling water as burner load increased.



Oxy-combustion flame

Coke breeze flow rate 20 kg/h	Coke breeze flow rate 50 kg/h	Coke breeze flow rate 80 kg/h
		

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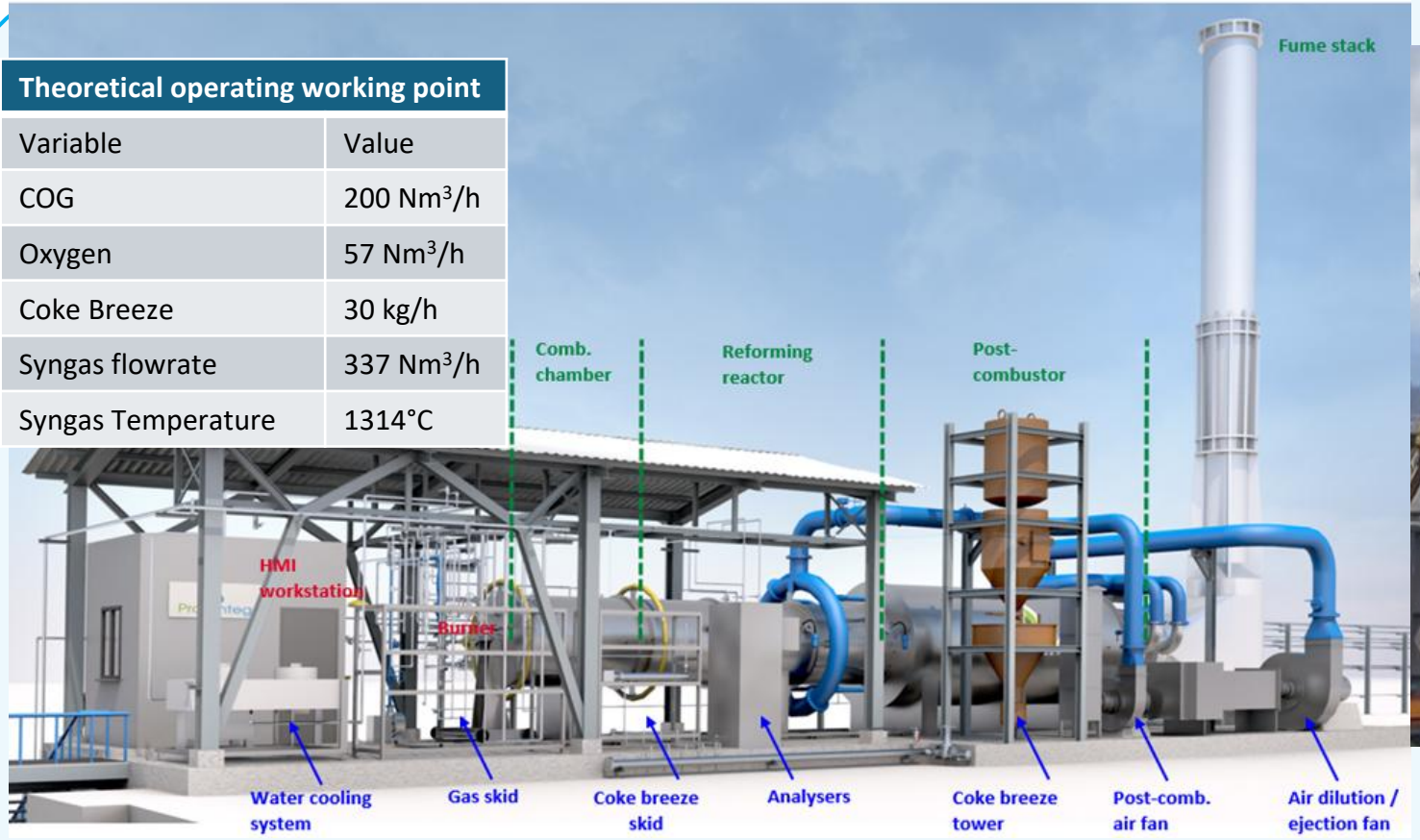
ProSynteg Pilot plant 3D view

Theoretical operating working point	
Variable	Value
COG	200 Nm^3/h
Oxygen	57 Nm^3/h
Coke Breeze	30 kg/h
Syngas flowrate	337 Nm^3/h
Syngas Temperature	1314°C





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Key Results and Achievements

1 Objective & Overall Results

Successful development and validation of the experimental oxy-combustion platform for pulverized coke breeze

2 Experimental Facility

A complete laboratory-scale facility was designed, installed and tested

3 Risk Management

All critical safety aspects were addressed through the definition of appropriate procedures

4 Coke breeze feeding system

Good operational reliability over the investigated range

Stable operation between 20-100 kg/h

5 Combustion tests

Stable Operation up to 50 kg/h

- Complete flame stabilization
- Reliable ignition
- Continuous operation in steady state

6 Flue gas analysis

Efficient combustion

- Very low CO emission
- High carbon conversion
- NOx increases with temperature

7 Thermal behaviour

~60% heat to cooling circuit at **20kg/h**

~70% heat to cooling circuit at **50kg/h**

In Summary

- ✓ Experimental oxy-combustion platform realized and validated
- ✓ Safe, reliable and instrumentation facility
- ✓ Stable combustion

A Solid foundation for the industial application

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Communication, dissemination, exploitation CDE

Website
https://www.prosynteg.eu/

LinkedIn page
https://www.linkedin.com/company/prosynteg-rfcs-project/



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Page Views	Sessions	Visitors
1.0K	435	356

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Thank you for your attention!

Eros Faraci, RINA-CSM



RINA PAUL WURTH SMS group CRM GROUP ArcelorMittal Acciaierie d'Italia

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