OXY-COMBUSTION OF COKE BREEZE FOR INTEGRATED DRY REFORMING FOR STEELMAKING DECARBONIZATION

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This work was carried out with support from the European Union's Research Fund for Coal and Steel (RFCS) research program under the ongoing project: Production of hot hydrogen-rich syngas in integrated plants for efficient injection in the blast furnace and CO2 mitigation – ProSynteg - GA number: 101057965.

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ProSynteg

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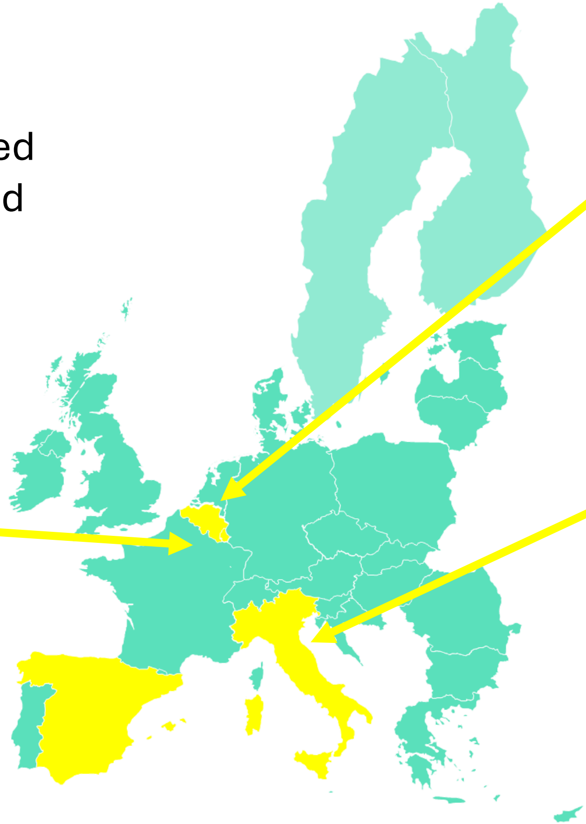
ProSynteg

Production of hot hydrogen-rich syngas in integrated plants for efficient injection in the blast furnace and CO2 mitigation.



ITALY – Third party

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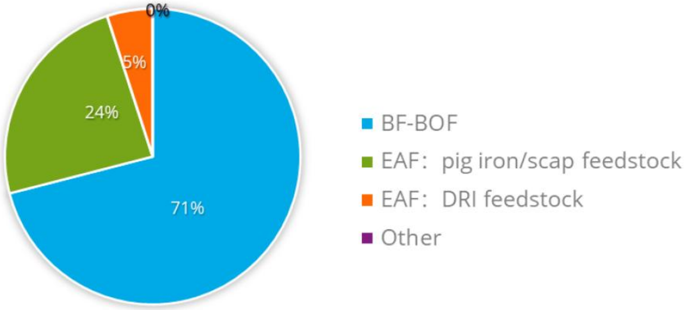
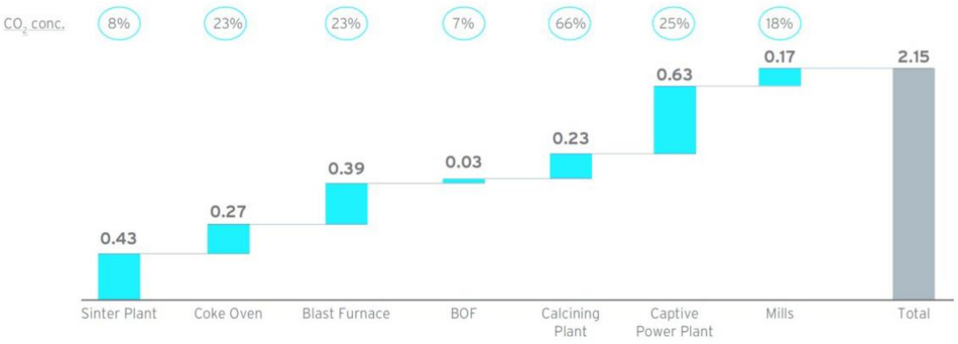
INTRODUCTION





70% of the world steel production is based on Blast Furnace – Basic Oxygen Furnace (BF-BOF) route, that has a strong impact on the CO_2 production.

1 tonne of crude steel → **2,15** tonnes of CO_2

PROBLEM ADDRESSED BY PROSYNTEG

In integrated steel plants **coke breeze** is used as a solid fuel in the ore/mineral mix of the sinter strand(s) but in the next future, due to **high environmental impact** of the sinter production, various steelmaking will be forced to close the sinter plants with the necessity to find an **alternative** of coke breeze **utilization**.

MAIN OBJECTIVES

Utilization of the coke breeze calorific value to produce hot H_2-rich syngas from dry-reforming of coke oven gas.

PROSYNTEG MAIN TASKS

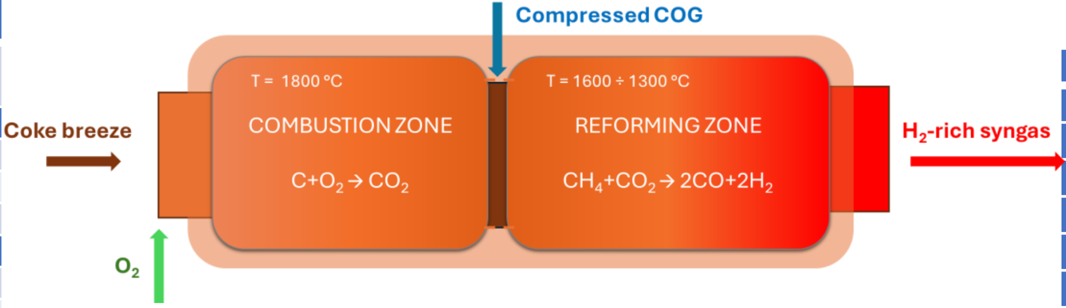
1. Material characterisation and tests on polit scale plant
2. Process modelling
3. Demo tests campaigns and data collection
4. Impact evaluation on industrial scale economic feasibility of the process

PROJECT CONCEPT

By combining COG with hot CO2, it is possible to thermally reform the methane (and higher hydrocarbons) contained in the COG according to the dry reforming reaction.

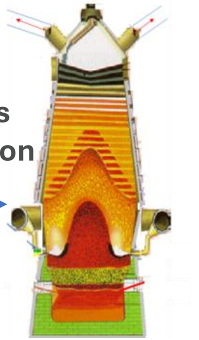
	CH_4	C_2H_6	C_2H_4	C_6H_6	O_2	H_2	H_2O	CO	CO_2	N_2
%	22.6	0.8	1.7	1.2	0.4	45.6	1.6	4.8	2.5	18.8

Value	Unit	Coke breeze
Bulk density	Kg/m3	854
Proximate analysis		
VM	% (db)	2,2
Ash	%(db)	11,8
FC	%(db)	86,0
Ultimate analysis		
C	% (db)	96,2
H	% (db)	0,3
N	% (db)	1,5
S	% (db)	0,8
O	% (db)	1,2



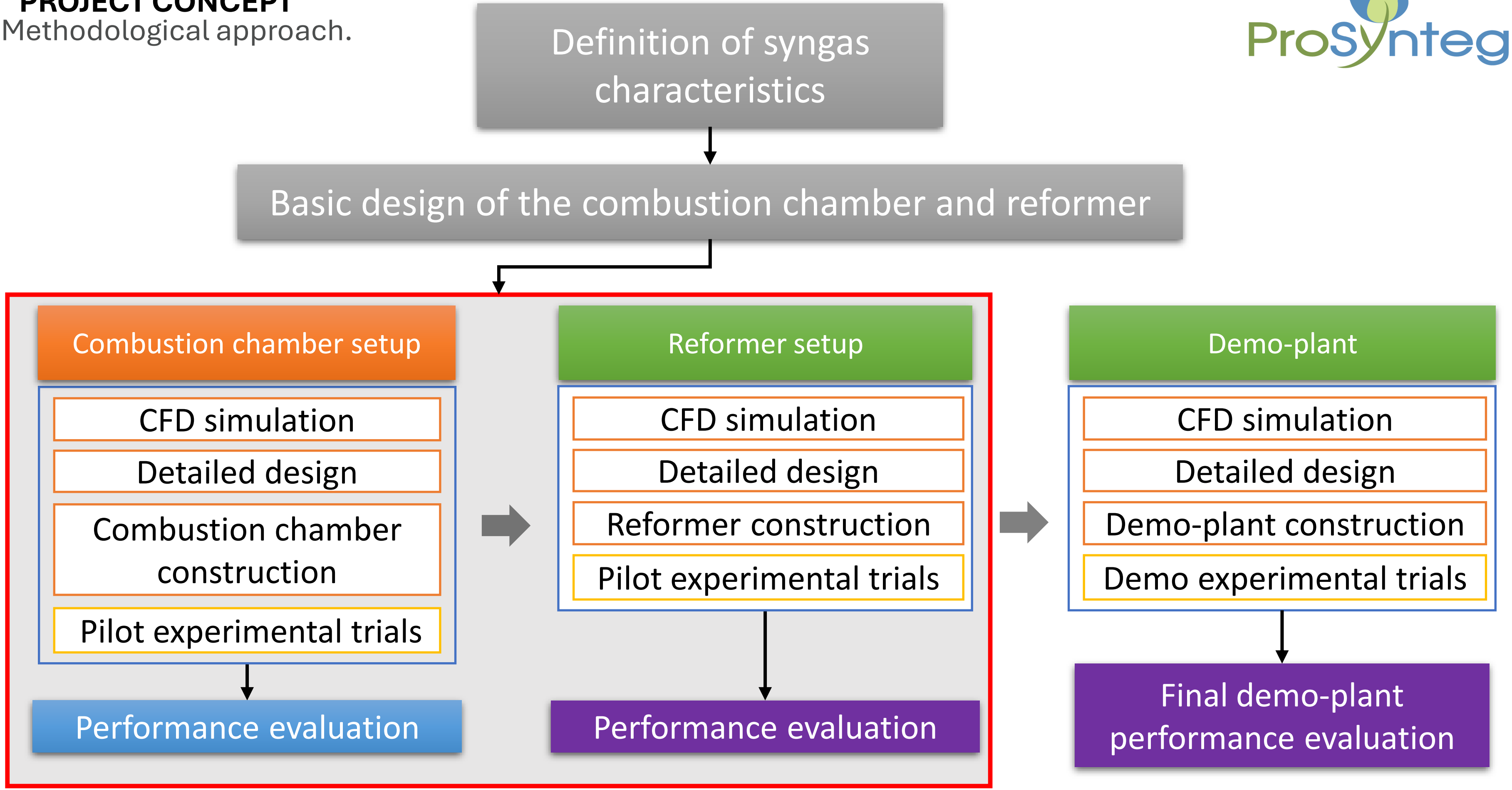
	%
H_2	43
CO	32.5
H_2O	6
CH_4	5
CO_2	2
Other	11.6

Syngas injection



Reduction of Coke rate and CO2 emissions.

PROJECT CONCEPT
Methodological approach.

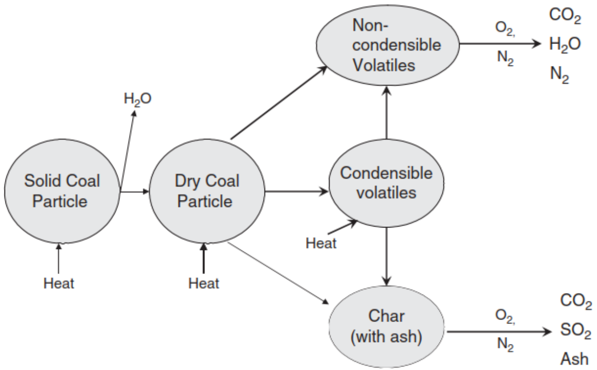


Combustion Chamber set up

CFD SIMULATION: BURNER MODEL SET UP AND RESULTS

Model setup

Symmetry: axyal simmetry (2D)
Chemistry-turbulence interaction: EBU
Particle modeling: lagrangian
Radiation: DO + WSGG
Kinetic scheme: *POLIMI*
Turbulence: k-ε
Cells: 15 000



Tillman Miller, Combustion Engineering Issues for solid fuels

Flame evaluation: heterogenous kinetic, semiempirical data
The O2 flow rate was recalculated to achieve **stoichiometric oxygen** in the combustion chamber.

For coke the main combustion mechanism is **char combustion**, due the very low content of volatiles

Combustion Chamber set up

CFD SIMULATION: BURNER MODEL SET UP AND RESULTS

Kinetic scheme

A **kinetic scheme** (POLIMI50) has been implemented in ANSYS Fluent® that includes a detailed analysis of the evolution of **heavy hydrocarbons** during **partial oxidation** and **reforming** reactions. This scheme represents the state-of-the-art in CFD codes for the prediction of soot precursors, considering time and computational limitations. The scheme comprises **50 species** (up to phenanthrene, $C_{14}H_{10}$) and **413 reactions**

CH4	O2	CO2	CO	H2O	O	H	OH	HO2	H2
CH3	CH2O	HCO	CH2	H2O2	C2H2	C2H4	C2H6	CH2S	CH3O
CH2OH	CH	C3H8	CH2CO	C6H6	C10H8	C2H	HCCO	C2H3	CH2CHO
C2H5	C3H3	C6H5	C10H7	CYC5H5	CYC5H6	C6H5OH	C6H5O	CH3OH	C3H2
INDENE	C12H8	C14H10	CH3CO	CH2CHCH2	C6H4C2H	INDENYL	C6H5C2H	C14H9	N2

This scheme will allow to assess also the reforming reactions in reforming section, e.g.:

$$CH_4 + H_2O \rightarrow CO + 3\,H_2$$ steam reforming

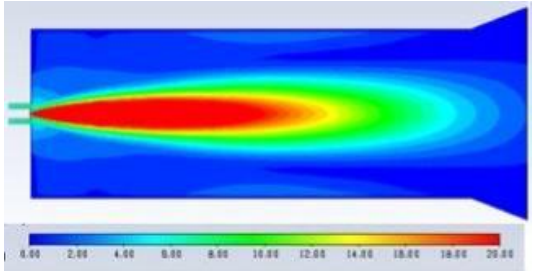
$$CH_4 + CO_2 \rightarrow 2\,CO + 2\,H_2$$ dry reforming

Combustion Chamber set up

CFD SIMULATION: BURNER MODEL SET UP AND RESULTS

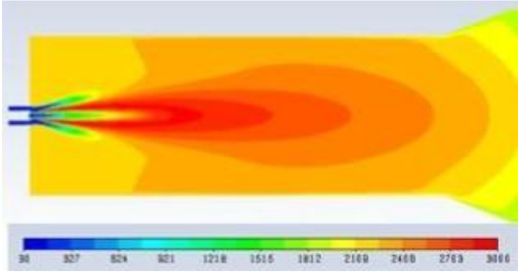
Results

The kinetic model of combustion and reforming reactions preliminary employed has been imported into the Fluent environment to verify the **reliability** of the kinetic scheme in a **complex simulation** (CFD)



The results show that:

1. the maximum temperature of 2900 °C.
2. The temperature of the flue gas to the reforming section is about 1800 °C.



Considering that the CFD simulation is related to the oxy-combustion of coke breeze the results obtained can be considered **realistic**.

Despite the promising results from simulations, the **pilot plant** trial will test a flow of oxygen slightly **above the stoichiometric conditions**. This is a **safety** procedure to avoid incomplete conversion during real working conditions.

Detailed design

PREPARATION OF THE SITE FOR THE EXPERIMENTAL TRIALS

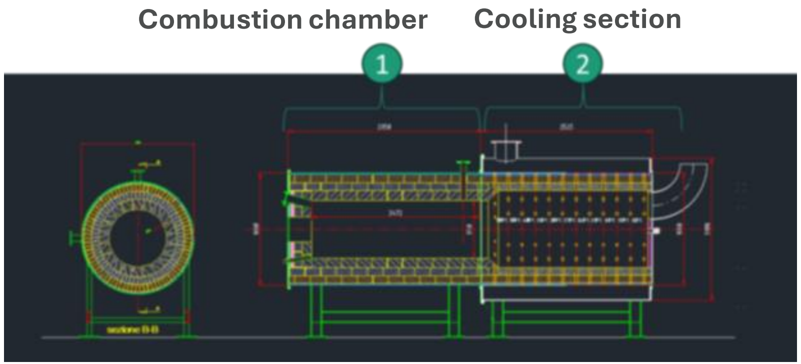
Combustion chamber and injection system design

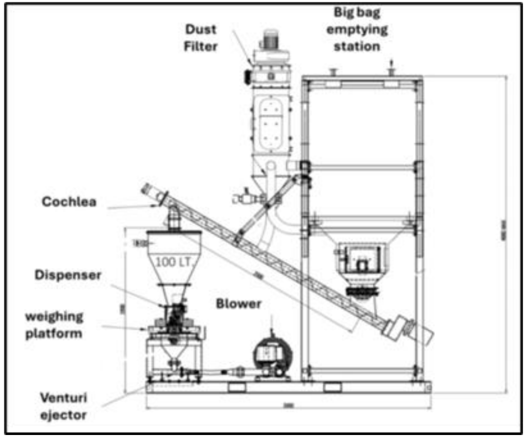
Some characteristics of the combustion chamber.

- Thermal potential: 1000 kWt
- Internal diameter: 1000 mm
- Internal length: 3500 mm
- Flue gas outlet T: 1600 °C

The system will be equipped with:

- an auxiliary heating system
- fuel and oxygen flow rate monitoring
- temperature monitoring system





Reformer set up

REFORMING MODEL APPLICATION FOR THE DEFINITION OF THE REFORMING REACTOR SIZES

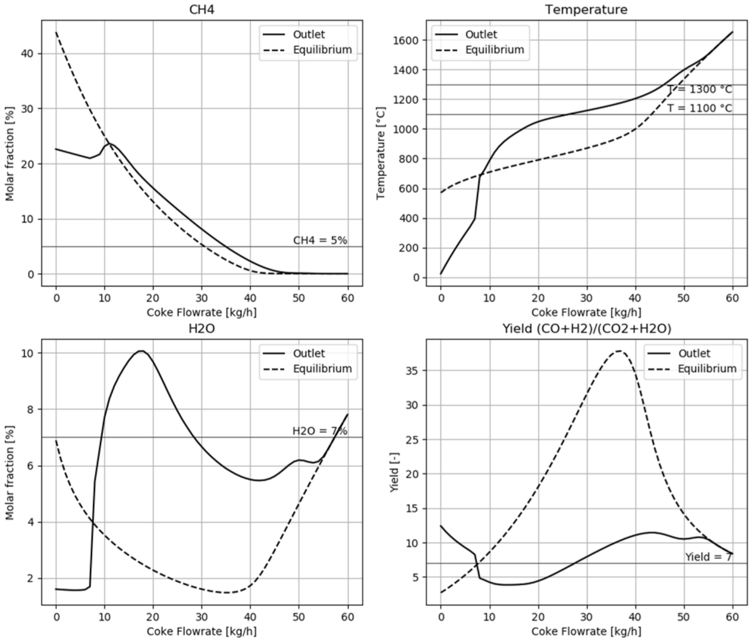
Main model parameters

- Fuel: coke breeze
- O_2: stoichiometric
- COG: 200 Nm^3/h

Results

- Feasible flowrate: between 35 and 46 kg/h
- Lower limits due to methane fraction
- Upper limit due to temperature

COG Nov-2023				
Fcoke (kg/h)	CH4 (% vol)	H2O (% vol)	Tout (°C)	Yield (-)
30	8,10	6,66	1123	7,92
31	7,43	6,48	1130	8,29
32	6,76	6,31	1136	8,65
33	6,12	6,16	1144	9,01
34	5,50	6,02	1151	9,36
35	4,89	5,89	1158	9,69
36	4,32	5,79	1166	10,01
37	3,76	5,69	1175	10,31
38	3,23	5,61	1183	10,59
39	2,73	5,55	1193	10,84
40	2,26	5,50	1204	11,06
41	1,82	5,47	1215	11,24
42	1,43	5,46	1228	11,37
43	1,07	5,48	1242	11,44
44	0,76	5,53	1259	11,43
45	0,52	5,61	1278	11,34
46	0,33	5,73	1300	11,18
47	0,21	5,87	1324	10,96
48	0,14	6,02	1349	10,74
49	0,11	6,14	1374	10,57
50	0,09	6,19	1397	10,51



Demo plant

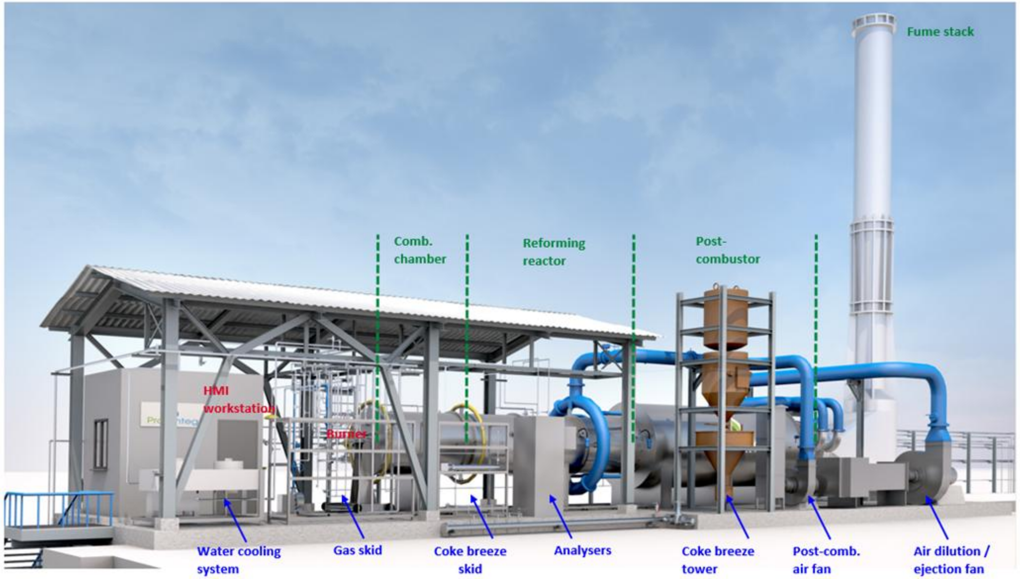
Demo Plant main characteristics

The demo plant consists of the following main components.

- Combustion chamber equipped with the oxy-burner (solid fuel burner)
- Reforming reactor
- Post-combustion chamber
- Coke-breeze injection system

Main characteristics

- Production of 500 Nm3/h of reformed gas at T > 1000 °C
- COG feed (200 Nm3/h max)
- Coke breeze feed (90 kg/h max)
- Oxygen feed (190 Nm3/h max)



CONCLUSIONS

- Prosynteg project aims to use the coke breeze calorific value to produce hot H2-rich syngas from dry-reforming of coke oven gas
- Setup of the CFD simulations for final design of the combustion chamber has been successfully implemented
- Setup of the simulation for the definition of the sizes of the reformer has been carried out
- Design of the combustion chamber pilot plant and reforming pilot plant are in realization phase.
- Preparation of site for oxy-burner experimental trial is in progress. Tests are foreseen in the last quarter of 2025.

NEXT STEPS

- CFD simulation of the combustion chamber, final design.
- Experimental campaign of the combustion chamber in pilot plant
- Tuning and validation of CFD model of the combustion chamber
- CFD simulation of the reformer
- Demo plant CFD simulation and experimental campaign (combustion zone + reforming zone)

OUR WEB PAGES

Website

https://www.prosynteg.eu/

LinkedIn page

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

Events

AKNOWLEDGMENTS

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THANK YOU FOR YOUR ATTENTION!

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