Prosynteg

Combustion Analysis of Coke Breeze Burner

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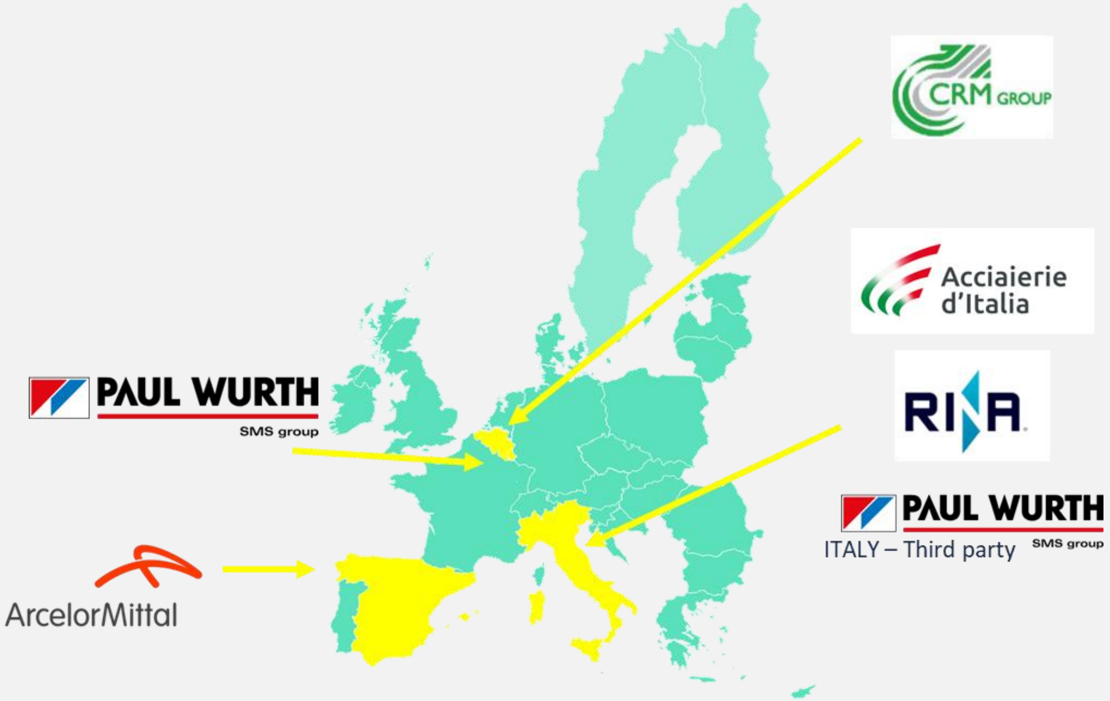
Introduction

ProSynteg

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



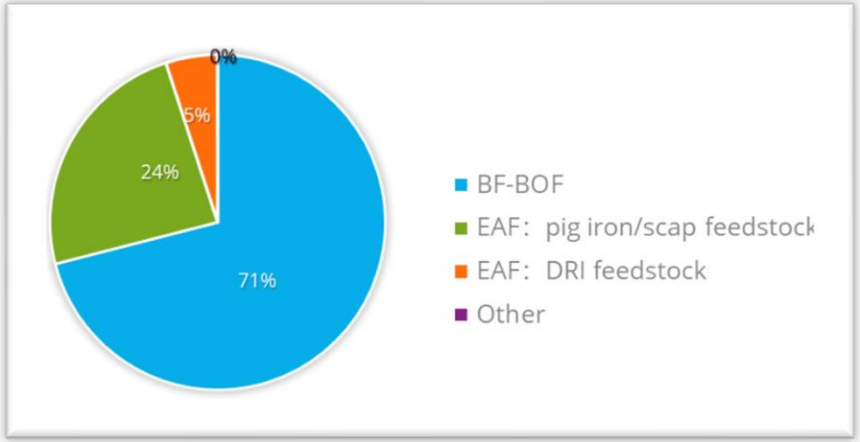
MAIN OBJECTIVES

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

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**.

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.

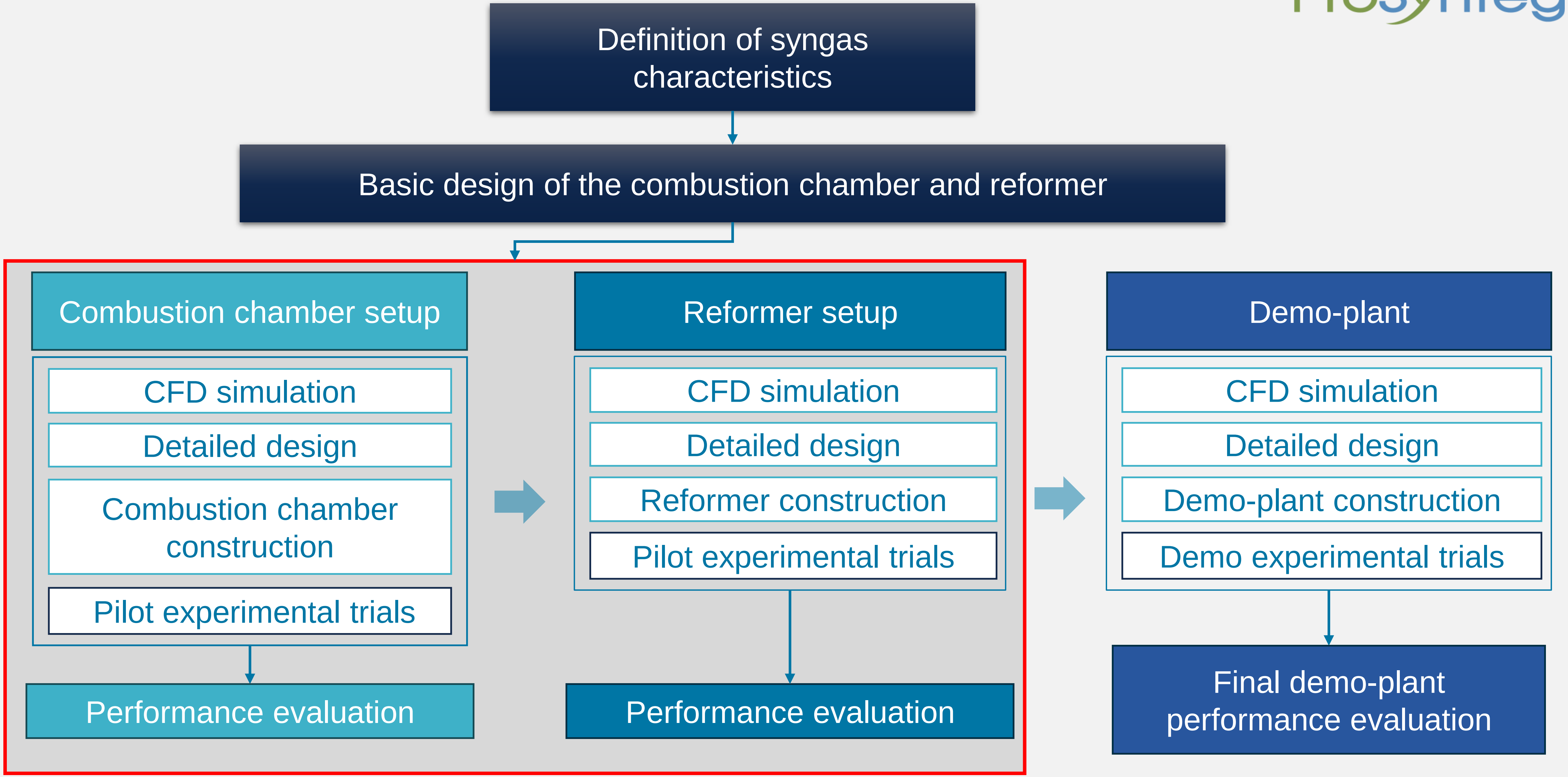
Introduction



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

Methodological approach

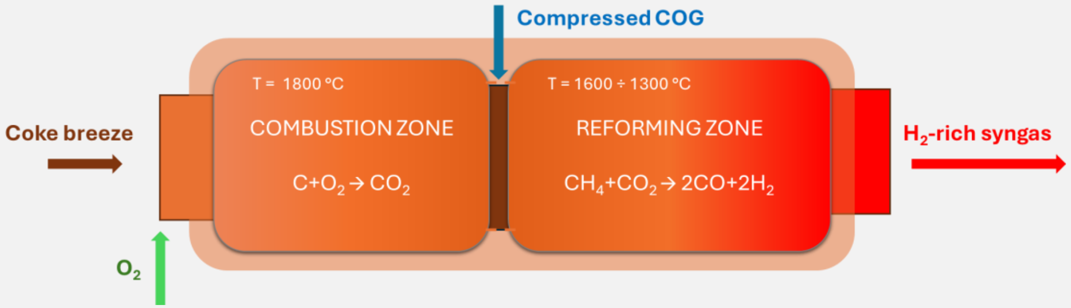


Project concept

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.

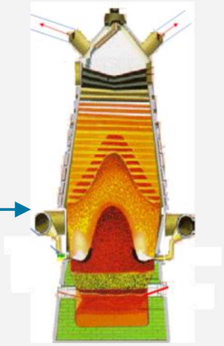
	CH_4	C_2H_6	C_2H_4	C_6H_6	O_2	H_2	H_2O	CO	CO_2	N_2
%	22.6	0.8	1.7	1.2	0.4	45.6	1.6	4.8	2.5	18.8

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



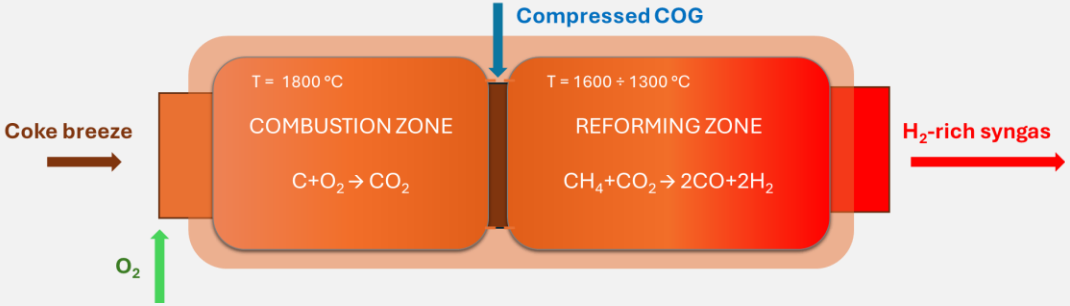
Reduction of Coke rate and CO2 emissions.

Operative conditions

Preliminary model

Objective: to investigate wide range of feasible process conditions

	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



1D Model:
Flame (CSTR) + Reformer (1D adiabatic PFR)

Kinetic scheme

evolution of heavy hydrocarbons during partial oxidation and reforming reactions.

Suitable for the prediction of soot precursors, considering time and computational limitations.

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

Constraints:
- ✓ $CH_4 < 5\%$
- ✓ $H_2O < 7\%$
- ✓ T < 1100-1300 °C
- ✓ $\frac{CO+H_2}{CO_2+H_2O} > 7$
- ✓ Soot: as low as possible

Figures of merits

First Run

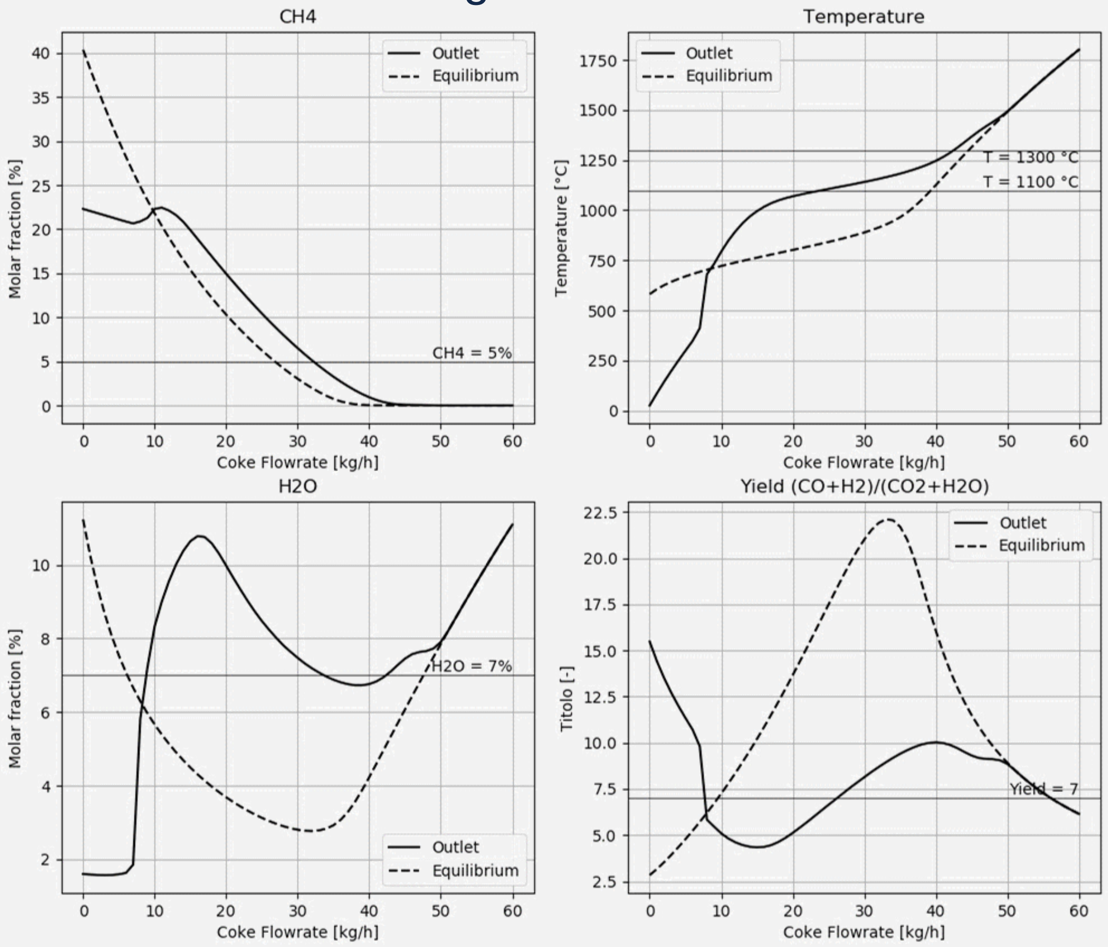
- Fuel: coke breeze
- O_2: stoichiometric
- COG: 200 Nm^3/h

Constraints:

- ✓ $CH_4 < 5\%$
- ✓ $H_2O < 7\%$
- ✓ T < 1100-1300 °C
- ✓ $\frac{CO+H_2}{CO_2+H_2O} > 7$
- ✓ Soot: as low as possible

Coke kg/h	CH_4 % v/v	H_2O % v/v	Tout °C	Yield -
30	6.51	7.47	1141	8.14
31	5.80	7.32	1148	8.42
32	5.12	7.19	1156	8.69
33	4.47	7.07	1164	8.94
34	3.85	6.96	1173	9.18
35	3.27	6.88	1182	9.40
36	2.71	6.81	1193	9.60
37	2.20	6.76	1204	9.77
38	1.73	6.73	1216	9.90
39	1.30	6.73	1230	9.99
40	0.93	6.76	1246	10.02
41	0.62	6.83	1265	9.99
42	0.38	6.95	1287	9.88
43	0.22	7.10	1312	9.71
44	0.13	7.28	1339	9.50
45	0.08	7.45	1367	9.31

Figure of Merits

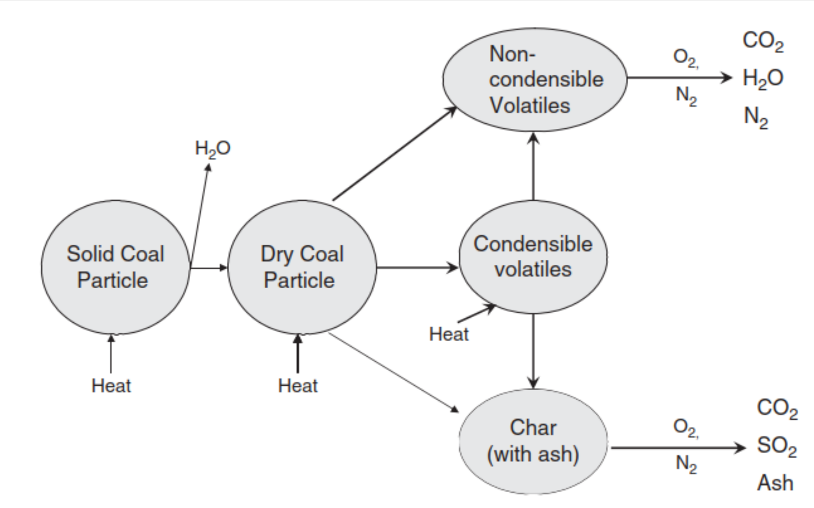


Coke breeze oxy-burner simulation

Burner model

Model setup

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



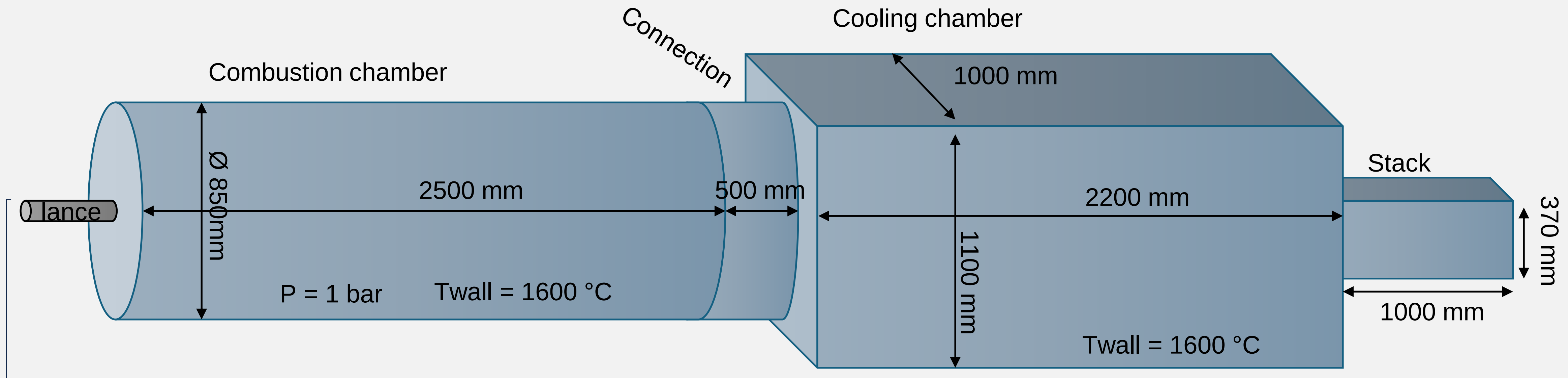
Tillman Miller, Combustion Engineering Issues for solid fuels

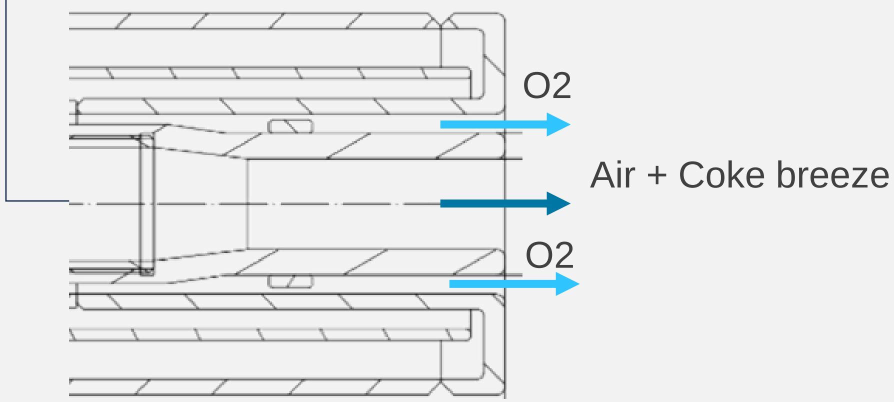
Objective:
evaluate the burner's characteristics and examine any dangerous operating conditions in the pilot plant

Flame evaluation: heterogenous kinetic, semiempirical data

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

Process Conditions





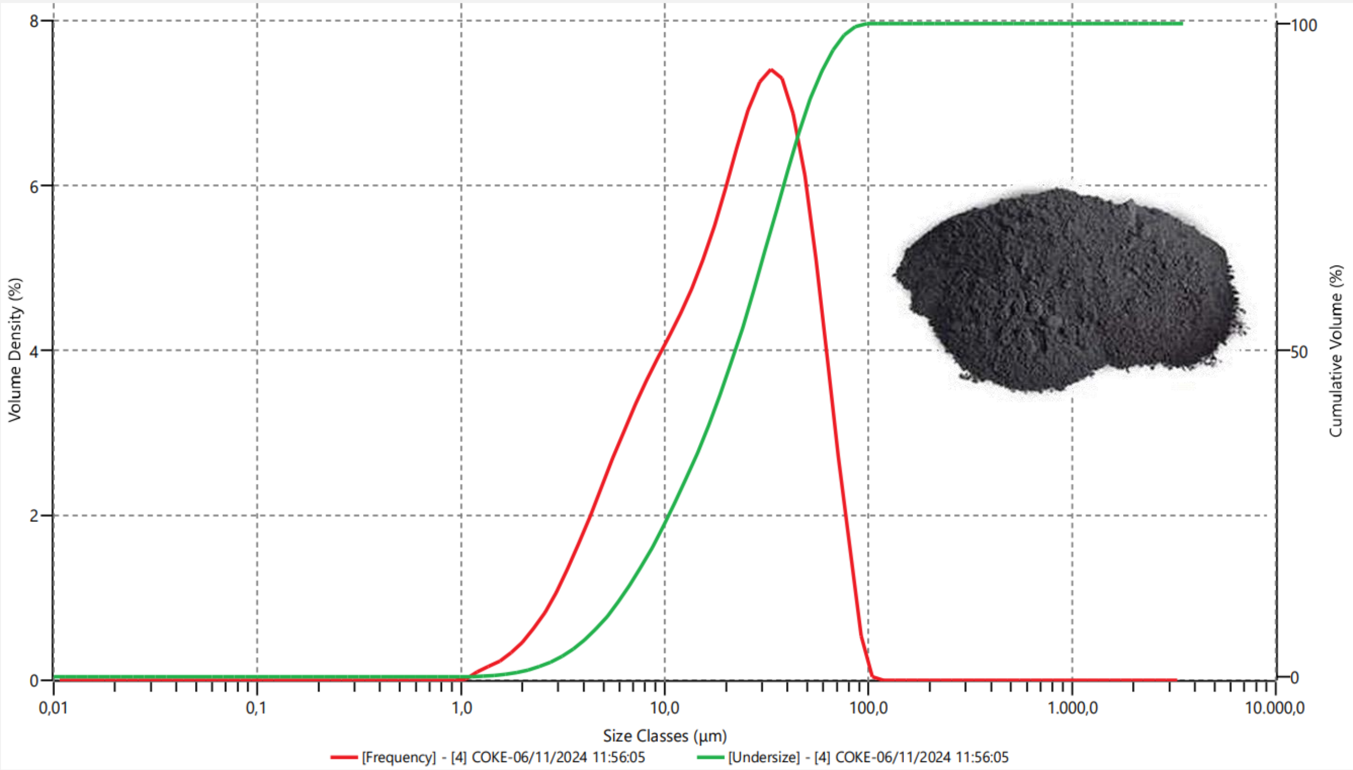
Process conditions				
Case		TR1	TR2	TR3
Coke breeze	(kg/h)	90	60	30
Transport air	(Nm3/h)	15	12	10
Oxygen	(Nm3/h)	146	96	47
Wall temperature	(°C)	1600	1600	1600
Thermal power	(kW)	720	480	240

Coke Breeze Analysis

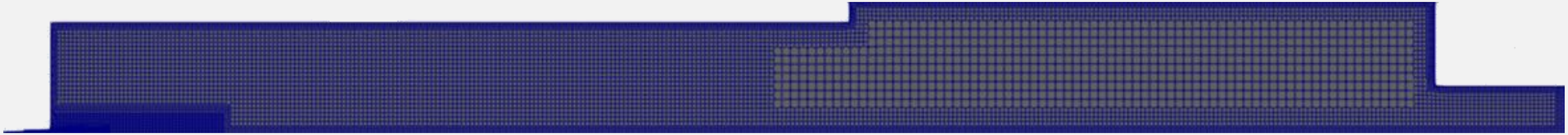
Proximate (as received)		
Volatile matter	3.0 %	% w/w
Fixed carbon	84.5 %	% w/w
Ash	11.7 %	% w/w
Moisture	0.8 %	% w/w
HHV	28.897	MJ/kg

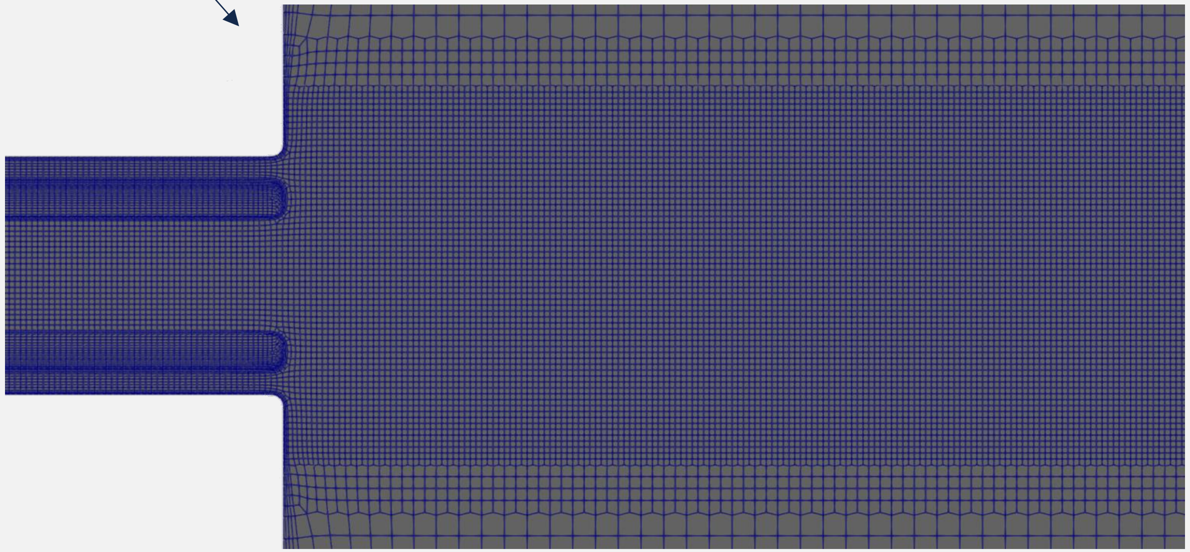
Ultimate (dry ash free)		
Carbon	97.0 %	% w/w
Hydrogen	0.4 %	% w/w
Oxygen	1.2 %	% w/w
Nitrogen	1.4 %	% w/w
Sulphur	0.0 %	MJ/kg

Size distribution (µm)



Mesh and Settings





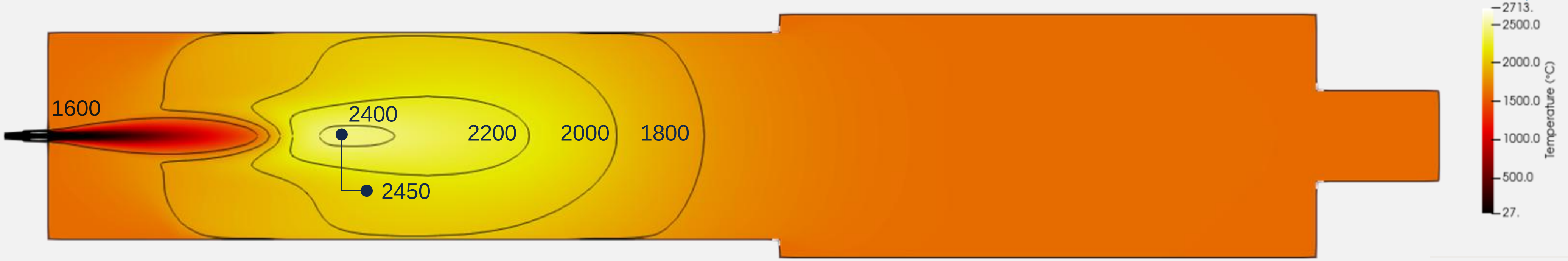
Numerical Set-up:

- Turbulence: k-ω SST
- Spatial Discertization: Second Order
- Pressure-velocity coupling: PRESTO!
- Radiation Model: DO – wsggm
- Turbulence-Chemistry interaction: Eddy Dissipation
- Particle: Discrete Particle Model (DPM)

- Automatic mesh refinement on temperature and velocity gradients. Start size: ≈410 000 cells

Results - Temperature

TR1
90 kg/h – 720 kW



TR2
60 kg/h – 480 kW

TR3
30 kg/h – 240 kW

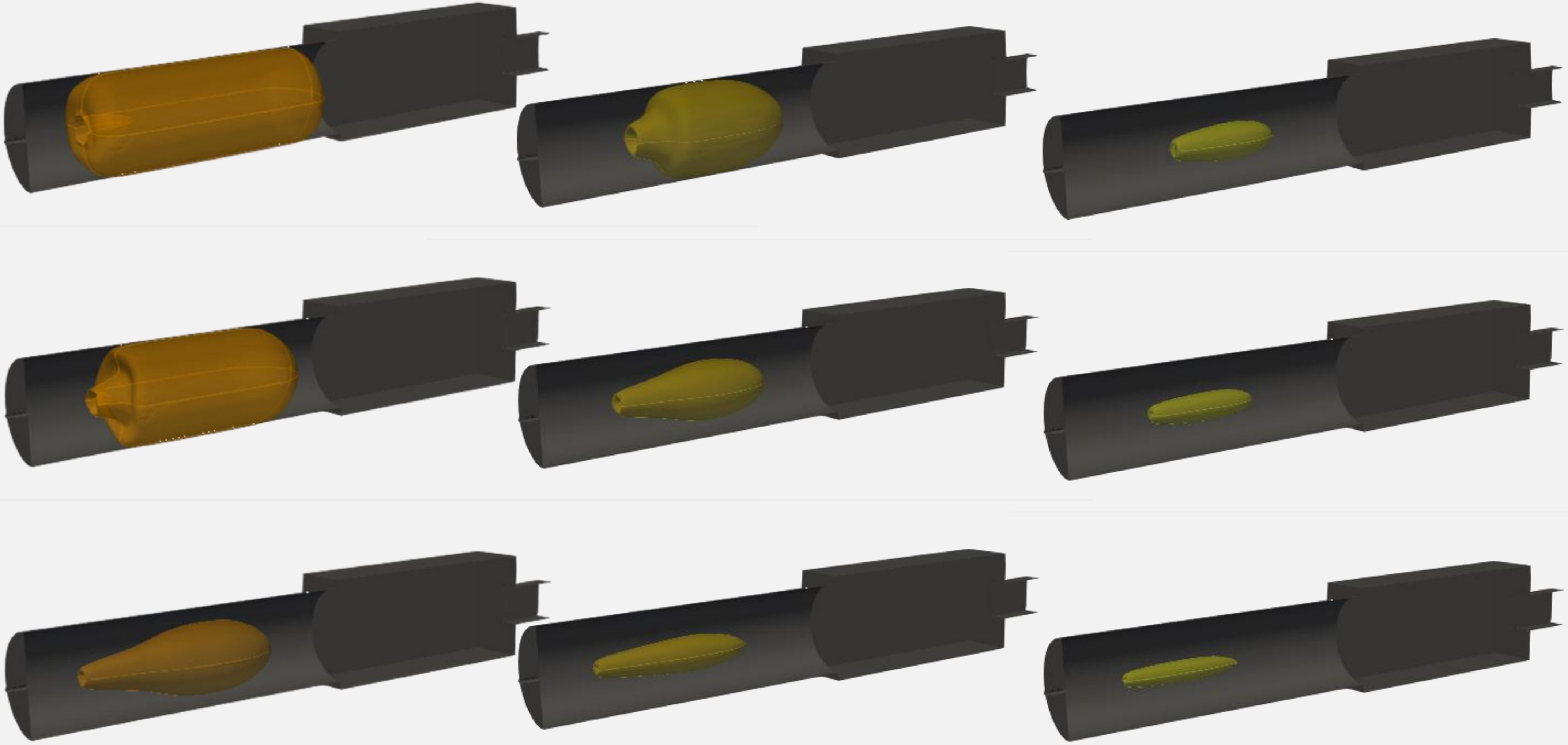
Results – IsoSurface Temperature

1800 °C | 2000 °C | 2200 °C

TR1
90 kg/h
720 kW

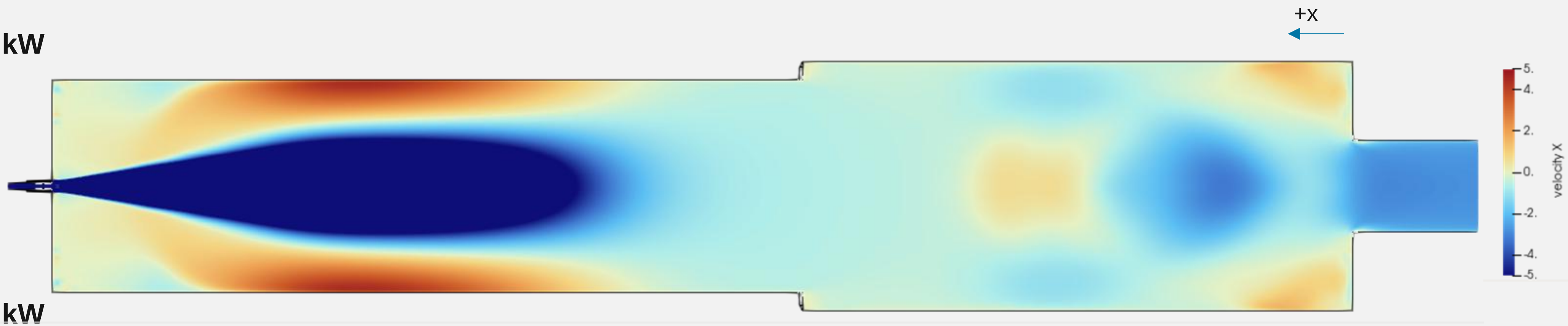
TR2
60 kg/h
720 kW

TR1
30 kg/h
240 kW

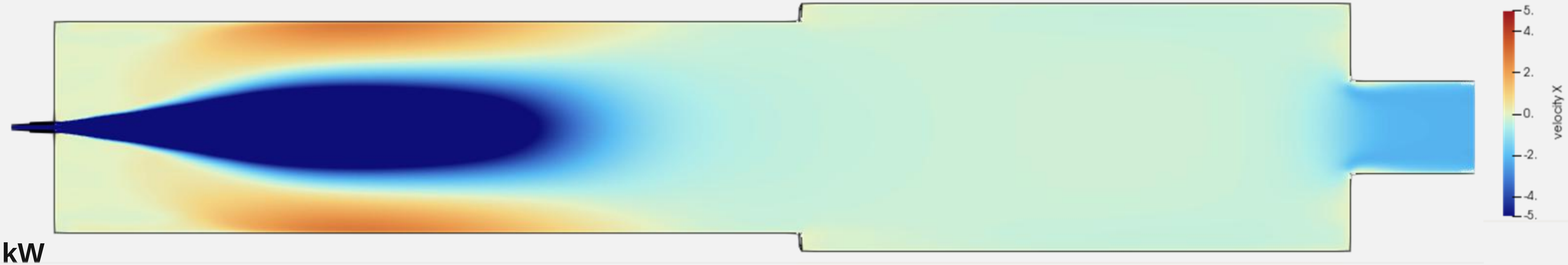


Results – Back Velocity X

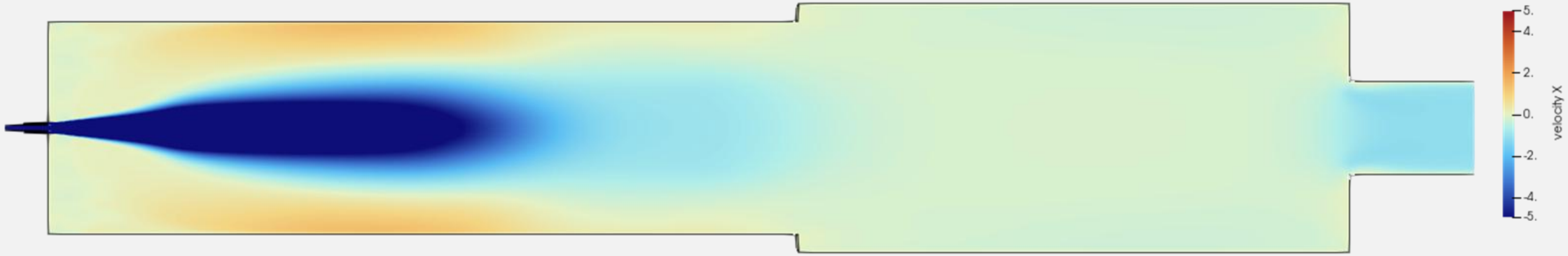
TR1
90 kg/h – 720 kW



TR2
60 kg/h – 480 kW



TR3
30 kg/h – 240 kW



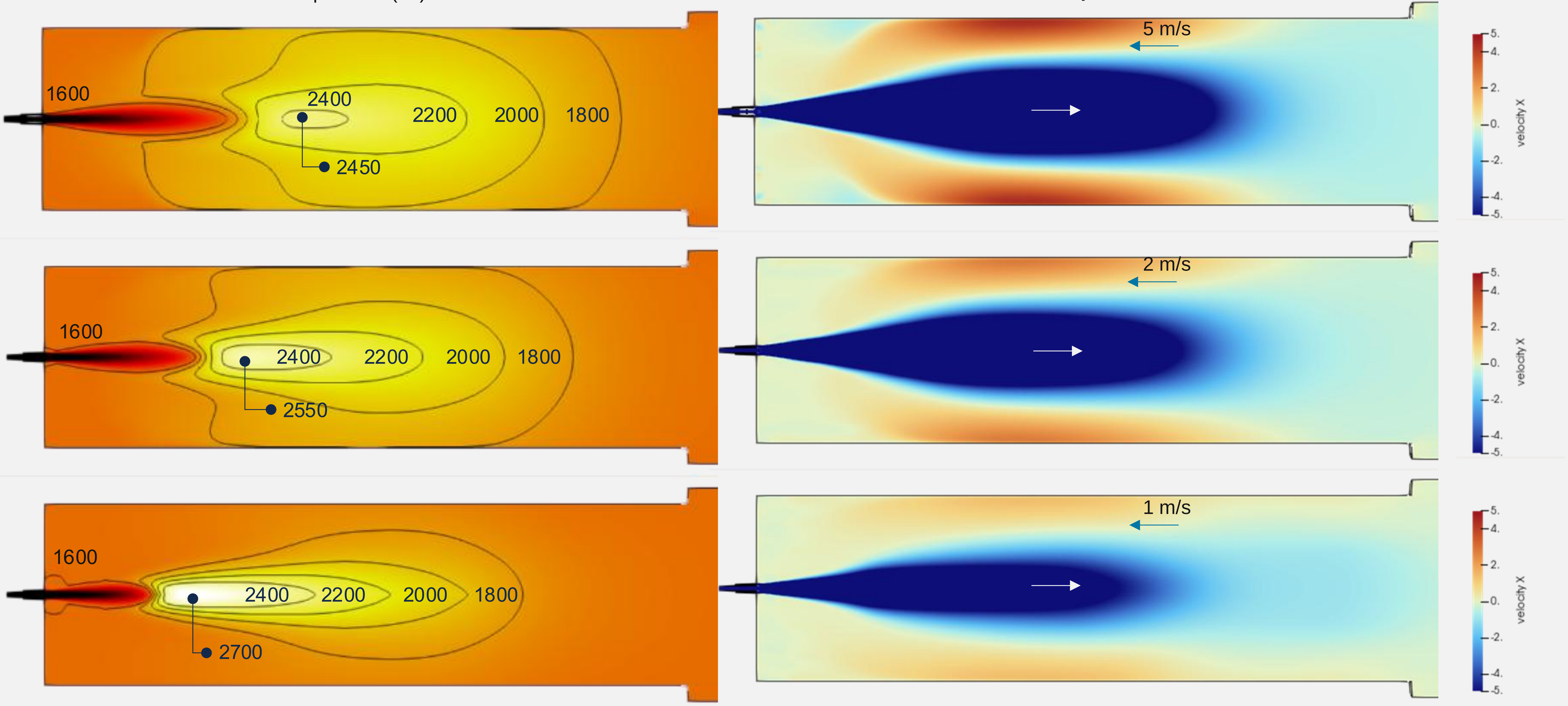
Results – Flue Gas Recirculation

Temperature (°C) | Velocity backwards

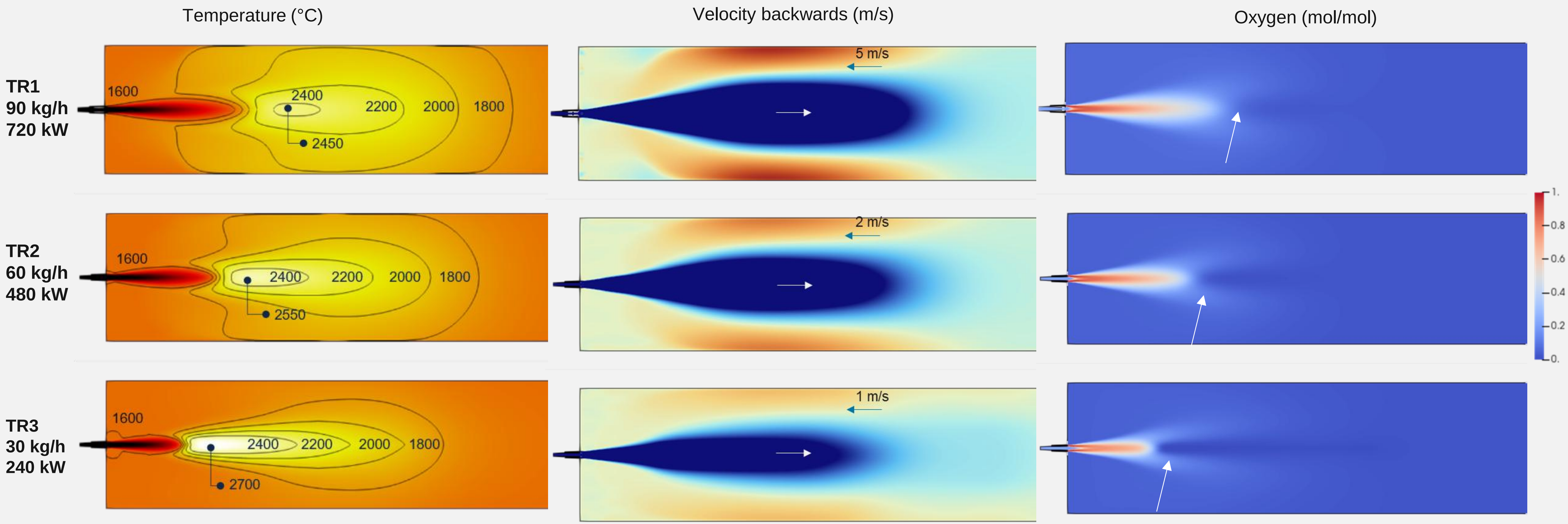
TR1
90 kg/h
720 kW

TR2
60 kg/h
480 kW

TR3
30 kg/h
240 kW



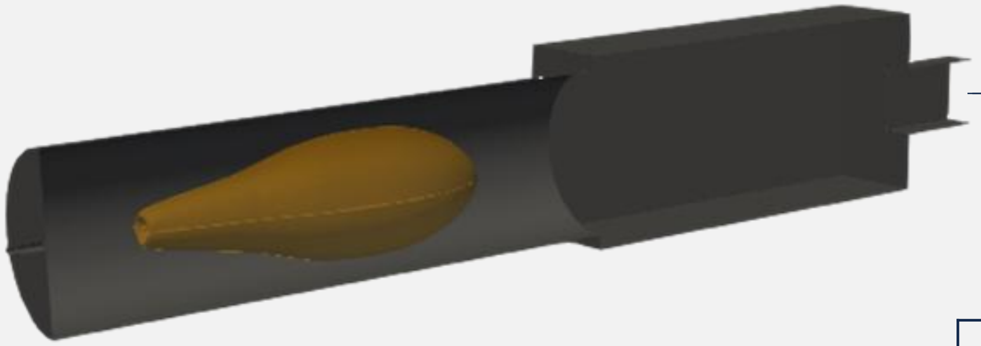
Results – Flue Gas Recirculation



Results - Summary

Process conditions				
Case		TR1	TR2	TR3
Coke breeze	(kg/h)	90	60	30
Transport air	(Nm3/h)	15	12	10
Oxygen	(Nm3/h)	146	96	47
Thermal power	(kW)	720	480	240

Flue gas				
Case		TR1	TR2	TR3
H_2O	(% mol/mol)	2.33%	2.33%	2.21%
CO	(% mol/mol)	0.00%	0.00%	0.00%
CO_2	(% mol/mol)	86.50%	86.16%	81.59%
O_2	(% mol/mol)	3.45%	2.44%	2.14%



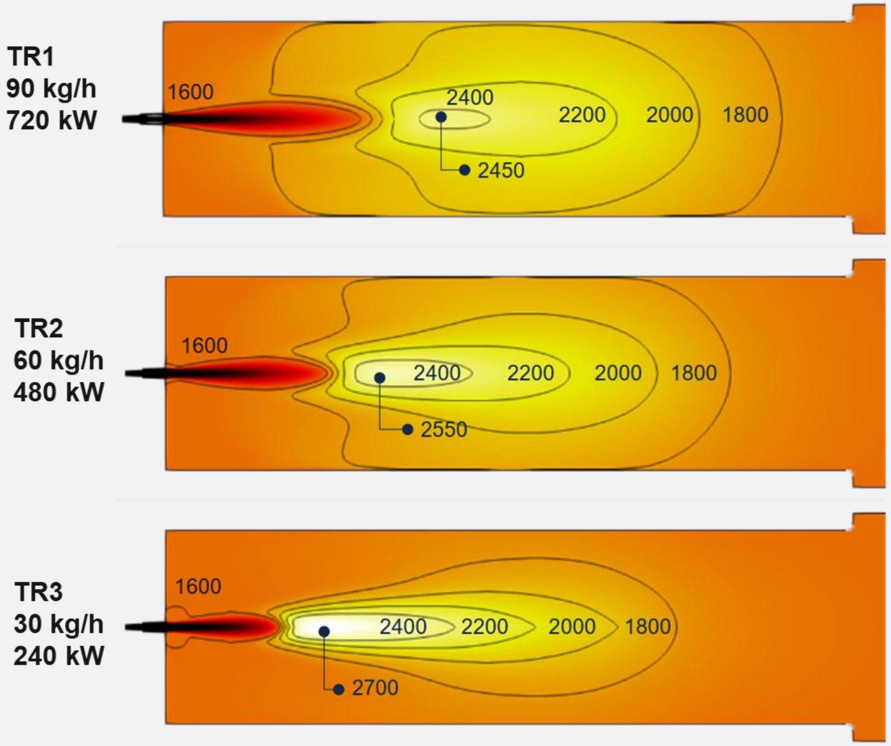
Power				
Case		TR1	TR2	TR3
Thermal power	(kW)	720	480	240
Heat Loss	(kW)	136.2	91.2	44.4
T max	(°C)	2450	2550	2700

Ashes				
Case		TR1	TR2	TR3
Flowrate	(kg/h)	10.66	7.00	3.54
Fraction of coke	(% w/w)	11.85 %	11.67 %	11.82 %

Conclusion and acknowledgments

Conclusion

- In the scope of Prosynteg project, a **coke oxy-burner** has been modeled by **CFD** simulation before the **experimental campaign**
- Fuel is **Coke Breeze**.
- The burner consumes all combustible fraction of coke. Only **ashes** and **combustion products** exit the combustion chamber.
- Since the **high velocity** of the oxygen, **strong recirculation** of flue gases occurs in the combustion chamber. Flue gas recirculation is proportional to coke breeze flowrate.
- **Higher recirculation** leads to:
  - **higher dilution** of comburent, and thus the **lower max temperature** (TR1)
  - **larger flames**, touching **walls** and possibly damaging the cooling system (needed for the experimental trial**)**
- At **60 kg/h** flowrate, the maximum wall temperature inside the combustion chamber is 1800°C.



Our web pages

Website
https://www.prosynteg.eu/

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

Events

Acknowledgments

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.

Thank you for your attention

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