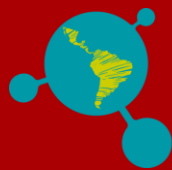


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**The use of hydrogen in the ceramic industry:
role of oxygen enrichment, emission assessment and its
economic feasibility.**

María Agustina Ravotti & Paolo Canu

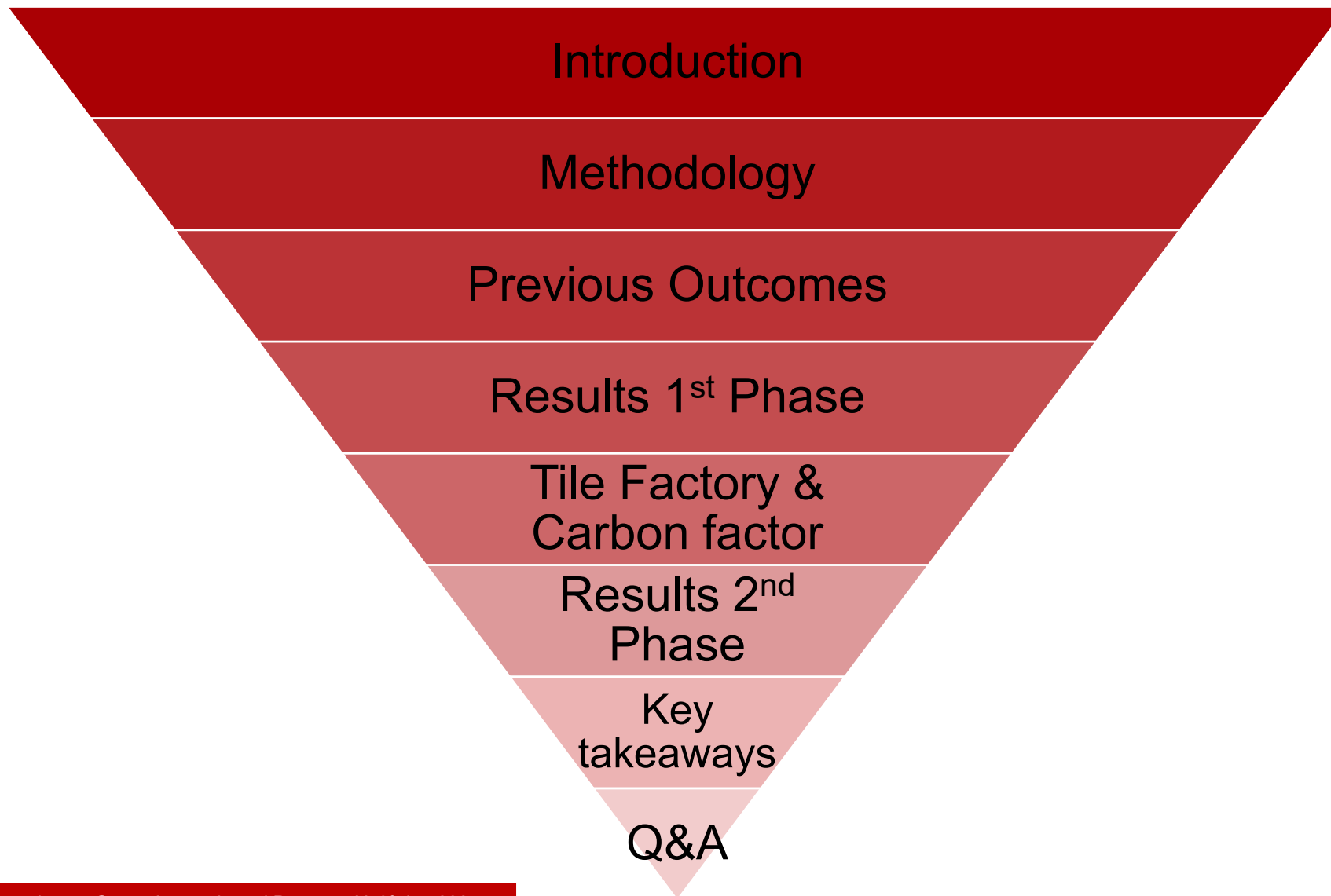


**2nd LATAM MEETING ON GREEN
AMMONIA AND POWER-to-X**

9th January 2025



Agenda





Introduction: PhD focus and previous work



Thesis topic:

“Upgrading of kilns for clay bricks production using H₂ as fuel”



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June – Nov 2024
6 months of joint research
collaboration



Paper under review

“Experimental study of the influence of oxygen enrichment in hydrogen-enriched natural gas combustion at a semi-industrial scale”



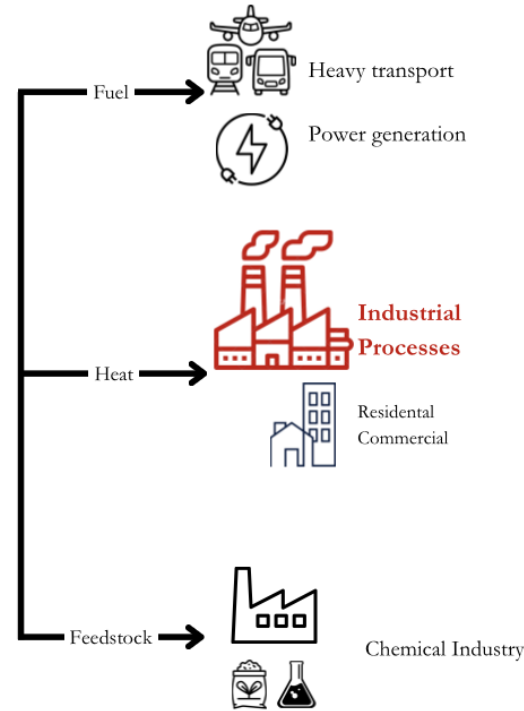
Introduction: Why?



Green
Hydrogen



Carbon
Neutrality
by 2050



Hydrogen is the essential solution for decarbonizing **hard-to-abate** sectors, where **full electrification is not feasible**

One major challenge: economic feasibility

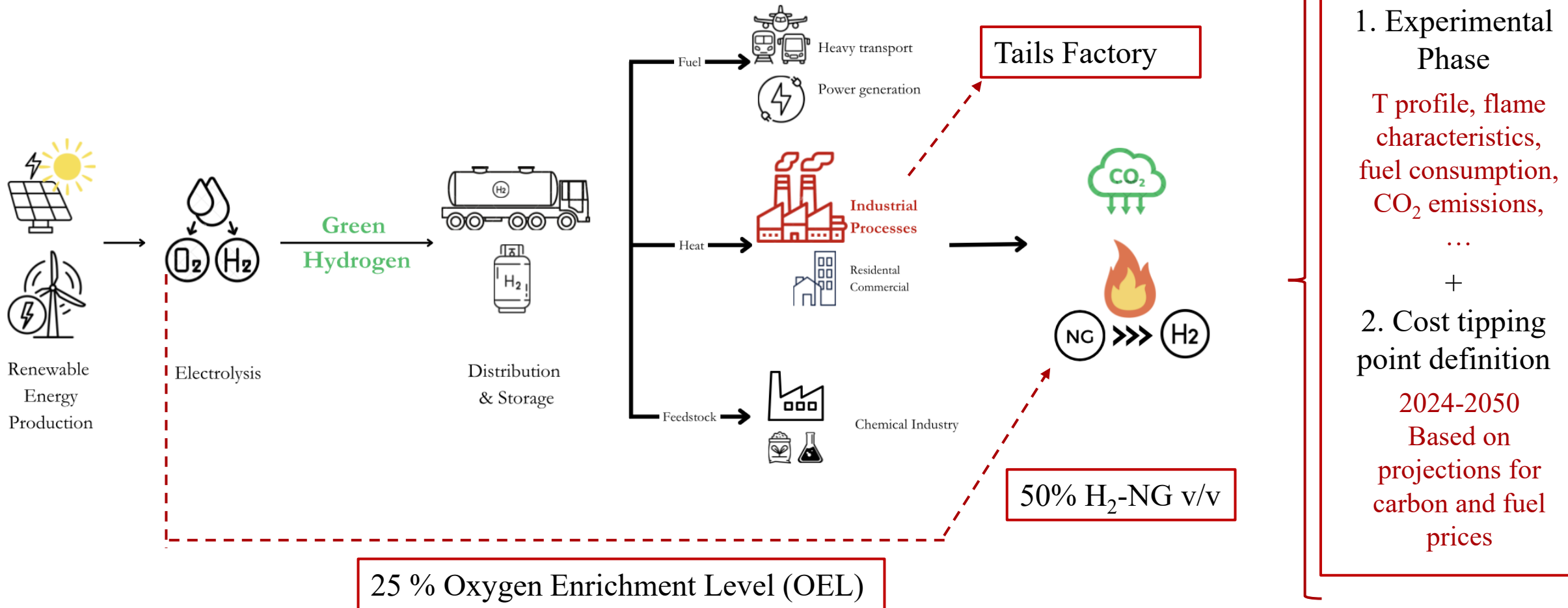
Oxygen enrichment (in NG-air)

- Boosts Efficiency
- Lowers Fuel Consumption

Could O₂, a by-product of electrolysis, accelerate the adoption of hydrogen in combustion systems?



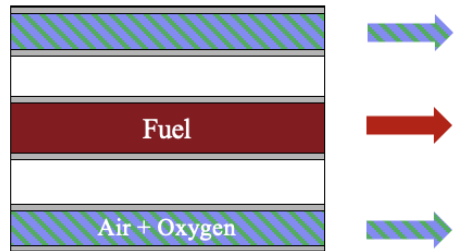
Methodology: the 2 phases



Methodology: 1) Experimental set-up

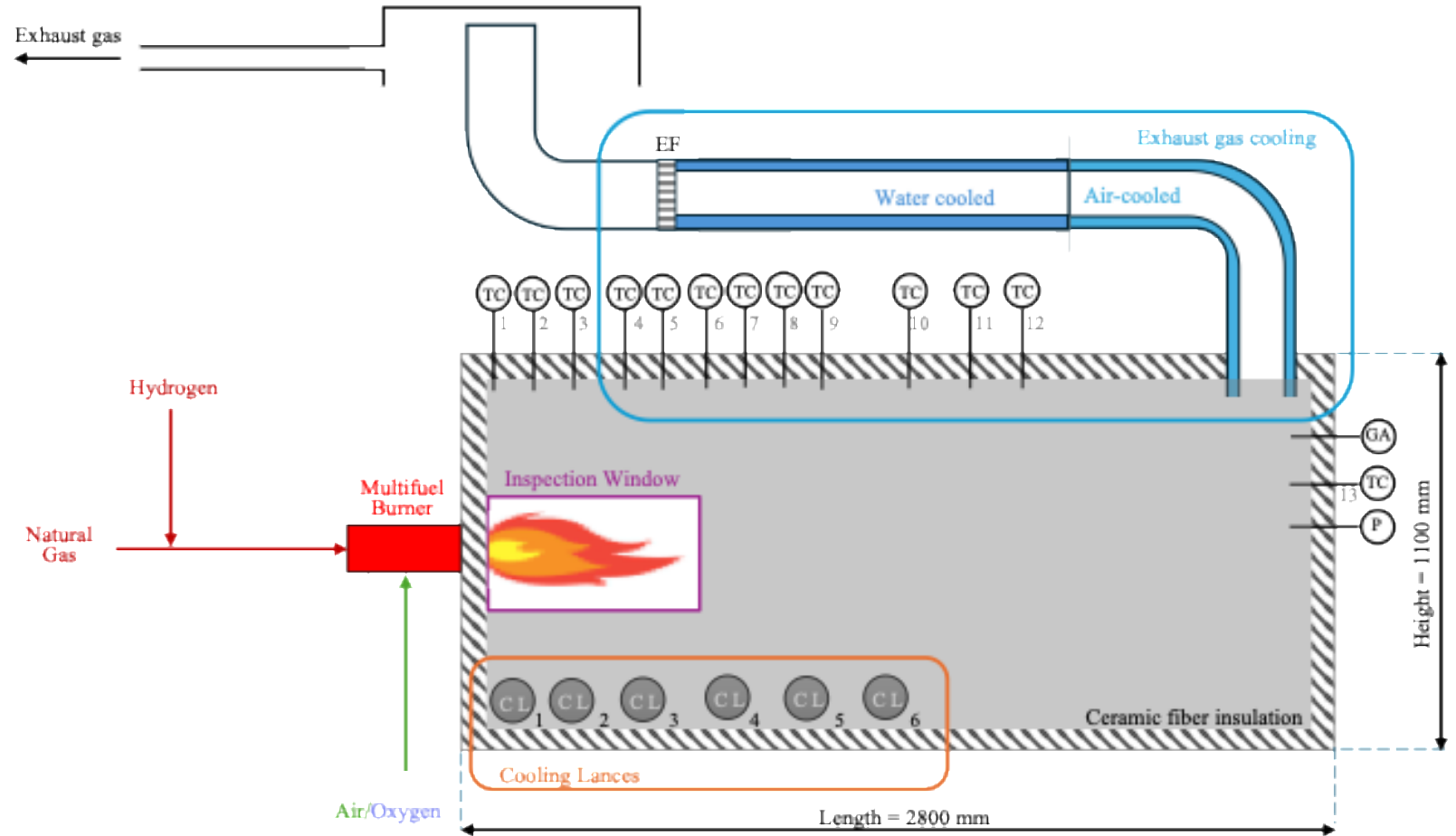
Cases of Study

	H ₂ [% v/v]	H ₂ [% energy]	O ₂ [%]
A	0	0	21
B	50	23	21
C	50	23	25



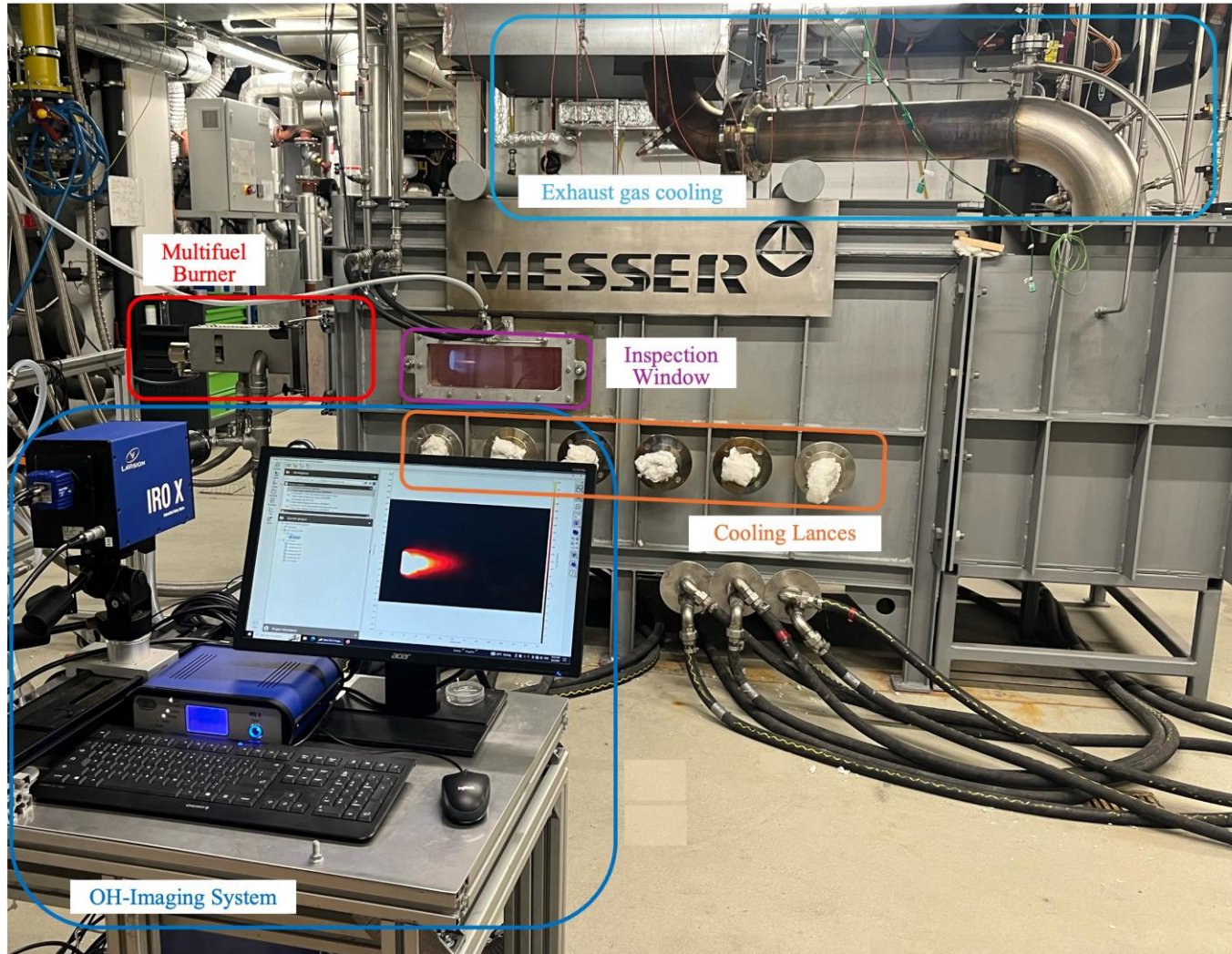
*Pre-mixed Oxygen Enriched
Combustion*

Oxygen Enriched Configuration



Test rig at the laboratory of the Institute of Thermal Engineering in Graz

Methodology: 1) Experimental set-up



Main Outcome from Phase A:

- Fuel consumption for constant furnace temperature
- Carbon factor: $\text{kg CO}_2/\text{kWh}$

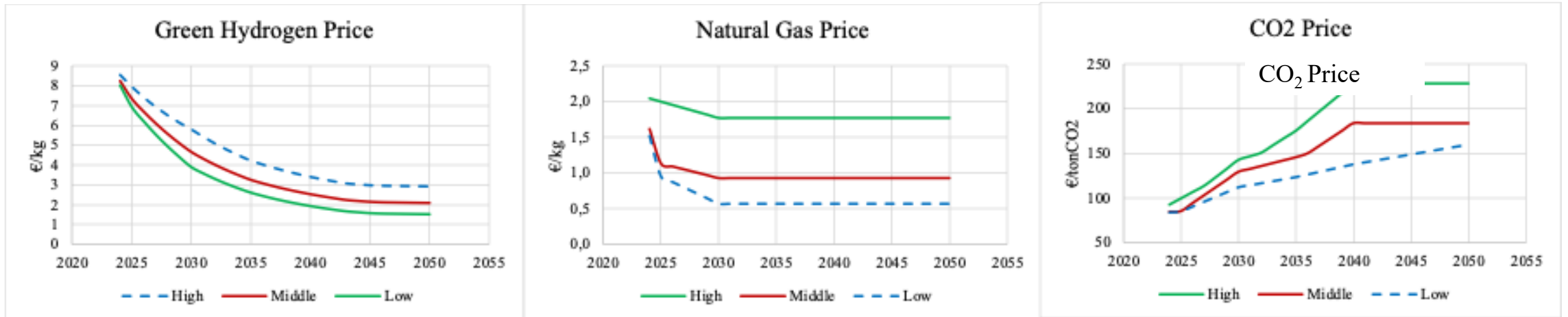
Photo of the actual furnace in the institute with the OH chemiluminescence camera equipment.*



Methodology: 2) Price projections

Conservative Scenario (1)	Based on “middle” values for hydrogen, natural gas, and carbon rates.
Optimal Scenario (2)	Assuming “low” projected prices for hydrogen and maximum costs for natural gas and carbon rates.

$$\text{Total Cost} = \text{Fuel} + \text{CO}_2 \text{ in } \frac{\text{EUR } 10^{-6}}{\text{year}} = \dot{m}_{\text{NG}} * \text{Cost NG} + \dot{m}_{\text{H}_2} * \text{Cost H}_2 + \text{CO}_2 * \text{Cost } \dot{m}_{\text{CO}_2}$$

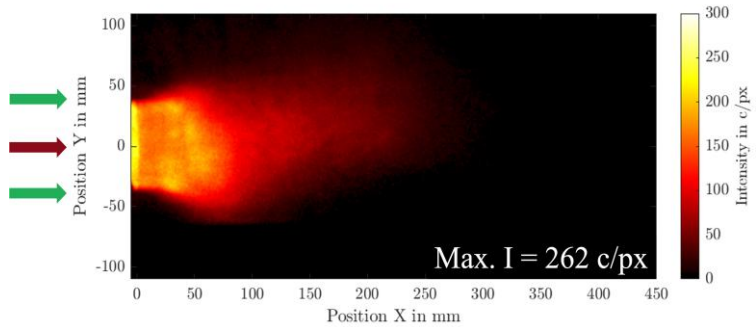


Projections by Impact Hydrogen, based on data from the Netherlands Environmental Assessment Agency (Planbureau voor de Leefomgeving, PBL) 2024 (Climate and Energy Outlook - KEV) and the "Renewable Hydrogen Cost Element Evaluation Tool" (RHCEET)

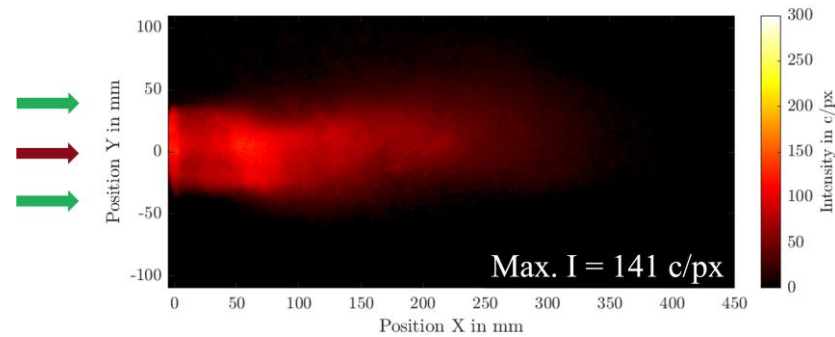


Previous Outcomes: *Flame Structure and NO_x Emissions*

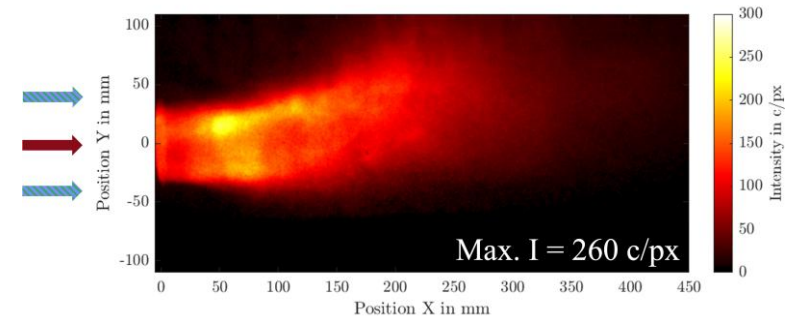
Constant Burner Power = 50 kW



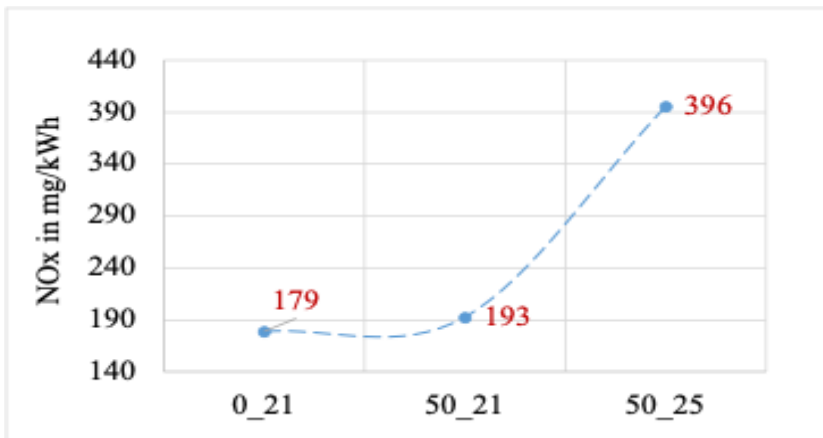
NG - Air



50% H₂ - Air



50% H₂ - 25% O₂



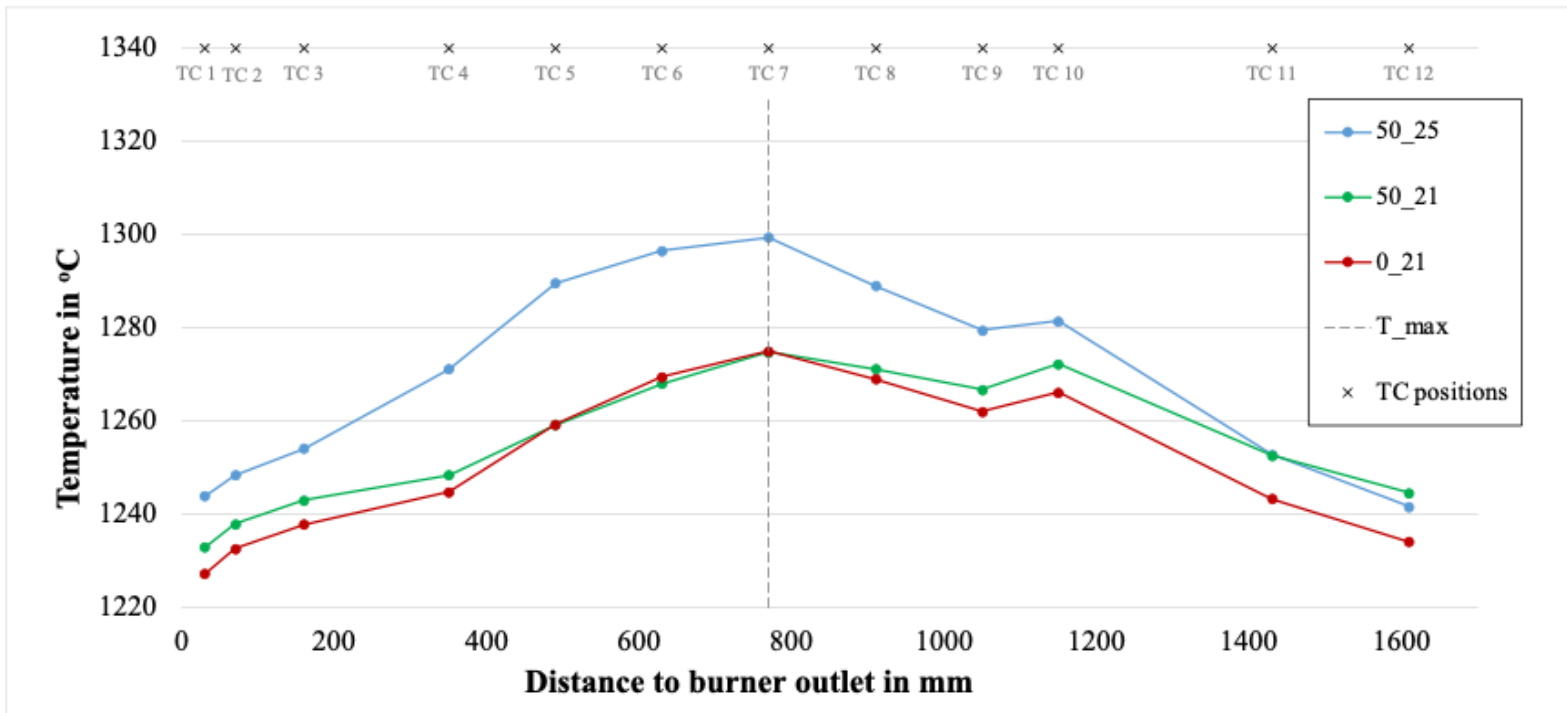
Constant T = 1300 °C

*NO_x emissions as a function of
fuel and oxidizer composition*

- Flame structure: repositioning of the reaction zone and thermal lift.
- NO_x increase: Slight rise with H₂ addition; more significant with oxygen enrichment

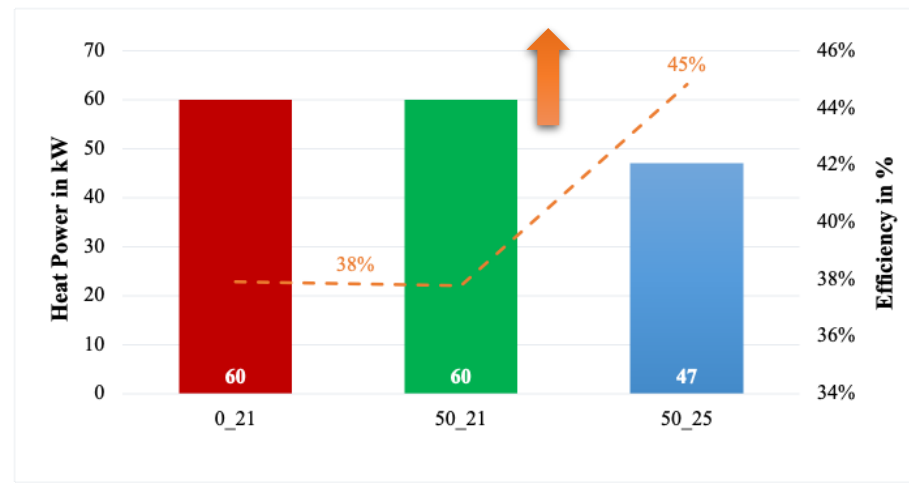


Experimental Results 1: Fuel Savings



Furnace temperature profile along the furnace ceiling.

Max T ~ 1300 °C
λ ratio = 1,2



Evolution of Heat Power and Efficiency

Cases	Power [kW]
A	60
B	60
C	47

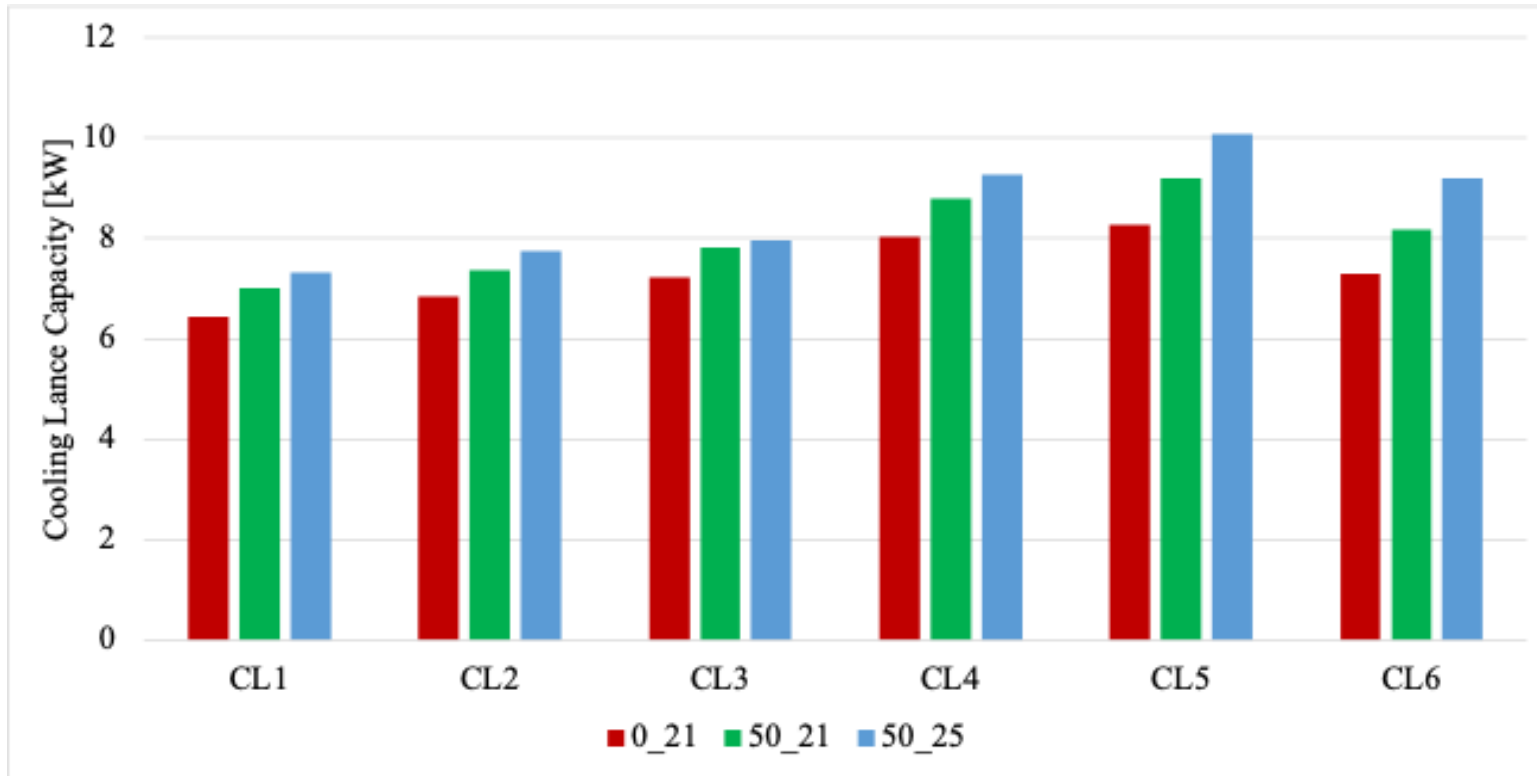


$$\eta_F = 1 - \frac{\dot{m}_{FG} c_p \left(T_{FG} - T_{ref} \right)}{\dot{m}_{fuel} LHV_{fuel}}$$

A or B → C
↑ 7% Furnace Efficiency (η_F)
↓ 22% Fuel consumption



Experimental Results 1: Heat Transfer



Evolution of total cooling lances total capacity

**Constant Burner
Power = 120 kW**

$A \rightarrow B = \uparrow 10\% \text{ kW}$
 $A \rightarrow C = \uparrow 16\% \text{ kW}$

Cases		Total in kW
A	0_21	44,13
B	50_21	48,36
C	50_25	51,61



Experimental Results 1: Carbon Factor



$$\text{CO}_2 \text{ Factor} \left[\frac{\text{kg CO}_2}{\text{kWh}} \right] = \% \text{CO}_{2, \text{wb}} \times V_{\text{FG, wb}} \times \rho_{\text{CO}_2} \times \frac{L\text{VH}_{\text{fuel}}}{V_{\text{fuel}}}$$

CO₂ d.b. (1- %H₂O)

Cases	CO ₂ w.b. in %	V_FG w.b. in Nm ³ /h	Carbon Factor in KgCO ₂ /kWh
A	7,98%	74,57	0,19
B	6,25%	72,86	0,15
C	7,13%	48,50	0,15

References

Fuel: NG + H₂

d.b.: dry base

w.b.: wet based

FG: Flue Gases

GA: Gas Analyzer

LHV: Low Heating Value

Reference Industrial Process: Tile Factory

135 MWh → 3500 Units/Day

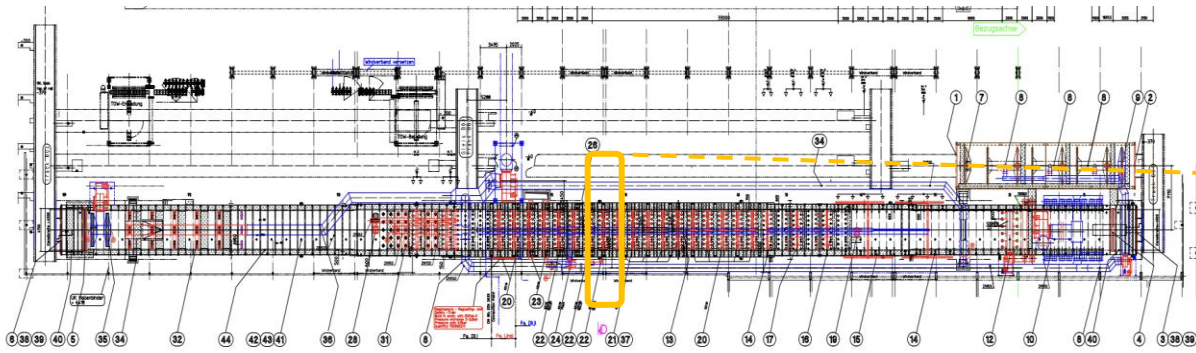
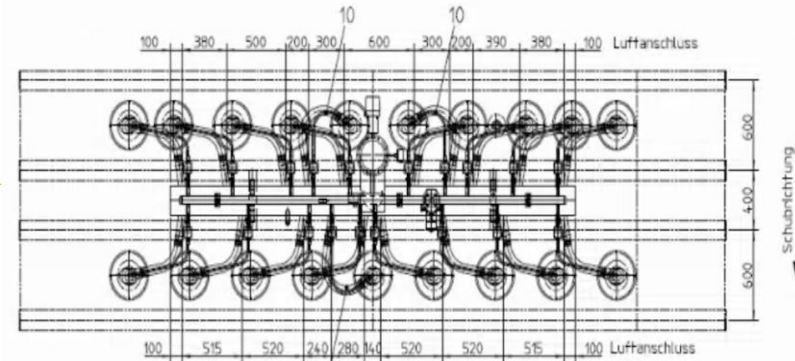


Diagram of a tunnel kiln for ceramic production



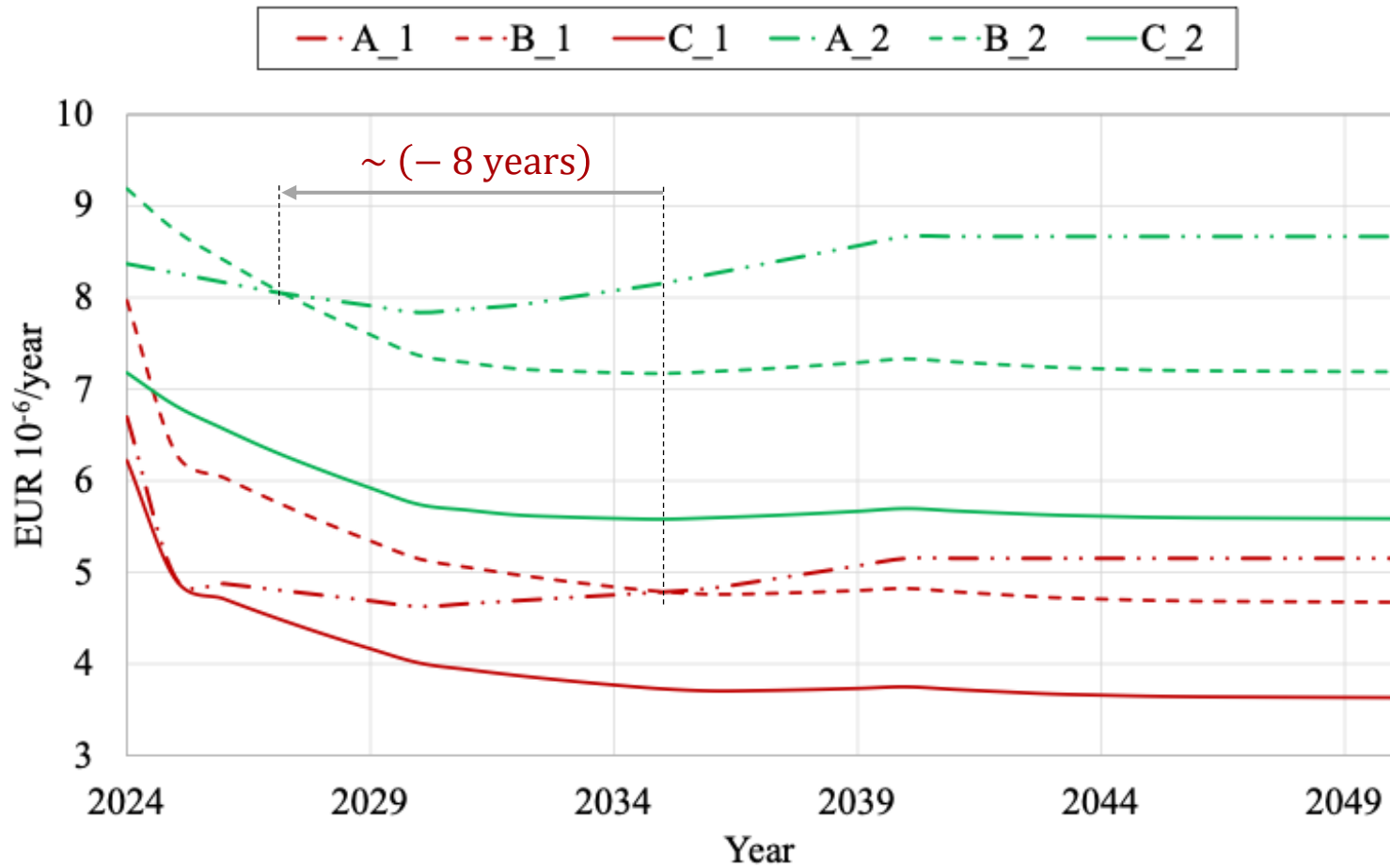
Group of roof burners

Cases	Annual CO ₂ emissions tCO ₂ /year	CO ₂ Savings [%]
A	9598	[-]
B	7372	23%
C	5602	42%

B → C = ↓ 19 % CO₂ emissions



Analysis Results: 2) Cost tipping point



- Oxygen enrichment could facilitate the economic viability of a 50% H₂-NG mix by compensating for hydrogen's higher cost through fuel savings.
- In the optimistic scenario, the 50/50 fuel mix could reach the tipping point nearly a decade earlier.

	H ₂ [% v/v]	O ₂ [%]
A	0	21
B	50	21
C	50	25

Conservative Scenario (1) vs Optimal Scenario (2)

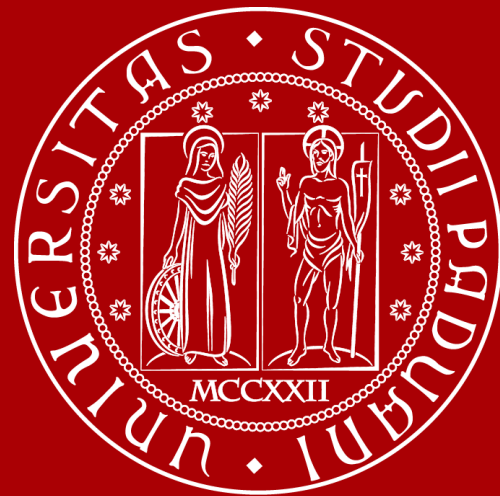
$$\text{Total Cost} = \dot{m}_{\text{NG}} * \text{Cost NG} + \dot{m}_{\text{H}_2} * \text{Cost H}_2 + \text{CO}_2 * \text{Cost } \dot{m}_{\text{CO}_2}$$



Conclusion

- Enriching Natural Gas - Air with up to a 50% H₂ mix **reduces CO₂** emissions by **23%**.
- A further **19%** reduction in the carbon footprint can be achieved with **25% oxygen enrichment**, driven by fuel savings.
- Cost **parity** between natural gas and 50% H₂ air-fuel combustion is projected by **2035** in a conservative scenario and **2027** in an optimistic scenario.
- Fuel savings from O₂ enrichment could make hydrogen-natural gas blends economically viable today.

Q & A



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Thank you!