Pilot tests at 1 MW_{th} scale on retrofitting fluidized bed boilers for oxyfuel-combustion of solid recovered fuel

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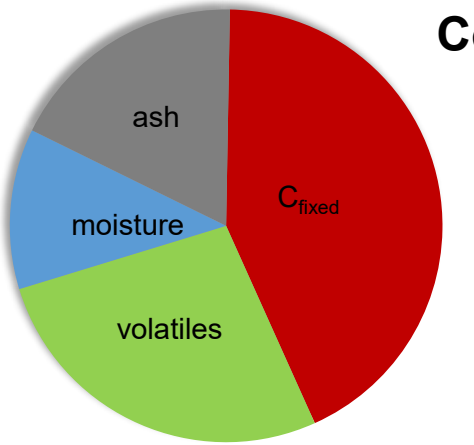
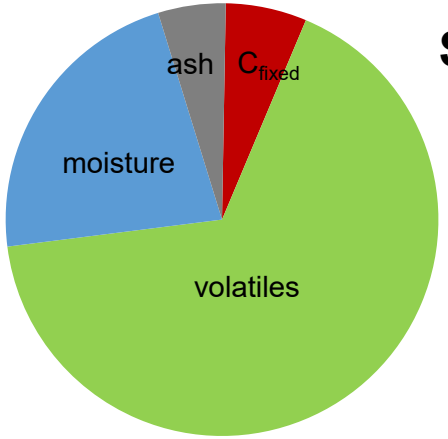
Funded by the European Union

MOTIVATION



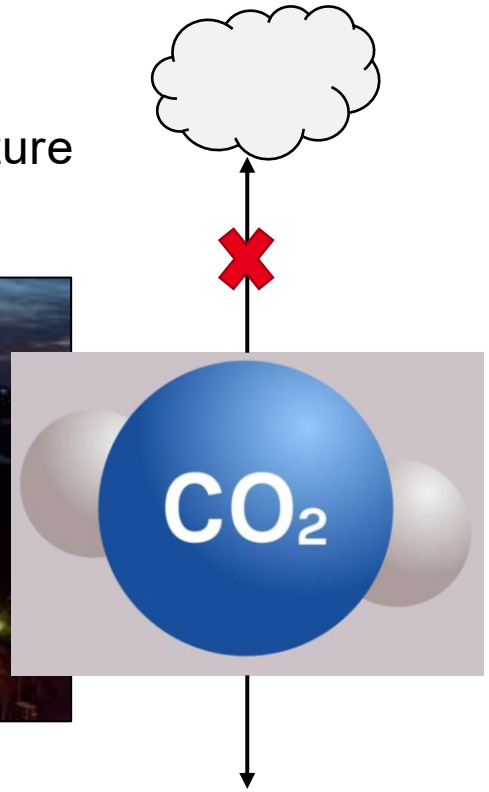
Coal



SRF

1. Utilization of existing infrastructure

[1] https://www.nationalgeographic.de/umwelt/kohle-wie-lange-noch

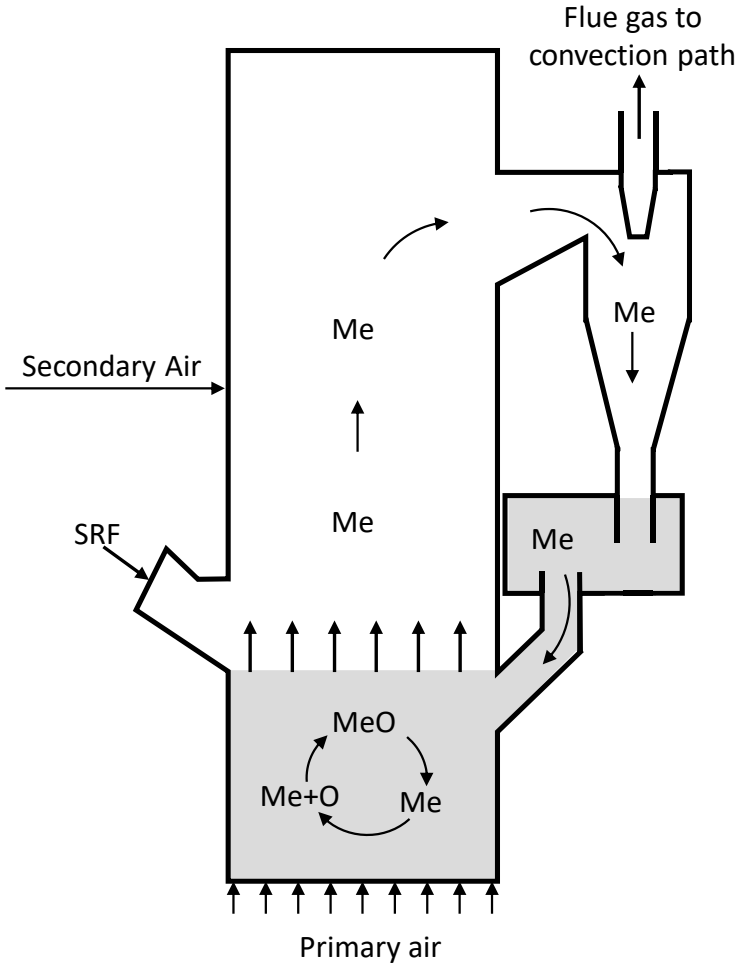


3. Integration of CO_2-capture

2. Reduction of fuel footprint

Net negative CO_2 emissions

OCAC (OXYGEN CARRIER AIDED COMBUSTION)



Sand
$\bar{d}_p$= 191 µm

Ilmenite
$\bar{d}_p$= 203 µm

Chemical Reactions:

Oxidation of OC:

$$Me + O \longleftrightarrow MeO$$

$$Me + NO \longleftrightarrow MeO + N_2$$

Reduction of OC:

$$MeO + CO \longleftrightarrow Me + CO_2$$

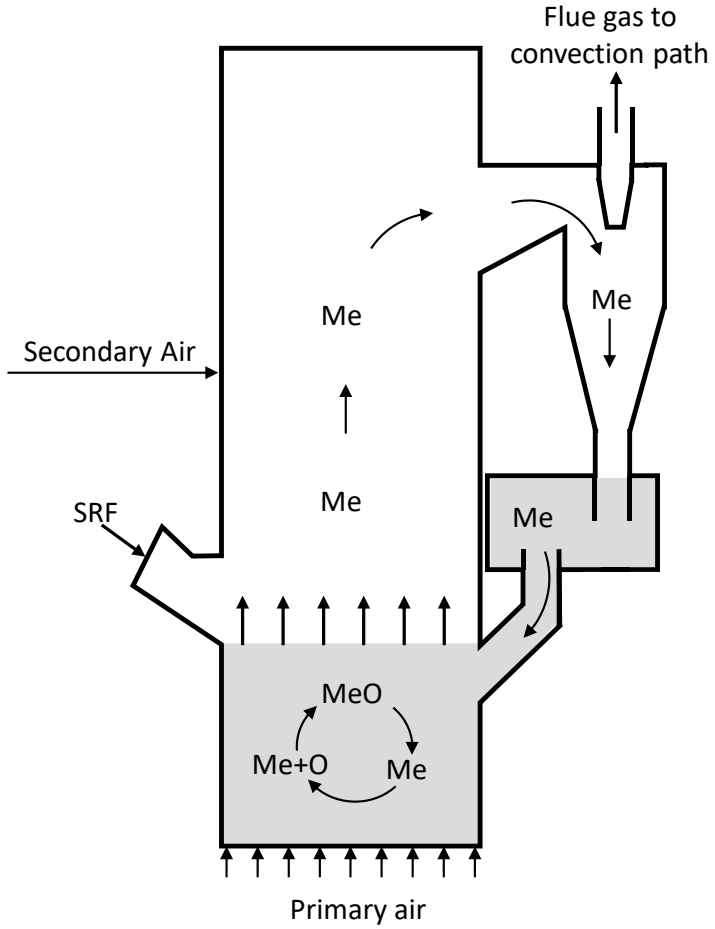
$$MeO + CH_4 \longleftrightarrow Me + CO_2 + H_2O$$

$$MeO + H_2 \longleftrightarrow Me + H_2O$$

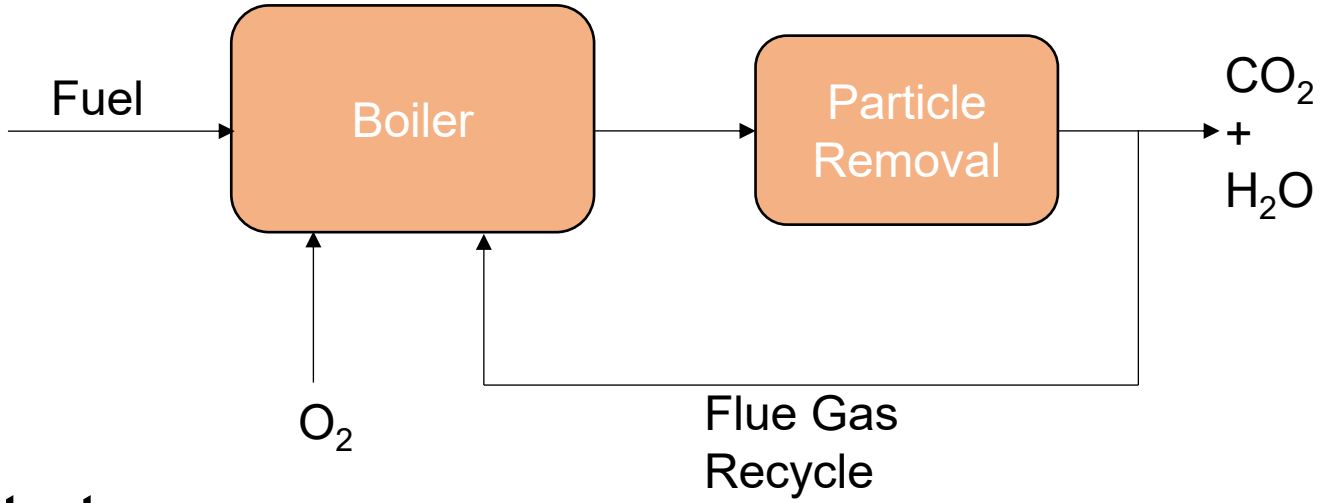
➔ Oxidation of volatile components

OXY-OCAC

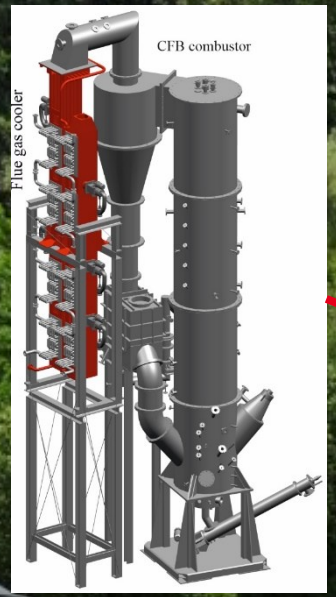
OCAC



Oxyfuel-Combustion



First pilot tests

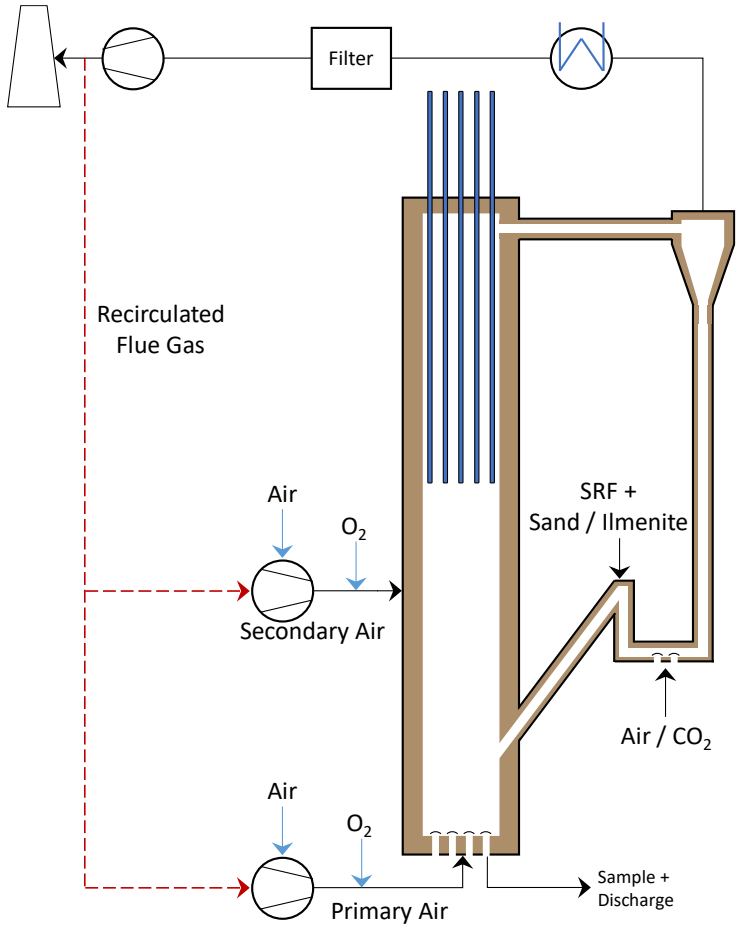


high temperature process facility

gas cleaning plant

synthesis test rig

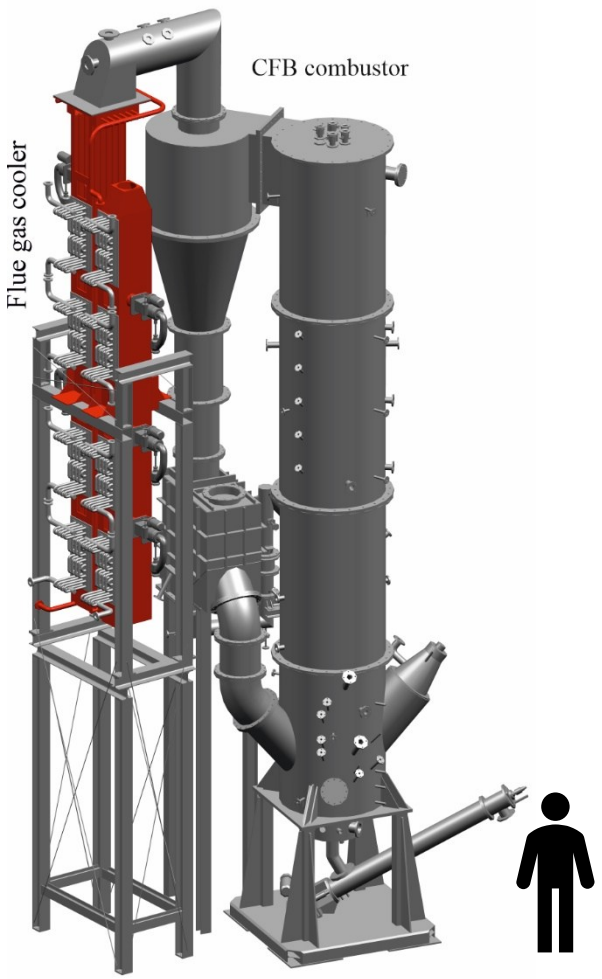
PILOT PLANT



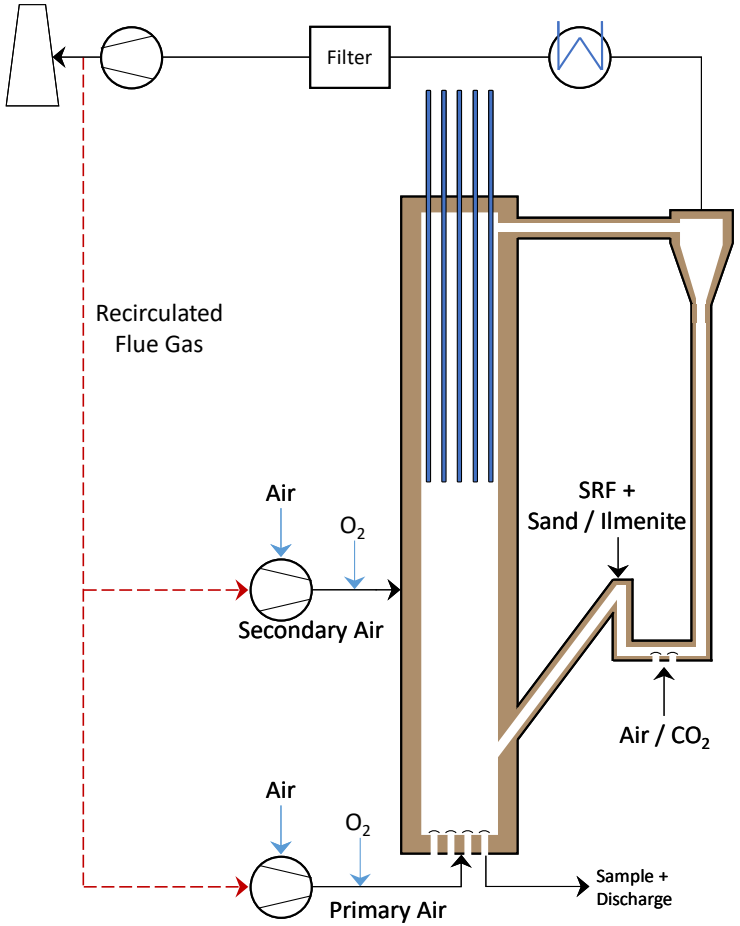
1 MW_{th} Combustion Reactor

- Inner diameter: 600 mm
- Outer diameter: 1300 mm
- Height: 8600 mm

- Fuel feed: up to 1 MW_{th}
- Solid inventory: ~ 130 kg
- Superficial velocity: 3 – 7 m/s



OXY-OCAC - SETUP



Plant adaptions:

- Flue gas recirculation (wet)
- Oxygen addition to fluidization lines

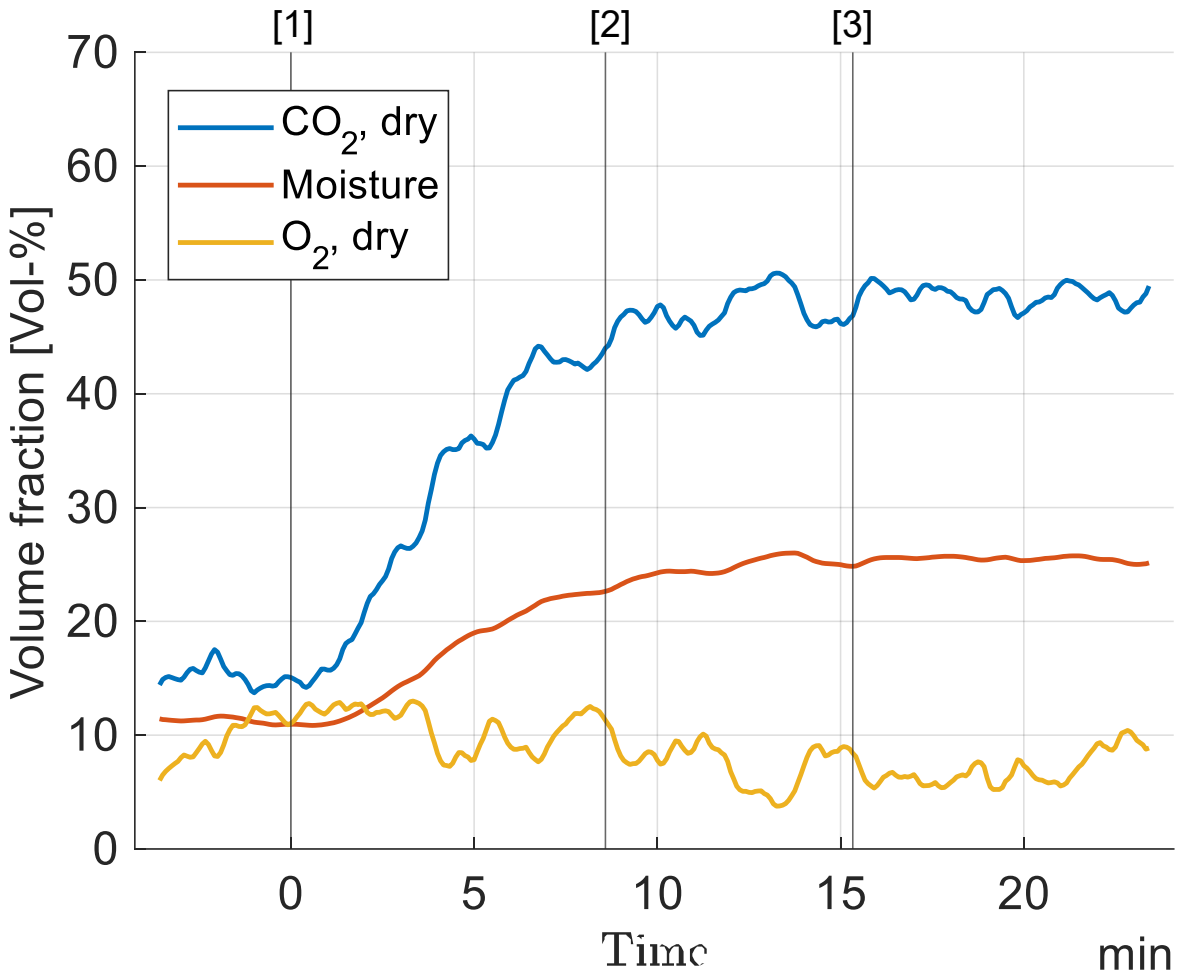
➔ O_2-content regulated independently

Sand
$\bar{d}_p$= 191 µm

Ilmenite
$\bar{d}_p$= 203 µm

		SRF 1	SRF 2
Moisture	[wt-% a.r.]	22.0	10.0
Ash	[wt-% dry]	6.6	10.8
Volatiles	[wt-% dry]	85.2	80.1
Fixed Carbon	[wt-% dry]	8.3	9.1
LHV	[MJ/kg a.r.]	20.9	23.0

TRANSITION AIR – OXY



[1]: Initiation of Fluidization medium change

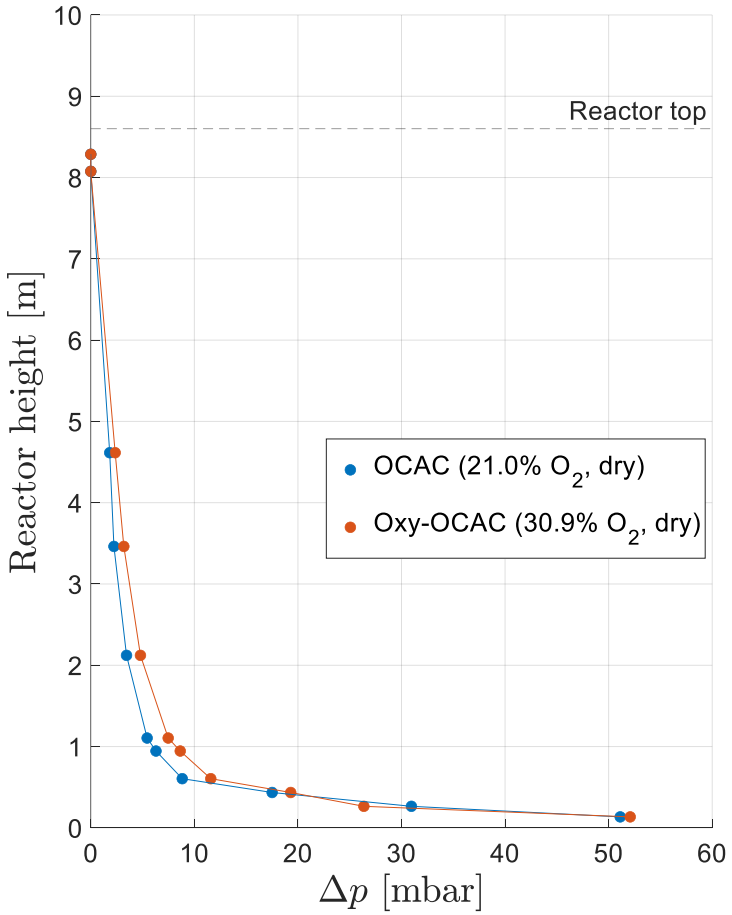
[2]: Completion of fluidization medium change

[3]: Stable conditions established

- Wet recirculation ➔ CO_2 + H_2O increase
- Stable conditions after ~ 16 minutes
- Air ingress ➔ ~ 50% CO_2

TEMPERATURE FIELD

Pressure effect:



$$\rho_{CO_2} > \rho_{O_2} > \rho_{N_2} > \rho_{H_2O}$$

Higher fluidization medium density

➔ Increased drag force

➔ Reduced terminal velocity

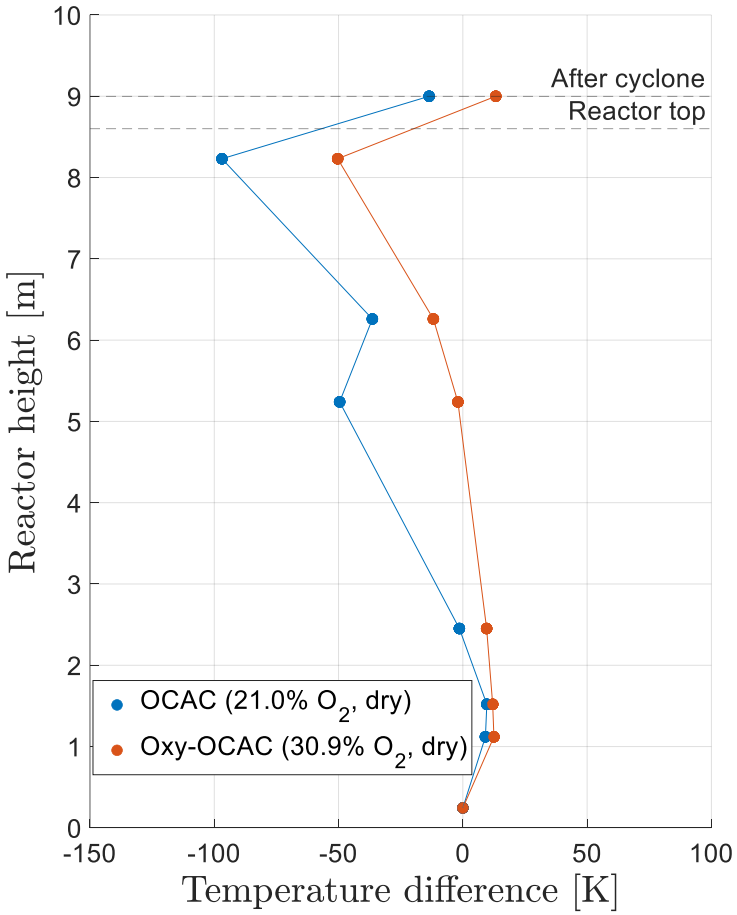
➔ Extended particle suspension time

➔ Enhanced thermal homogenization

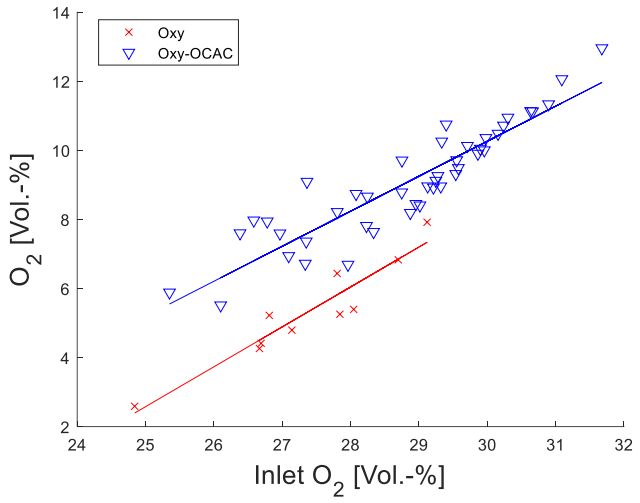
$$c_p(H_2O) > c_p(CO_2) > c_p(N_2) > c_p(O_2)$$

➔ Lower T reduction in freeboard

Temperature effect:



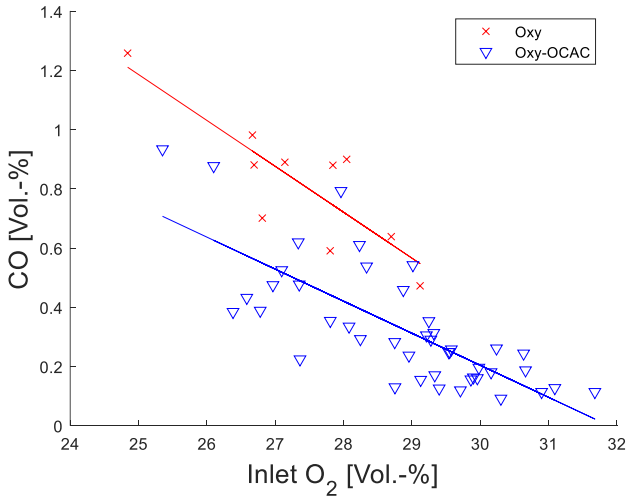
OFF-GAS COMPOSITION



Flue-gas O_2 increases with inlet-O_2

Oxy-OCAC with reduced slope

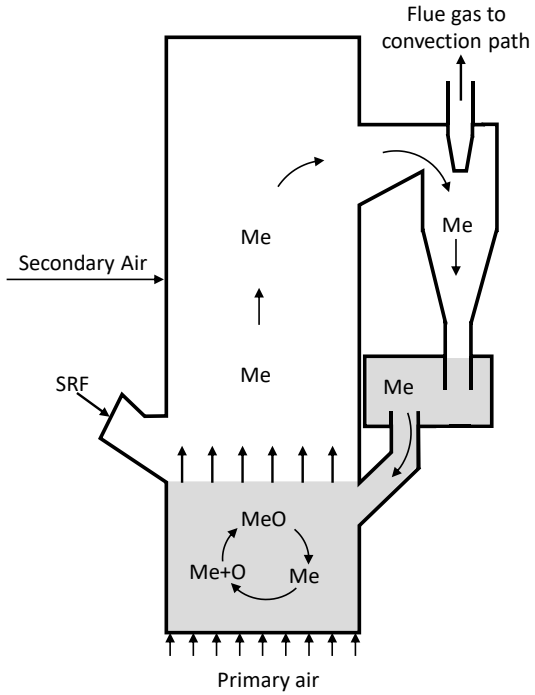
Species	Bed Material	Slope	R^2
O_2	Sand	1.16	0.90
	Oxygen Carrier	1.01	0.83
CO	Sand	-0.16	0.71
	Oxygen Carrier	-0.11	0.58



$$MeO + CO \longleftrightarrow Me + CO_2$$

Lower overall CO-concentrations

Reduced reduction rate



CONCLUSIIONS

✓ Summary

- Stable transition to oxyfuel in ~ 16 minutes
- Increased pressure in the freeboard
- More even temperature distribution along reactor height
- Ilmenite enhances combustion performance

⧖ Outlook

- Evaluation of different feedstocks
- Scale-up to commercial scale

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Full Length Article

Experimental study on oxyfuel-combustion of solid recovered fuel using ilmenite as bed material in a 1 MW_{th} fluidized bed reactor

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ABSTRACT

The transition from coal-based power generation to carbon-neutral alternatives remains a critical challenge in mitigating climate change. Circulating Fluidized Bed (CFB) boilers offer fuel flexibility, enabling the integration of more environmentally friendly biogenic or waste-derived fuels such as Solid Recovered Fuel (SRF). However, replacing conventional fuels with high-volatile alternatives poses challenges related to combustion stability and efficiency. Oxygen Carrier Aided Combustion (OCAC) with ilmenite as a bed material enhances combustion efficiency and reduces emissions by facilitating oxygen transport within the fluidized bed. Additionally, oxyfuel combustion offers a promising pathway for carbon capture but is hindered by high oxygen demand. This study combines OCAC and oxyfuel combustion, presenting the first autothermal Oxyfuel-OCAC (Oxy-OCAC) experiments conducted at the 1 MW_{th} scale, utilizing 100 % SRF as feedstock. The pilot plant enables oxyfuel operation with wet flue gas recirculation and pure oxygen supply, allowing a controlled transition from air-fired to oxyfuel conditions in 16 min. Differential pressure profiles revealed increasing particle loads in the free board zone with increasing inlet oxygen concentration, leading to a more uniform temperature distribution throughout the CFB reactor. Flue gas analysis confirmed that Oxy-OCAC improves combustion stability compared to oxyfuel combustion with sand as bed material, enhancing oxygen distribution within the reactor. These findings demonstrate that Oxy-OCAC is a promising approach to increasing the efficiency and economic viability of oxyfuel combustion in CFB systems. The combination of ilmenite with SRF in an oxyfuel environment enhances CO_2 capture potential while ensuring stable reactor operation, supporting sustainable energy production.

1. Introduction

Climate change, driven by anthropogenic greenhouse gas (GHG) emissions, remains a critical global concern ("Human Influence on the Climate System," 2023). The energy sector – particularly coal combustion – continues to be one of the primary contributors to these emissions (International Energy Agency, 2023). Despite longstanding awareness of its environmental consequences, coal consumption is projected to hit a record 8.77 billion tons in 2024, with China and India accounting for the majority of this growth (International Energy Agency, 2024). In 2023, global coal-fired electricity generation increased by 175 TWh, maintaining its dominance with over 35 % of global electricity output, even as the United States (169 TWh) and European Union (125 TWh) saw sharp declines (International Energy Agency, 2024). These trends highlight the strategic urgency of deploying emissions reduction technologies – particularly Carbon Capture and Storage (CCS) – in coal dependent regions to achieve meaningful global climate impact.

Among available decarbonization strategies, CCS plays a crucial role in reducing CO_2 emissions from industrial processes and power generation by capturing and sequestering carbon in geological formations. This technology is especially relevant in hard-to-abate sectors where conventional emissions reduction pathways are insufficient (Saraji and Chen, 2023). When combined with the substitution of high-carbon fuels such as coal and petroleum coke with alternatives like biomass or solid recovered fuels (SRF), CCS enables not only the reduction of CO_2 emissions but also the potential to achieve carbon neutrality or even negative emissions (Bui et al., 2017; Gough and Upham, 2011; Ling et al., 2023; Mishra et al., 2020; Wienchol et al., 2020). In this context, circulating fluidized bed (CFB) boilers represent a valuable opportunity due to their operational flexibility and efficiency. CFB technology offers advantages over traditional systems, such as high fuel flexibility, efficient sulfur capture, and low nitrogen oxide emissions, thanks to staged combustion and in-bed desulfurization. Moreover, particle recirculation within the CFB allows extended residence time, improving burnout and combustion efficiency (Basu, 1999; H. Li et al., 2014; Lockwood, 2013; Miller, 2011;

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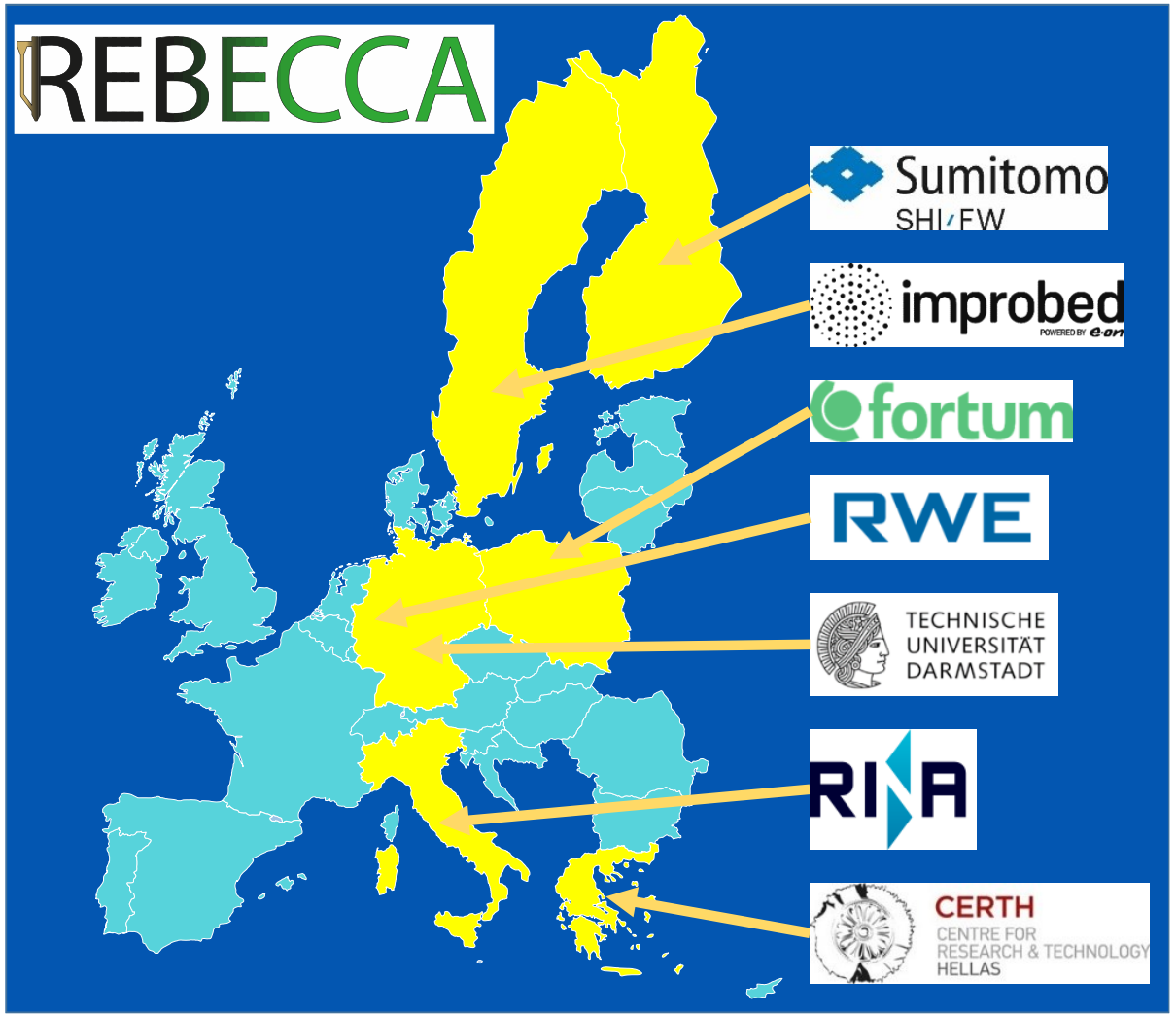
REBECCA PROJECT

Retrofitting Fluidized **Be**d Power Plants for Waste-Derived Fuels and **C**O_2 **Ca**pture



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THANK YOU FOR YOUR ATTENTION!

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EST HOMEPAGE

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