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Sustainable Glass Industry

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The GIFFT Project has received funding from the Horizon Europe program under grant agreement No 101122257.

SUSTAINABLE GLASS INDUSTRY WITH FUEL-FLEXIBLE TECHNOLOGY

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SUSTAINABLE GLASS INDUSTRY WITH FUEL-FLEXIBLE TECHNOLOGY

Program: Horizon Europe

Project Duration: 2023.10.01 - 2027.09.30

Call: HORIZON-CL5-2022-D3-03-06 Efficient and low-emission technologies for industrial use of combustion and gasification systems from low-value biogenic residues and wastes

Estimated Project Cost: 4 478 775.00 EUR.

Coordinator: Lithuanian Energy Institute, Lithuania.

Partners: CHALMERS TEKNISKA HOGSKOLA AB, Sweden; TECHNISCHE UNIVERSITAET MUENCHEN (TUM), Germany; VYTAUTO DIDZIOJO UNIVERSITETAS (VMU), Lithuania; WIRTSCHAFT UND INFRASTRUKTUR GMBH & CO PLANUNGS KG (WIP), Germany; AB PANEVEZIO STIKLAS, Lithuania; SCHOTT AG, Germany; PLASMAAIR AG OXIDATIVE ABGASBEHANDLUNG UND PLASMASYSTEME (Plasmaair AG), Germany; SHEFFIELD HALLAM UNIVERSITY (SHU), United Kingdom.

GIFFT context

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CO_2 Glass Melting: One of Europe's Most Energy-Intensive and Hard-to-Abate CO_2 Sources

Production Growth

39.5 mln. tons of glass in the EU in 2022 (+~20 % from 2013)

Photo of AB Panevėžio stiklas

High Energy Demand

- Glass melting (1200 - 1750°C) accounts for over 75% of the total energy requirements (3 – 8 GJ/t melted glass);

- Final energy consumption ~250 PJ in the EU in 2022;

- Highly dependent on natural gas (NG) 178 PJ (69.2%) or ~5.1 billion. m^3 annually;

High Carbon Footprint

- The CO_2 (22 Mt in 2022) emissions are directly linked to the energy used: about 75-85% come from the combustion, while the remaining 15-25% come from the decomposition of carbonates.

Key problem GIFFT addresses

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Glass industry is hitting the CO_2-reduction limit — new solutions are required.

Innovative cross-sectoral solutions are sought:

- ***Green electricity*** **-** limited to <85% CO_2***;***
- ***Circularity process*** **-** virgin material replacement, limited to <15-25% CO_2**;**
- ***Green alternatives to natural gas –*** *carbon-neutral fuels,* limited to <85% CO_2***;***
- ***Hybrid fuels scenarios –*** *flexibility in extremely challenging situations.*

GIFFT proposed solution

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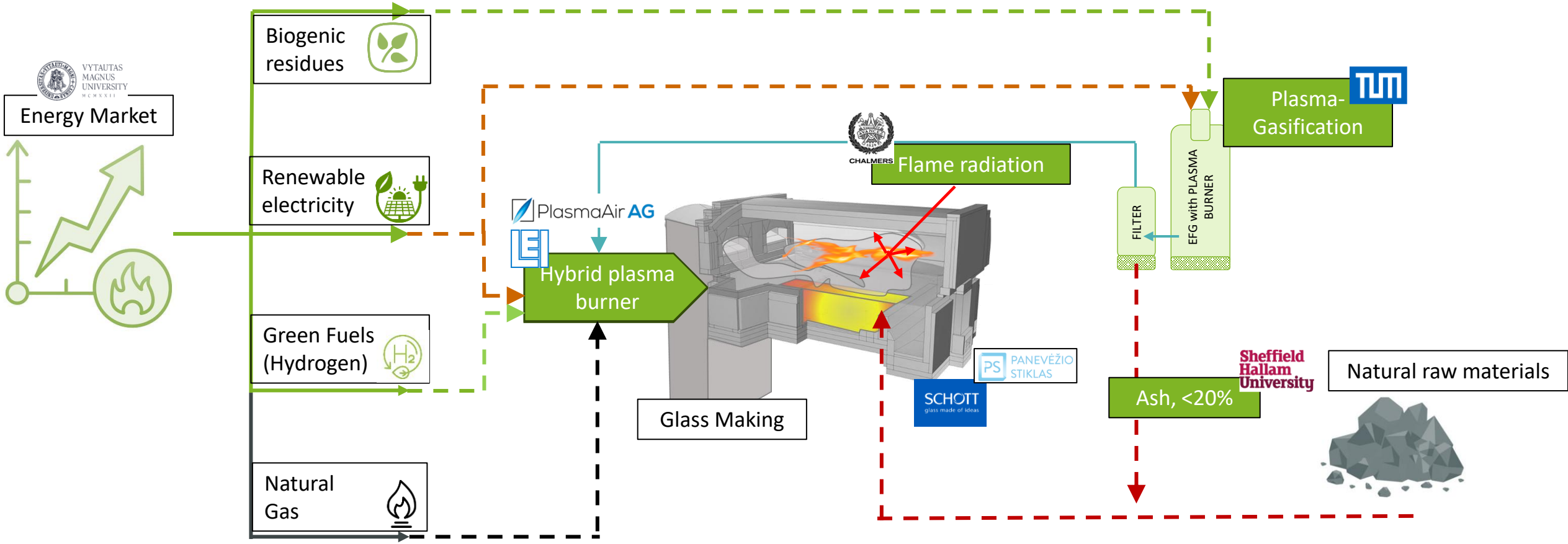
GIFFT aims to create a flexible hybrid furnace that replaces natural gas with biogenic residues and green electricity, unlocking low-carbon heat production.



GIFFT operational flexibility (1)

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Operation example of GIFFT for container glass production for container glass production

Base case

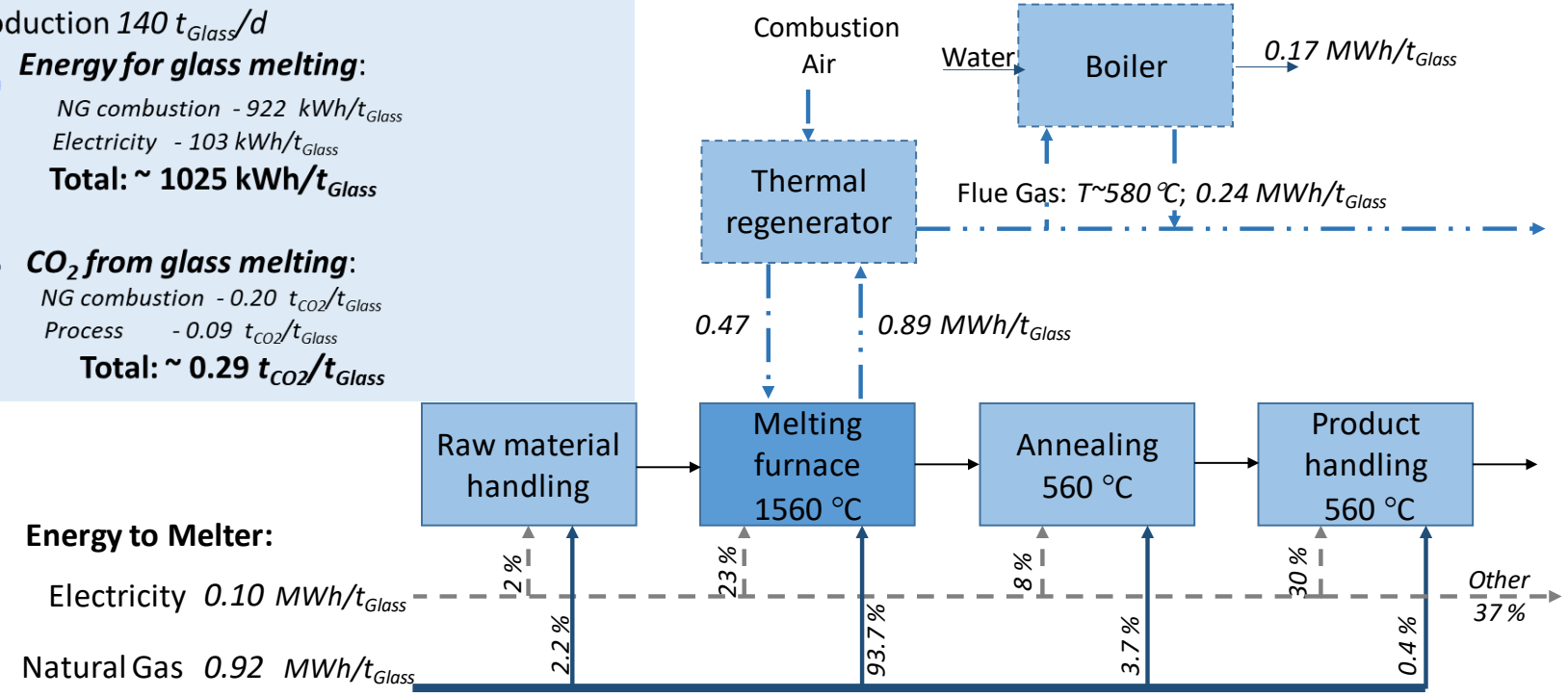
Production *140* t_{Glass}/d

Energy for glass melting:

NG combustion - 922 kWh/t_{Glass}
Electricity - 103 kWh/t_{Glass}
Total: ~ 1025 kWh/t_{Glass}

CO_2 from glass melting:

NG combustion - 0.20 t_{CO2}/t_{Glass}
Process - 0.09 t_{CO2}/t_{Glass}
Total: ~ 0.29 t_{CO2}/t_{Glass}



GIFFT operational flexibility (2)

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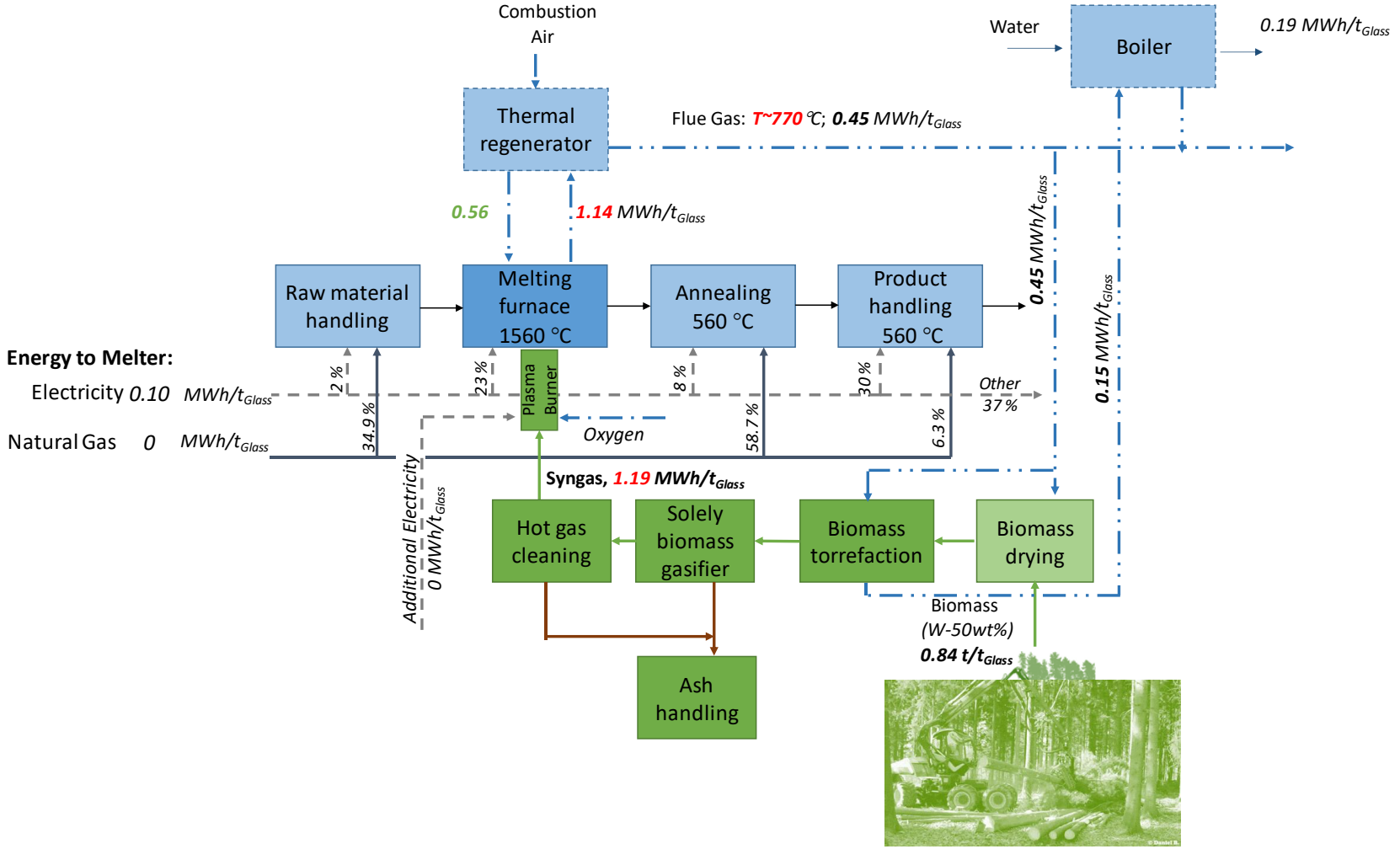
Biomass (Solo) Case

Production *140 t_{Glass}/d*

Energy for glass melting:
NG combustion - 0 kWh/t_{Glass}
SynGas combustion - 533 kWh/t_{Glass}
Electricity (plazma+tenai) - 507 kWh/t_{Glass}
Total: ~ 1040 kWh/t_{Glass}

CO_2 from glass melting:
NG combustion - 0 t_{CO2}/t_{Glass}
SynGas combustion - 0.30 t_{CO2}/t_{Glass}
Process - 0.05 t_{CO2}/t_{Glass}
Total: ~ 0.35 t_{CO2}/t_{Glass}



GIFFT operational flexibility (3)

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Green Electricity Case

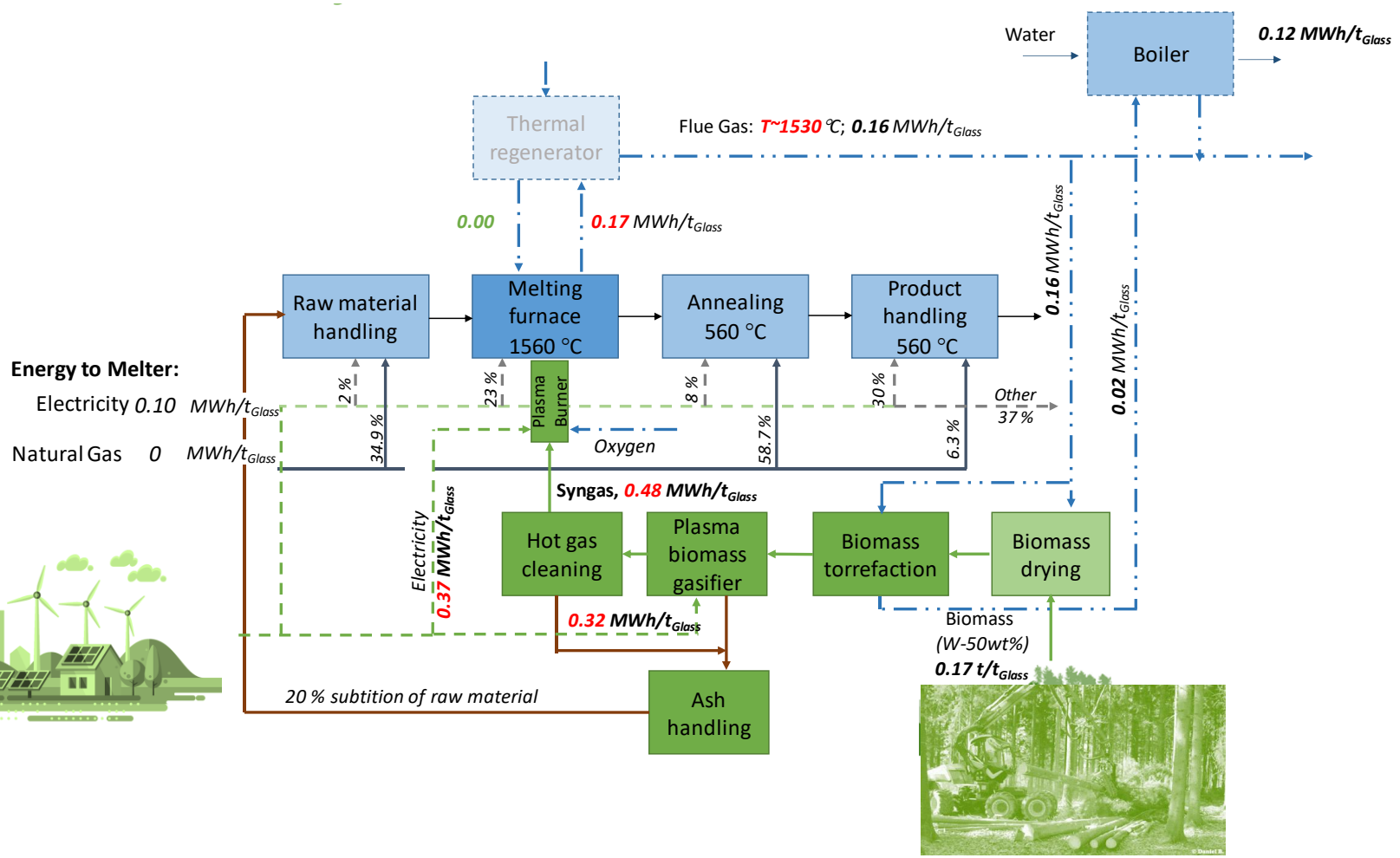
Production *140* t_{Glass}/d

Energy for glass melting:

NG combustion - 0 kWh/t_{Glass}
SynGas combustion - 493 kWh/t_{Glass}
Electricity (plazma+tenai) - 480 kWh/t_{Glass}
Total: ~ 973 kWh/t_{Glass}

CO_2 from glass melting:

NG combustion - 0 t_{CO2}/t_{Glass}
SynGas combustion - 0.12 t_{CO2}/t_{Glass}
Process - 0.05 t_{CO2}/t_{Glass}
Total: ~ 0.17 t_{CO2}/t_{Glass}



GIFFT operational flexibility (4)

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Hydrogen Case

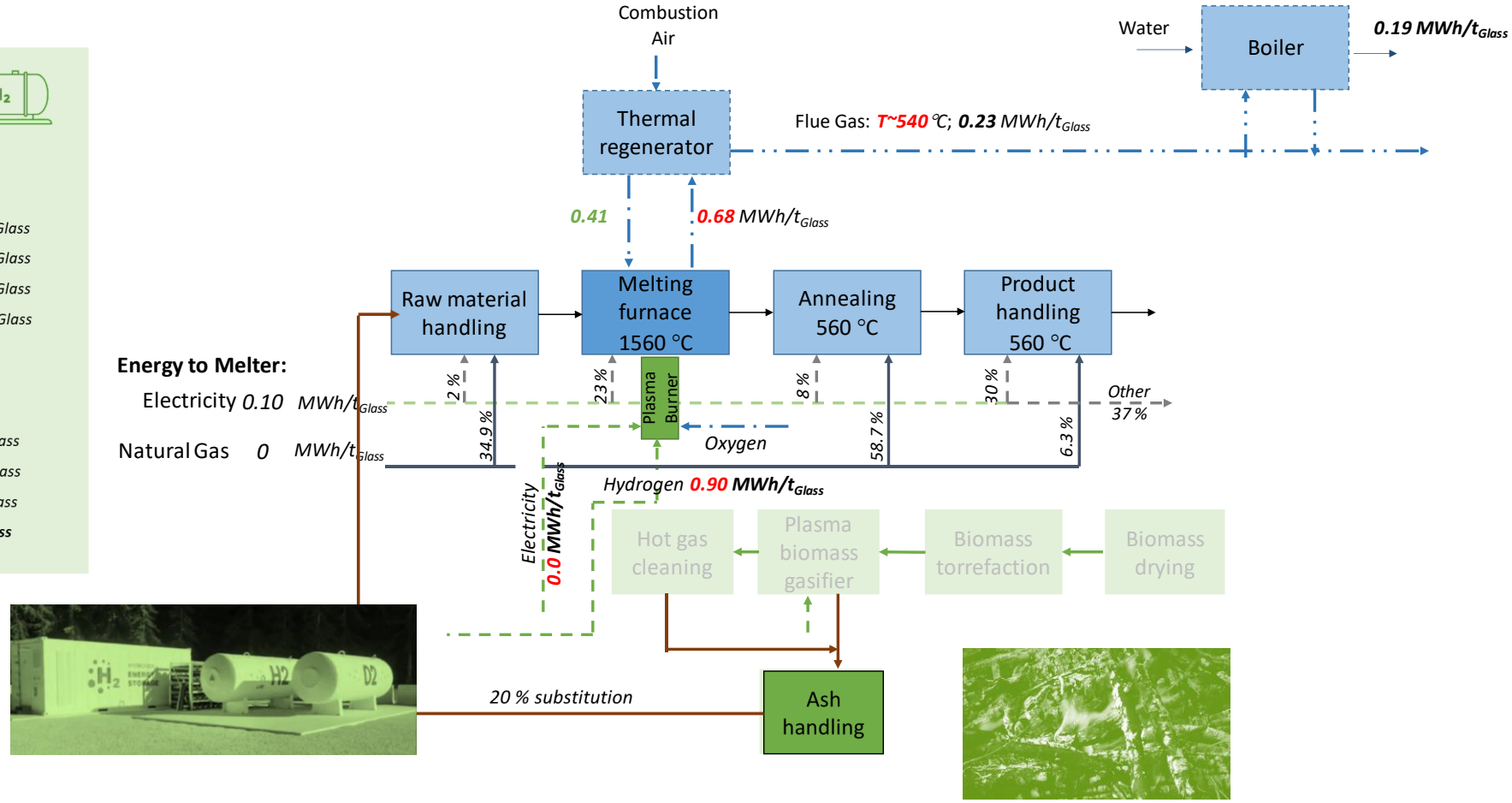
Production *140* t_{Glass}/d

Energy for glass melting:

NG combustion - 0 kWh/t_{Glass}
H_2 combustion - 478 kWh/t_{Glass}
Electricity (plasma+rods) - 473 kWh/t_{Glass}
Total: ~ 951 kWh/t_{Glass}

CO_2 from glass melting:

NG combustion - 0 t_{CO2}/t_{Glass}
H_2 combustion - 0.12 t_{CO2}/t_{Glass}
Process - 0.05 t_{CO2}/t_{Glass}
Total: ~ 0.05 t_{CO2}/t_{Glass}



Expected Impact

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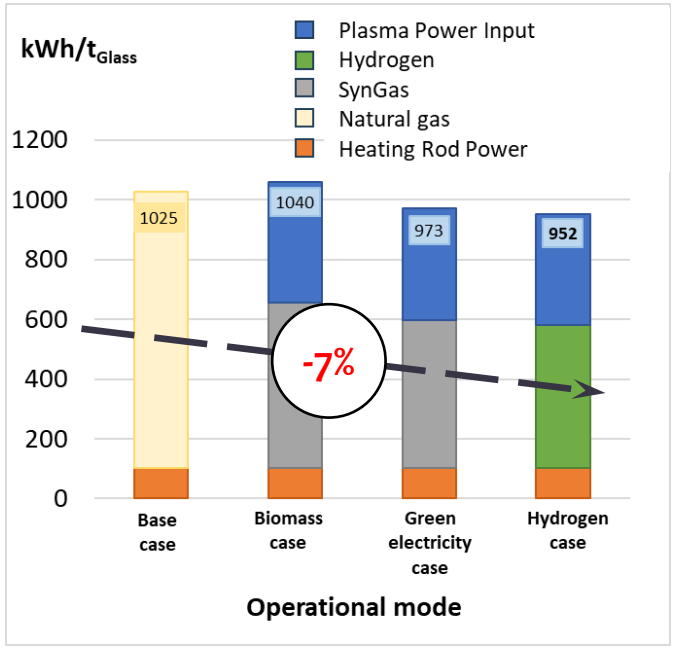
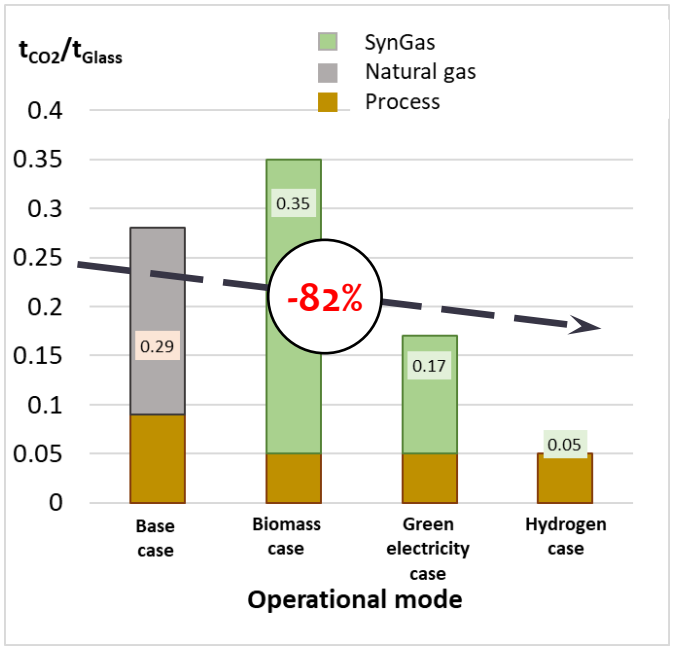
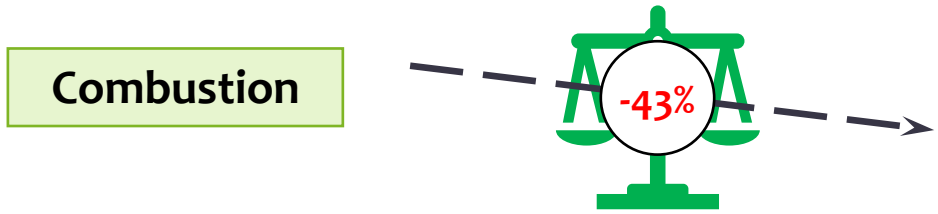
Energy consumption

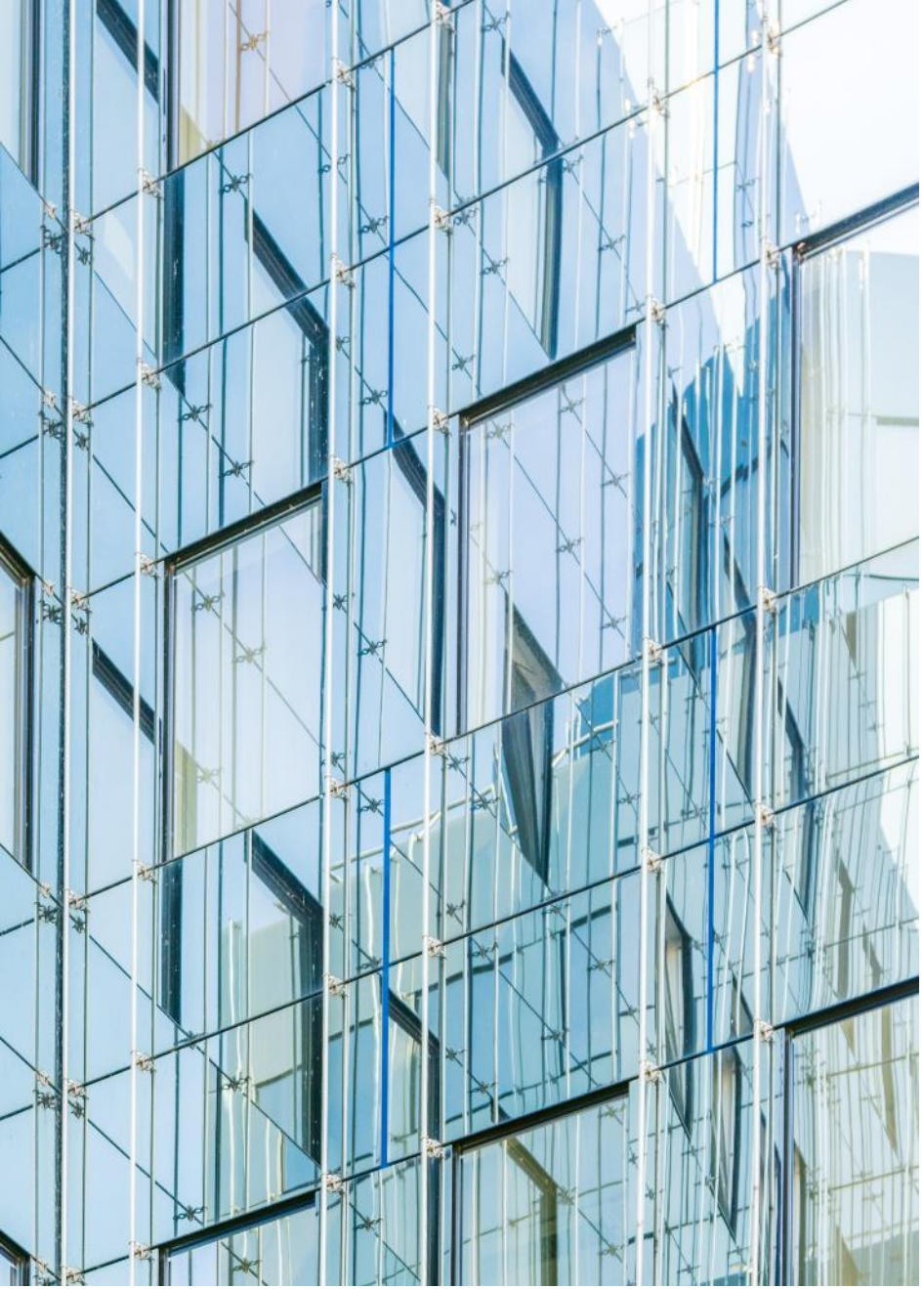


CO2 emissions



Fuel consumption





Key Innovations

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- Plasma-assisted biomass gasification (EFG) (TUM🇩🇪, PlasmaAir🇩🇪);
- Hybrid fuel flexible plasma burner (LEI🇱🇹, PlasmaAir🇩🇪, CTH🇸🇪);
- Flame heat radiation parameters (CTH🇸🇪, LEI🇱🇹);
- Biomass gasification ash as feedstock for glass production (SHU🇬🇧).

Visual Comparison of Conventional and Hybrid Burner Flames

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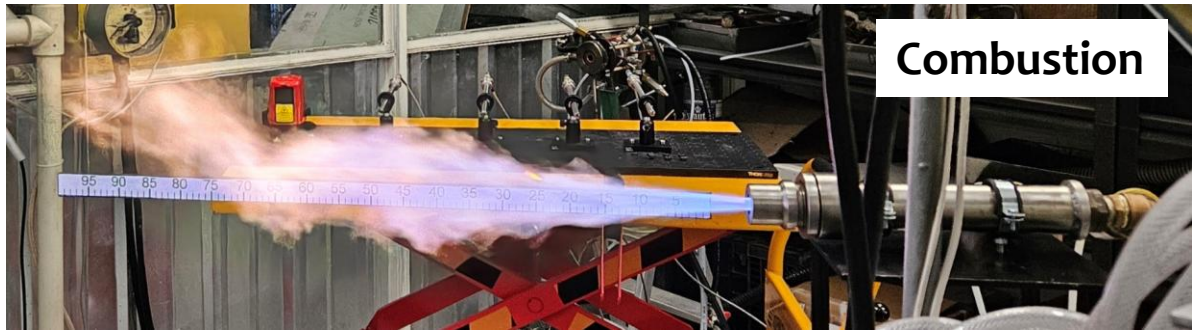
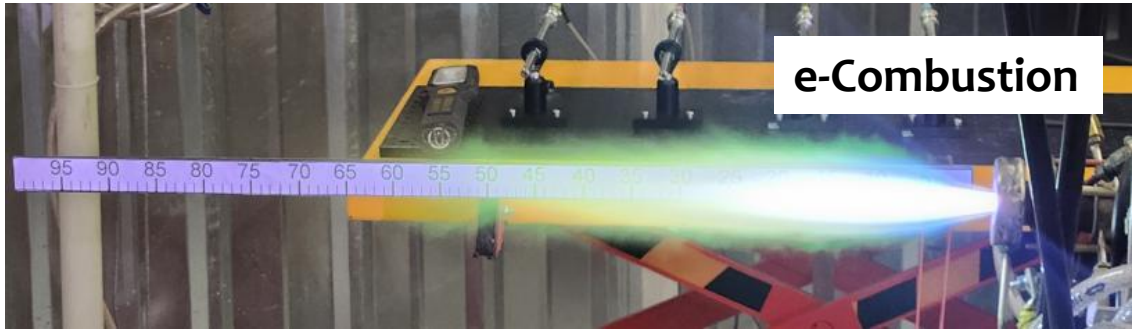
CH4/O2

H2/O2



50% chemical energy + 50% electrical energy



Flexible fuel plasma burner configuration testing

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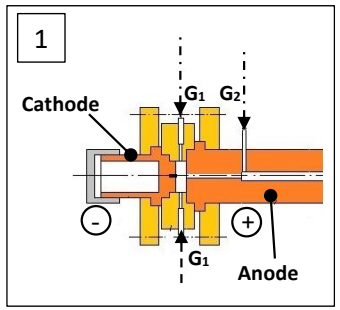
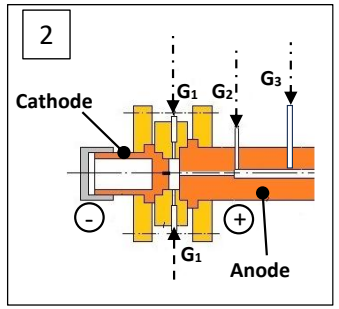
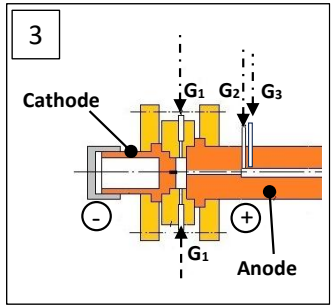
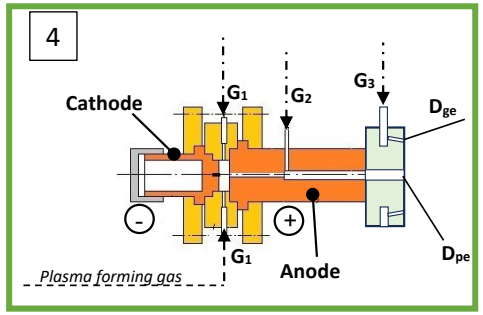
The best case - oxygen as plasma forming gas

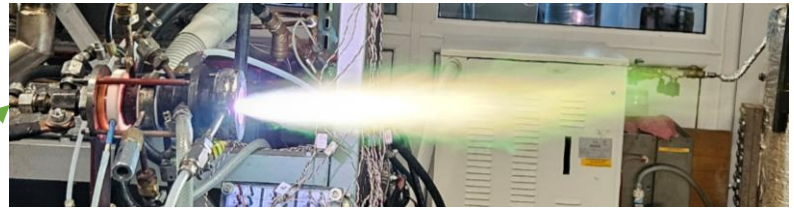








Gas case	Type	G_1	G_2	G_3	Comment
Hydrogen	1	H_2	O_2		stable, long flame
	2	O_2	O_2	H_2	stable, short flame
	3	O_2	O_2	H_2	unstable, short flame
	4	O_2	O_2	H_2	stable, long flame
Natural gas	1	CH_4	O_2		unstable, long flame
	2	O_2	O_2	CH_4	stable, short flame
	3	O_2	O_2	CH_4	unstable, short flame
	4	O_2	O_2	CH_4	stable, long flame



LEI plasma-assisted burner prototype

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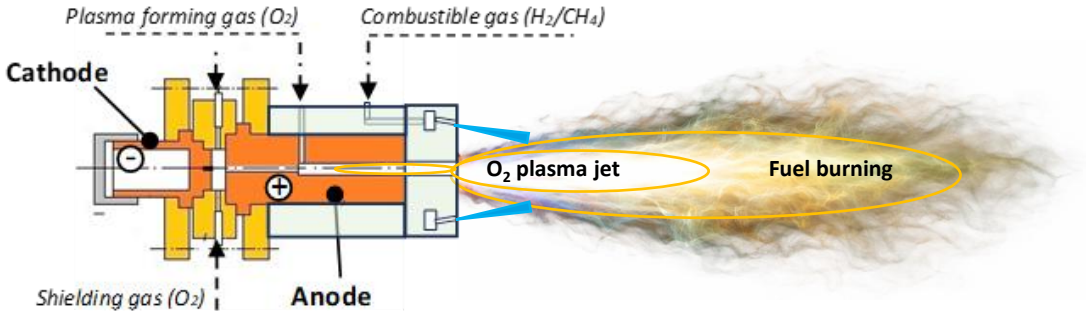
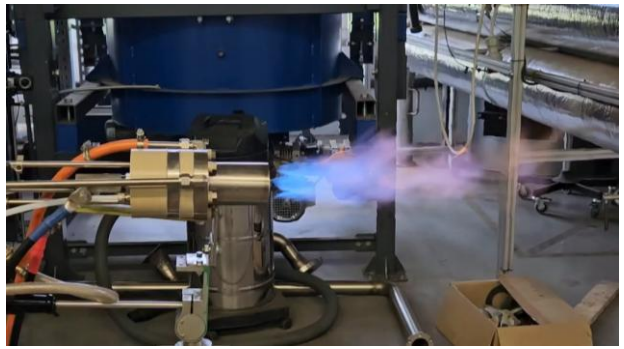
Operation modes allow to switch in a short time from 100% combustion to 50% electric heat and 50% combustion



LEI Plasma burner in test operation

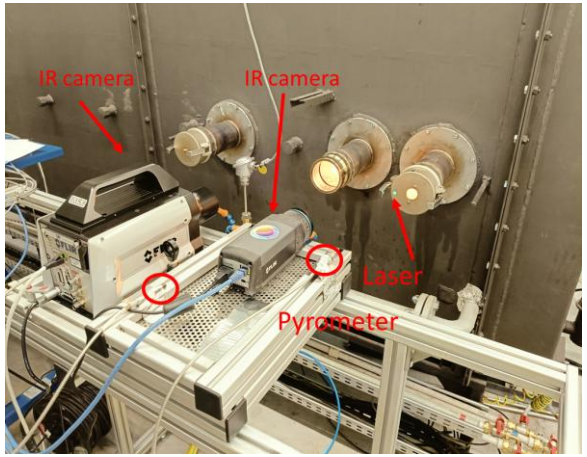


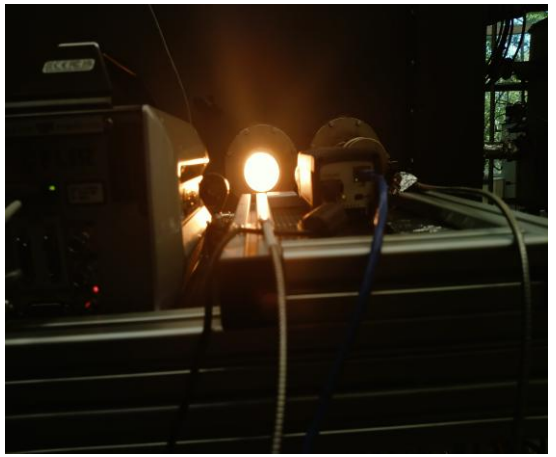
The main parameters of the burner

Parameter	Value	Comment
Shielding gas	Oxygen	Constant
O_2 , Nm^3/h	1,2	
Plasma-forming gas	Oxygen	Variable depending on operating mode
O_2 , Nm^3/h	3,8–14,5	
Combustible gas	H_2 or CH_4	
H_2 , Nm^3/h	10,0–21,6	Variable depending on operating mode
CH_4 , Nm^3/h	3,0–8,0	
Plasma torch power, kW	25–52	
Arc current, A	120–220	
Plasma voltage, V	150–250	
Total burner capacity, kW	70–116	

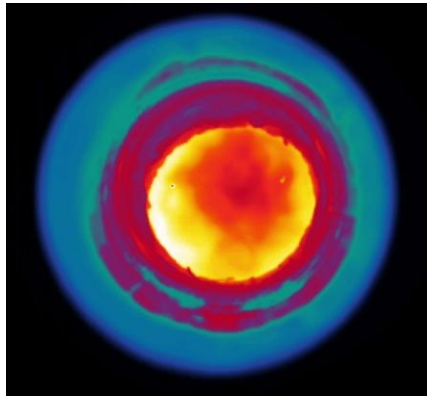
Aim of the experimental test

- To compare **conventional and plasma-assisted burners** under stable operation using both **CH_4 and H_2 fuels** over extended operation (full shift), maintaining a furnace temperature of ~1500–1600 °C;
- To assess whether **radiative heat transfer and temperature fields** are comparable to those of conventional combustion;
- To evaluate the potential of a **hybrid plasma burner** as a robust technological solution for **electrification of crown heating in glass melting furnaces**.

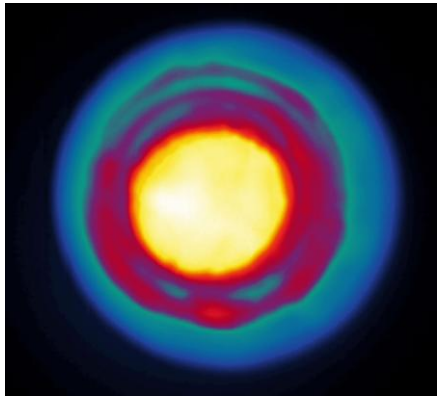




CO_2 spectrum



IR intensity



Plasma-assisted combustion test configuration

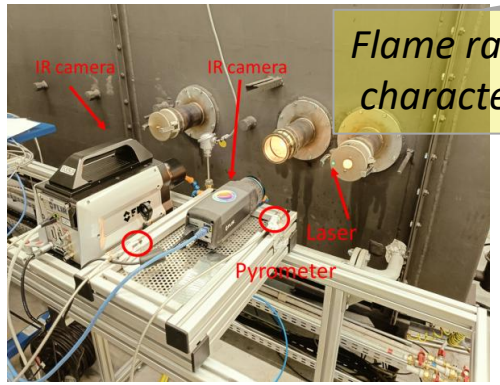
Flue gas composition

Boiler

Test chamber

Torch water cooler

Glycol cooler



Flame radiative characteristics

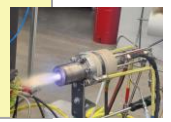
O_2

O_2

H_2

NG (CH_4)

Conventional or plasma-assisted burner



Gas supply

Energy demand at set process temperature

Parameter	Conventional combustion		Plasma-assisted Combustion	
Fuel type	**NG**	**H_2**	**NG**	**H_2**
Fuel flow rate, m^3/h	5.9	20.2	3.3	13.7
Oxygen flow rate, m^3/h	14.3	10.7	8.2	7.2
Flue gas flow rate, m^3/h	20.2	20.8	11.9	15.4
Flue gas temperature, °C	83.5	91.2	67.1	69.7
Plasma parameters: Current, A Voltage, V Power, kW Efficiency, %	-	-	 157.6 219.6 34.7 67	 157.6 209.5 33.0 64
LHV, kWh/m^3	9.65	3.0	9.65	3.0
Energy from fuel combustion, kW	56.9	62.9	31.8	41.3
Energy from electricity (to combustion), kW	-	-	34.7 (23.2)	33.0 (21.0)
Total energy input, kW	**56.9**	**62.9**	**66.5 (55.0)**	**74.3 (62.3)**
Heat losses: Flue gas, kW Plasma cooling, kW Condensate, kW Glycol heat, kW Wall losses, kW Unknown losses, kW	 0.7 - 0.5 44.4 11 0.3	 0.3 - 3.7 48.2 11 -0.3	 0.2 11.6 2.8 41.1 11 -0.1	 0.04 12.0 7.0 44.5 11 -0.2
Total heat loss, kW	**56.9**	**62.9**	**66.5**	**74.3**
Thermal utilisation efficiency	0.97	0.94	0.78	0.75
Fuel reduction, %	0	0	44.1	32.2
CO_2 reduction from combustion,%	0	100	44.1	100

1. The hydrogen (H_2) case required a higher total fuel energy input than natural gas (NG) to maintain the same process temperature.

2. The increase may be attributed to the higher volumetric flow (~×3.2) of H_2, indicating that a larger fraction of energy is carried to the exhaust rather than transferred to the furnace walls.

3. Plasma assistance replaces a portion of the chemical energy with electrical input (≈40%).

4. Plasma operation reduces flue-gas heat losses and improves internal heat utilisation compared to conventional combustion.

5. Plasma operation exhibits lower thermal utilisation efficiency and requires further reduction of torch cooling losses.

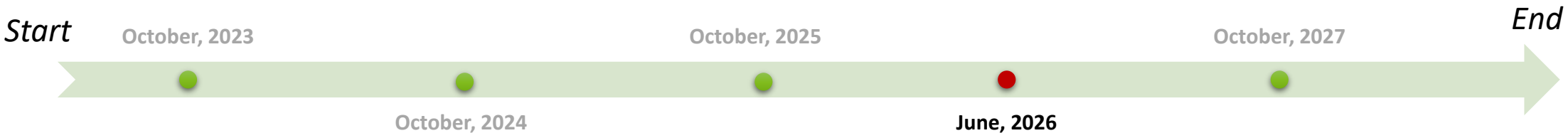
$$\eta_{th} = \frac{Q_{wall} + Q_{glycol}}{Q_{total}}$$

So what's next?

- **Radiative properties of plasma flames**. Ongoing analysis of experimental data to quantify emissivity and heat-transfer characteristics

- **Validation testing at industrial partner (SCHOTT, Germany).** Deployment of the plasma torch in a simulated glass melting furnace (TRL 5). First campaign planned for Autumn 2026.

- **Extended operational validation**. 72-hour semi-continuous testing to evaluate stability, performance, and flexibility across all GIFFT operating modes.



Conclusions

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- **Plasma assistance enables partial electrification**, reducing natural gas consumption by **44%** and hydrogen by **32%;**

- **However, 16–17% of the electrical input was lost via torch cooling**, limiting overall efficiency gains and needs further improvement;

- **Hydrogen eliminated direct CO_2 emissions**, while plasma-assisted natural gas reduced emissions by **44%**, highlighting the need to optimise electrical coupling and minimise cooling losses.

Biomass gasification ash as feedstock for glass production

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Biomass ash can partially replace up to 20% of raw materials such as high-value soda ash, limestone, and dolomite.

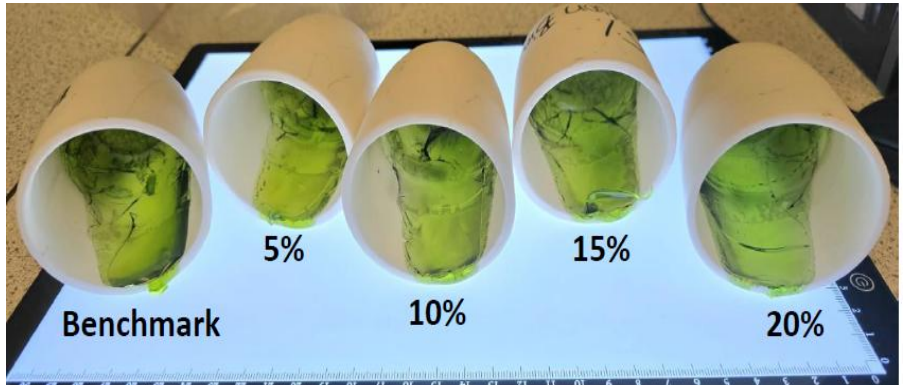
Biomass ash enables up to 20% CO_2 reduction from the avoided production of these raw materials. Ash-derived glass batches allow further CO_2 saving.

Our collaboration with glass artists Lulu Harrison and Elliot Walker has led to production of glass pieces and exhibitions of biomass ash-glasses at QEST 35 Johnnie Walker (Edinburgh) and the Bank of England (London).

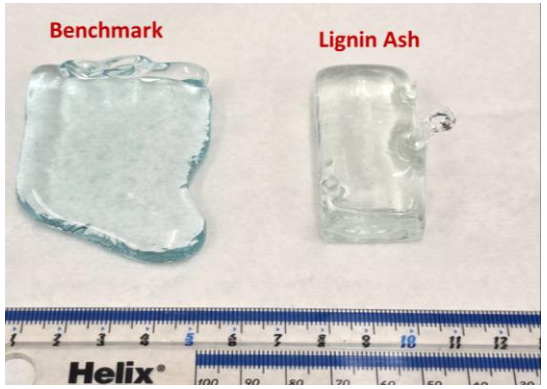
Post processing of ash via different separation techniques improves the quality of the ash.

Utilising ash from gasification process minimises landfill disposal, promotes waste-to-resource strategies, supporting industrial circularity.

Green glass (different ash additions)



Colorless glass (5% ash addition)



Amber glass (5% ash addition)

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Project partners

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Knowledge Applied

PS PANEVĖŽIO STIKLAS

PlasmaAir AG

SCHOTT
glass made of ideas

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