SOFCOM: results from the operation of the first biogas fed SOFC quadri-generation plant with CO_2 capture and re-use

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SOFCOM Project

sofcom
FCH-JU project

▷SOFCOM is an applied research project devoted to demonstrate the technical feasibility, the efficiency and environmental advantages of CHP plants based on SOFC, fed by different typologies of biogenous primary fuels (locally produced), also integrated by a process for the CO_2 separation from the anode exhaust gases.

▷Partnership:

POLITECNICO DI TORINO

smat gruppo

ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

sofcom FCH-JU project

UNIVERSITÀ DEGLI STUDI DI TORINO

MATGAS

VTT

TUM Lehrstuhl für Energiesysteme

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Demo → **Results** → **Lessons learned**

1.

SOFCOM DEMO PLANT

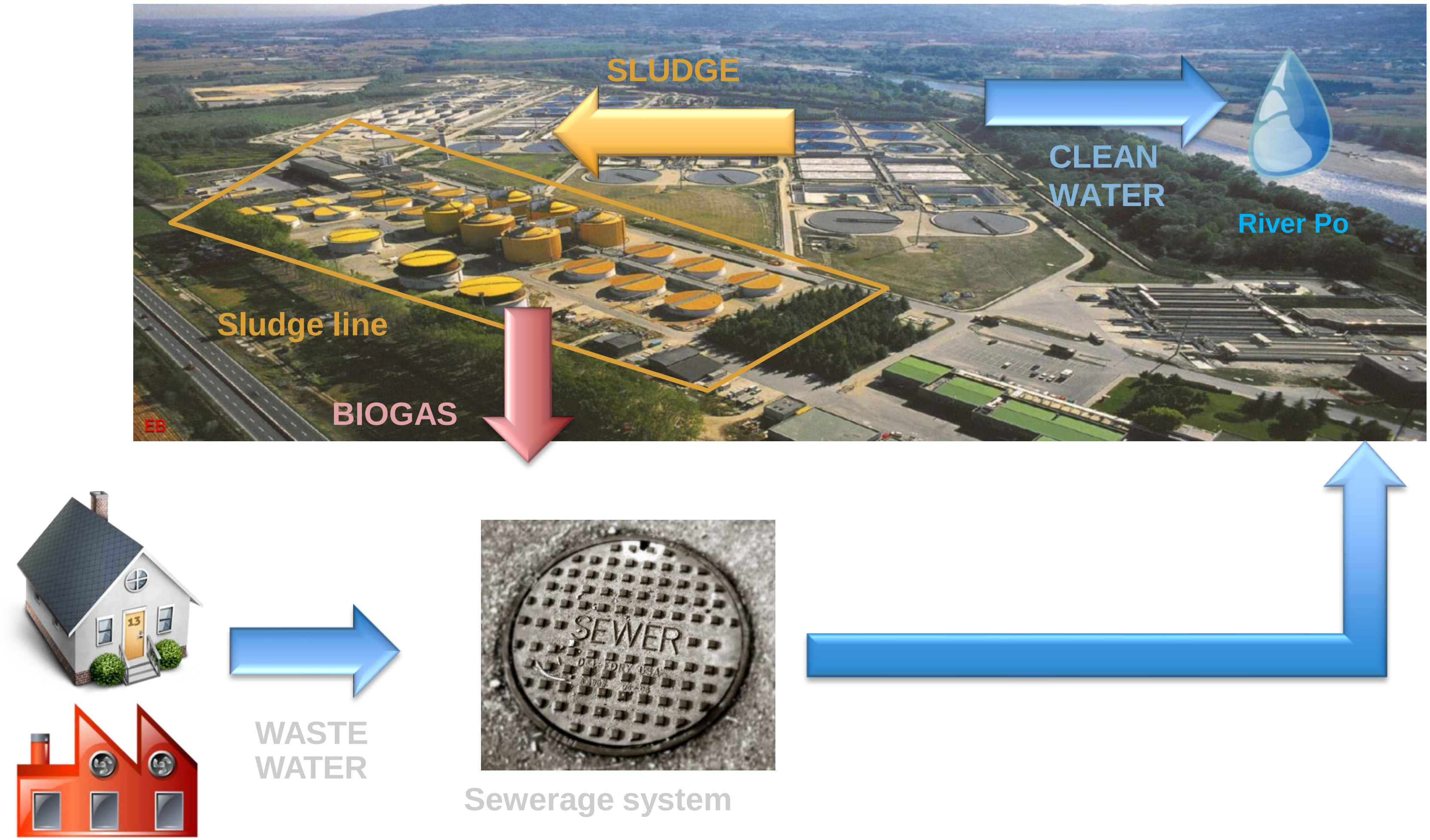
Plant localization: SMAT Waste Water Treatment Plant

SMAT Waste Water Treatment Plant

WASTE
WATER

Sewerage system

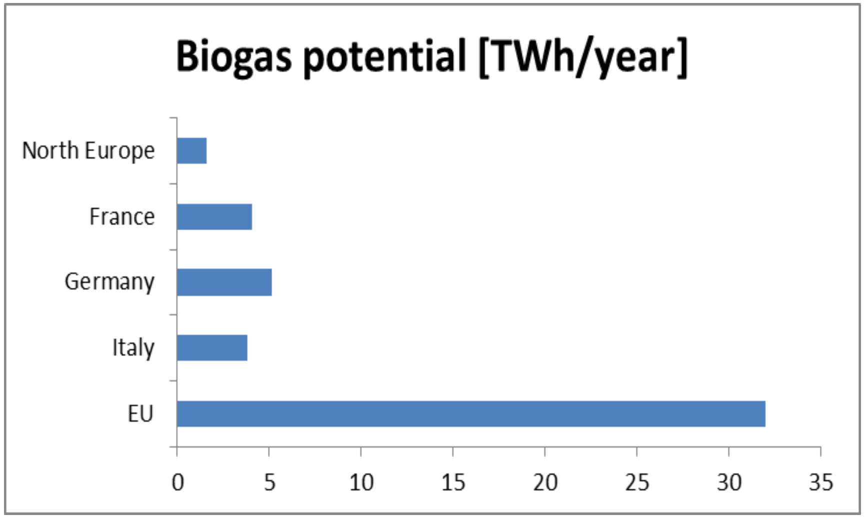
SMAT Waste Water Treatment Plant



SOFCOM Demonstration Plant

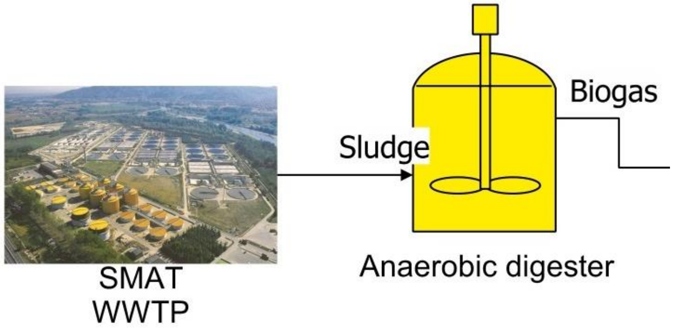
SOFCOM
Demonstration
plant

WWTP biogas potential in EU

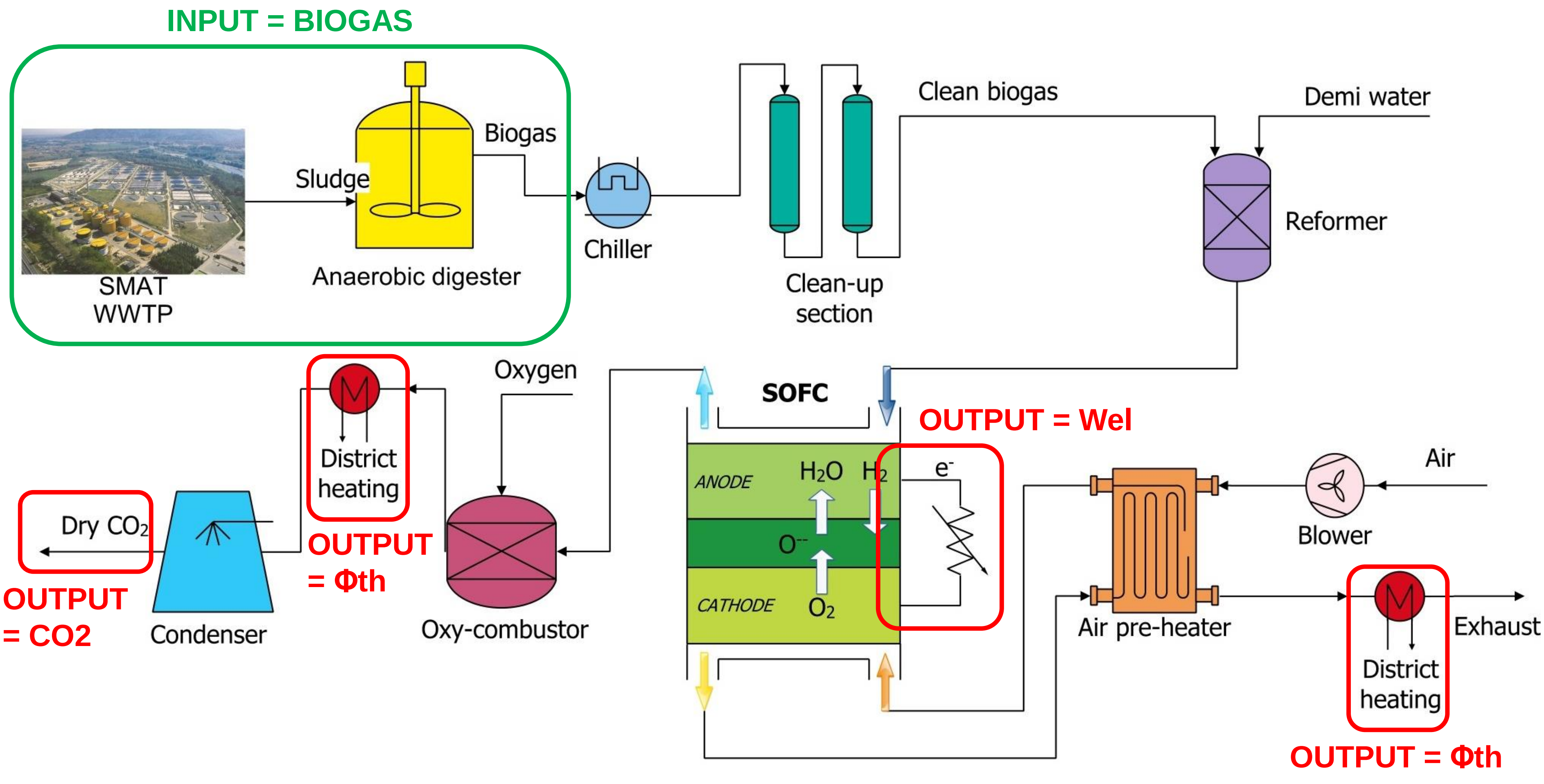


WASTEWATER	Electrical potential [TWh/year]	Thermal potential [TWh/year]
EU	16.933	10.224
North Europe	0.854	0.516
Germany	2.736	1.652
France	2.140	1.292
Italy	2.022	1.221

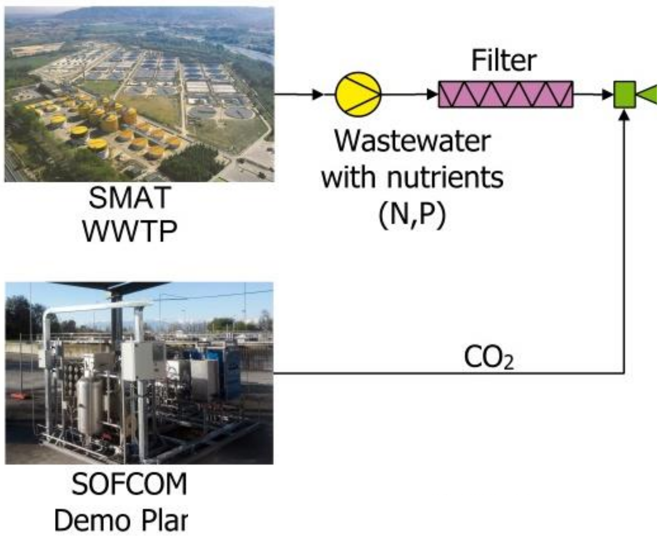
SOFCOM Demo Layout - 1



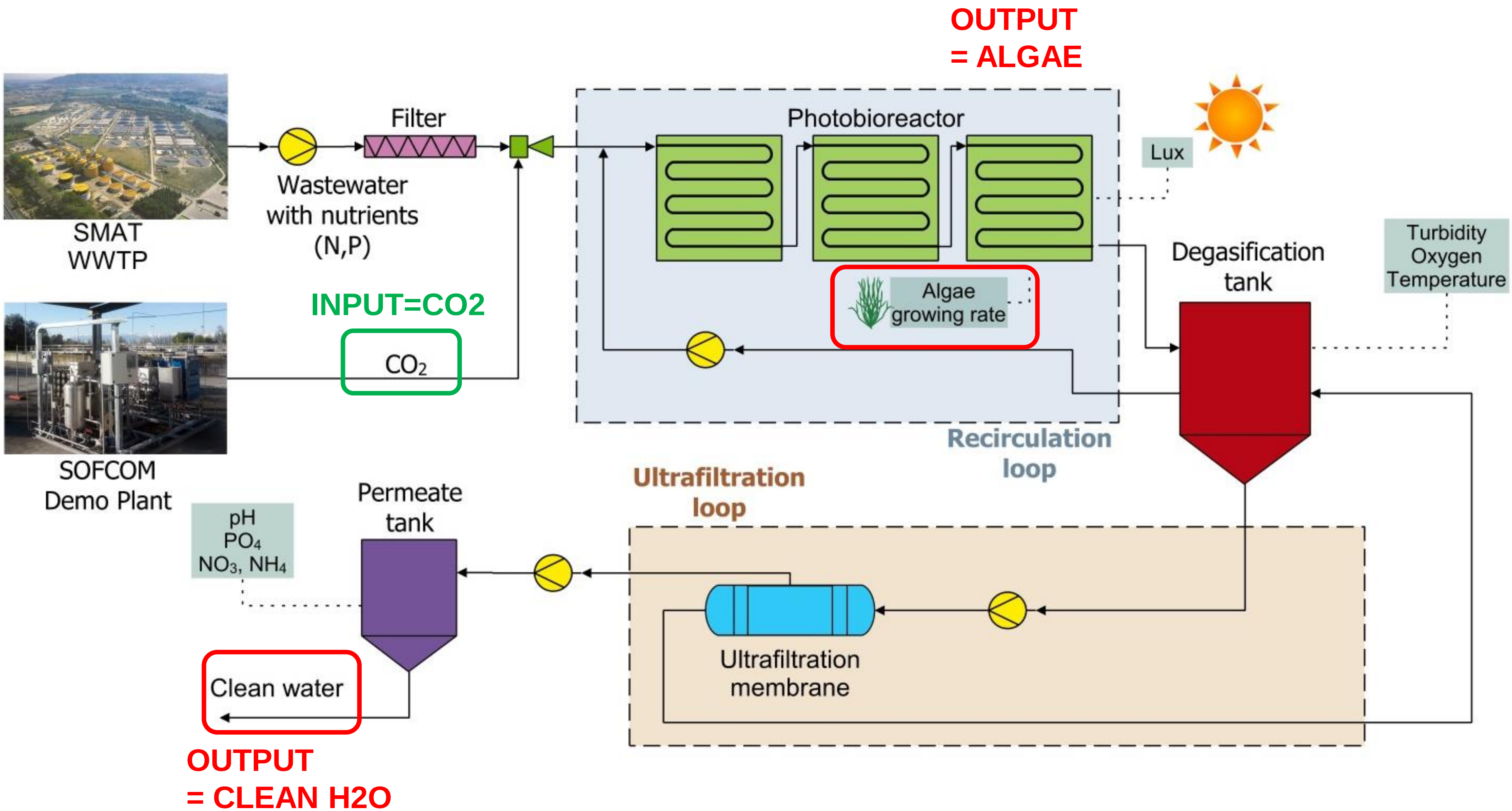
SOFCOM Demo Layout - 1



SOFCOM Demo Layout - 2



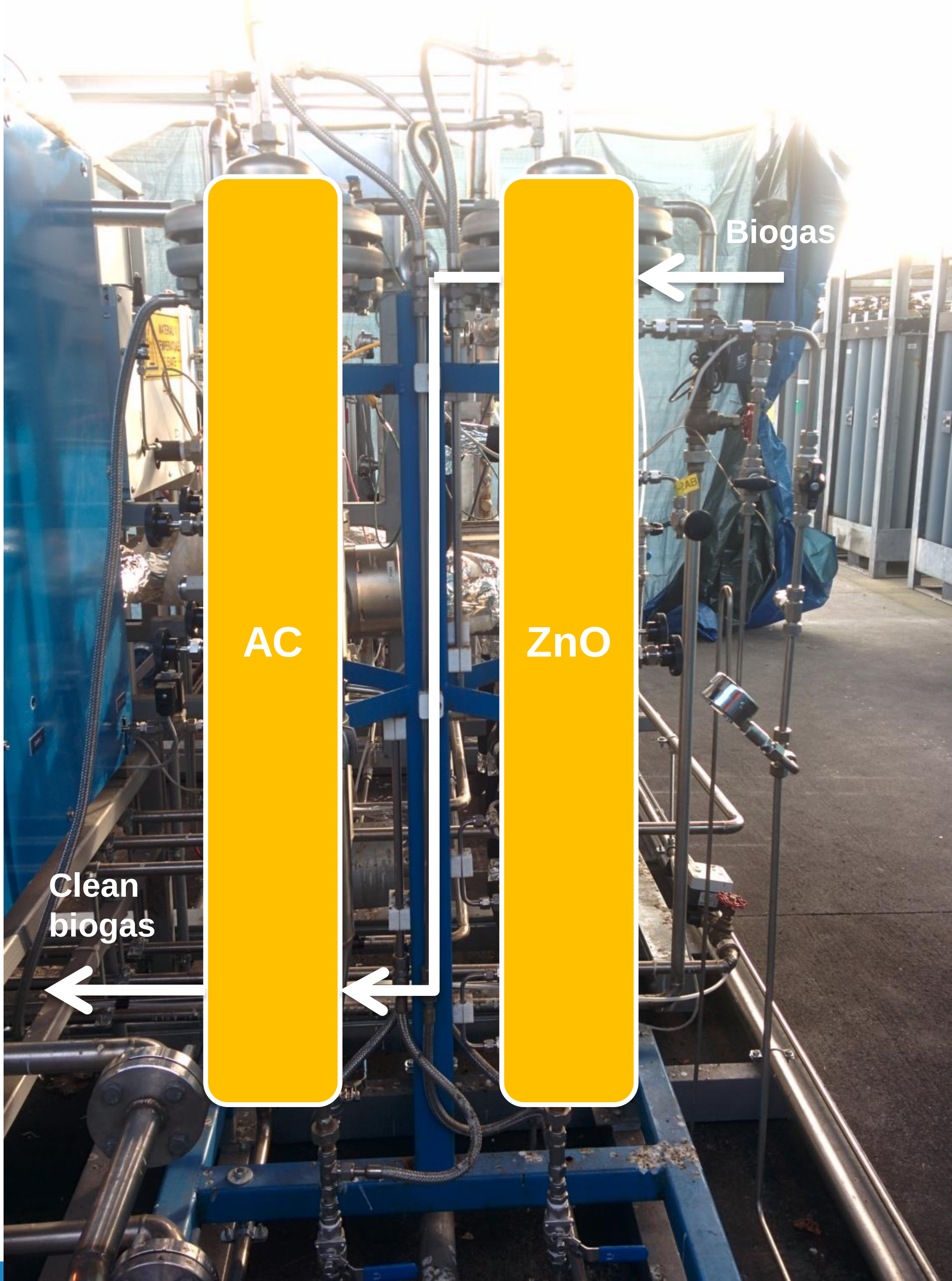
SOFCOM Demo Layout - 2



Biogas cleaning system

2 vessels in series for sulphur and siloxanes removal (ZnO + AC)

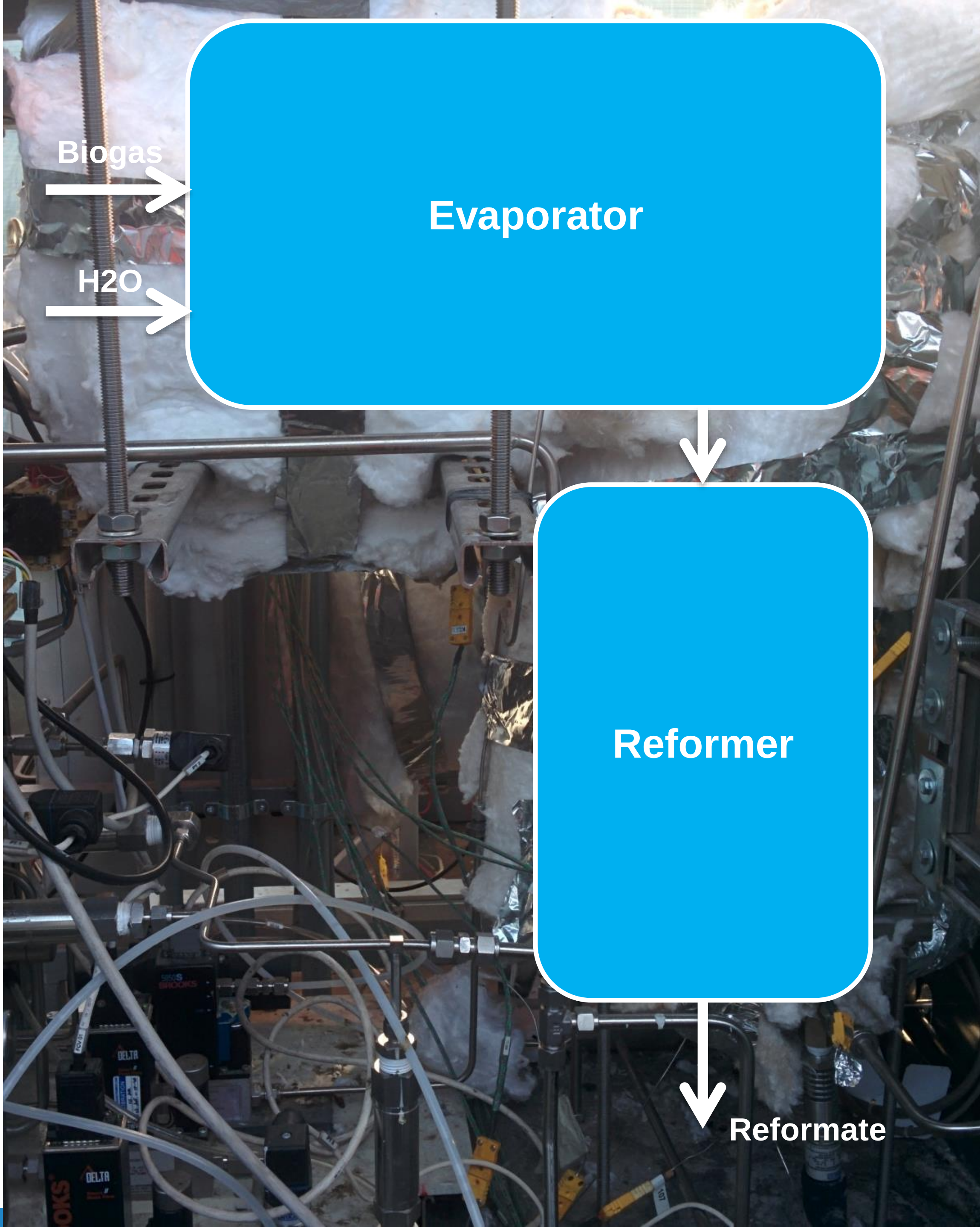
2 parallel lines for continuous operation



Biogas processing system

Water evaporator (400-500°C)

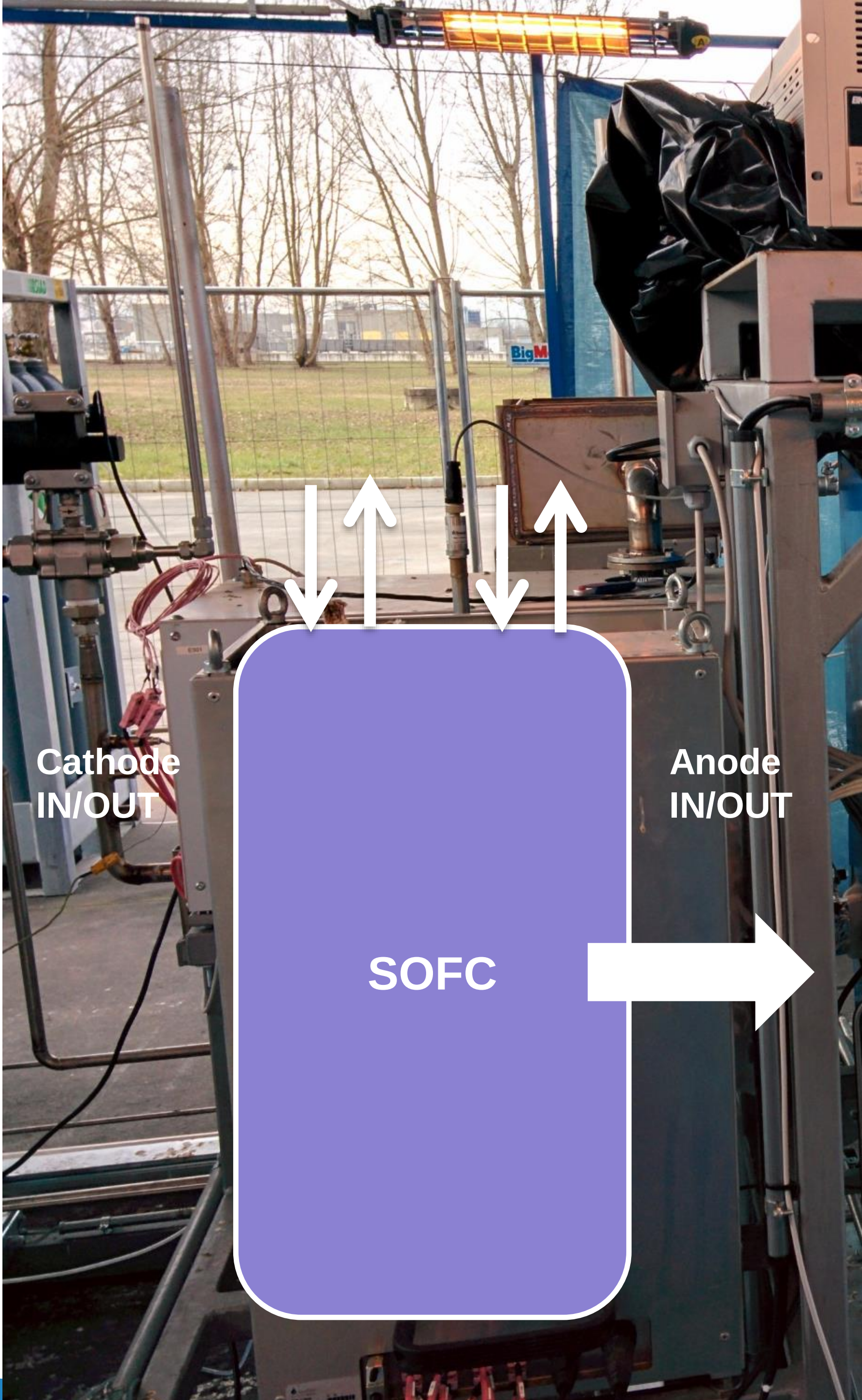
Steam – Pox reformer (700-800 °C)



SOFC
Fuel Cell

2 kWe electrical generation

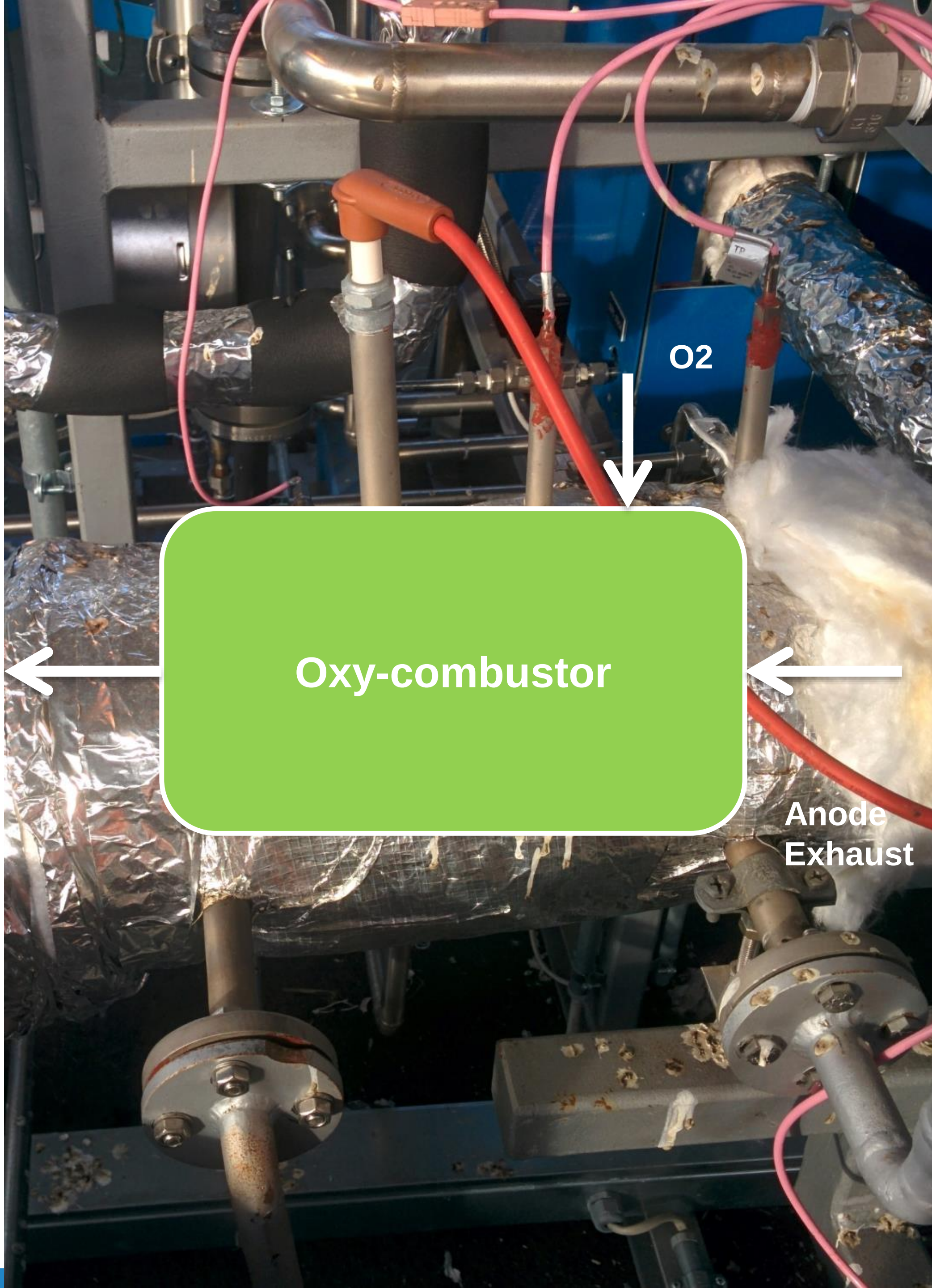
800 °C



Oxy-combustion system

H2 combustion with pure oxygen

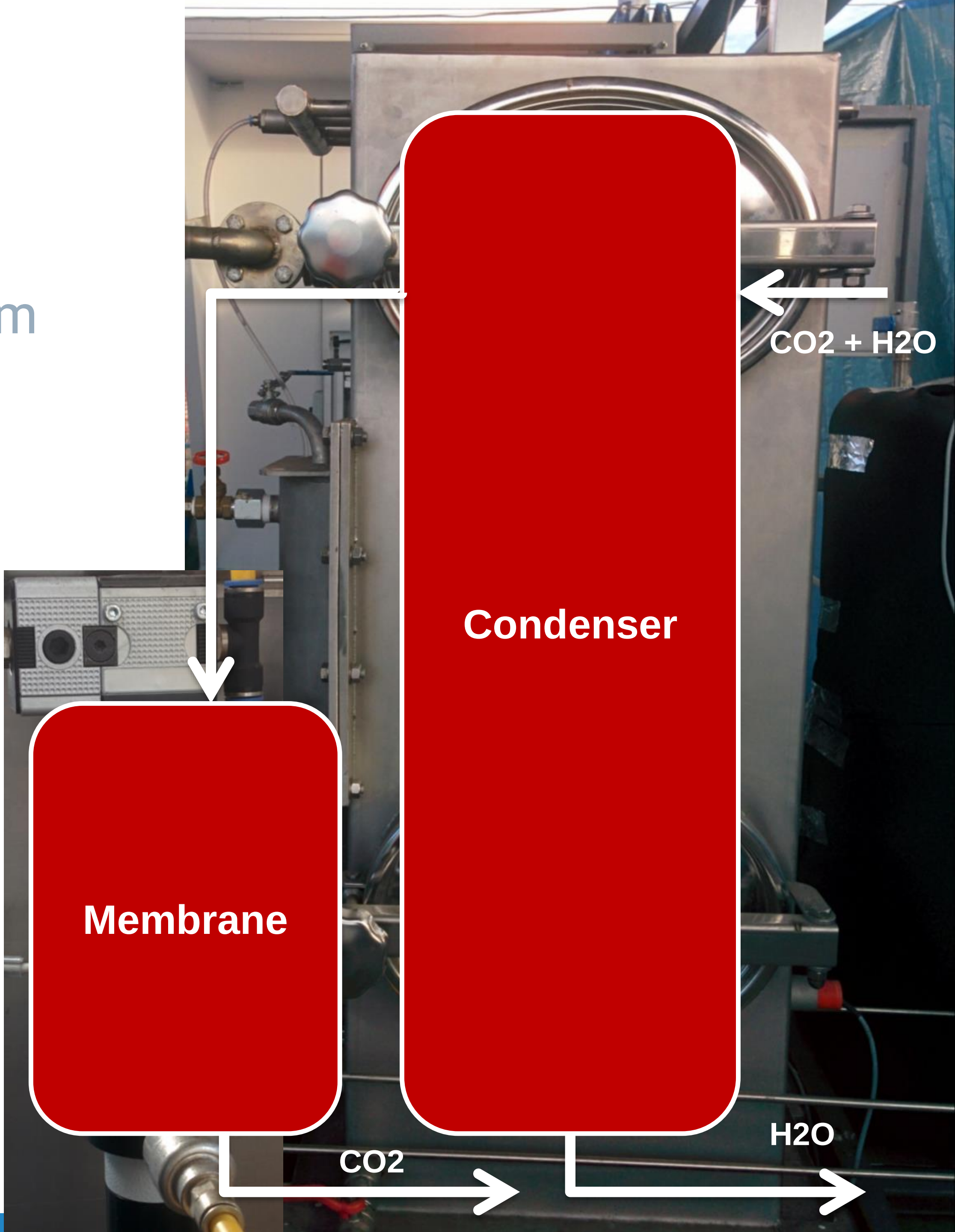
T max 1200 °C



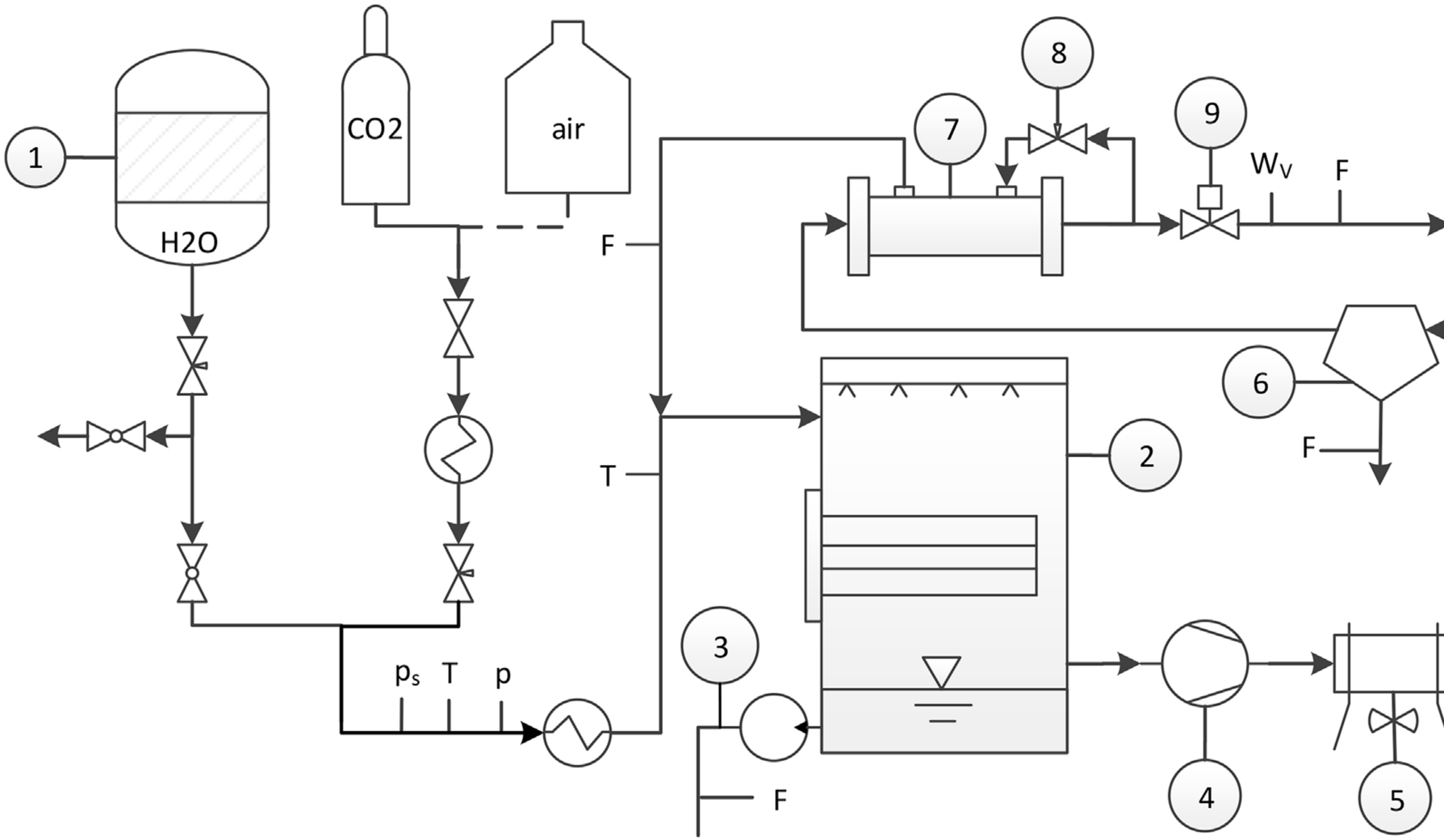
CO_2 separation system

Water Condenser

Dry-point membrane for $H_2O < 500$ ppm



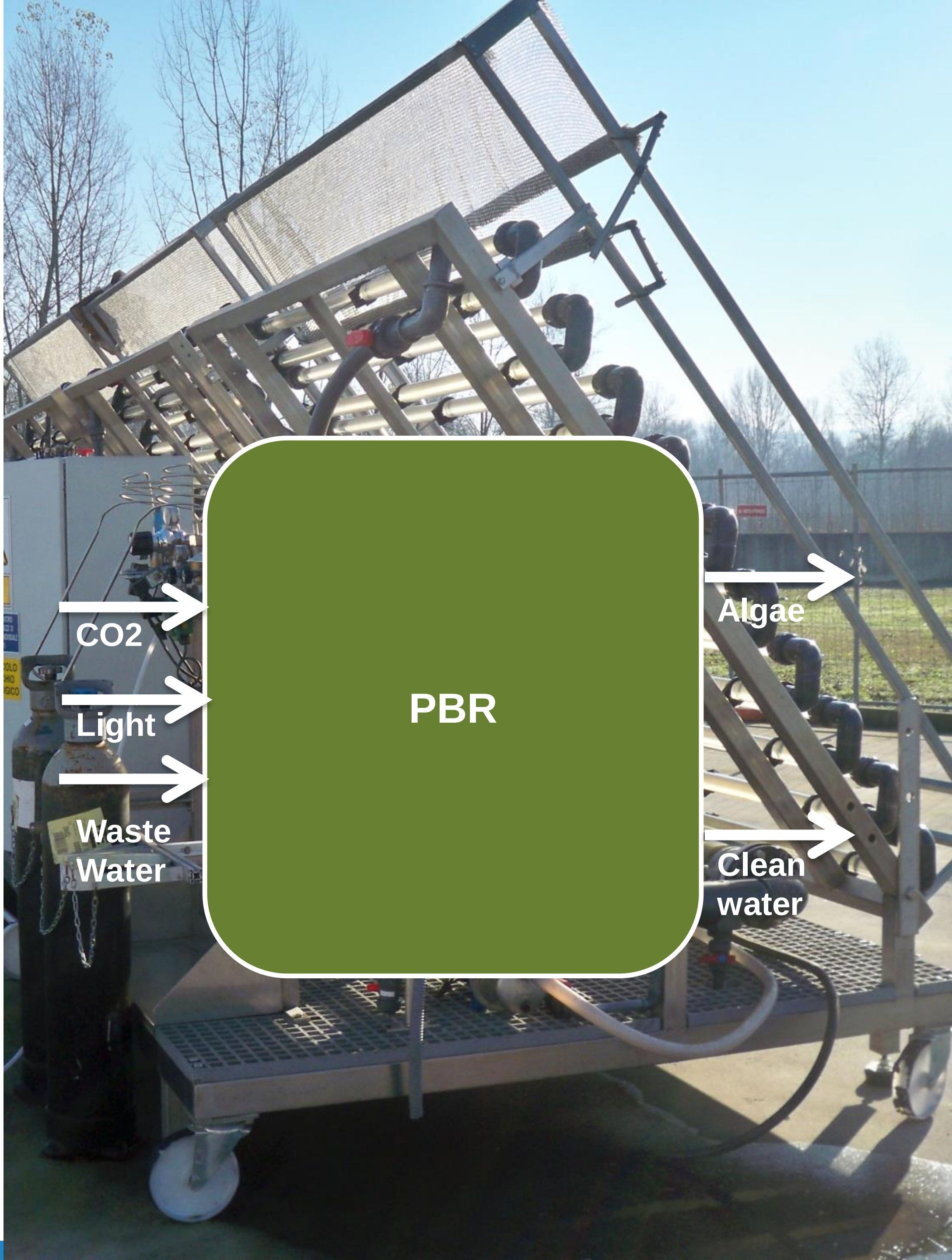
Water condenser layout: lab test setup



Schematic of the test setup: 1. Steam generator 2. Condenser 3. Condensate drain 4. Compressor unit 5. Gas cooler 6. Fog/Water separator 7. Membrane 8. Purge gas split control 9. Membrane pressure regulation.

Photobioreactor system

Active area = 9 sqm

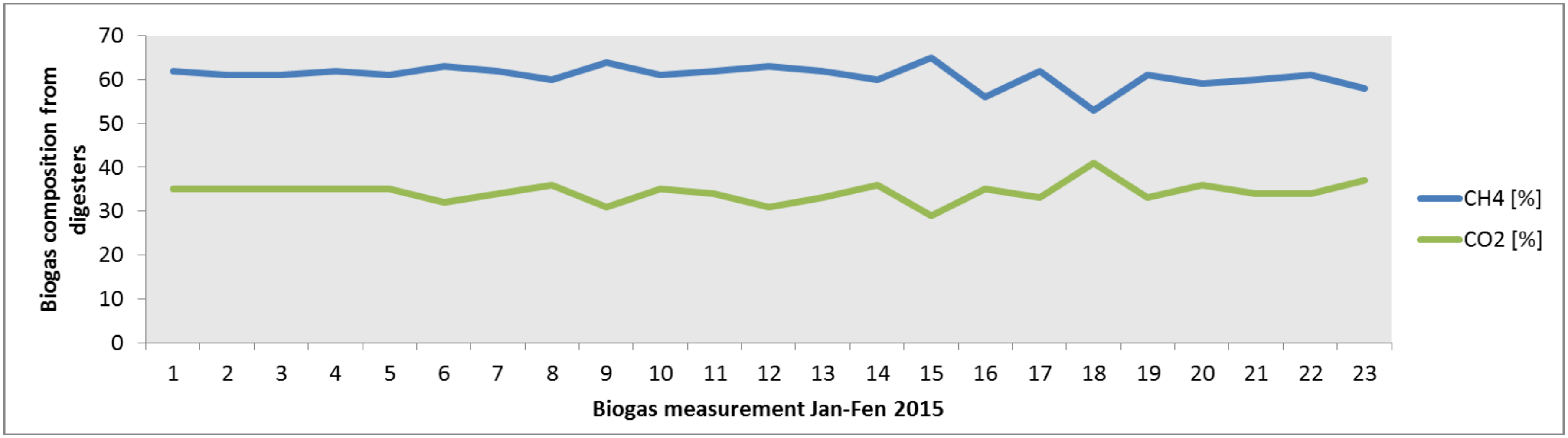


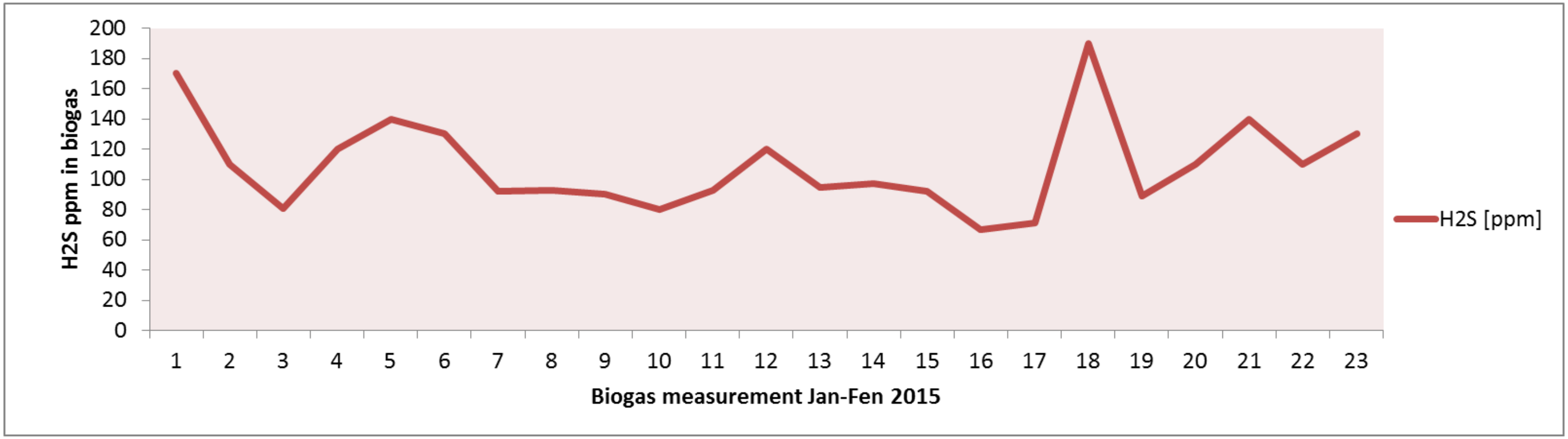
2.

RESULTS

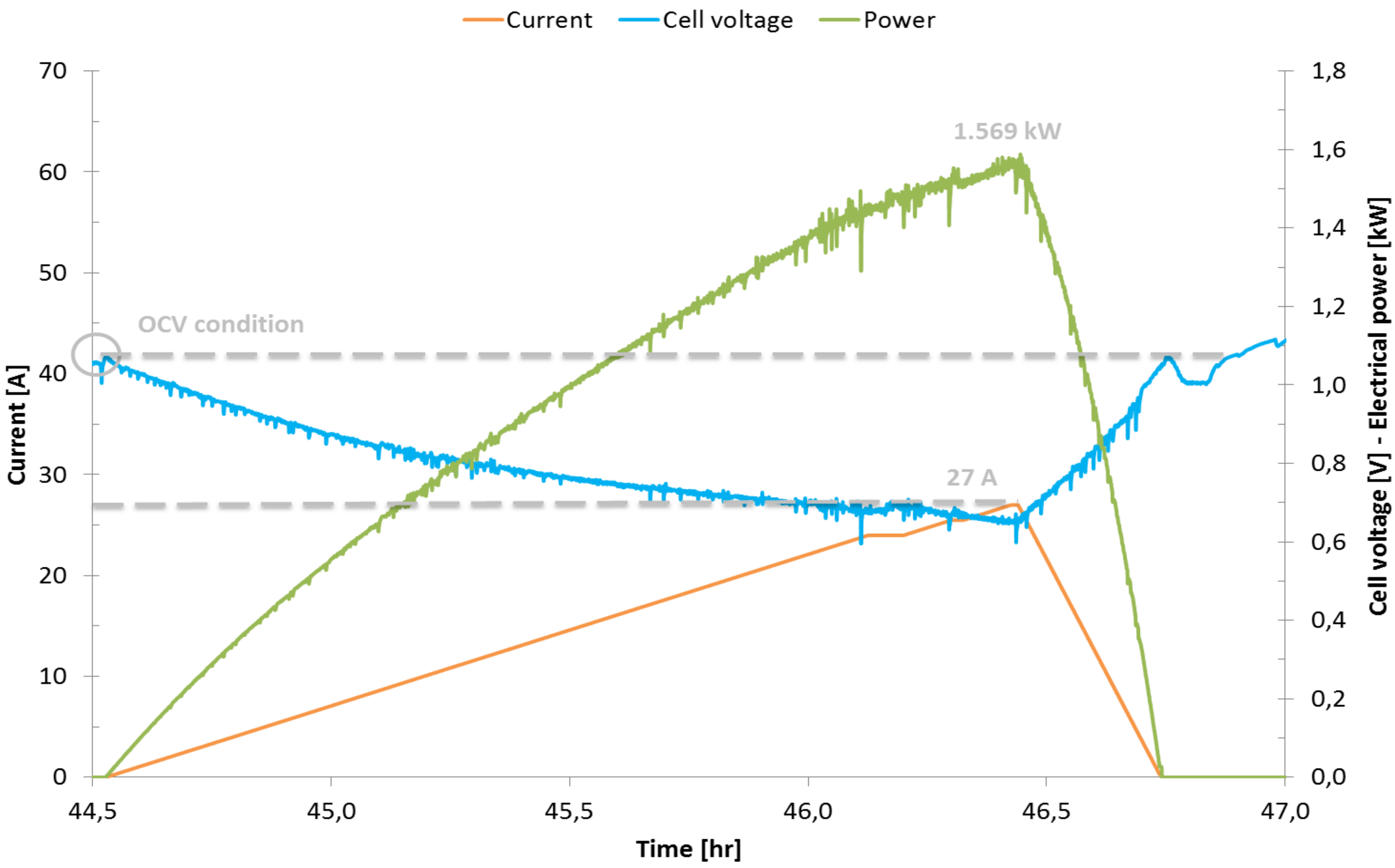
Parameter	Value	Unit
Biogas flow rate	8.36	NLPM
Air flow rate	150-250	NLPM
Biogas inlet pressure	220	mbar
Reformer temperature	650-850	°C
S/C	2.5	-
Anode inlet temp.	750	°C
Cathode inlet temp.	650	°C
SOFC working temp.	820-850	°C
Current	24	A
Oxy-combustor temp.	< 1200	°C
O2% in exhaust	1.1	%
Compressor out pressure	8	bar
Membrane out water	< 500	ppm(v)

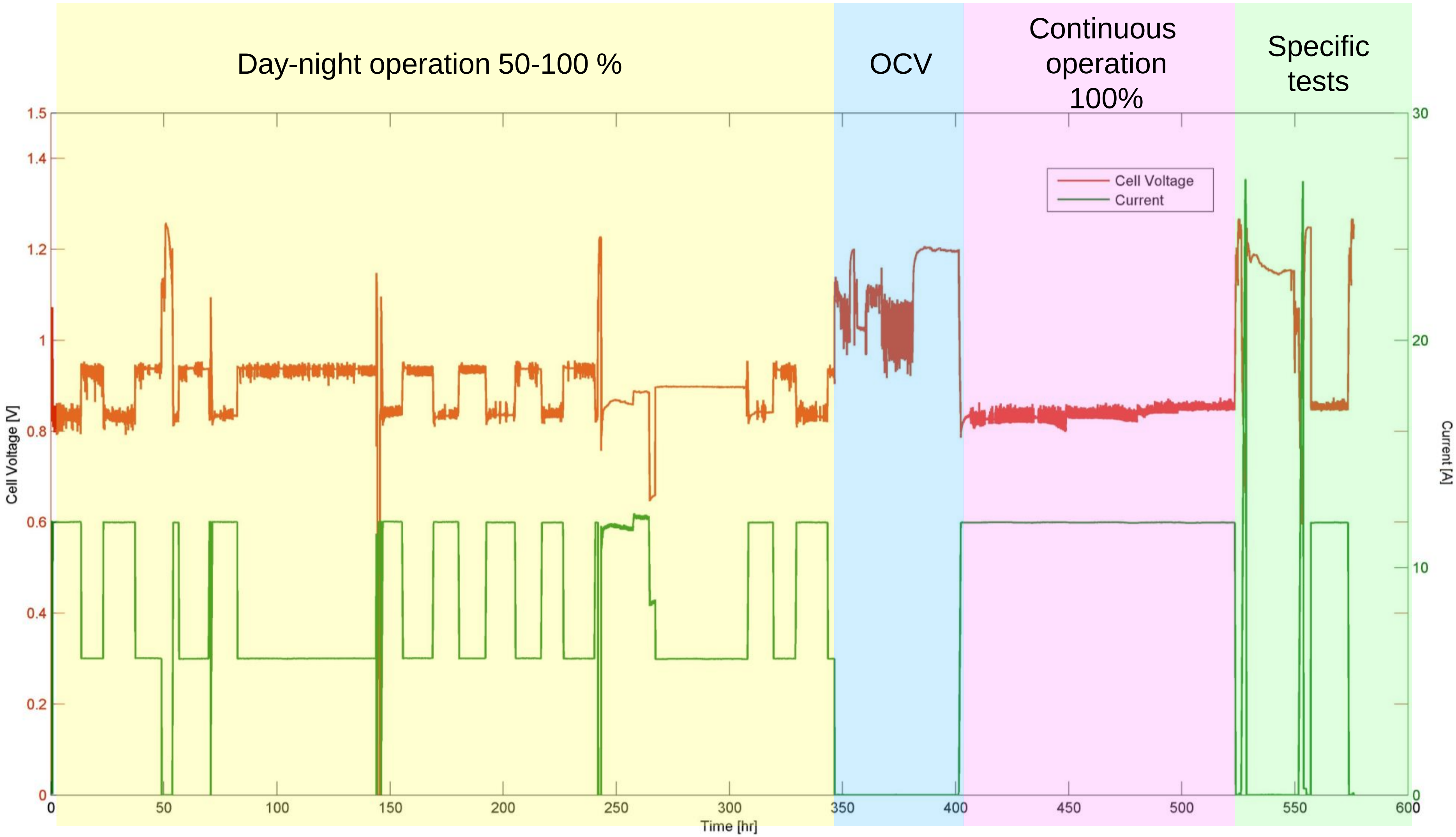
Biogas composition





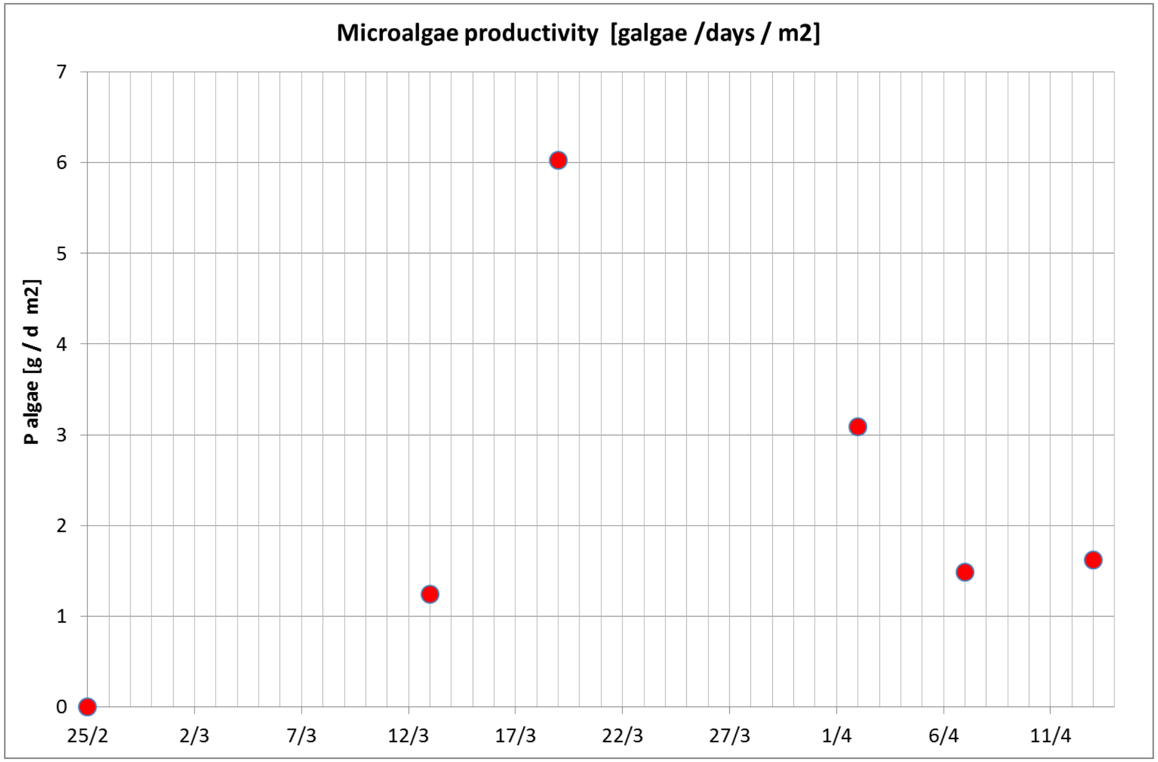
SOFC polarization curve



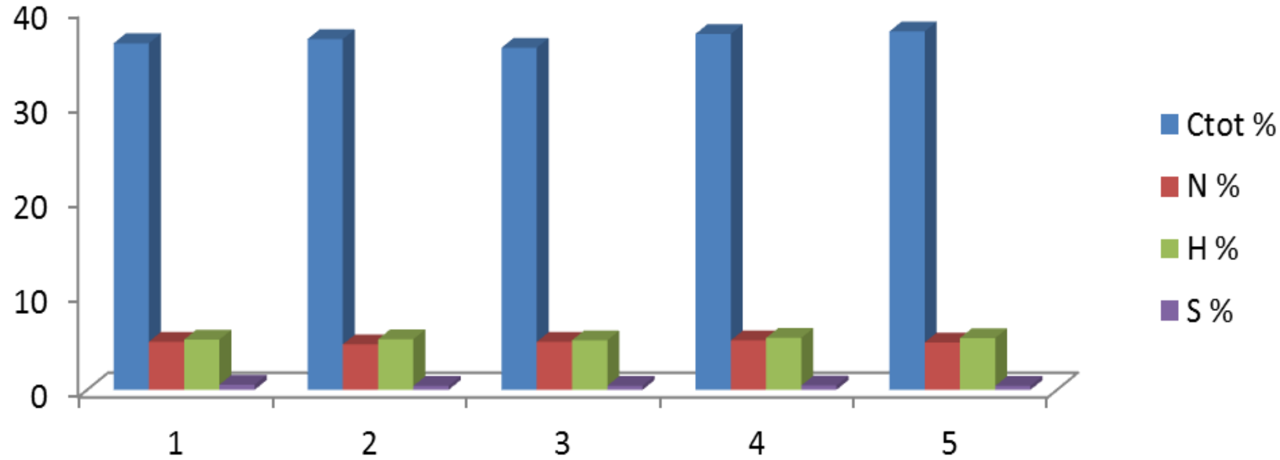


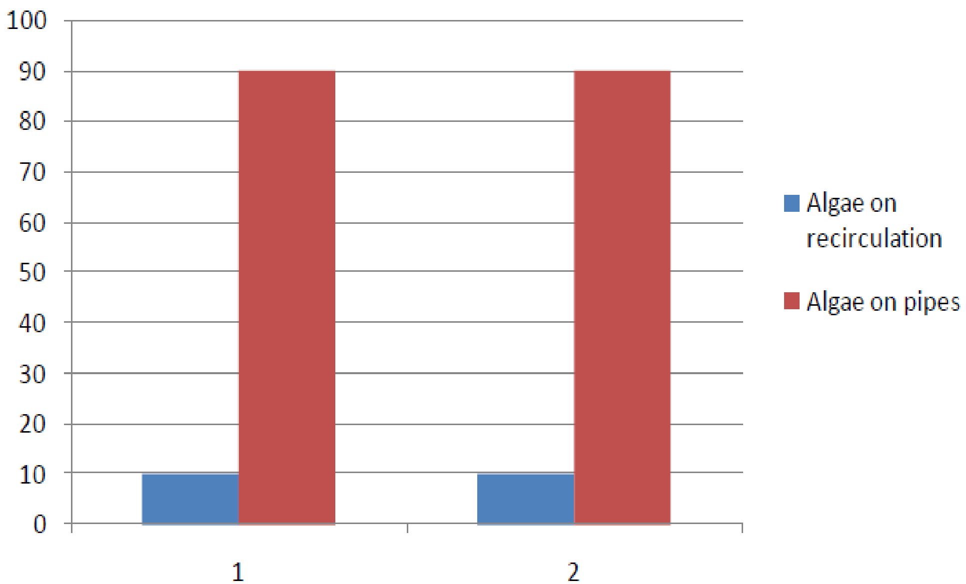
Day-night operation 50-100 %
OCV
Continuous operation 100%
Specific tests
Cell Voltage
Current
Cell Voltage [V]
Current [A]
Time [hr]
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.5
0
10
20
30
0
50
100
150
200
250
300
350
400
450
500
550
600

PBR operation

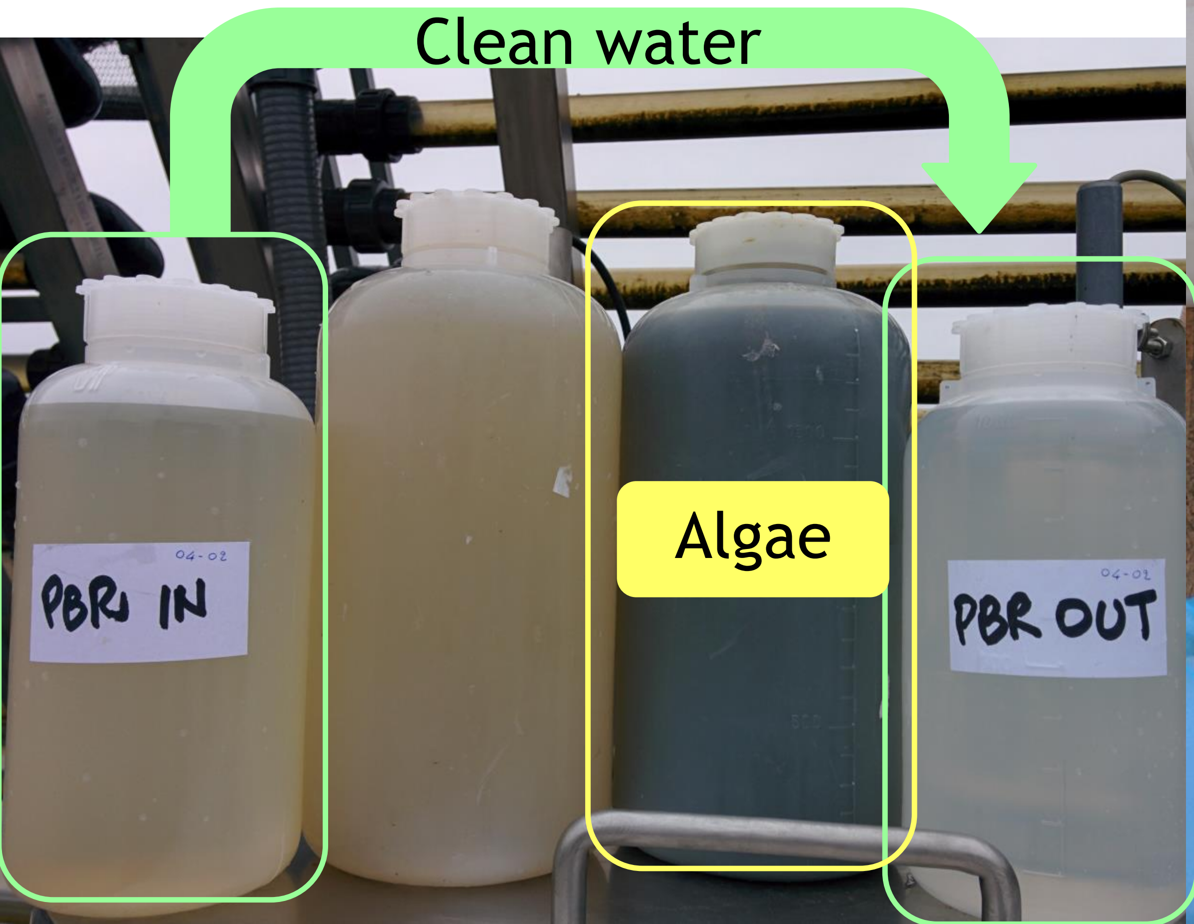


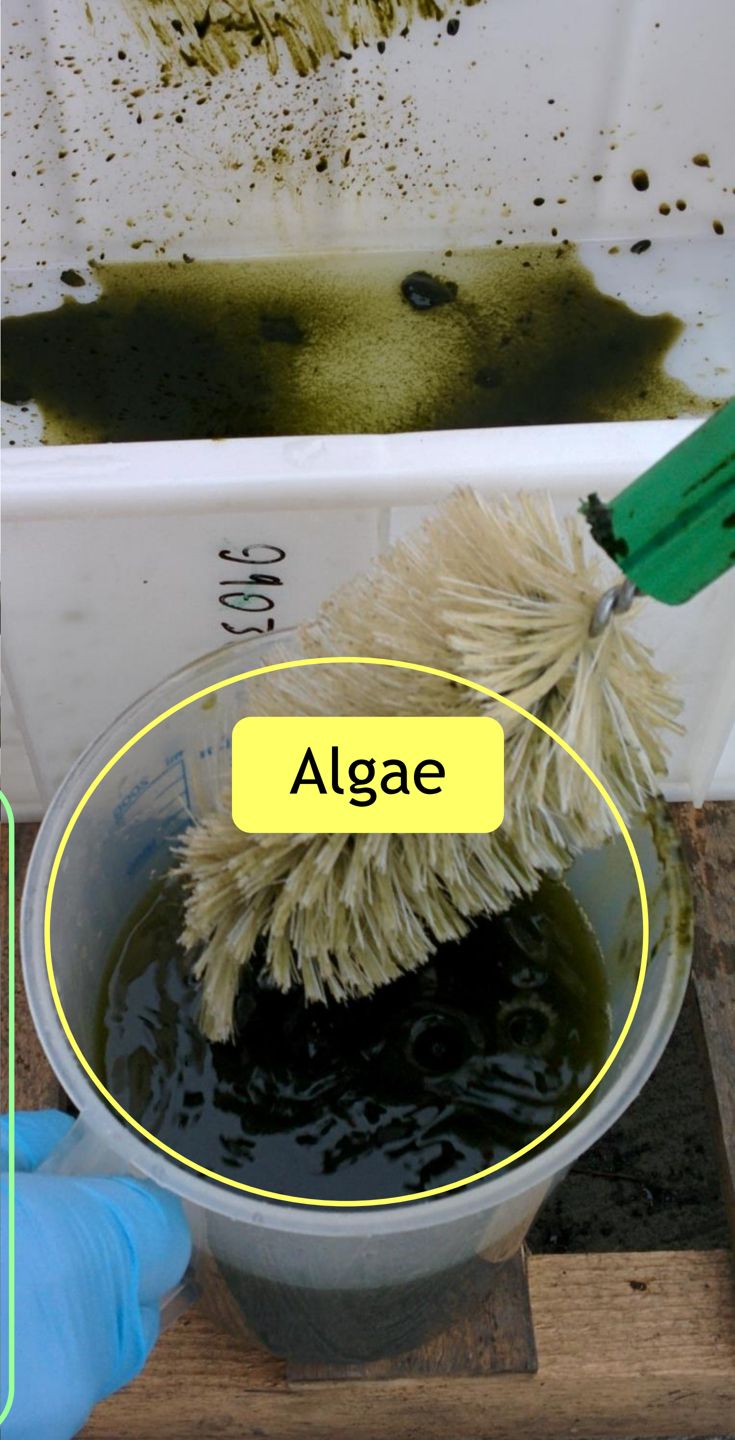
Algae composition



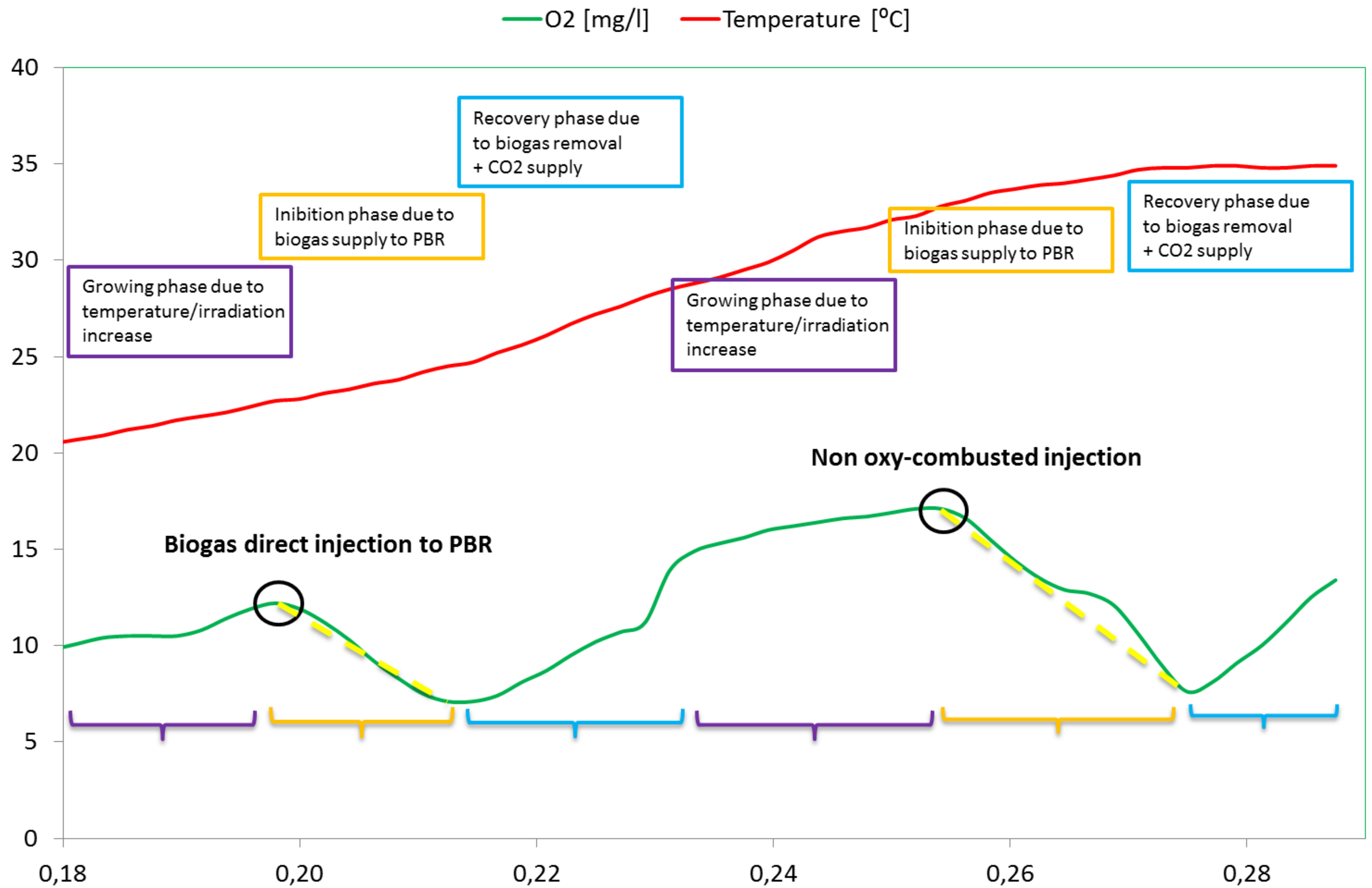


PBR output





PBR specific test



3.

LESSONS LEARNED

Lessons learned: technology

- **Oxy-combustion** step: does not present technical limitations, but it can be enhanced with some improved management of the plant:

  (a) operate the SOFC at a higher Fuel Utilization in order to reduce the amount of residual H_2 and CO in the anode exhaust;

  (b) in order to fully oxidize the residual H_2 and CO molecules, make use of the O_2 recovered from the downstream photo-bio-reactor, coming from the algae photosynthetic reaction (also mixed with residual CO_2)

- **H_2O separation** step: is not problematic from the technical point of view. A possible solution to reduce the energy cost related to the compression of the mixture before the membrane separator could be to operate the whole process in pressure

Lessons learned: technology

- **PBR:** is the most “problematic” component of the chain:

  (a) the productivity of the PBR in terms of micro-algae has proven to be satisfactory (maximum cumulated value 18.8 g/m2/day), even though it might be further improved;

  (b) the energy consumption of the PBR (around 9 W/m2) is too high and should be reduced;

  (c) the micro-algae tend to stick to the surface of the tubes, and this adhesion has to be reduced as it precludes further microalgae growth;

  (d) there is the necessity to control the injection of CO_2 in the water in order to avoid a too high reduction of the local pH, because an acidic water is detrimental for the grow up of most of the algae;

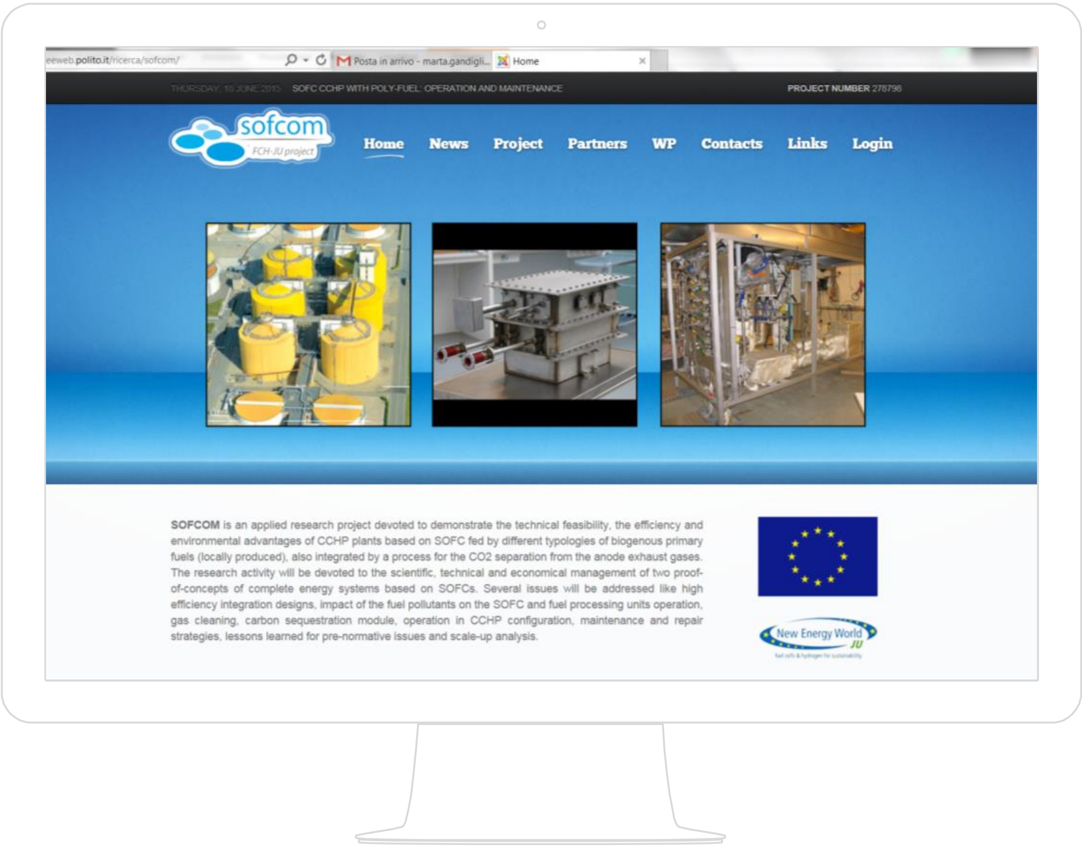
  (e) the need to accumulate the CO_2 coming from the SOFC plant during the dark periods (ie. algae not growing) in a storage buffer.

Learned from the proof-of-concept

- **Effectiveness of the micro-algae solution:** micro-algae are really a fast growing biomass (weekly peak of 4.18 W/m2 in terms of growing rate)

- **Carbon impact of the tested solution:** the CO_2 emissions from the SOFCOM system are 0 $kgCO_2/kWh_{el}$, but only if considering the intermediate buffer able to store the CO_2 during the period of null irradiance and if the unexploited CO_2 at the PBR outlet is recirculated with the O_2 to the oxycombustor

- **Considerations about the interest and effectiveness of the process in relation to global emissions actions:** carbon capture from biogas power plants can contribute to an overall emissions cut of 1.6% of the current CO_2-equivalent emissions in EU-28 zone.



Website project

Visit us on www.sofcom.it

Acknowledgments

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- Andrea Lanzini
- Davide Papurello
- Giuseppe D’Andrea
- … and all the steps research group!

Thanks!

Any questions?