The DEMOSOFC project

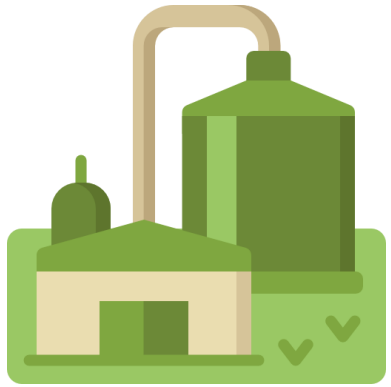
Marta Gandiglio

Department of Energy, Politecnico di Torino (IT)

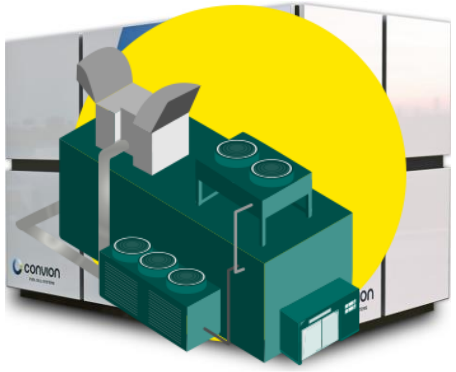
BIOCOGEN 2030 stories of innovation from the cogeneration world, e-EUBCE conference

July 7th 2020

The DEMOSOFC EU project



Anaerobic digestion for biogas production



Internal Combustion Engine
Solid Oxide Fuel Cell

Electricity

Heat

POLITECNICO DI TORINO (IT): project coordinator

CONVION (FI): SOFC technology provider

SMAT (IT): WWTP owner / end-user of electricity and thermal energy

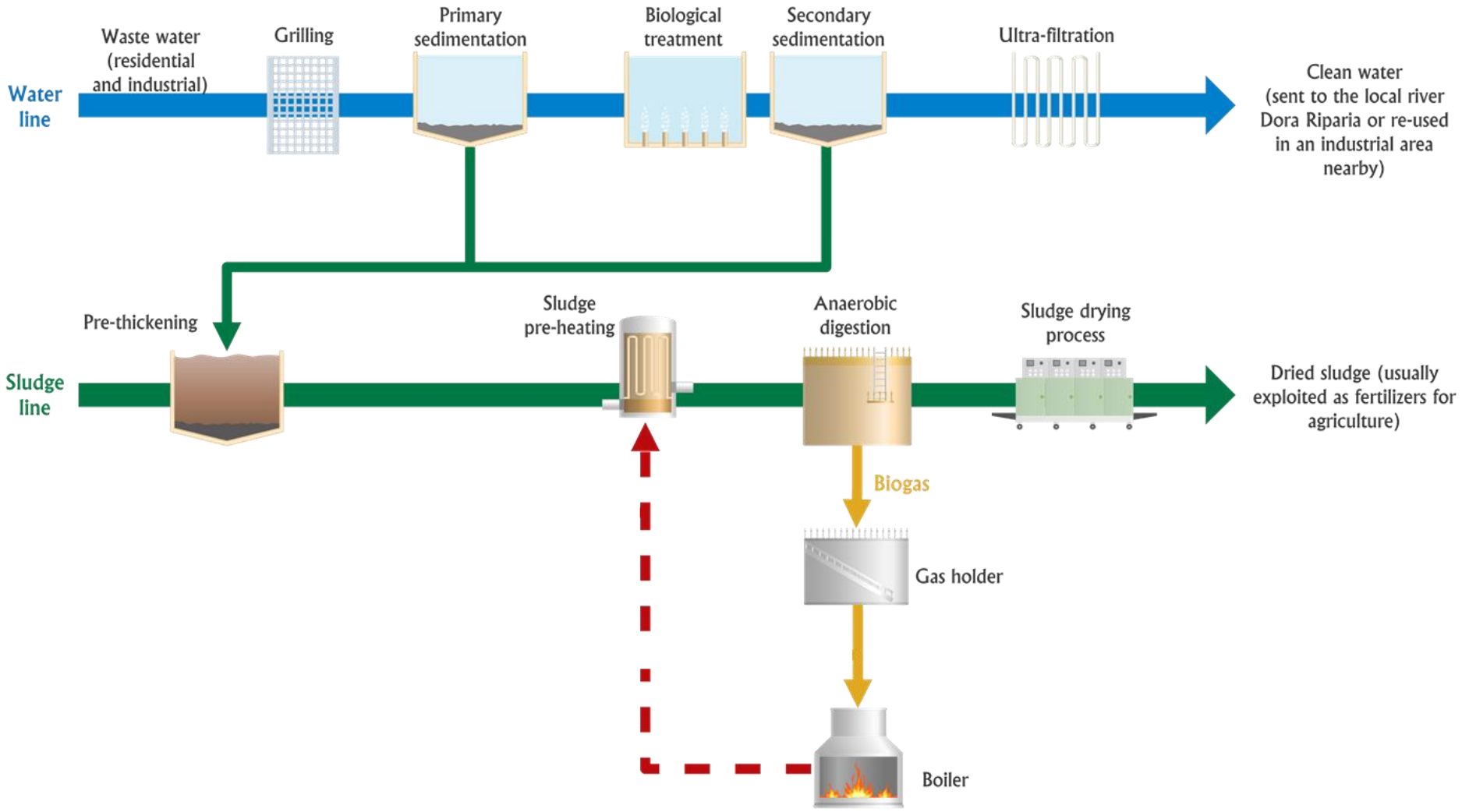
VTT (FI): performance evaluatio

IMPERIAL COLLEGE (UK): business analysis

The site: SMAT Collegno Waste Water Treatment Plant

- **Medium size WWTP**
- Entering load: **180’000 P.E.**
- # 50 for entering load among all IT WWTPs
- Previous biogas exploitation: boiler for anaerobic digester heating and flare

Plant layout



The DEMOSOFC plant

Biogas purification system

Required purification level for SOFC

H_2S: 30 ppb

Siloxanes: 10 ppb

QUALVISTA
SMART BIOGAS MONITORING

M. Gandiglio, A. Lanzini, M. Santarelli, M. Acri, T. Hakala, M. Rautanen, "Results from an industrial size biogas-fed SOFC plant (the DEMOSOFC project)", International Journal of Hydrogen Energy, Volume 45, Issue 8, 2020, Pages 5449-5464, https://doi.org/10.1016/j.ijhydene.2019.08.022

The SOFC modules

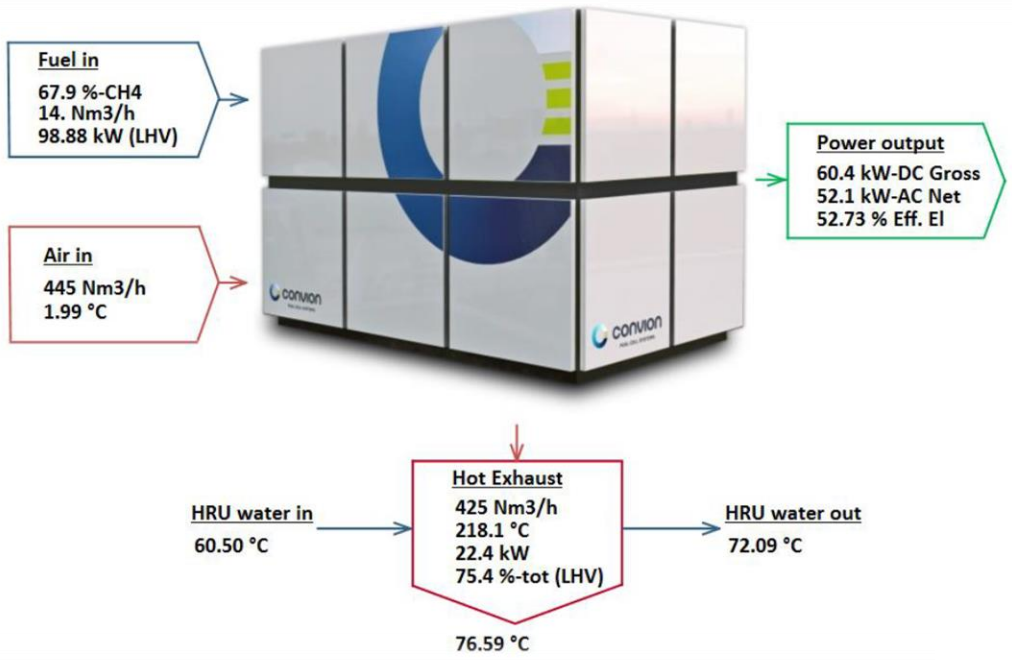
Inlet flows:

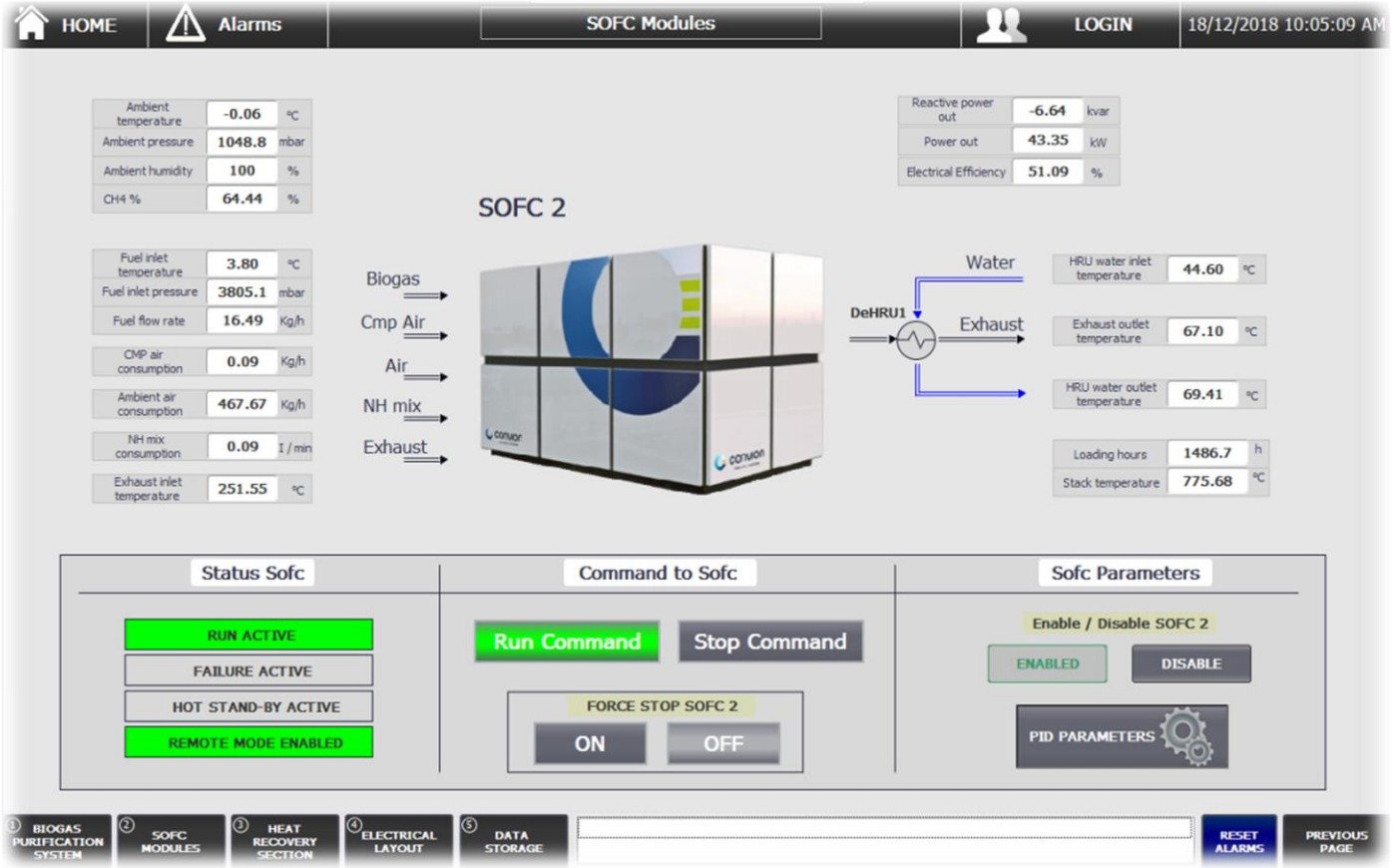
- Biogas @ 4 bar(g)
- Ambient air
- Compressed air (for start-up)
- N-H mix purge gas (for stand-by)

Outlet flows:

- Electrical power
- Thermal power
- Exhaust gas (CO_2 + H_2O + N_2)

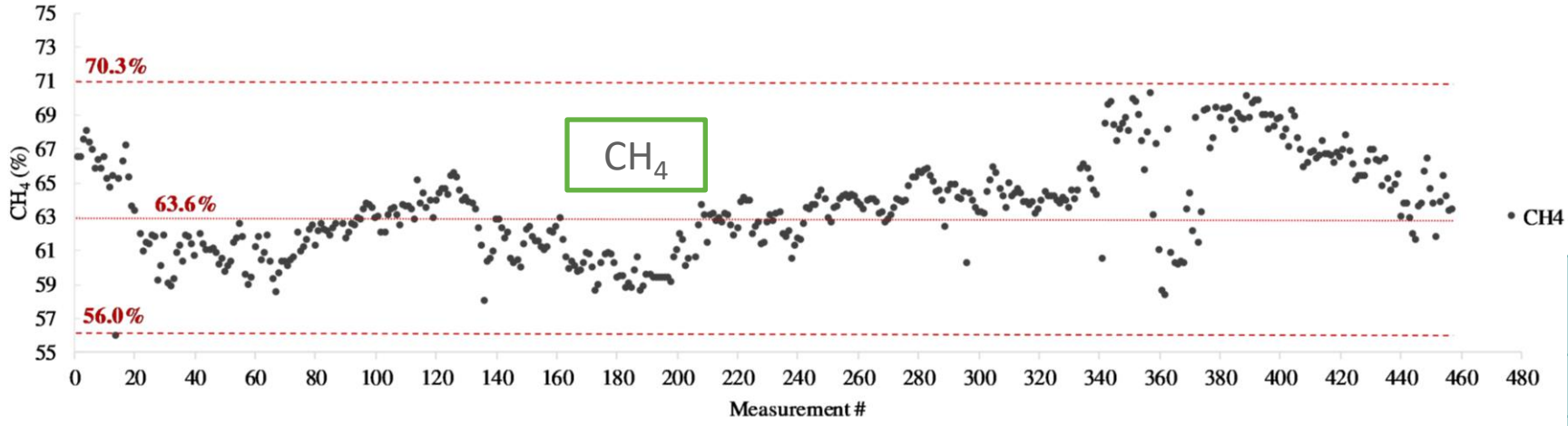
- 1st SOFC module started in October 2017 → **4600+ hours of operation onsite** (+1000h at Convion), currently under maintenance at Convion facilities
- 2nd SOFC module started in October 2018 → **9700+ hours of operation onsite**, currently in operation
- The DEMOSOFC plant has been running for **13'600+ hours**


Fuel in
67.9 %-CH4
14. Nm3/h
98.88 kW (LHV)
Air in
445 Nm3/h
1.99 °C
Power output
60.4 kW-DC Gross
52.1 kW-AC Net
52.73 % Eff. El
Hot Exhaust
425 Nm3/h
218.1 °C
22.4 kW
75.4 %-tot (LHV)
HRU water in
60.50 °C
HRU water out
72.09 °C
76.59 °C

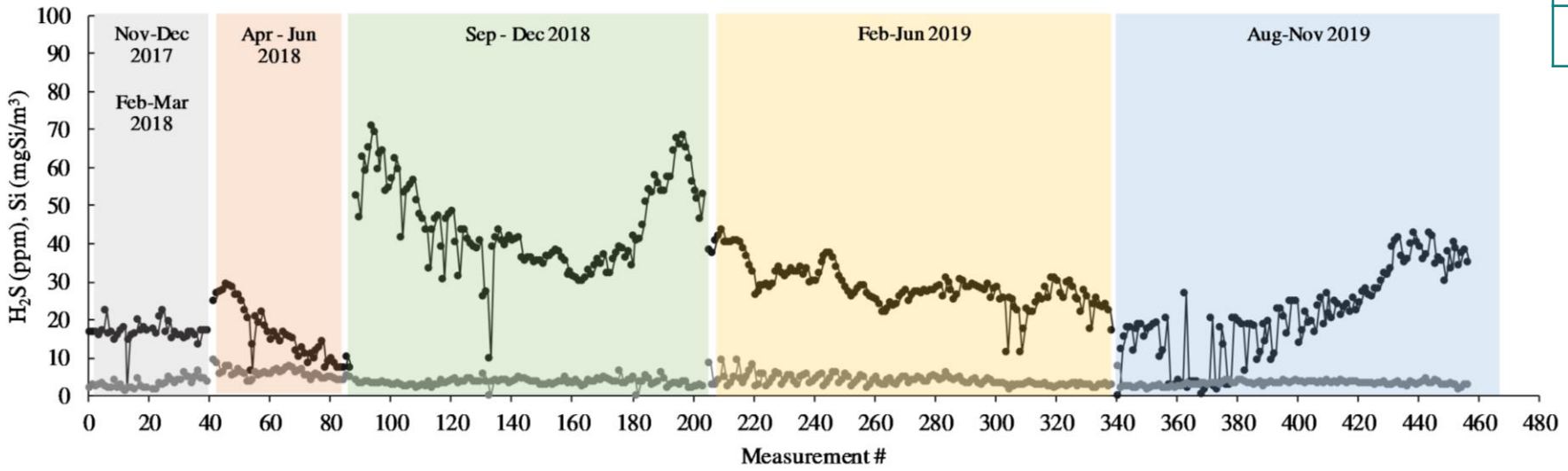

HOME
Alarms
SOFC Modules
LOGIN
18/12/2018 10:05:09 AM
Ambient temperature -0.06 °C
Ambient pressure 1048.8 mbar
Ambient humidity 100 %
CH4 % 64.44 %
Reactive power out -6.64 kvar
Power out 43.35 kW
Electrical Efficiency 51.09 %
SOFC 2
Fuel inlet temperature 3.80 °C
Fuel inlet pressure 3805.1 mbar
Fuel flow rate 16.49 Kg/h
CMP air consumption 0.09 Kg/h
Ambient air consumption 467.67 Kg/h
NH mix consumption 0.09 l / min
Exhaust inlet temperature 251.55 °C
Biogas
Cmp Air
Air
NH mix
Exhaust
DeHRU1
Water
Exhaust
HRU water inlet temperature 44.60 °C
Exhaust outlet temperature 67.10 °C
HRU water outlet temperature 69.41 °C
Loading hours 1486.7 h
Stack temperature 775.68 °C
Status Sofc
RUN ACTIVE
FAILURE ACTIVE
HOT STAND-BY ACTIVE
REMOTE MODE ENABLED
Command to Sofc
Run Command
Stop Command
FORCE STOP SOFC 2
ON
OFF
Sofc Parameters
Enable / Disable SOFC 2
ENABLED
DISABLE
PID PARAMETERS
1 BIOGAS PURIFICATION SYSTEM
2 SOFC MODULES
3 HEAT RECOVERY SECTION
4 ELECTRICAL LAYOUT
5 DATA STORAGE
RESET ALARMS
PREVIOUS PAGE

Results

Raw biogas quality



	H_2S (ppm)	Si ($mgSi/m^3$)	CH_4 (%)
Average	28.66	3.78	63.57
Min	0.00	0.00	56.04
Max	71.05	9.43	70.35

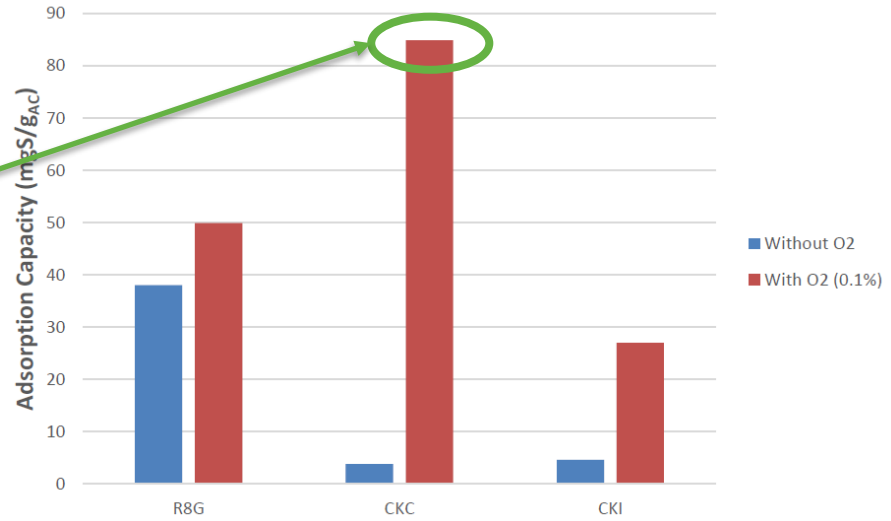


Contaminants

Cleaning system performance

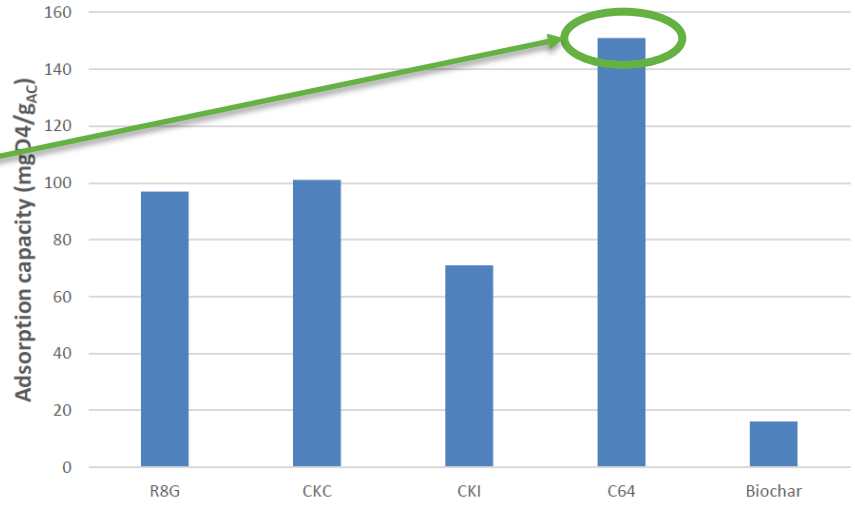
H2S (kg)	5.95
S (kg)	5.60
Loading rate (%)	2.38%
Ads. capacity (mgH_2S/g)	23.80
Ads. capacity (mgS/g)	**22.40**

26.40%

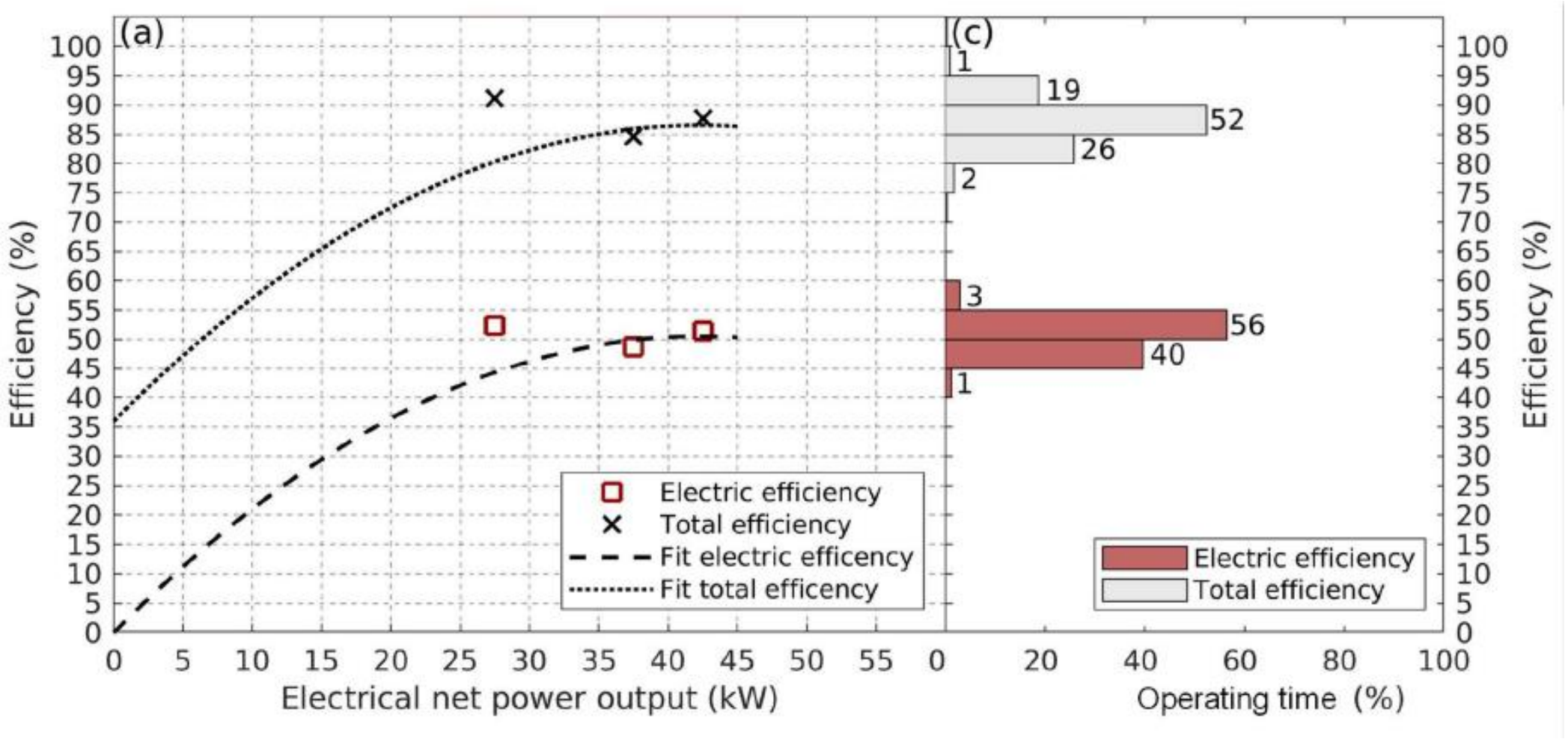


Si (kg)	0.48
Loading rate (%)	0.19%
Ads. capacity (mgSi/g)	**1.93**

1.28%



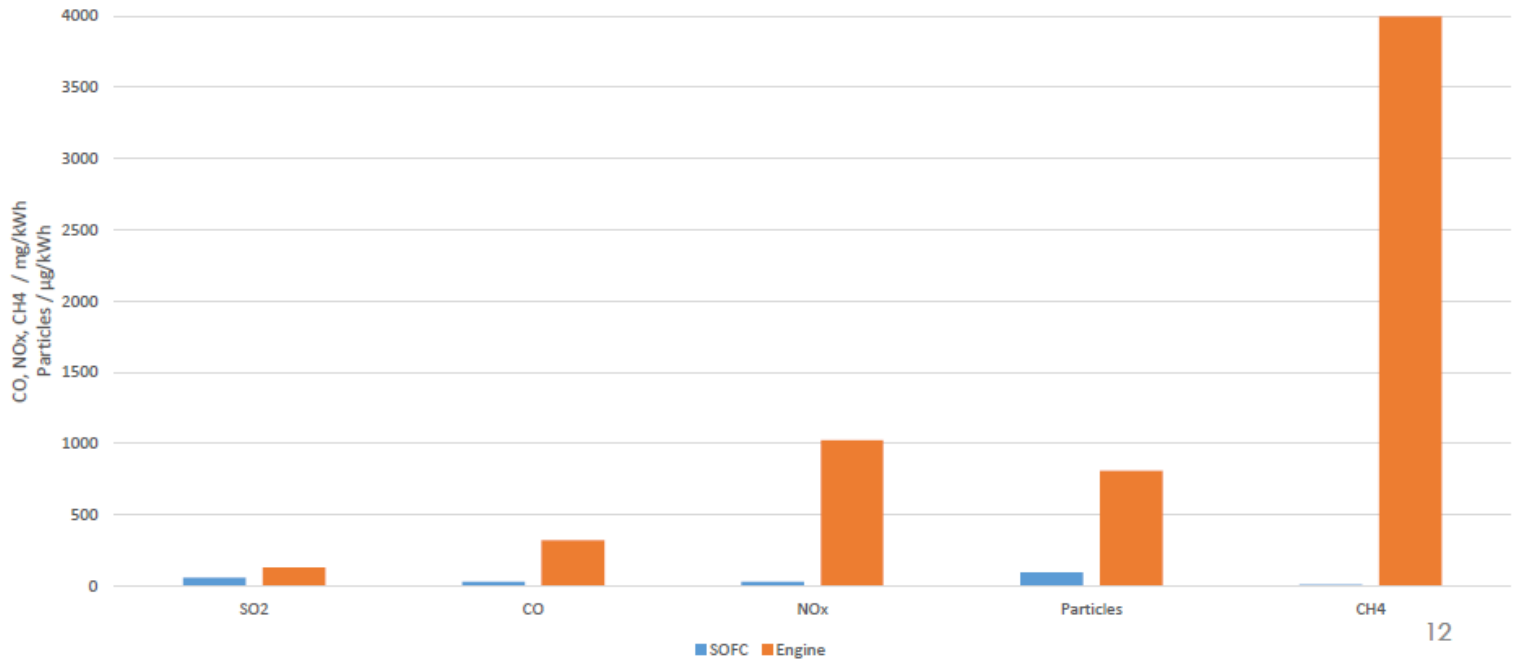
SOFC Modules Performance



H. Langnickel, M. Rautanen, M. Gandiglio, M. Santarelli, T. Hakala, M. Acri, J. Kiviaho, "Efficiency analysis of 50 kWe SOFC systems fueled with biogas from waste water", Journal of Power Sources Advances, Volume 2, 2020. https://doi.org/10.1016/j.powera.2020.100009

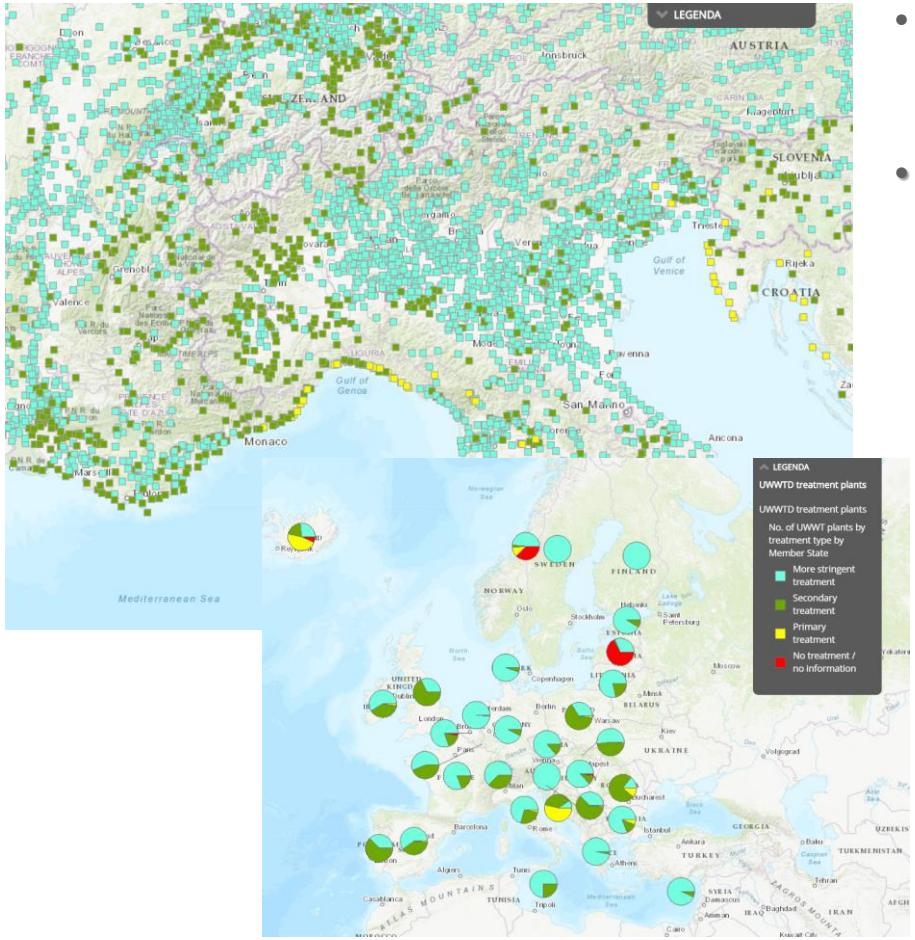
Emissions analysis

Species	Unit	Measured value	Typical emission limits of gas engines and turbines[1,2]
H_2O	Vol-%	4.7	
CO_2	Vol-%	3.4	
CO	mg/m^3	<9	100
CH_4	mg/m^3	<2	
N_2O	mg/m^3	<8	
NO	mg/m^3	<20	
NO_x (as NO_2)	mg/m^3	<20	75…200
SO_2	mg/m^3	<8	15…60
C_2H_6	mg/m^3	<14	
HCHO	mg/m^3	<7	
HF	mg/m^3	<10	
HCl	mg/m^3	<10	
SO_2	mg/m^3	<10	
O_2	Vol-%	18.3	
Particulate	mg/m3	0.01	Ambient air EU reference values[3] 0.025 (PM2.5), 0.05 (PM10)



1: Limitation of emissions of certain pollutants into the air from medium combustion plants (MCP-directive), DIRECTIVE (EU) 2015/2193
2: Industrial emissions (integrated pollution prevention and control) (IED-directive), DIRECTIVE 2010/75/EU
3: Air quality in Europe — 2016 report, EEA Report No 28/2016

Waste Water Treatment Plant in Europe

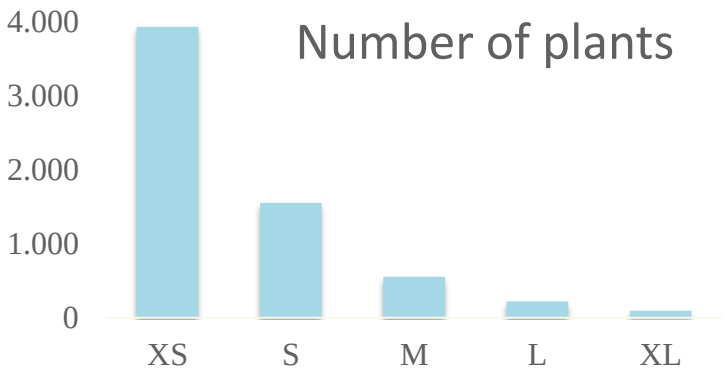


- Number of Active WWTPs in Europe: **23'423** (with loading or capacity data available)
- **Minimum entering load suitable for biogas production**: 20'000 P.E. (20-40 kW SOFC)
  → 19 % of total WWTPS

EU potential biogas production
1.86 - 5.44 billion m^3/y

→

EU potential SOFC Power installed
930 - 2550 MW_{el}



XS	20,000-60,000 P.E.	25 – 80 kW
S	60,001-150,000 P.E	80 – 200 kW
M	150,001-350,000 P.E.	200 – 500 kW
L	350,001-750,000 P.E.	500 - 1000 kW
XL	>750,0000	1000 - 1500 kW

Urban Waste Water Treatment map
https://eea.maps.arcgis.com/apps/MapJournal/index.html?appid=7fa4f0267d8249888b077803714e39fe&embed=true#

Thank you for your attention!

Marta Gandiglio

marta.gandiglio@polito.it

www.demosofc.eu

waste2watts-project.net

Steps POLITO

Steps POLITO

Steps POLITO

These project have received funding from the Fuel Cells and Hydrogen 2 Joint Undertaking under grant agreement No 671470 & N 826234. This Joint Undertaking receives support from the European Union's Horizon 2020 research and innovation programme, Hydrogen Europe and Hydrogen Europe research.