DEMOSOFC Project:

Results from an Industrial-Size Biogas-Fed Solid Oxide Fuel Cell plant



The DEMOSOFC EU project



London



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



DEMOSOFC





The **DEMOSOFC** plant



Biogas purification system



Biogas purification system







bio-kap









The SOFC modules

Inlet flows:

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





Outlet flows:

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

- Fuel flexibility (NG+biogas)
- Black box for the end-user, easy to install&operate





Electrical layout: island mode operation





ISLAND MODE





Results



Biogas quality – online gas analyzer

75 73 71 68.1% 69 CH4 (%) 65 63 H₂S Si CH₄ (ppm) (mgSi/m³) (%) 61 Average 31.561 4.065 62.493 59 57 58.1% 1.833 0.000 56.038 55 71.048 9.429 68.114 51 101 151 201 251

Measurement #



Raw biogas analysis \rightarrow

Min.

Max.

351

301

SOFC – Electrical & Total efficiency

- Until May 27th, more than 7500 hours of operation onsite have been reached (+1000h @ Convion facilities)
- Electrical power production: 322'526 kWh_{el}
- Thermal recovery for sludge pre-heating: **195'085 kWh**_{th}





Emissions from SOFC

(onsite analysis done by **VTT** on Dec 2017)

Species	Unit	Measured value	Typical emission limits of gas engines and turbines ^{1,2}
H ₂ O	Vol-%	4.7	
CO ₂	Vol-%	3.4	
СО	mg/m ³	<9	100
CH ₄	mg/m ³	<2	
N ₂ O	mg/m ³	<8	
NO	mg/m ³	<20	
NO _x (as NO ₂)	mg/m ³	<20	75200
SO ₂	mg/m ³	<8	1560
C ₂ H ₆	mg/m ³	<14	
НСНО	mg/m ³	<7	
HF	mg/m ³	<10	
HCI	mg/m ³	<10	
SO ₂	mg/m ³	<10	
O ₂	Vol-%	18.3	
Particulate	mg/m3	0.01	<u>Ambient</u> 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



Future perspectives & Conclusions



Waste Water Treatment Plant in Europe



- P.E. : People Equivalent corresponds to a BOD5 equal to 60 g of oxygen per day
- 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. (40 kW SOFC) → 19 % of total WWTPS

Urban Waste Water Treatment map

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

SOFC market potential in Europe



Installed MWel Number of plants 250 4.000 200 3.000 150 EU potential biogas 2.000 production 100 1.86 - 5.44 billion 1.000 50 0 0 XL XS XS S Μ L



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

m³/y

XS	20,000-60,000 P.E.	25 – 80 kW
S	60,001-150,000 P.E	80 – 200 kW
Μ	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

Which could be the price of an SOFC system?



Conclusions

- → The DEMOSOFC plant has demonstrated the advantages of the waste-to-energy process by coupling sewage biogas and SOFCs.
- → SOFCs could become a best practice for electricity production from biogas:
 - Higher electrical and lower thermal production (usually unexploited);
 - Zero pollutants to atmosphere (important especially in urban areas).
- → Small-medium size plants are a niche starting market for the technology because of the higher benefits compared to ICEs and biomethane. The replication potential is huge.
- → Because of their modulation capability, SOFC could work in grid balancing and in micro-grids, together with renewables.





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