



BIOGAS-POWERED FUEL CELLS

WssTP Stakeholders event

1/6/10, Brussels

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AGUAS DE MURCIA

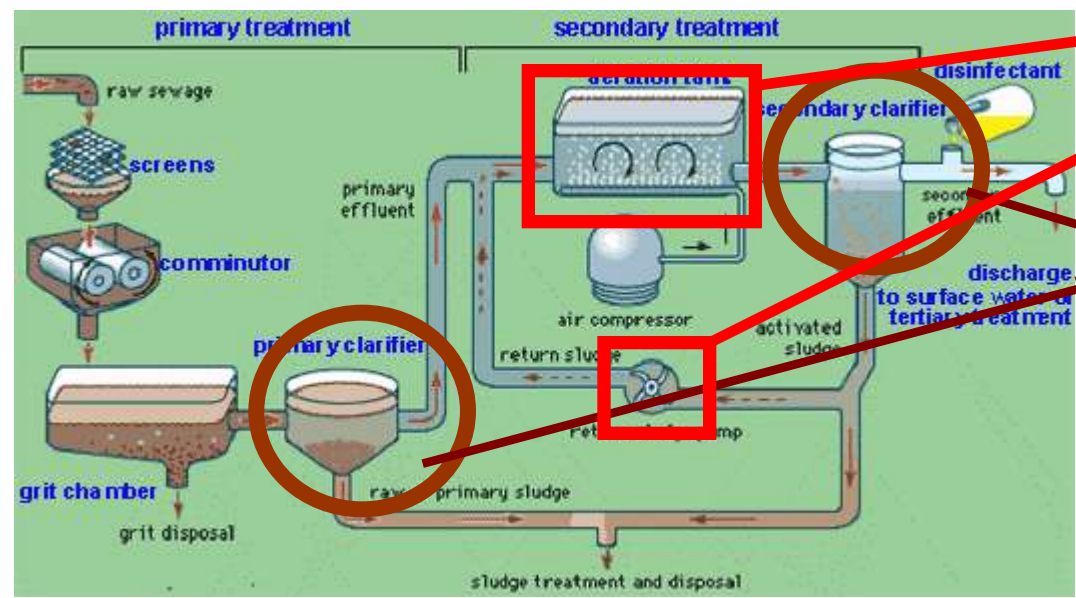


Environmental problem targeted (1/3)

Drivers:

- Rise of electricity costs: in Spain it has increased by 39% between 2007 – 2009
- Climate change awareness: reduction of the carbon footprint
- Use of renewable energies: target of 20% of the total in the UE by 2020

The energy context in a WWTP

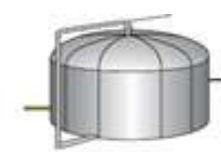


Electric consumption

Sludge

~~= Waste to dispose of~~

= Source of Energy



→ BIOGAS

Anaerobic digester

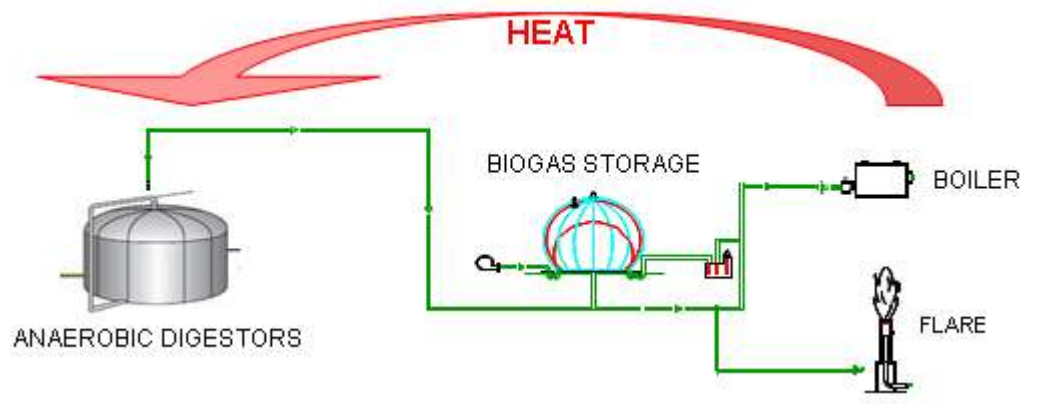
Energy in a WWTP

Inlet: pumping and aeration Outlet: Sewage Biogas



Today

Part of the biogas is lead to a boiler (to heat digesters)
BUT the rest is flared



Is this an efficient way to use biogas in WWTP?

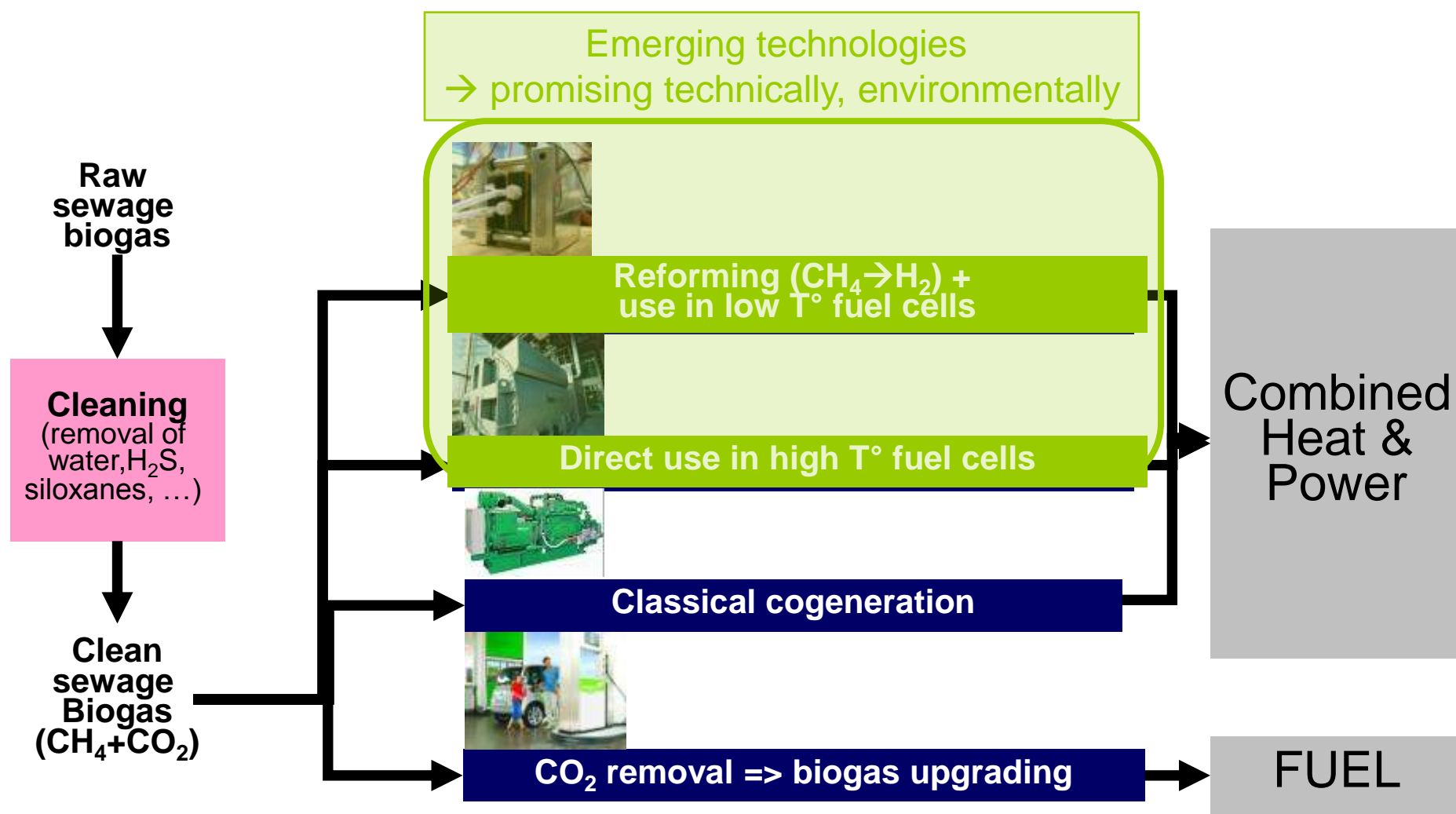
- As electricity is the major energy demand in a WWTP, other technologies from boilers must be promoted.

Electricity: requirements and potential



Depends on the efficiency of the end-use technology!

How can we use biogas efficiently?



■ Fuel cells: advantages and drawbacks

● Fuel cell: electrochemical combustion (fuel is oxidized in the anode and air is reduced in the cathode)

● Advantages

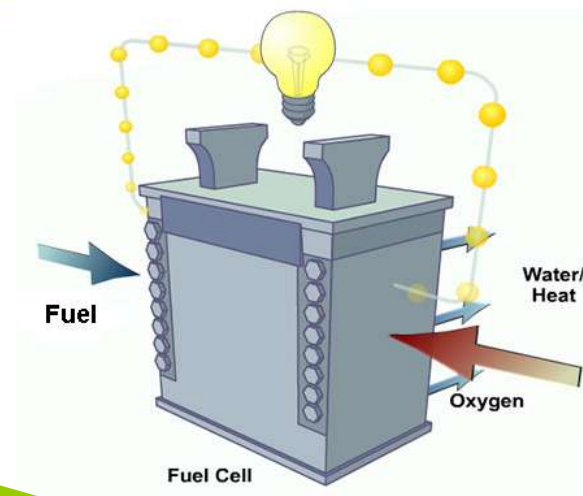
- High electric efficiencies
- Low emissions: NO_x , CO , CH_4 , noise...
- High energetic density (lower footprint)
- Stable operation both in electric and thermal outputs

● Drawbacks

- High investment costs
- Low operating time
- Fuel cleaning and processing is energy consuming

Fuel cells are as clean as the fuel they use

↓ if
 BIOGAS



Climate change mitigation

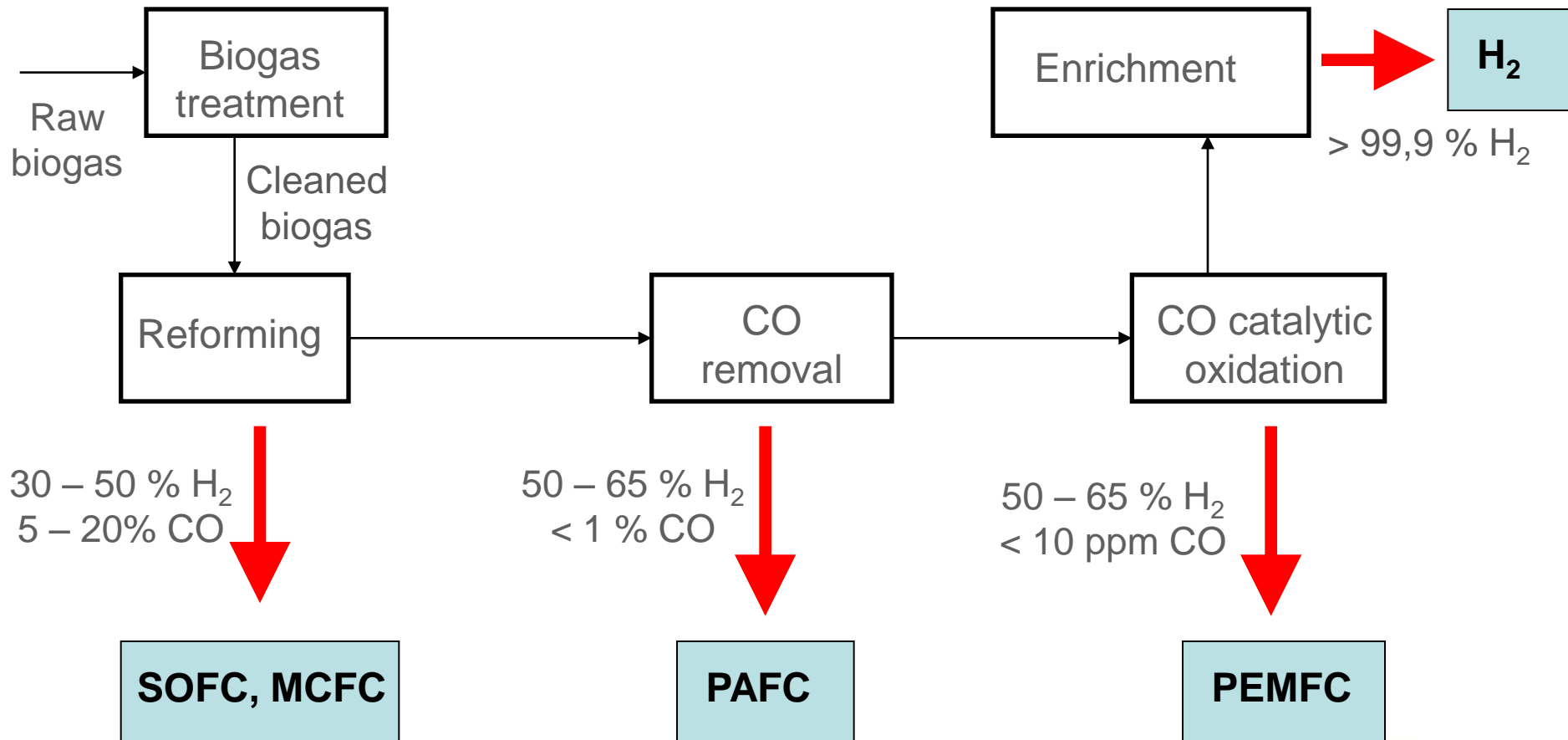
WHICH FUEL CELL ???

- Several fuel cells can be adapted to Sewage biogas, two of them are Proton Exchange Membrane Fuel Cells (PEMFC) and Solid Oxide Fuel Cell (SOFC)

	PEMFC	SOFC
Operating temperature	50 – 100°C	600 – 1.000°C
Electrical efficiency	50 – 60%	50 – 60%
Fuels that can be used	H ₂	H ₂ , CO, CH ₄
Requires removal of	S-compounds, NH ₃ , CO	S-compounds
Outputs	Power	Heat and Power
Maturity (general applications)	Yes	No
Maturity (biogas)	No	No

■ Biogas processing for different fuel cells

Every fuel cell accept fuels of different quality => Biogas processing are the preliminary stages in order to adapt our fuel to the fuel cell requirements



The BIOCELL project (1/3)

Title: Energy self-sustaining and environmental footprint reduction on wastewater treatment plants via fuel cells (BIOCELL)

Duration: 01 – 01 – 2009 to 31 – 12 – 2011 (3 years)

Coordinator: **CETAQUA**
CENTRO TECNOLÓGICO DEL AGUA

Partners:



Stakeholders:



Agència Catalana
de l'Aigua



Àrea Metropolitana de Barcelona
Entitat del Medi Ambient



esamur
Fundació Saneament
i Depuració
de la Regió de Murcia



Budget: 2,42 M€

Funding: LIFE+ program (LIFE07 ENV / E / 000847)



■ **Objective:**

Demonstrate the technical feasibility of energy production on WWTP from biogas via PEMFC and SOFC fuel cells

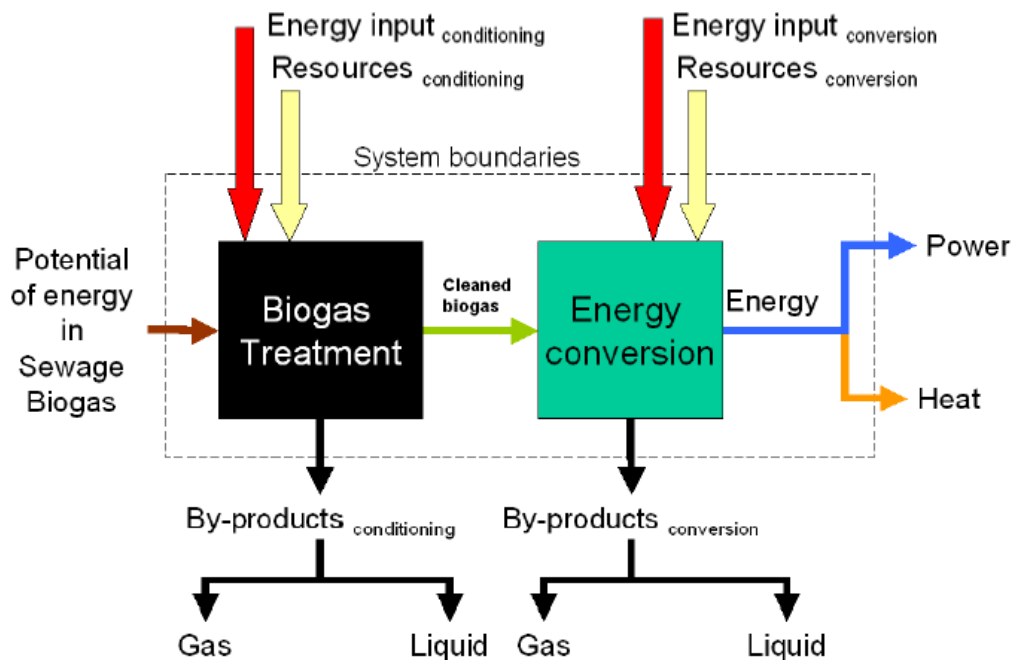
- **Technical assessment.** Guidelines on selection, implementation, operation and optimization energy production from biogas via fuel cells adapted to WWTP
- **Feasibility and impact assessment.** Energy self-sustainability, economic feasibility and reduction of environmental impact of WWTP using biogas recycling via fuel cells.
- **Application field.** Biogas as a fuel: requirements and limits

Methodology

- Construction and operation of two pilot plants: PEMFC (Murcia) y SOFC (Mataró)
 - Biogas flow rate: 5 – 10 Nm³/h
 - Power: 2,2 – 3 kW_e
- The whole line (biogas treatment + fuel cell) should be considered together



Biogas treatment plant in Murcia Este WWTP



- Technical study
- Economical study
- Environmental study (via Life Cycle Assessment)
- Energy Balance

The PEMFC pilot plant (1/2)

- WWTP Murcia
 - Sewage treatment capacity: 100.000 m³/day (980.000 PE)
 - Biogas production: 15.000 Nm³/day
- Challenges treatment:
 - Very high H₂S concentration
 - Thorough cleaning is necessary
- Challenges reforming/fuel cell
 - Avoid soot formation in the reformer
 - Comply with the low CO limit
 - Obtain high H₂ purity
 - Few feedback biogas-powered PEMFC
 - 190 kW_e unit powered with sewage biogas in Tomakomai WWTP

From sewage biogas

CH ₄	61 – 65%
CO ₂	30 – 34%
H ₂ S	2.500 – 5.500 ppm
Siloxanes	2 – 5 mgSi/Nm ³
Halogens	Not detected

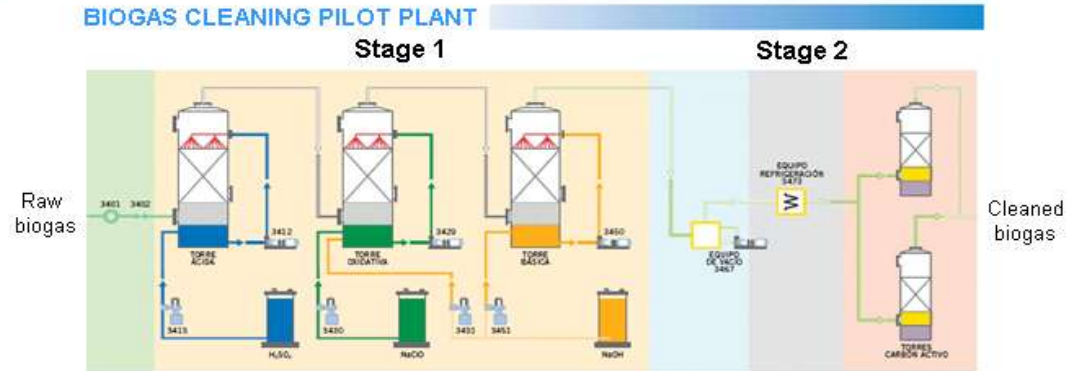
To PEMFC requirements

H ₂	99,99 – 99,999% > 72% (Ballard)
CO	10 ppm
H ₂ S	0,1 ppm
NH ₃	10 ppm
Siloxanes	1 mgSi/Nm ³
Halogens	0,1 ppm

The PEMFC pilot plant (2/2)

Solutions treatment:

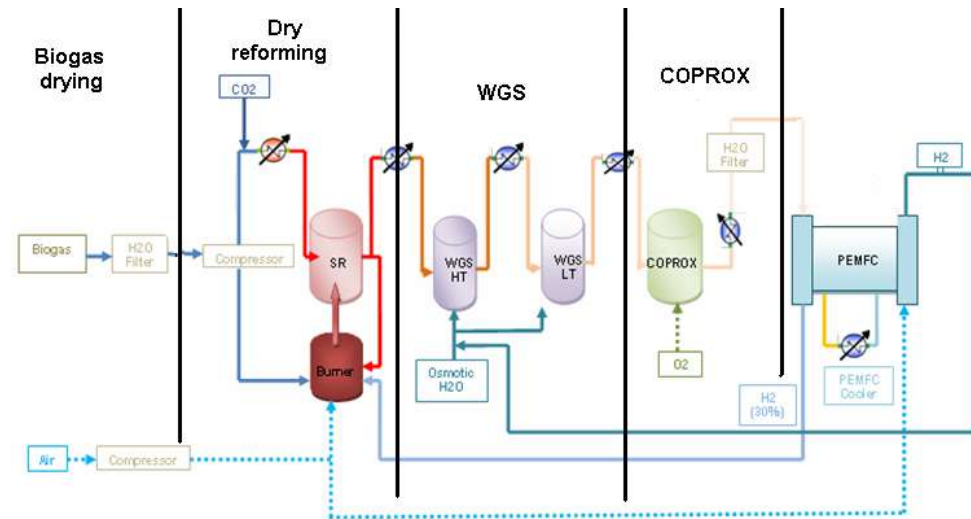
- A chemical washing is required for H₂S removal
- Final polishing with activated carbon to comply with the limits



The pilot plant treatment has been operating for 2 years with efficiencies greater than 99% for all compounds

Solutions reforming/fuel cell:

- Full reforming process with 4 stages implemented
- Inlet conditions: CH₄:CO₂ 1:1 to avoid soot formation
- Long catalyst lifetime (compared to conventional reformers)
- Outlet gas: 56% H₂



The fuel cell will run with the reformatte gas without any enrichment!

The SOFC pilot plant (1/2)

● WWTP Mataró

- Sewage treatment capacity: 57.000 m³/day (450.000 PE)
- Biogas production: 5.750 Nm³/day

● Challenges treatment

- Thorough cleaning is necessary

● Challenges fuel cell

- SOFC designed for natural gas applications
- No previous experience is available
 - 3 kW_e SOFC powered by semi-upgraded biogas (BIOSOFC project)
 - 3 kW_e SOFC in Stockholm powered by upgraded biogas for 1.700 h

From sewage biogas

CH ₄	61 – 66 %
CO ₂	39 – 36 %
H ₂ S	1.900 – 3.300 ppm
Siloxanes	3,5 – 6,5 mgSi/Nm ³
Halogens	Not detected
Hydrocarbons	1 – 110 mg/Nm ³

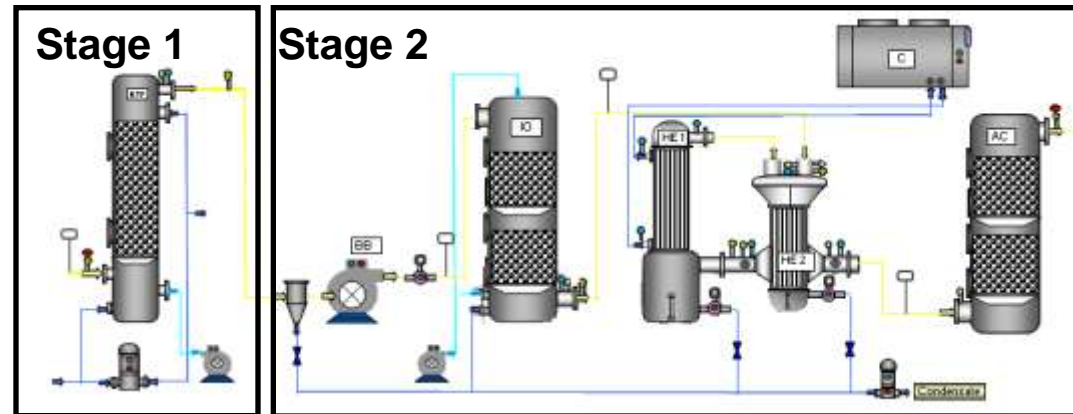
To SOFC requirements

CH ₄	No requirement
CO ₂	No requirement
H ₂ S	1 ppm
Siloxanes	1 mgSi/Nm ³
Halogens	0,1 ppm
Hydrocarbons	< 1 mg/Nm ³

The SOFC pilot plant (2/2)

Solutions treatment:

- A biological H₂S removal will be installed
- Final polishing with iron oxides and activated carbon (2 beds in series!)



Solutions fuel cell

- 21 manufacturers were contacted. They were divided in 3 main groups:
 - Suitable technology BUT no interest for biogas or pilot demonstrations
 - Interest for biogas BUT no suitable technology
 - Interest for biogas AND suitable technology → **Adequate for the BIOCELL project**
- The SOFC unit will run without any biogas upgrading
- Heat integration will be adapted to biogas

Pilots comparison

	Pilot in Murcia	Pilot in Mataró
Biogas treatment	Chemical and polishing	Biological and polishing
Biogas reforming	External (three stages)	Internal
Fuel cell electric power	PEMFC 2 x 1,5 kW _e	SOFC 2 x 1,1 kW _e
Exhaust gases' temperature	50 – 70°C	200 – 250°C
Heat recovery	No	Yes: Hot water production at 50°C

Photos of the full pilots will be available from September 2010!

■ **Biogas**

- Biogas is a valuable resource that should not be flared: its potential in Europe in 2007 was 6.000 ktoe (1.000 ktoe in WWTP)
- Sewage biogas plays a key role in energy self-sufficiency in WWTP

■ **Biogas treatment**

- Several technologies can be adapted to fuel cells
- It should be very efficient and robust to protect the fuel cell

■ **Fuel cells**

- Can be adapted to run with sewage biogas
- CAPEX (8-100 k€/kW_e), OPEX and low lifetime hinder development
- Biogas reforming for H₂ production is the key stage in PEMFC
- Fuel processing in high temperature fuel cells is more simple

■ **BIOCELL project global approach: technical, economical, LCA**



Thanks a lot for your attention!

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More information in www.life-biocell.eu