Potential applications and synergies of biogas fuel cells as an efficient alternative energy conversion technology

Hydrogen and fuel cell based energy systems, 31. March and 1. of April 2004, Vienna, Austria

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Background

Fuel cell scenario

•If we are looking for susatainable and clean energy future and we choose fuel cells as a tool therefore, then we have to think about where we get our hydrogen or prime fuel from.

•This prime energy has to be, up to a certain extent, a renewable energy source and be as far as possible directly suitable for its energy transformation in fuel cells in order to avoid a neutralisation of it advantages.

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Biogas

Advantages

•Renewable energy with the highest potential[1] for green house gas reduction

•Decentralised energy production (<1MWel)

•Cost reduction of waste disposal and new income for the agricultural sector

•Closing of the nutrient cycle (agriculture)

•Several directives encourage biogas utilisation

[1]Greenhouse gas emissions (IEA Bioenergy Task 25, G. Jungmeier gerfried.jungmeier@joanneum.ac.at)

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Why MCFC?

High temperature versus low temperature

	Low Temperature FC			High temperature FC		
FC Type	**PEFC** 80	**AFC** 100	**PAFC** 200	**MCFC** 650	**ITSOFC** 800	**TSOFC** 1000
H_2	F	F	F	F	F	F
CH_4 & CnHm	IG	poison	IG	IG/F	F	F
CO_2	IG	poison	IG	React.	IG	IG
CO	poison (<50ppm)	poison	poison (<500ppm)	F	F	F
H_2S, COS	nd	poison	poison (<50ppm)	poison (<0.5ppm)	poison	poison (<1.0ppm)
NH_3	poison	F	poison	F	F	F

Analysis on siloxanes, halides, tar, dust, and other contaminants are missing!!!

F.....Fuel, IG.... Inert gas, Reactant ..... Takes part in electrode reaction

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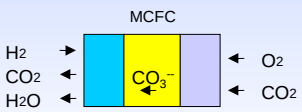
Why MCFC

- High temperature FC
- Ideally suitable for biogas (due to the biogas composition: CO_2 and CH_4)
- High system efficiency (~49%), due to beneficial impact of carbon dioxide as well as internal reforming
- Near to market

MTUs Hot Module Stack (250 kW)



Operating temperature MCFC: ~ 650 °C, enabeling internal CH4 reforming

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Synergies MCFC - Biogas

- Utilisation of RES in FC Technology – leading to a sustainable cycle
- Efficient and clean energy conversion of valuable RES
- High user potential for utilising the process heat which is released from the MCFC-process
- Decentralised energy production

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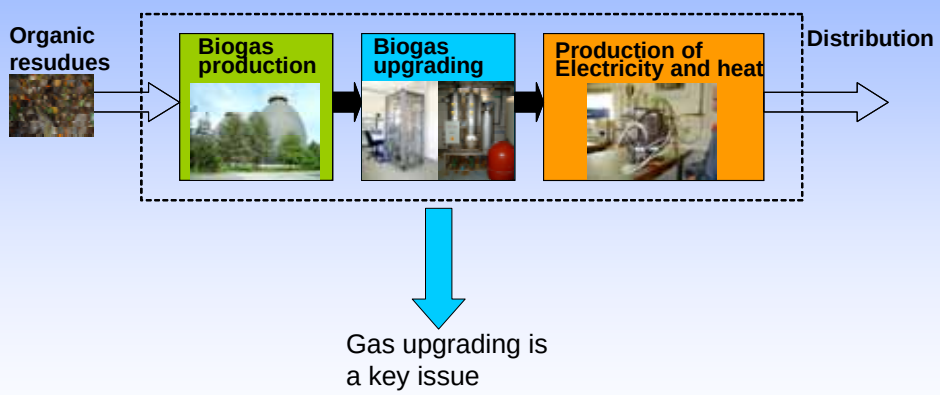
The EFFECTIVE concept



Gas upgrading is a key issue

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The EFFECTIVE project

Biogas usage in fuel cells

Holistic integration of MCFC technology towards a most EFFECTIVE systems compound using biogas as a renewable source of energy.

- **Project start:** 07 / 2000
- **Duration:** 4 years
- **Budget:** ~ 3.5 Mio Euro

- Financing: Own contribution, EU - Commission, bm:bwk

- **Partners:** Profactor (A), Studia (A), Linz Strom GmbH (A), MTU (D), Seaborne (D), Uni Nitra (SK), Ciemat (E), Urbaser (E)

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EFFECTIVES approach

- Development and construction of 2 gas upgrading systems for H_2S removal
- Construction of two test beds:
  - One mobile system to be installed in Germany, Austria and Spain
  - One stationary system in which long term tests are made at the Univ. of Nitra (Slovakia)
- Tests (endurance and performance) with different gas qualities on basis of six lab scale stacks (300 W)
- Socio technical integration of biogas-FC technology in Spain and Slovakia

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EFFECTIVES gas upgrading

Biological gas upgrading

- Biological biotrickling filter, built by Profactor:
- 24 month endurance operation in Nitra, Slovakia, achieving the aim of less than 10 ppm H_2S in the outlet gas
- Capacity: 200 l/h

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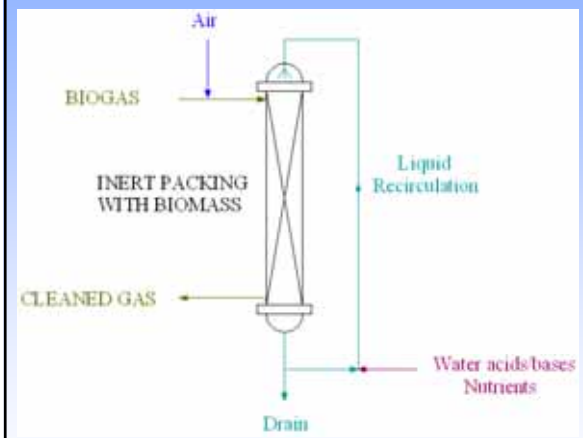
EFFECTIVES gas upgrading

Biological gas upgrading: basic concept



BASIC PROBLEMS:

- Mixture of oxygen and biogas
  safety problems
- Oxygen damage anode
  of fuel cells
- N_2 from air dilutes the biogas

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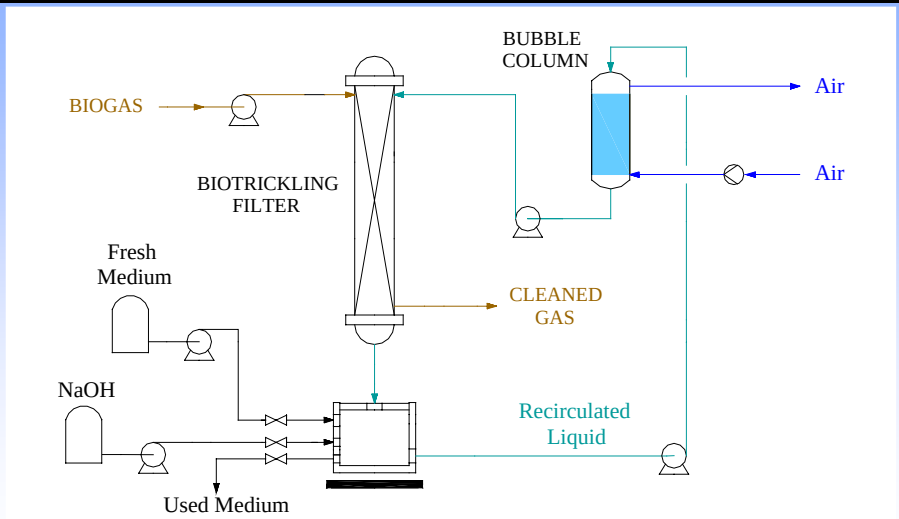
EFFECTIVES gas upgrading

Biological gas upgrading: EFFECTIVES design



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EFFECTIVES gas upgrading

Site for long term endurance tests

Foto Gadus

Foto Gadus

Biogasplant from the University of Nitra, Slovakia

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EFFECTIVES gas upgrading

Biological gas upgrading: EFFECTIVES design

Gas analytic for raw gas & cleaned gas, Micro GC for MCFC gas analytics (not on the picture)

Biotricklingfilter coupled with MCFC testbed

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EFFECTIVES gas upgrading

Chemical gas upgrading

- Chemical filter, built by Seaborne:
- 6 month endurance operation in Germnay and 2 months in Austria, also achieving the aim of less than 10 ppm H_2S in the outlet gas
- Capacity: 200 l/h

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EFFECTIVES gas upgrading

Chemical gas upgrading: test cycle in Asten

MCFC Testbed and chemical biogas filter in Asten 2003 (Austria)

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EFFECTIVE

MCFC Testbeds

Designed and constructed by MTU CFC Solutions

Right	Control Unit
Center	Operator
Left	Operation Unit

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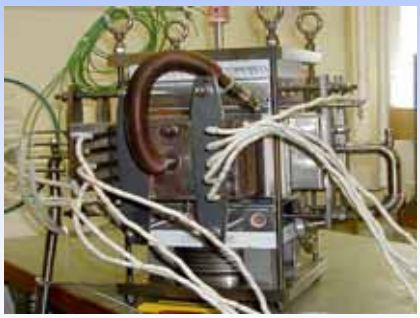
EFFECTIVE

MCFC Stack used for the project (300W)

- 300 W stack
- With 10 cells each
- Six units available for the project
- After each of the 6 test cycles the used stacks are removed and undergo a series of material analysis (CIEMAT and MTU)



EFFECTIVES 300W Stack, manufactured by MTU

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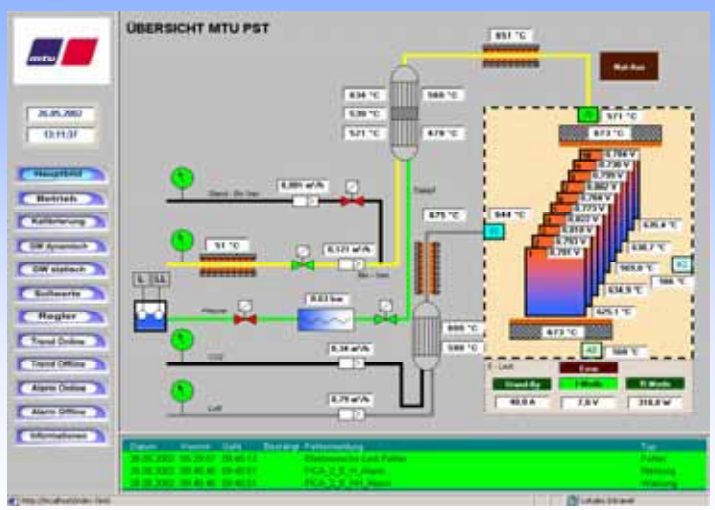
EFFECTIVE

The process of the MCFC test bed



Screenshot of control unit

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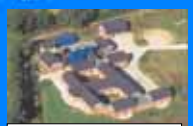
Locations for Biogas – MCFC test cycles in EFFECTIVE



Owschlag, **Germany**, 2.200 hours operation (Industrial research center, Seaborne GmbH)

Linz, **Austria**, 1.500 hours operation (Waste water treatment plant in Asten, Linz AG)

Nitra, **Slowak Republic**, 2.400 hours in operation in first cycle, over 3.300 hours in the 2nd and since Dec. 2003 ongoing cycle (Agricultural Biogas plant at Uni Nitra)

Pinto, **Spain**, Start: 2.2004 (Waste treatment plant, Urbaser)

Test locations for the EFFECTIVE Testbeds in:

- **Slovakia:** agricultural biogas
- **Germany:** industrial waste biogas
- **Austria:** waste water treatment biogas
- **Spain**: Landfill gas

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Biogas – Fuel Cell aplications

A general overview…

- In Germany: **full scale** PC25C (200 kW PAFC) in the waste water treatment plant of Köln-Rodenkirchen, achieving el. efficiencies of 39%.
- In Germany: Schmack Biogas **test scale** with 300 W MCFC testbed with agricultural biogas
- In Germany: Biogas –PEM project at the FAL institute with cofermentation gas at testing scale (~300 W)
- Also in Japan und USA demo projects have been started or are starting soon, mainly with full scale PAFC operated with waste water treatment gas

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Biogas – Fuel Cell aplications

A general overview…

•In Switzerland: SULZER Hexis operates a **full scale** 1 kW SOFC Pilot plant at an agricultural biogas plant in Lully. achieving el. efficiencies of 35%. Operating time: approx. 5.000 h

•EFFECTIVE is a project that involves also own development of gas upgrading and that gathers that large experience with different gas qualities

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Biogas – Fuel Cell aplications

Main applications:…

•Decentralised: Biogas from agricultural and industrial wastes

•Stationary energy production

•Large scale (<200kW)

•Mainly with high temperature fuel cells (MCFC & SOFC)

•Different source gases possible provided a suitable gas upgrading is available

•If mobile applications, then with stationary reforming and gas upgrading for PEM

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EFFECTIVE

Technical conclusions

- Biogas operation of MCFC without any problems (more than 11.000h operating experience)
- Challenging operation with MCFC testbed, which is delicate to changes in the surrowndings
- Thermocycling has a negative effect on the stack
- Posttest analyzes indicates no severe interaction between biogas and fuel cell system components
- MCFC electr. efficiency of over 50% achieved (Seaborne)
- Gas upgrading systems fulfilled our expectations
- NH_3 reduction by catalytic decomposition (labscale single cell experiments)

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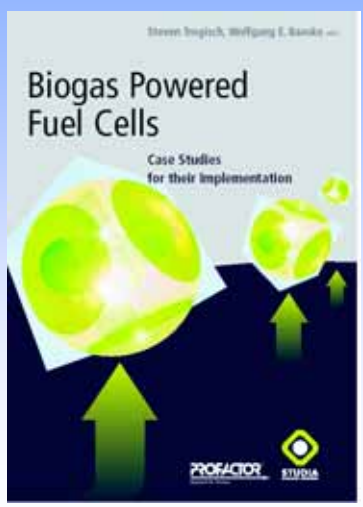
… EFFECTIVE publishes a book !



Release: June 2004.

Relevant topics in over 120 pages will be:

•Hydrogen and fuel cell perspectives for Europe

•Synergies of biogas and fuel cell application

•Marketability analysis of biogas-FC in Spain

•A quality approach for Biogas-FC in Austria, Slovakia and Spain: a site selection

More info under www.profactor.at

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