11th ERA-NET Bioenergy Joint Call / 1st add. call of BESTF3

BIO-CCHP: Advanced biomass CCHP based on gasification, SOFC and cooling machines

Project introduction

BLAZE Meeting, Rotondella, 10.10.2019

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Stefan Martini (Bioenergy 2020+)

General overview

Gernot Pongratz

TU Graz Institute of Thermal Engineering

Austria

- Graz University of Technology (TUG), Institute of Thermal Engineering Coordinator; Scientific Partner / University
- Bioenergy 2020+ GmbH (BE2020): Scientific Partner / Research organization
- SynCraft Engineering GmbH (SYC): Company partner / SME
- Hargassner Ges.mbH (HRG): Company partner / SME

Poland

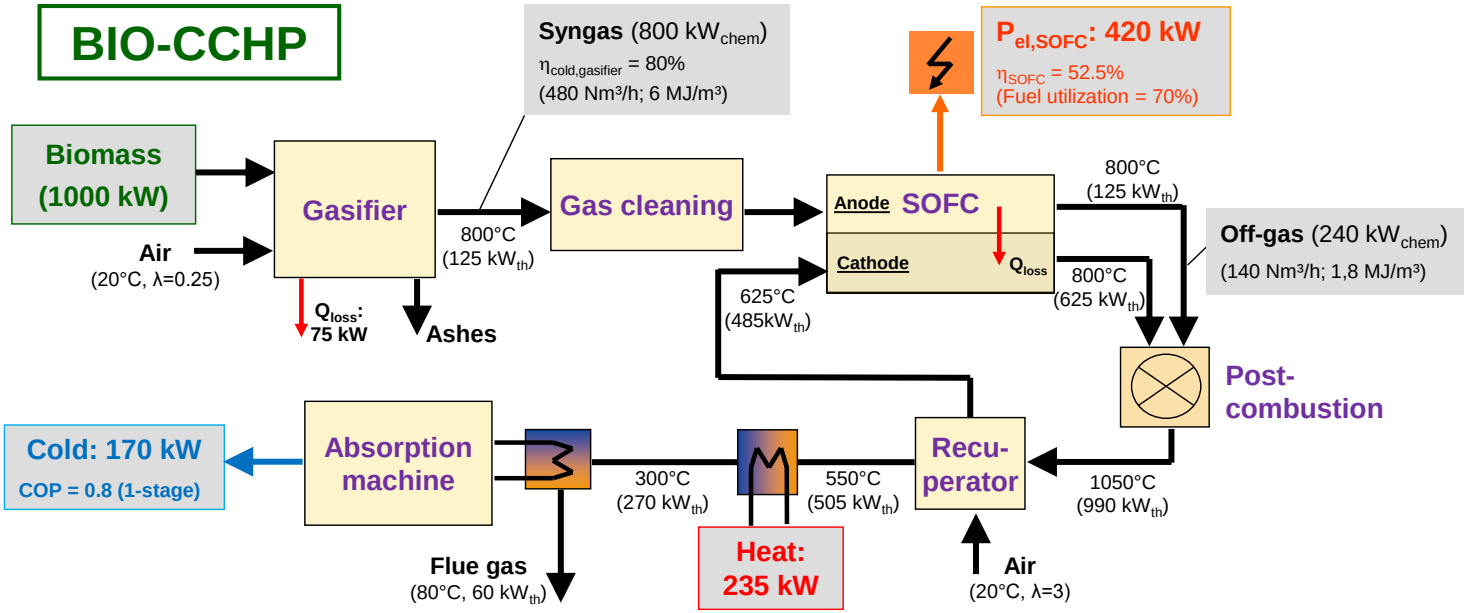
- Institute of Power Engineering (IEN): Scientific partner / Research organization
- Modern Technologies and Filtration Sp. z o.o (MTF): Company partner / SME

Sweden

- RISE Research Institutes of Sweden, Energy and Circular Economy (RISE): Scientific partner / Research organization
- Cortus Energy AB (CRT): Company partner / SME

Overall objectives of BIO-CCHP

- Development of a **novel trigeneration system**, BIO-CCHP, for production of **electricity**, **heat** and **cold** from biomass based on:
  (i) Biomass gasification reactor (ii) SOFC (iii) Absorption cooling machine
- **High flexibility** in terms of feedstock, plant size, gasification technology, load changes and demand of power (max. efficiency), heat and cold.
- **Target** electrical efficiency: **> 40%**
- Preliminary estimation of **reduction** of normalized operating **costs** (€/kWh) compared to reference biomass-CHP based on gasification**:** **approx. 30%**



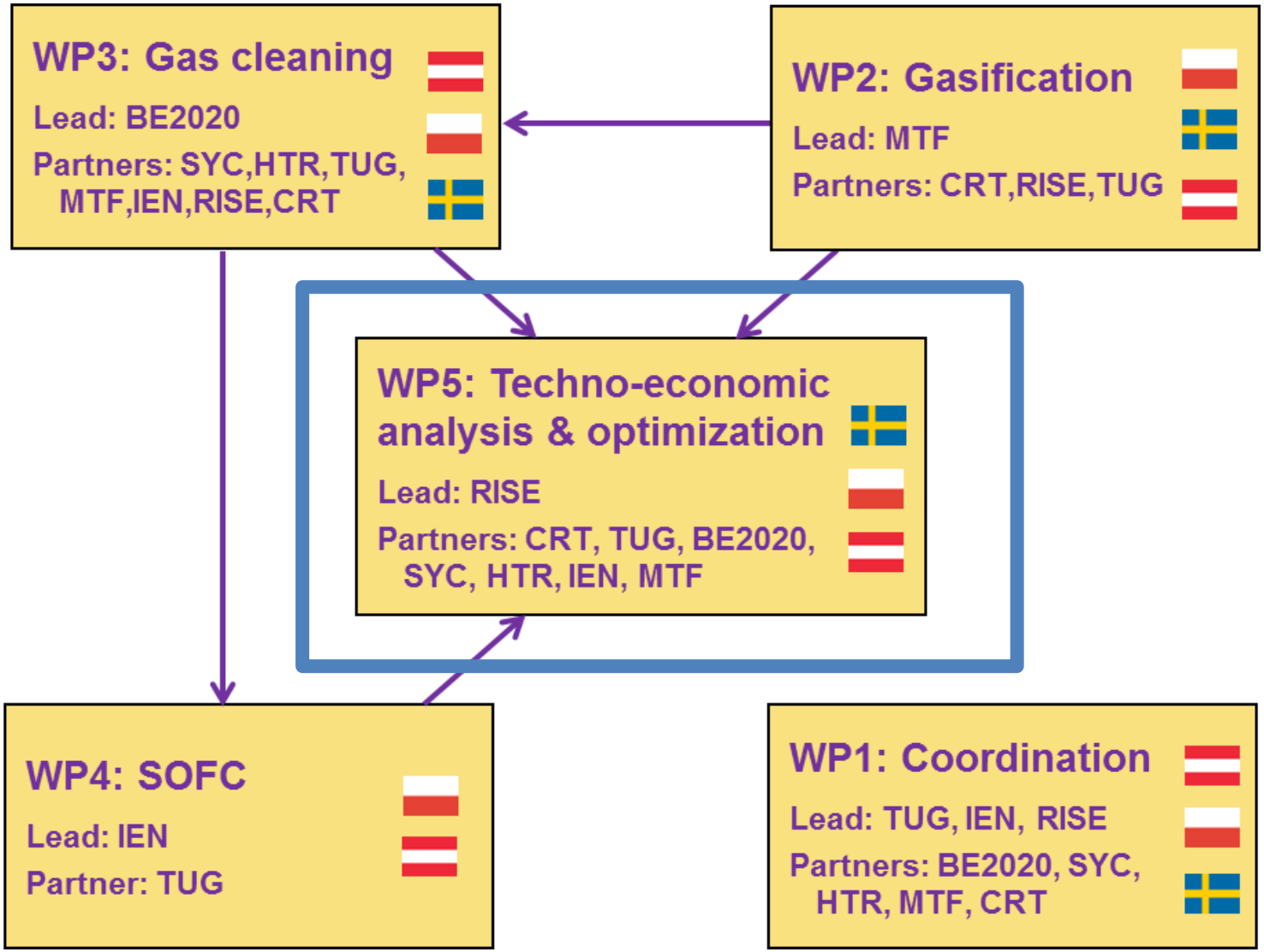
Key issues to be addressed within the project

Start: April 2018

	Y1				Y2				Y3			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
WP1: Project management												
WP2: Gasification technology												
WP3: Gas cleaning and producer gas characterization												
WP4: SOFC												
WP5: Techno-economic analysis and optimization												

- **WP2 Gasification technology:** Adaptation and enhancement of gasification technologies to optimize the coupling with a SOFC.
- **WP3 Gas cleaning and producer gas characterization:** Development of a hot gas purification process for the proposed BIO-CCHP concept
- **WP4 SOFC:** Optimization of SOFC operation based on long-term tests (> 300h) and supported by CFD simulations
- **WP5 Techno-economic analysis and optimization:** basis for an optimized integration of the chiller and an optimization of costs and efficiency of the novel CCHP technology

Interaction of work packages and partners



Analysis and optimization of the proposed BIO-CCHP, including a **comparison** to current state-of-the-art biomass CHP systems.

Evaluation

- feedstock
- gasifier type
- inclusion of a gas turbine
- absorption or compression machine
- storage systems

Discussion

- barriers for market implementation
- industrialization plan.

WP3: Gas cleaning

Stefan Martini
bioenergy2020+

Gasification technologies

	SynCraft	Hargassner	CORTUS	Institute of Power Engineering	MTF	TU Graz, IWT
Gasification technology	Staged, floating fixed bed	Fixed bed downdraft	Entrainment flow gasifier	Fixed bed, downdraft	Fixed bed, updraft	Fluidized Bed
Gasification agent	Air	Air	Steam	Air, Steam	Air, Steam+O2	Steam
Feedstock specification	Wood chips	Wood chips, pellets	Pulverized pyrolysis char	Wood chips, pellets	Wood chips, chicken feathers	Wood pellets
Nominal power (feedstock)	1 MW	0.1 MW	1 MW	0.15 MW	3.5 MW	1.5 kW
Status of plant	Commercial plant	Commercial series product	Operating in campaigns, test plant	Research facility	Commercial plant	Research facility

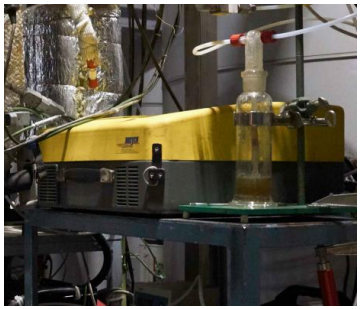
Producer gas matrix

permanent gases	*sulfur compunds*	*alkali & halogenes*	*BTXE & PAH*
H_2O	**H_2S**	HCl	**benzene**
H_2	**COS**	KCl	**toluol**
O_2	CS_2	NaCl	**xylol_o**
CO	SO_2	KOH	**xylol_m**
CO_2	**Thiophene**	NaOH	**xylol_p**
CH_4	**Benzo[b]thiophene**		**styrol**
N_2	**Dibenzothiophen**		**Naphthalin**
Ethane	Mercaptans		**AceNaphthylen**
Ethene	Thioethers		**AceNaphthen**
Acethylene	Disulfides		**Fluoren**
Propane			**Phenanthren**
Propen	***nitrogen compounds***		**Anthracen**
i-Butane	NH_3		**Fluoranthen**
n-Butane	HCN		**Pyren**

Evaluation of measurement methods

Online methods for permanent gases, inorganic compounds and BTXE

- heated FTIR-analysing system
- Micro-GC-System (CP-Sil 5 CB and a PoraPlot U column)
- Multi component gas analysing device including an infrared photometric detector (NDIR) and a thermal conductivity detector (TCD)

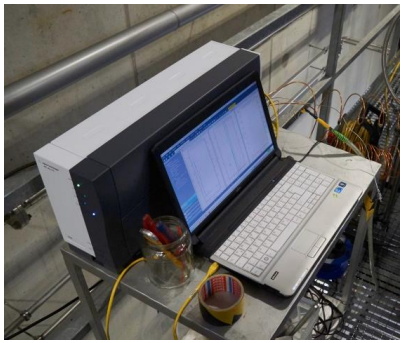


FTIR

GA

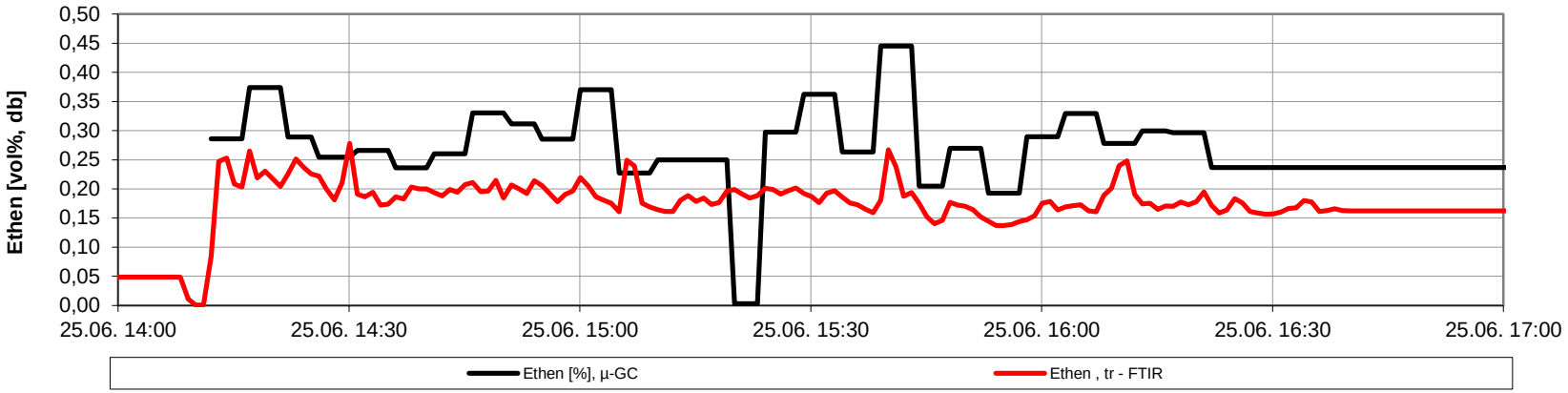
Offline methods for

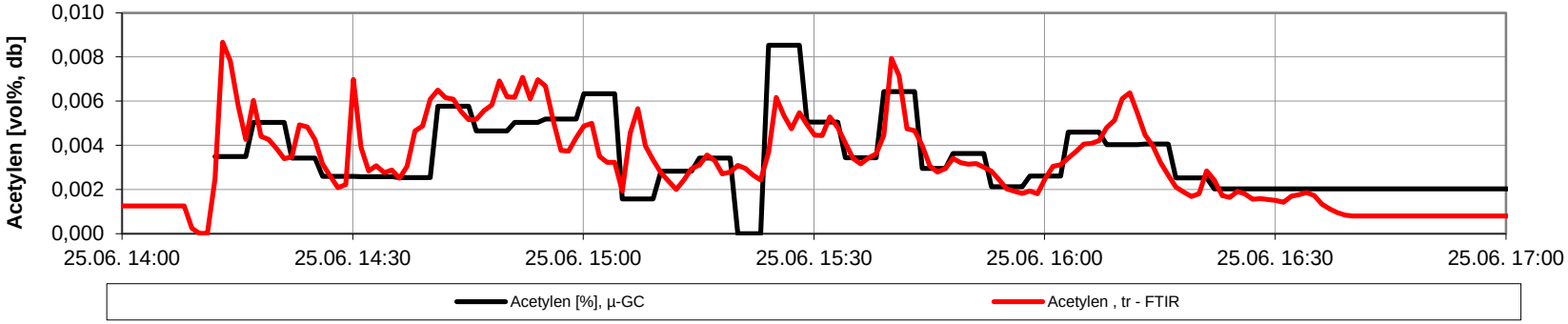
- **H_2S**, photometric & ICP-OES
- **NH_3**, photometric
- **organic sulphur** components via GC-MS
- **tar-compounds (BTXE, PAHs)** via GC-MS



Micro-GC

Evaluation of measurement: C2-compounds comparison µ-GC and FTIR

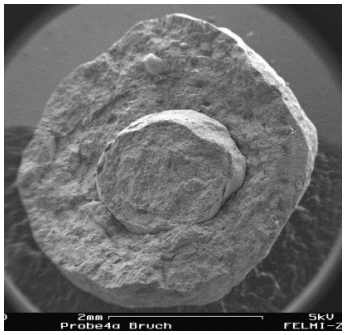




Desulphurisation tests - methodology

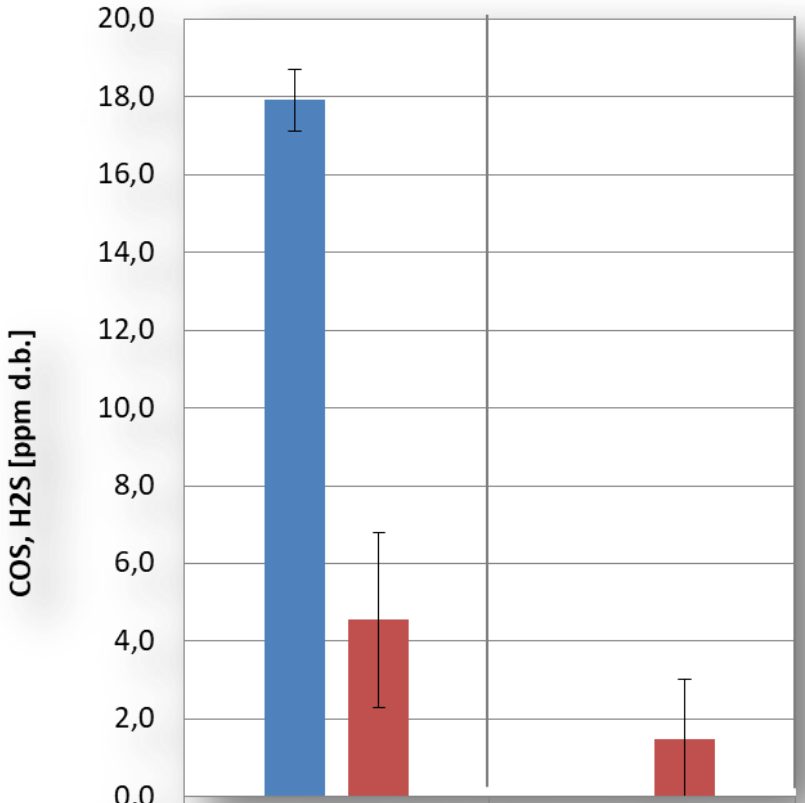
Key data desulfurization unit:

- fixed bed adsorption column of stainless steel
- diameter of 40mm
- 150mm active height
- 320 to 380 ° C, (tubular furnace, max 900° C)
- Gas volume flow 0.25 to 0.5 m³/h, usc
- ZnO-based sorbent, spherical shape 3 to 4 mm with an inactive core as support material

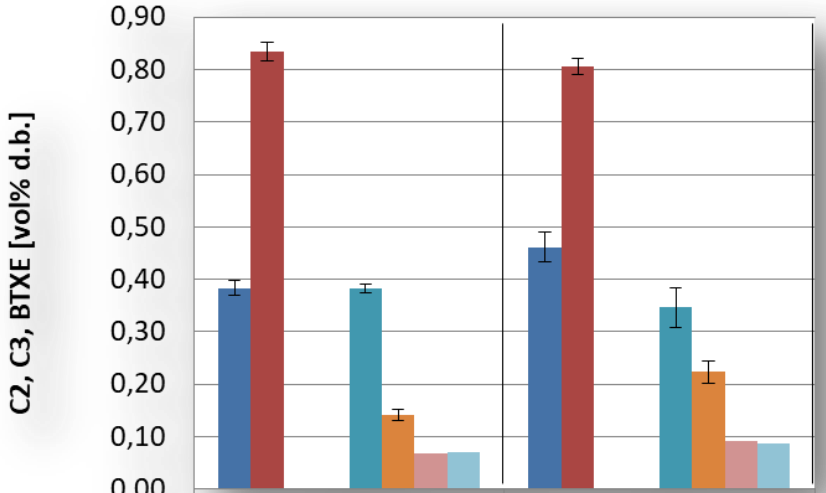


\+ good properties regarding adsorption-capacity, resistance against thermal stress and good mechanical properties.

Desulphurisation tests - exemplary results



	before desulphurisation	after desulphurisation
H2S , µ-GC	17,9	< 0,5
COS , tr - FTIR	4,558	1,473



	before desulphurisation	after desulphurisation
Ethan , tr - FTIR	0,383	0,461
Ethen , tr - FTIR	0,835	0,806
Acetylen , tr - FTIR	0,002	0,000
Propan , tr - FTIR	0,000	0,000
Propen , tr - FTIR	0,382	0,346
Benzol , tr - FTIR	0,142	0,223
Xylol-o , tr - FTIR	0,069	0,090
Styrol , tr - FTIR	0,070	0,087

WP4: SOFC

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TU Graz Institute of Thermal Engineering

Cell performance

Cell degradation

- carbon deposition
- catalyst poisoning

=f

?

Operating point

- syngas composition
- temperature
- electric load

Syngas cleaning level

- tar compounds
- sulfur compounds
- chlorine compounds
- dust

Strategy

Evaluation of relevant

- Fuel gas
- Cell type
- Impurity amounts

→ **promising configuration**

Single cell testbench

Short-term experiments

H_2, H_2O, CO, CO_2, CH_4 mixtures

→ **advantageous component ratios**

Long-term experiments

synthetic product gas

→ **operation stability**

addition of **H_2S, HCl**, Tars

→ **understanding of degradation**

impure synthetic product gas

→ **operation stability**

Mobile testbench (in progress)

Real coupling
IWT gasifier
+ gas cleaning

→ **degradation stability under „real“ conditions**

CFD simulation acceleration

Degradation model development & simulations
→ **performance as a function of degradation**

Cells used in the project

Type: **Ni/YSZ ASC SOFC**

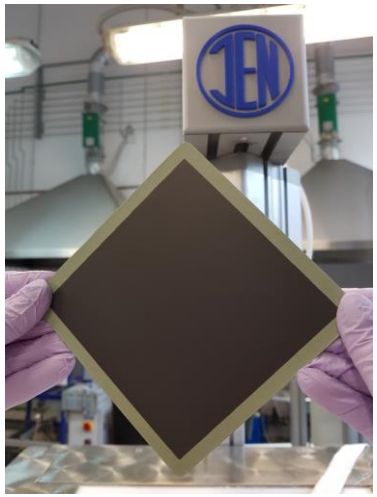
Supplier: **IEN**

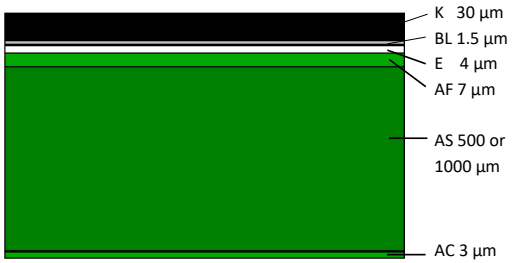
Size: 10x10cm²

\+ high H2 reactivity

\+ low cost (injection molded)

\- low contaminant tolerance





Type: **Ni/GDC ESC SOFC**

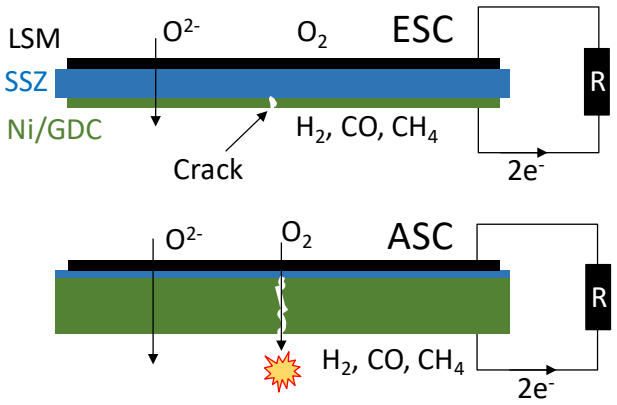
Supplier: **IKTS**

Size: 10x10cm²

\+ high contaminant tolerance

\+ better failure behaviour

\- less performance



Thank you for your attention!

www.bio-cchp.net

Key issues to be addressed within the project (1)

Technology	Current limitations	Proposed solutions in BIO-CCHP
Gasification	**Systems** are **not optimized** for SOFCs. Higher **fuel flexibility** is needed.	• **optimize operating conditions** of several gasifiers / feedstocks • **coupling** with a **SOFC**. • **switch** in an **updraft** gasifier from **air to H_2O / O_2** gasification.
Gas cleaning	**High temperature** cleaning is **not optimized**. Emissions of minor **impurities** in different gasifiers and required **cleaning methods** are **not known**.	• **Development** and optimization of a **mobile** high temperature **gas cleaning unit** with experiments at different gasifiers. • Development of **cleaning methods** for minor impurities of producer gas from **low cost biomass**. • Producer **gas characterization before / after cleaning**, including all SOFC-relevant compounds.

Key issues to be addressed within the project (2)

Technology	Current limitations	Proposed solutions in BIO-CCHP
SOFC	The **optimal operation conditions** for different producer gas compositions are **unknown**, as well as the **influence** of **minor impurities** in the **long term**	Determination, based on long term tests (>300h) and supported with a **CFD** dedicated model, of: • **Optimal** (η_{SOFC} > 40%) SOFC **process conditions** for different producer gas compositions. • **Degradation effects** caused by minor impurities: alkali metals or chlorine compounds (besides sulphur, dust and tars).
Cooling machine	**Integration** with SOFCs is **not resolved**.	To model and evaluate the required working conditions for an absorption chiller driven by the high temperature SOFC heat.