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Competence Center Energy and Mobility

WoodGas-SOFC

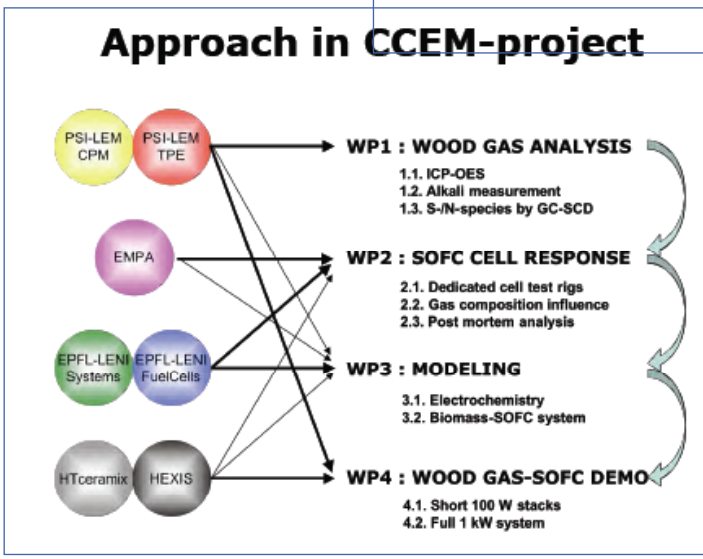
Integrated Biomass – Solid Oxide Fuel Cell Cogeneration

Scope of project

Biomass conversion, via gasification of solid fuel (wood), typically achieves 25 to 30 % electrical efficiency and 50 % thermal efficiency in engines or turbines. With high temperature fuel cells, capable of direct conversion and of thermal integration of process steps like the gasification, an electrical efficiency of up to 50 % is possible. Part of the remaining heat fraction is available at useful temperature levels for cogeneration applications. It is a particular challenge to achieve this for small scale application (< 1MWe), where biomass exploitation could be widespread.

The strategic goal is to prove the techno-economical feasibility of wood gas as representative case of a (renewable) fuel obtained by gasification fed to a temperature-compatible, emerging Combined Heat and Power (CHP) system like the solid oxide fuel cell (SOFC), and identify optimal scales of such integrated systems. The aim of the project is the development of competence (understanding) and technologies (methods, tools).

Structure of the project WoodGas-SOFC.



Goals and activities

The project is structured in 4 workpackages (WP):

- Wood gas analysis (WP1): hot process gas analysis –> insight in gasification and cleaning processes.
- SOFC cell response (WP2): electrocatalytic behavior study –> understanding of deactivation processes.
- Modeling (WP3): application of modeling tools/techniques to highly integrated multi-component system.
- Wood gas SOFC Demo (WP4): hard/software development –> calibration / validation.

Wood gas analysis (PSI)

Task 1.1 is to develop the SPECTRO multi-element diagnostic system for hot gases in order to measure elemental traces of heavy metals, alkalis, chlorine and sulphur in hot, wet, tar and particle laden process gases from wood gasification.

Task 1.2 consists of the adaptation of an alkali detector system for the hot gases from wood gasification. Both tasks are within the joined projects of swisselectric research (TREPGAS, Trace Elements in Process Gases) and Federal Office of Energy (MOPSID, Monitoring of Process Gases with a Surface Ionization Detector).

The aim of task 1.3 is the development of gas chromatography including sulphur quantification (GC-SCD) for S- and N-species measurement. Measuring sulphur and nitrogen species in hot gas is a challenge.

Main Investigator
Jan Van Herle, EPFL

Project Partners
EPFL
Empa
PSI
Hexis
HTceramix

As the gas is loaded with steam, tars and dust, dedicated sampling systems are needed to collect selectively species such as H_2S, COS, organic sulphur, NH_3 and HCN. Design of special devices for such applications is part of the CCEM glue activity.

We consider GC/SCD as the most powerful combination for such an application. Complementary, other analytical instruments such as mass spectrometry (MS) and micro gas chromatography (µGC) will be tested.

SOFC cell response (Empa)

The scope of the work at Empa is to analyse the critical inorganic components in woodgas which influence the SOFC performance.

Electrochemical tests in controlled gas atmosphere on so-called «button cells», in dedicated test rigs, will be used to derive empirical relationships, and post mortem analyses on anode catalysts performed. In this first reporting period the test rigs were ordered and received.

Modeling (EPFL)

EPFL-Systems considers thermo-environomic modelling of a complete unit comprising wood gasification, cleaning and feeding to a SOFC. In this reporting period, first steps (data reconciliation, parameter identification, gasifier models) were to be started.

Wood gas SOFC demo (PSI)

Wood gas operation of 1 kWel SOFC System: for each project year minimum one long duration campaign is planned. At the beginning the setup consists of an updraft gasifier, cyclone and catalytic partial oxidation (CPO) with a wood pellet throughput of 1 to 3 kg/h. At 1 kg/h pellet the full stream of the generated gas is directly fed to the HEXIS fuel cell. Tests are planned primarily on a system stack scale, not on button cell or mini-stack. The setup is subject to further improvements, i.e. in taking slipstream for different test systems such as HTceramix or Siemens and gas processing (CPO, desulphurisation, methanation).

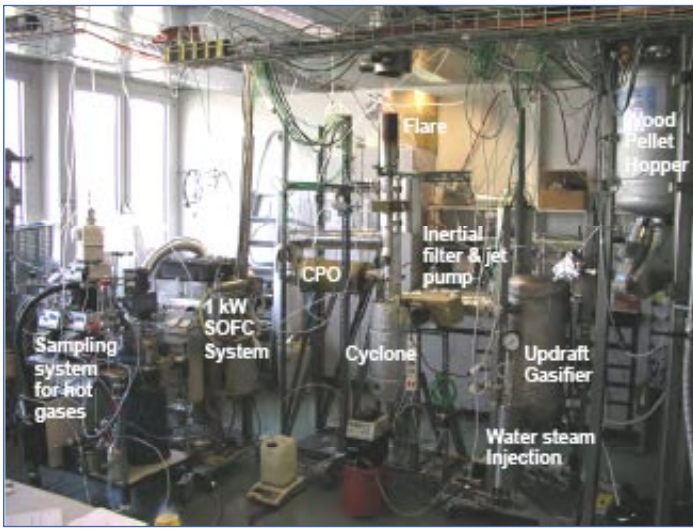
Main scientific results of workgroups

PSI–CPM

A measuring campaign was conducted at the wood power station at Kleindöttingen (CH), and another one at Wila's wood gasification plant (CH) was taken into schedule. The calibration method was developed. Now it is possible to either quantify all relevant elements from the gaseous sampling line with a standardisation procedure or with an addition method.

The mobile SPECTRO Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES) system was developed and adapted for gas measurements with a newly developed universal interface for process gas introduction to the plasma. A 32 m long flexible heated sampling line was built and used for sampling process gases from the wood power station at Kleindöttingen. 32 elements were monitored on-line at 3 different points in the exhaust gas (after boiler, before catalyst, after catalyst). Traces of Ca, Cu, Fe, K, Na, P, Pb, S, Si, Zn were detected after boiler. Detailed analysis of the first field measurements is ongoing.

The experiences of these field measurements are very important for further development of the system. Improvements of the flow measuring system, preventing condensation, need of better control and analysing software are some of the lessons learnt.



Setup for woodgas production and long term testing.

PSI–TPE

Focus in the development of measurement techniques (task 1.3) was put on sulphur species

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as this knowledge is critical for the selection of SOFC systems and appropriated desulphurisation technologies. Next step is the adaptation of the basis sampling system to the Woodgas-SOFC application, i.e. sampling of raw gas at 600°C, highly tar loaded.

For the wood gas operation of a 1 kWe SOFC System several adaptations have been realised on the feeding system, gasifier internal and cyclone. A slip stream system has been designed and built up.

Empa–HLK

As dedicated test rigs for WP2, the established «Probostat™» product from NorECs (Norway) was selected and ordered, delivery of both units followed to Empa in November. From there one unit was shipped to EPFL in December.

EPFL–Systems/Fuel Cells

For the test unit (WP2) a new hood has been installed at EPFL for the button cell experiments. It remains to be equipped with necessary gas lines, which will take place in Jan-Feb 2008 during set-up of the test rig in parallel. Special care is required for feeding trace compounds, for which advice from the Energy research Centre of the Netherlands was sought, where a similar arrangement has been built up.

In collaboration with the Tokyo Institute of Technology, a model of tar production in gasification processes has been developed. This study addressed the thermo economic assessment of a mid-scale (20 MWth, wood) wood gasification, gas cleaning and energy conversion process, with particular attention given to electricity generation costs and tar control.

The model has been integrated with gasification models and integrated with conventional power production cycles (gas turbine and gas engines). This model will serve as a basis for the future models to be considered for integration with a SOFC.

After validation, the model will be used in an optimisation framework to generate optimal design. The first analysis shows that optimal cogeneration schemes will be mandatory to increase the efficiency of the system.

Publications

- T. Kowalski: Evaluating a Surface Ionsisation Detector for Measuring Alkalies in Biomass Gasification, Diss. ETH Nr. 17067, 2007.
- T. Kowalski, Chr. Ludwig, A. Wokaun: Qualitative Evaluation of Alkali Release during the Pyrolysis of Biomass, Energy & Fuels 2007, 21, 3017–3022.
- «Methodology for the optimal thermo-economic, multi-objective design of thermochemical fuel production from biomass». Gassner, Martin ; Maréchal, François, submitted to Computers and Chemical engineering, 2007.
- «Thermo economic analysis for the optimal conceptual design of biomass gasification energy conversion systems», Brown, David ; Gassner, Martin ; Fuchino, Tetsuo ; Maréchal, François, accepted for Applied Thermal Engineering.
- «A methodology for thermo-economic modeling and optimization of solid oxide fuel cell systems», Palazzi, Francesca ; Autissier, Nordahl ; Marechal, François ; Favrat, Daniel In: Applied Thermal Engineering, vol. 27, num. 16, 2007, p. 2703–2712.

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