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Thermo-economic and experimental investigation of small to medium-scale integrated biomass gasification solid oxide fuel cell systems

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1. Introduction

High temperature fuel cells, such as solid oxide fuel cells (SOFC) are amongst the most efficient devices for conversion of gaseous fuels to electricity. At the same time biomass is one of few renewable energy sources which can, in contrast to wind and solar energy, be used in a reliable fashion, and even to balance other non-reliable renewables. Thus, combining biomass with SOFC by means of gasification offers a highly efficient, reliable way of producing electricity without net CO_2 emissions. In combination with carbon capture and storage or usage (CCS/U) even a negative CO_2 balance is possible.

2. Experimental investigation

Thus in the frame of the FCH-JU project SOFCOM contaminant limits for integrated biomass gasification SOFC systems are studied experimentally by means of single cell testing with contaminant loaded gases. The main focus of the research is the effect of tar compounds on SOFC anodes, especially different tar classes present in bio-syngas.

Experimental investigation is carried out using a FUELCON Evaluator C1000-HT SOFC test station in combination with a tar mixing station. The tar mixing station is capable of supplying variable mixtures of tars in different concentrations. Typical concentrations are shown in Table 1.

Table 1. Tar concentrations in g/Nm³.

Tar compounds	Typical concentration	Maximum concentration
Phenol	1.19	5
Toluene	1.50	5
Naphthalene	1.79	5
Flouranthene	0.11	0.25

3. Thermo-economic evaluation

Complementary to the experimental investigation concepts are studied in thermo-economic simulations with the aim to achieve higher system efficiency, increased flexibility, heat recovery and lower costs.

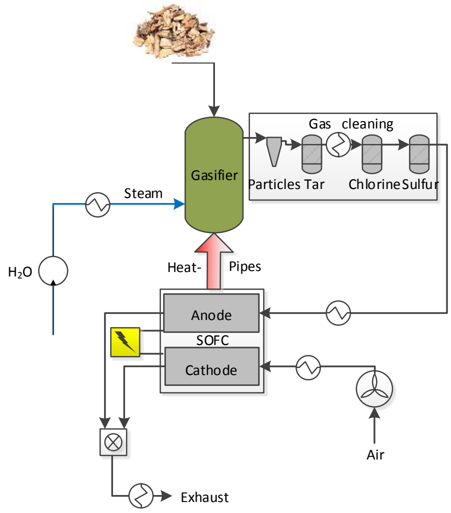

Figure 1. Integrated SOFC heat-pipe reformer system

This is achieved by rigorous heat and material stream integration. One system example is shown in Figure 1, where an SOFC is thermally integrated with a gasifier by means of heat pipes. The investigations are carried out using a combination of ASPEN Plus and the Matlab based optimization algorithm OSMOSE, which has been developed by the Ecole Polytechnique Lausanne [1].

4. Thermo-economic results

For an $8MW_{th}$ feedstock system analogous to the scheme shown in Figure 1 the resulting optimized heat integration curve is shown in Figure 2.

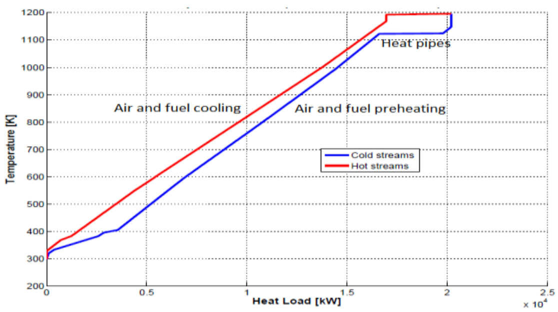

Figure 2. Q-T diagram for integrated system

As can be seen from the figure almost all available heat is used. Due to the optimized heat integration the electrical efficiency of the system rises to 49.5% based on LHV of the feedstock.

However, the specific investment costs of the systems under study do not yet fulfil the constraint of economic viability. The specific investment costs are still as high as 15925 $\$/kW_{el}$, mainly because of the very high cost for the SOFC. Thus, not even at high subsidy rates, for example around 14ct/kWh for biomass based electricity in Germany [2], the systems can be operated commercially.

5. Conclusions

Based on the observations in this study it can be concluded that combined gasification SOFC systems are a promising technology for highly efficient conversion of biomass to electricity. However, the technology is not yet mature enough for commercial operation.

6. References

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[2] Bundesministerium für Umwelt. Naturschutz und Reaktorsicherheit: Vergütungssätze. Degression und Berechnungsbeispiele nach dem neuen Erneuerbare-Energien-Gesetz (EEG) vom 04. August 2011 (‚EEG 2012'). Available September 24th 2013 from: http://www.bmu.de/fileadmin/bmu-import/files/pdfs/allgemein/application/pdf/eeg_2012_verguetungsdegression_bf.pdf