Development of a novel highly efficient energy supply system
for energy autonomous multi-family buildings
based on biomass gasification coupled with an SOFC and a PV system

Operation of a SOFC with MK35x stacks within a biomass micro-CHP system based on wood pellet gasification

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Outline

- Motivation
- System concept
- Stack tests
- Stack module development
- System operation
- Restart at IKTS
- Conclusion and outlook

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Motivation

Motivation and objective

- Development of an innovative system for heat and electricity supply based on renewable energy sources for an almost energy autonomous multi-family building
- Technology based on updraft gasifier, gas cleaning system and SOFC combined with a PV system and energy storage solutions
- SOFC nominal gross capacity of about 2.5 kW_{el}
- 55% to 65% reduced NO_x emissions compared to other biomass CHP technologies
- Contribution to reaching the EU climate and clean air goals

Micro-Bio-CHP plant at site of project coordinator BIOS in Graz

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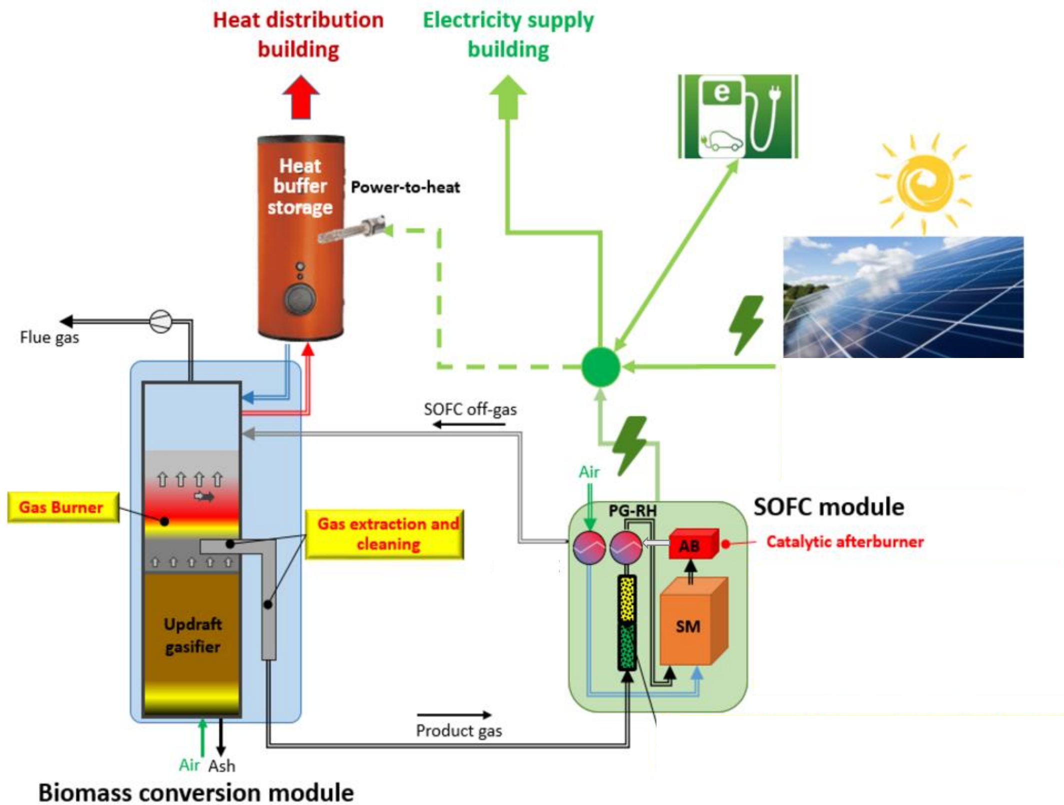
System concept

Micro-Bio-CHP concept

- 15 kW fixed-bed updraft gasifier operated with humidified air, product gas partly burned in a gas burner
- Remaining product gas passing through combustion chamber, followed by a catalytic tar reformer
- High temperature particle filter for soot precipitation and HCl/H_2S-removal reactor integrated in the SOFC system housing
- Cleaned product gas passes through the SOFC system for electricity production
- Hot off gases from the SOFC-system returned to the biomass conversion module for heat recovery
- Achievable stack efficiency shall be up to 44%



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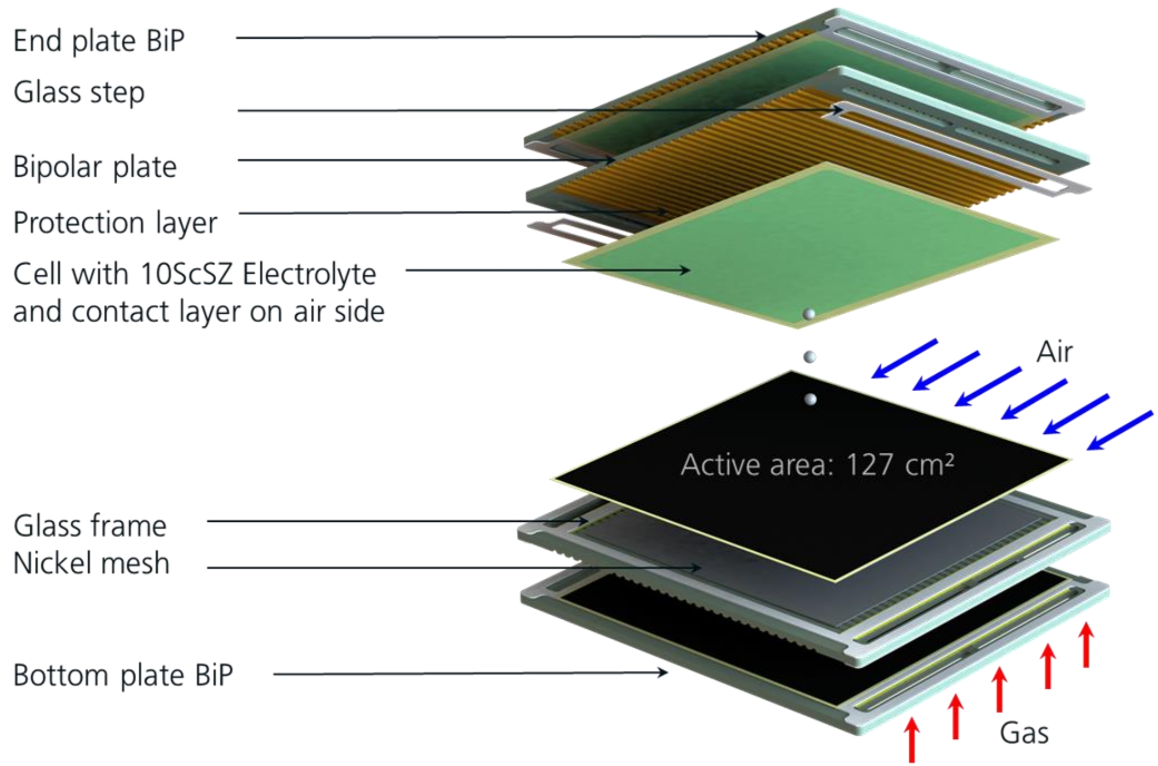
Stack tests

Performance tests

- Variation of different model product gas compositions
- Endurance test with a single 10-layer stack

Benzene contamination test

- 300 ppm Benzene, 500 h



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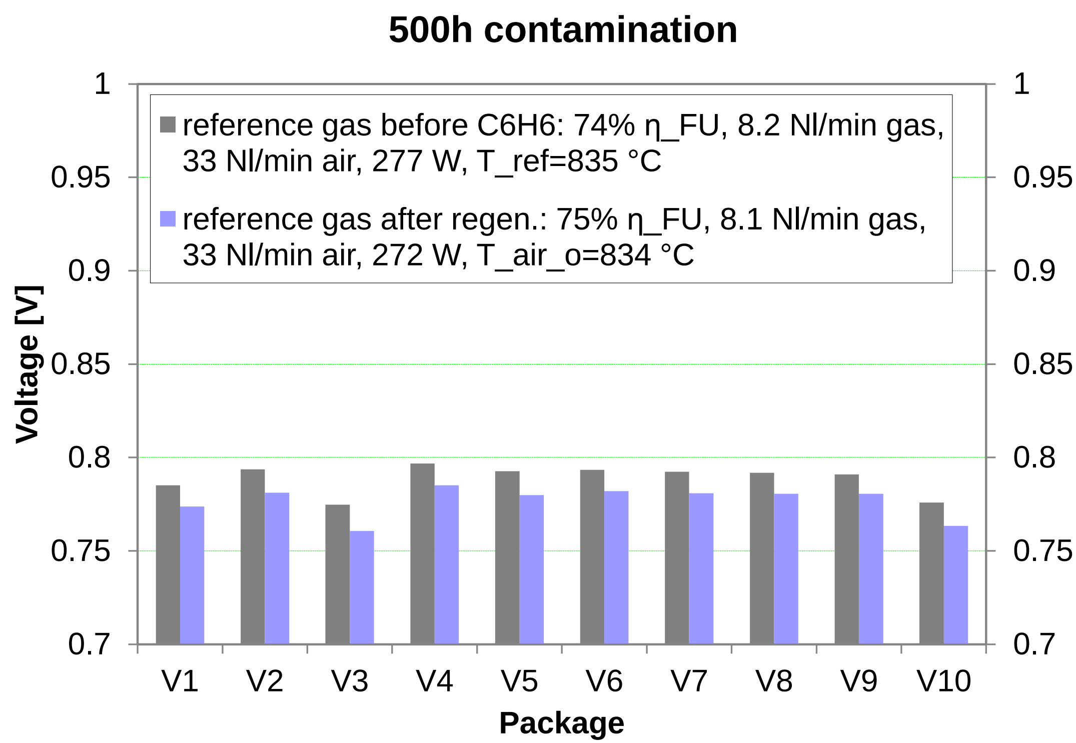
Stack tests

Degradation due to Benzene contamination

- Calculation of degradation with reference gas (40% H_2 in N_2) applied before and after contamination test
- 5 W power loss
  → $\Delta P/P_0$ = 2.2%/1000h
- Degradation during endurance test $\Delta P/P_0$=1.2%/1000 h
  → Benzene contamination leads to 1% additional degradation per 1000h
- Degradation has to be reduced for economic efficiency



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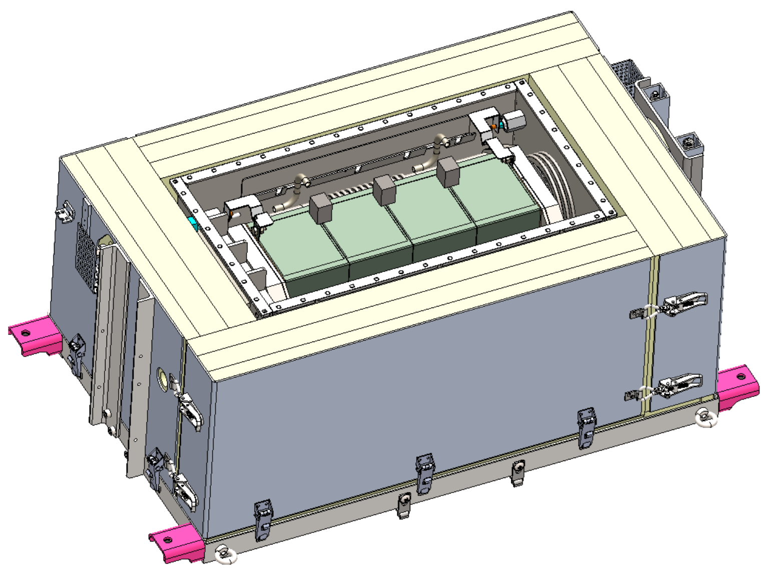
Stack module development

Stack module set up

- Tower of three 40-layer stacks, 120 layers in total
- 6 package voltages with 20 cells each and single cell monitoring
- Thermocouples measuring air and product gas temperatures, pressure sensing
- Insulated with a microporous material



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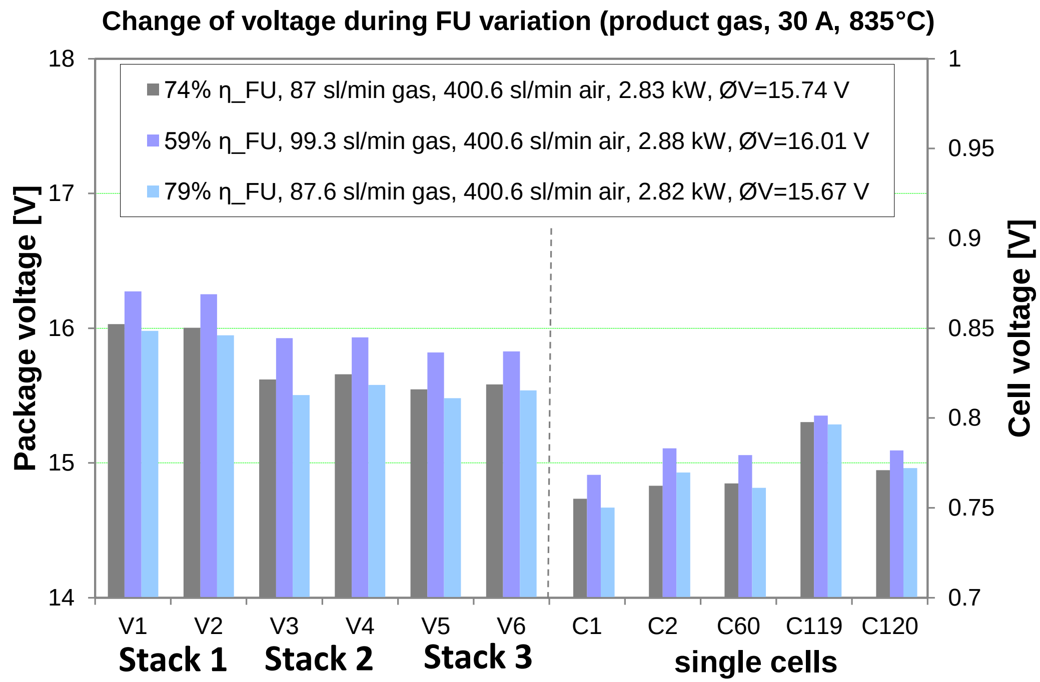
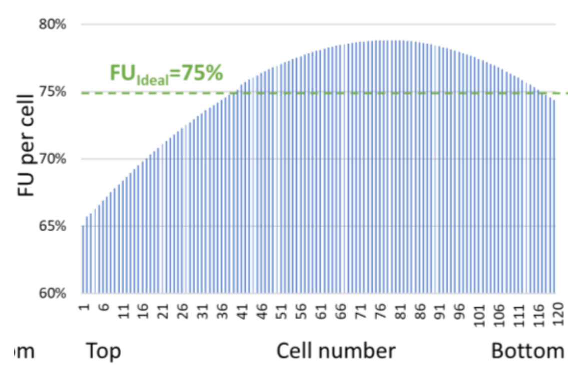
Stack module development

Commissioning tests – product gas

- Product gas at 30 A (full load), air: 400 Nl/min, η_{FU} = varia, T_{ref} = 835°C, P_{el} = 2.8 kW_{el} @ 74% FU
- Higher voltages at V1 and V2 indicate a better flow distribution at this stack (see simulation)
- Centre of the stack tower gets lower product gas flow rates compared to the outer layers which leads to locally higher FU
  → Maximum FU of 75% and separate monitoring of cell 60 during operation
- Power output sufficient for CHP plant





	Product gas
CO	12.7 %
H_2	29.9 %
H_2O	29.4 %
CO_2	11.6 %
CH_4	0 %
N_2	16.4 %

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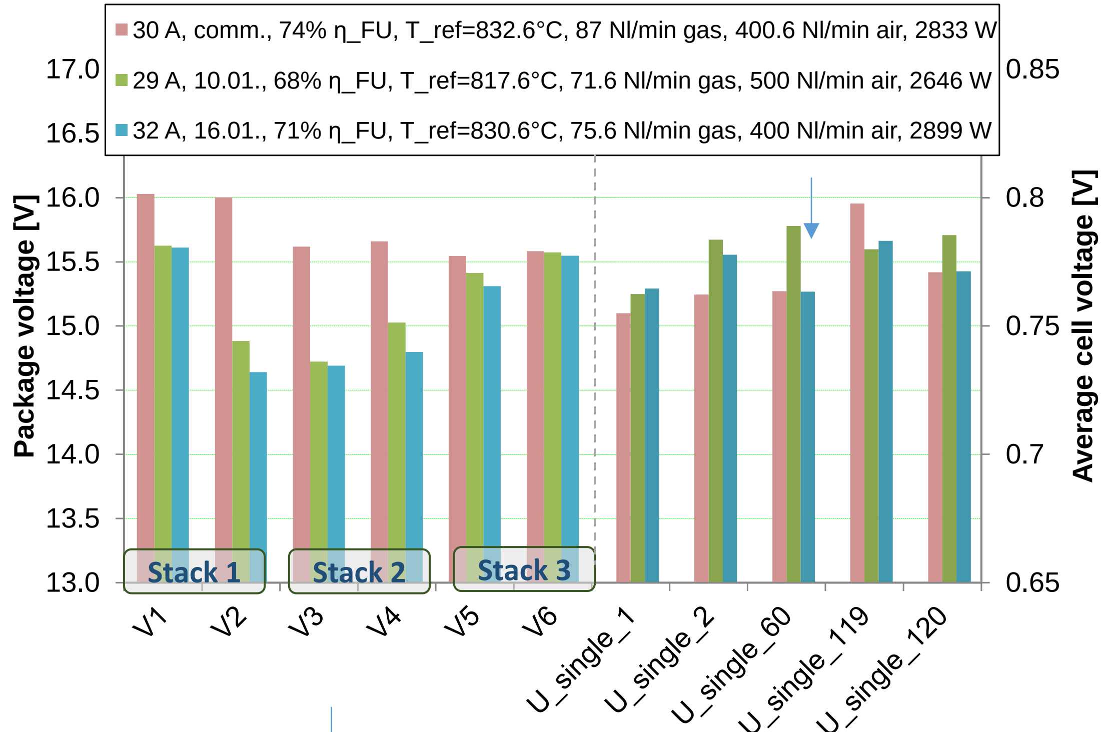
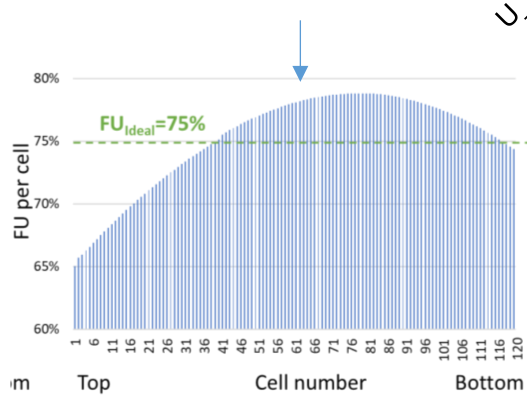
System operation

Test runs – January

- System operation $\eta_{el\text{-}DC\text{-}Stack}$ = 40%, P_{el} = 2.9 kW_{el}
- Different gas composition than commissioning tests (synthetic gas)
- Voltages 2, 3, 4 with lower performance (degradation due to damage in initial system operation)
- Average cell voltage V2-V4 lower than edge single cells
  →leakage assumed (improper compression vs internal leakage)
  →no fuel starvation (according to simulation)
- Successful system operation over 400 h for several testing phases





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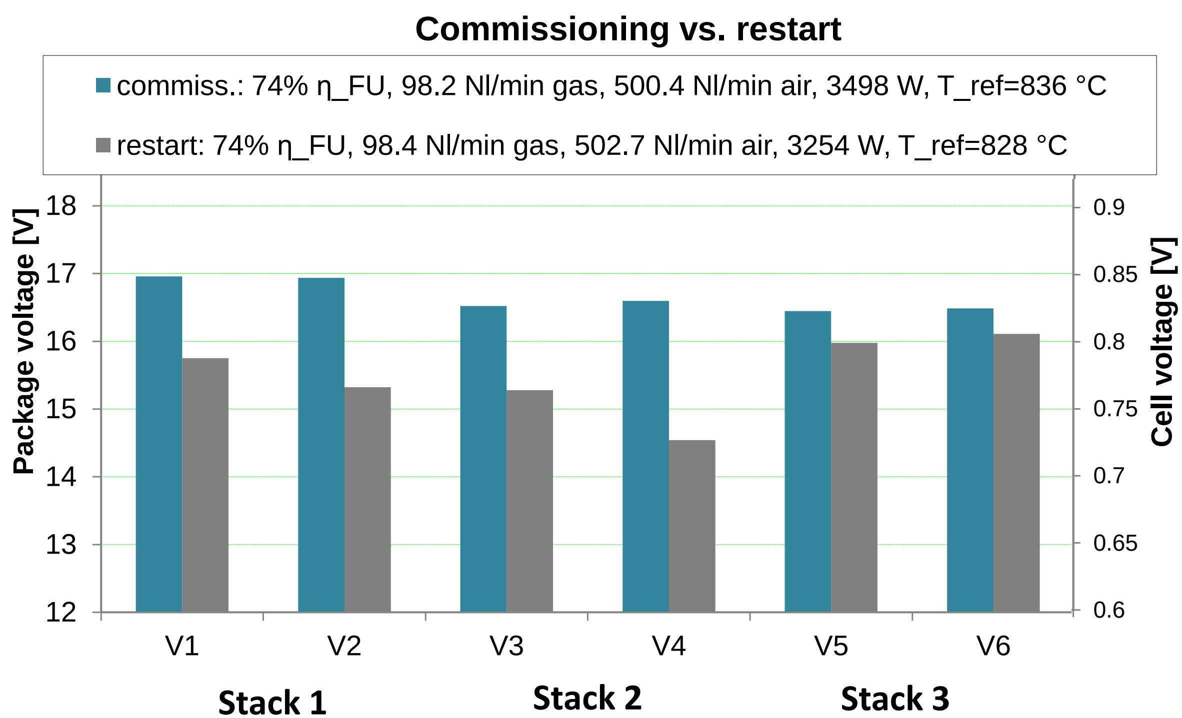
Restart at IKTS

Test with reference gas

- P_{el} = 3.25 kW_{el} at 35A, FU = 75%
  40% H_2 in N_2
- Degradation after 400 operating hours especially in Stack 1 and 2 due to initial system operation
- Leakage was detected in fuel path at sealing to adapter plate
- Stack 3 with low degradation



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Conclusion and outlook

Contamination tests

- Benzene contamination leads to 1% additional degradation per 1000h at a concentration of 300 ppm
- Last gas analysis in CHP plant: 200 ppm Benzene in product gas → degradation caused by Benzene needs to be reduced for improved economic efficiency

System operation and causes of degradation

- Testing plant shows stable operating behavior and runs close to the design target concerning electric efficiency and power output
- Degradation while initial commissioning at CHP-plant
  → will be reduced with optimized system operation

Outlook

- Post-mortem analysis of the used stacks
- Commissioning of a new stack module with improved tightness
- Optimization of automated system operation

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Thank you for your attention!

Contact

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