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

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Introduction and objectives

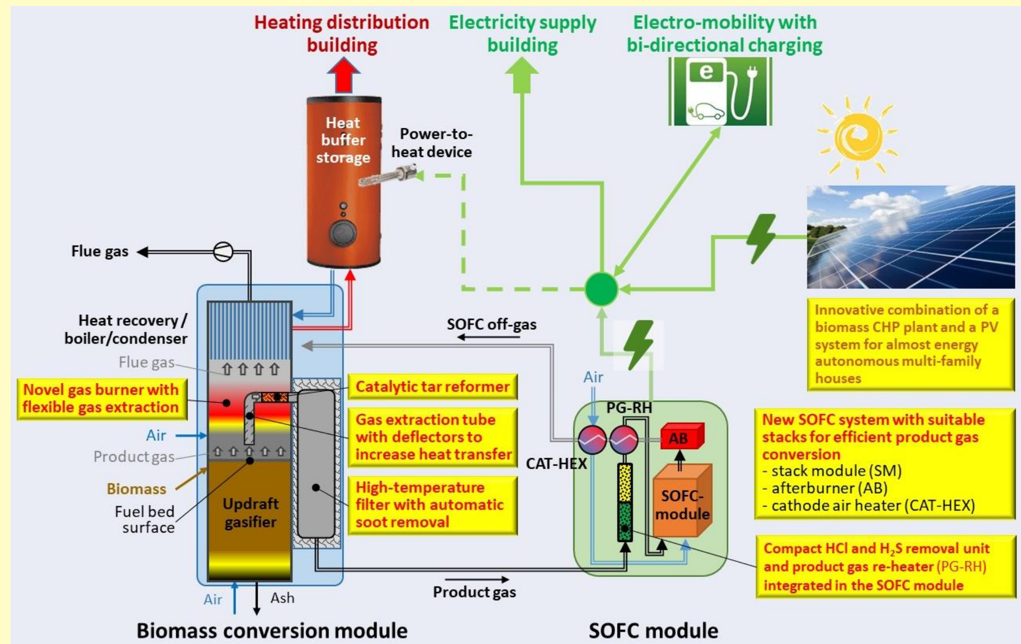
- The project aims at the development of an innovative system for heat and electricity supply to achieve an almost energy autonomous multi-family building.
- The system is based on the combination of a biomass CHP plant, a PV system and appropriate heat and electricity storage technologies.
- Novel biomass CHP system based on pellets updraft gasification with dual product gas utilization:
  - Direct combustion for flexible heat generation
  - As fuel in a solid oxide fuel cell (SOFC) for electricity and heat generation

Approach

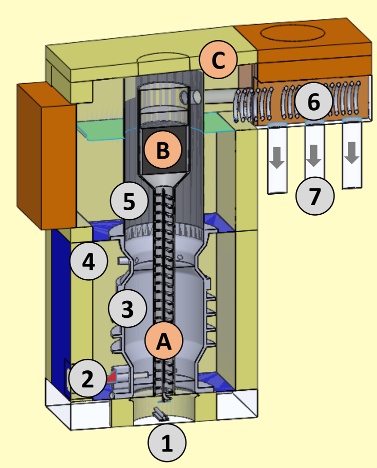
- 15 kW (fuel power related to the NCV) fixed-bed updraft gasifier operated with humidified air.
- A part of the product gas is burned in a gas burner.
- The remaining product gas is extracted through a pipe passing through the combustion chamber and is heated-up to 950°C to facilitate thermal tar reforming followed by a catalytic tar reformer operating at about 900°C.
- High-temperature particle filter for soot precipitation and HCl/H_2S-removal reactor (dry sorption reactor).
- The cleaned product gas passes through the SOFC system for electricity production. The achievable stack efficiency shall be up to 44% (related to the NCV of the product gas).
- Hot off-gases from the SOFC-system are returned to the biomass conversion module for heat recovery. The overall efficiency of the CHP system shall be close to 90% (related to the NCV of the fuel).

Current status

- A first testing plant with a fuel power of 15 kW has been designed and constructed.
- Commissioning tests with the gasifier, the gas burner and the product gas extraction system as well as with the stack module have successfully been performed.
- Test runs with the testing plant will start in July 2024.



Basic scheme of the Micro-Bio-CHP concept



Flue gas pathway
1. Gasifier bed surface
2. Secondary air nozzles
3. Secondary combustion zone
4. Tertiary air nozzles
5. Tertiary combustion zone
6. Evaporator coils (steam production for primary air and product gas humidification)
7. Inlet to convective heat exchanger

Product gas extraction for utilisation in the SOFC module

A Product gas extraction pipe including the thermal tar reforming section

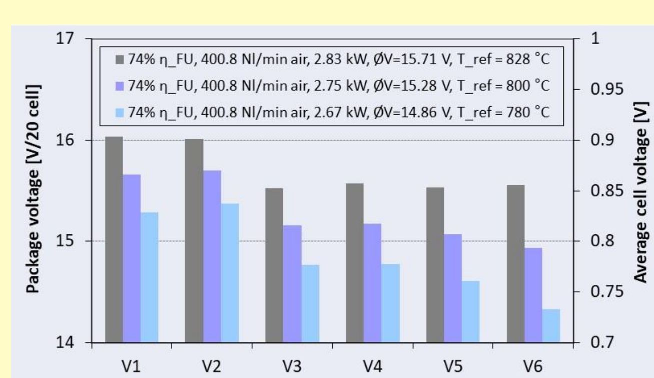
B Catalytic tar reformer (CTR)

C Product gas exit to the high-temperature particle filer

Biomass conversion module with staged gas burner and product gas extraction with integrated tar reforming

		At extraction pipe inlet	Upstream CTR	Downstream CTR	Downstream particle filter
CH_4	[vol% w.b.]	1 – 1.5	3.14	0.23	0.41
CO_2	[vol% w.b.]	7 – 8	7.66	10.99	11.28
CO	[vol% w.b.]	8 – 11	15.82	16.69	16.05
H_2O	[vol% w.b.]	44 – 47	37.74	23.04	23.04
H_2	[vol% w.b.]	8 – 10	9.52	28.15	28.97
N_2	[vol% w.b.]	18 - 20	23.80	20.81	20.08
Dust content	[mg/Nm³ d.b.]	n.d.	21.3	5.4	0.3
Gravimetric tars	[g/Nm³ d.b.]	100	1.28	0.34	0.23
NCV	[kJ/kg w.b]	5.20	5.19	5.94	6.01

Product gas compositions determined during commissioning tests
(d.b. … dry basis, w.b. … wet basis, n.d. … no data available)



Package voltages of the SOFC stack unit at different air outlet temperatures

Explanations:
Test stand operation with simulated product gas
η_FU: fuel utilization
V1-V6: cell package number
T_ref: air outlet temperature

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µ BIO CHP