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Burner Development for the Utilization of Low Calorific Value Waste Gas for Biogas to Hydrogen Processes

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Motivation

- Sustainable and decentralized H_2 production from Biogas, employing Oxidative Steam Reforming and Water-Gas-Shift
- Process efficiency of 80% (HHV-basis)
  - KIT-task: Waste Gas enthalpy valorization

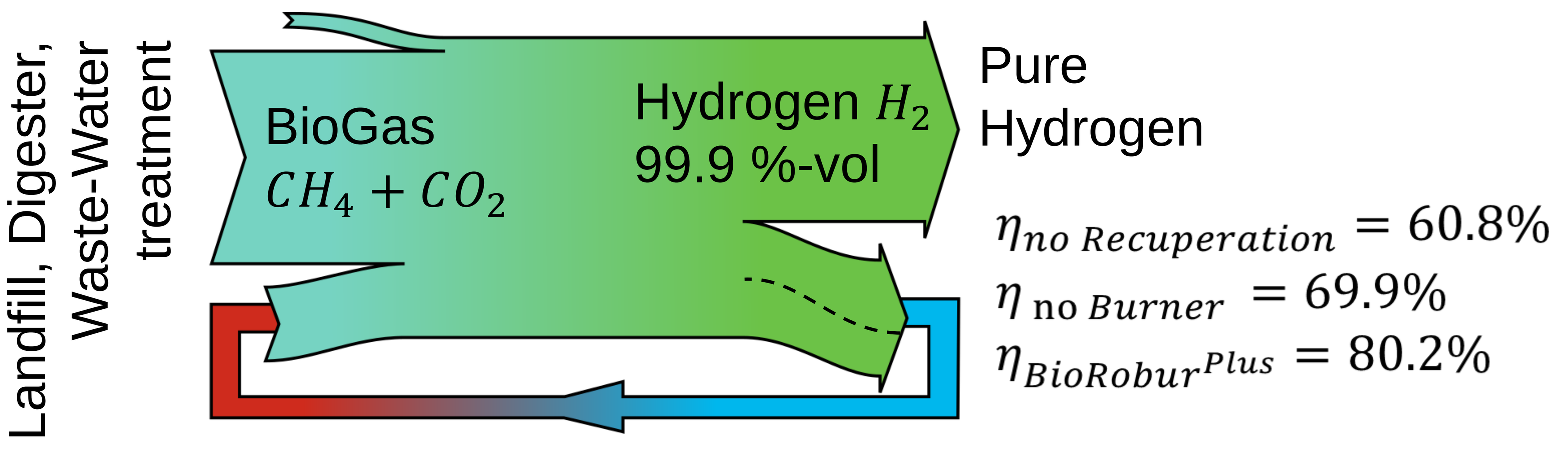

Figure 1: Qualitative Process Enthalpy flow scheme

Challenges

- Waste Gas (varying fuel composition)
  - Low heating value
  - Low content of combustible components
  - High pre-heating temperature (550°C)
  - High laminar burning velocity
- BioGas (entirely different fuel)

Table 1: Fuel compositions and lower heating values (LHV)

%-vol	CO_2	CH_4	H_2	LHV (MJ/kg)
WasteGas	70.4	1.2	20.9	2
BioGas	40	60	–	18

Approach: Porous Burner

- Flame zone within porous inert medium (PIM)
  - Robust flame stabilization in PIM
  - Solid body radiation
  - High effective burning velocities S_{eff}
  - Low pollutant emissions

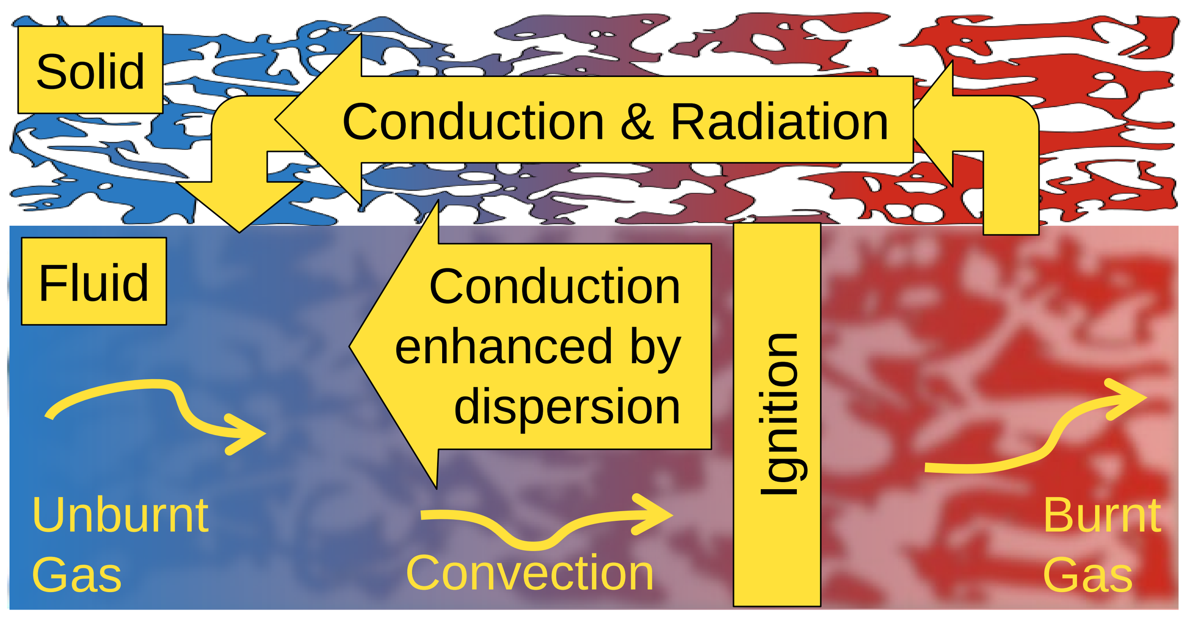

Figure 2: Schematic illustration of upstream heat transport in porous media; adapted from [1]

Methods

Preliminary calculations

- 1-D Flame calculations based on PREMIX [2]
  - Additional energy balance for solid phase
    - Effective conductivity including radiation
  - Correlations accounting for Fluid-PIM interaction [3]
    - Heat transfer: $Nu_V = a + b \cdot Pr^c \cdot Re^d$
    - Dispersion: $\Phi_{eff} = \Phi_M \cdot \left(1 + \frac{Pe}{K_{ax}}\right)$
  - Accounting for variable cross-section area
- Detailed Chemistry Simulations based on GRI3.0 Mechanism [4]

Results

- Calculations for 10 PPI SiSiC foam $\left(d_{pore} \approx 5\ mm\right)$
- Specific surface $A_s = 500\ m^{-1}$
- Porosity $\epsilon = 90\%$
- $d_{Pe} = 0.6\ mm;\ \ K_{ax} = 0.55$
- $a = 0.3; b = \frac{2}{3}; c = \frac{1}{3}; d = \frac{1}{2}$

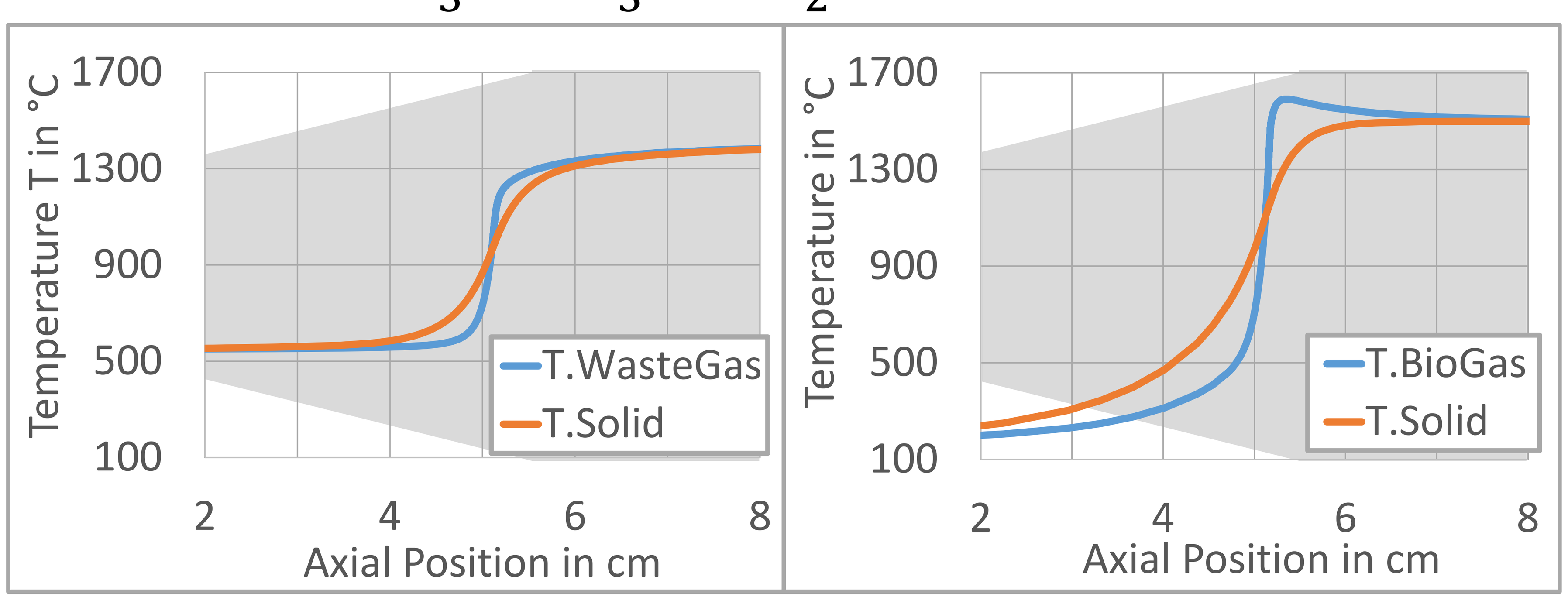

Figure 3: Calculated, adiabatic 1D temperature profiles in solid / fluid phase
Left: WasteGas: $\Phi = 0.833; T_{in} = 550°C$; 10 PPI random foam
Right: BioGas: $\Phi = 0.588; T_{in} = 180°C$; 10 PPI random foam

- $S_{eff}(WasteGas) = 14.2\ \frac{m}{s}$ $\left[S_L(WG) = 1.15\ \frac{m}{s}\right]$
- $S_{eff}(BioGas) = 0.99\ \frac{m}{s}$ $\left[S_L(BG) = 0.16\ \frac{m}{s}\right]$

Burner Design

- Diffusor shaped conical porous burner
- Kinematic flame stabilization:

$$u_{Gas} = S_{eff}$$

- Operation with different fuels
- Operation with blends of these fuels
- Wide range of power modulation
- Burner Dimensions:

$$d_{in} = 12\ mm; d_{out} = 120\ mm; L = 150\ mm$$

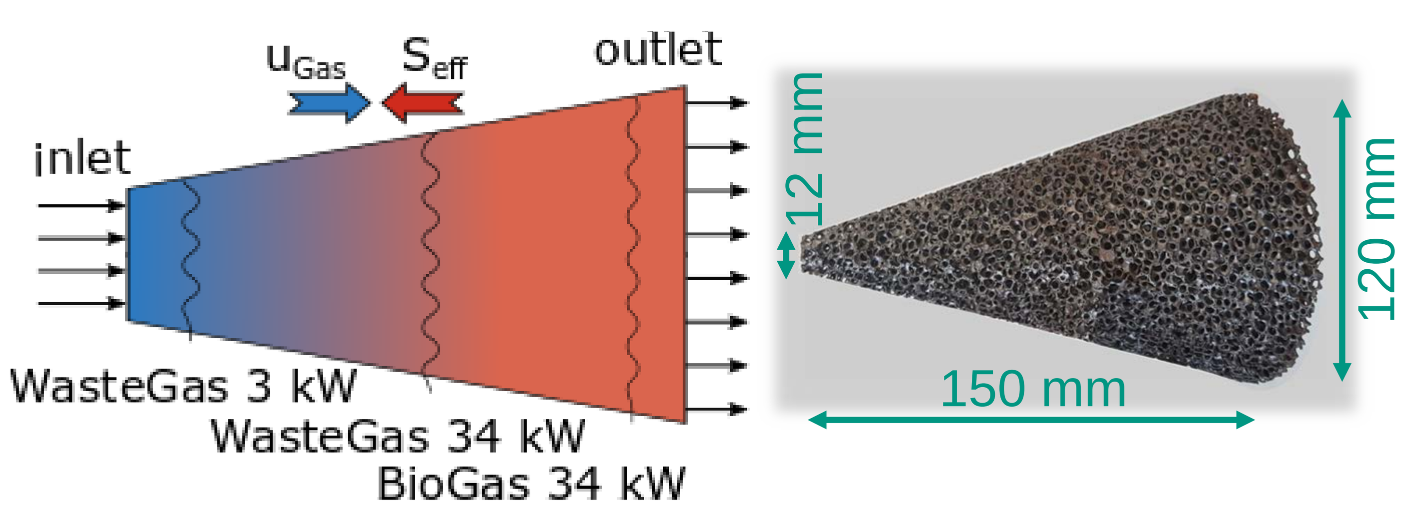

Figure 4: Left: Schematic illustration of conical shaped porous burner with flame position for different operation modes. Right: picture of manufactured 10 PPI foam with

References
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