TECHNISCHE UNIVERSITÄT WIEN
VIENNA UNIVERSITY OF TECHNOLOGY

Institute of Chemical Engineering

Solid Biomass Gasification as Fuel Source for Fuel Cells

Workshop: Hydrogen- and Fuel Cell Based Energy Systems in a Future Sustainable Energy World

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reNet AUSTRIA
[energy from biomass]

Industrielle Kompetenzzentren und Netzwerke
EIN PROGRAMM DES BMWA

Outline

1. Gas generation
2. Gas conditioning for fuel cell applications
3. Combined heat and power (CHP) from biomass using fuel cells
4. Technological status & projects
5. Conclusion

Thermal gas generation from solid fuels (1)

Definition:

Gasification means the transformation of solid fuels into combustible gases in presence of an oxygen carrier (air, O_2, H_2O, CO_2) at high temperatures.

The necessary energy for thermochemical conversion is provided by partial oxidation of fuel or producer gas.

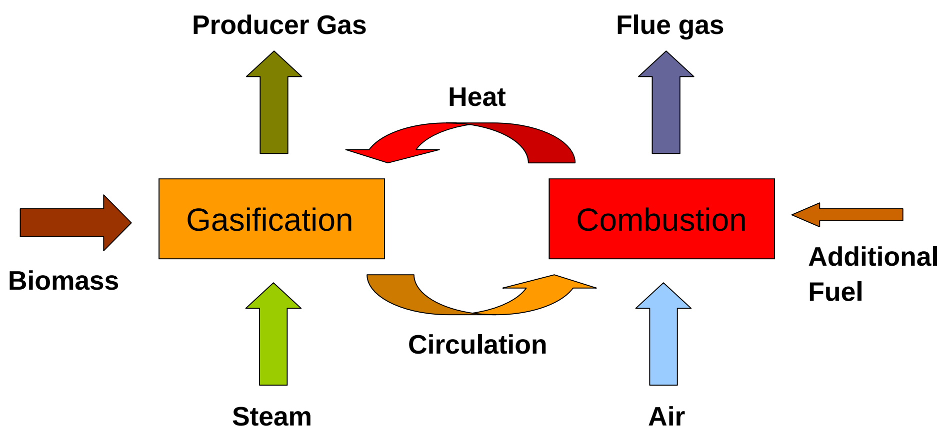
Gas generation (2): Main gasification technologies

- ***Air gasifiers:*** Fixed or fluidized bed, autothermal,
  ~ 50 % N_2 in dry producer gas, low calorific gas
  ☐ producer gas from air gasifiers not suitable for syntheses and fuel cell applications

2. ***Steam gasifiers:*** Dual fluidized bed, allothermal,
   two gas streams (producer gas and flue gas),
   ~ 40 v-% H_2 in dry producer gas, medium calorific gas
   ? steam gasification provides gas resembling partially reformed natural gas

3. ***Oxygen/steam gasifiers:*** Fluidized bed, autothermal,
   producer gas like from steam gasification
   ? availability of pure O_2 problematic for small plant capacities

Gas generation (3): Dual fluidized bed steam gasification



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Gas conditioning (1): Fuel requirements of different cell types

Fuel cell	*Electrolyte*	*Operating temperature*	*fuel gas*	*catalyst poisons*
AFC	KOH solution	70-260 °C	pure H_2	CO, CO_2
PEM	Polymer membrane	50-120 °C	pure H_2	CO > 10 ppm
PAFC	H_3PO_4	180-210 °C	H_2	CO > 0.5 %, H_2S > 50 ppm
MCFC	molten alkaline carbonates	650 °C	H_2/CO	H_2S > 0.5 ppm
SOFC	solid oxide ceramics	800-1000 °C	H_2/CO (CH_4)	H_2S > 1.0 ppm

Source: Larminie & Dicks, "Fuel Cell Systems Explained", J. Wiley & Sons, 2000.

Gas conditioning (2): Cleaning technologies

Low temperature (< 200 °C)	**Pollutant**	**High temperature (> 400 °C)**
bag filter, wet scrubber, electrostatic precipitator (ESP)	Particles	Cyclone, granular-medium filter, ceramic filter, metal filter
Physically: wet scrubber, wet ESP, cyclone, adsorption/bag filter	Tar	*Thermally/catalytically:* Steam cracking with metal and non-metal catalysts
removal as solid particles or in liquid solution	Alkali-compounds	removal as solid particles < 600 °C
wet scrubber	NH_3	catalytic transformation to N_2
wet scrubber, chemical adsorption (ZnO)	H_2S, COS, R-SH	under development
wet scrubber	HCl	under development

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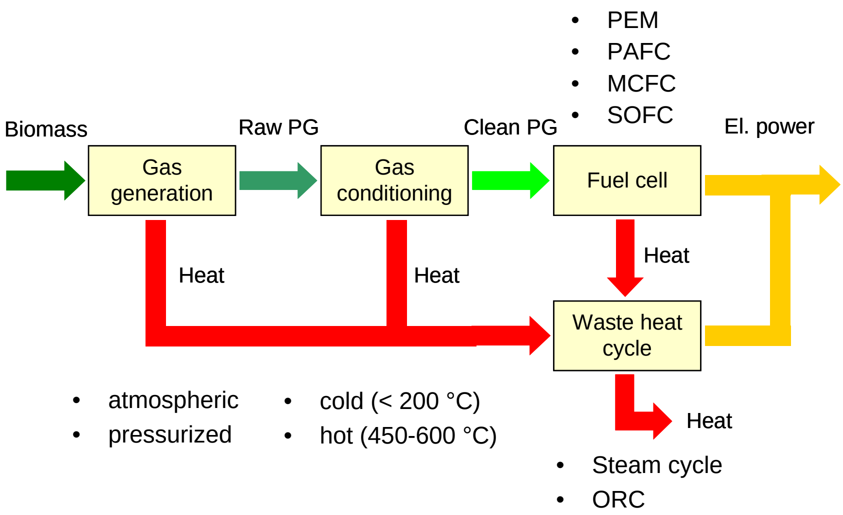
CHP with fuel cells: Typical plant configuration



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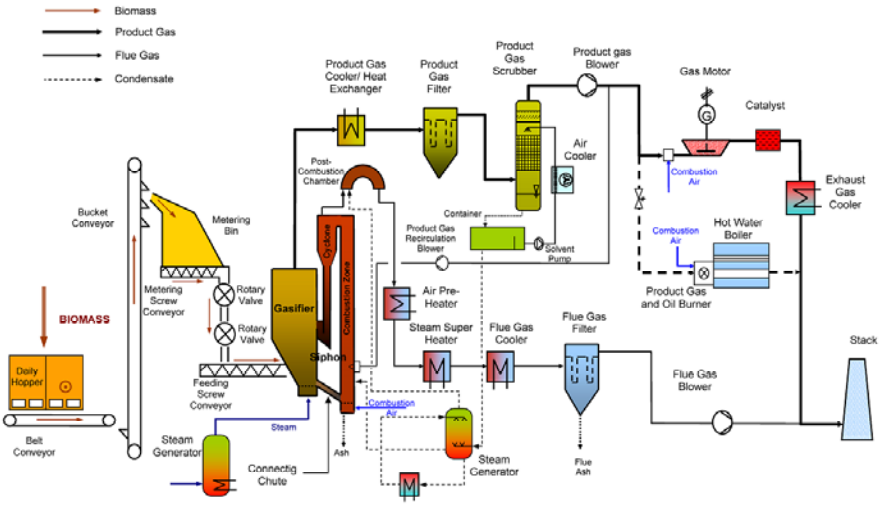
Technological status of biomass gasification

- Atmospheric steam gasification at industrial scale in successful operation (Güssing/Austria)

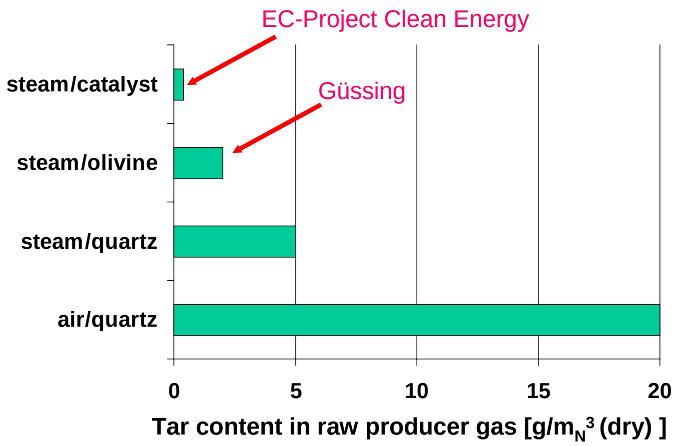
Güssing power plant (8 MW fuel power, 2 MW el. power)



Technological status of biomass gasification

- Industrial scale atmospheric steam gasification in successful operation (Güssing/Austria)
- Lower tar and higher H_2 content with catalytically active bed materials (EC Proj. Clean Energy 5th FP)

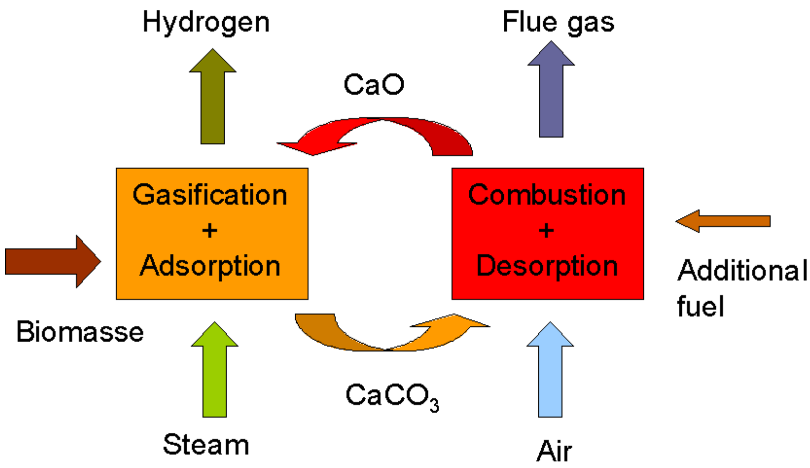
Tar reduction by primary measures



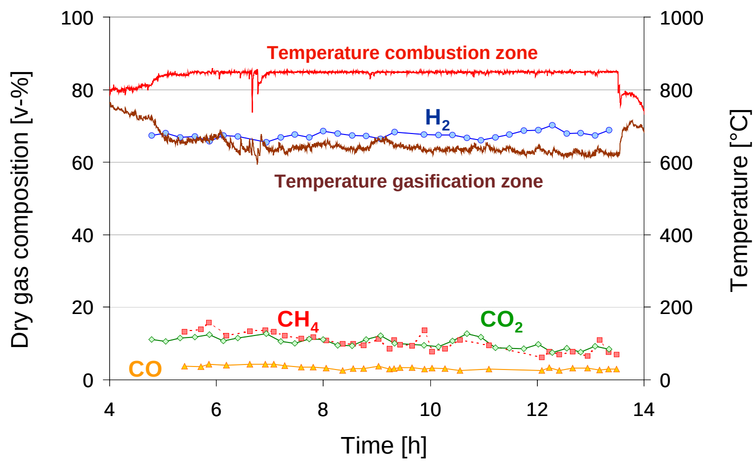
Technological status of biomass gasification

- Atmospheric steam gasification at industrial scale in successful operation (Güssing/Austria)
- Lower tar and higher H_2 content with catalytically active bed materials (EC Proj. Clean Energy 5th FP)
- CO_2 capture in the gasifier for high H_2 content up to 80 v-%(dry) (EC Proj. AER-Gas 5th FP)

Hydrogen rich syngas from biomass (1)



Hydrogen rich syngas from biomass (2)



Technological status of biomass gasification

- Atmospheric steam gasification at industrial scale in successful operation (Güssing/Austria)
- Lower tar, higher H_2 content with catalytic active bed materials (EC Proj. Clean Energy 5th FP)
- CO_2 capture in the gasifier for high H_2 content up to 80 v-%(dry) (EC Proj. AER-Gas 5th FP)
- Pressurized systems under development (Värnamo/Sweden – EC-Proj. ChrisGas, 6th FP)

Technological status of gas cleaning

- Cold gas cleaning steps for particle and tar removal demonstrated
  - Combination bag filter / organic solvent scrubber
  - Combination water quench / wet electrostatic precipitator
- Trace removal of H_2S same as for synthesis gas preparation
- Hot gas cleaning steps under development

Conclusion

- Good match in size between decentralized CHP and fuel cell technology
- High electric efficiency of gasification based CHP plants – especially in combination with fuel cells

Electric Efficiencies of CHP concepts in the capacity range of 10 MW fuel power (based on LHV of fuel input):

- Combustion/steam cycle: 12-20 %
- Gasification/gas engine: ~ 25 %
- Gasification/PAFC: 25-30 %
- Gasification/MCFC: 32-37 %
- Gasification/SOFC/GT: 40-45 %

Fuel cells are the key technology for high efficiency electricity generation from solid biomass