Biomass & waste conversion in Supercritical Water

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Gasification in Supercritical water (1)

Supercritical water:
- T > 374 °C
- P > 22 MPa
- one fluidium (no gas-liquid interface)

Why gasification in supercritical water ?

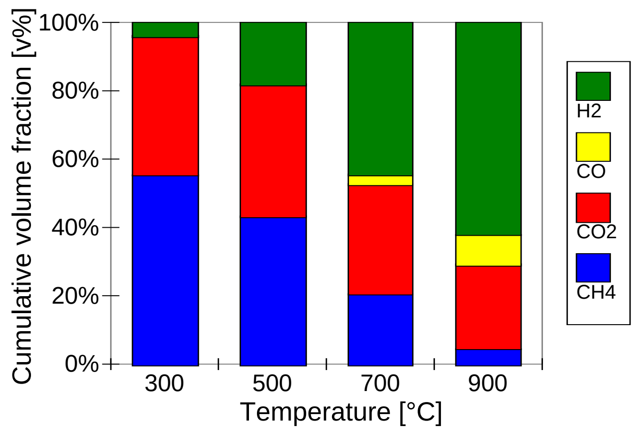
- Suitable for very wet biomass (moisture content > 70 wt.%)
- Produced gas rich in hydrogen (> 50 vol.%)
- Gas available at high pressure (~ 300 bar)
- Gas is rather clean (no minerals, tars etc)
- Enables counter-current heat exchange between feedstock and product

Example: reaction of glucose (650 °C)

$$2C_6H_{12}O_6 + 7\,H_2O \rightarrow 9CO_2 + 2CH_4 + CO + 15\,H_2$$

vol.% → *30* *7* *4* *56*

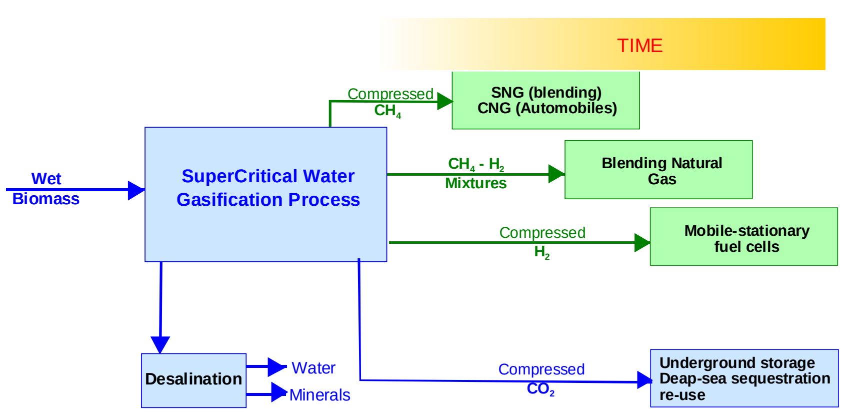
Thermodynamics

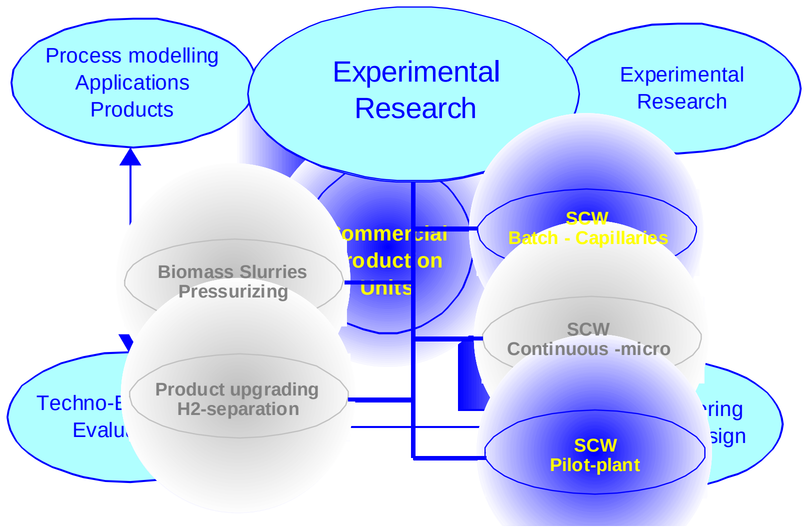


Gas composition at equilibrium; P = 300 bar; solids = 20 wt%

Gasification in Supercritical water (2)

Objective: Development of the SCW process for the production of SNG / Hydrogen from wet biomass/waste





Batch micro scale experiments (quick & safe)

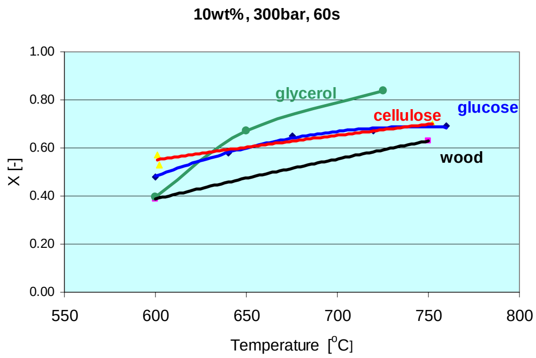
- Quarts capillaries (I.D. = 1 mm)
- Metal autoclave (I.D. = 5.2 mm)

- Explore the effects of process conditions (T,P,c,t,cat.) on the reaction
- Identify possible problems (blockage, waste streams)
- catalysis, total mass balance

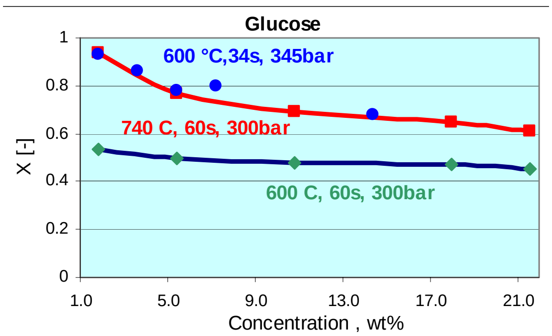

Capillary reactors compared with 1 Euro coin


Photo of metal autoclave setup

Effect of temperature



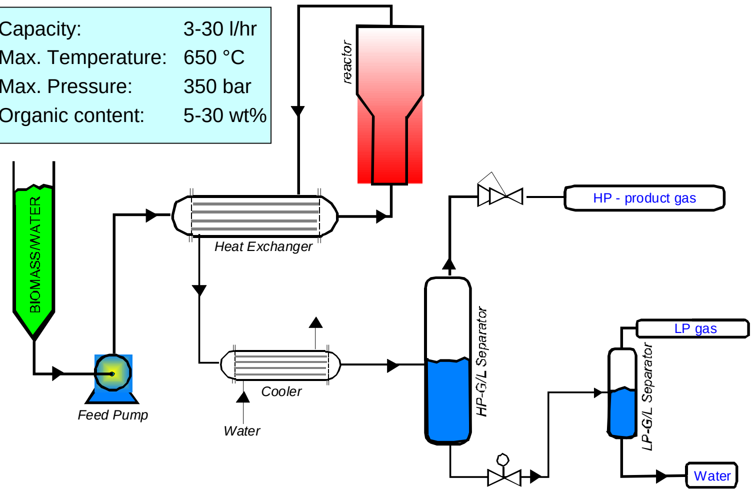
Effect of concentration



● 1. D. Yu, M.J. Antal, *Hydrogen Production by Steam Reforming Glucose in Supercritical Water*, Energy & Fuels (7), p. 574-577, 1993.

Pilot-plant for the supercritical gasification process

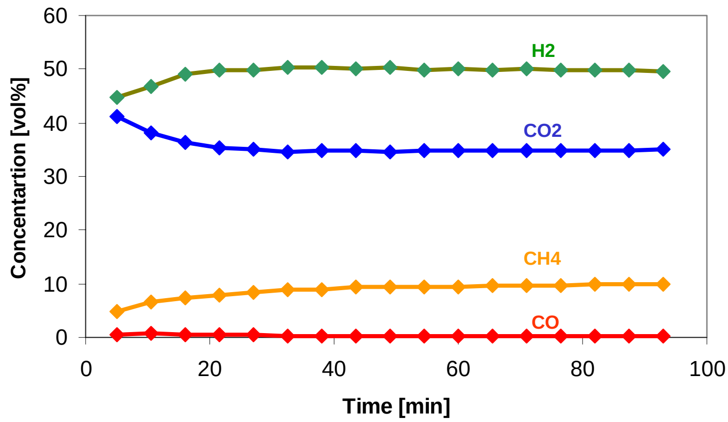
Capacity:	3-30 l/hr
Max. Temperature:	650 °C
Max. Pressure:	350 bar
Organic content:	5-30 wt%



Feeding section & process control

Reactor & gas separation

Pilot plant



Concentration of main gas components after the reactor as a function of time on stream;

Feedstock: 5 wt.% glycerine, 0.0075 wt.% NaOH; flow = 7 kg/hr; T = 580 °C; P = 270 bar.

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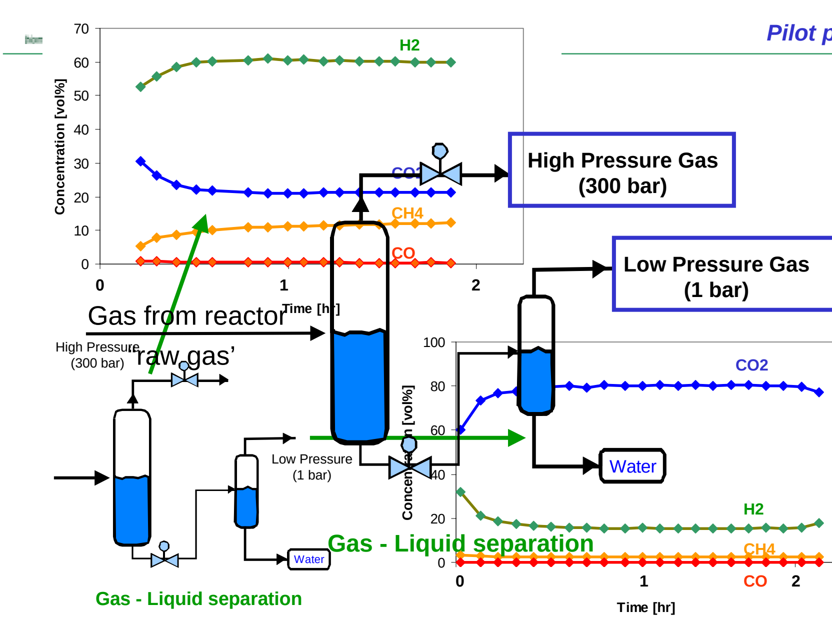
Pilot plant



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Typical gas concentrations (high pressure product gas)

- *Gasification of 5 wt.% glycerine with and without additives*
- *Capacity: 7 kg/hr*
- *T = 580 °C; P = 270 bar*

Additives / Compound (vol.%)	-	Na_2CO_3 0.01 wt.%	NaOH 0.0075 wt.%	KOH 0.01 wt.%
Hydrogen (H_2)	28.6	59.2	60.2	60.4
Carbon Monoxide (CO)	30.2	1.6	0.4	0.0
Carbon Dioxide (CO_2)	12.6	20.8	21.3	20.9
Methane (CH_4)	15.4	12.7	11.9	13.9
C2 -	11.2	4.6	4.7	4.8
C3 -	2.1	1.0	1.5	0.0
LHV (MJ/Nm^3)	21.4	15.1	15.2	14.6

Thermal efficiency

Efficiency: chemical energy in product gas / chemical energy in feedstock

- Feedstock - 5 wt%: ~ 70% energy in HP product gas
  ~ 6% in LP product gas
- Feedstock - 10 wt%: ~ 79% energy in HP product gas
  ~ 5% in LP product gas

CO_2 - removal

Amount of CO_2 removed from the main product via LP product gas

- CO_2 concentration in LP gas ~ 80 v%
- Between 35 - 60% of total CO_2 removed via LP gas

Summary

- Gasification in supercritical water is a new process for the complete conversion of wet biomass.
- Raw gas from the reactor may already contain 60% of hydrogen.
- Efficiencies of over 70% can be achieved.
- Main products are Methane and Hydrogen; actual application depends on the market:
  - Short-medium term: SNG/CNG
  - Long term: hydrogen
- Concentrated CO_2 is largely removed in-situ; Sequestration / re-use of CO_2 can be considered for the long term (negative CO_2 balance)