Biomass Conversion in Supercritical Water

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BIO-ENERGY
ENLARGED PERSPECTIVES

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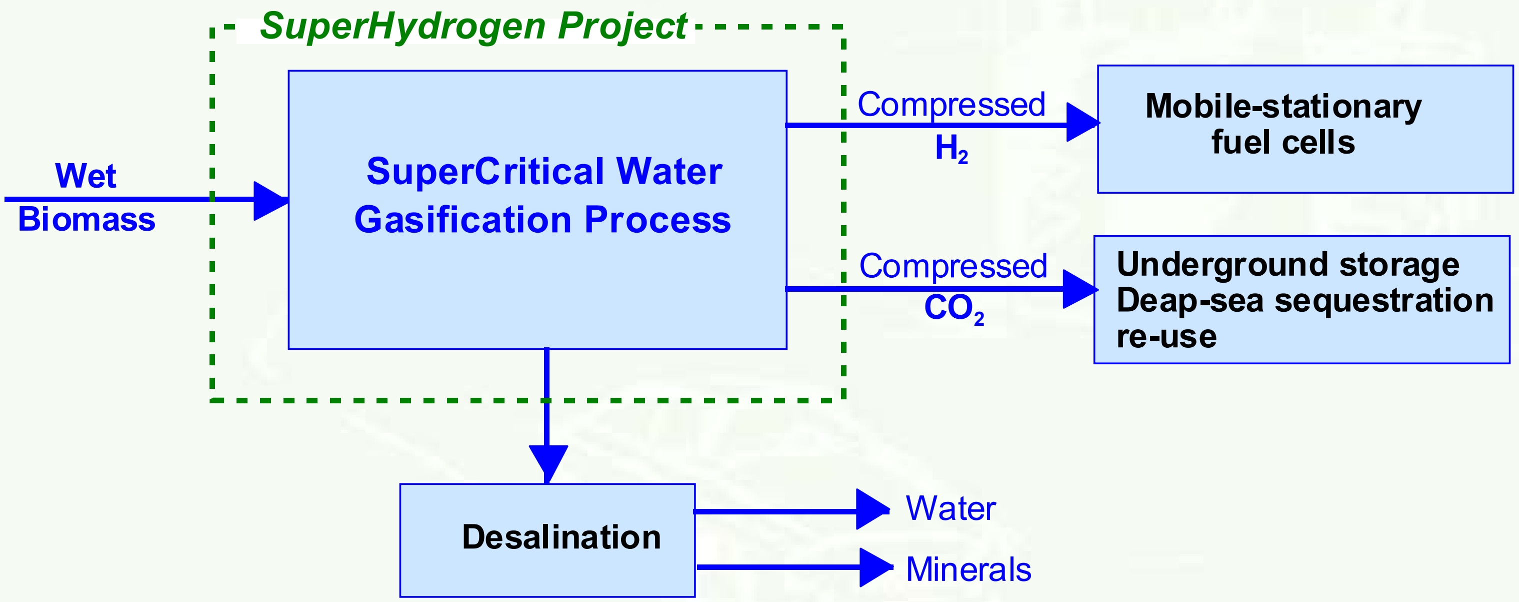
Biomass and waste conversion in supercritical water for the production of renewable hydrogen

SuperHydrogen



Gasification in Supercritical water

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

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

vol.% ⟶ 30 7 4 56

Overall Objective of SuperHydrogen:

Development supercritical water gasification process for cost-effective (< 12 €/GJ) conversion of wet biomass/waste into hydrogen with energy efficiency exceeding 60%.

1. Feedstock selection, preparation & pressurizing

- Selection wet biomass/waste streams in Europe
- Development of process to produce pumpable slurries (up to 30 wt.%)
- Pump selection and testing

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TNO

2. Development supercritical water gasification process

- Process fundamentals using micro-set-ups
- Pilot-plant tests with model components
- Pilot-plant tests with real biomass

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3. Product upgrading: development catalytic membrane reactor

- Shift CO for at least 70%
- Reform methane for at least 70%
- Separate hydrogen (purity > 98 vol.%)

WMG

Dytech Ltd.

4. Process Modelling

- Kinetics and phase equilibria models
- Modules for unit operations
- Overall process model

TNO

5. Basic engineering & cost estimate

- Basic engineering of complete process from biomass to pure hydrogen
- Cost estimates (investment & operational)

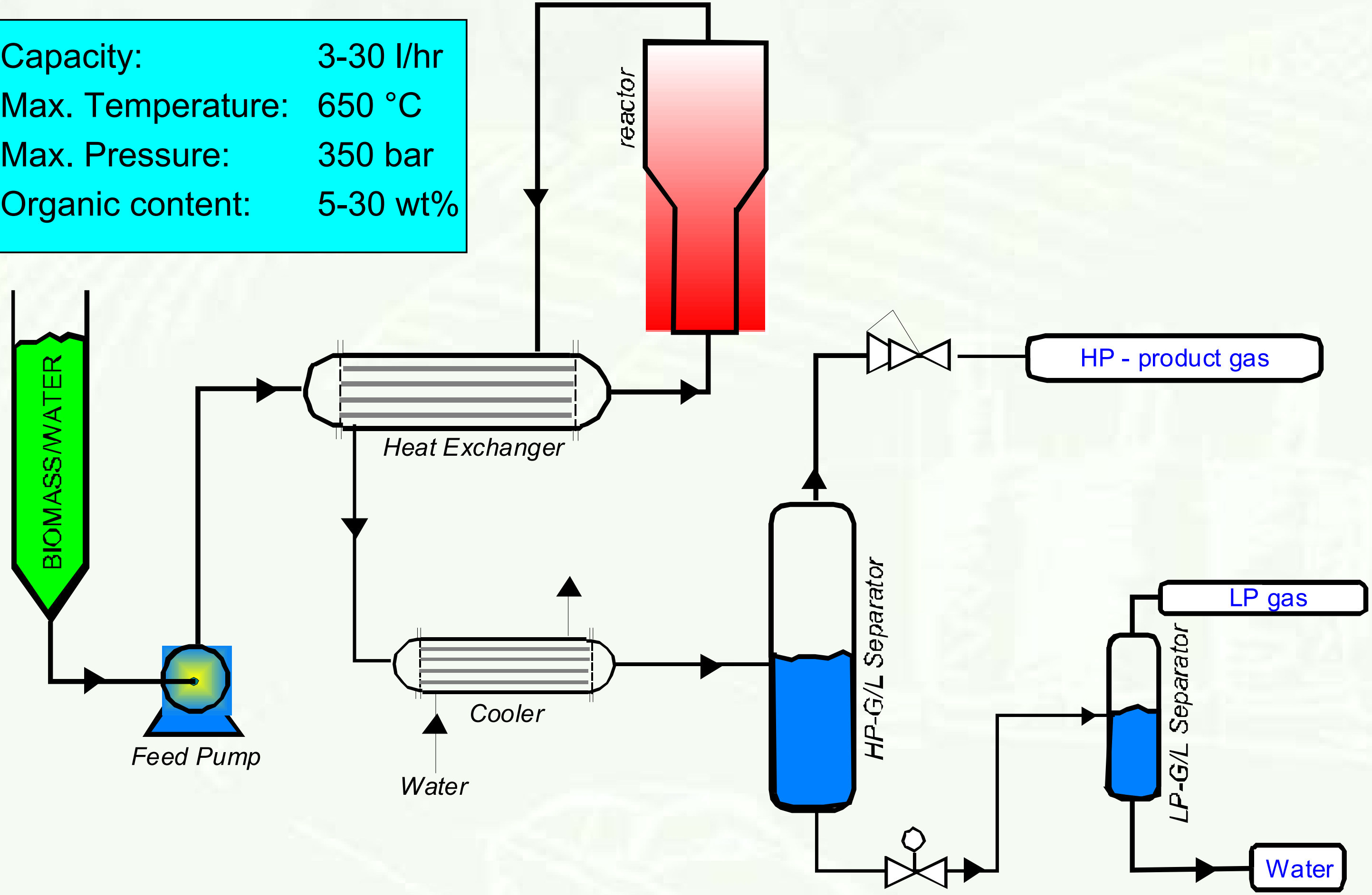
UHDE
High Pressure Technologies

6. Specification of H_2, safety aspects and alternatives

- Specifications of H_2 for different end-uses
- Alternative processes for H_2 production
- Safety aspects of H_2 production

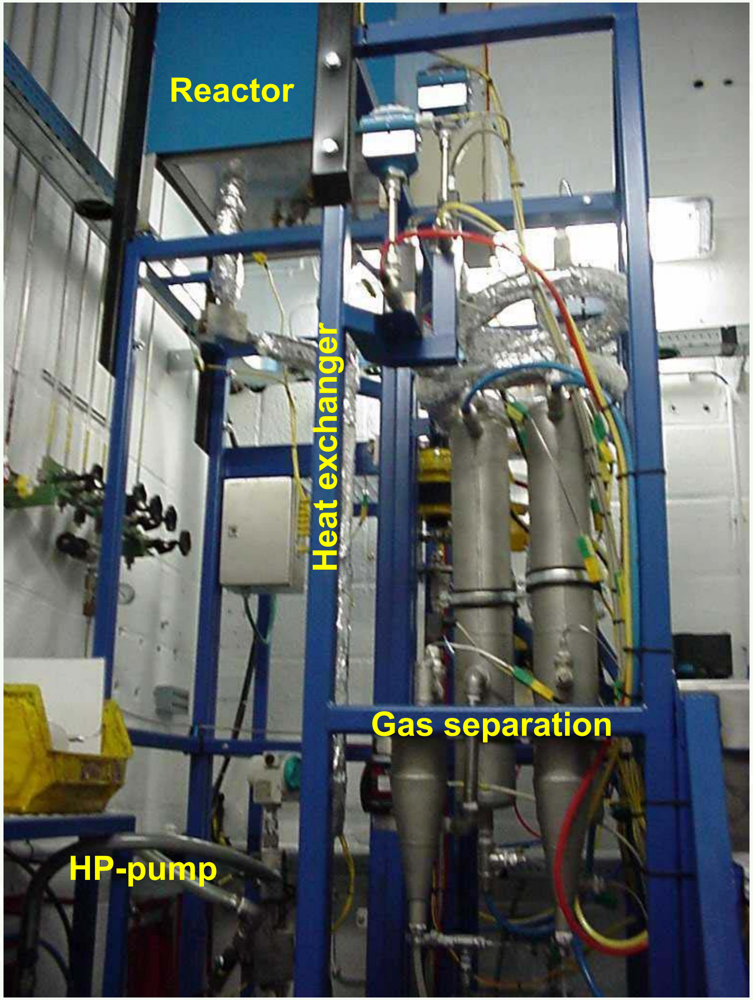
SPQL

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

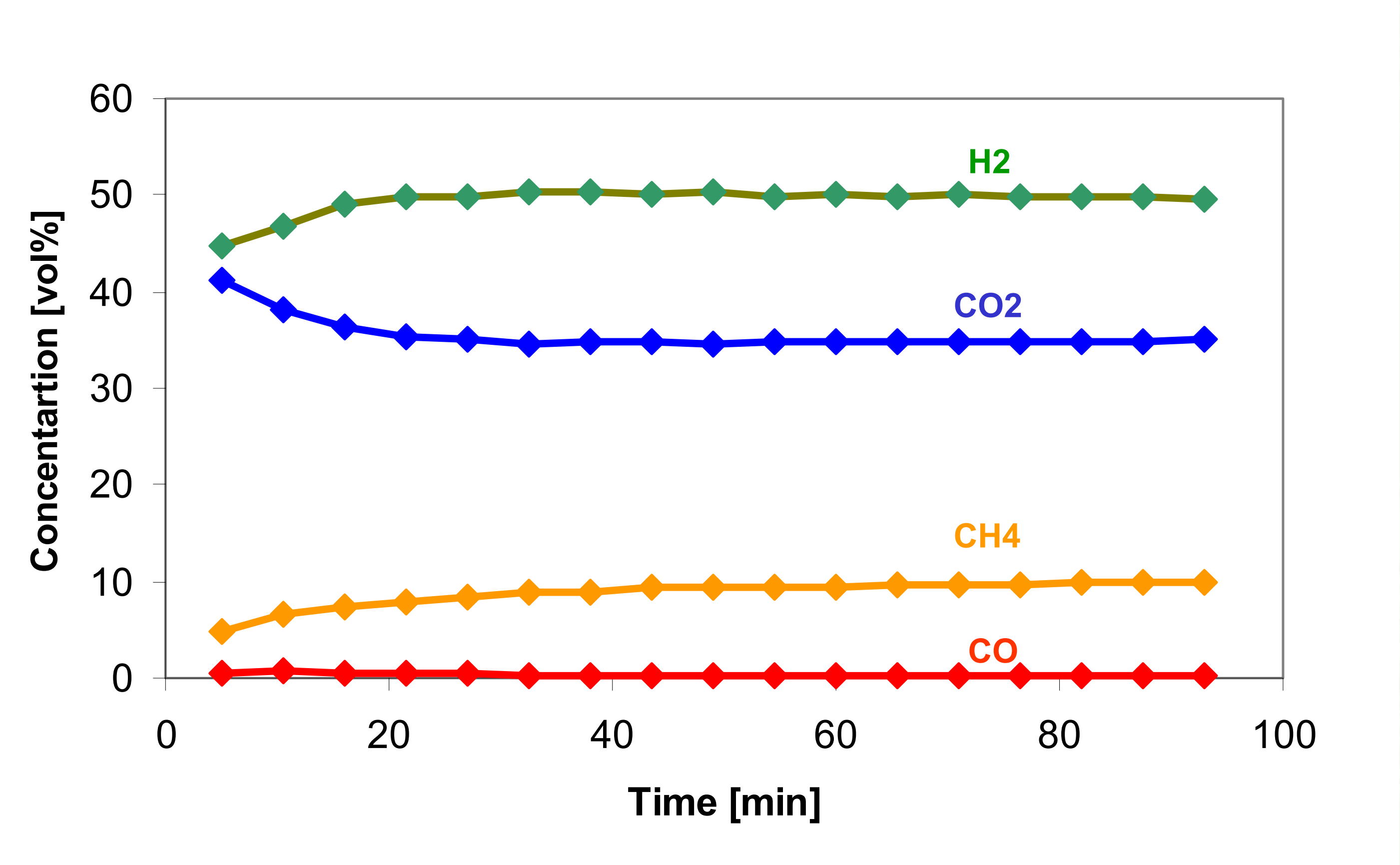


Basic flow diagram supercritical gasification process (pilot-plant)

Feeding section & process control

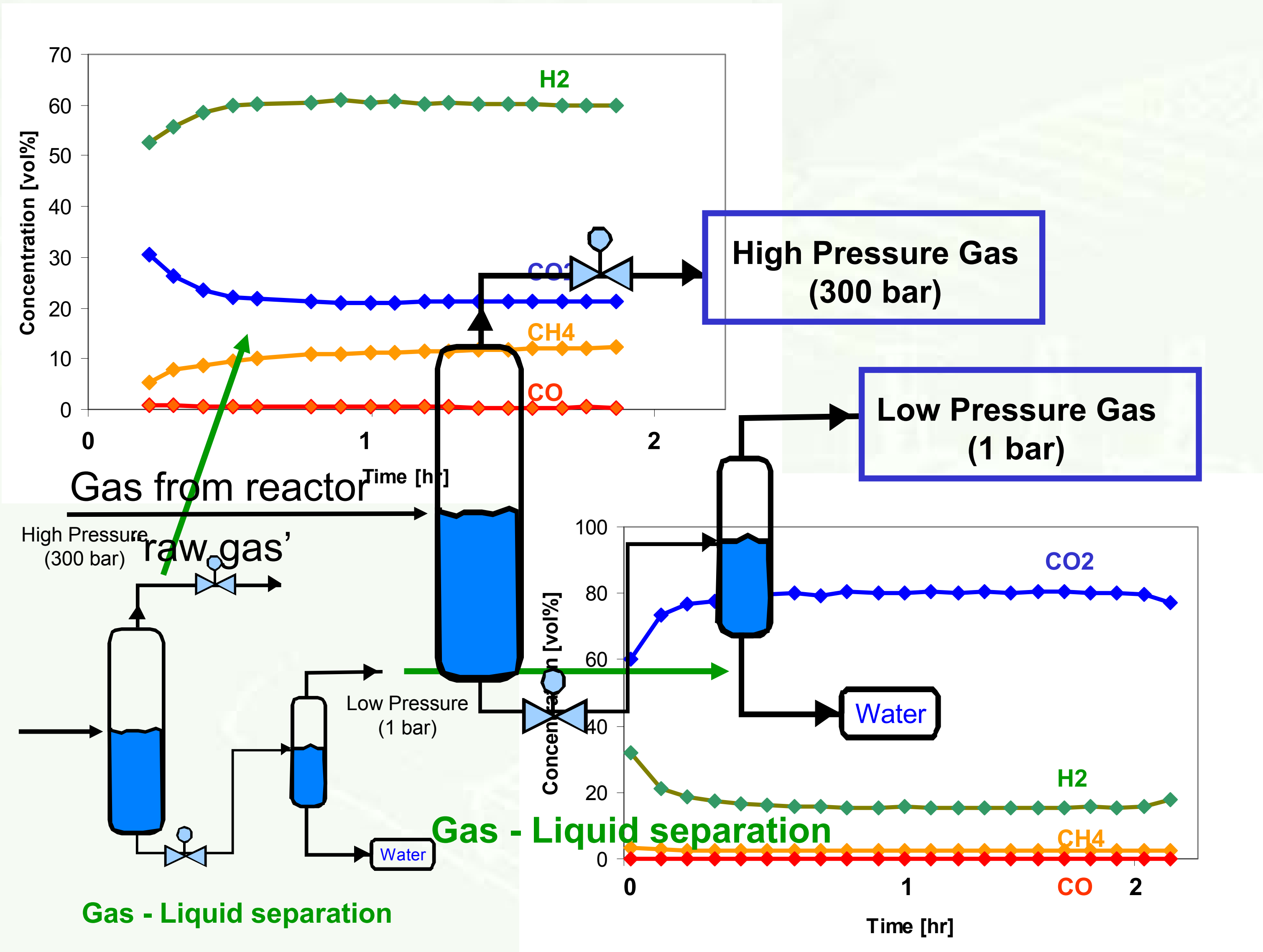


Reactor & gas separation



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.



H2
CO2
CH4
CO
Concentration [vol%]
Time [hr]
High Pressure Gas
(300 bar)
Low Pressure Gas
(1 bar)
Gas from reactor
'raw gas'
High Pressure
(300 bar)
Low Pressure
(1 bar)
Water
Water
Gas - Liquid separation
Gas - Liquid separation

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.%
Hydrogen (H_2)	29	59	60
Carbon Monoxide (CO)	30	1.5	0.4
Carbon Dioxide (CO_2)	13	21	21
Methane (CH_4)	15	13	12
C2 -	11	4.7	4.7
C3 -	2	1.0	1.5
LHV (MJ/Nm^3)	21.1	15.1	15.2

Future work

2004	Slurry preparation demonstrated and tested with pump
2003 - 2005	Fundamental research in capillaries / continuous micro set-up
2003	Pilot-plant tests with model components (glycerol, MeOH, starch)
2004 - 2005	Pilot-plant tests with real biomass
2004	Prototype gas upgrading reactor to be tested with artificial gas
2005	Integration upgrading reactor in pilot plant and integrated testing
2003	Preliminary techno-economic evaluation overall process
2005	Final techno-economic evaluation

More info: http://superh2.grensy.info