



Wir schaffen Wissen – heute für morgen

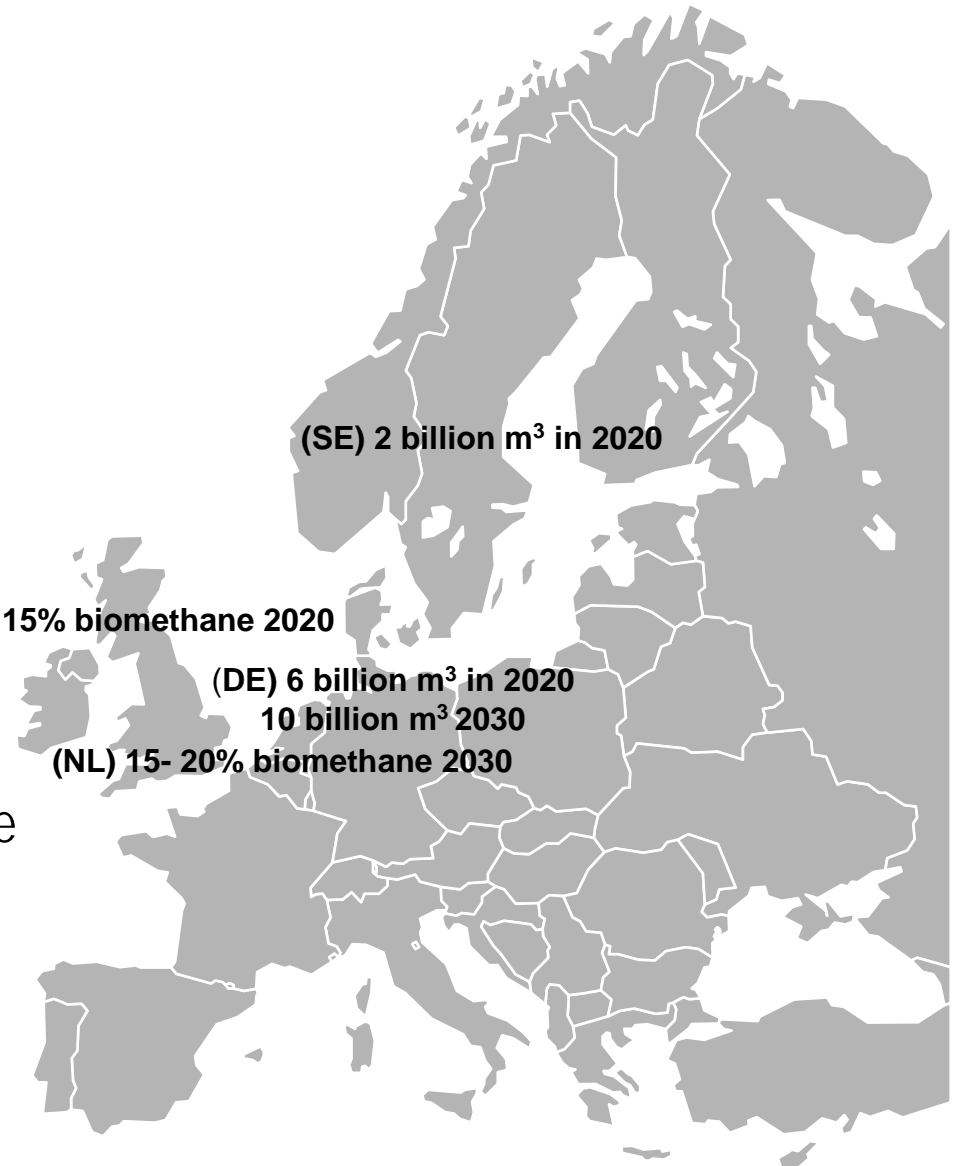
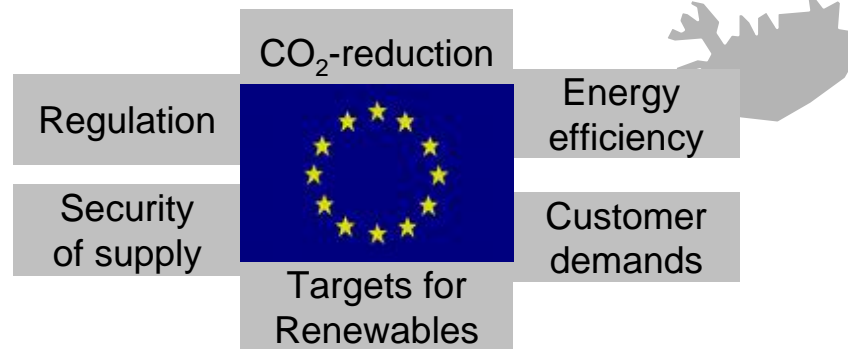
**Paul Scherrer Institut**

Oliver Kröcher, Frédéric Vogel, Serge Biollaz

**Löst BioSNG die Vergärung ab?**

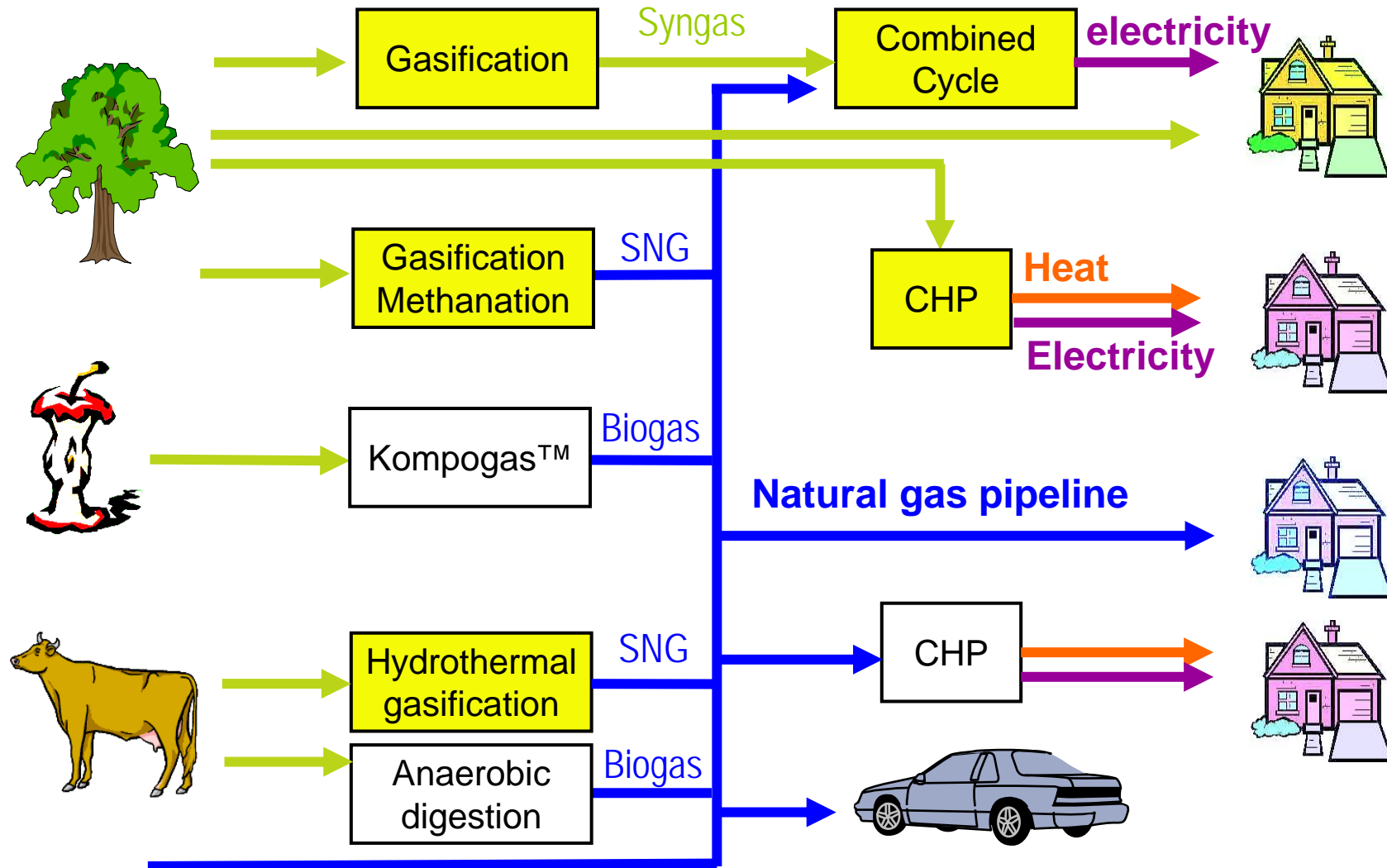
# Status 2009: Renewable methane in Europe

Political Targets EU, communicated from E.ON



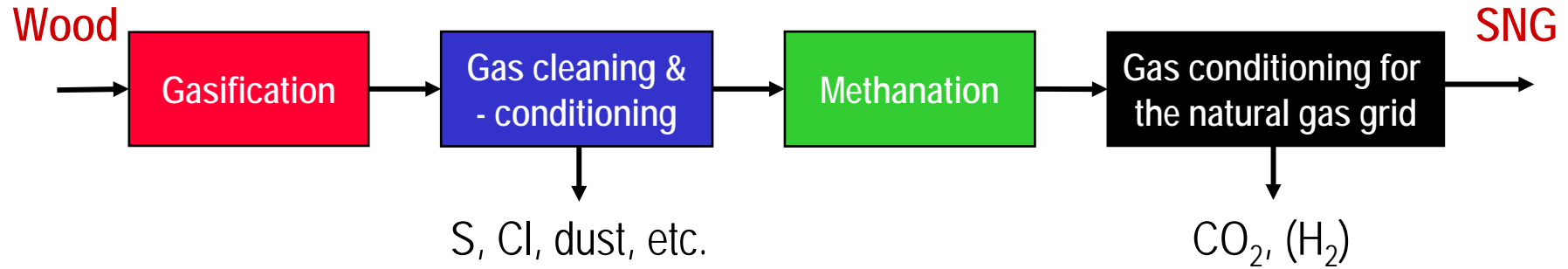
- ~10% renewable methane in 2030
- corresponds to 55 billion m<sup>3</sup>/year methane (550 TWh/year = 70 GW<sub>SNG</sub>)
- investment volume of + 60 billion €

# Integration of biomass into existing grids

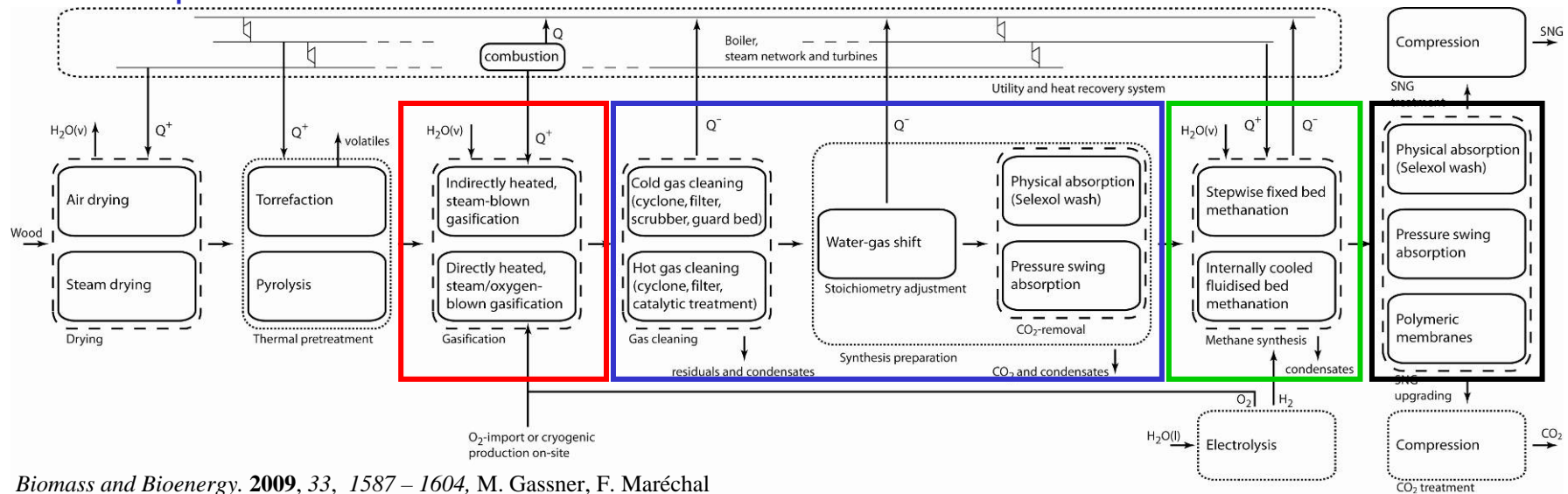


# Process units for conversion of wood/dry biomass to SNG

## Conventional thermo-chemical pathway

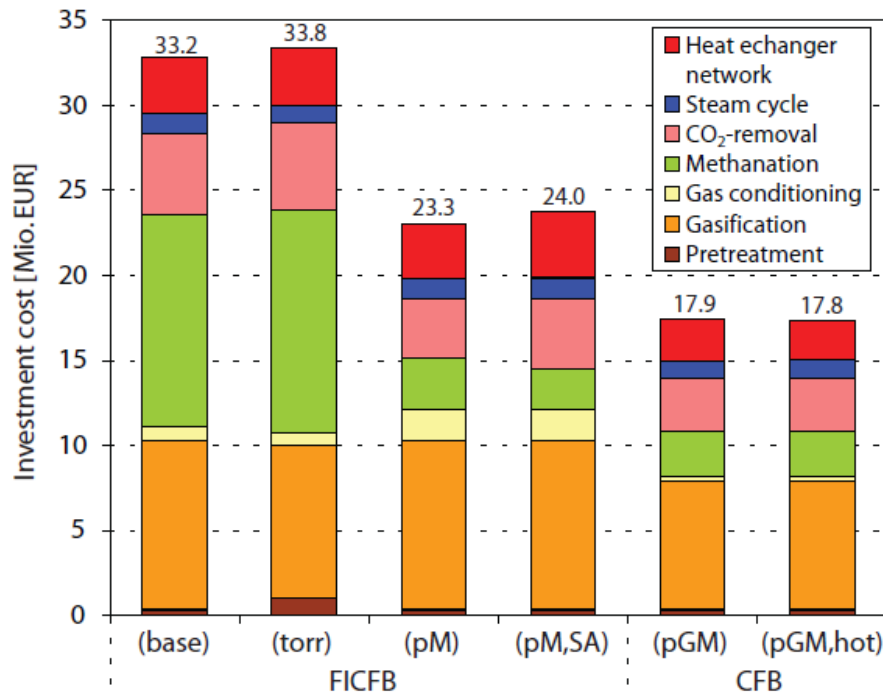


### Process superstructure

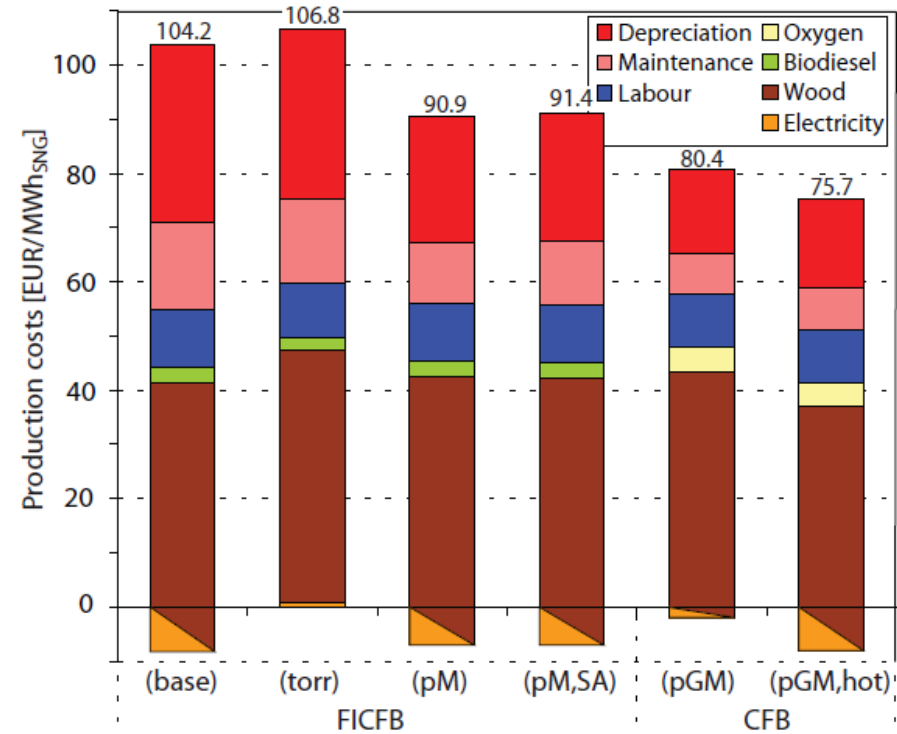


*Biomass and Bioenergy*. 2009, 33, 1587 – 1604, M. Gassner, F. Maréchal

### Total investment cost [M€]



### Production costs [€/MWh<sub>SNG</sub>]



Biomass and Bioenergy. 2009, 33, 1587 – 1604, M. Gassner, F. Maréchal



Güssing CHP plant, 2004

1 MW<sub>SNG</sub> PDU

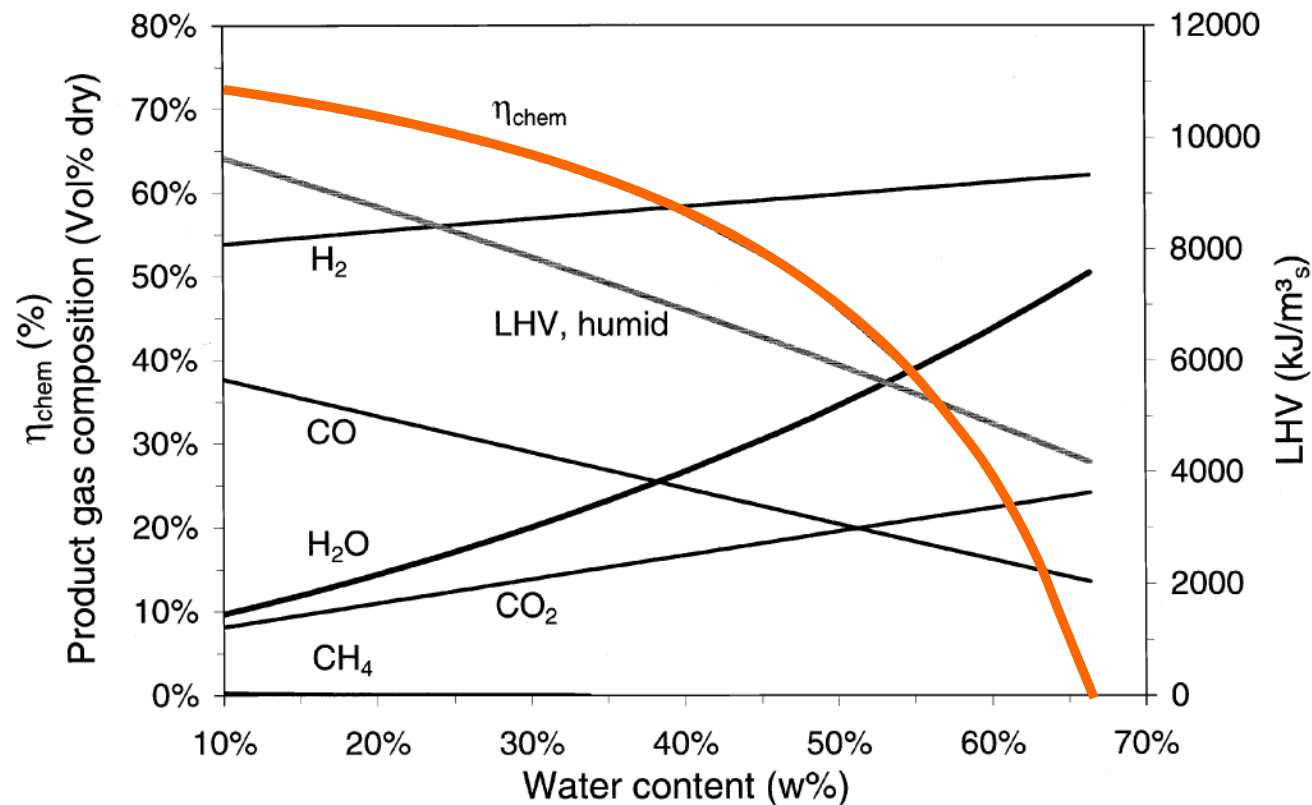


BioSNG PDU, 2008

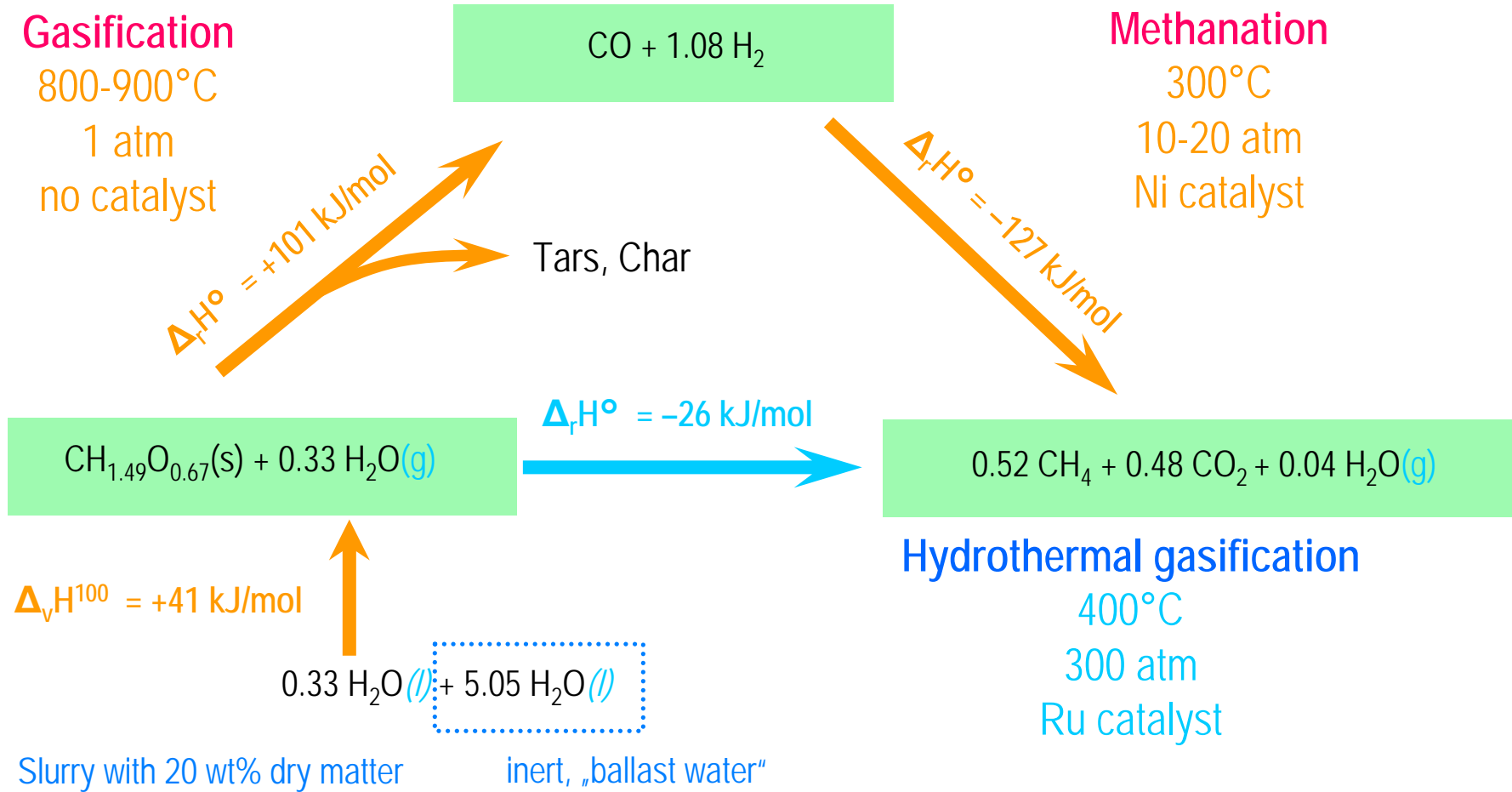
## Milestones:

- December 2008: First conversion of product gas into rawSNG.
- June 2009: BioSNG at Natural Gas quality produced.
- June 24th: Inauguration – CNG cars were fuelled using BioSNG from wood.
- June 2009: CNG-car was successfully used for 1000 km with BioSNG.

## Atmospheric gasification: Process efficiency vs. water content

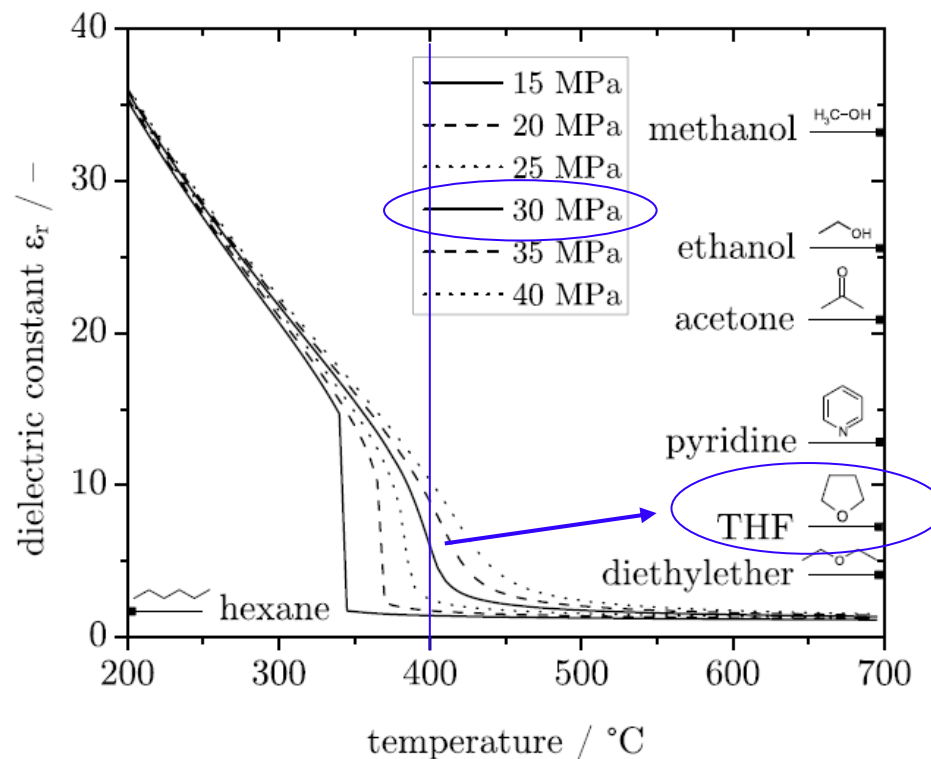
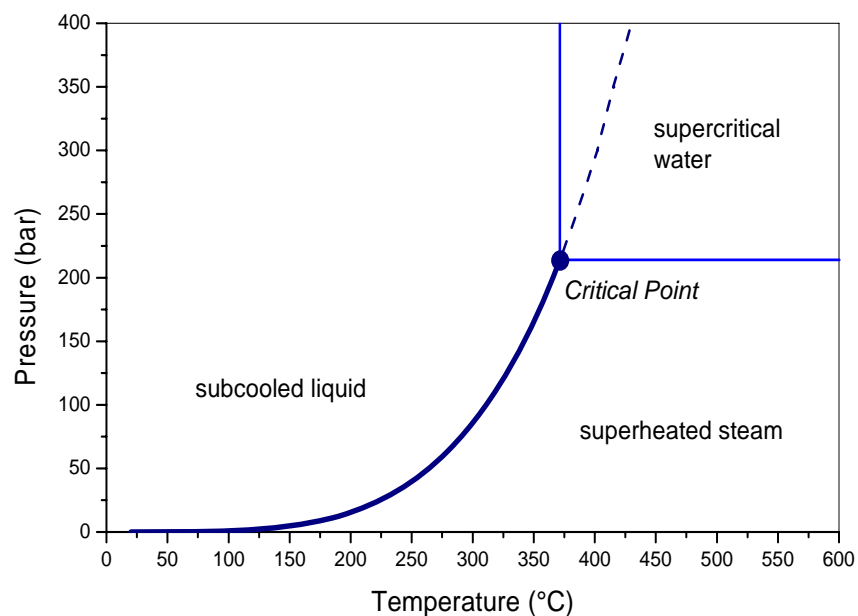


G. Schuster, G. Löffler, K. Weigl, H. Hofbauer, *Bioresource Technology* 2001, **77**, 71-79



## Supercritical water – the **greenest** “organic” solvent

„Hydrothermal“ refers to conversions in **pressurized water** (100-400 bar) at temperatures of ca. 250-600°C.



Supercritical water behaves like nonpolar solvent

Good solubility of tar-like and oily compounds  
Reduced solubility of salts

# The catalyst is the key!

## Gasification of wood sawdust in an autoclave

400°C, ca. 30 MPa,  $\tau = 98$  min.

No catalyst



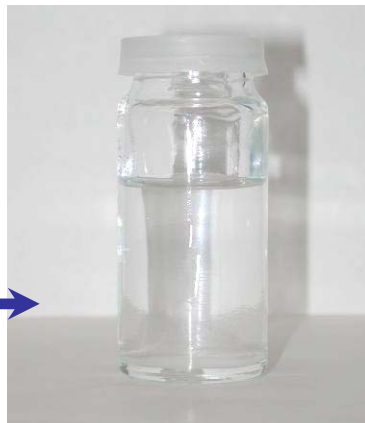
Carbon gasification: 21%  
Yield: 0.02 g CH<sub>4</sub>/g wood<sub>daf</sub>

Excessive **tar** and **char** formation and only modest gasification.

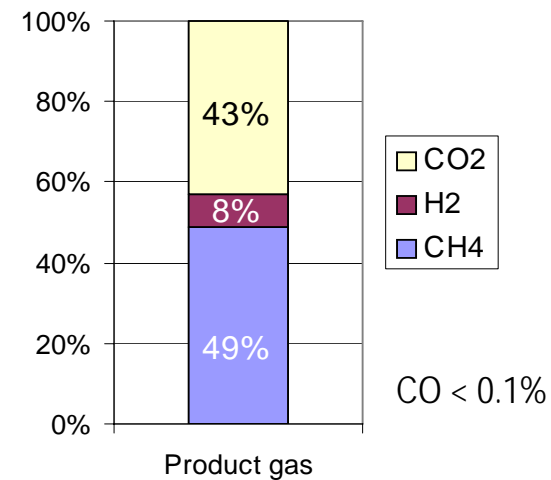


10% wood in water  
(TOC: 49 g/L)

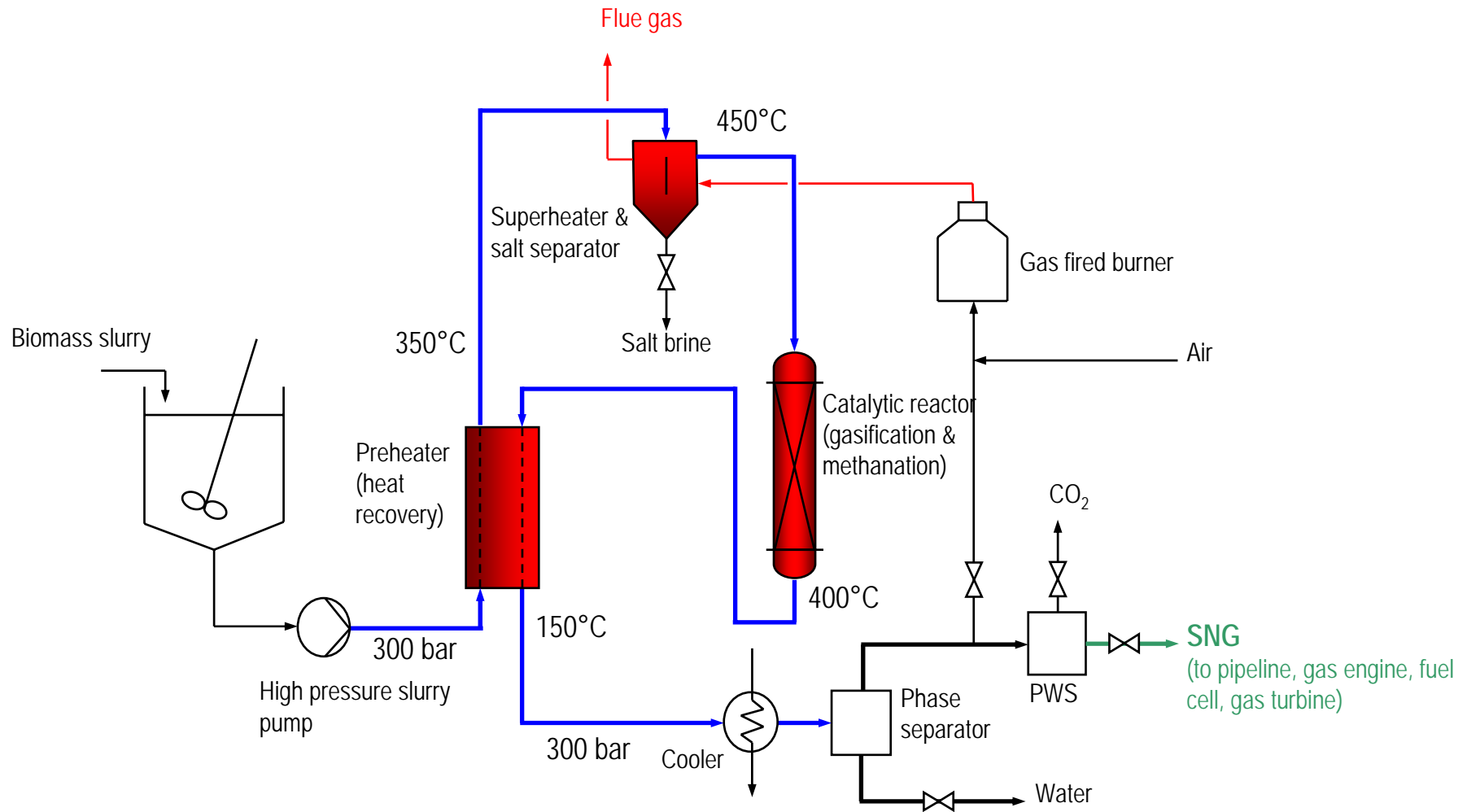
Raney Ni<sup>®</sup>

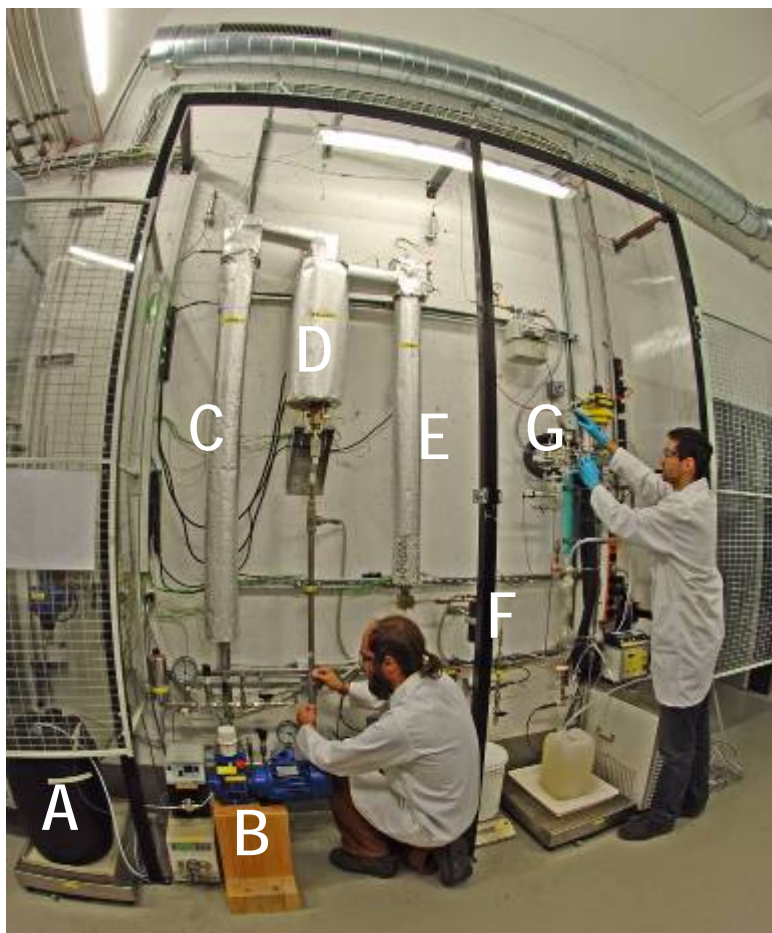


Carbon gasification: >99%  
Yield: 0.33 g CH<sub>4</sub>/g wood<sub>daf</sub>



Waldner and Vogel, *I&ECR* 44:13, 2005



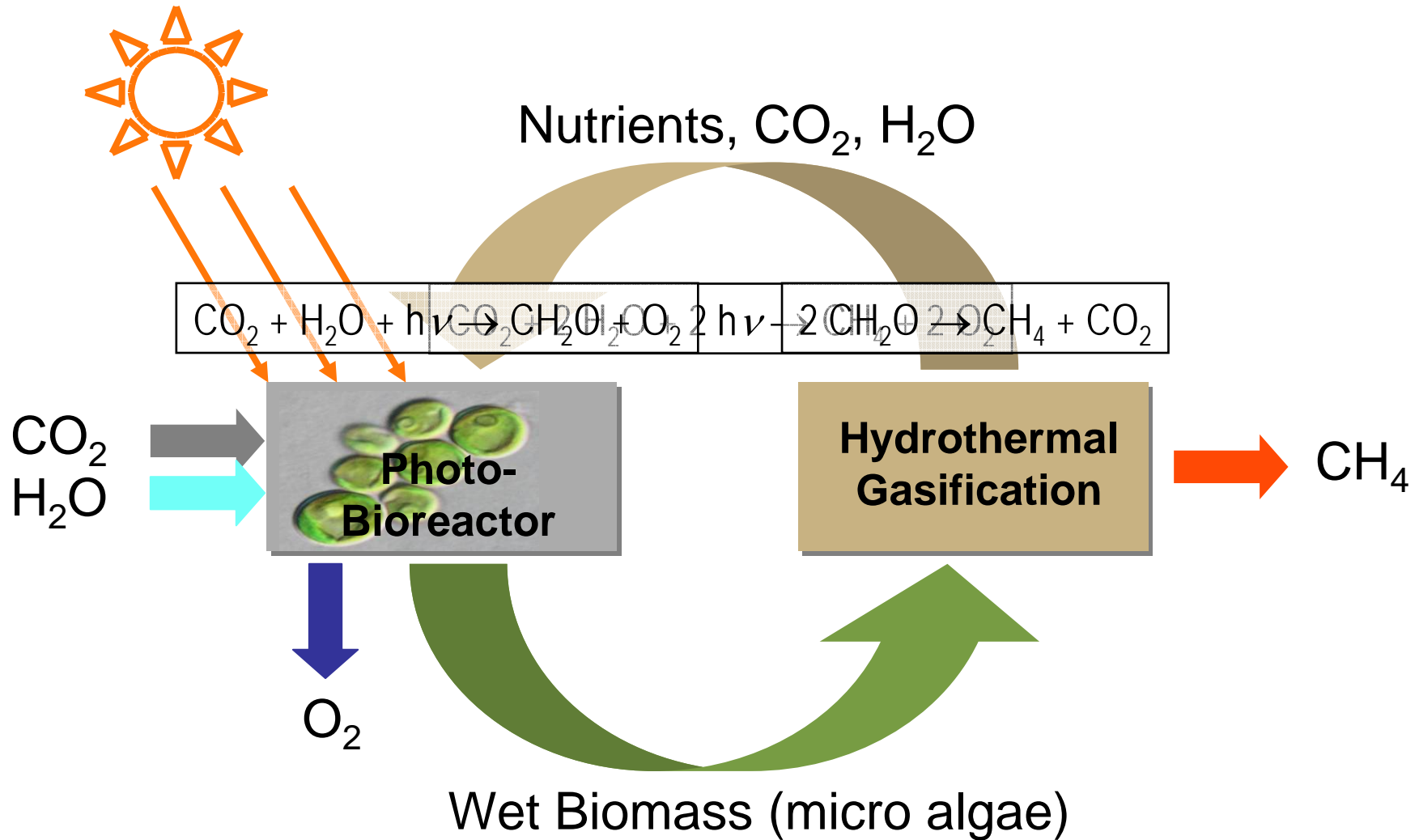




- A Feed container
- B High pressure feed pump
- C Preheater
- D Salt separator
- E Fixed-bed reactor
- F Coolers
- G Pressure letdown & G/L separation
- H on-line gas analysis

<p>Max. 1 kg/h 500°C 350 bar</p>
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- The spin-off company **Hydromethan AG** was founded in May 2010 to commercialize PSI's catalytic hydrothermal gasification process.
- Next steps: Pilot plant in Switzerland by 2011 ⇒ Demo plant by 2013
- Size range of commercial plants: ca. 5-50 MW<sub>biomass</sub>
- Possible feedstocks:
  - Manure
  - Sewage sludge
  - Distillers' dried grains & solubles (DDGS)
  - Fermentation residues (from anaerobic digestion)
  - Algae processing residues
  - Wet organic wastes and sludges from food processing etc.
- Advantages:
  - Full conversion of organic matter to SNG (including woody biomass)
  - Recovery of nutrients as a concentrated brine
  - High net process efficiency biomass-to-SNG of 60-70%
  - SNG can be obtained directly at high pressure (up to 300 bar)
  - Allows processing of a wide range of low-cost wet feedstocks and residues
- Prerequisite: pumpable feed with a minimum of ca. 10 wt% of organic matter



	conventional gasification & methanation	anaerobic digestion	hydrothermal gasification
feed type	Wood, grass ( $w_{\text{water}} < 15\%$ )	manure, household residues, sewage sludge	most wet types ( $w_{\text{water}} > 60\%$ )
thermal efficiency (biomass to SNG)	54 – 58 % [1] (feed absolutely dry)	25 – 35 % [2] ( $< 8\text{ wt \% DM manure}$ )	<b>62 – 71 % [3]</b> manure, wood, algae
residence time $\tau$	$< 1\text{ min.}$	<b>20 days [2]</b>	<b><math>&lt; 10\text{ min.}</math></b>
technological readiness	good (PDU 1 MW <sub>SNG</sub> in Güssing 2008)	<b>very good (commercially available)</b>	<b>not yet (1 MW<sub>th</sub> PDU planned 2011)</b>
	high efficiency for dry biomass, close to commercialization	established, commercialized	<b>full conversion, high efficiency, fertilizer by-product</b>
	low efficiency for wet biomass	residues, low efficiency, plant size	<b>technical barriers to be solved</b>

[1] A. Duret et al., Journal of Cleaner Production. 13(15), 2005: p. 1434.

[2] Y. Yoshida et al., Biomass & Bioenergy. 25(3), 2003: p. 257

[3] J. Luterbacher et al., Environ. Sci. & Technol. 43(5), 2009: 1578–1583.

- The resource basis for biomass is **limited**:
  - High area requirement;
  - Agricultural areas are primarily needed for food production;
  - Residual and waste biomass are sustainable resources (with a limited potential)
- Significant extension of sustainable resources only possible if independent of agricultural areas (⇒ **algal biomass**)
- Don't forget: Biomass is the only resource for organic carbon. Production of **materials** and **chemicals** will be a long-term target
  - ⇒ increased competition between biomass for energy and materials and chemicals.

- Methane is a universal and clean fuel, which can be produced with high efficiency from biomass and distributed by an existing gas grid.
- The ambitious European BioSNG objectives can only be reached by applying all BioSNG production routes:
  - Digestion
  - Conventional gasification of dry biomass
  - Hydrothermal gasification of wet biomass
- Conventional gasification of dry biomass
  - Technologically ready: A 1 MW SNG PDU has successfully been commissioned.
  - Biomass supply chain is important factor, which determines the optimum scale for biomass-to-SNG plants.
- Hydrothermal gasification:
  - Economically attractive: For feedstocks with high water content (removing water as vapor require a lot of energy).
  - Technologically challenging: Conversion in supercritical water using a catalyst. The separation and recovery of salts must be considered.
- Closed bioenergy systems, based on micro-algae and hydrothermal gasification, are a promising concept for CO<sub>2</sub> mitigation and BioSNG production, but much research work has still to be done!