Non thermal production of pure hydrogen from biomass: HYVOLUTION

H_2 Expo, Hamburg October 22-23, 2008

Disadvantages of fossil fuels

- Net increase of [CO_2]
  - Global climate change
- Security of supply
  - Geopolitical issues
  - Increasing price
- Pollution
- Exhaustible

→ Clear need for renewable energy

Sources of renewable energy

- Hydropower
- Wind
- Solar
- Geothermal

} Electricity

- Biomass

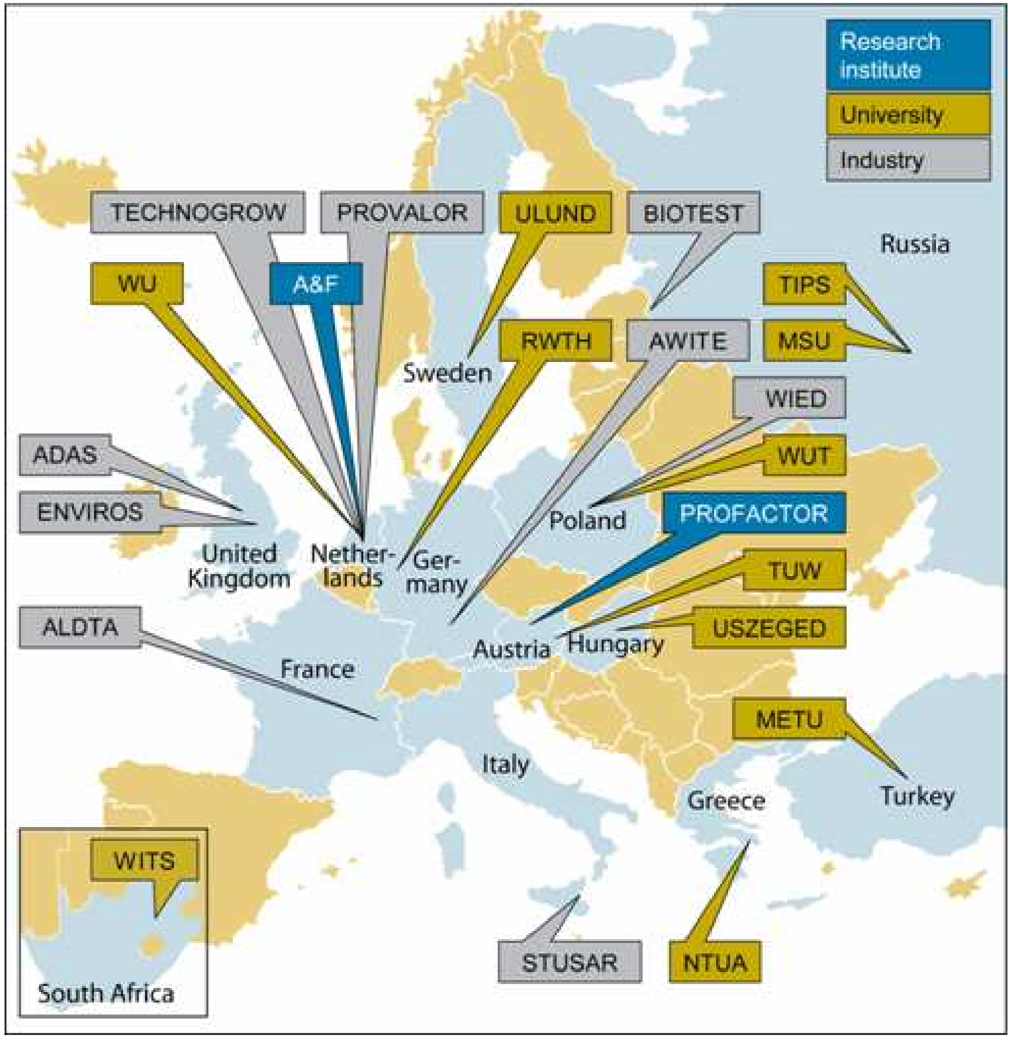
{ Electricity
Bio-oil/gas
Biodiesel
Ethanol
Methane
Butanol
Hydrogen

volution

HYVOLUTION: European FP6 project

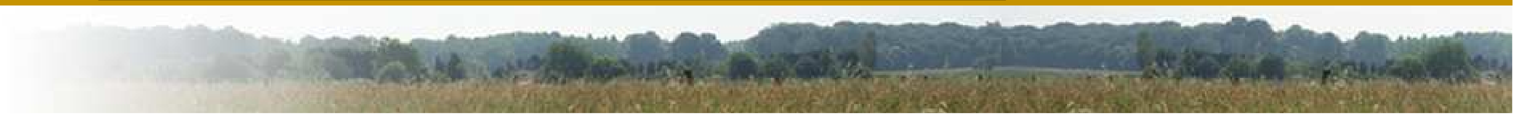
- non-thermal production of pure hydrogen from biomass
- 22 partners from 13 countries
- from January 2006 until January 2011
- 14 M€ budget
- 10 M€ EU grant

HYVOLUTION: the partners



HYVOLUTION: the partners

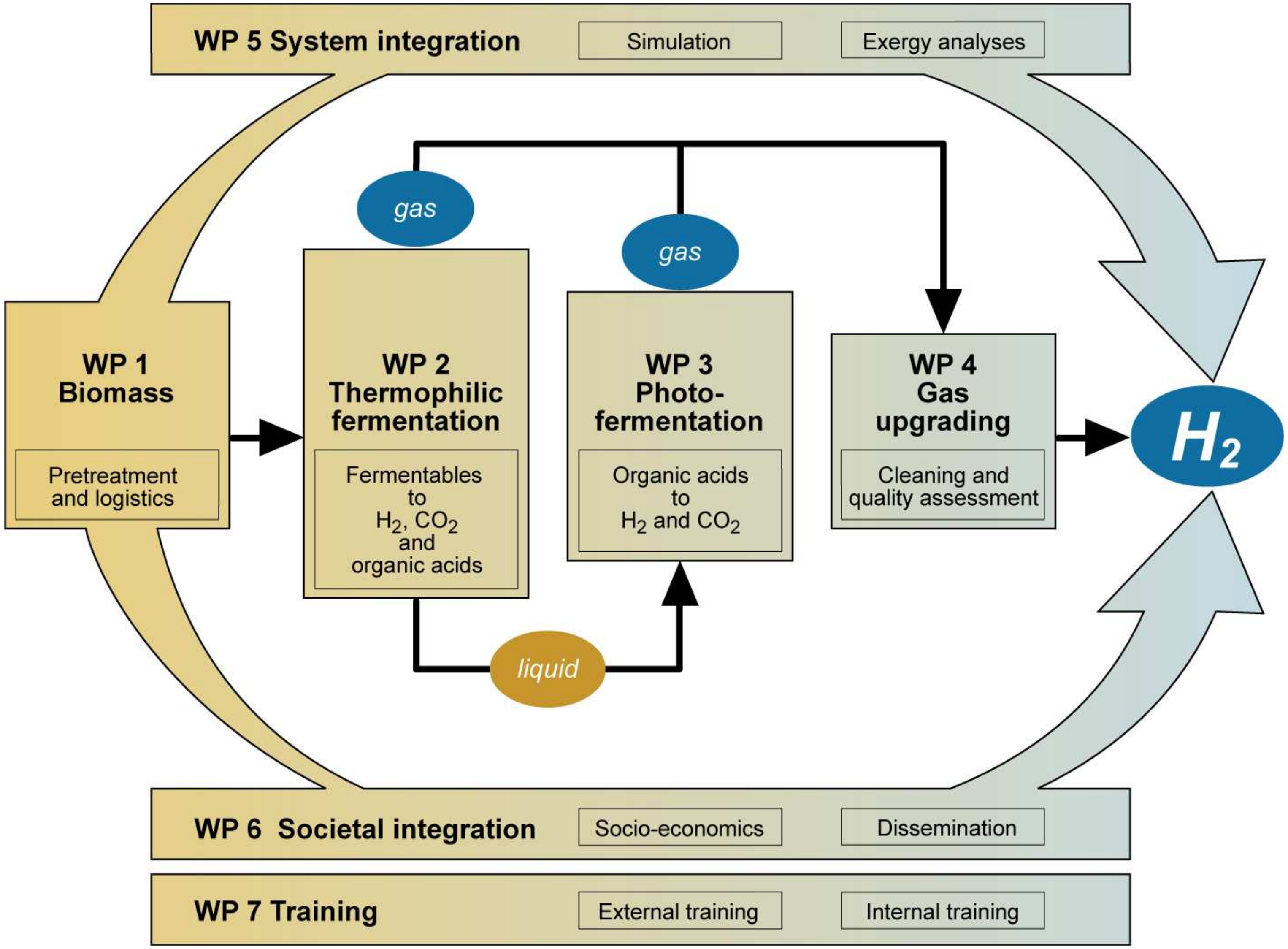
A&F Agrotechnology & Food Innovations	NL
ADAS	UK
AL DTA Air Liquide – Division des Techniques Avancées	FR
AWITE Awite Bioenergie,	GE
BIOTEST Bioreactors and membrane systems	RU
ENVIROS Ltd	UK
METU Middle East Technical University	TU
MSU Moscow Lomonosov State University	RU
NTUA National Technical University of Athens	GR
PROFACTOR Produktionsforschungs GmbH	AT
PROVALOR B.V.	NL
RWTH Rheinisch-Westfälische Technische Hochschule Aachen	GE
STUSAR Studio Sardo	IT
TECHNOGROW B.V.	NL
TIPS A.V. Topchiev Institute of Petrochemical Synthesis	RU
TUW Vienna University of Technology	AT
ULUND Lunds universitet	SE
U-SZEGED University of Szeged	HU
WIED Wiedemann Polska	PL
WITS University of the Witwatersrand	SA
WU Wageningen University	NL
WUT Politechnika Warszawska	PL



Aim of HYVOLUTION

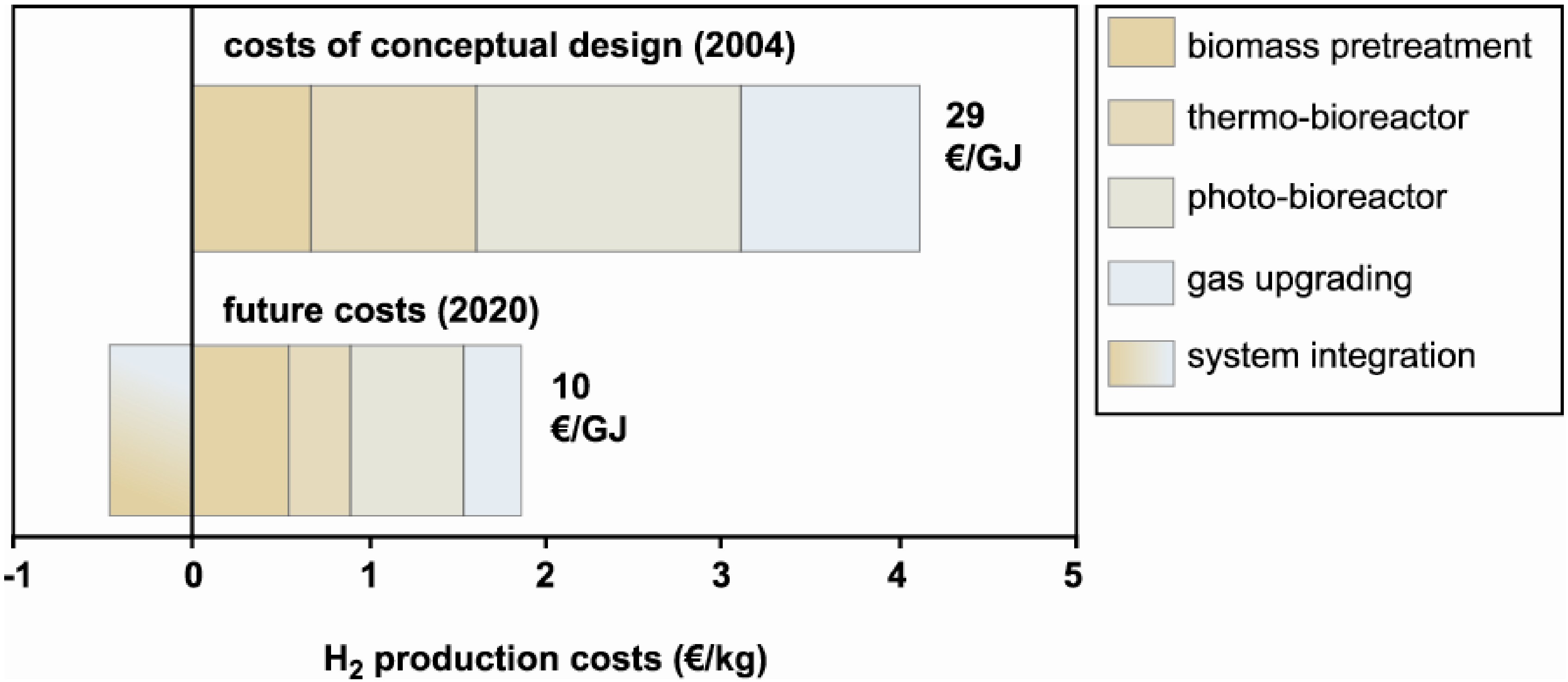
The aim of HYVOLUTION is to deliver prototypes of process modules which are needed to produce hydrogen of high quality in a bioprocess which is fed by multiple feedstocks

HYVOLUTION: the whole chain!



Development of a 2-stage bioprocess and construction of prototype modules for production of hydrogen as a 3rd generation biofuel

Target of HYVOLUTION



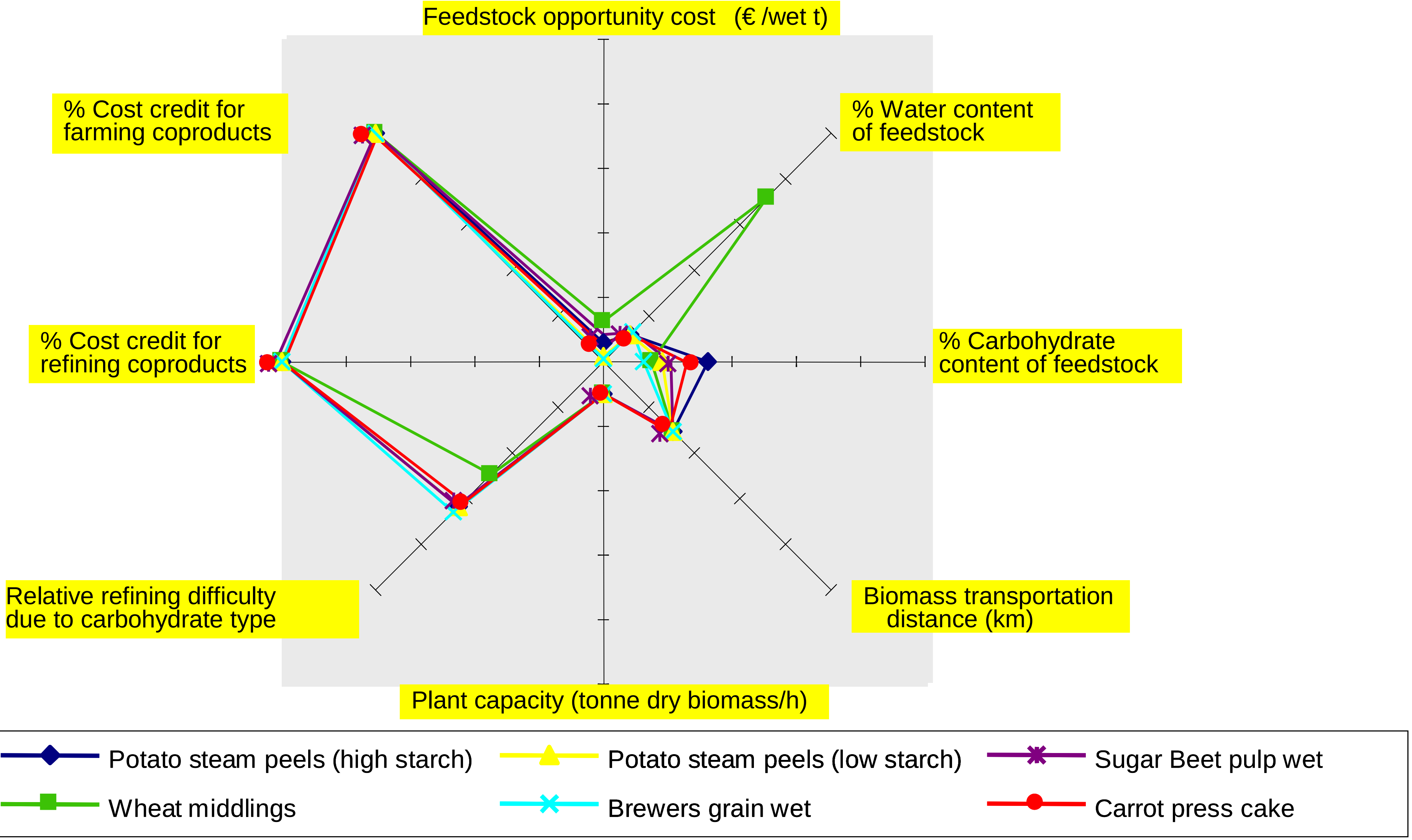
Production costs of hydrogen in a conceptual design deemed feasible and as envisaged for a hydrogen industry developed by HYVOLUTION

Potential biomass

- Residues from food processing: **potato steam peels**, molasses, carrot press cake, brewer‘s spent grain
- Sugar containing biomass: **sugar beet juice**, sweet sorghum juice
- Starchy biomass: potato, cereals, wheat grain, corn
- Lignocellulosic biomass: **wheat bran, barley straw**, wheat straw, sweet sorghum or sugar cane bagasse, Miscanthus, corn stover

Hydrogen production potential from selected feedstocks in EU-25:
~4 Mt/year ($\leq$10% of all selected biomass)

Methodology for selecting biomass



Miscanthus as energy crop

- Lignocellulose-rich feedstock
- Hydrolysate made by chemical (NaOH, NaAc) and enzymatic treatment (cellulase, ß-glucosidase)
- Approx 60% mobilisation efficiency



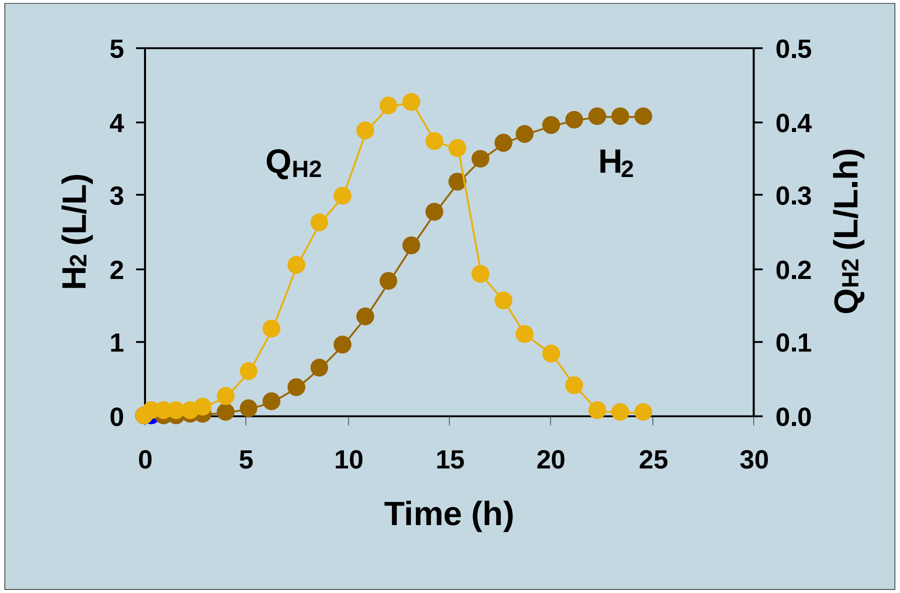
Potato steam peels as bioresidue

- Starch-rich feedstock
- Hydrolysates made by enzymatic treatment (amylase and glucoamylase)
- >95% mobilisation efficiency



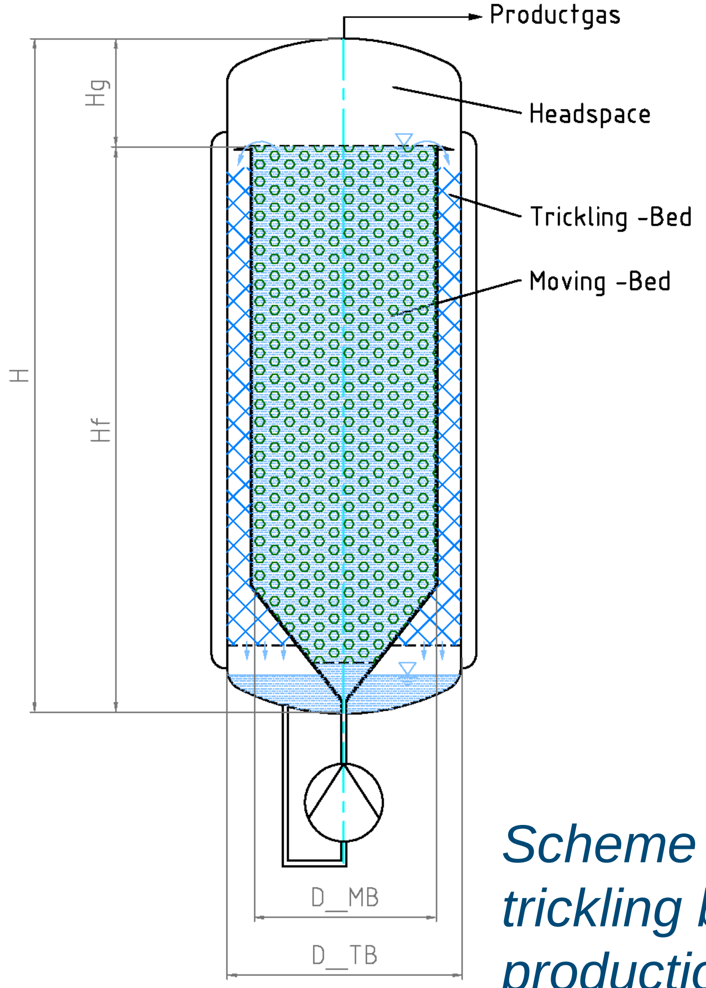
Bioprocess issues

- Strain selection
  - Yield
  - Productivity
  - Feedstock adaptation
- Strain improvement
  - Genetic modification
  - Hydrogen metabolism
- Robust fermentations
  - Mixed cultures
- Bioreactor configuration
- Process control



Cumulative hydrogen production and volumetric hydrogen production by C. saccharolyticus *during growth on hydrolysate of carrot press cake.*

Reactor for thermophilic fermentation



R&D issues:

- Material costs
- Pumps
- Low hydrogen pressure
- Ease of use
- Reactor volume
- Operation mode

Scheme of CMTB (combined moving and trickling bed) reactor for thermophilic hydrogen production from saccharides

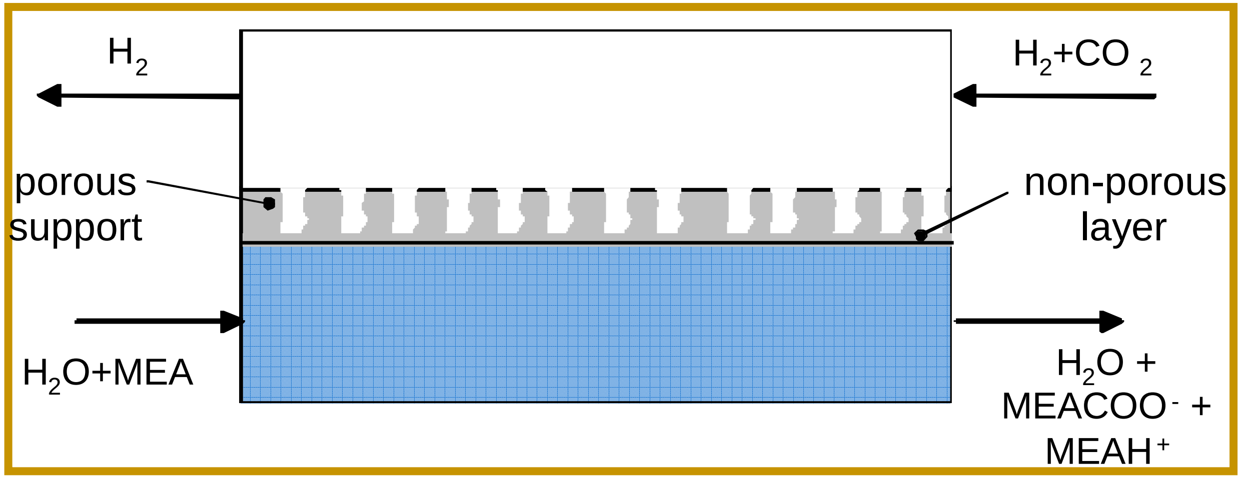
Reactors for photofermentation

R&D issues:

- PE, glass, EFTE….
- Evaluation of energy costs of production
- Ease of use
- Reactor area
- Ground area
- Reactor volume
- Operation mode

Outdoor operation of a tubular reactor (65 L) and a panel reactor (112 L) for phototrophic hydrogen production from acetate and lactate

Gas upgrading using a membrane contactor



Advantages

- No evaporation of the liquid carrier enables use of hazardous carriers
- No compression of the gas required
- Low energy demand for a liquid pump only
- Applicable for fluctuating gas flow rates and compositions
- Can be recycled after desorption

Development of sensor systems for process control

Process control requirements

- High concentration measurements (up to 100%)
- Commercial availability at low price
- Resistant to the main components (H_2, CO_2, H_2O, H_2S)
- Measurement of other components (O_2, CH_4)
- Low cross sensitivities

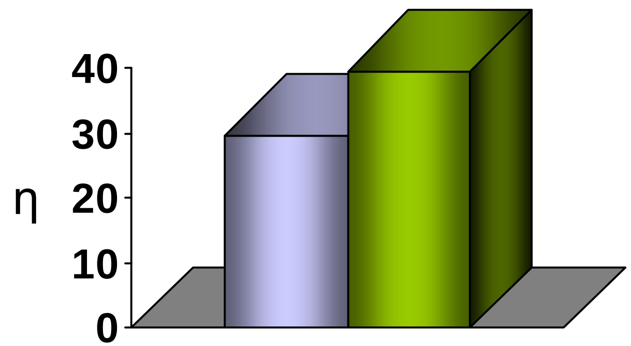
CO_2, CH_4, O_2: state of the art (infrared, electrochemically)
H_2 and H_2S: no sensor fulfils all requirements

⇨ Development of a dilution device

Mass and energy balance and exergy efficiency

- Aim: maximize product output and minimize energy demand and cost

Feedstock		**Wheat**	**Wheat**
Sugar concentration	Kg/L	**0.01**	**0.05**
Stripping		**No**	**CO_2**
Gas-upgrading		**VSA**	**MEA**
Feedstock	Kg/h	**1212**	**970**
Water	Kg/h	**179000**	**56000**
Strip-gas(CO2)	Kg/h	**0**	**1710**
H2 in raw gas	Mol/mol	**65**	**34**
Heat flow	kJ/s	**5100**	**2570**
Min. heat flow	kJ/s	**3700**	**2200**
Electric power	kJ/s	**210**	**120**
H_2 losses	%	**25**	**0**



$$\eta = \frac{\text{chemical exergy gases}}{\text{chemical exergy biomass}}$$

Conclusions: Increase sugar concentration, reduce water consumption, reduce energy demand, exploit process integration

Life cycle analysis

- Identification of environmental impacts
- Reference case H_2 production from natural gas

- Preliminary results:
  - Prevent use of strip gas
  - Replace NaOH by $Ca(OH)_2$
  - Recycle process water
  - Prevent addition of external nutrients

Acknowledgement

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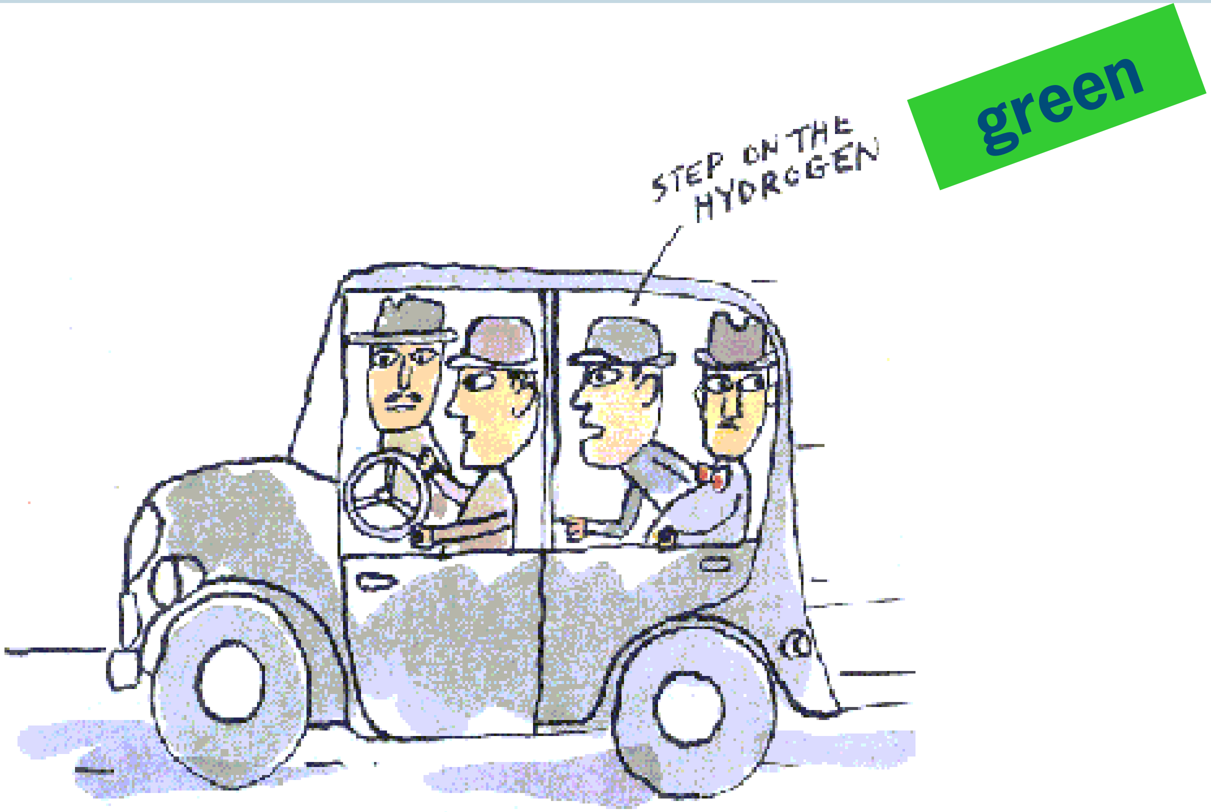
Hydrogen as the future bio-fuel



Thank you for your attention!

www.hyvolution.nl