

Non thermal hydrogen production from biomass

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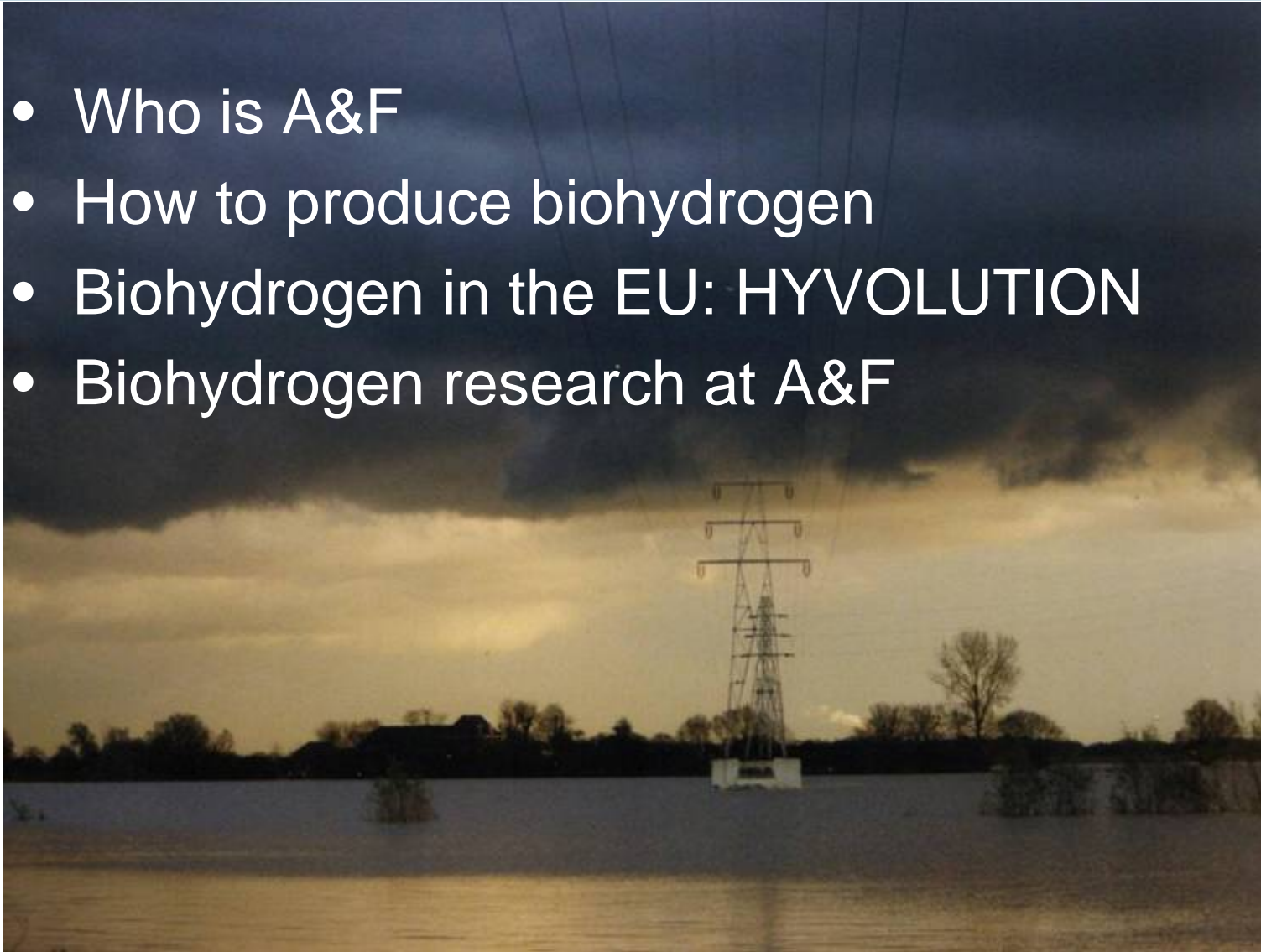


www.biohydrogen.nl; www.hyvolution.nl

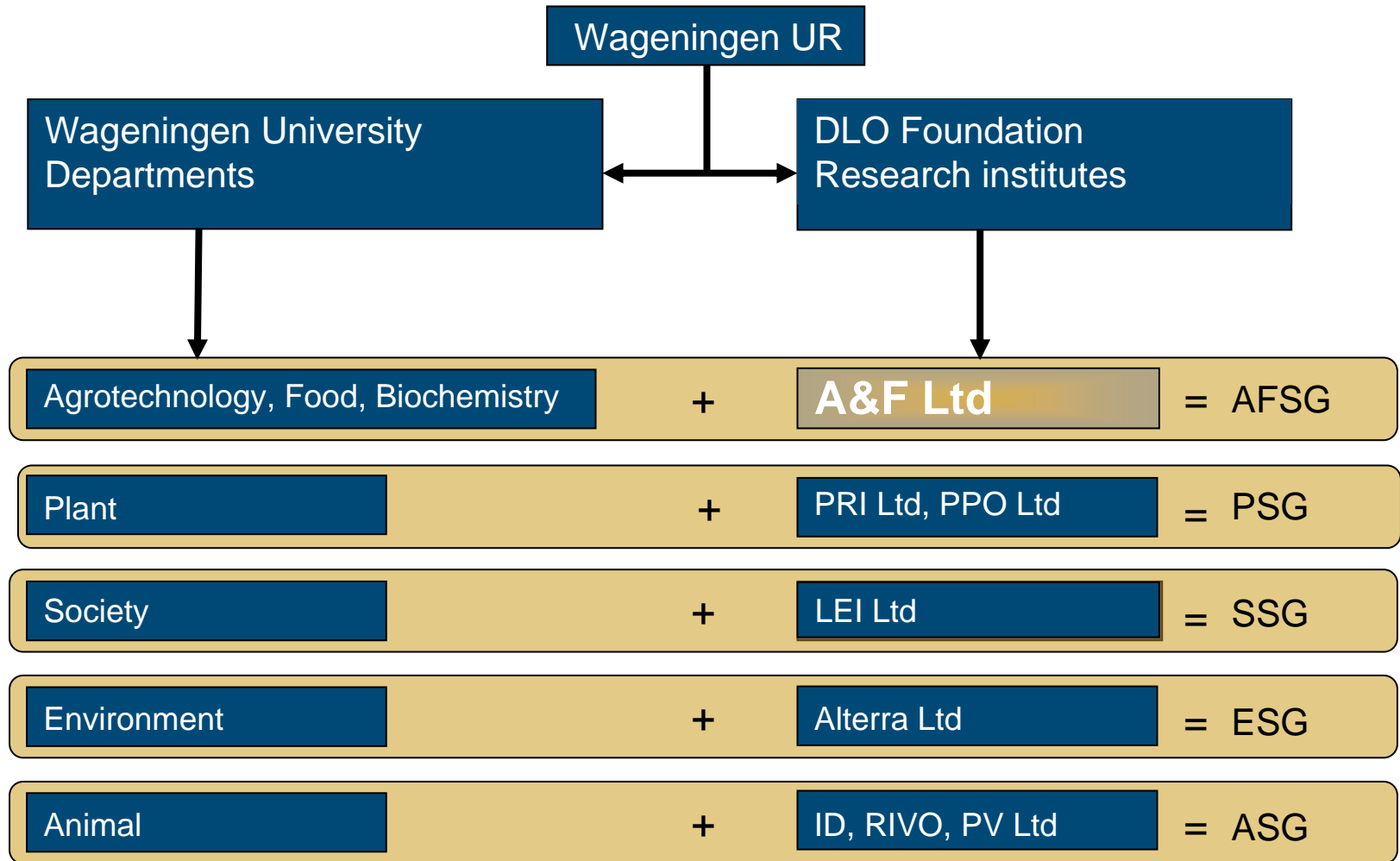


Programme of the lecture

- Who is A&F
- How to produce biohydrogen
- Biohydrogen in the EU: HYVOLUTION
- Biohydrogen research at A&F



Wageningen UR and its Sciences Groups



A&F Business Unit Biobased Products

Biobased Products

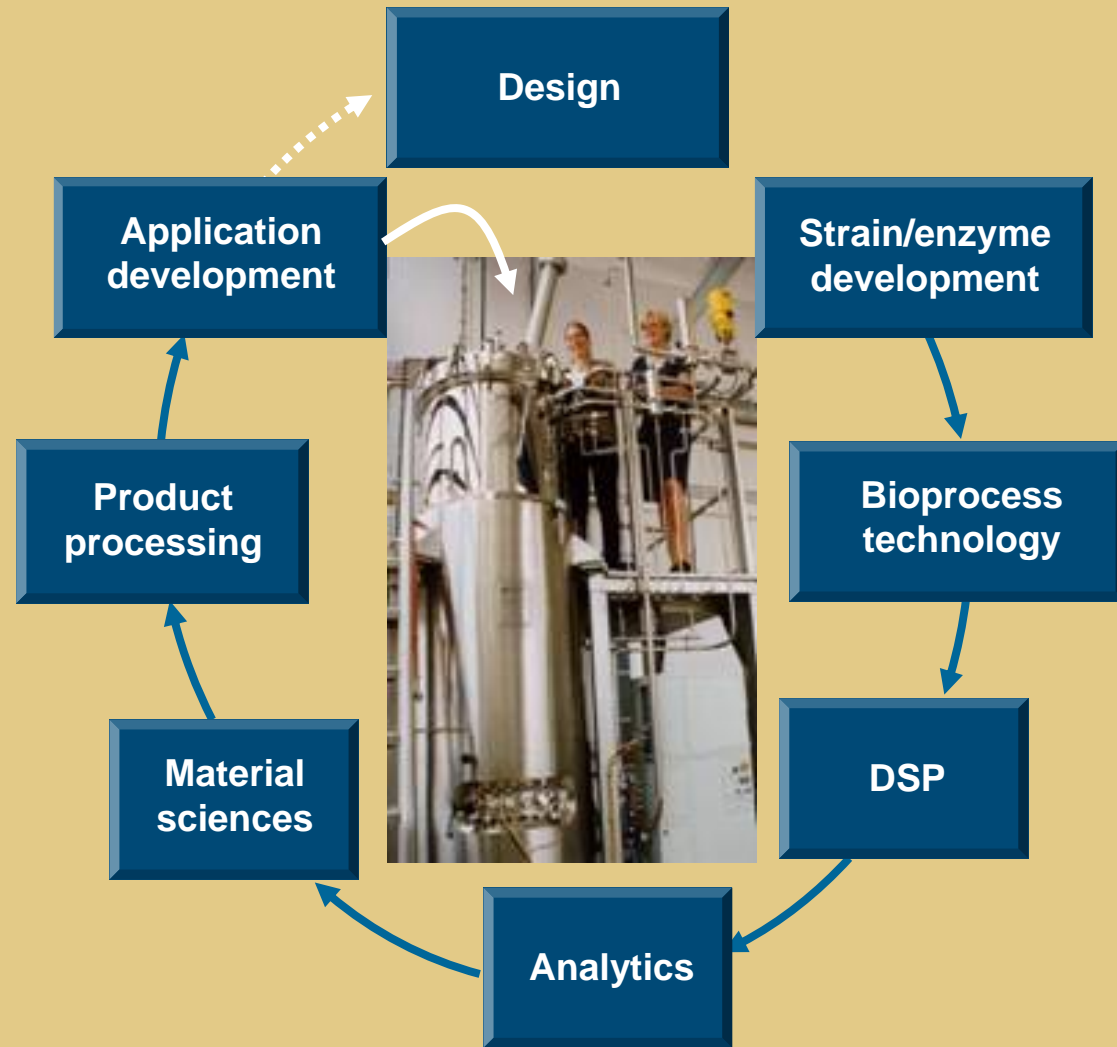
Performance materials

Performance chemicals

Base chemicals

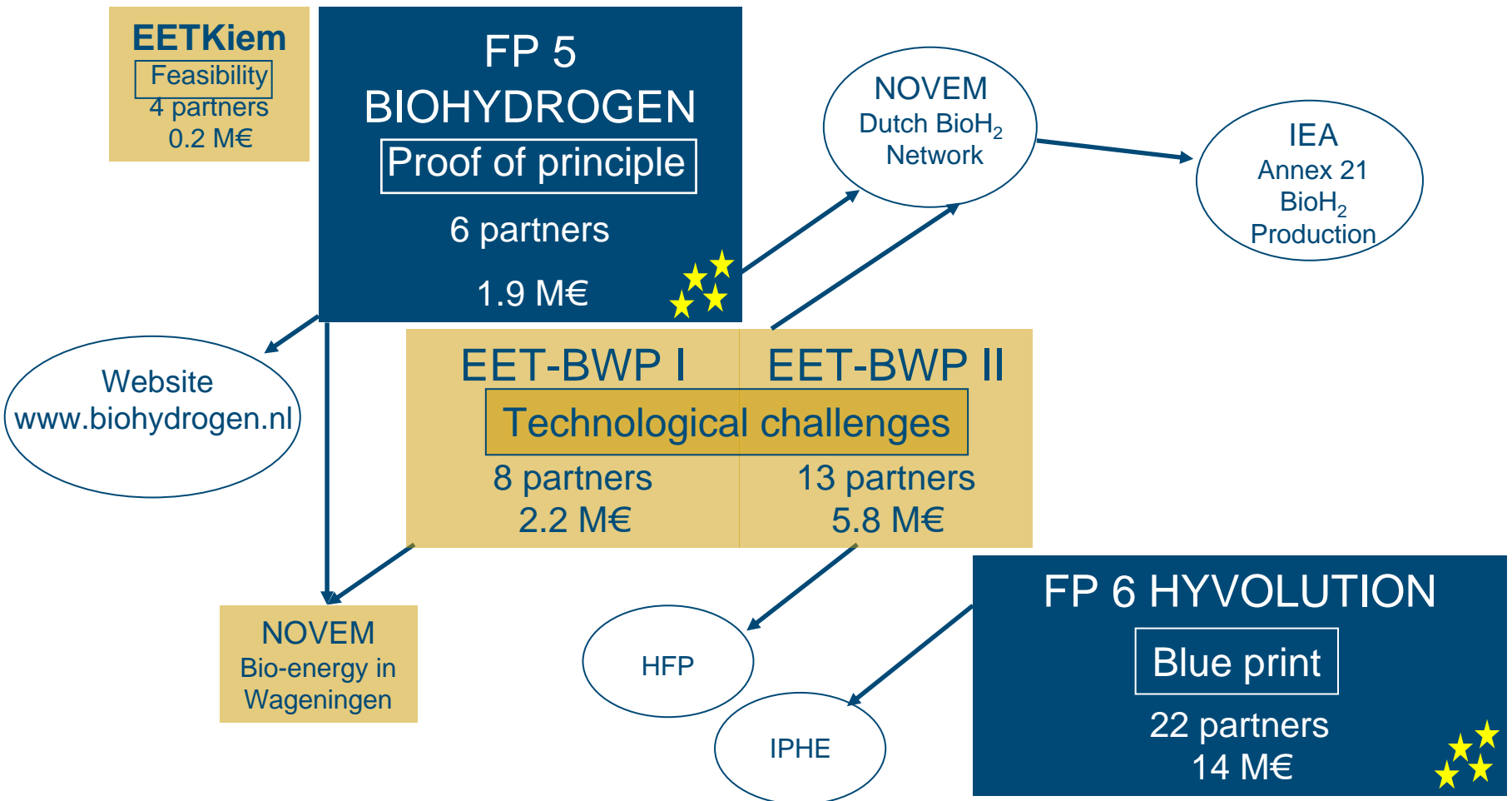
Bio-energy

Recycling

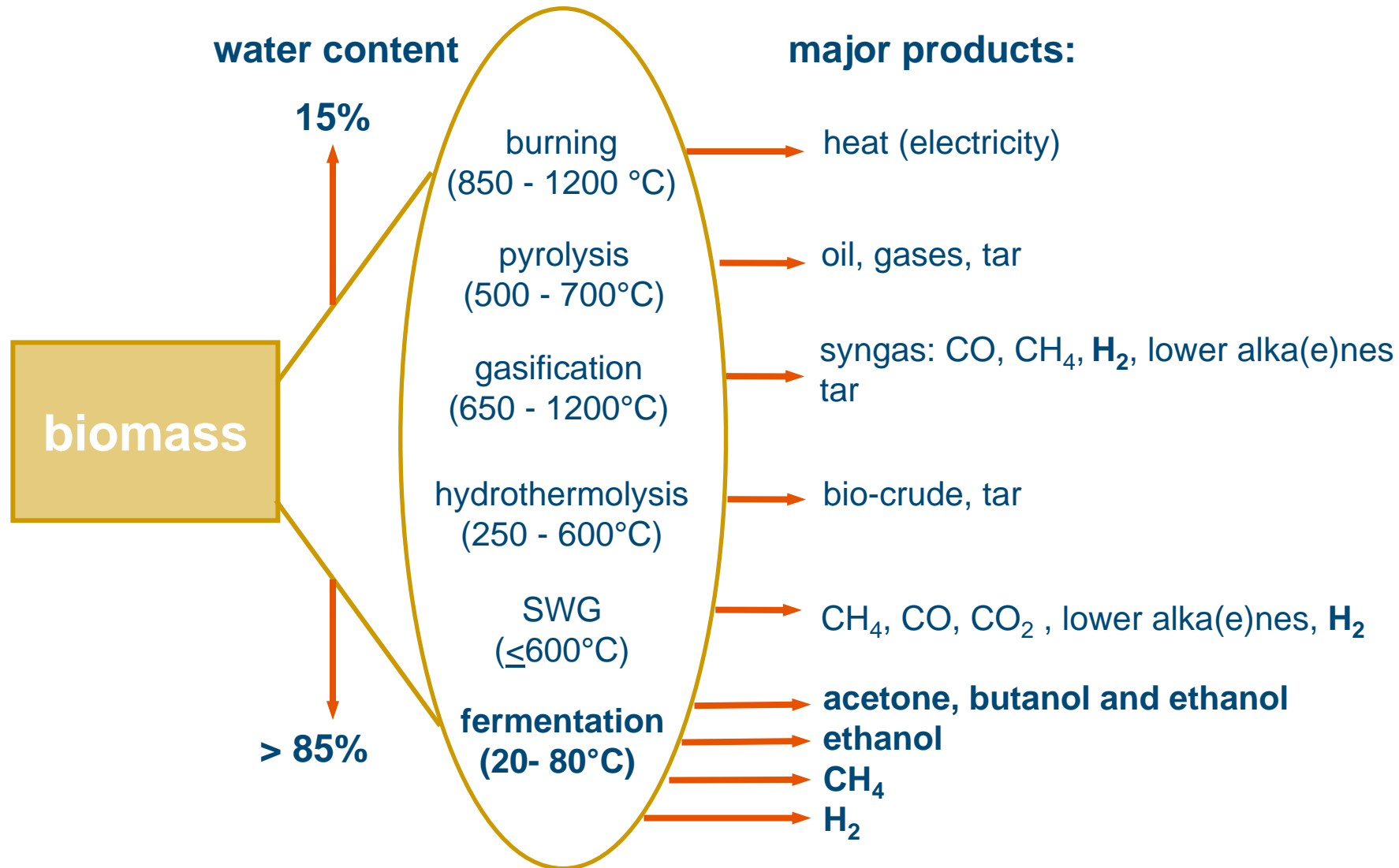


History of biohydrogen research at A&F

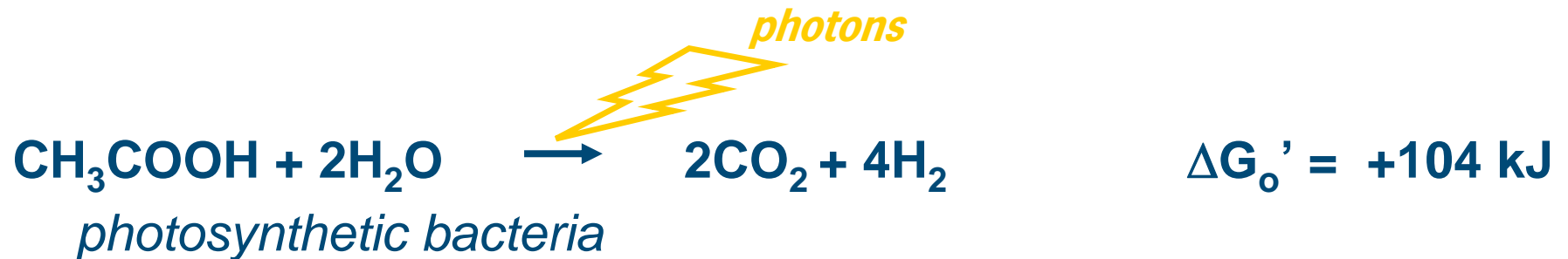
1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | **2006** | **2007** | **2008** | **2009** | **2010** | 2011



Biomass to energy conversion technologies



The theory of the hydrogen bioprocess



Unique selling points at A&F

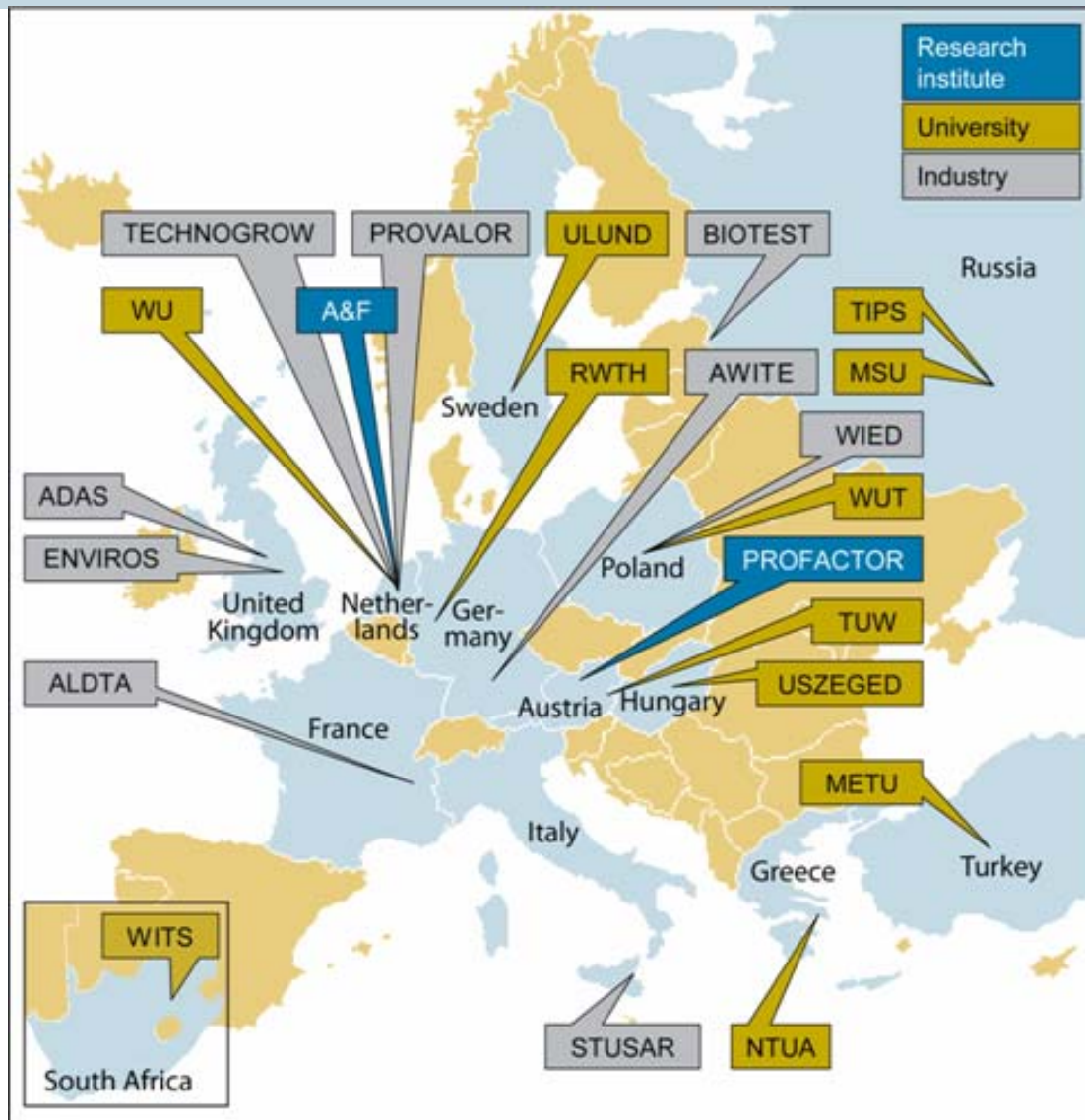
Thermophilic fermentation (70 - 80 °C):

- High yield on various saccharides: ± 3.2 mol H₂
- High selection pressure
 - Temperature
 - Low hydraulic retention time
 - Neutral to acidic pH
- Sanitation

Coupling of thermophilic and phototrophic fermentation:

- High efficiency: ± 8 mol H₂

Partners in FP6-SES: HYVOLUTION

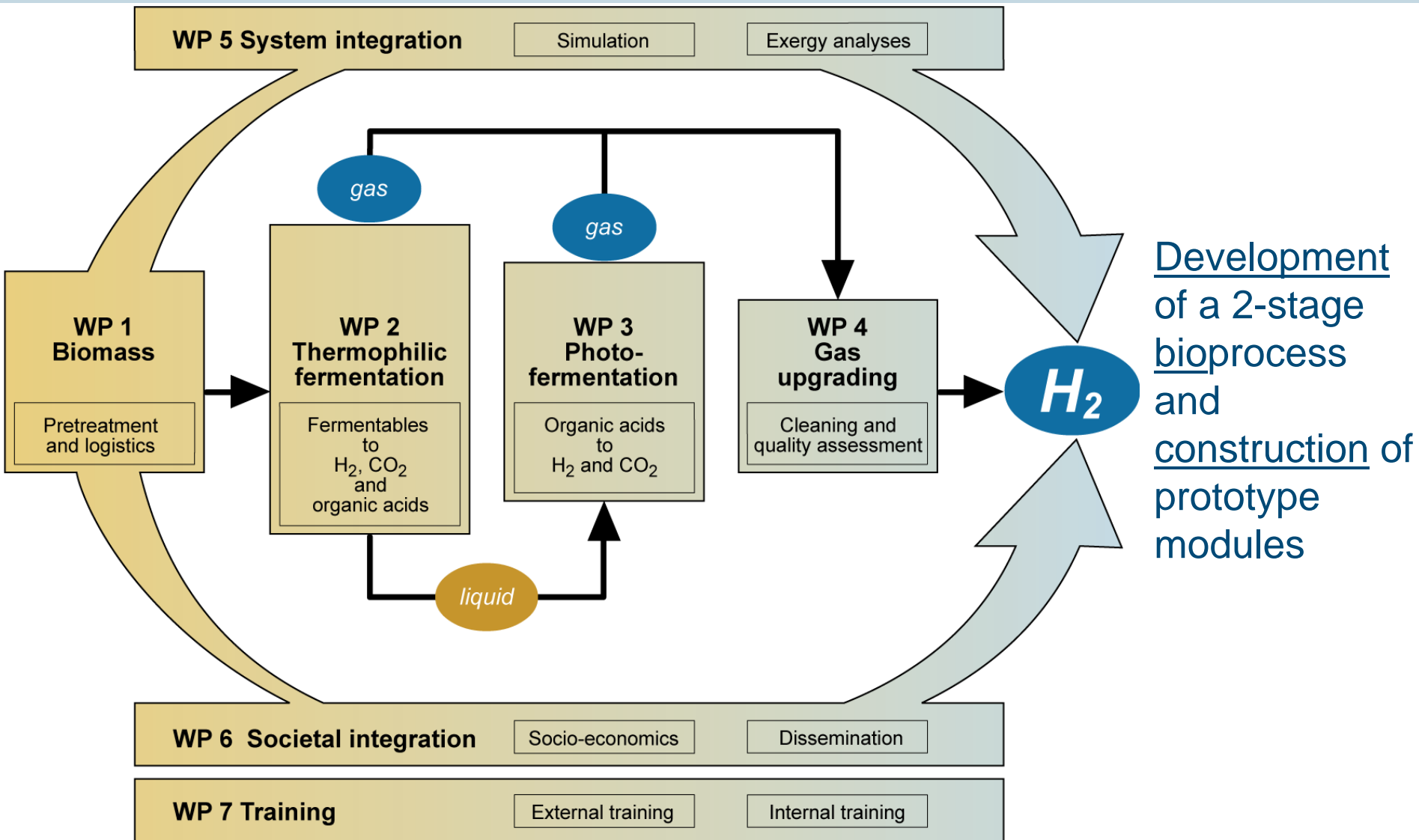


HYVOLUTION:

Non-thermal production of pure hydrogen from biomass

- 22 partners from 13 countries
- January 2006 – January 2011
- 14 M€ budget
- 10 M € EU grant

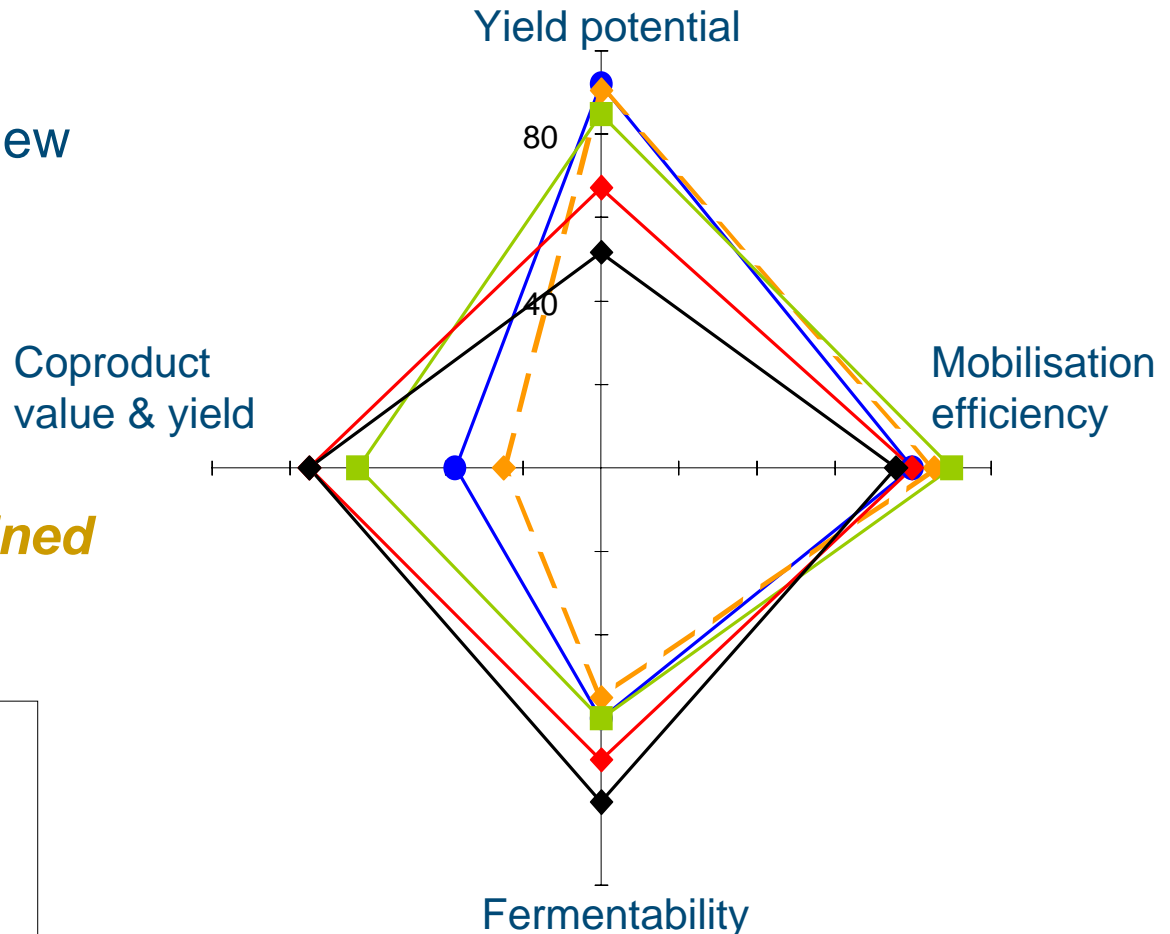
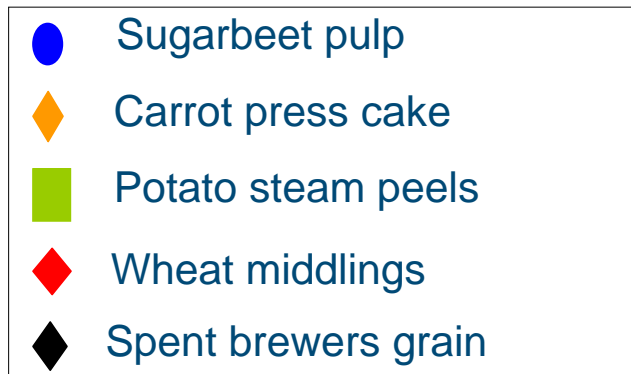
HYVOLUTION: the whole chain!



WP 1 BIOMASS

- Data collection on suitability/availability
- Field experiments with new biomass
- Pretreatment
- Modelling of biomass potential

Construction of combined cost-suitability maps



Technical suitability map (preliminary)

WP 2 THERMOPHILIC FERMENTATION

- Cellulose degrading thermophiles
- New hydrogen thermophiles, pH_2 effects
- Genome of *C. saccharolyticus*, metabolic pathways on various sugars
- Fermentation of mixtures of (poly) saccharides in CSTR bioreactors
- Construction of bioreactors

**>75% conversion efficiency
achieved at 15 mmol/L.h**

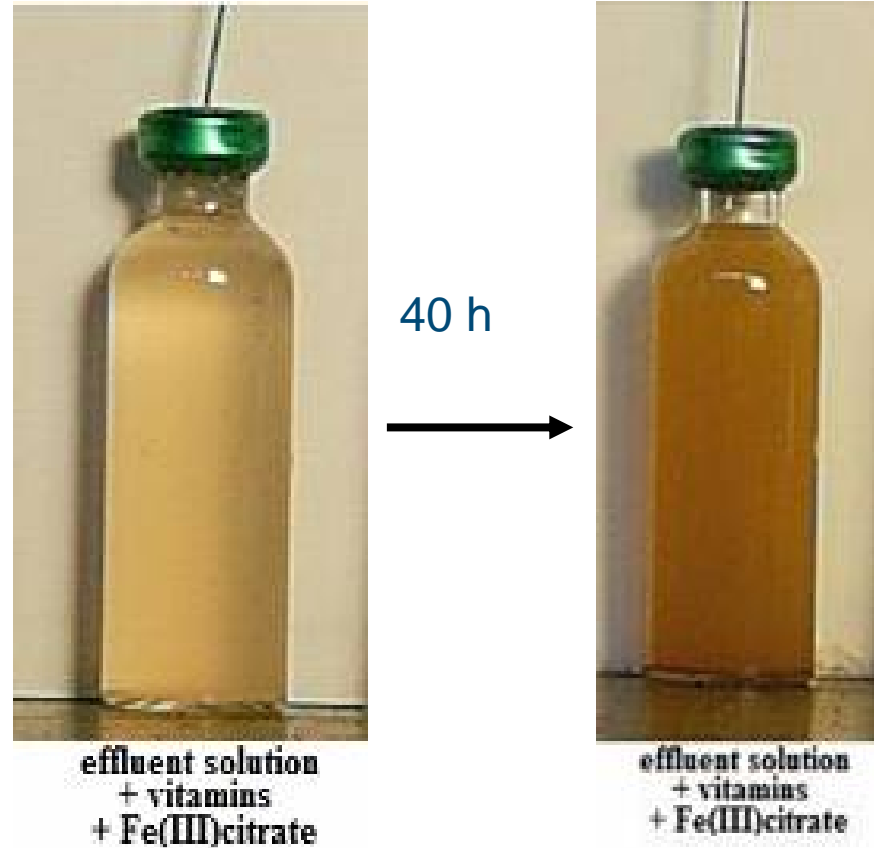


Fixed bed bioreactor at Profactor

WP 3 PHOTOFERMENTATION

- Conversion efficiencies on acetate/lactate for *R. capsulatus*
- Development of genetic tools
- Phototrophic H₂ production from (thermophilic) effluents
- Construction of photobioreactors

**75% conversion efficiency
achieved at 0.7 mmol/L.h**



Growth of *R. capsulatus* on effluent from *Miscanthus* hydrolysate fermentation (86 % H₂, 14% CO₂) at RWTH

WP 3 PHOTOFERMENTATION

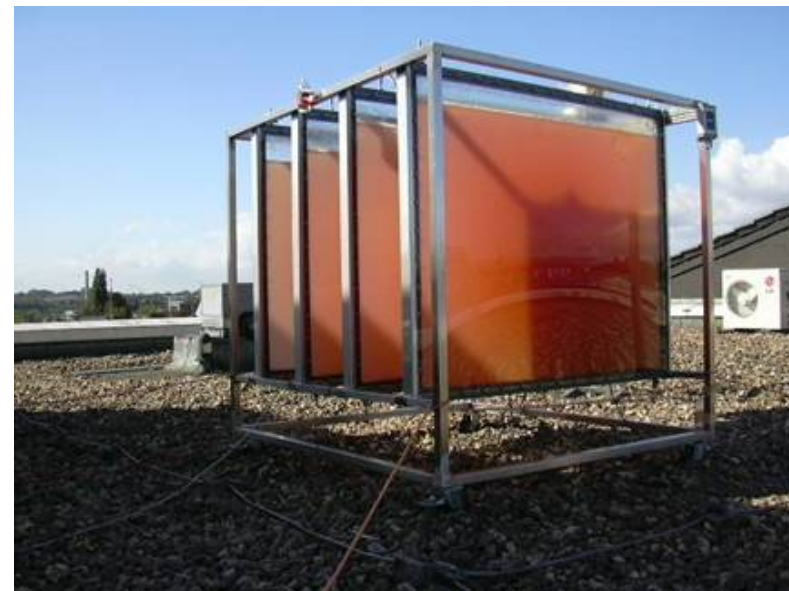


Greenhouse at Technogrow



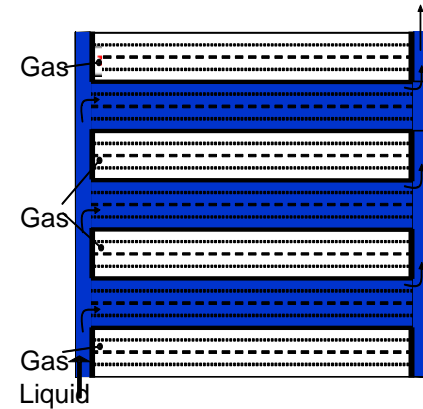
RWTH

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



WP 4 GAS UPGRADING

- Upgrading/storage options for HYVOLUTION H₂
- Devices for monitoring (H₂ dilution device)
- CO₂ removal with membrane contactor prototype
- Implementation using MEA or K₂CO₃
- Determination of 30% CO₂ tolerance of fuel cell



Membrane module from TIPS and BIOTEST

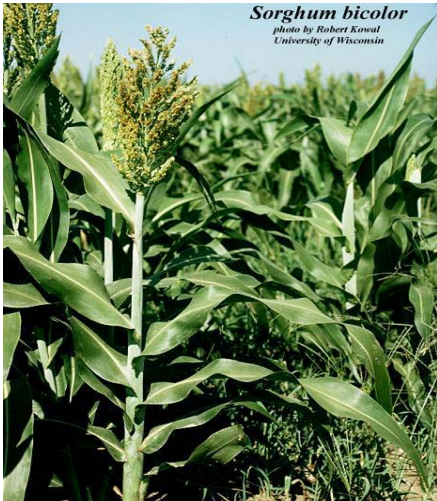


Prototype gas-sensor at AWITE

Wageningen UR A&F



A&F: Biomass



Sorghum bicolor



Carrot press cake



Paper sludge



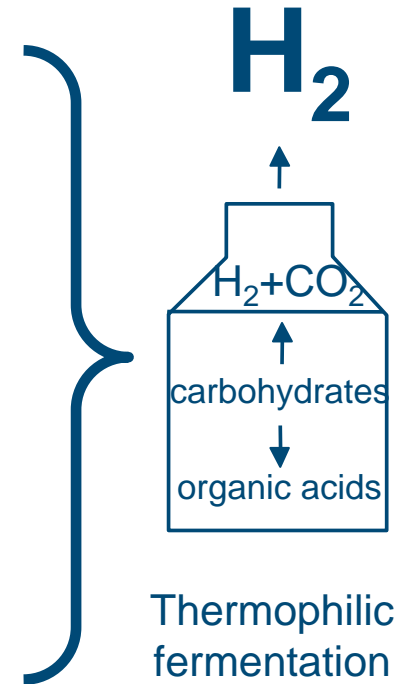
Potato steam peels



Organic waste

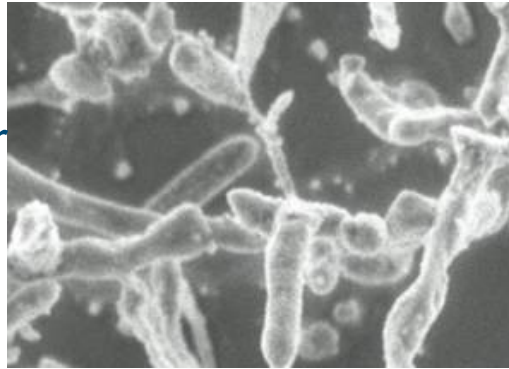


Miscanthus

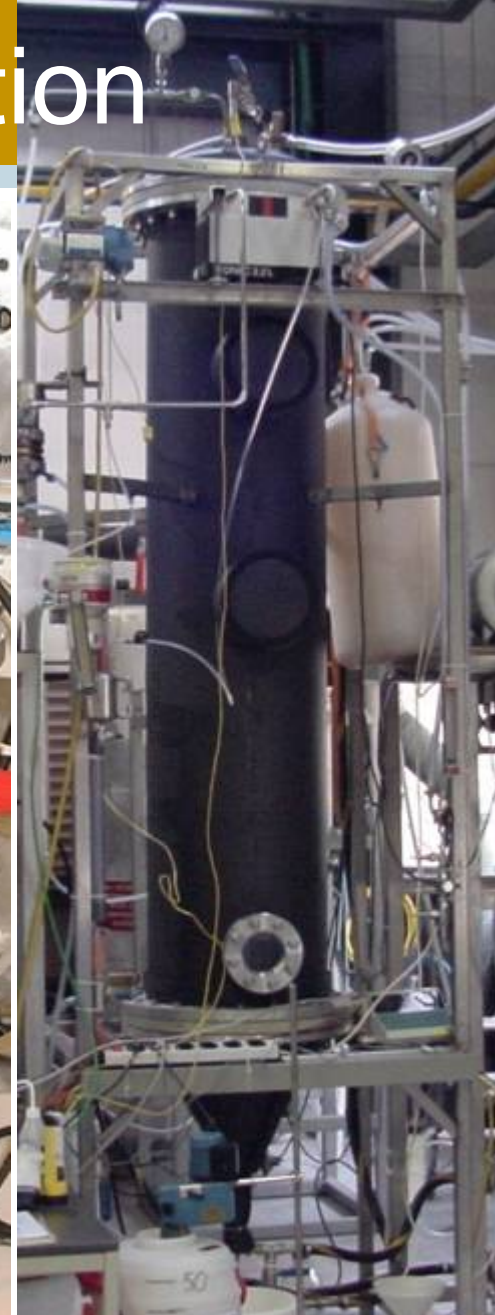


A&F: Thermophilic fermentation

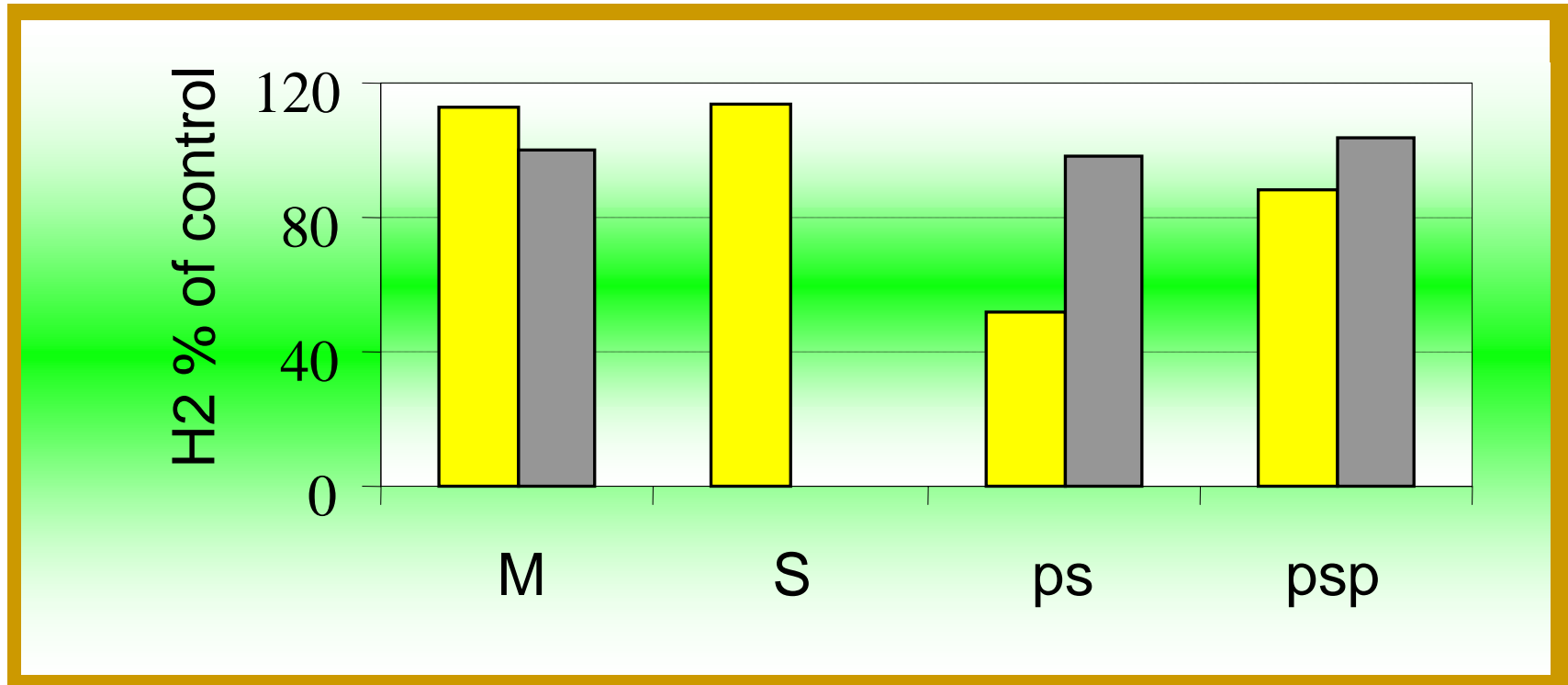
*Caldicellulosiruptor
saccharolyticus*



30 mL suspension
to 400 L trickle bed
cultures with 66% H₂
in dry gas
(A&F and TNO)



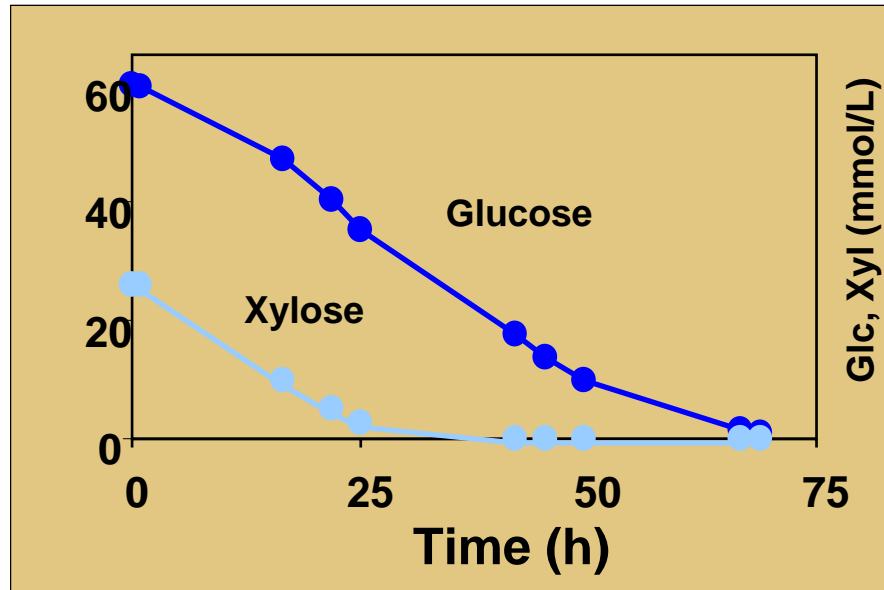
Thermophilic H₂ production from biomass



H₂ production by *Caldicellulosiruptor saccharolyticus* (yellow) and *Thermotoga elfii* (grey) on enriched sweet sorghum juice (S) or hydrolysates of *Miscanthus* (M), paper sludge (ps) and potato steam peels (psp)

Thermophilic fermentation of Miscanthus

Sugar utilisation and hydrogen production by *Caldicellulosiruptor saccharolyticus* on enriched hydrolysate of Miscanthus.

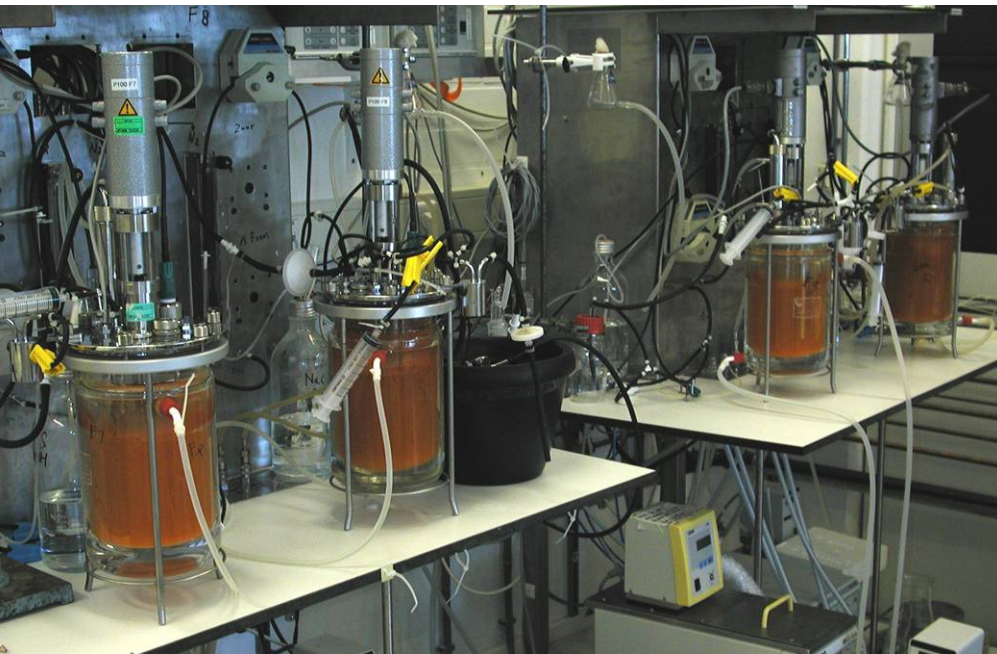


	Pure sugars	Miscanthus
End of fermentation (h)	34	69
Total H ₂ production (L/L)	5.7	7.2
Max. volumetric H ₂ production (mL/L.h)	290	233

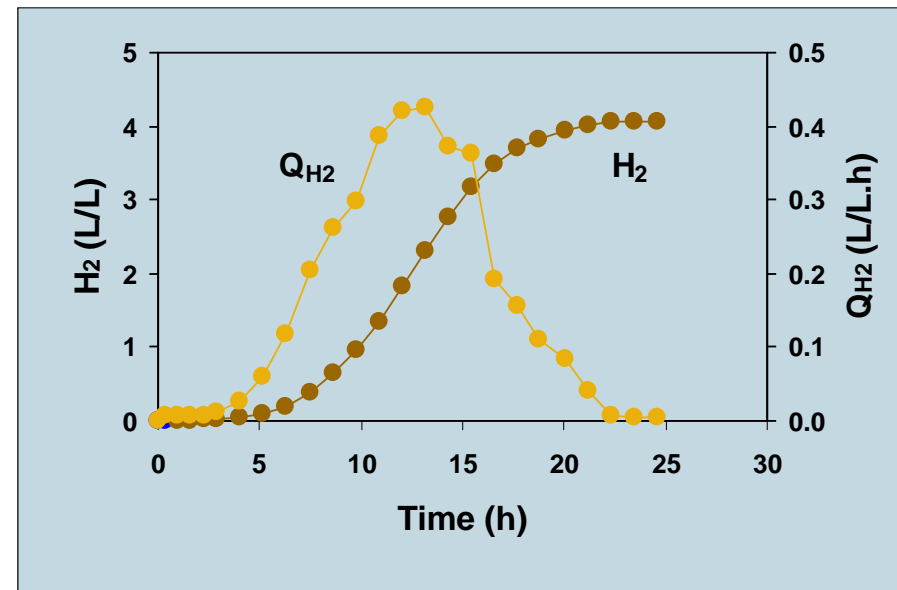
Thermophilic fermentation of carrot press cake



Sugar-rich feedstock with some cellulose. Enzymatic treatment with cellulase and β -glucosidase. Carrot press cake was provided by Provalor B.V., NL



*Batch cultures of *C. saccharolyticus* (70 °C, left) and *T. neapolitana* (80 °C, right) on carrot press cake at 10 (left) and 20 (right) g sugar/L.*



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

Hydrogen production from bioresidues in CSTR

Sugar to H₂ conversion efficiency

Y_{H_2} (mol/mol C6-eq)	<i>C. saccharolyticus</i>	<i>T. neapolitana</i>
Batch cultures	10 g sugars/L	
Potato steam peels (glucose)	3.1	2.9
Potato steam peels (oligo)	2.6	2.9
Carrot press cake	2.5	2.6
Miscanthus	3.1	2.7

Note: at higher sugar concentrations a decrease in yield is observed

Conclusion: Hydrogen is the future bio-fuel



www.biohydrogen.nl;
www.hyvolution.nl