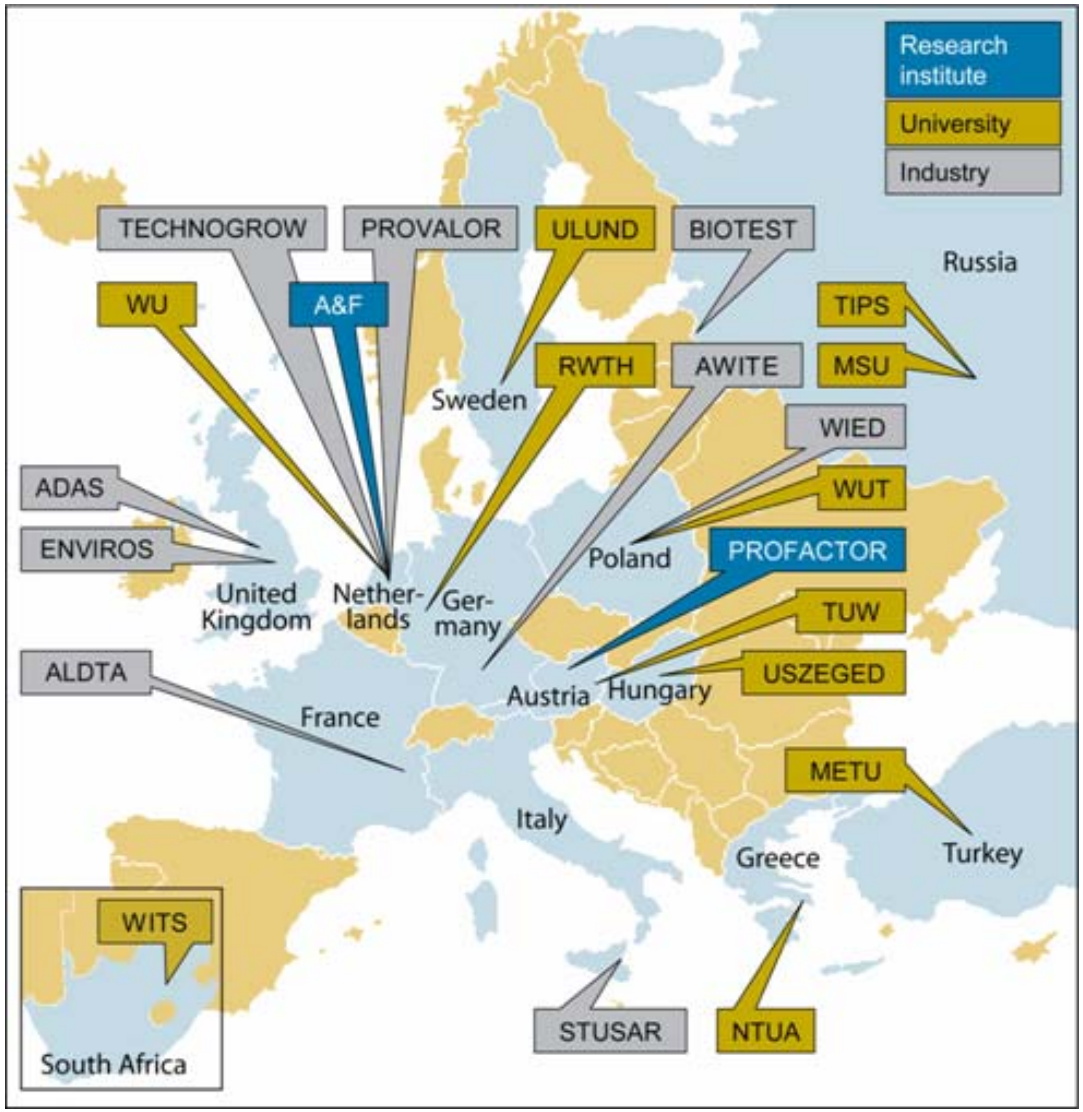
Non-thermal production of pure hydrogen from biomass

EU FP6-SES Integrated Project

HYVOLUTION

Pieternel Claassen on behalf of partners in HYVOLUTION: www.hyvolution.nl

Partners in HYVOLUTION

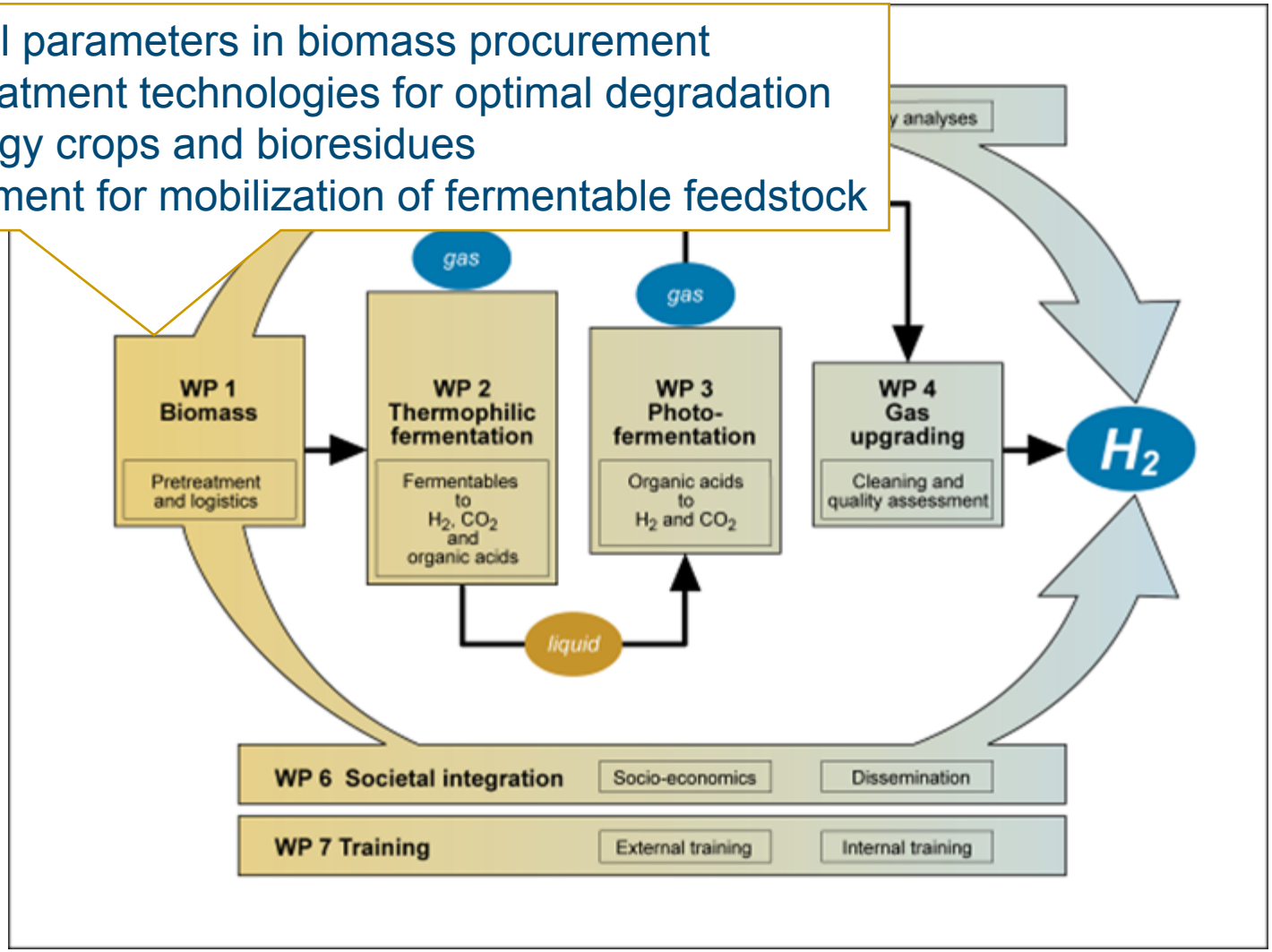


Aim:
Blue print for a bioprocess for decentral hydrogen production from biomass

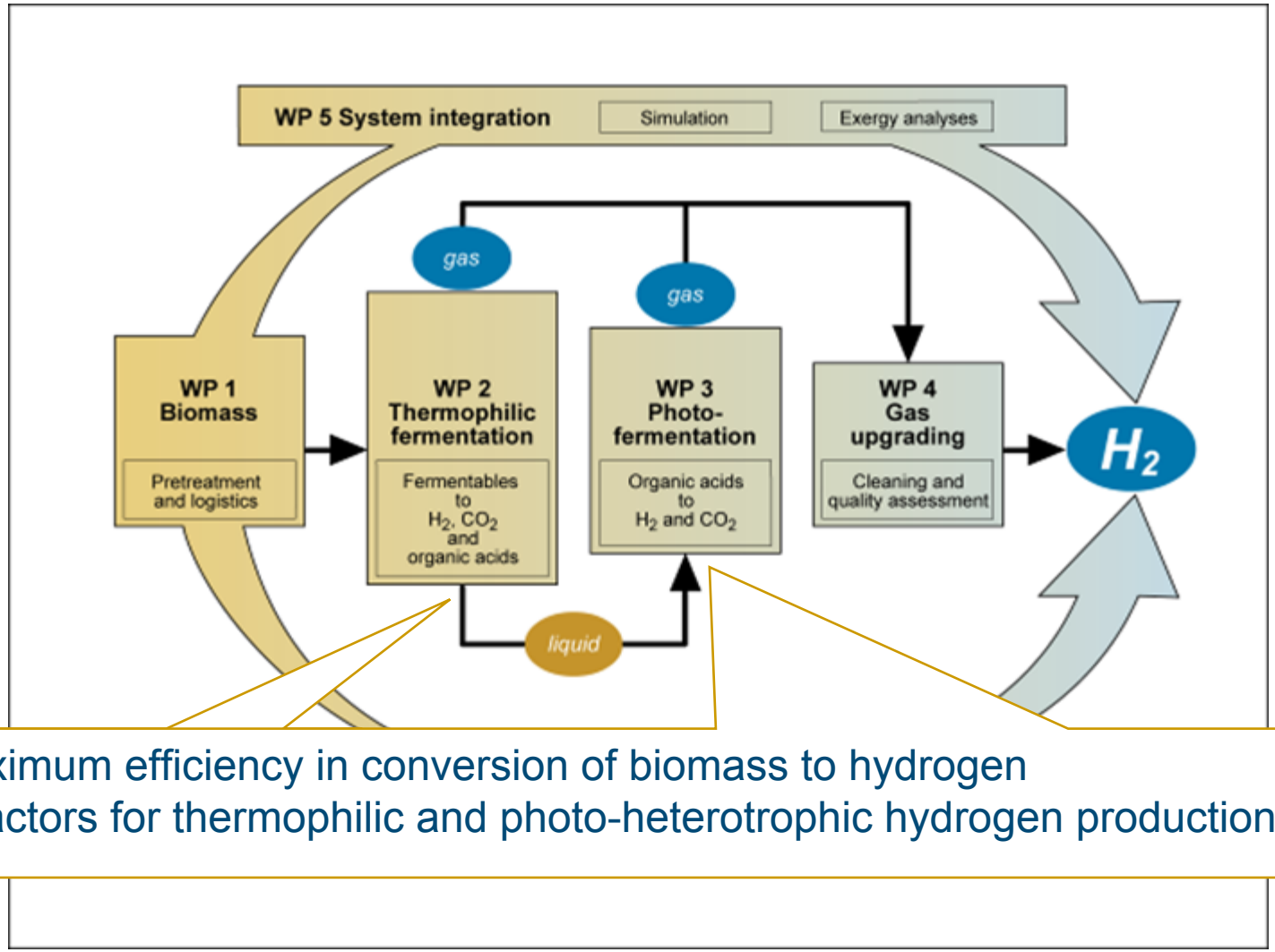
22 partners
13 countries
Jan 2006 – Dec 2010
14 M€ budget
10 M€ EC grant
www.hyvolution.nl

Objectives in workpackages

-Critical parameters in biomass procurement
-Pretreatment technologies for optimal degradation of energy crops and bioresidues
-Equipment for mobilization of fermentable feedstock

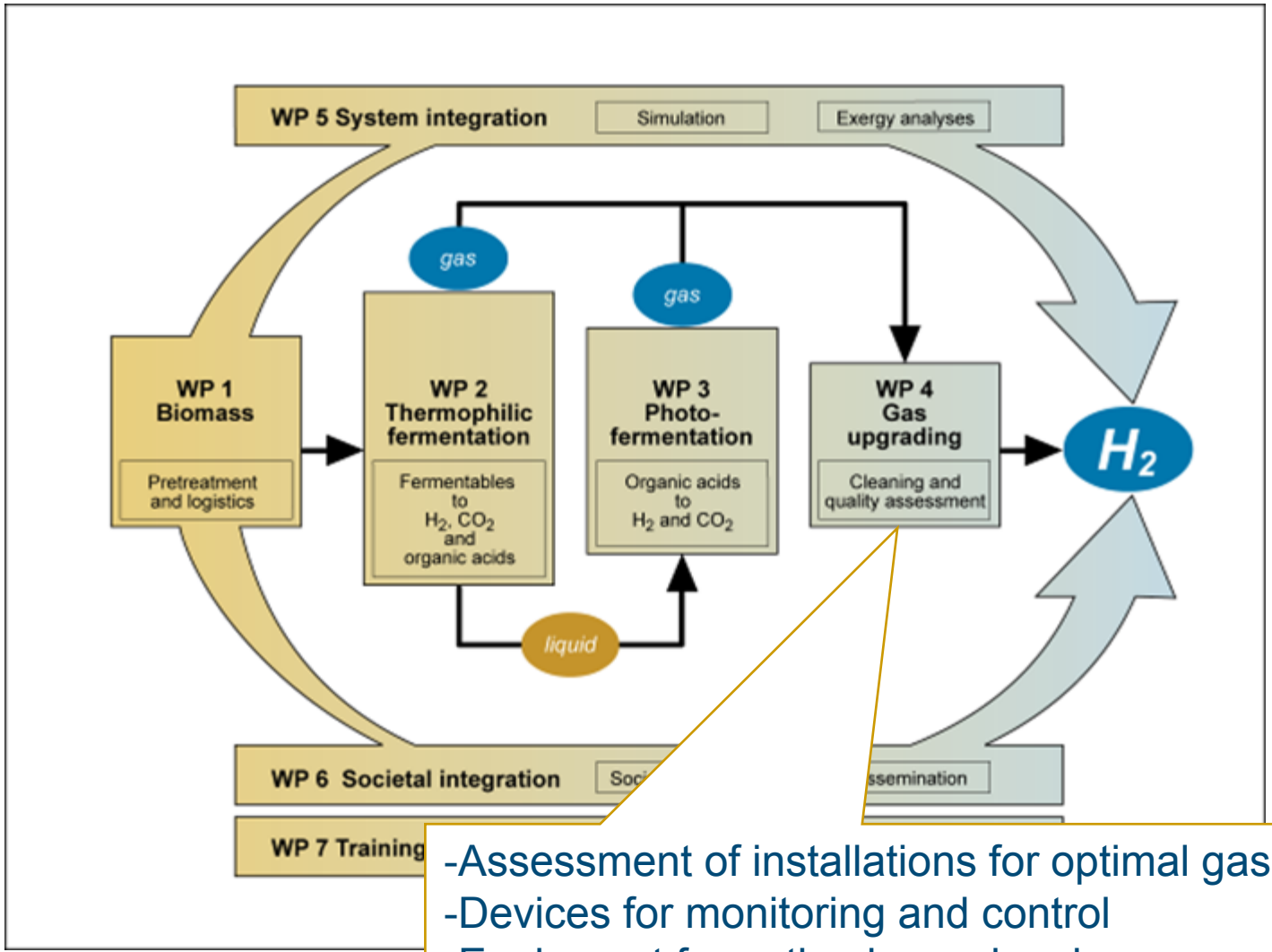


Objectives in workpackages



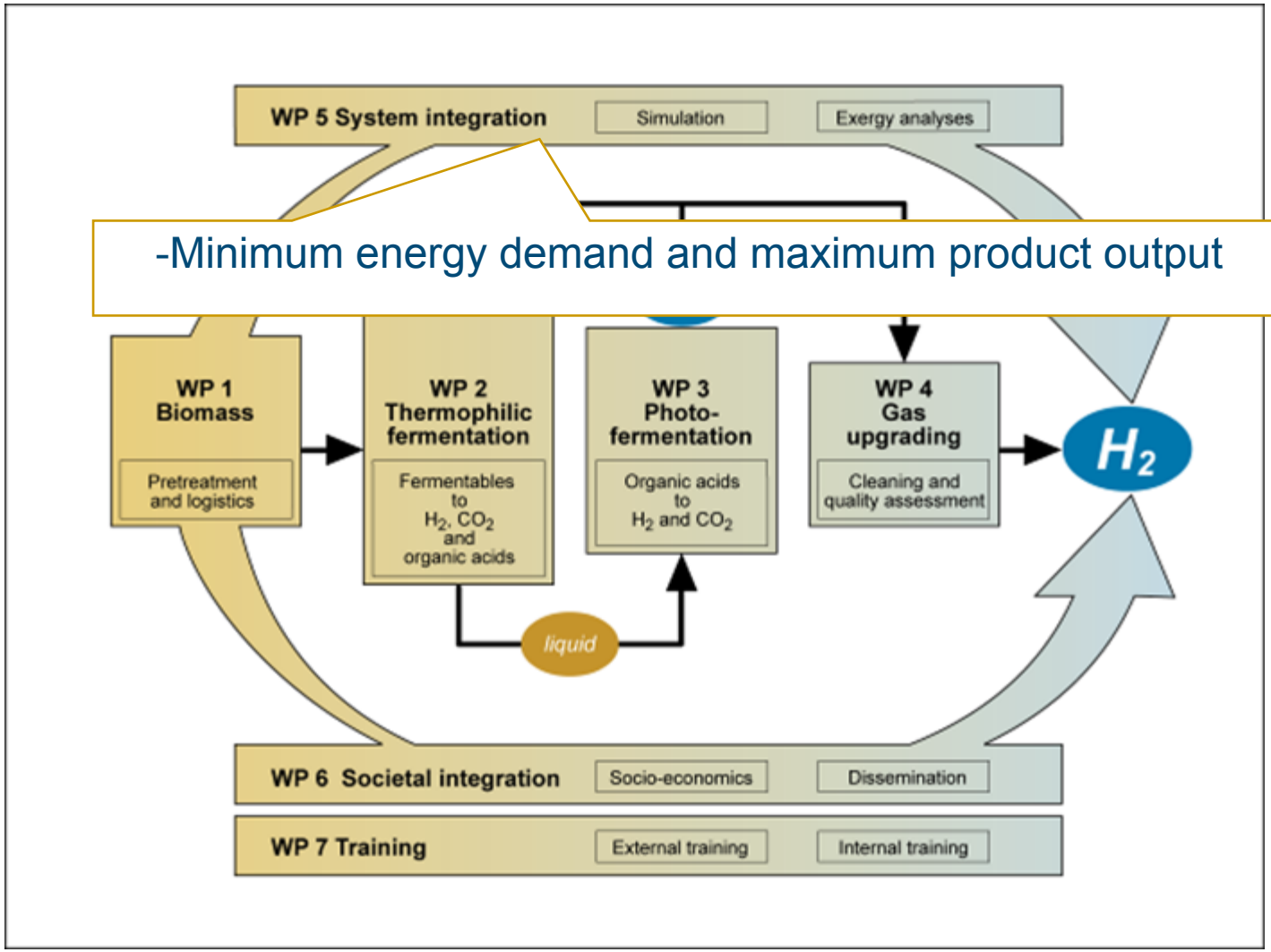
-Maximum efficiency in conversion of biomass to hydrogen
-Reactors for thermophilic and photo-heterotrophic hydrogen production

Objectives in workpackages



-Assessment of installations for optimal gas cleaning
-Devices for monitoring and control
-Equipment for optimal gas cleaning

Objectives in workpackages



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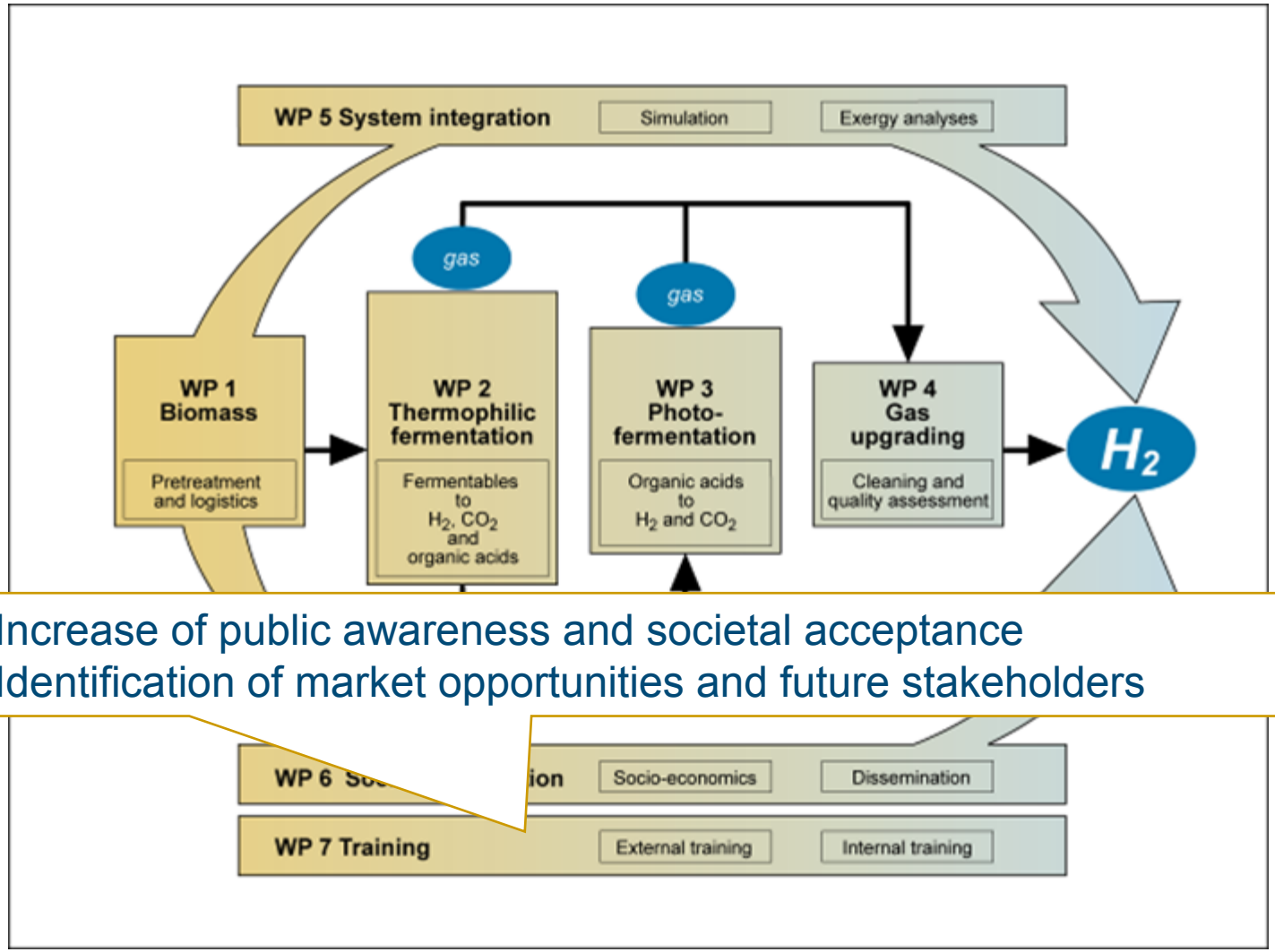


-Increase of public awareness and societal acceptance
-Identification of market opportunities and future stakeholders

The core of HYVOLUTION

$C_6H_{12}O_6 + 6\ H_2O \rightarrow 6\ CO_2 + 12\ H_2$ $\quad \Delta G_o' = +3\ kJ$

$C_6H_{12}O_6 + 2H_2O \longrightarrow 2CO_2 + 2CH_3COOH + 4H_2$ $\quad \Delta G_o' = -206\ kJ$

(hyper)thermophilic bacteria

photons

$CH_3COOH + 2H_2O \longrightarrow 2CO_2 + 4H_2$ $\quad \Delta G_o' = +104\ kJ$

photosynthetic bacteria

Advantages of thermophilic fermentation

- Equilibrium towards hydrogen production
- High yield as compared to mesophilic fermentation
- Natural selection pressure
- Decrease of size for subsequent photofermentation

Caldicellulosiruptor sp., *Thermotoga* sp., co-cultures and new isolates.

WP 1 BIOMASS; some highlights

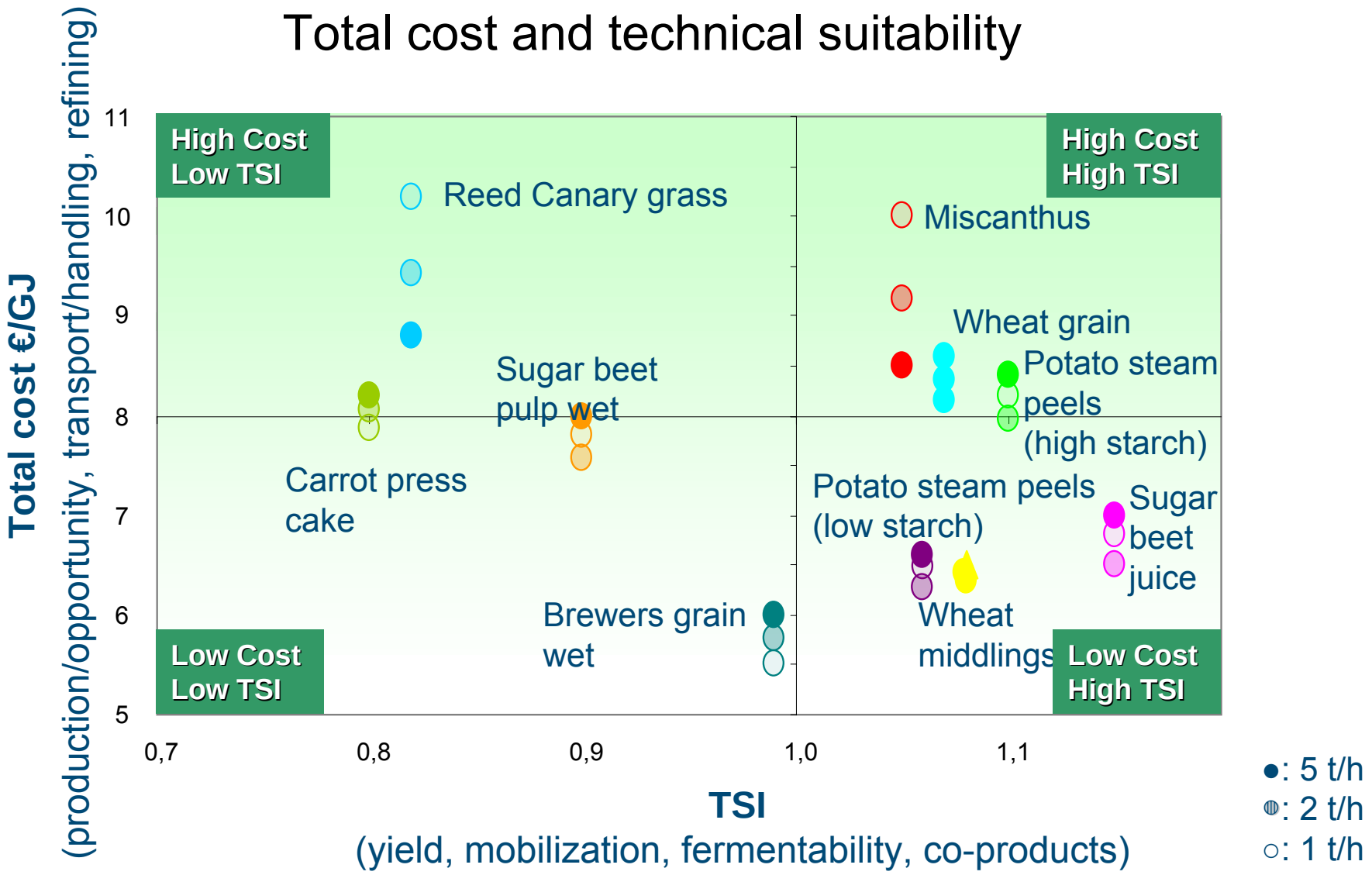
Agro-industrial residues and energy crops

Biomass critical parameters:

- Composition
- Regional availability in EU-27
- Cost
- Sustainability
- Co-products utilization

- Socio-economic desk studies
- Experimental practices

Biomass mapping



Biomass selection

- Selected biomass for HYVOLUTION:

Sugar beet: sucrose

Potato steam peels: starch

Wheat bran: starch and lignocellulose

Barley straw: lignocellulose

Biomass pretreatment

High solids, conical screw reactor

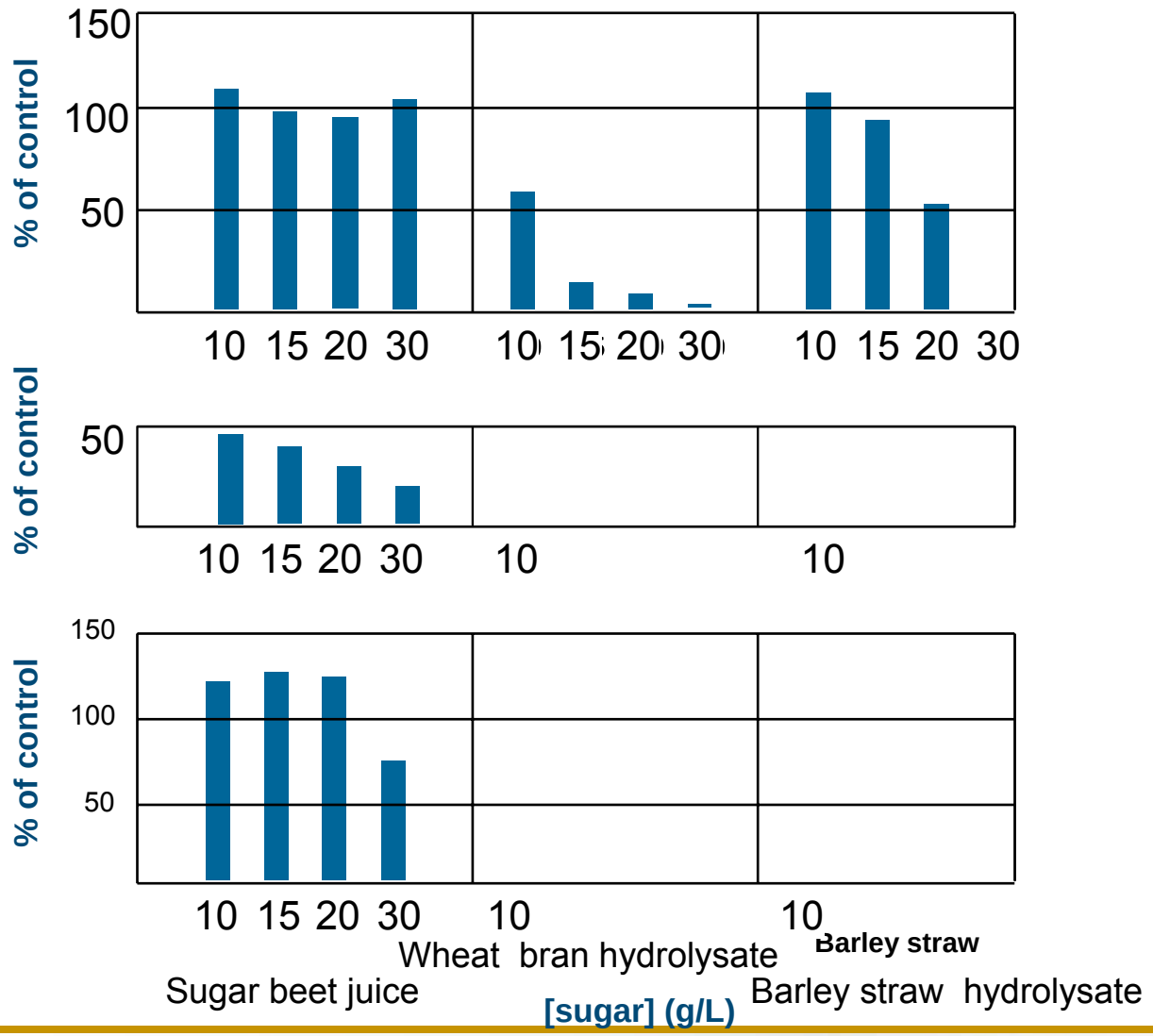
Experimental parameters:
-acid/ alkaline
-temperature(s)
-duration
-enzymes

Fermentability test: production of acids

Caldicellulosiruptor saccharolyticus

Caldicellulosiruptor owensensis

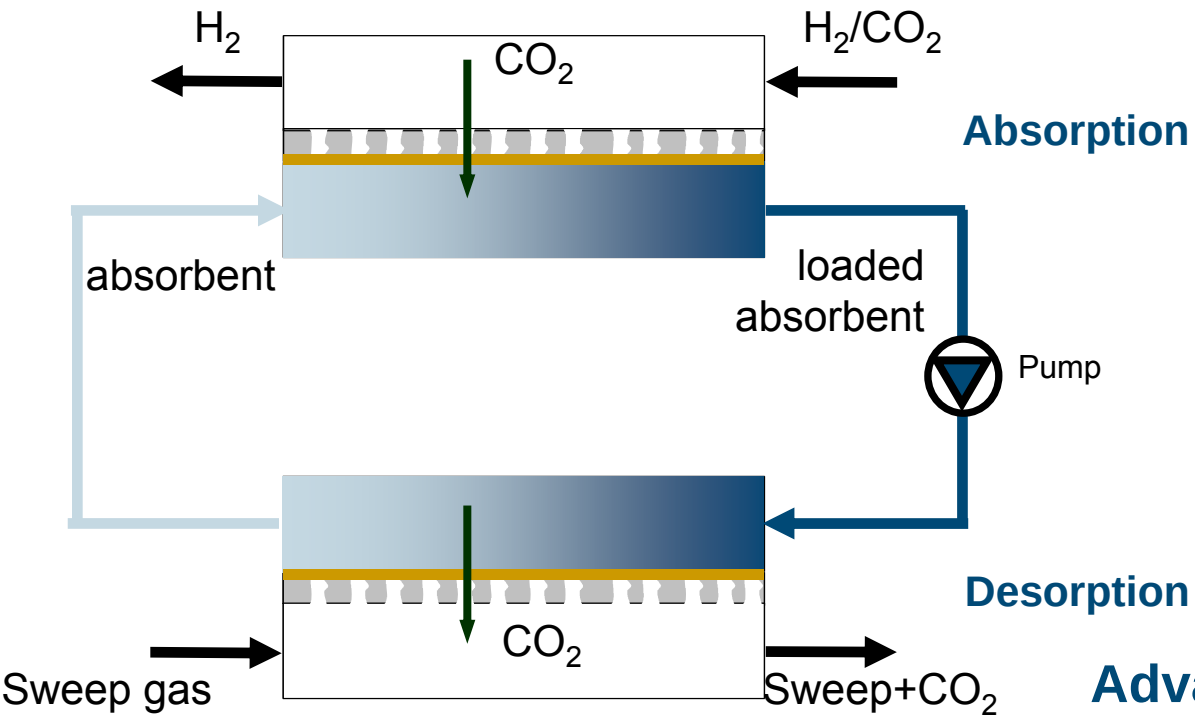
Thermotoga neapolitana



WP 4 GAS UPGRADING; some highlights

- Gas upgrading critical parameters
  - Low concentrations and quantities of hydrogen:
    60 kg H_2 /h (2 MW_{th})
  - Fluctuating concentrations
  - Energy demand
  - Sustainability
  - Security and risk analysis
  - Process control

Membrane contactor separation

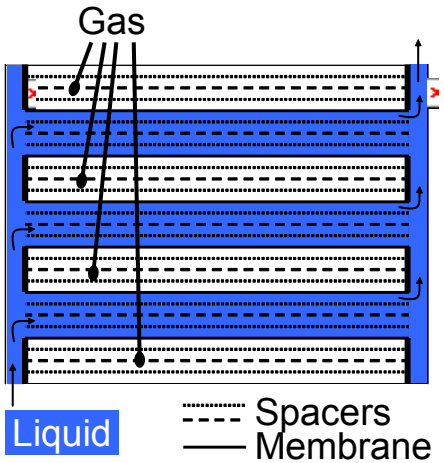


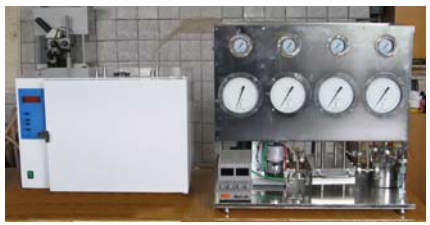
Active,
dense membrane
(0.5 mm);
Driving force; selective absorption

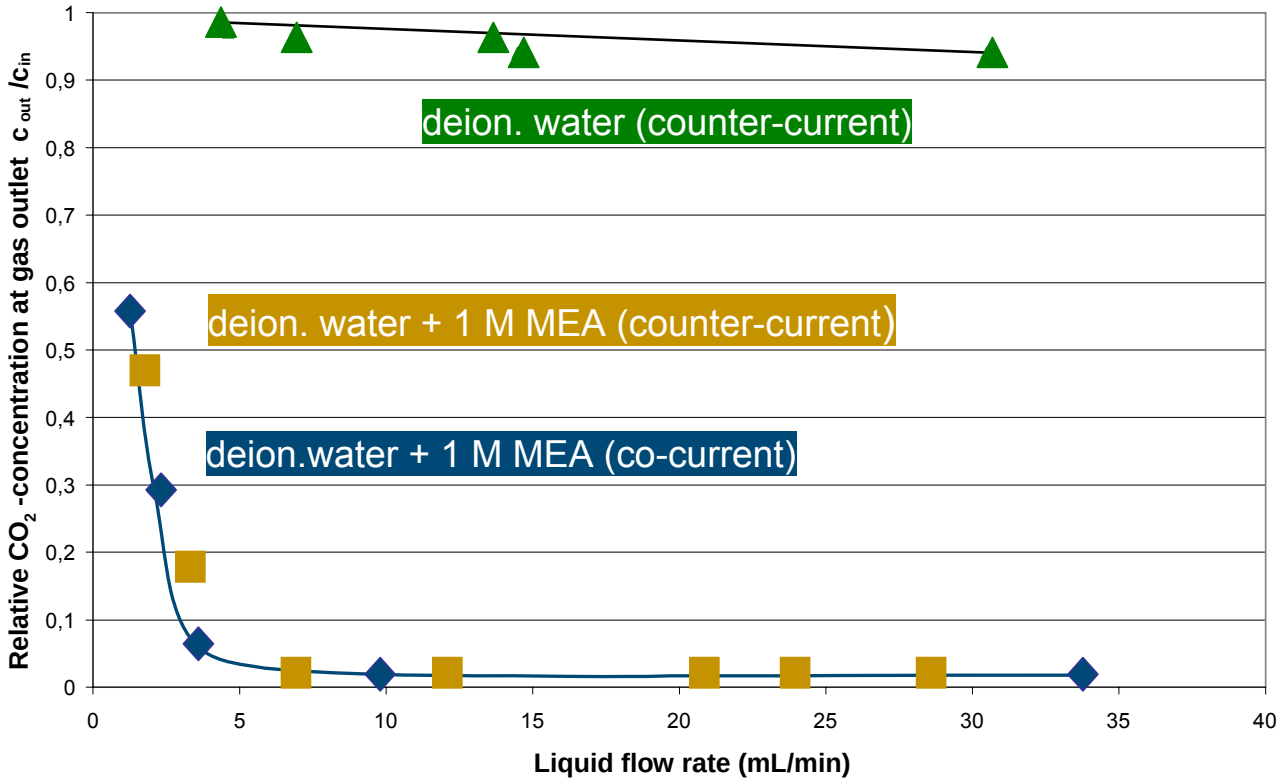
Advantages of MC separation:

- No loss of liquid carrier
- Compression of gas not required
- Low energy demand
- Flexible in application
- Recirculation possible

Membrane contactor prototype

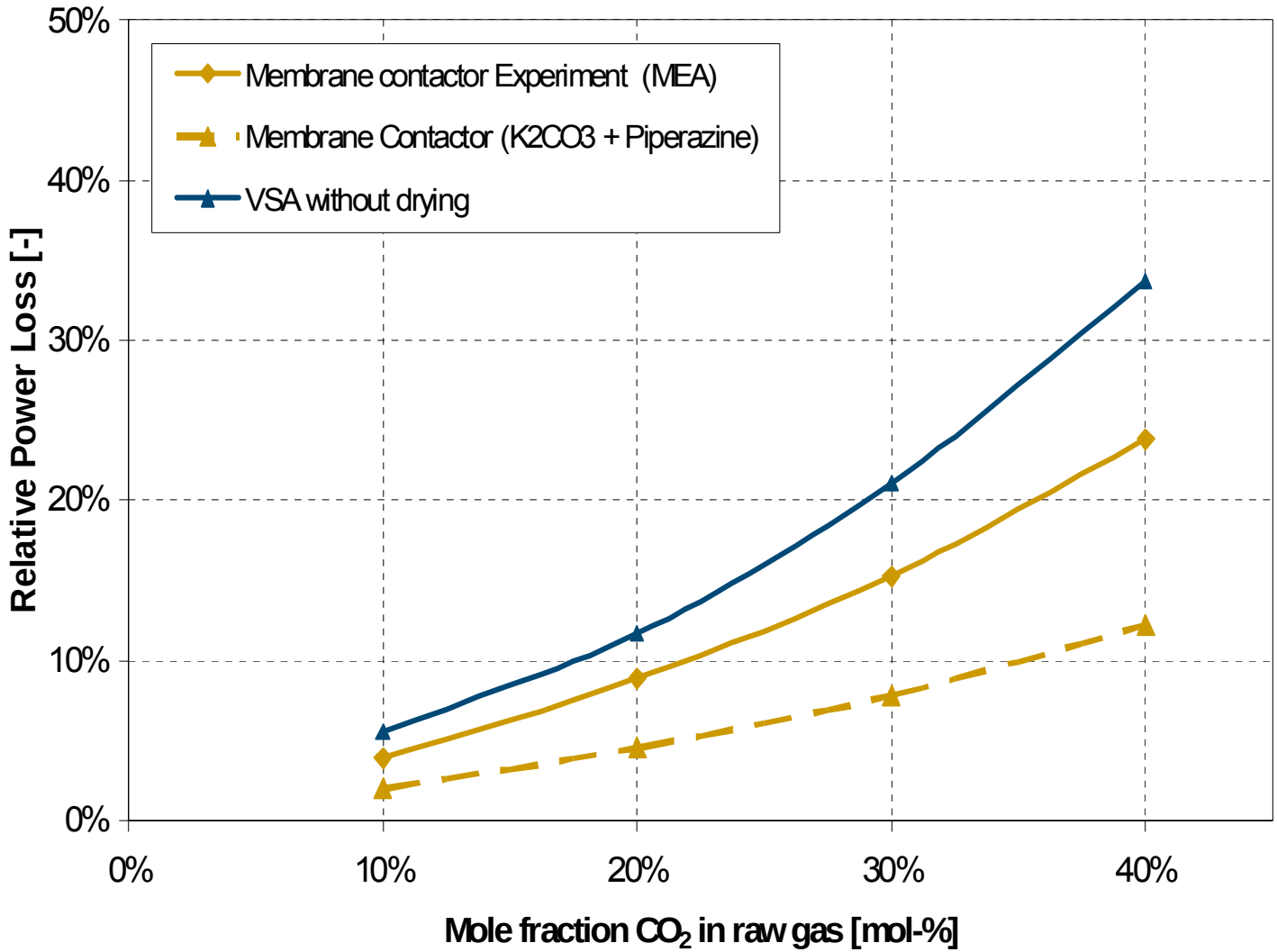






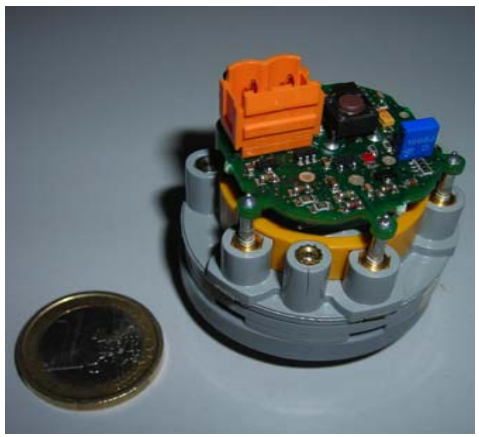
CO_2 removal at T=293 K.
Influent gas is He=87%, CO_2=13%(v/v) at flow rate 200 mL/min.

Energy demand for gas upgrading

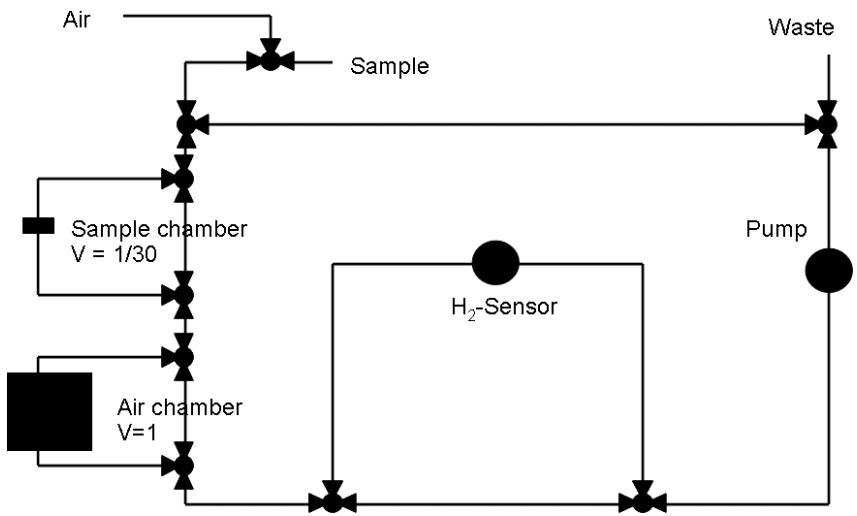


Gas analysis

- Use of electrochemical H_2-sensors (measuring range: 0-5%; ~ € 500 / sensor);
- Inclusion of state-of-the-art sensors (CO_2, CH_4, O_2, H_2S) in separate channels
- Development and construction of a dilution device

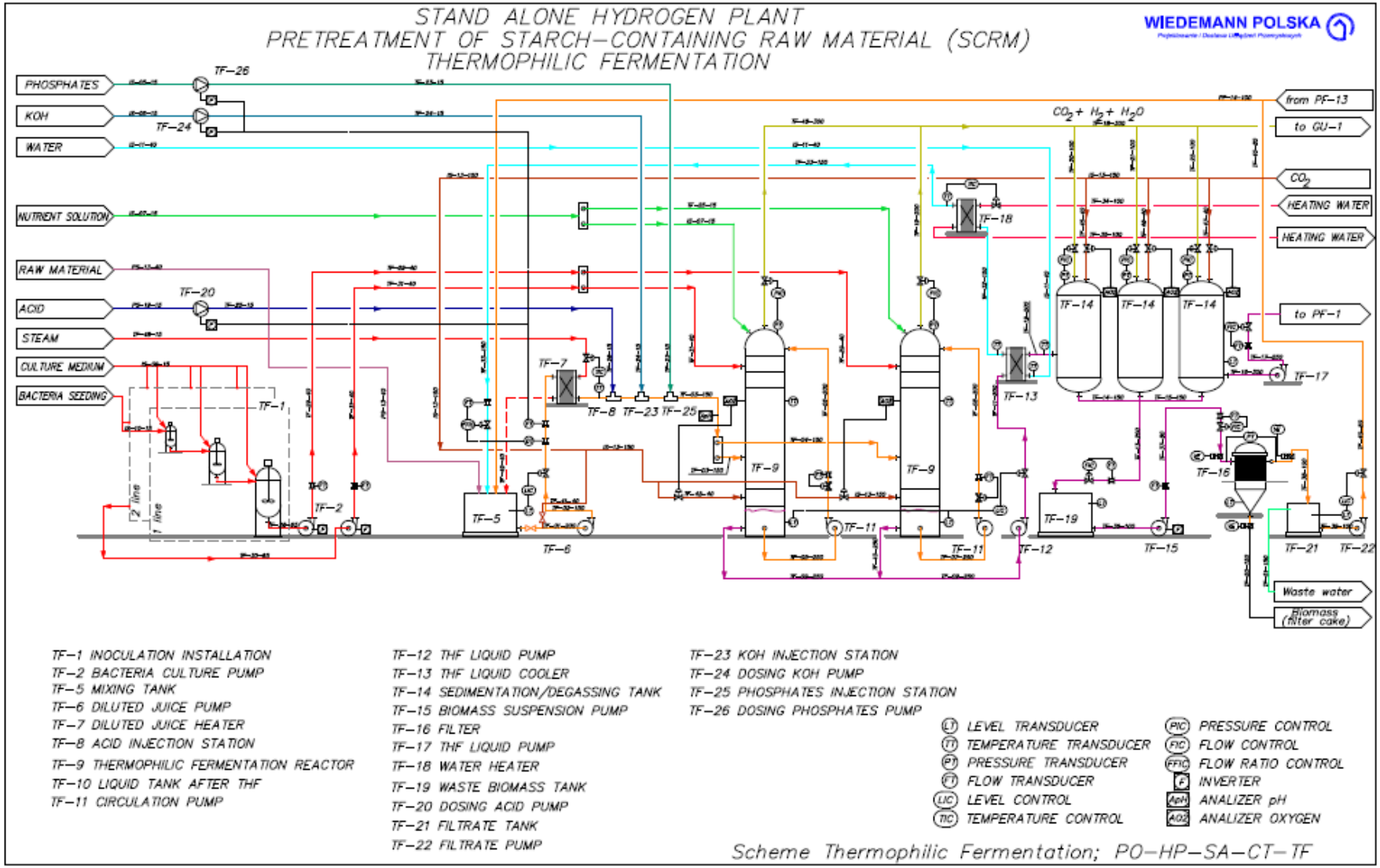


Hydrogen sensor



Automated dilution device

Blue print for a 2 MW HYVOLUTION plant



Future scenario's and state of the art

	Scenario's		Current HYVOLUTION data	
	Base case	Longterm case: >2030		
Thermophilic fermentation	Glucose	Biomass	Biomass [1]	Biomass [2]
Substrate (g glucose /L)	13	40	7.5	10
Yield (% of maximum)	67	85	88	60
Productivity (mmol H_2/L.h)	5.4	53	29	17
Stripping	CO_2	-	~N_2	N_2
Photofermentation	Acetate	DFE	DFE[3]	DFE[4]
Substrate (mM acetate)	40	120	40	40
Yield (% of maximum)	50	85	67	34 - 45
Productivity (mmol H_2/L.h)	0.33	3.3	1.5	0.3 - 0.5

[1]: CFTB Thick juice; [2]: CSTR Molasses; [3]: Hup$^-$ mutant; [4]: Wild type

Future hydrogen production costs

Cost breakdown into process steps.

	Base case Cost (€/kg)	Long term case Cost(€/kg)
Raw material (PSP)	1.19	0.70
Pretreatment	1.74	1.23
Thermophilic fermentation	6.07	1.47
Photofermentation	8.78	1.37
Gas up-grading	2.15	1.37
Total production cost	**19.93**	**6.14**

Critical parameters from cost-point of view:

-raw material and pretreatment	lignocellulosics
-thermophilic fermentation	substrate concentration and yield
-photofermentation	productivity
-gas upgrading	energy demand

HYVOLUTION presentations