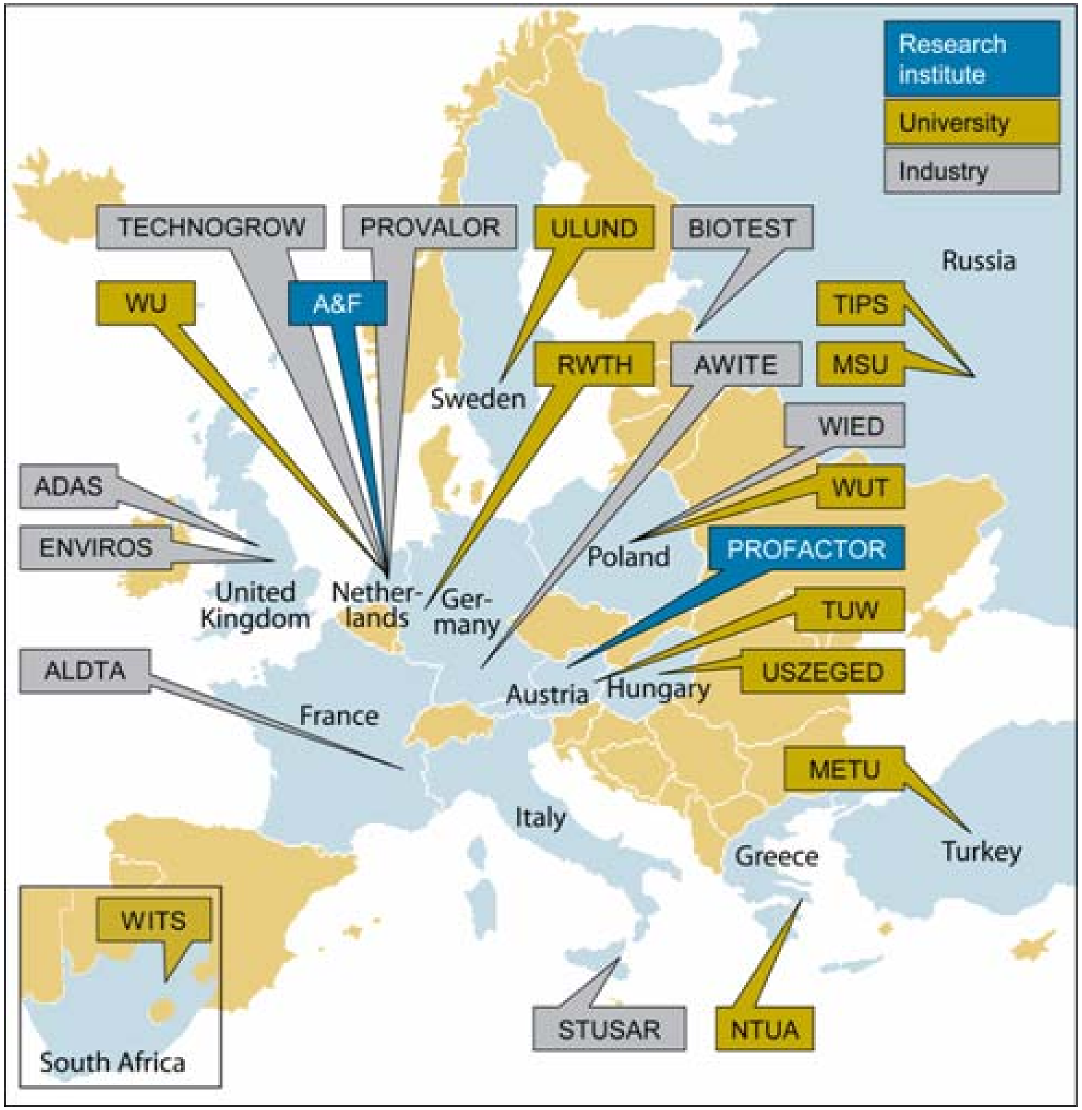
Non-thermal production of pure hydrogen from biomass

EU FP6-SES Integrated Project

HYVOLUTION

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

Partners in HYVOLUTION

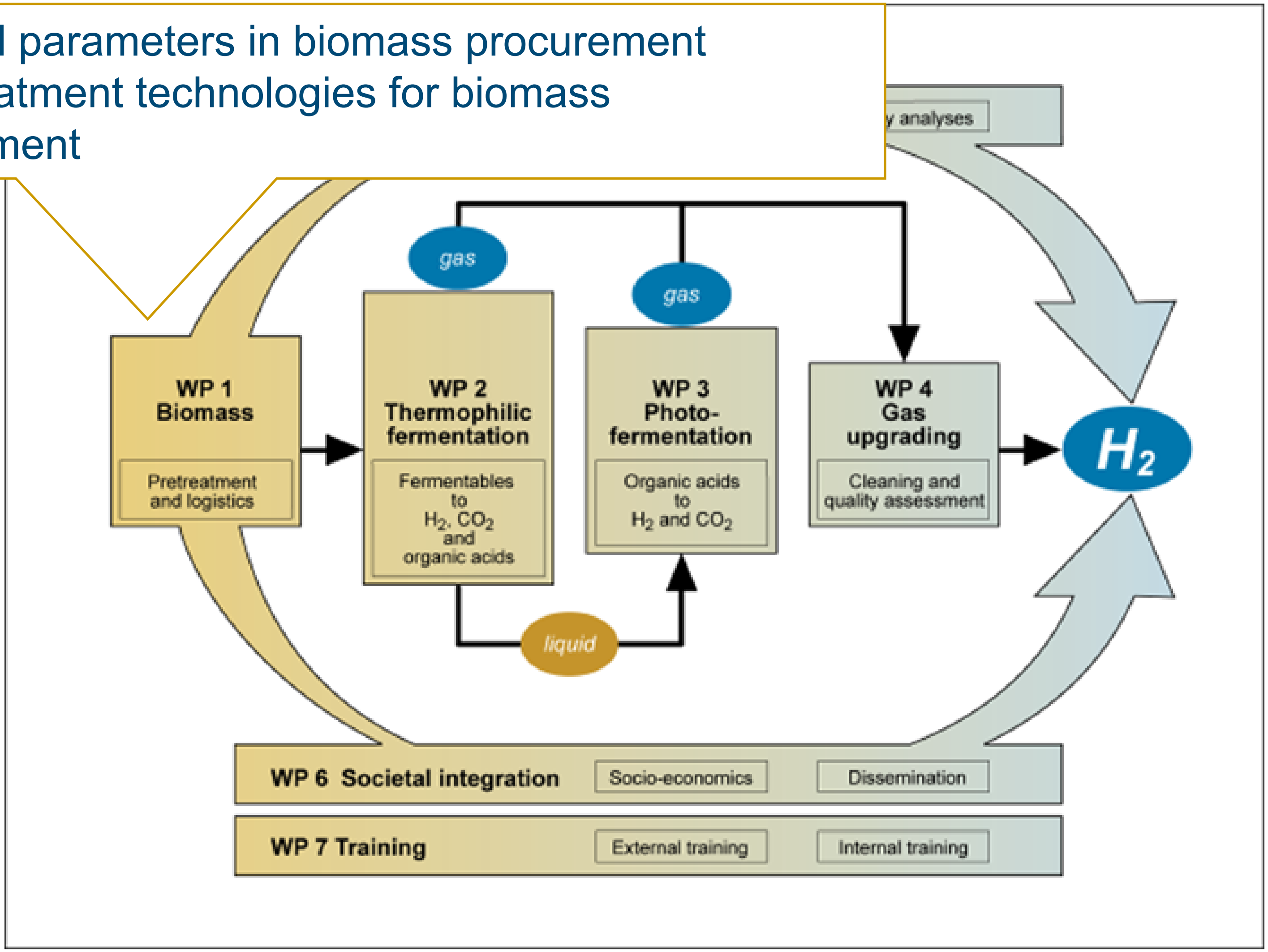


Aim:
Blue print for a bioprocess for decentral hydrogen production from biomass

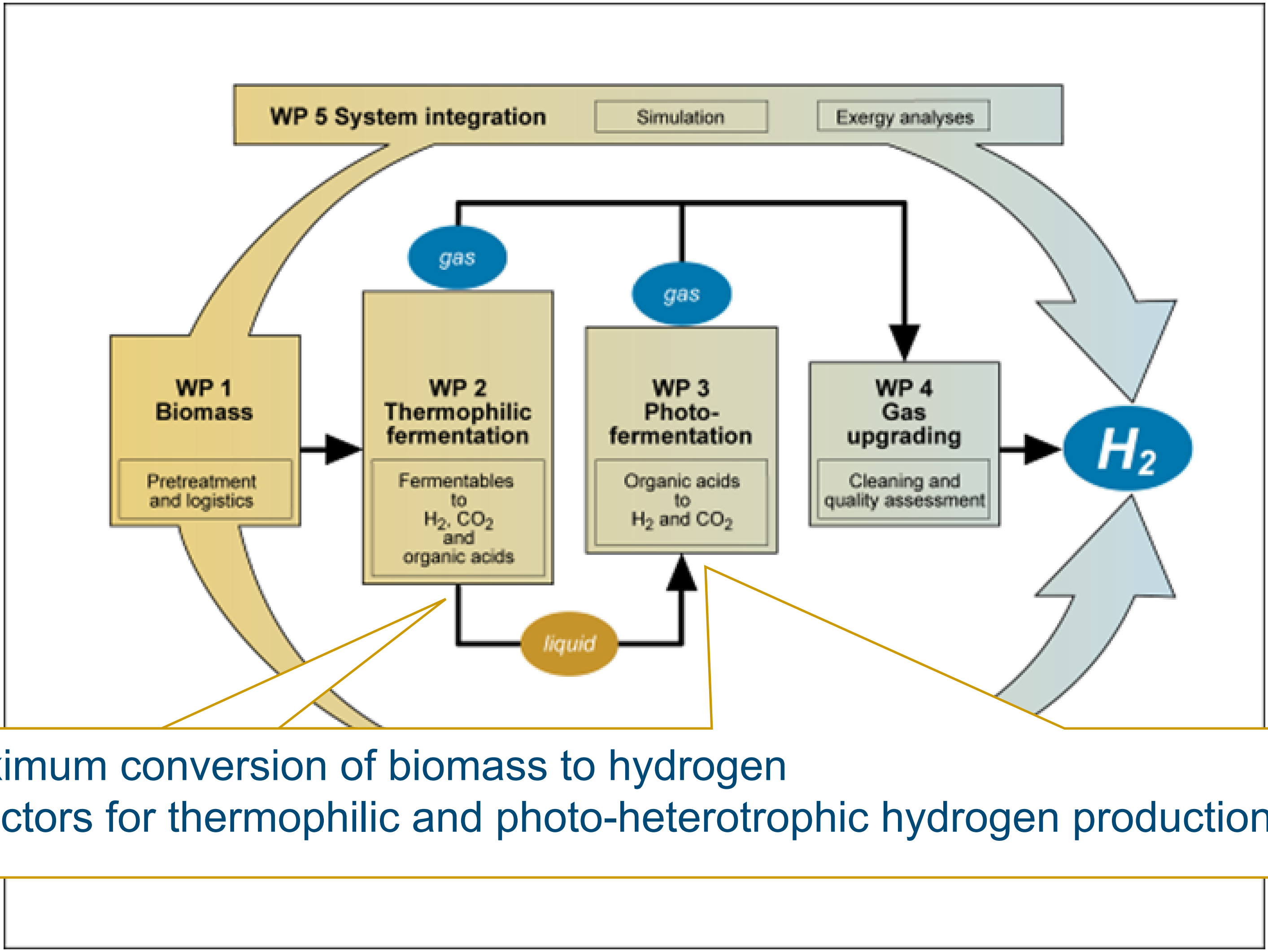
22 partners
13 countries
Jan 2006 – Dec 2010
14 M€ budget
10 M€ EC grant
www.hyvolution.nl

Objectives in workpackages

-Critical parameters in biomass procurement
-Pretreatment technologies for biomass
-Equipment

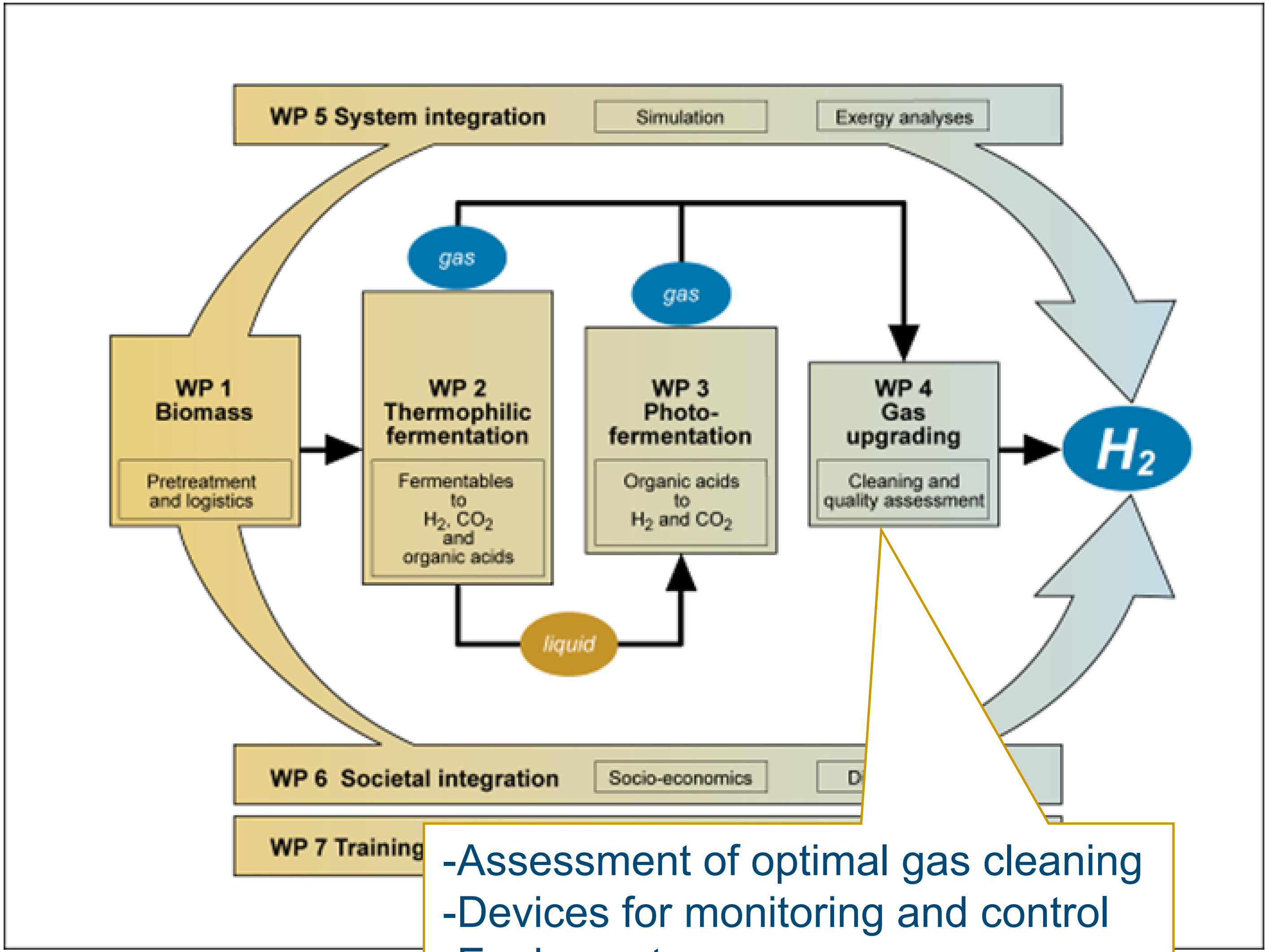


Objectives in workpackages



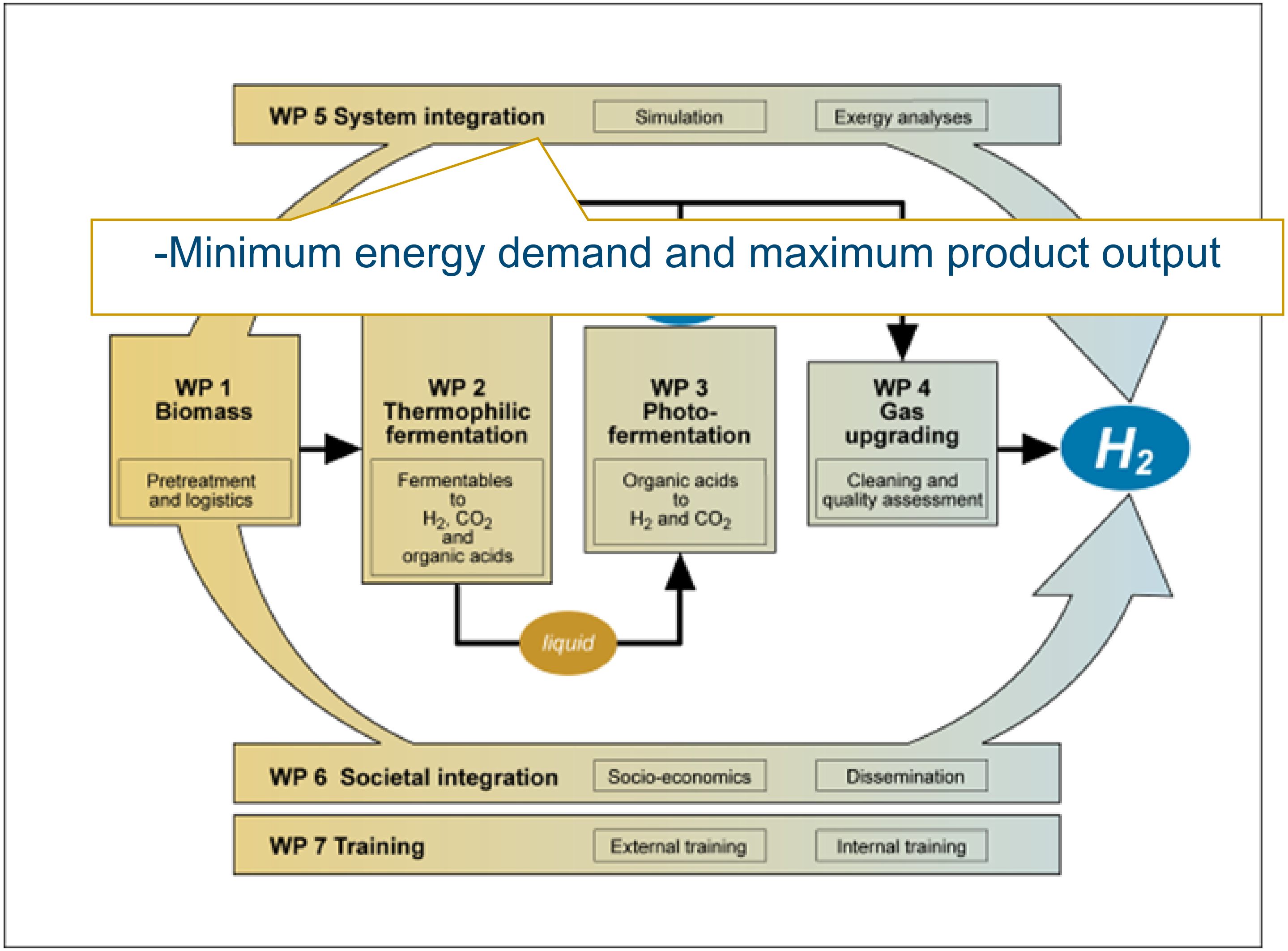
-Maximum conversion of biomass to hydrogen
-Reactors for thermophilic and photo-heterotrophic hydrogen production

Objectives in workpackages

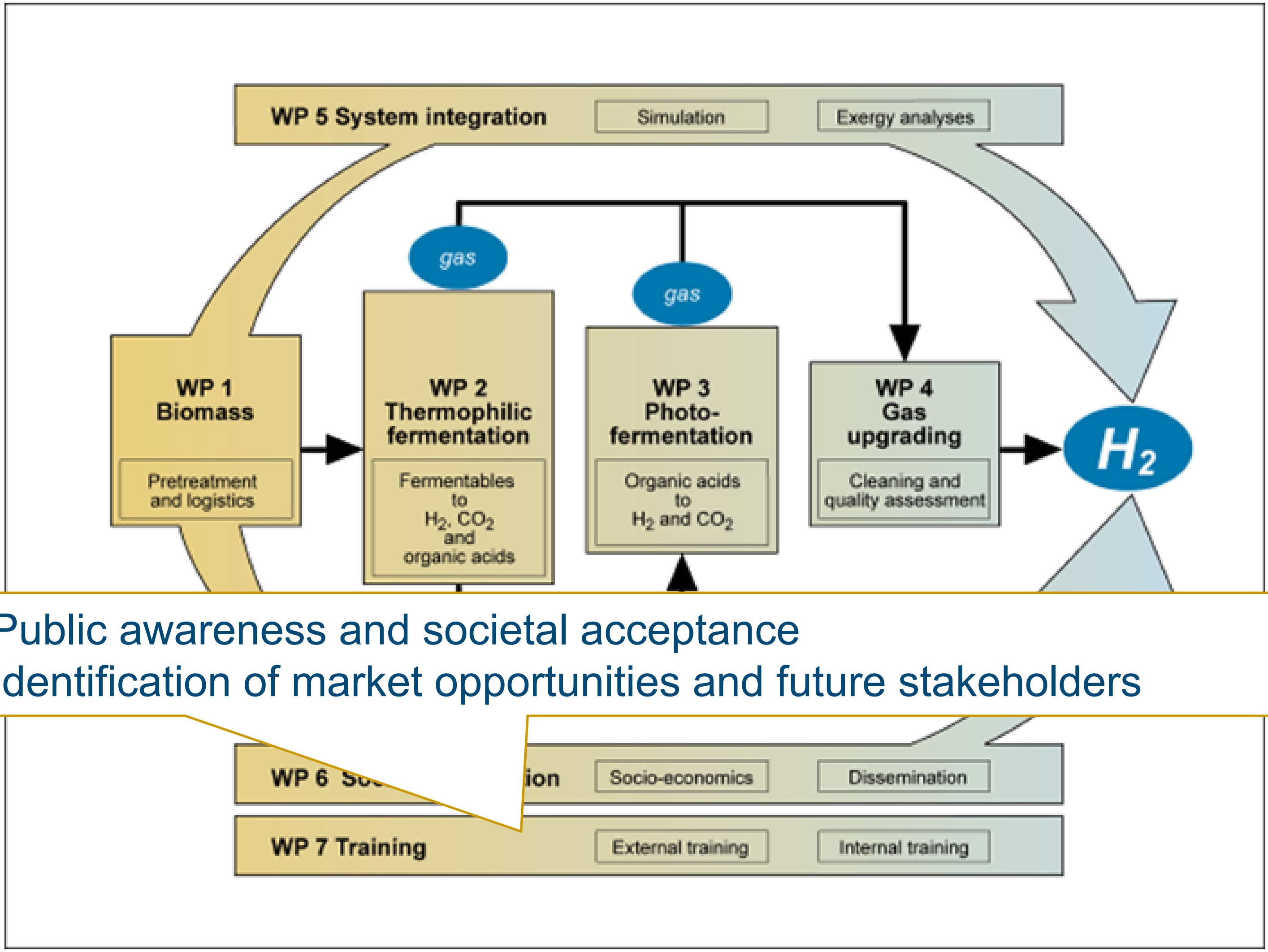


- Assessment of optimal gas cleaning
- Devices for monitoring and control
- Equipment

Objectives in workpackages

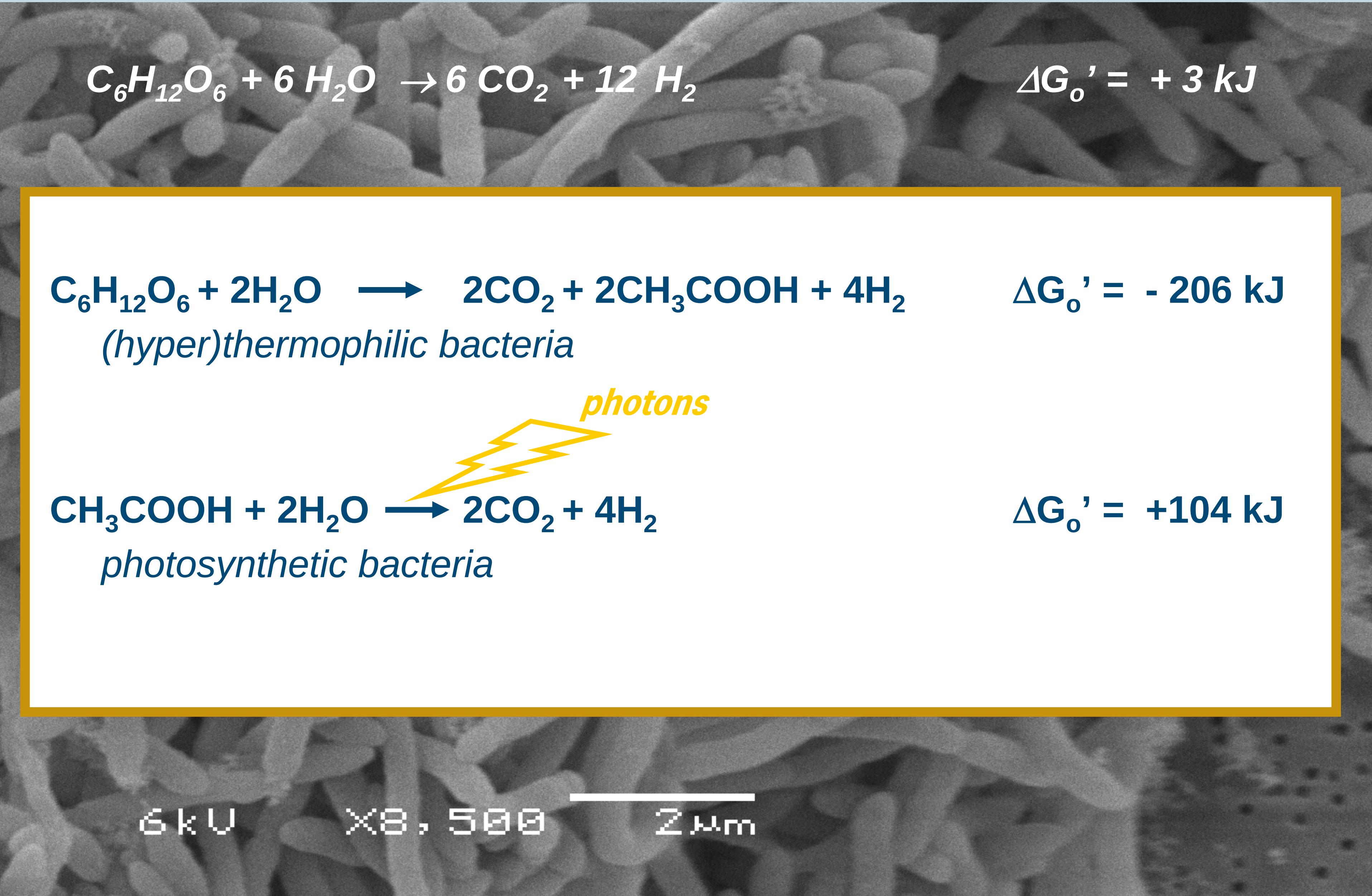


Objectives in workpackages



-Public awareness and societal acceptance
-Identification of market opportunities and future stakeholders

The core of HYVOLUTION



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

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

(hyper)thermophilic bacteria

photons

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

photosynthetic bacteria

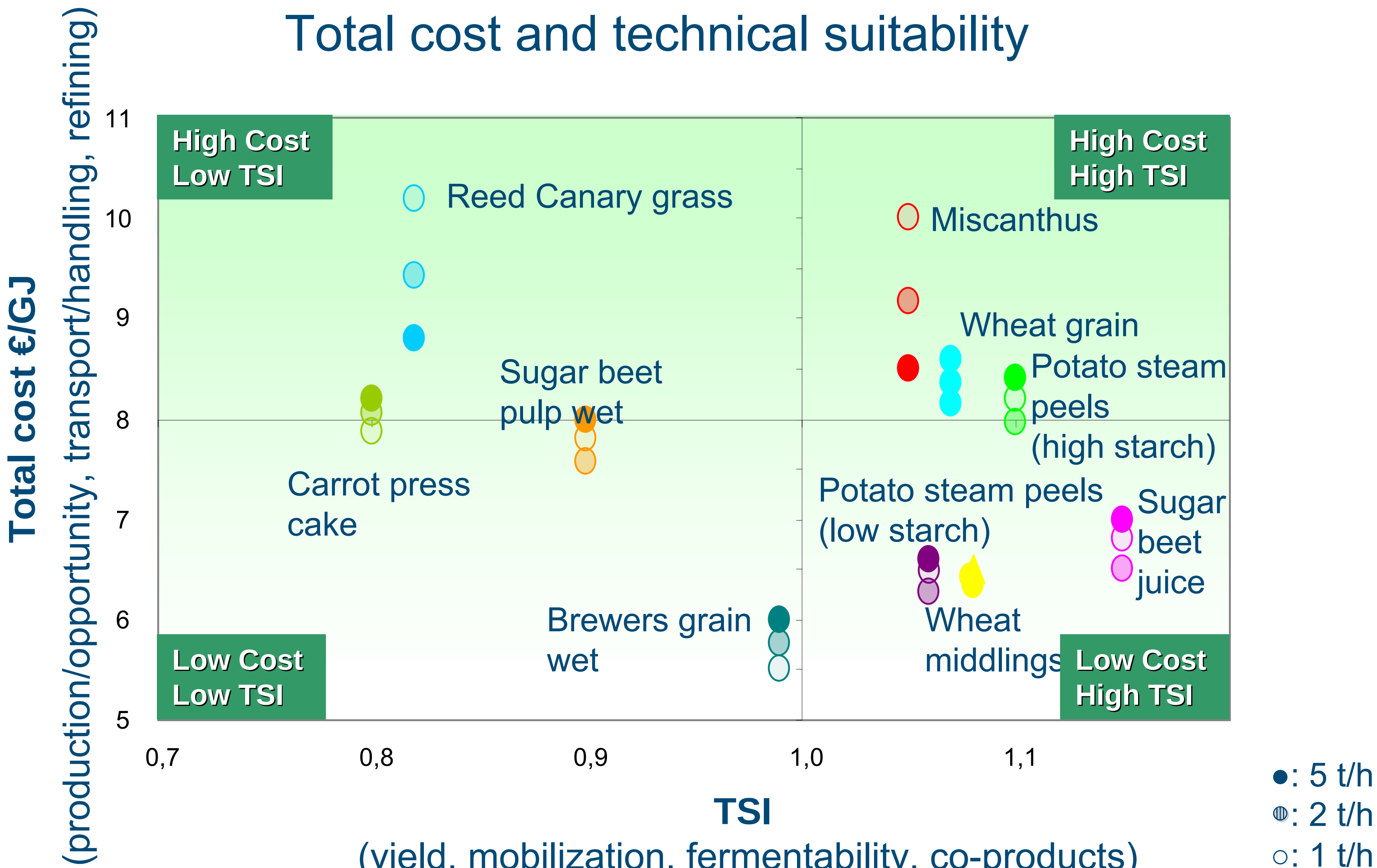
WP 1 BIOMASS

Agro-industrial residues and energy crops

- Composition
- Regional availability in EU-27
- Cost (opportunity costs)
- 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

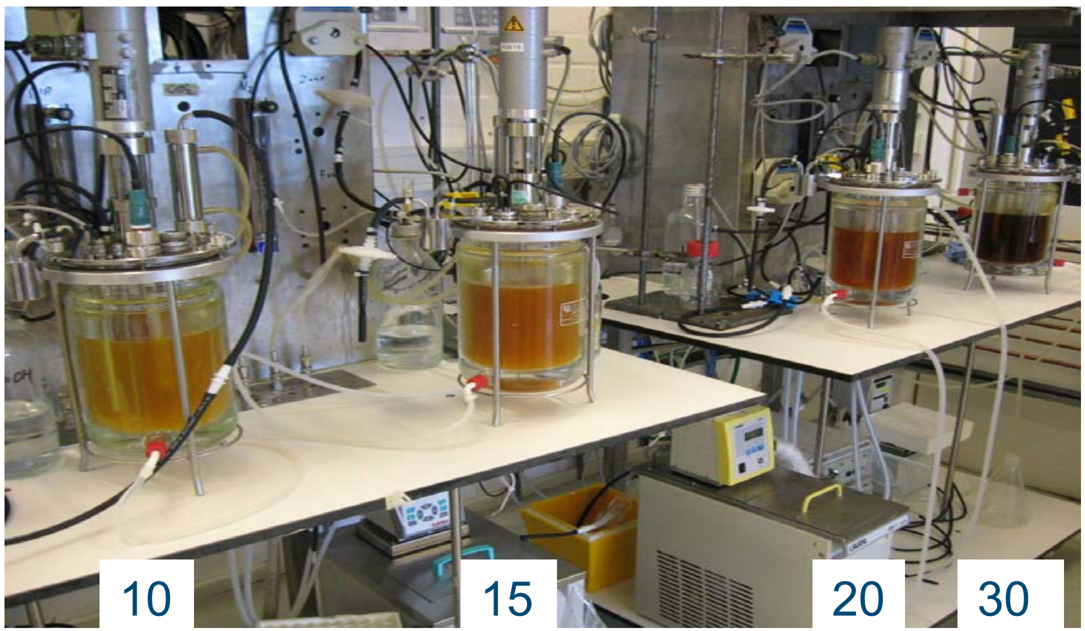
Barley straw: lignocellulose

WP 2 THERMOPHILIC FERMENTATION

AIM

- Maximum efficiency in conversion of biomass feedstocks to H_2 through cost-effective, stable, optimized thermophilic fermentation

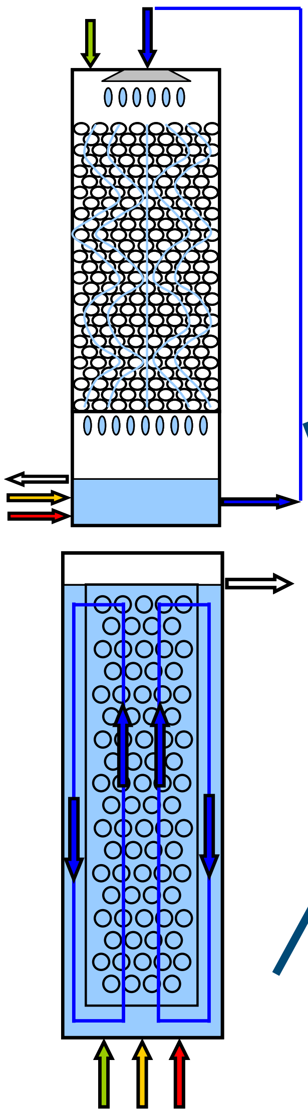
P_{H2}
CO_2
π
Sugar type
[Sugar]
Nutrients

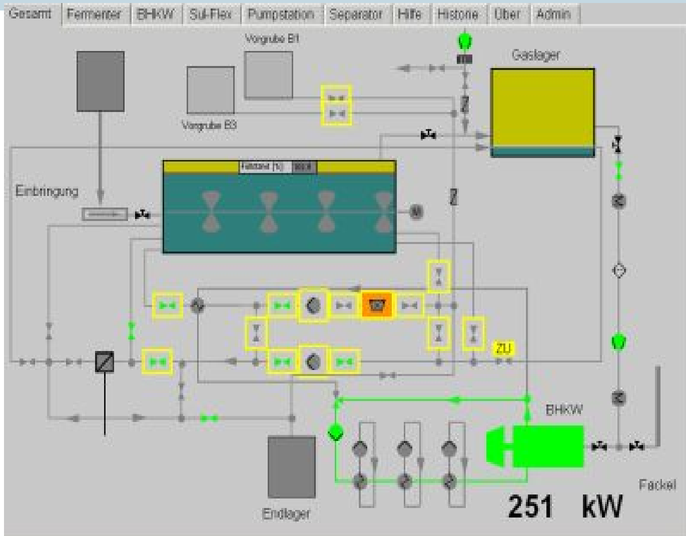


Molasse g/L

Yield
Productivity

Bioreactor design and construction



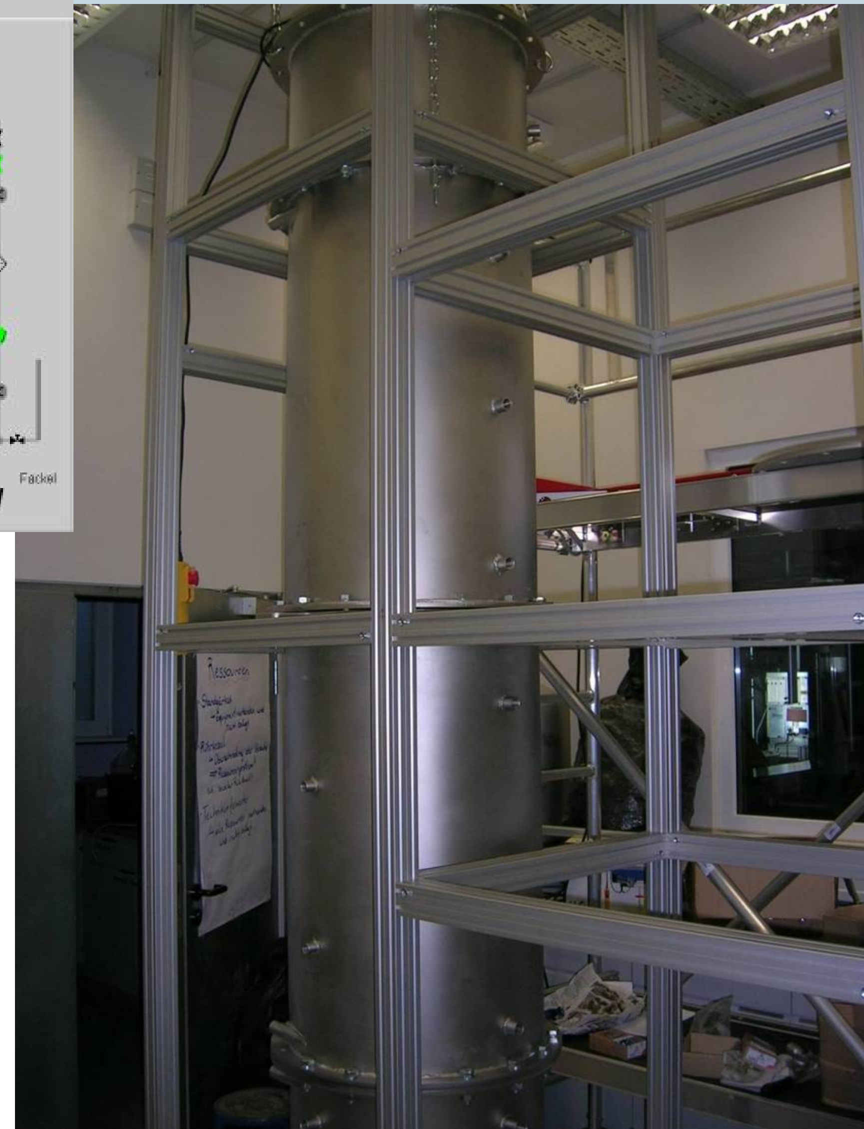


Process control

Combined fluidized and trickle bed reactor

Designed thermo-reactors

L: 30 L; R: 600 L



Awite Profactor

WP 3 PHOTOFERMENTATION

AIM

- Design, construction and operation of prototype photobioreactors for maximum yield and productivity

ACHIEVEMENTS

- Continuous cultivation in outdoor photobioreactors
- Photofermentation of dark fermenter effluent

Outdoor continuous photofermentation

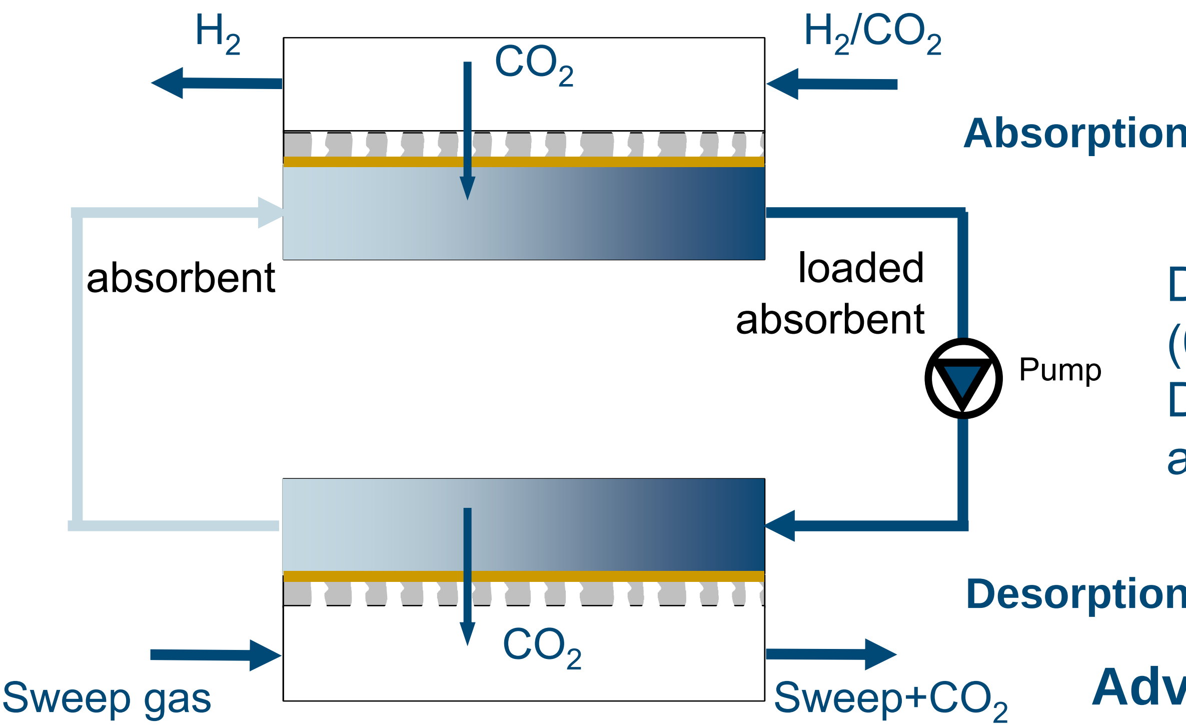
Aachen

Ankara

WP 4 GAS UPGRADING

- 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

Membrane contactor separation

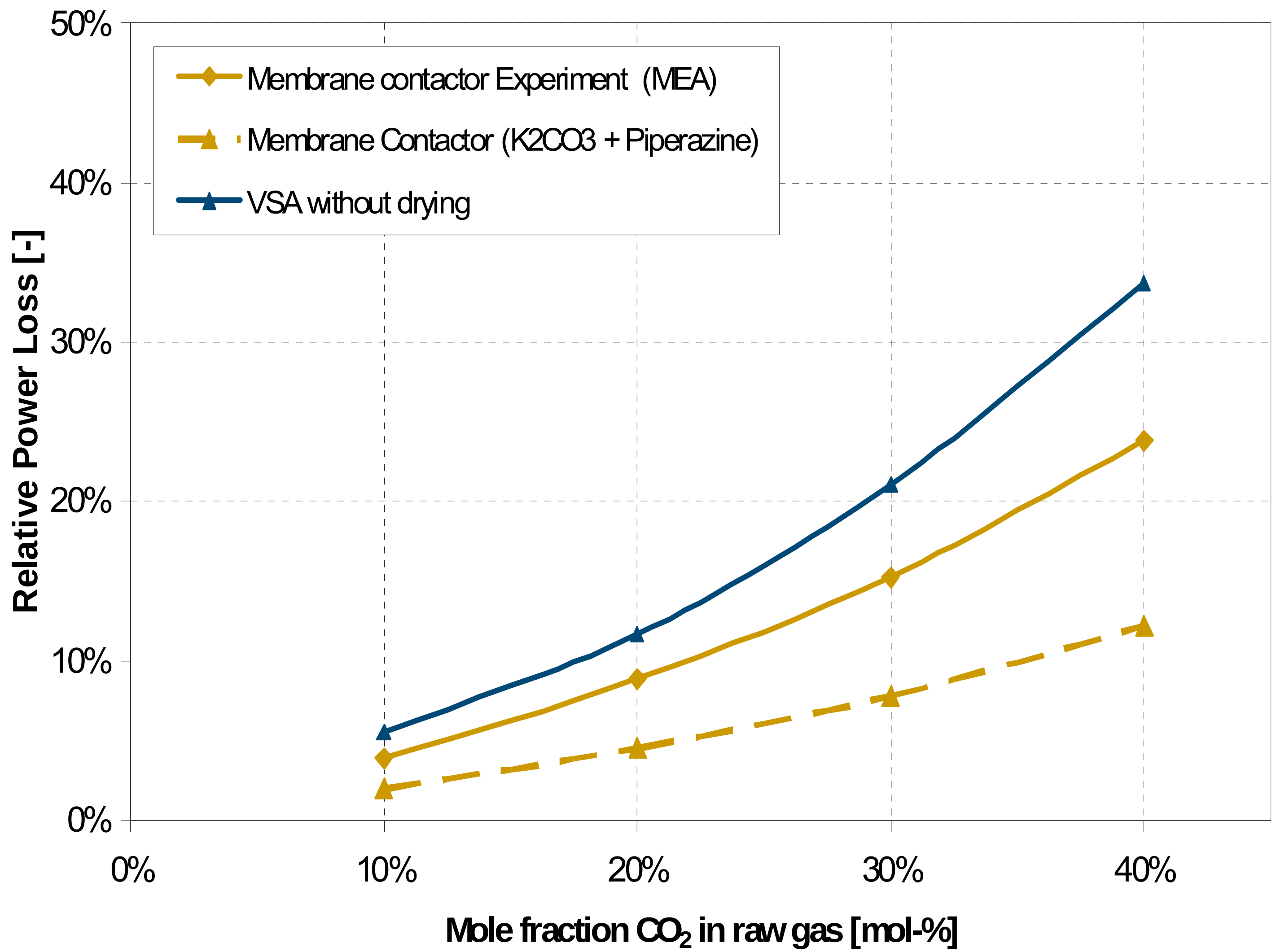


Dense membrane (0.5 mm);
Driving force; selective absorption

Advantages of MC separation:

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

Energy demand for gas upgrading



WP 5 SYSTEM INTEGRATION

AIM

- Selection of the optimum route for HYVOLUTION

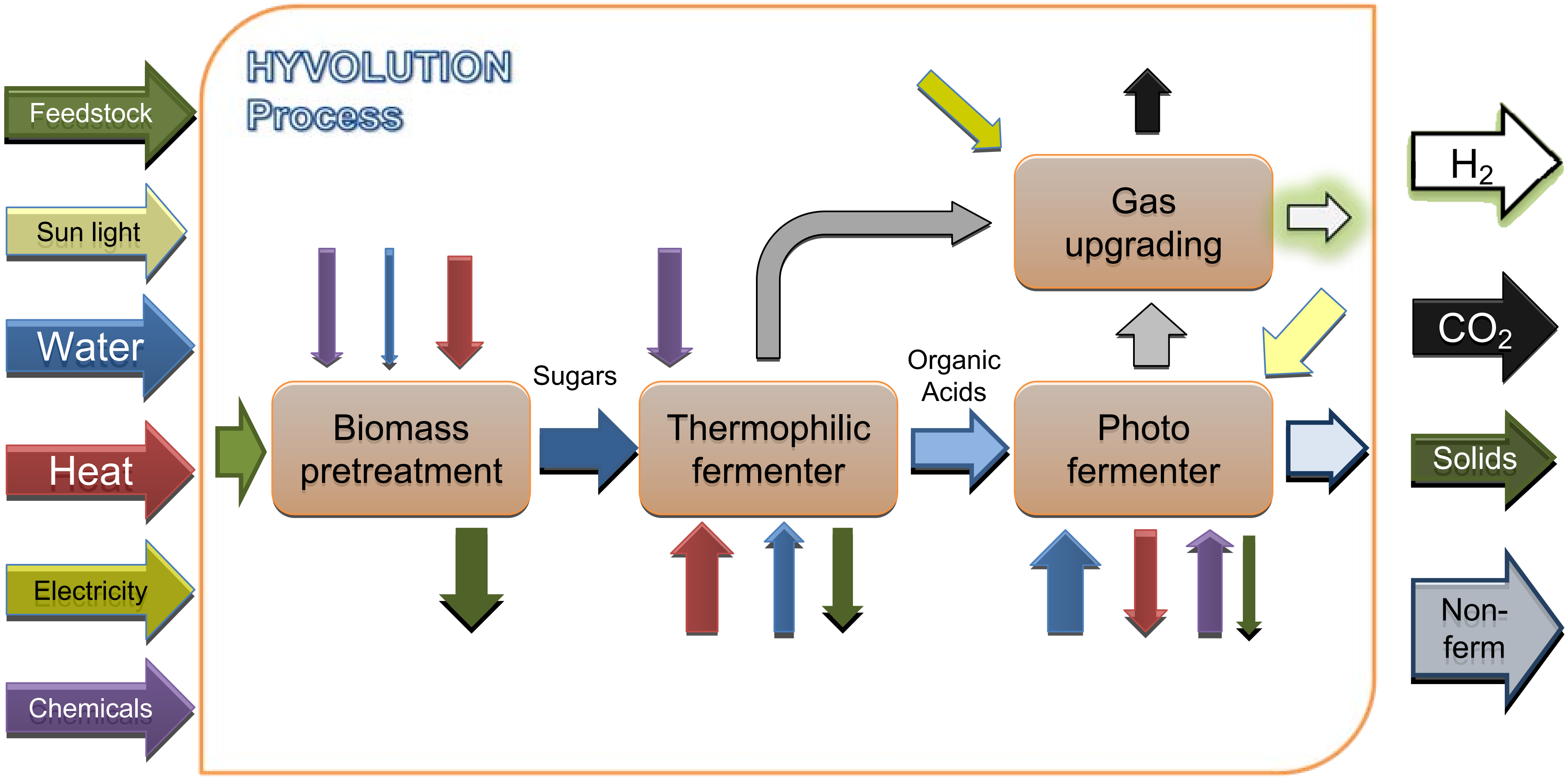
APPROACH

- Integration of single process steps
  - -Process simulation and exergy analyses
  - -Process integration and pinch technology
  - -Process engineering
  - -Cost estimation

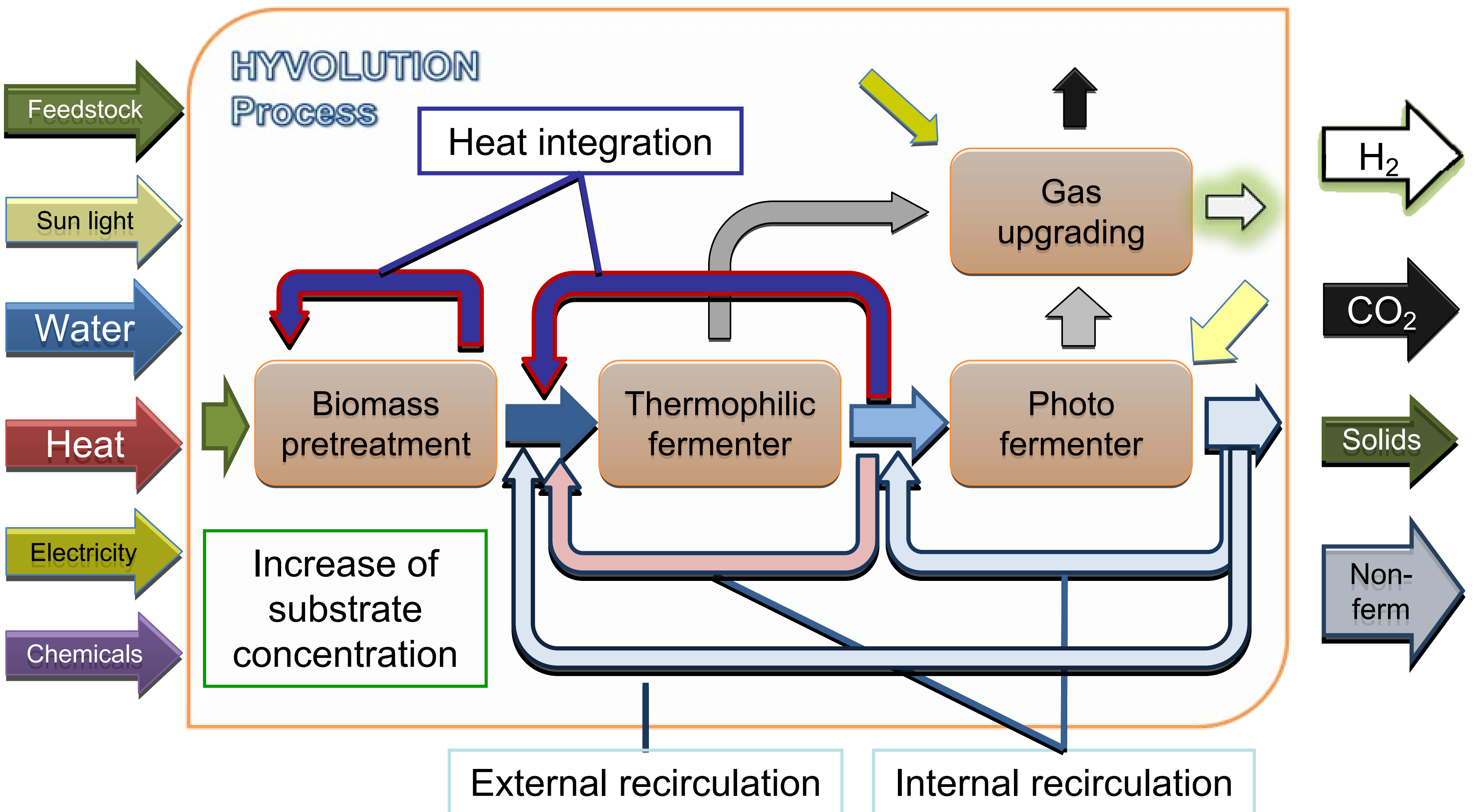
ACHIEVEMENT

- Blue print of HYVOLUTION process

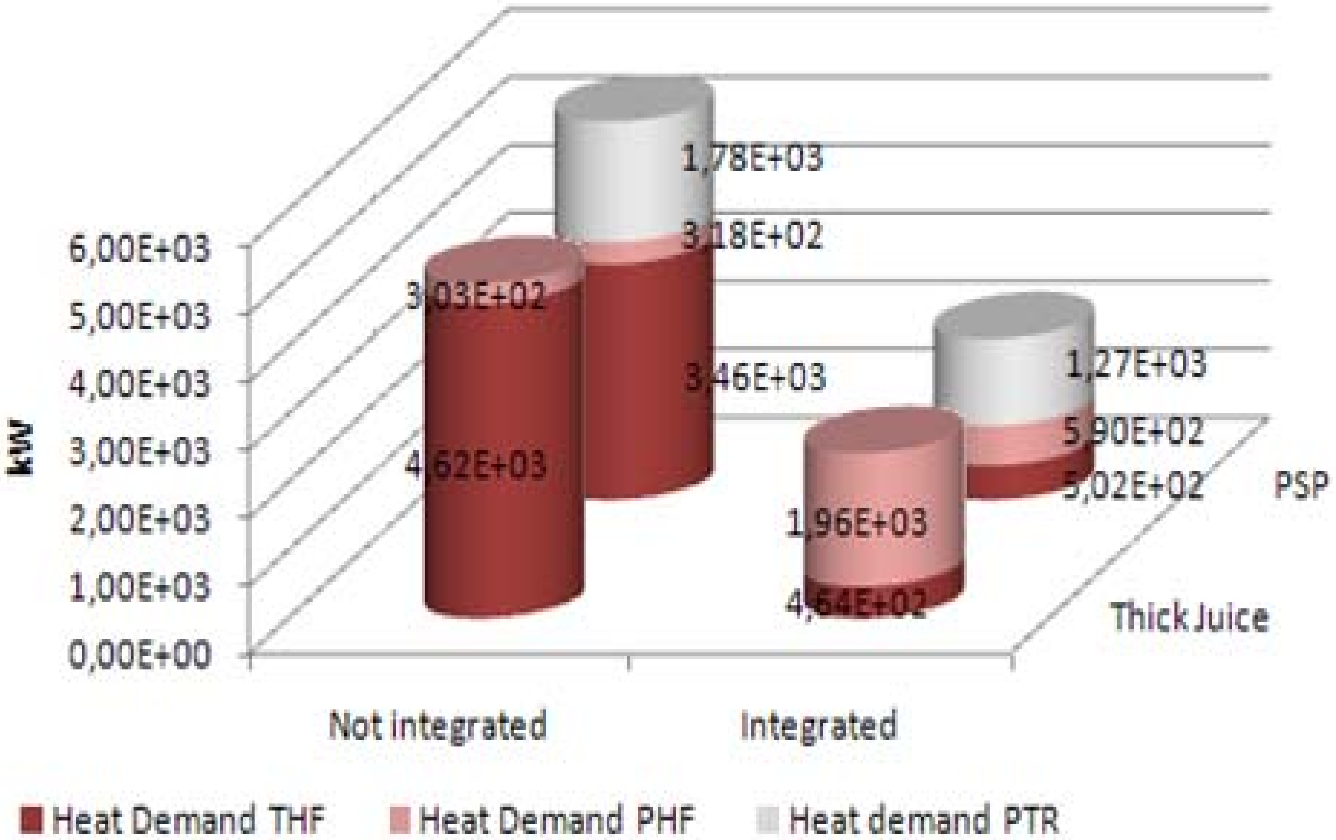
HYVOLUTION – Process



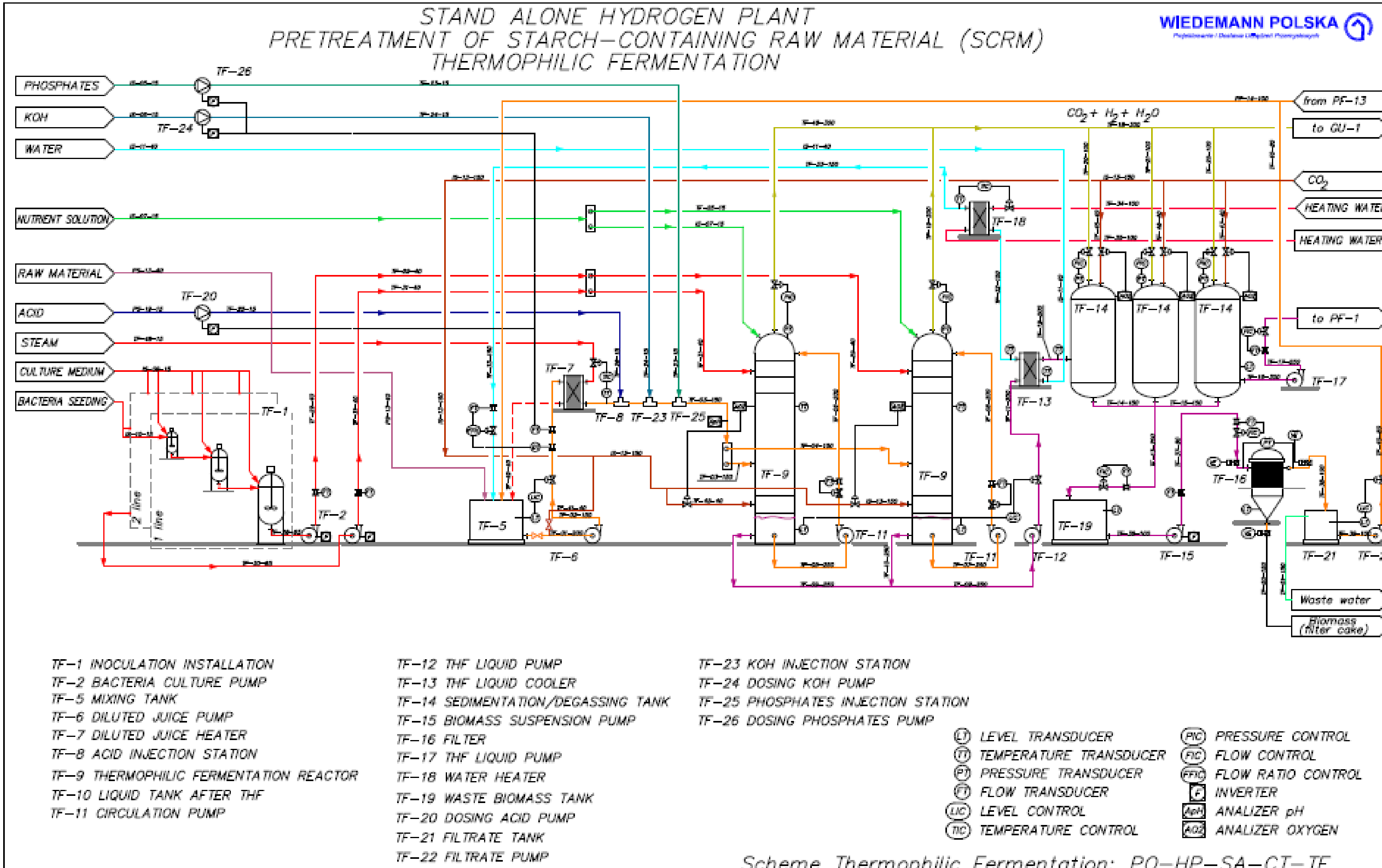
Integration options



Heat integration

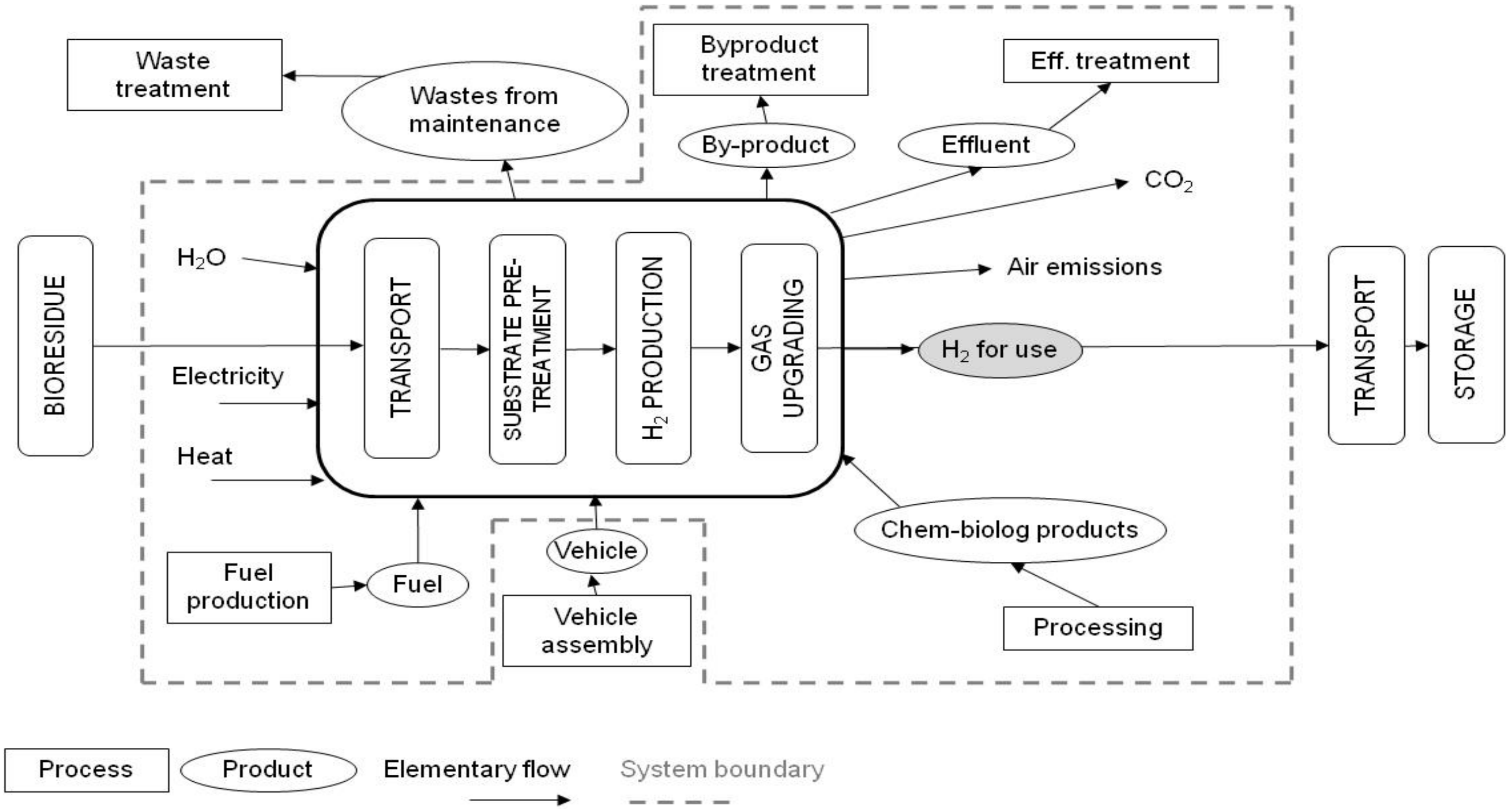


Blue print for a 2 MW HYVOLUTION plant



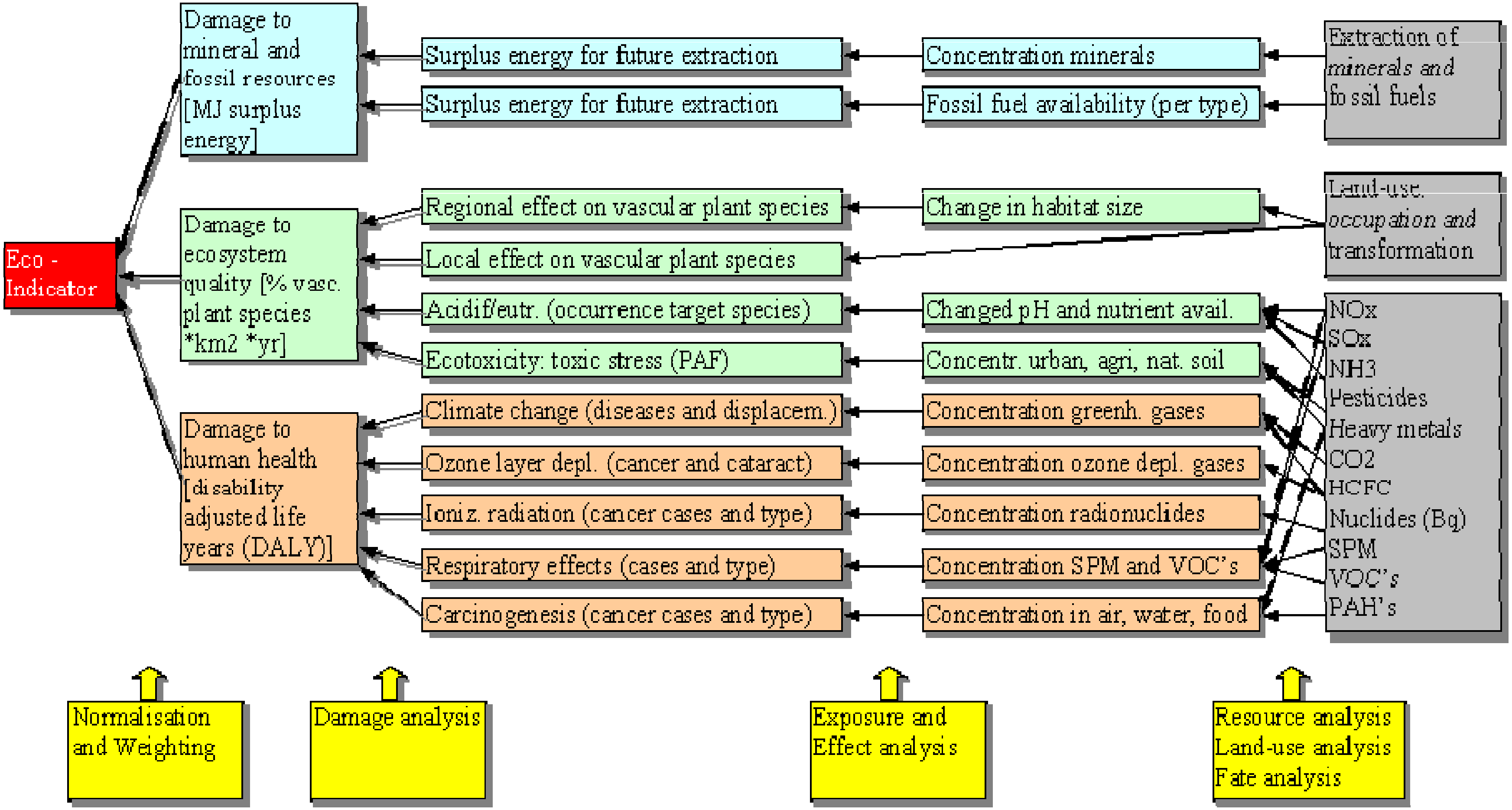
One of the AIMS

- Identification of environmental impacts

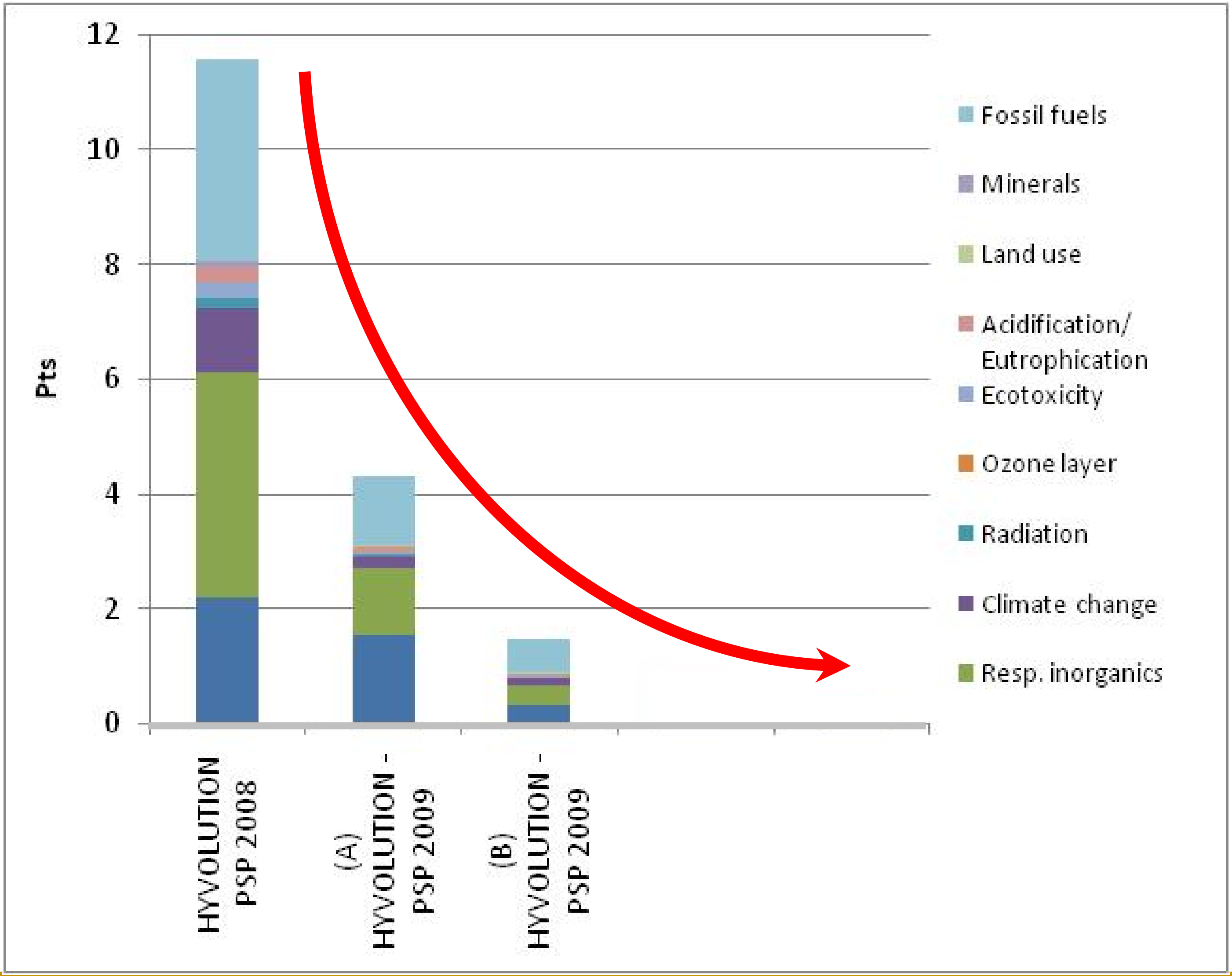


Methodology

Eco-indicator 99



Decrease of impact by process modification



WP 7 TRAINING

Genome annotation and principles of genetic engineering

Combined biomass cost and suitability mapping

Process simulation

Fermentability of biomass substrates

gas purification systems

Configuration, maintenance and calibration of analysis and process-control device

Metabolic pathways and bio-energetics

Current state of the art and outlook

	Scenario's		Current HYVOLUTION data	
	Base case	Longterm case: >2030		
Thermophilic fermentation	Glucose	Biomass	Thick juice [1]	Molasses [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	91
Productivity (mmol H_2/L.h)	0.33	3.3	1.5	1.1

[1]: CFTB; [2]: CSTR; [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

Hydrogen as the future bio-fuel

green

Thank you for your attention!

www.hyvolution.nl