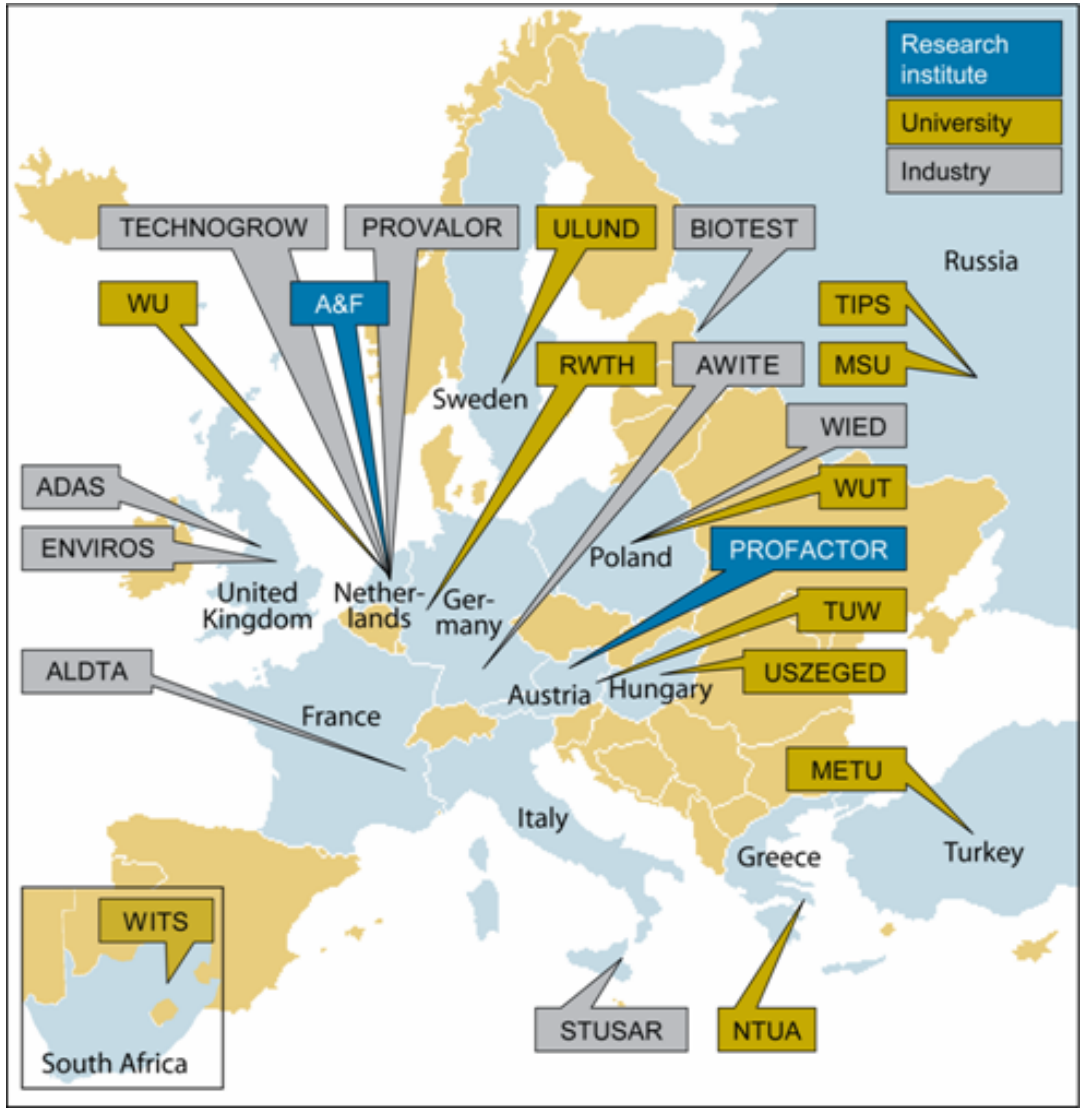
Non-thermal production of pure hydrogen from biomass

EU FP6-SES Integrated Project

HYVOLUTION

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

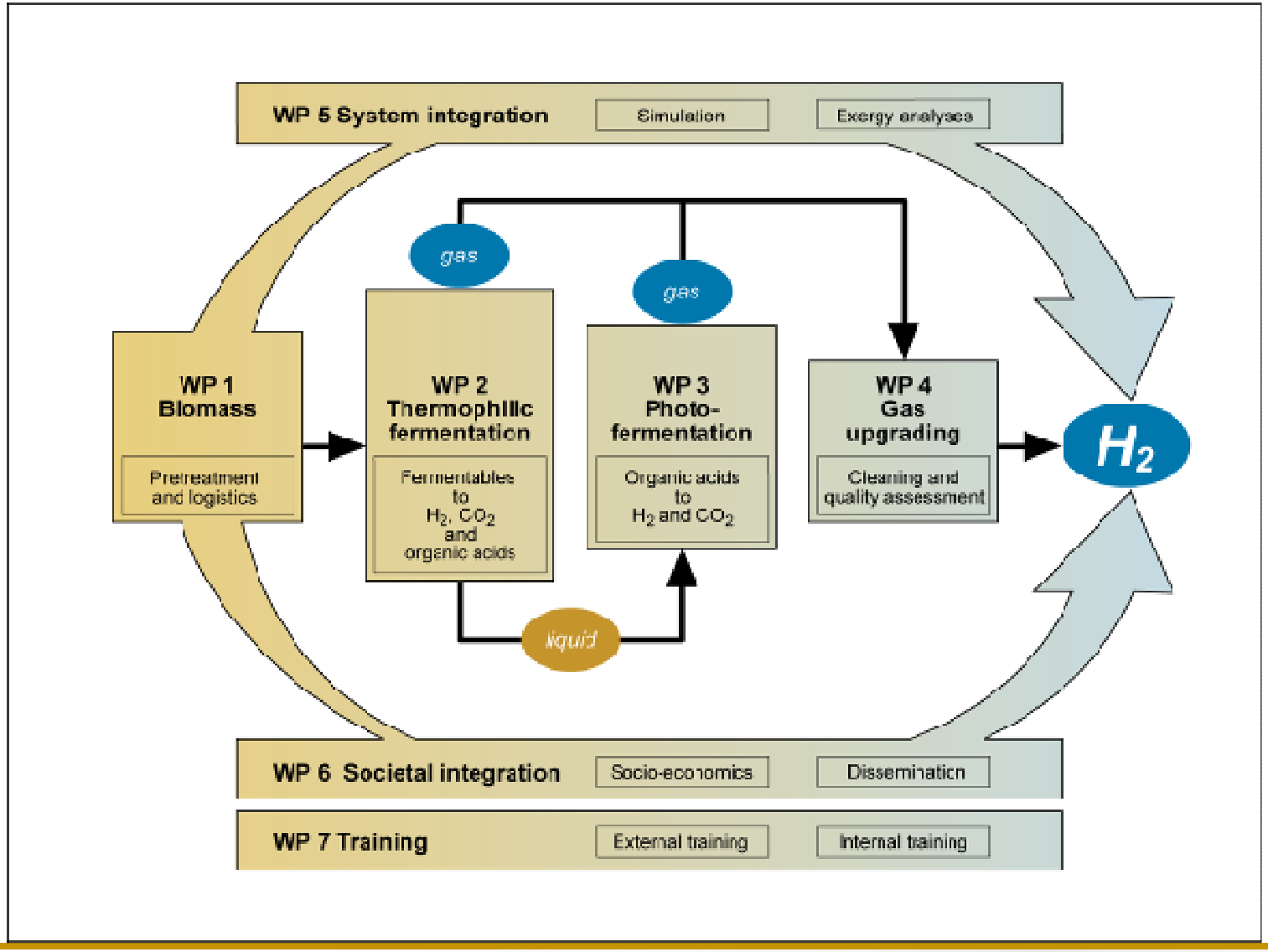
Partners in HYVOLUTION



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

Workpackages in HYVOLUTION



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

$CH_3COOH + 2H_2O \longrightarrow 2CO_2 + 4H_2$ $\quad \Delta G_o' = 0$ kJ

photosynthetic bacteria

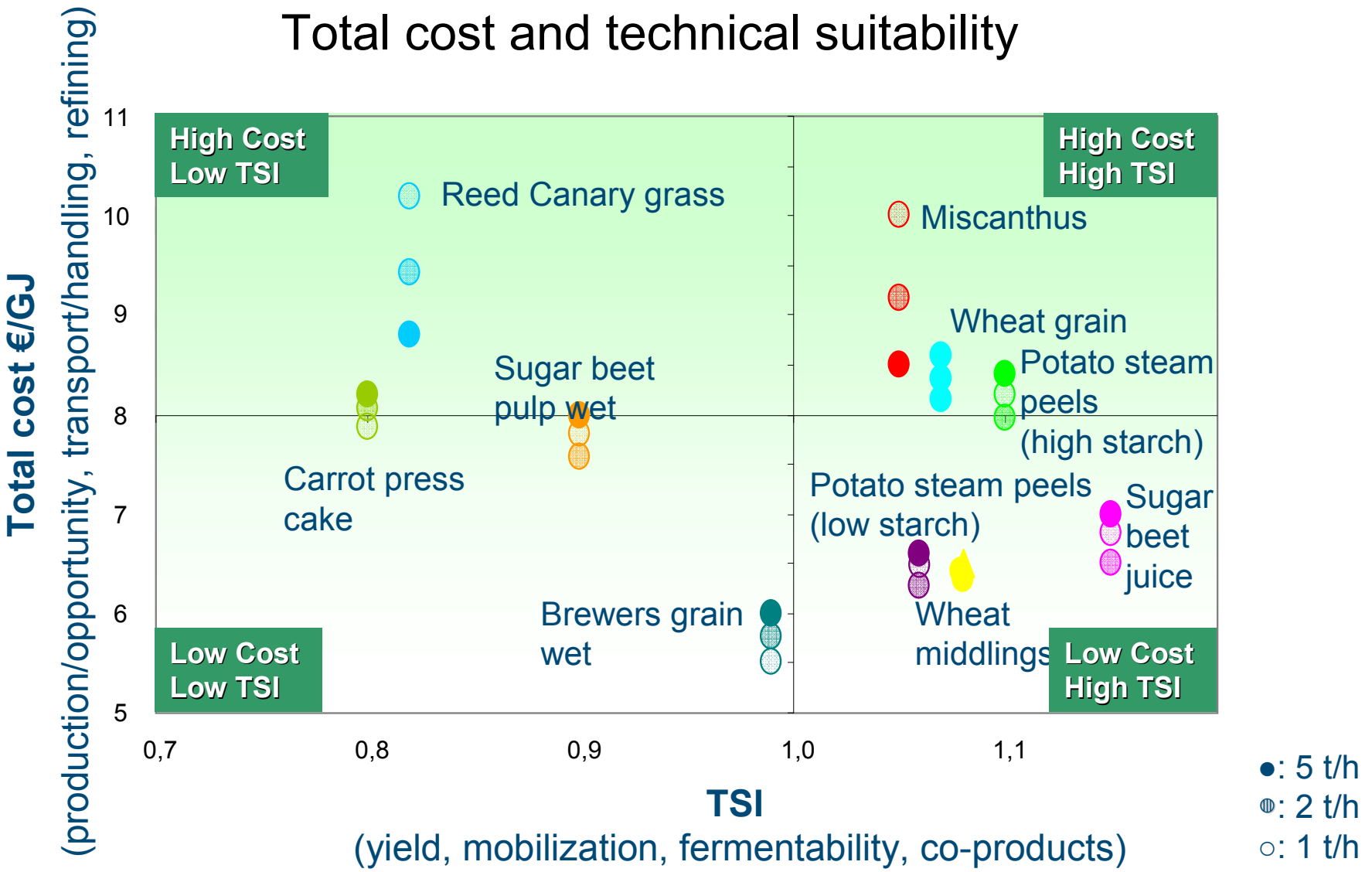
Primary by-products from agriculture

	Crop Category	Crop	Main product	Primary by-products	
				Leafy	Stems
			Million ton dry matter		
Crops already cultivated for nutritional needs	Sugar Crops	Sugar beet	18.1	7.3	-
	Starch Crops	Potato	12.9	8.8	-
		Wheat	97.5	-	82.6
		Barley	48.2	-	40.8
		Maize	43.8	-	74.5
		Other cereals	25.7	-	18.3
		Rice	2.3	-	1.7
	Other Food Crops	Grapes	12.7	-	10.9
		Apples	1.7	-	2.0
		Other fruits	3.6	-	15.1
		Vegetables	5.4	7.3	-
		Oil seeds	9.4	-	40.3
Energy crops	Sugar Crops	Sweet sorghum	19.5	4.9	7.8
	Lignocellulosic crops	Miscanthus	21.6	5.6	-

Total production:
322 Mton
Total by-products:
328 Mton

Potential H_2:
13 Mton annually

Total cost and suitability of biomass



Biomass selection

- Selected biomass for HYVOLUTION:

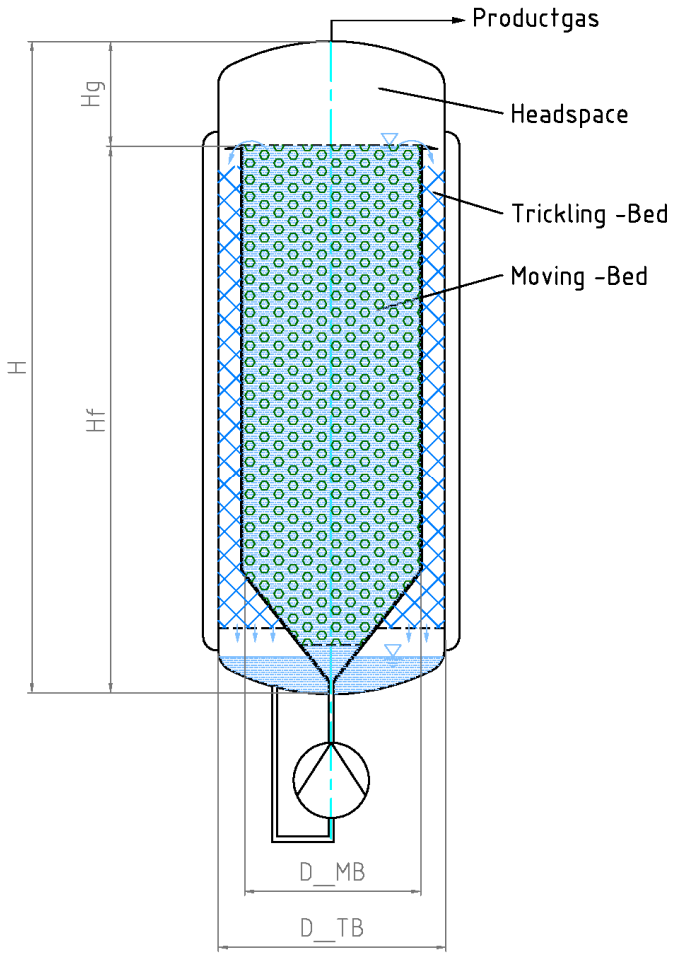
Sugar beet
sucrose

Potato steam peels
starch

Wheat bran
starch and
lignocellulose

Barley straw
lignocellulose

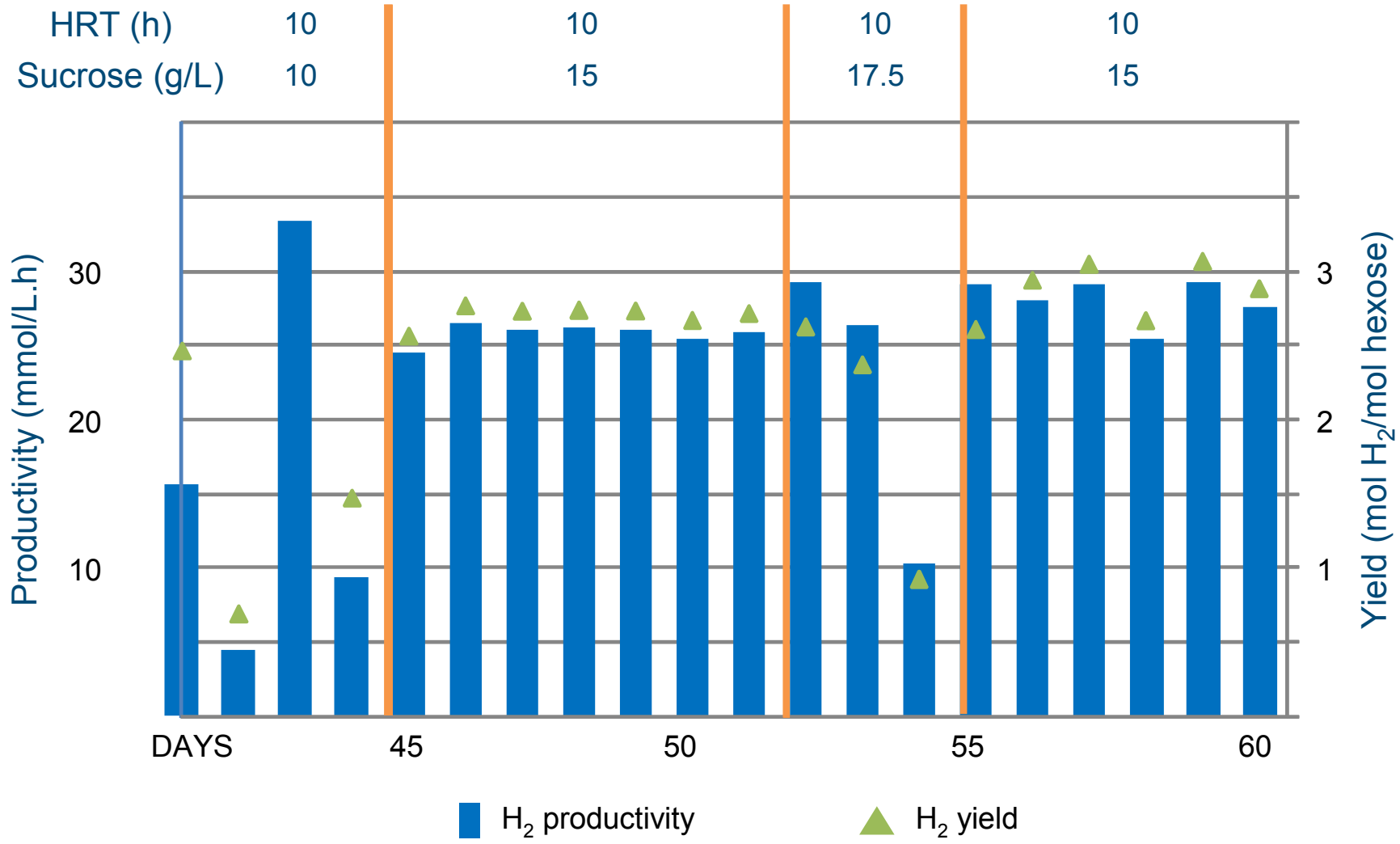
Bioreactor development



30 L CFTB

600 L CFTB

Continuous H_2 fermentation using thick juice

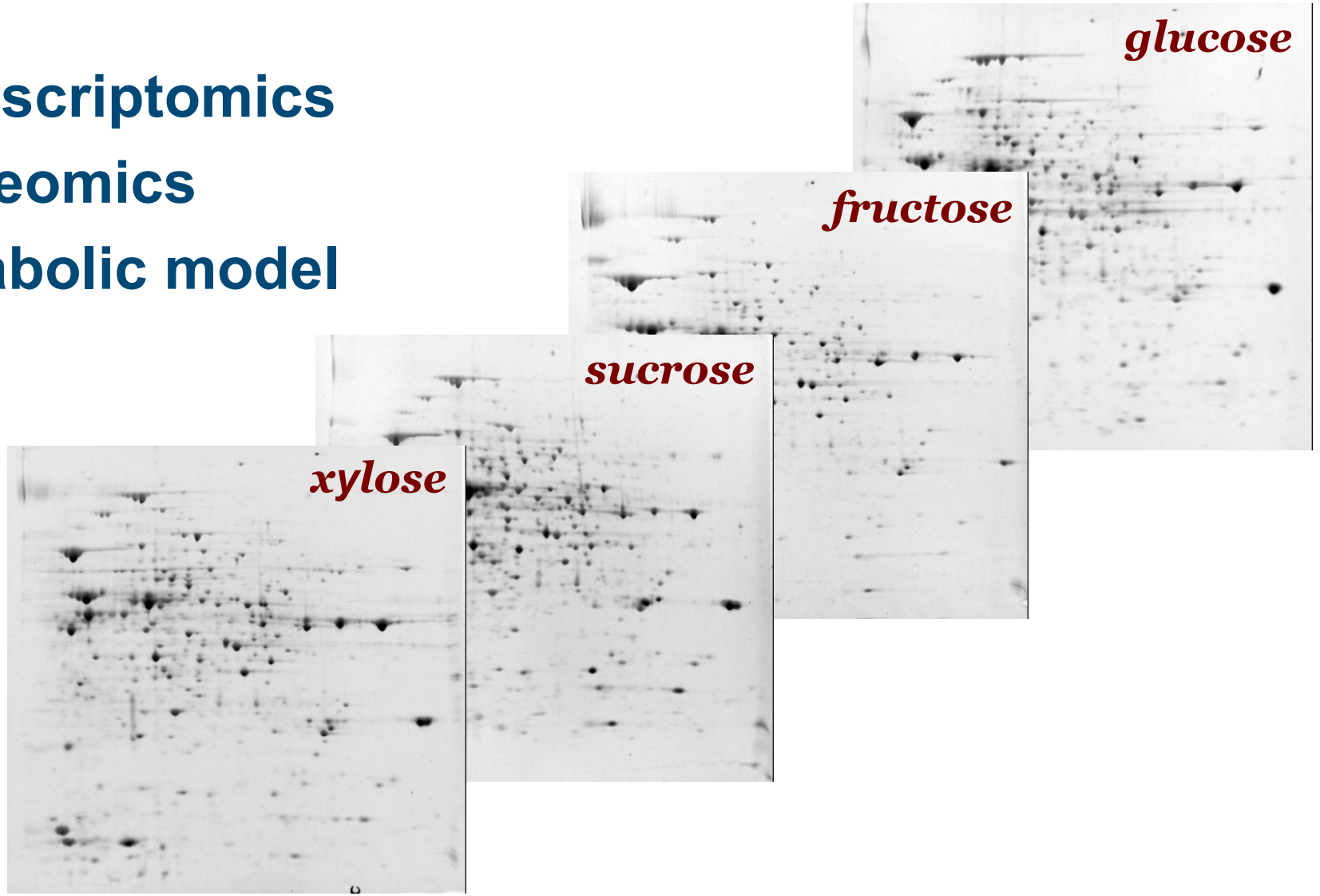


Physiology of *C. saccharolyticus*

Transcriptomics

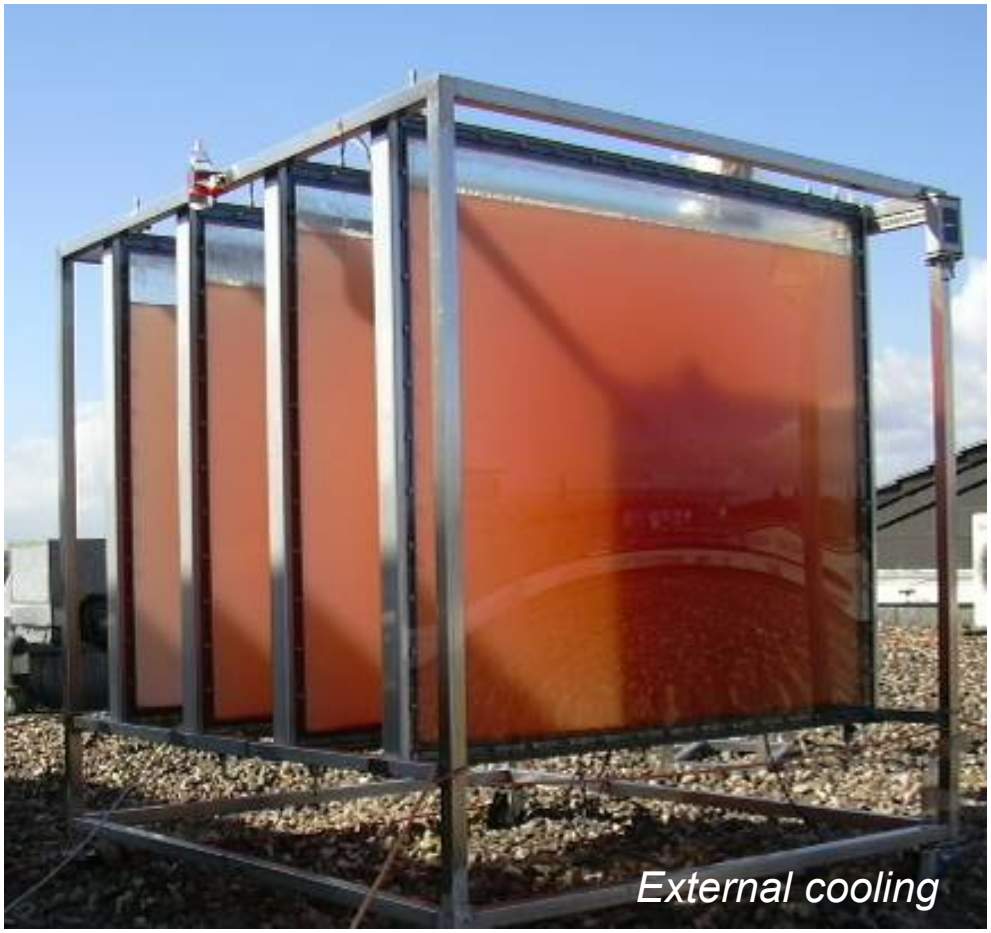
Proteomics

Metabolic model



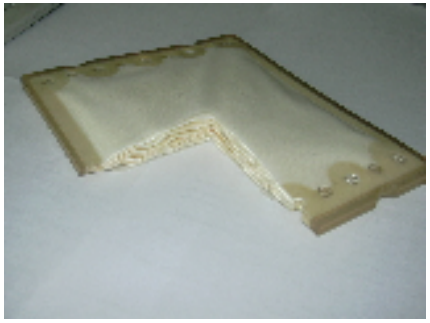
Outdoor continuous photofermentation

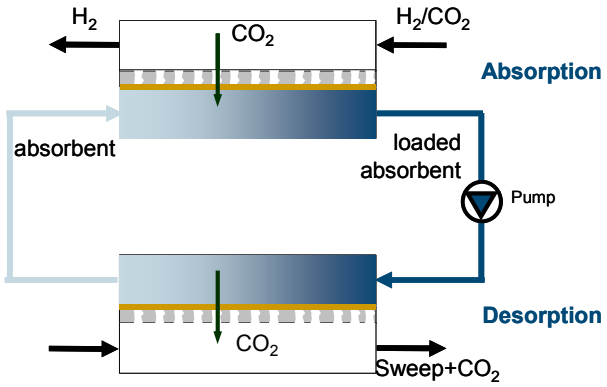
Aachen

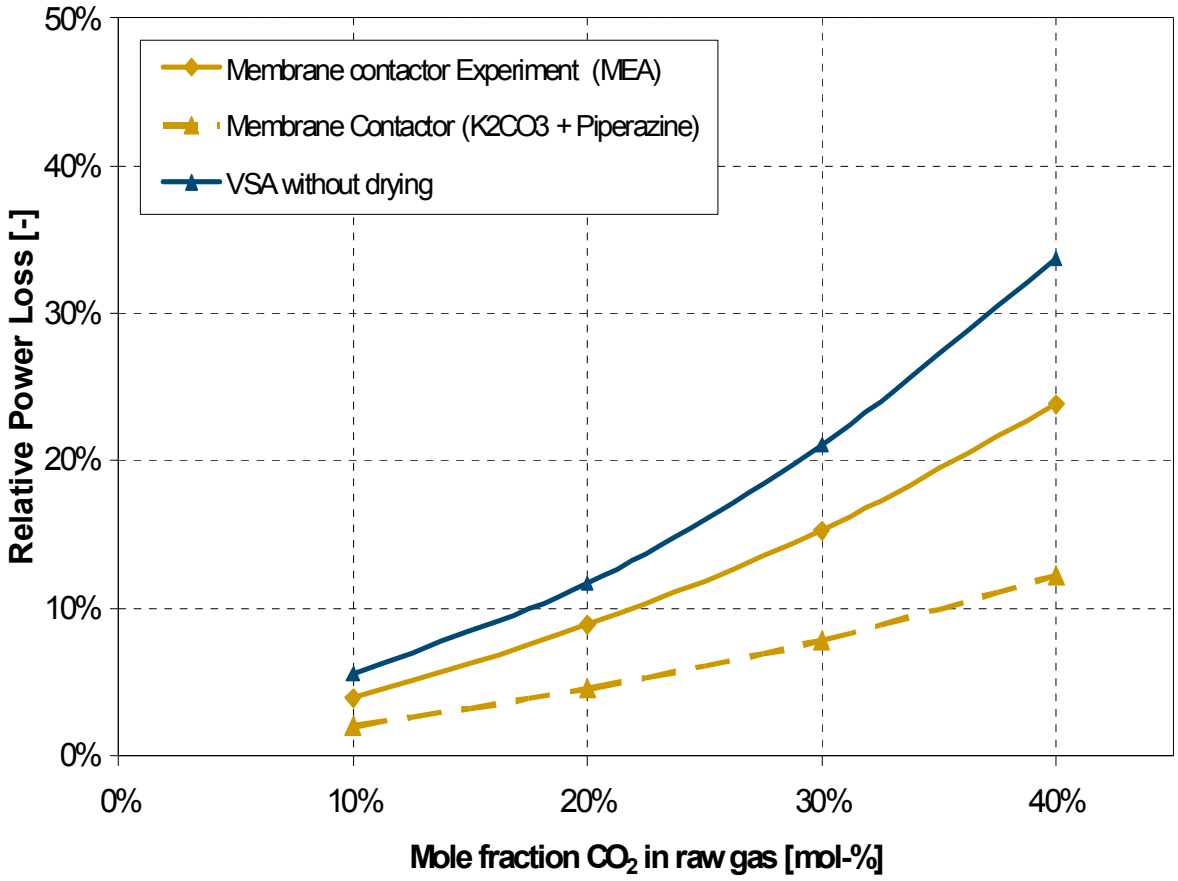


Ankara

Energy demand for gas upgrading

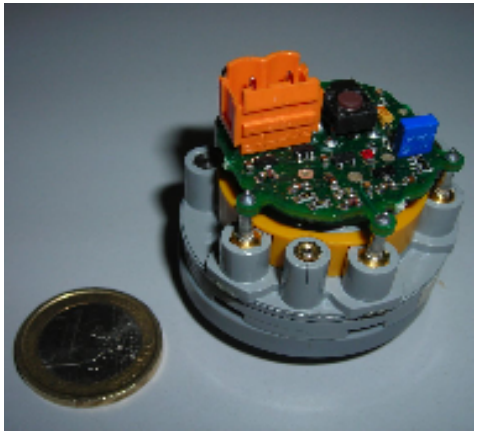




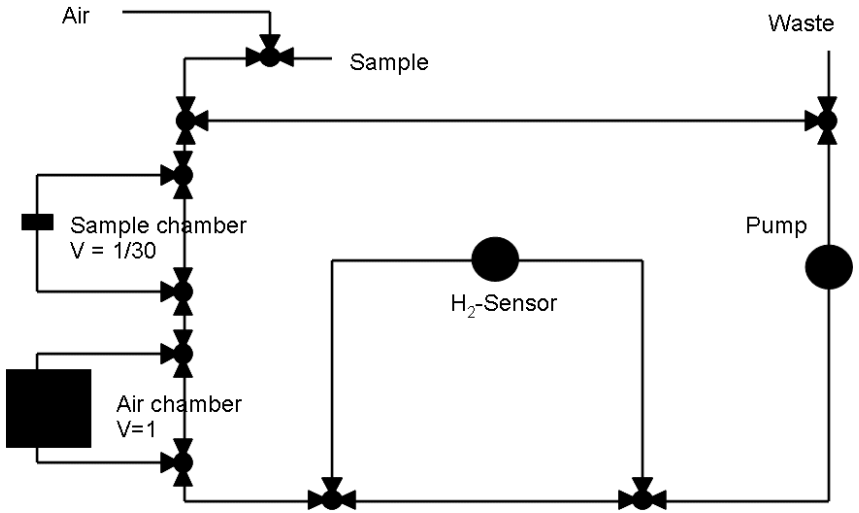


Gas analysis

- 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 dilution device

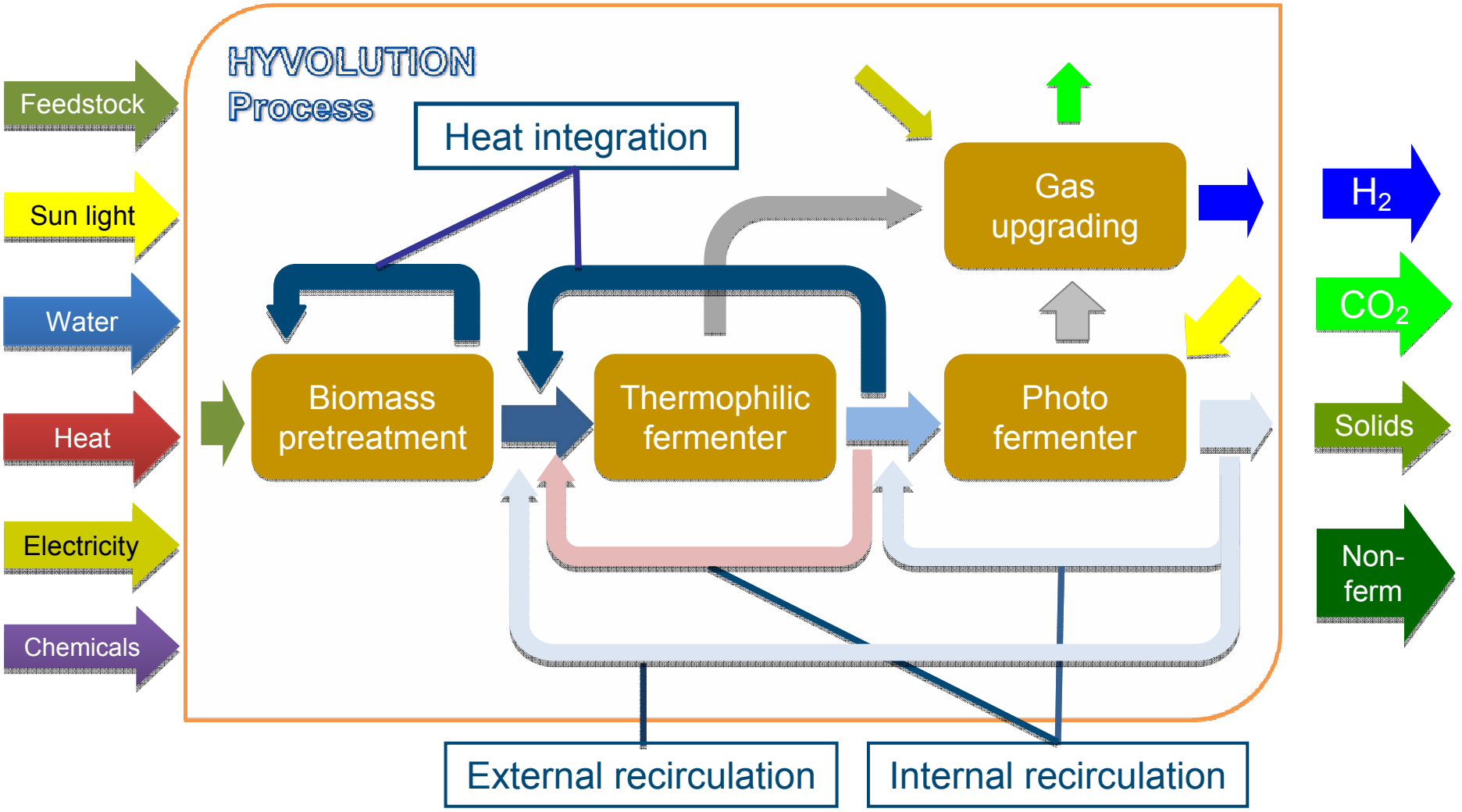


Hydrogen sensor

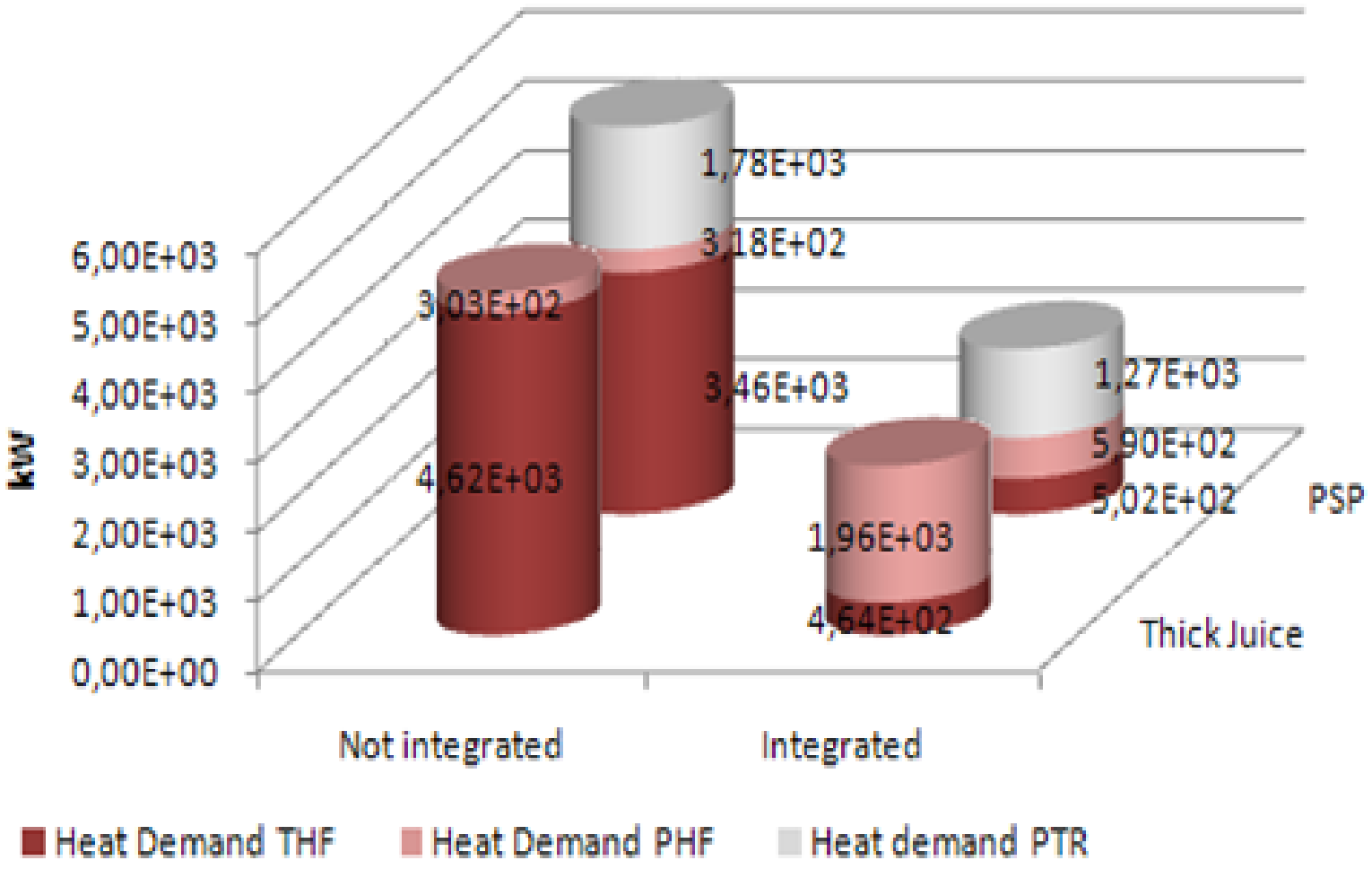


Automated dilution device

Integration options

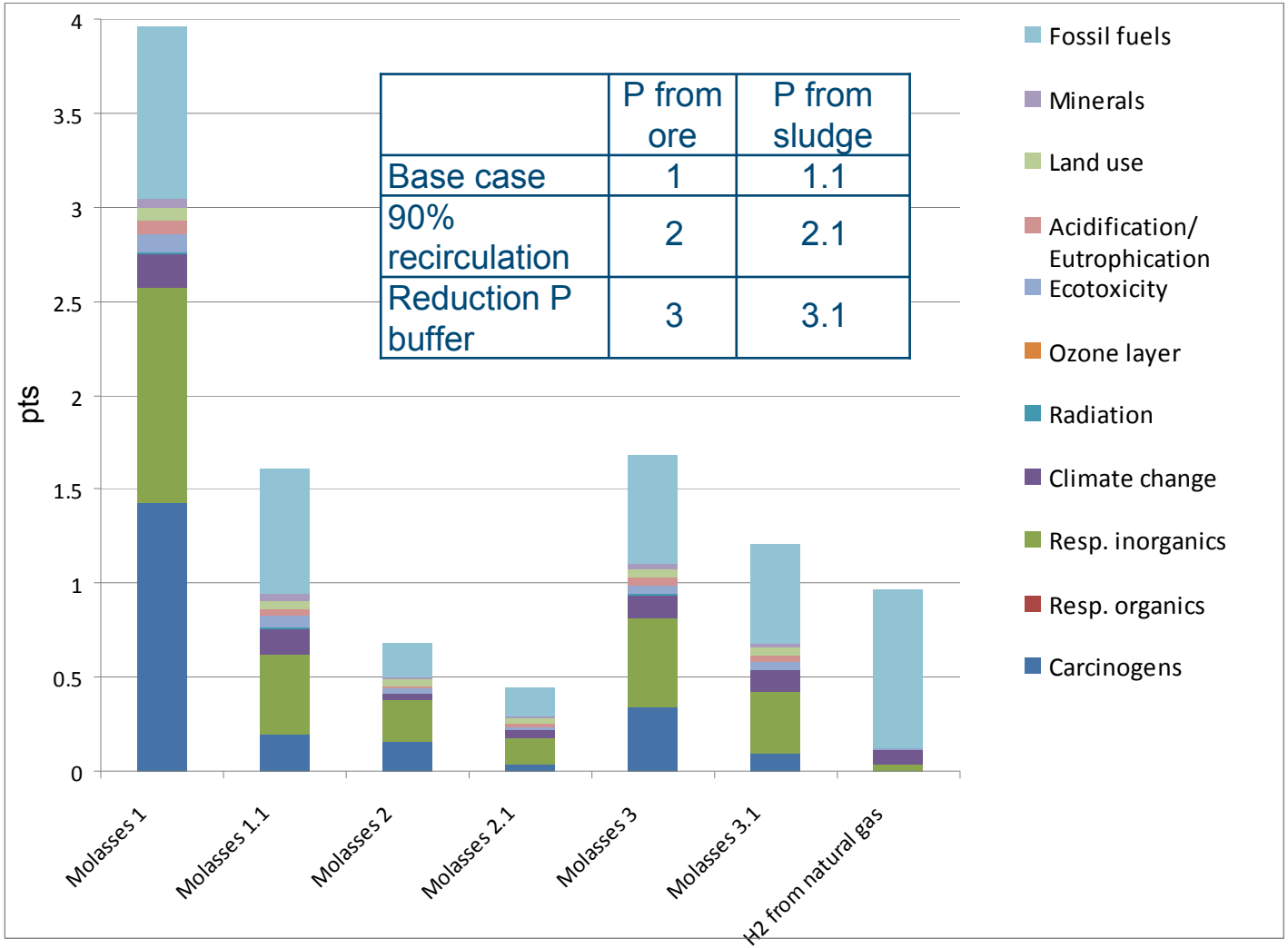


Heat integration



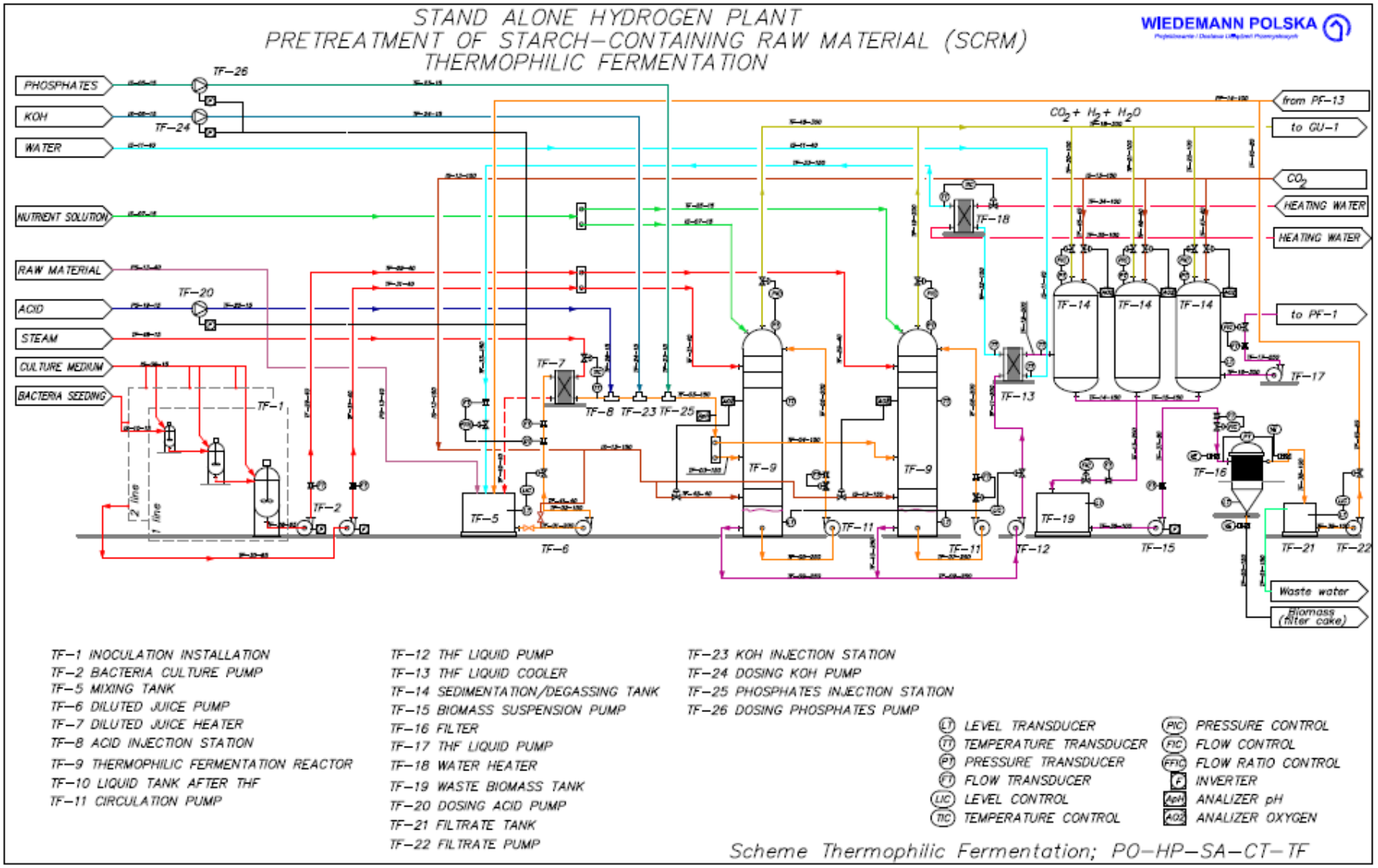
LCA of molasses as feedstock

Environmental impact



	P from ore	P from sludge
Base case	1	1.1
90% recirculation	2	2.1
Reduction P buffer	3	3.1

Blue print for a 2 MW HYVOLUTION plant



Achievements in HYVOLUTION

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

Objectives of HYVOLUTION	**State of the art**
Pretreatment technologies for degradation of biomass	Extensive progress
Equipment for mobilization of feedstock	50 L high density reactor
Maximum efficiency in conversion of biomass to hydrogen	43 ± 20 % achieved instead of 75%
Reactors for hydrogen production	600 L and 110 L dedicated reactors developed
Assessment of installations for gas cleaning	Completed
Devices for monitoring and control	Completed
Equipment for optimal gas cleaning	In progress
Minimum energy demand and maximum product output	Extensive progress
Increase of public awareness and societal acceptance	>300 activities and 27 PhD's but could be improved
Identification of market opportunities and future stakeholders	Completed

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:

-thermophilic fermentation	productivity and hydrogen removal
-photofermentation	productivity and bioreactor design

Thank you for your attention

Join us in greening the HyWay!