HYVOLUTION – Biological Production of Hydrogen from Biomasses: Process Balances and Process Integration

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Highlights der Bioenergieforschung
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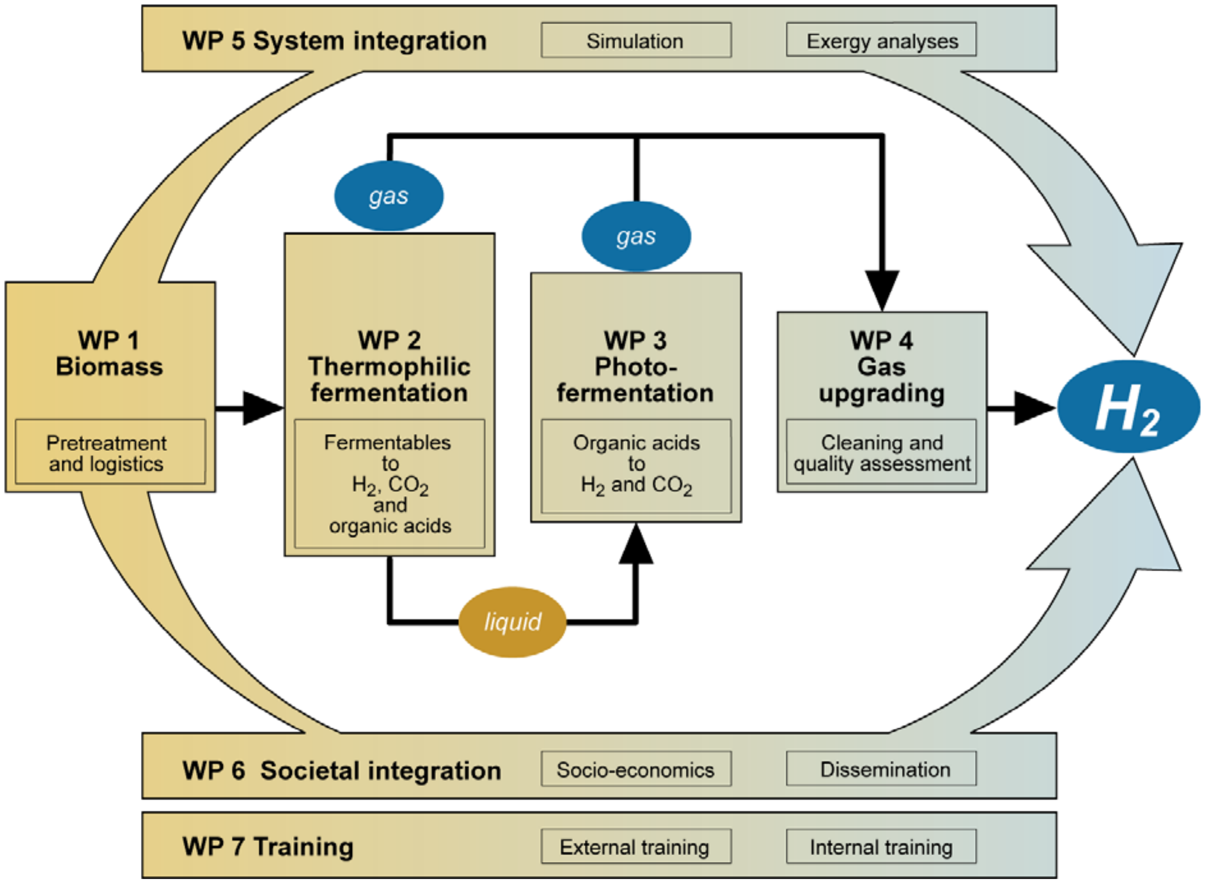
TU WIEN

TVT www.thvt.at

HYvolution

Project Structure



HYVOLUTION

Non-thermal production of pure hydrogen from biomass

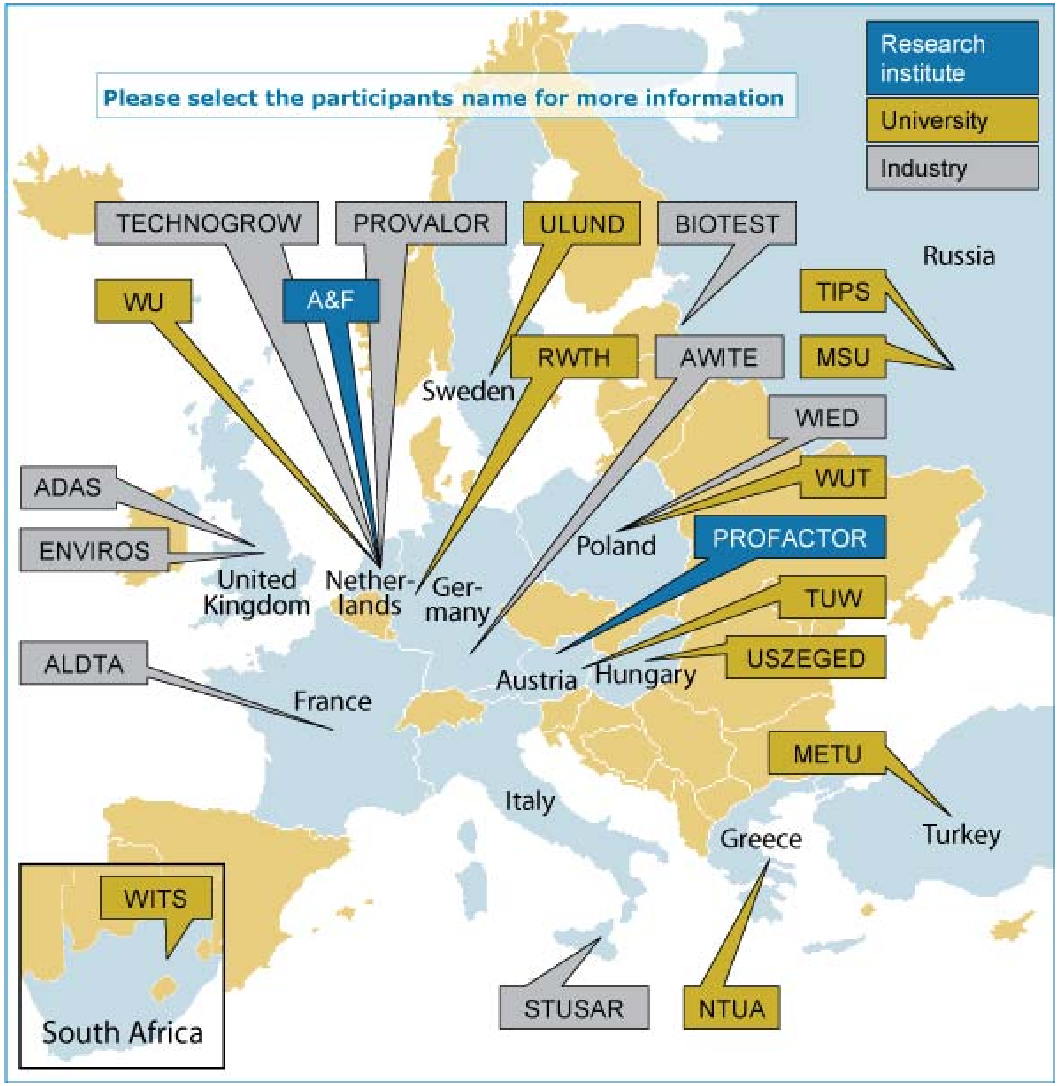
IP, 6th FP

2006 – 2011

14 M€ budget

www.hyvolution.nl

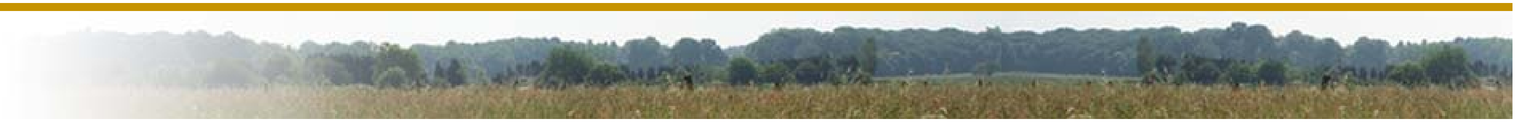
Project Partners



- **22 Partners**
  - **11 University**
  - **2 Research Intitutes**
  - **9 Industry/SME**
- **13 Countries**
  - **10 EU**
  - **Turkey**
  - **Russia**
  - **South Africa**
- **2 Partners from Austria (TU-Wien, Profactor)**

Project Objectives / Project Goals

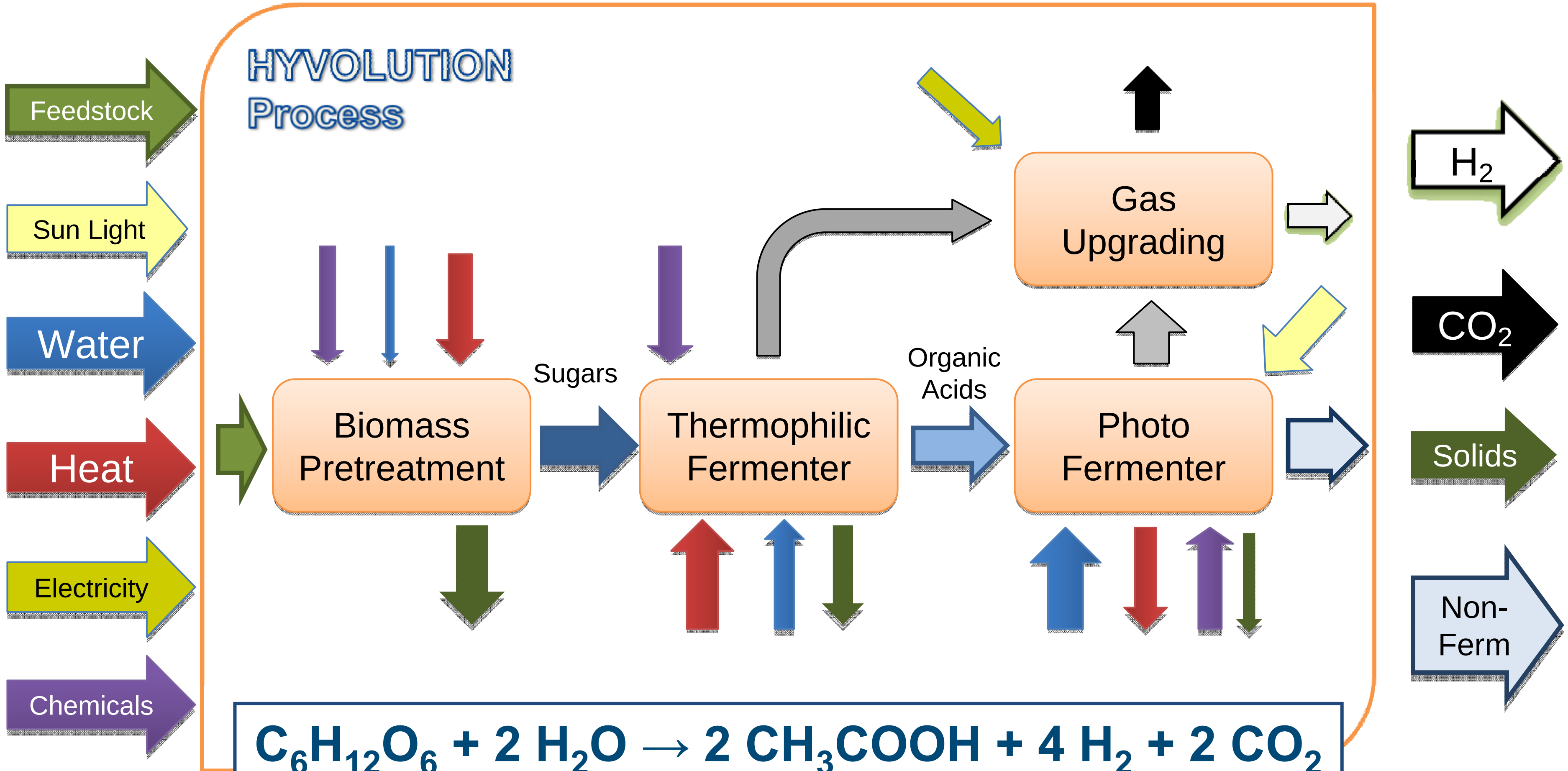
- Selection of suitable feedstock and development of dedicated pre-treatment procedures
- Identification of bottlenecks for hydrogen production in microorganisms
- Optimization of fermentation conditions and scale-up of bioreactors
- Development of gas-upgrading concept
- Detailed mass, energy and exergy balances of overall process
- Plant layout, process control concept as well as risk and safety analysis for Hyvolution plant
- Estimation of hydrogen production costs
- Environmental and socio-economic impact of Hyvolution plant



Process Simulation / Process Integration

- Process simulation to provide
  - Mass balances
  - Energy balances
- Integration of single process steps to HYVOLUTION process to
  - Maximize product output
  - Minimize energy demand
  - Minimize cost
- Selection of the optimum route for overall HYVOLUTION process by applying
  - Process simulation and exergy analyses
  - Process integration and pinch technology
  - Process engineering
  - Cost estimation

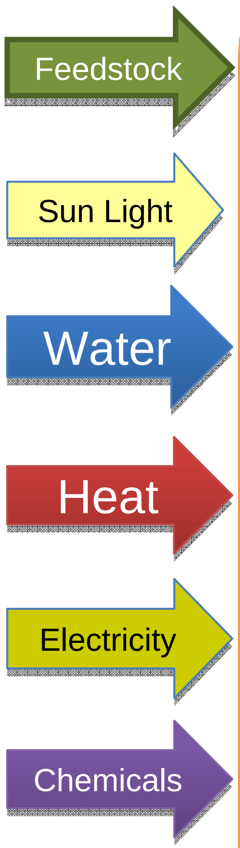
HYVOLUTION – Overall Process



$$C_6H_{12}O_6 + 2\ H_2O \rightarrow 2\ CH_3COOH + 4\ H_2 + 2\ CO_2$$

$$CH_3COOH + 2\ H_2O + \text{light} \rightarrow 4\ H_2 + 2\ CO_2$$

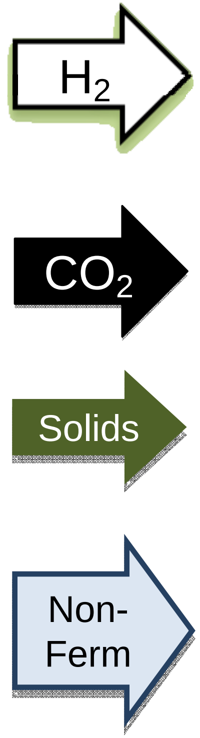
HYVOLUTION – Overall Process



	Water Demand [t/h]	Heat Demand [MW]	Cooling Demand [MW]
PSP	173	5.5	3.5
Molasses	198	4.7	2.2

@ Plant Capacity of

60 kg/h Hydrogen / 2 MW thermal power



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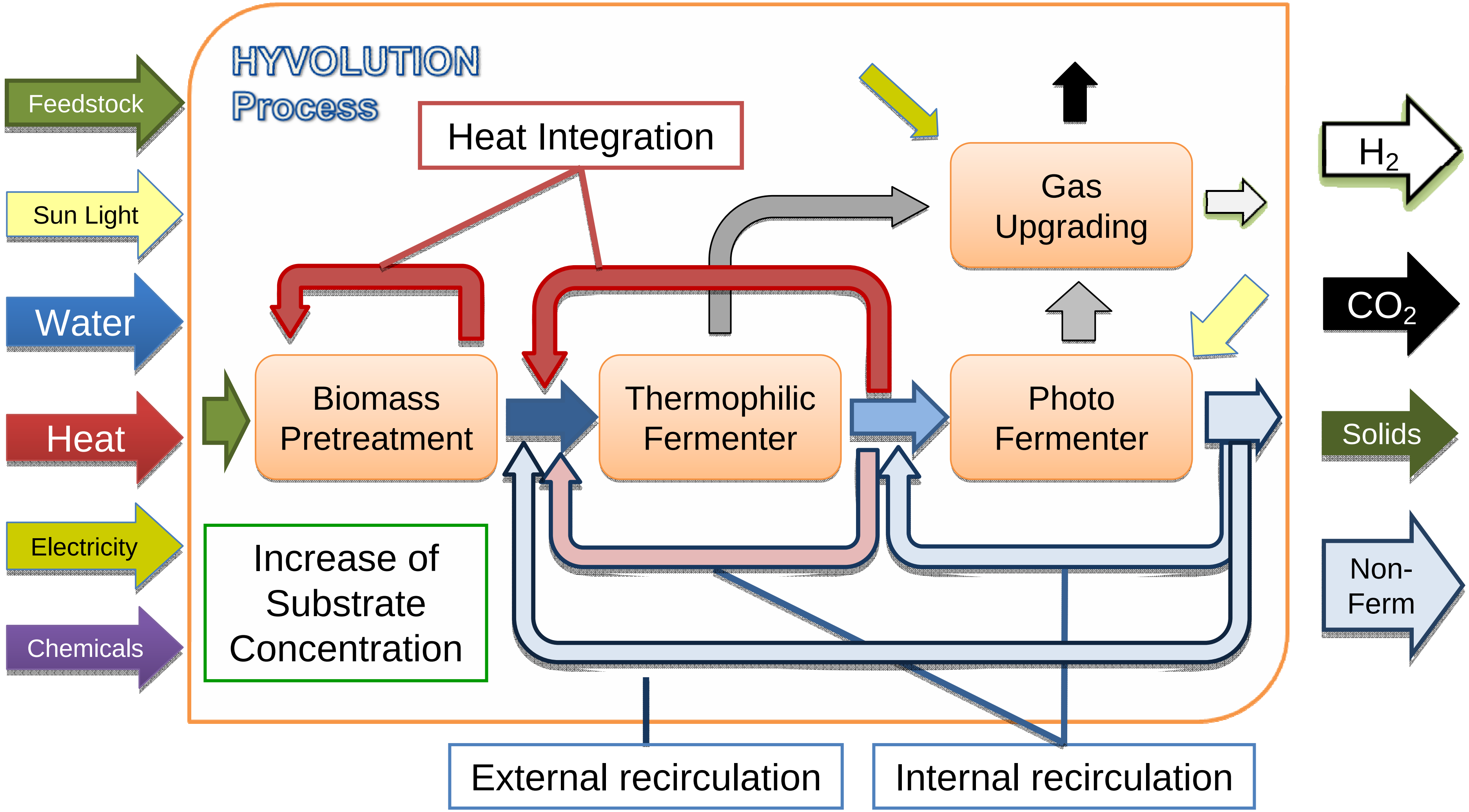
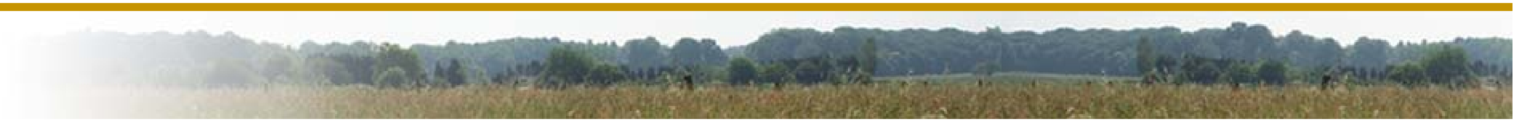
Integration Options

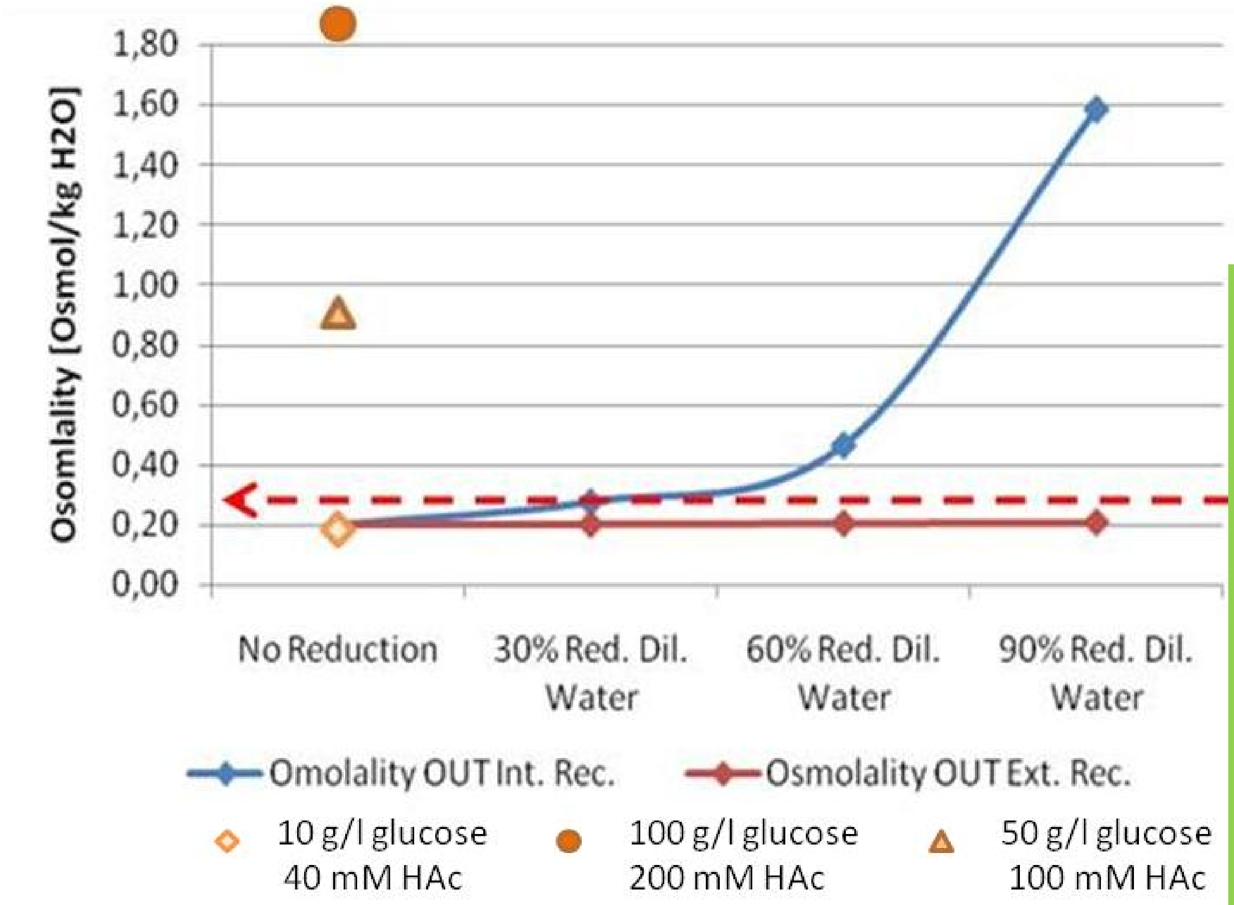


Assumed Process Conditions (Engineering)

Plant capacity	60 kg/h Hydrogen
Hydrogen purity	97 % (vol)
Feestock	PSP, Molasses, Thick Juice, Barley Straw
Gas-Upgrading	VSA
Hydrogen losses	10 % (vol)
Substrate conversion to Hydrogen THF / PHF	80 / 60 % (wt)
Substrate conversion to Cell Mass THF / PHF	15 / 15 % (wt)
Substrate losses THF / PHF	5 / 5 % (wt)
Temperature THF / PHF	70 / 30 °C
Substrate concentration THF / PHF	10 g/l Sugar / 40 mM Acetate
pH THF / PHF	6.5 / 7.3



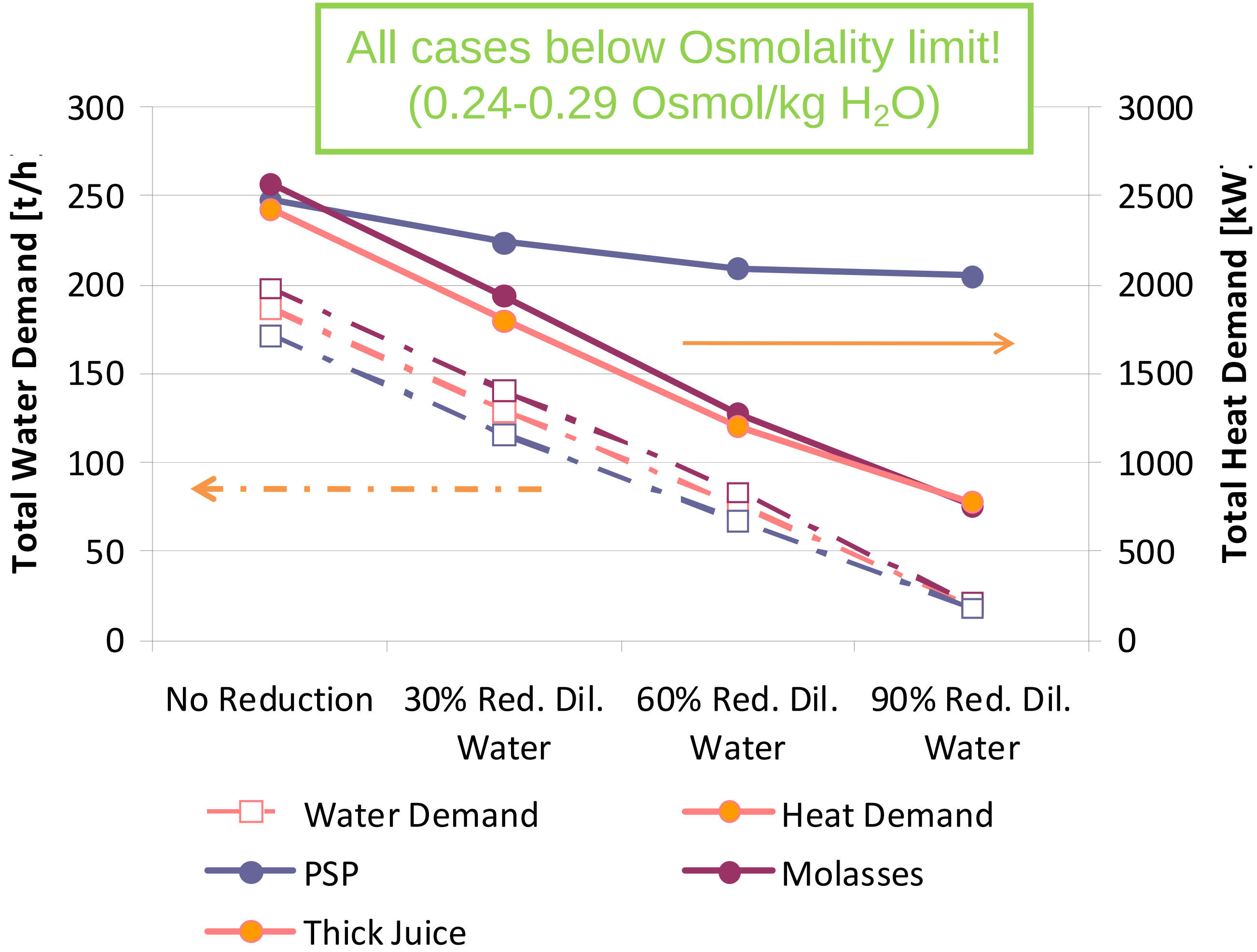
Limitations – Osmolality in THF



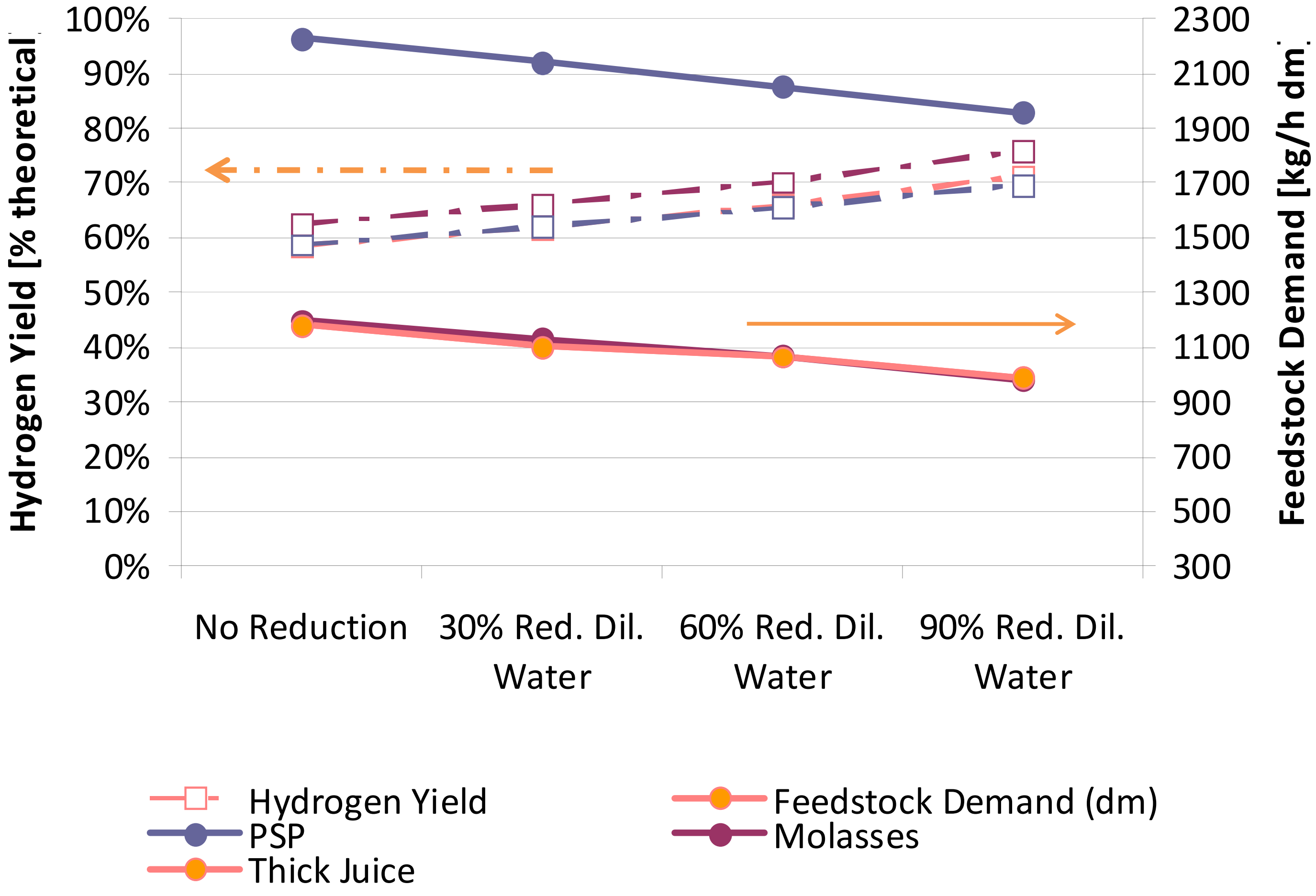
10 g/l glucose
40 mM HAc

- Internal recirculation PHF
- External recirculation PHF → THF
- Restricted substrate concentration
- Focus on heat integration reactor outlet/inlet

Intermediate Results - Integrated Process (1)



Intermediate Results - Integrated Process (2)



Actual Results – „Engineering“ Parameters

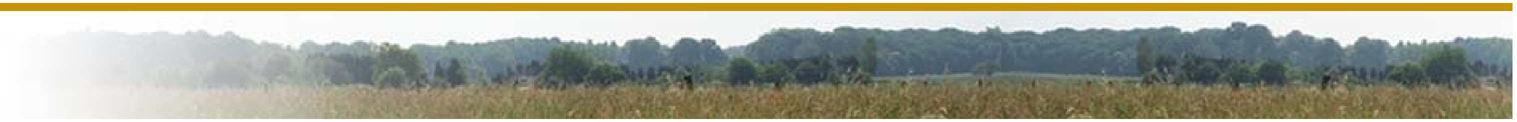
		PSP	Thick Juice	Molasses	Barley Straw
Feedstock Demand	t/h	17.6	1.1	1.5	1.9
Water Demand	t/h	74.6	80.4	80.7	93.0
Heat Demand	MW	0.92	0.74	0.74	0.96
Enzyme Demand	kg/h	0.93	-	-	629
KOH Demand	kg/h	335	310	265	333
Buffer Demand	kg/h	273	250	221	283

Assuming no heat demand in PHF

Rearrangement of Heat Integration

“Engineering” Assumptions:

- Conversion PTR: PSP 90% / Barley Straw 45%
- Conversion to H_2 in THF: 80%
- Conversion to H_2 in PHF: 60%



Comparison Molasses (Eng. / Real)

		Molasses (Eng.)	Molasses (Real/wild)	Molasses (Real/hup-)
Feedstock Demand	t/h	1.5	1.6	1.3
Water Demand	t/h	80.7	109.0	71.6
Heat Demand	MW	0.74	0.89	0.74
Enzyme Demand	kg/h	-	-	-
KOH Demand	kg/h	265	403	310
Buffer Demand	kg/h	221	337	221

Conversion THF (%) : 80 → 85 → 85

Productivity THF (mmol/l*h): 20 → 16 → 16

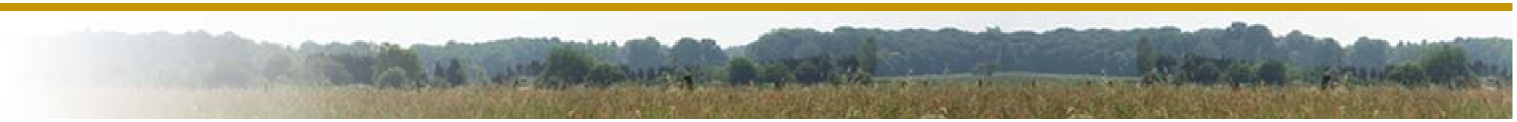
Conversion PHF (%) : 60 → 40 → 70

Productivity PHF (mmol/l*h): 0.5 → 0.6 → 0.9

Simulation / Integration - Summary / Outlook

- Process Simulation allows a clear view of the potential of HYVOLUTION process
- A proper recirculation setup allows reduction of water demand without comprising the osmotic pressure
- Recirculation improves heat balance and overall biomass to hydrogen conversion
- Heat integration in THF and PTR reduces considerably the heat demand (by 85% and 30%, respectively)

- Improvment of productivites in both fermentors
- Reduction enzyme (Barley Straw) and chemical demand
- Covering heat demand from residues



Partners and Acknowledgement

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