

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

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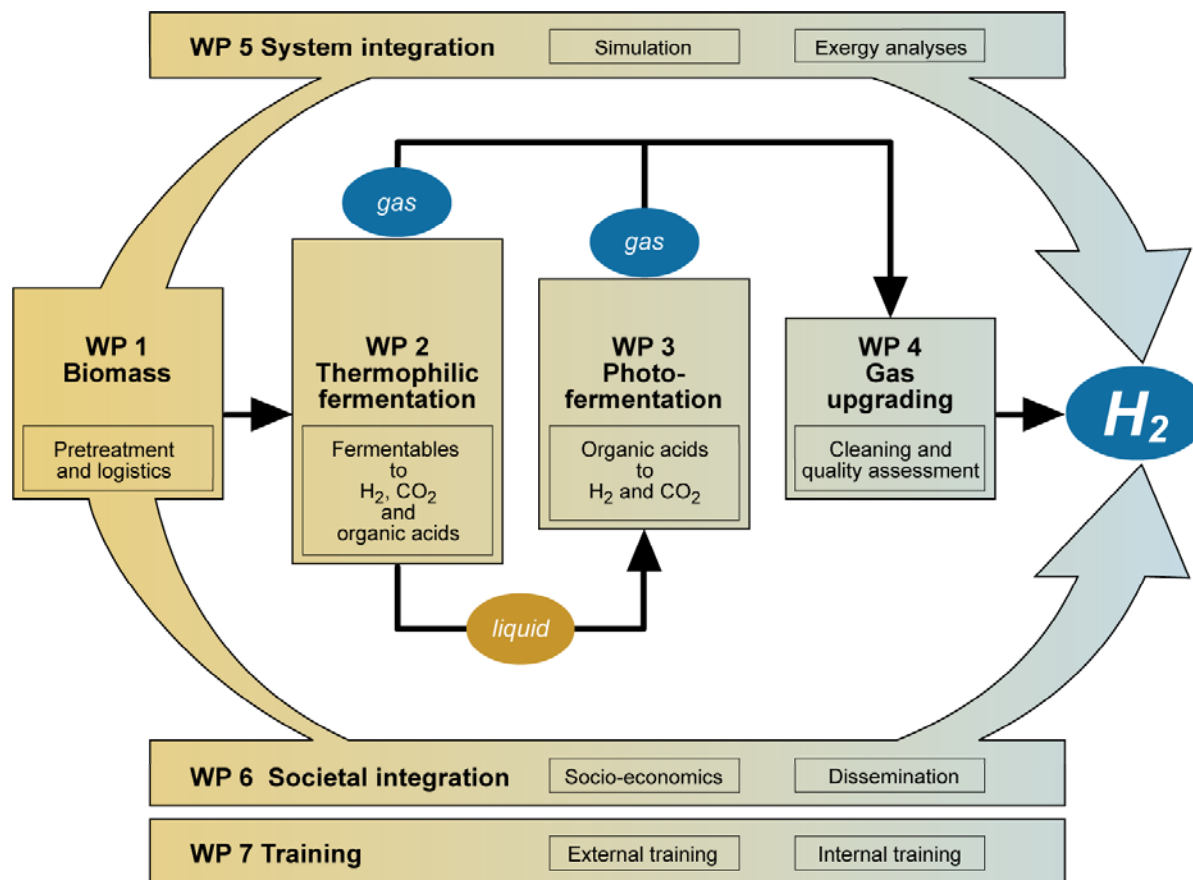
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Highlights der Bioenergieforschung  
March 31<sup>st</sup>, 2011, Wieselburg, Austria



# Project Structure



## HYVOLUTION

Non-thermal  
production of  
pure hydrogen  
from biomass

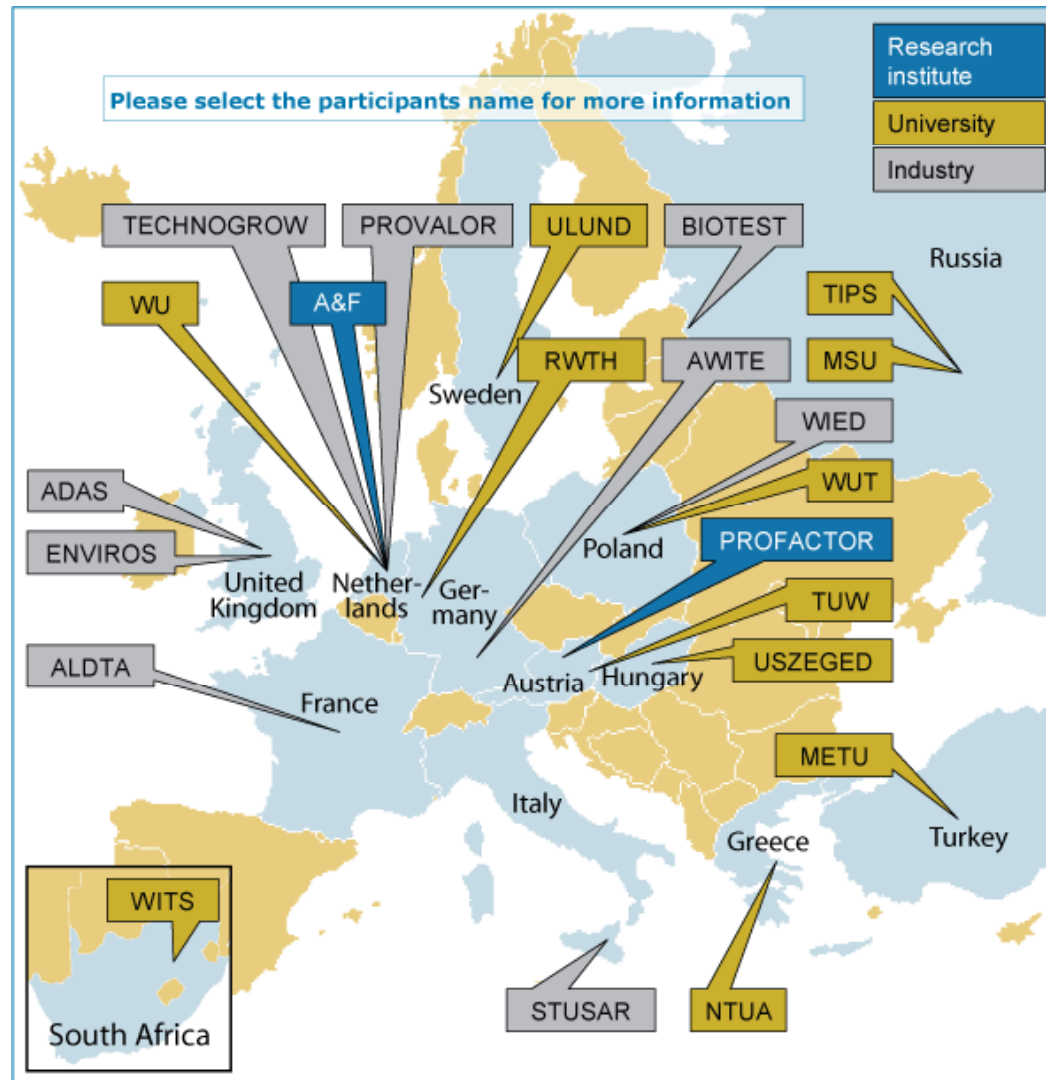
IP, 6th FP

2006 – 2010

14 M€ budget

[www.hyvolution.nl](http://www.hyvolution.nl)

# Project Partners



- **22 Partners**
  - 11 University
  - 2 Research Institutes
  - 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

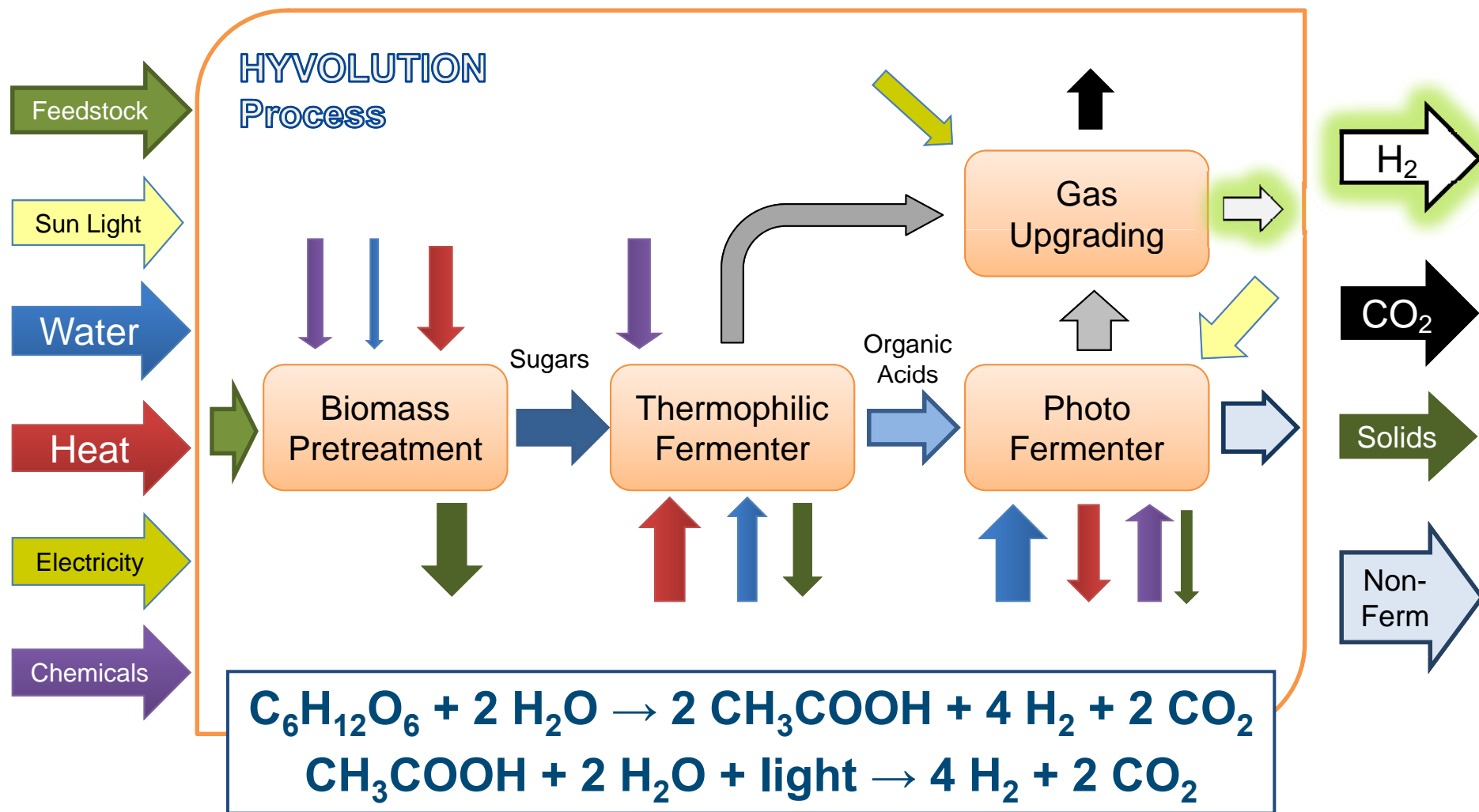


# Process Simulation / Process Integration

- 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

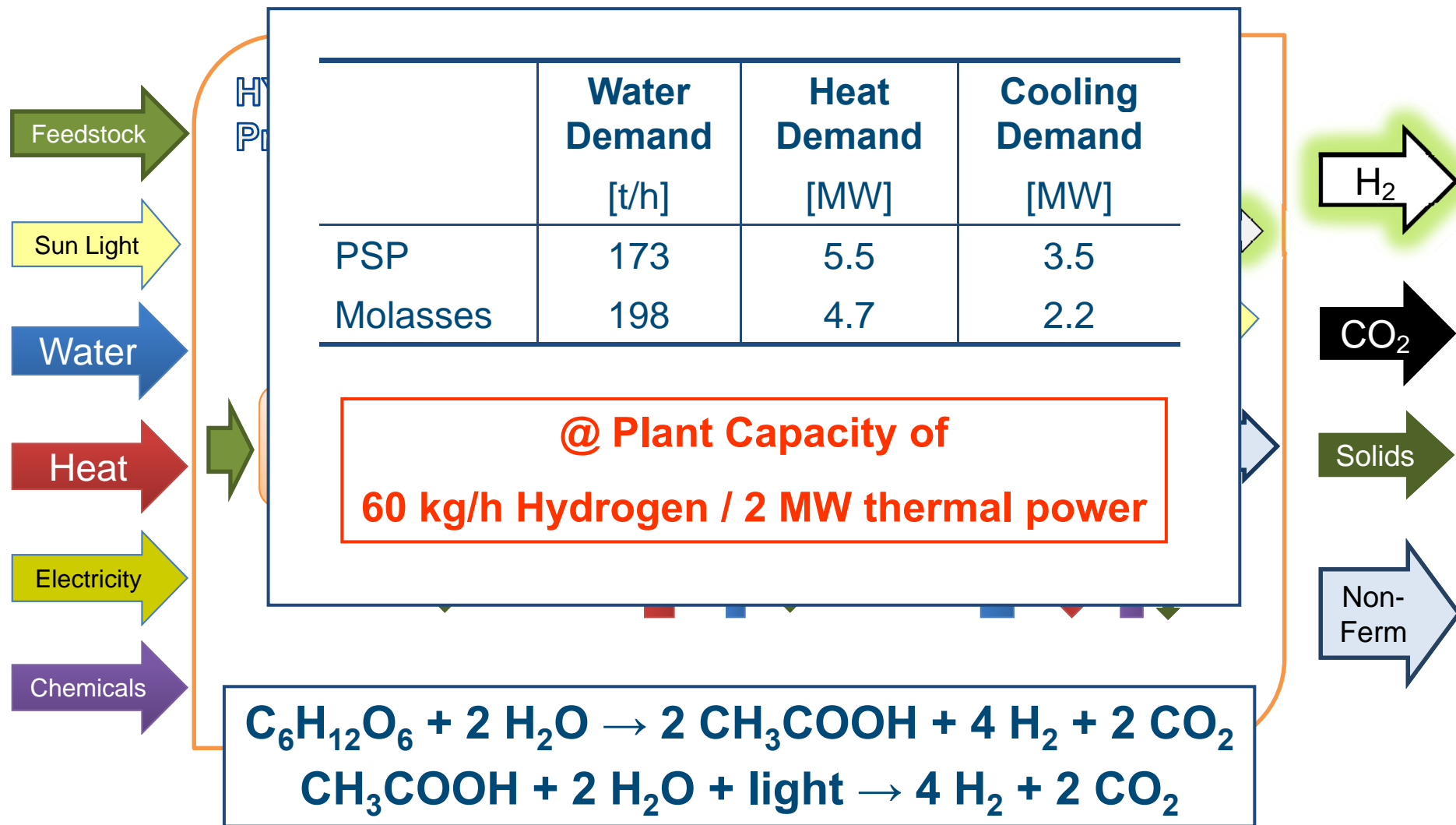


# HYVOLUTION – Overall Process

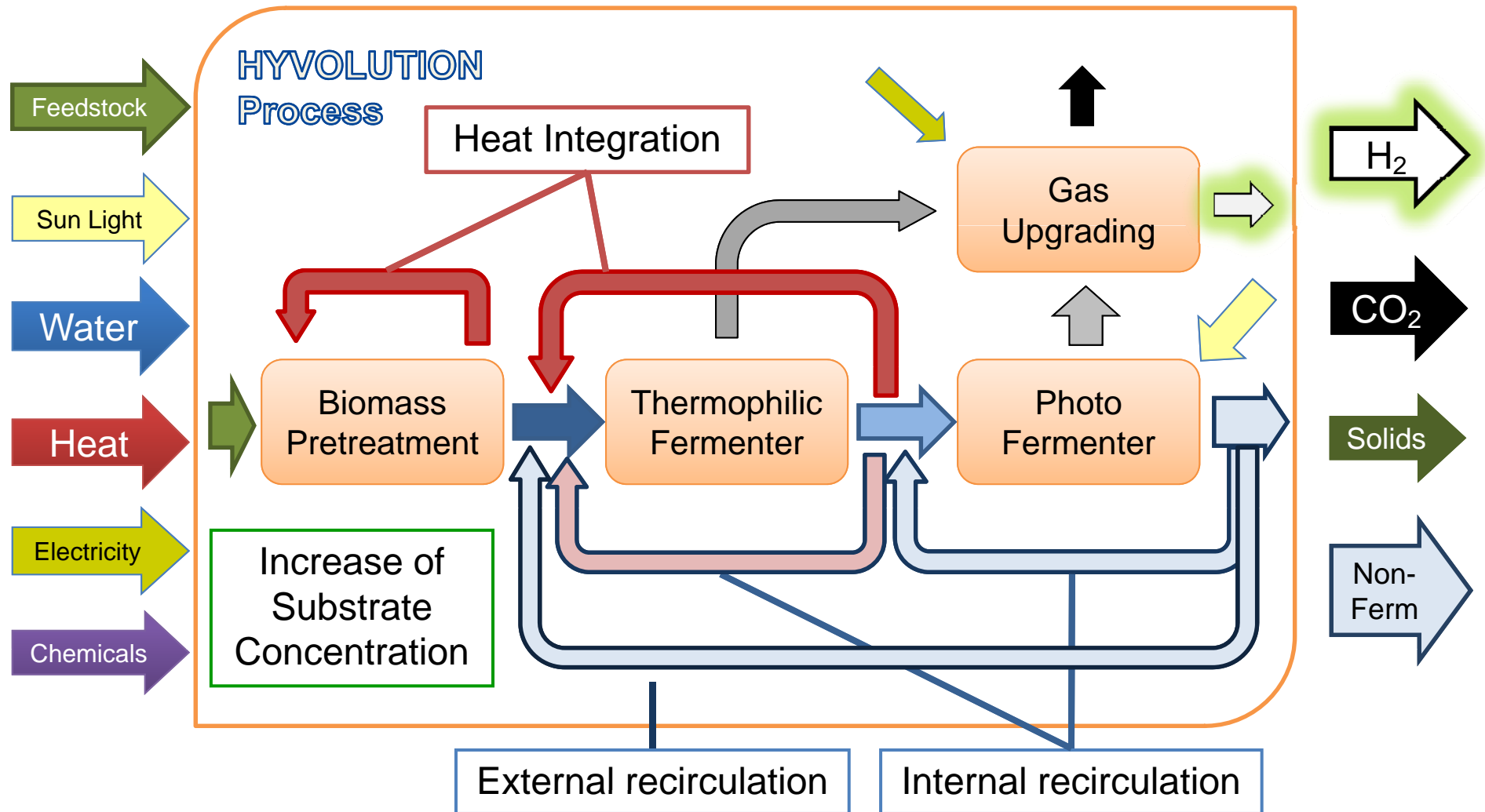




# HYVOLUTION – Overall Process



# Integration Options





# Assumed Process Conditions (Engineering)

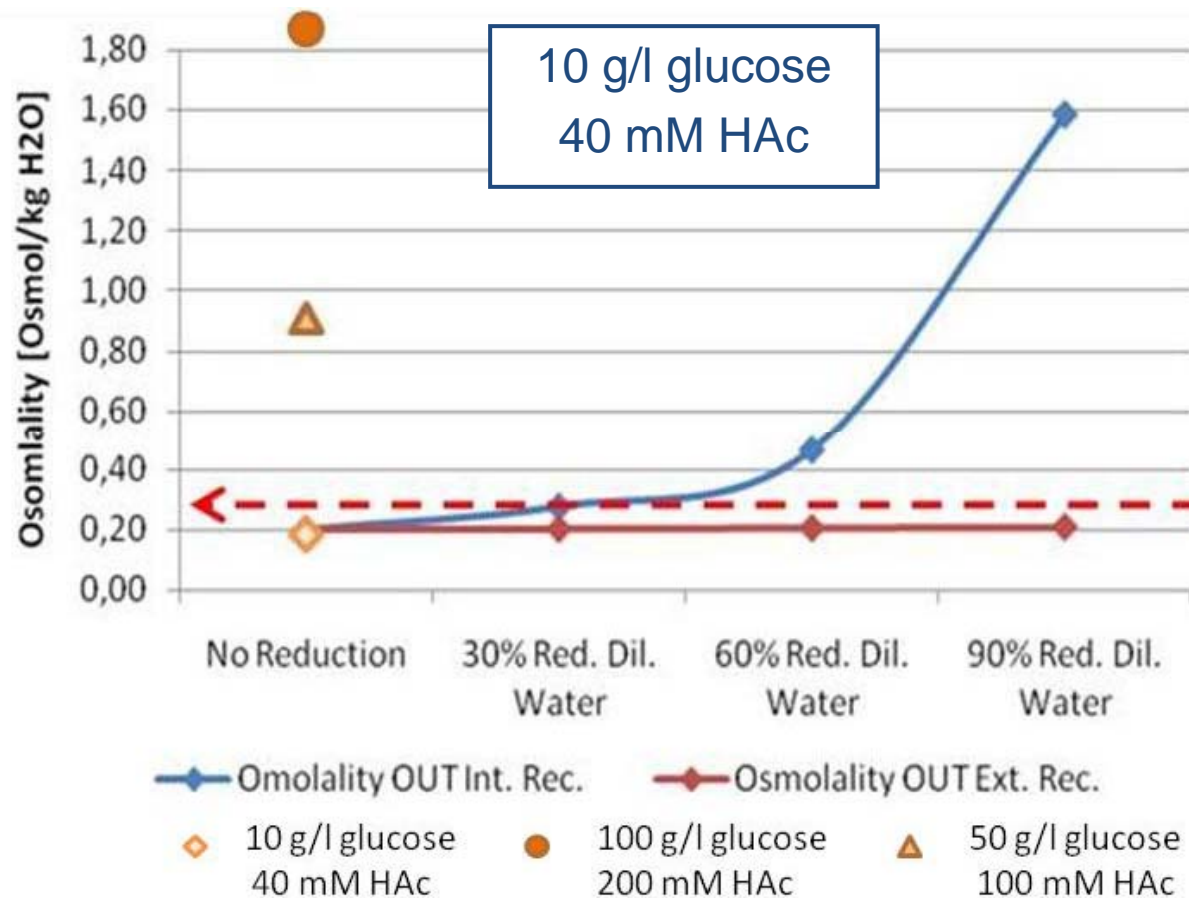
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Plant capacity	60 kg/h Hydrogen
Hydrogen purity	97 % (vol)
Feestock	PSP, Molasses, Thick Juice, Barley Straw
Gas-Upgrading	VSA
Hydrogen losses	10 % (vol)
Substrate conversion to Hydrogen THF / PHF	80 / 60 % (wt)
Substrate conversion to Cell Mass THF / 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

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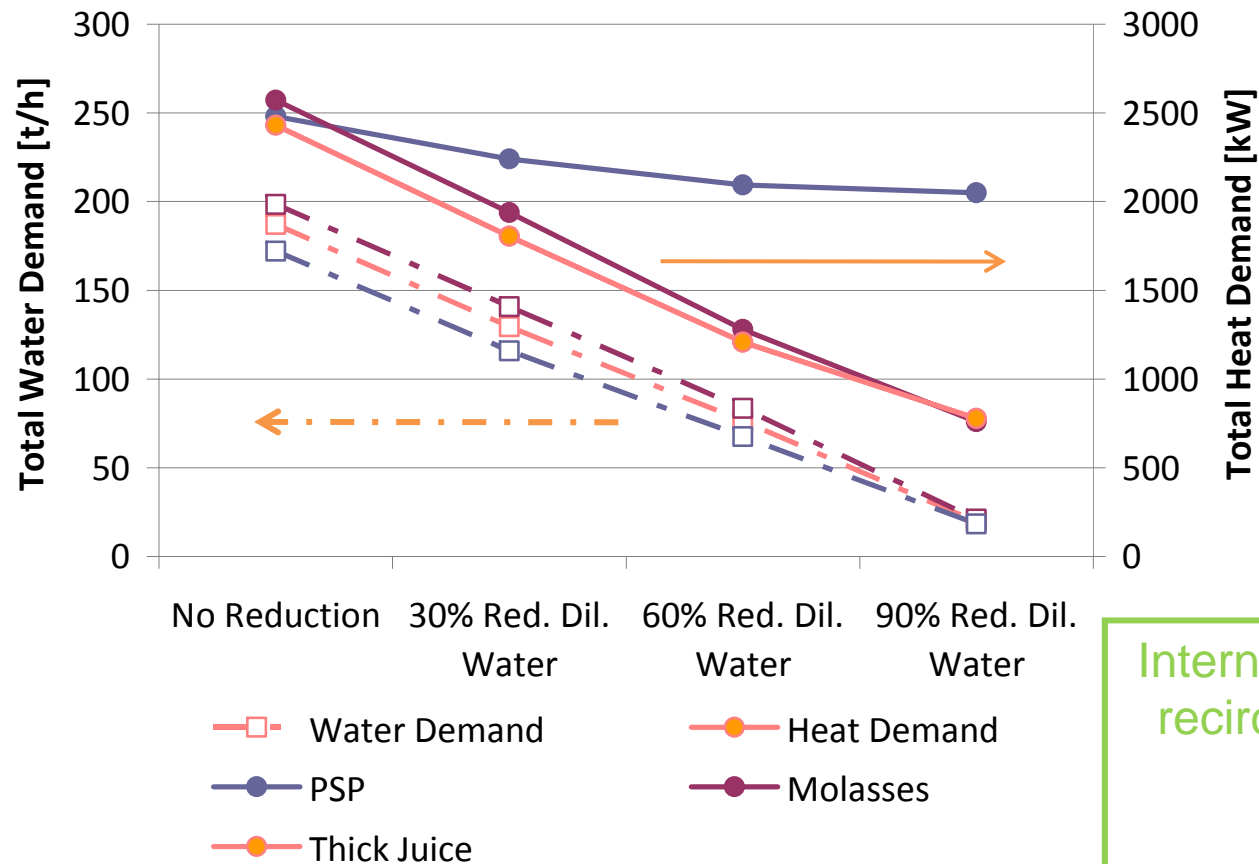


# Limitations – Osmolality in THF



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

# Intermediate Results - Integrated Process (1)

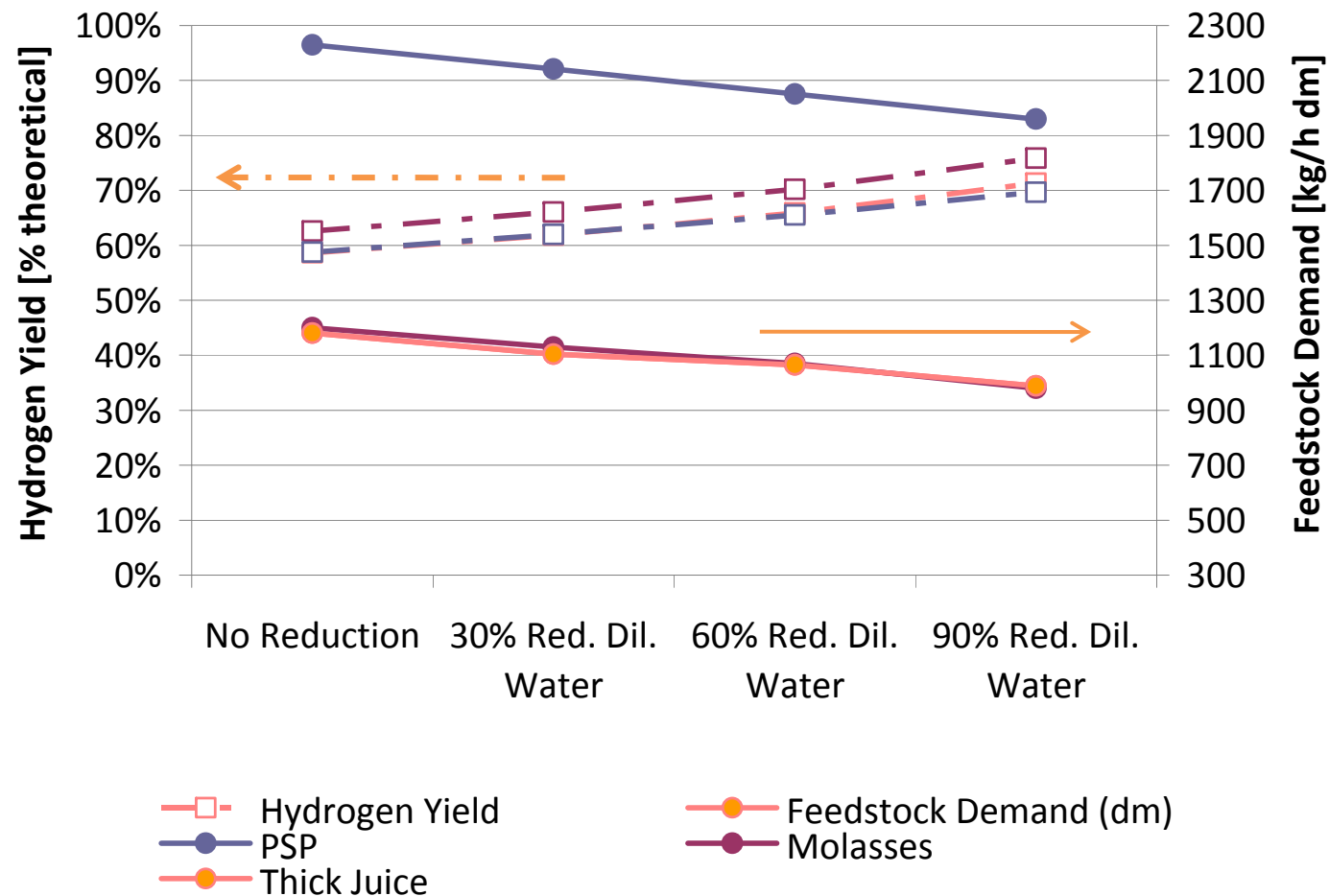


Internal recirculation PHF & recirculation PHF → THF:

All cases below  
Osmolality limit!  
(0.24-0.29 Osmol/kg H<sub>2</sub>O)



# 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<sub>2</sub> in THF: 80%
- Conversion to H<sub>2</sub> 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)
- Improvement of productivities in both fermentors
- Reduction enzyme (Barley Straw) and chemical demand
- Covering heat demand from residues



# Partners and Acknowledgement



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project by the European Union's  
6<sup>th</sup> Framework Program  
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# Publications and further Reading

- P.A.M. Claassen and T. de Vrije, Non-thermal production of pure hydrogen from biomass: Hyvolution, Chem. Eng. Trans., 18 (2009) pp. 333-338.
- D. Foglia, W. Wukovits, A. Friedl, M. Ljunggren, G. Zacchi, K. Urbaniec and M. Markowski, Effects of feedstocks on the process integration of biohydrogen production, Clean Technol. Environ. Policy, DOI: 10.1007/s10098-011-0351-7
- P.A.M Claassen, T. de Vrije, E. Koukios, E. van Niel, E. Özgür, I. Eroglu, I. Nowik, M. Modigell, W. Wukovits, A. Friedl, D. Ochs and W. Ahrer, Non-Thermal Production of Pure Hydrogen from Biomass : HYVOLUTION; in: D. Stolten (Ed.) "Hydrogen and Fuel Cells - Fundamental, Technologies and Applications", Wiley-VCH, Weinheim, 2010, ISBN: 978-3-527-32711-9, pp. 169 - 188.
- Journal of Cleaner Production, 18 (2010) Suppl. 1 – Special Issue on Hyvolution / (Bio-) Hydrogen
- Project Webpage: [www.hyvolution.nl](http://www.hyvolution.nl)

