

# Wageningen UR: Research in Biofuels

Robert Bakker, Ed de Jong, Ruud Weusthuis, Erik van Seventer  
Wageningen UR-Biobased Products

[robert.bakker@wur.nl](mailto:robert.bakker@wur.nl)



# Overview presentation

- Biofuels
- Lignocellulose as feedstock
- Bioethanol
- Butanol
- Questions?



# Biofuels: transportation fuels from biomass

- Legislation leads to higher demand for biofuels
- Bioethanol: primary biofuel in the world
- Large scale production: Brazil, U.S.A.
- Current EU producers: Spain, France, Sweden, Germany
- Current raw materials for biofuels:
  - Sugarcane
  - Maize
  - Wheat, Barley
  - Sugarbeets
- Current feedstocks are expensive, and require large amounts of productive agricultural land -> need for other feedstocks



# Why use lignocellulose as raw material?

## Feedstock= starch, sugars

- high raw material cost
- limited carbon benefits
- Competition with food crops
- cattle feed as byproduct
- sugars are easily released from the biomass



## Feedstock = lignocellulose:

- low raw material cost
- high carbon benefits
- Complementarity with food crops
- diversity of byproducts: lignin, electricity, heat
- significant pretreatment needed to release sugars

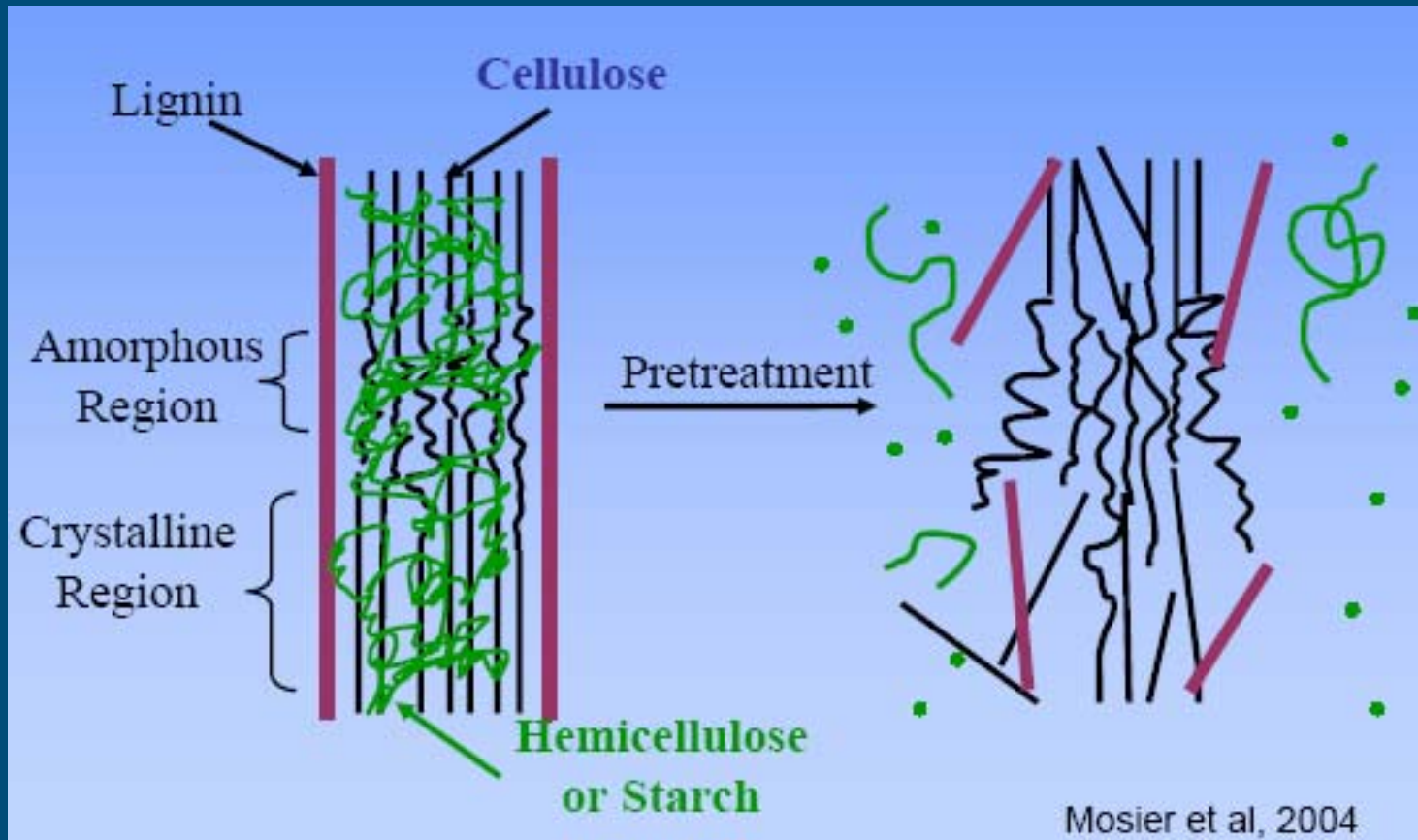
# Ethanol from cellulose?



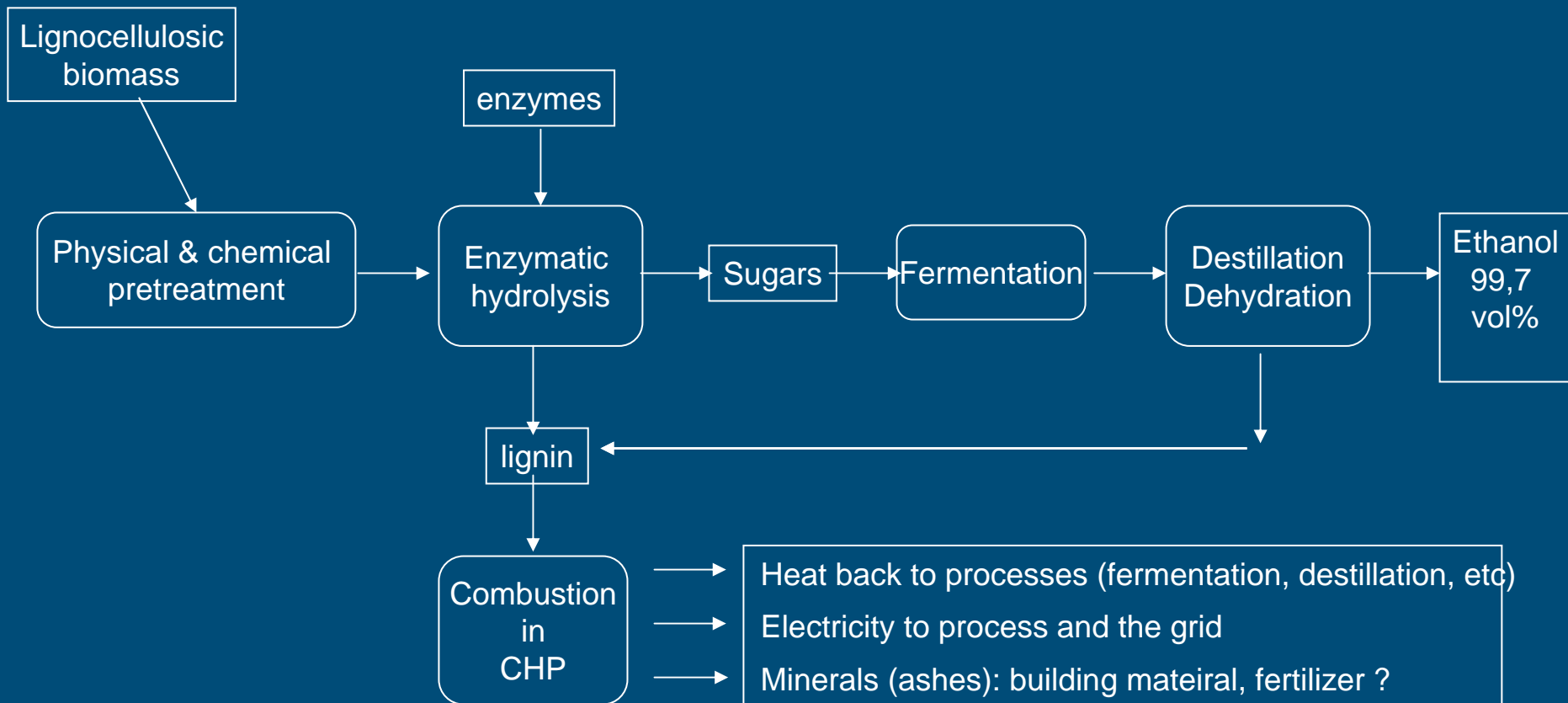
- Ethanol produced from fibrous plant material
  - Hardwood, softwood, grasses, straw, bagasse, leaves, etc.
- Feedstock: “Lignocellulose”
- Lignocellulose = source of fermentable sugars and renewable energy
  - cellulose: polymer of glucose
  - hemi-cellulose: polymers of xylose and other sugars
  - lignin: source of process heat and electricity
  - minerals: fertilization, building materials
- Key: Lignocellulosic Biomass needs to undergo pretreatment to release fermentable sugars for fermentation



# Pretreatment of lignocellulose



# Bioethanol from lignocellulose: schematic



# Key technologies needed for industrial implementation

## ■ Pretreatment

- Make cellulose + hemicellulose fractions available for enzymatic hydrolysis

## ■ Enzymatic hydrolysis

- Cost effective use of enzymes in the process

## ■ Fermentation

- Fermentation kinetics (inhibition)
- Conversion of all sugars (C5 and C6) during fermentation

## ■ System integration

- Effective integration of all parts!

# Bioethanol programme

- Goal: Bioethanol and lactic acid from lignocellulose
- Public-Private Partnership
- 4.5 yr, 6 M€ program
- Integrated approach to lignocellulose-to-endproduct:
  - Feedstock quality & logistics
  - Pretreatment and enzymatic hydrolysis
  - Fermentation to ethanol, lactic acid
  - Combined heat & power from non-fermentables
  - Process design & integration

economieecologie**t**technologie



*Wheat straw : model  
feedstock*

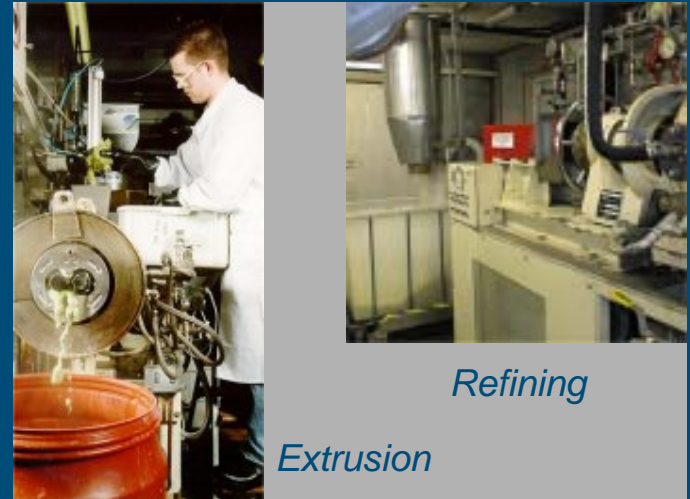
# Biomass for 2nd generation biofuels in NL

	Fresh weight (ton/jr)	Avg. dm-%	Dry weight (ton/jr)
Domestic Organic waste	1.569.000	48	753.000
Gras roadsides	500.000	50	250.000
Grass natureparks	100.000	50	50.000
Grass managed grasslands	200.000	50	100.000
Woodwaste agriculture, natureparks	470.000	50	235.000
Straw wheat and other grains	753.000	85	640.000
Straw grassseedproduction	117.000	85	100.000
Beet leaves	1.232.000	15	185.000
Total	4.941.000		* 2.313.000

\* Approximately 525 M liter bio-ethanol

# Biomass Pretreatment & Hydrolysis

- Process development
  - Mechanical pretreatment
  - Extrusion-pulping
  - Thermal pretreatment
  - Alkaline pretreatment
  - High-solids processing
  - Enzymatic hydrolysis at lab- and pilot-scale

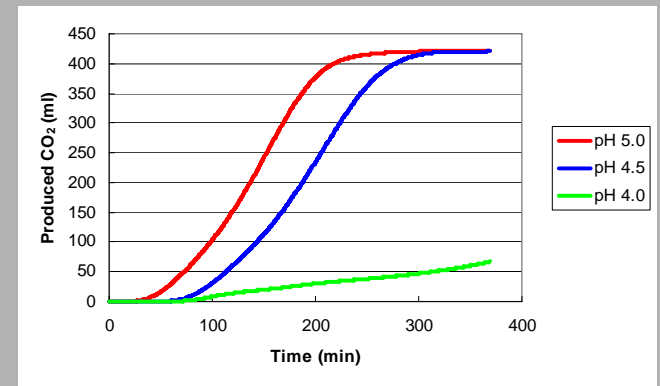


# Fermentation Research

- Fermentation kinetics:
  - Effect of pretreatment on sugar composition, yield, and fermentation inhibitor concentrations
- Fermentation products:
  - Ethanol (*S. Cerevisiae*, *Rhizopus*)
  - Lactic acid (*Rhizopus*)
- Simultaneous Fermentation and Saccharification (SSF)
  - Pilotscale (100L and up)

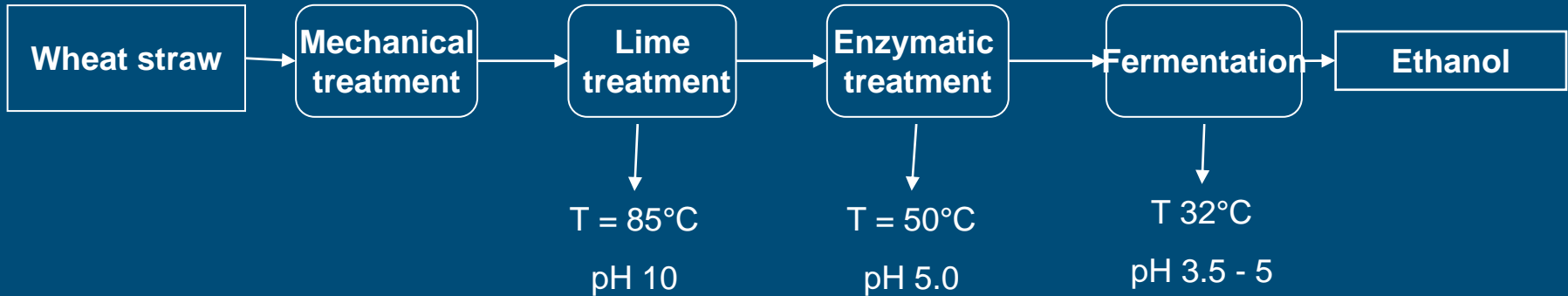


*Bench-scale fermentation with on-line CO<sub>2</sub> monitoring*

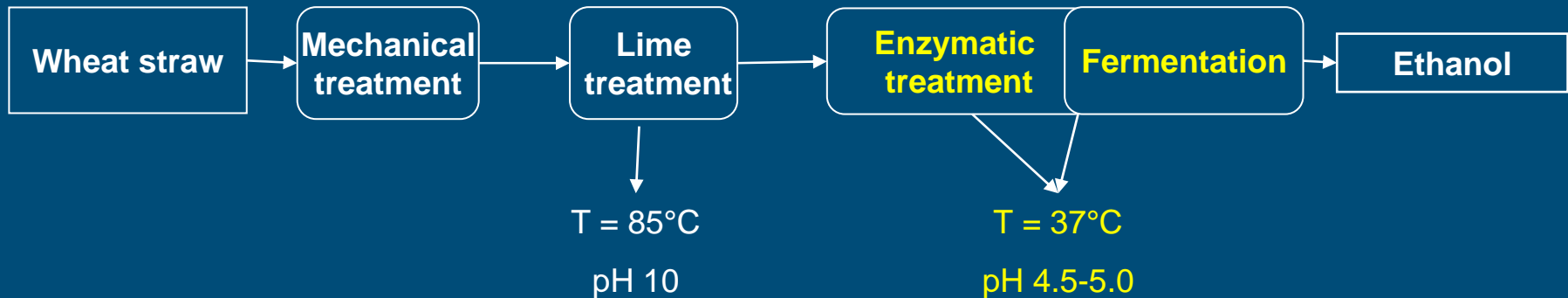


*Results fermentability tests*

# SSF-ethanol



*Separate Hydrolysis and Fermentation*

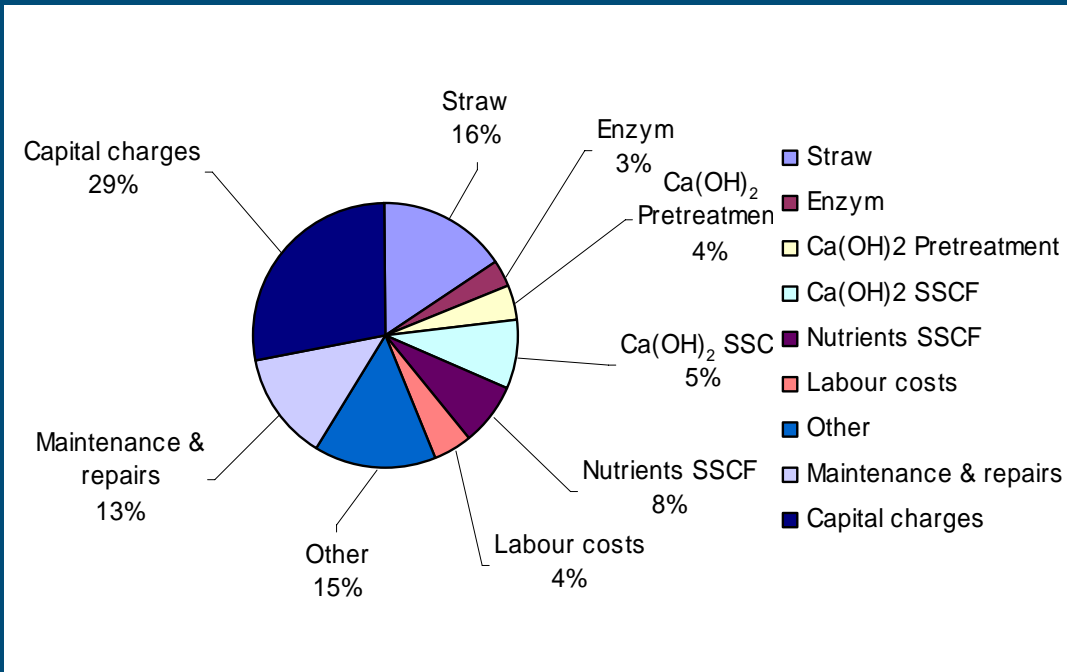


*Simultaneous Saccharification and Fermentation (SSF)*

# Pilot scale tests



# Process Design and Economic evaluation\*



Variable costs:	0,11	Euro/kg <sub>Sugars</sub>
Energy costs:	0,00	Euro/kg <sub>Sugars</sub>
Fixed costs:	0,07	Euro/kg <sub>Sugars</sub>
Capital charges:	0,08	Euro/kg <sub>Sugars</sub>
Sugar production costs:	0,26	Euro/kg <sub>Sugars</sub>
Electricity revenue:	0,03	Euro/kg <sub>Sugars</sub>
Value of steam to DSP	0,04	Euro/kg <sub>Sugars</sub>
Cost price Sugars:	0,19	Euro/kg <sub>Sugars</sub>

# Developments Bioethanol in the Netherlands

- Nedalco: New bioethanol production facility (220 Miljon L/jr; 2008) in Sas van Gent
  - Feedstock: various byproducts from agroprocessing
  - Integration with 2<sup>nd</sup> generation technology
- BER/HES Beheer: Ethanol plant in Rotterdam
  - Plans for integration with new fermentation technology

# Outlook

- Increasing feedstock costs will move industry towards 2<sup>nd</sup> generation-lignocellulosic biomass
- From 2012: implementation of 2<sup>nd</sup> generation biofuels on large/commercial scale
- Up to then:
  - Increase and improvement of 1<sup>st</sup> generation
  - For bioethanol: gradual move from 1<sup>st</sup> to 2<sup>nd</sup> generation

# Butanol

- Fuel adaptable for blending in gasoline, and diesel
- Up to 1970: large scale industrial production by fermentation
  - Outcompeted by petrochemical production
- Renewed interest in fermentative production
  - Need for renewable and sustainable production pathways (Bio-butanol)
  - New tools in biotechnology
  - New separation techniques

# Research Aspects of Bio-Butanol

- Use of lignocellulosic feedstocks in ABE fermentation
- Improving (volumetric productivity) of ABE fermentation
  - E.g. cell retention combined with product removal
- Genetic modification of ABE producing organisms
  - Higher end-product tolerance
  - Production of a “butanol-only” microorganism

Goal: develop a new bioprocess concept for ABE

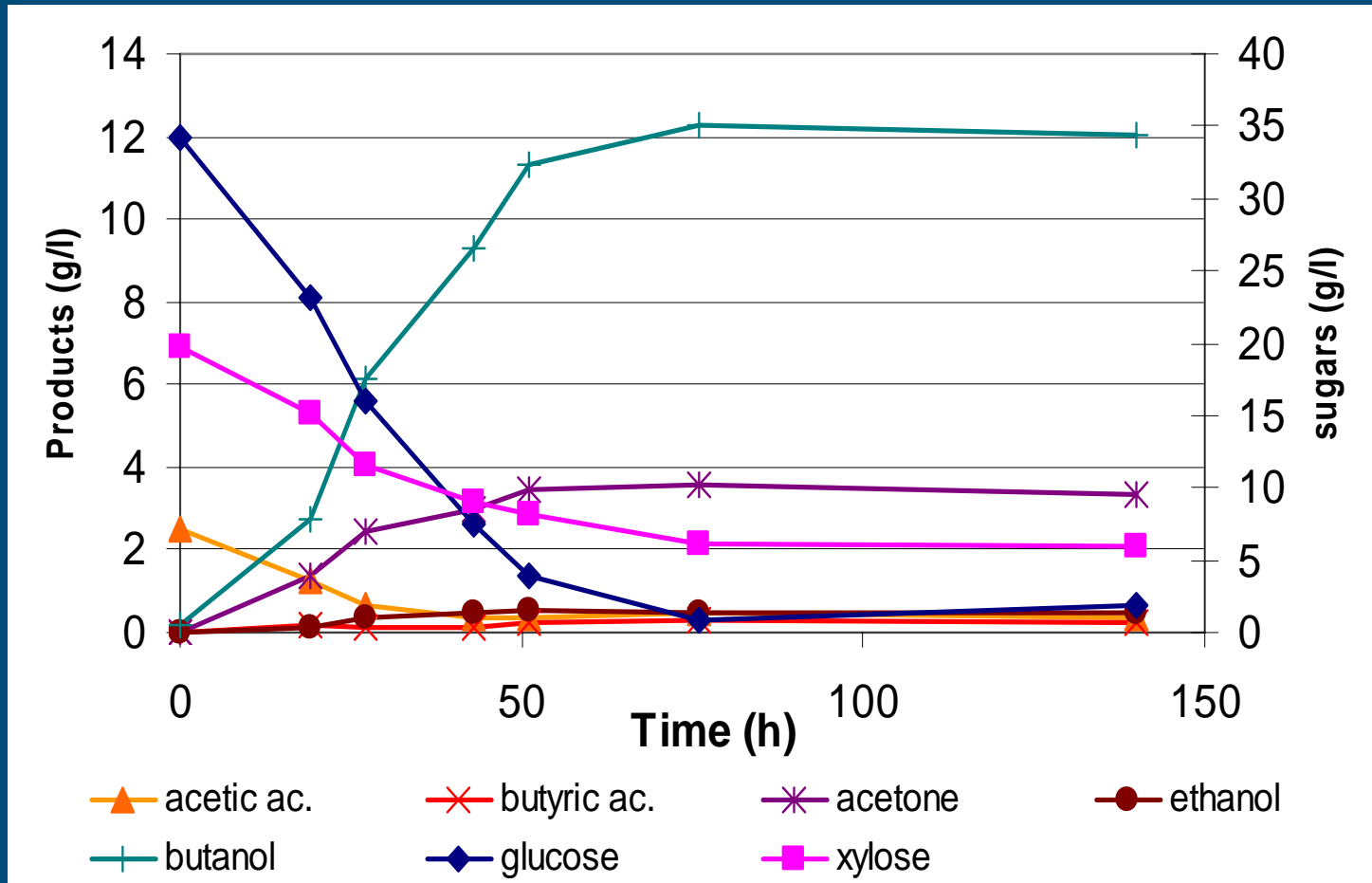
- Primary biorefinery: pretreatment
  - Focus on wet feedstocks
- Secondary biorefinery: fermentation
  - Integration with separation technology
- Systemdesign + economic evaluation
- Life cycle analysis
- [www.biobutanol.nl](http://www.biobutanol.nl)

# Overview



# Biobutanol: procesintensificatie

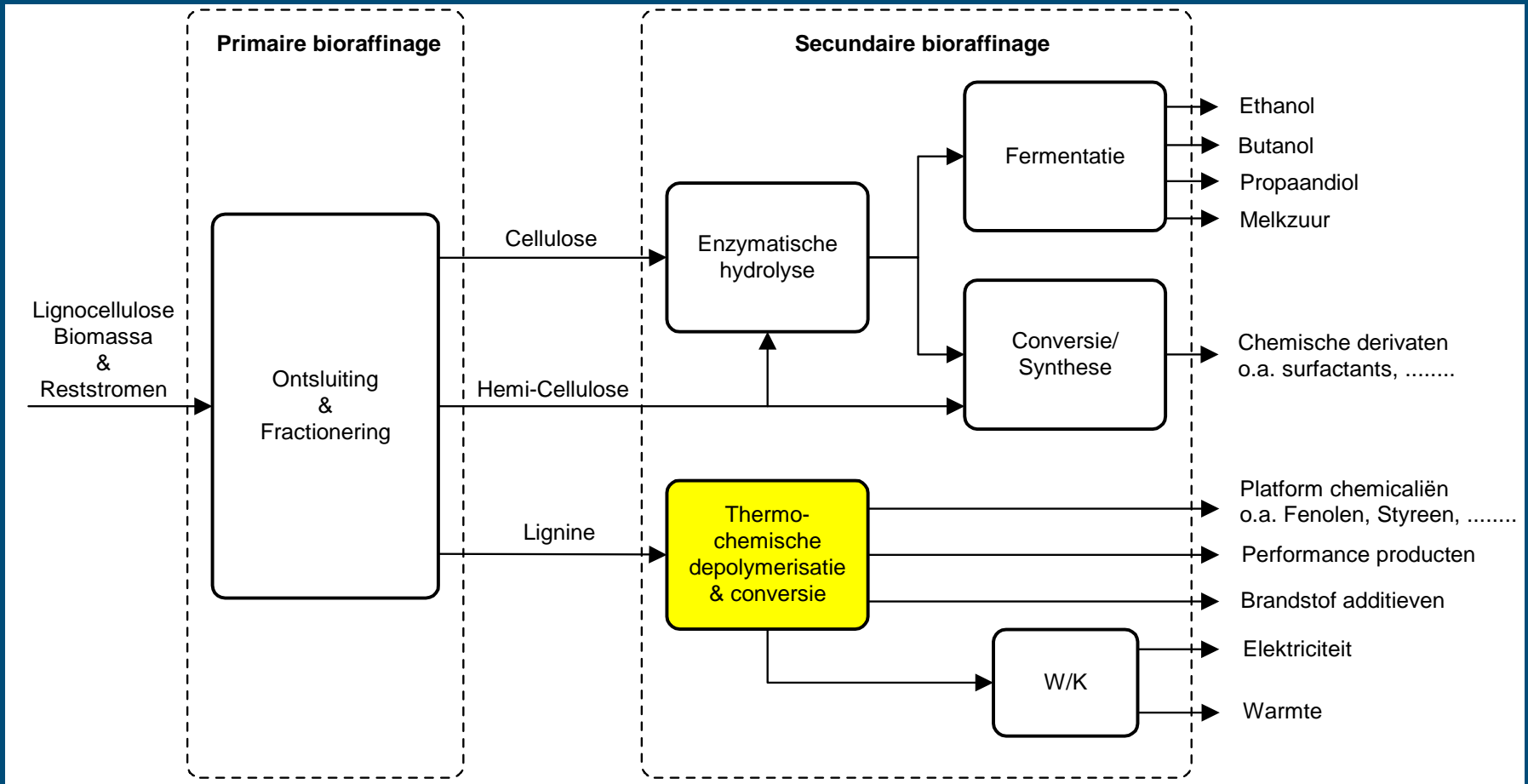
- Batch fermentation of glucose/xylose by *C. beijerinckii* NCIMB 8052



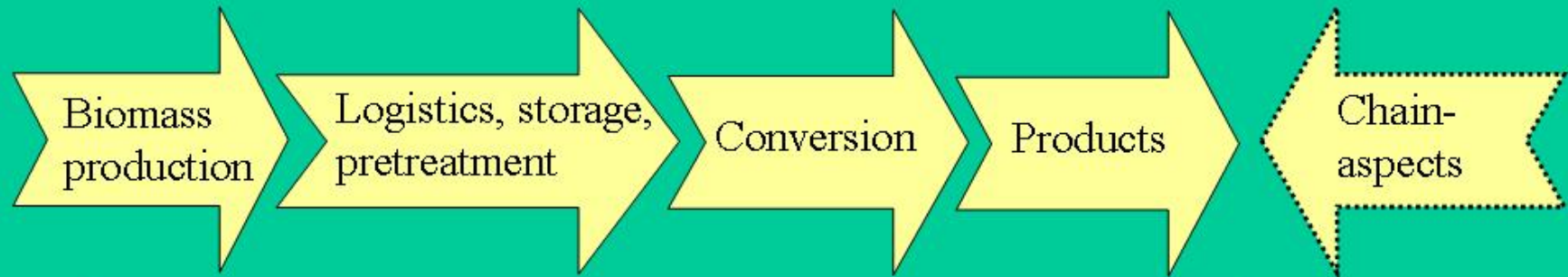
# Current/future Biofuel project portfolio at A&F

Name Project	Focus	R&D aspects	Period	Partners
Hyvolution	Biological Hydrogen	Feedstocks, pretreatment, fermentation	2006-2011	across EU
EOS Biobutanol	ABE (acetone, butanol, ethanol)	Pretreatment, Fermentation, DSP	2006-2008	ECN
B-basic Recycling	Closed-loop fermentation	Pretreatment of spent microbial biomass; Fermentation	2005-2008	Shell GS, Paques
B-Basic 1.1	Butanol-only			Bbasic consortium
MACHT	Oil production in Fungi	Direct microbial Fermentation	2004-2006	WU
Jatropha	Biorefinery	Fractionation, conversion	2006-2010	RU Groningen, IBT, BPPT
EOS Lignovalue	Adding value to lignin	Fractionation, conversion	2007-2010	WU, ECN, Aston U, RU Groningen
IP Biosynergy	Biorefinery	Fractionation, conversion	2007-2011	ECN, Abengoa, other EU

# Project Lignovalue (EOS)



# Bio2Value: partnership with ECN



Large scale importation

Torrefaction, pyrolysis

Thermo-chemical conversion: co-firing, torrefaction, pyrolysis, gasification

Elektricity, heat, Substitute Natural Gas (SNG) FT-diesel, chemicals

Byproducts and aquatic biomass

Logistics, planning, drying

Combine thermo-/biochemical processes, incl. biorefinery

Co-productie of wide range "products"

Multifunctional landuse, crop production, agro-residues

(Bio)chemical pretreatment, storageaspects

(Bio)chemical conversion: fermentation, digestion, ...

Materials, chemicals, bioethanol, biodiesel, bio-hydrogen

Integral chainanalysis/-optimisation, beta/gamma-aspects, policy, demandanalysis, procesdesign, sustainability....

# More information?

- [www.biomassandbioenergy.nl](http://www.biomassandbioenergy.nl)
- [www.bioethanol.nl](http://www.bioethanol.nl)
- [www.hyvolution.nl](http://www.hyvolution.nl)
- [www.bio2value.nl](http://www.bio2value.nl)