Targeted discovery of novel cellulases and hemicellulases and their reaction mechanisms for hydrolysis of lignocellulosic biomass: DISCO

Theme 2: Food agriculture and biotechnology
KBBE 3-2-01 Lignocellulosic enzymes

Kristiina Kruus
VTT, Technical Research Centre of Finland

Business from technology

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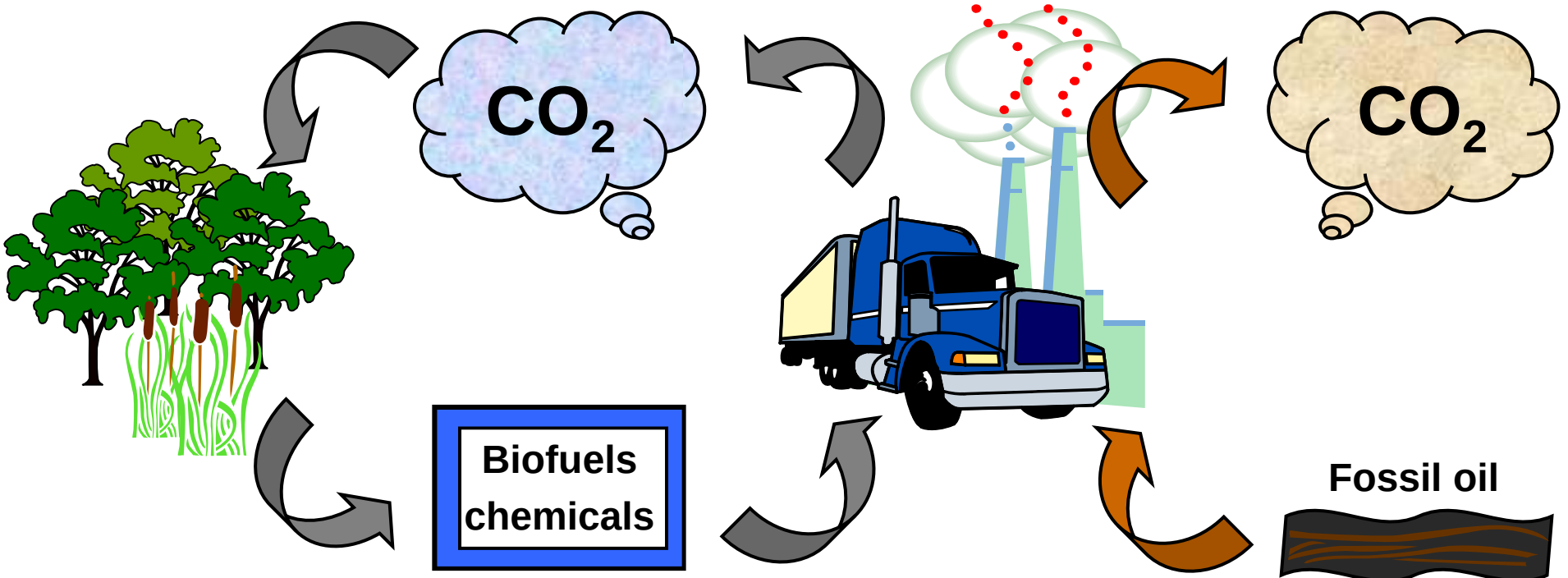
Drivers for lignocellulosic biomass utilization for energy and chemicals

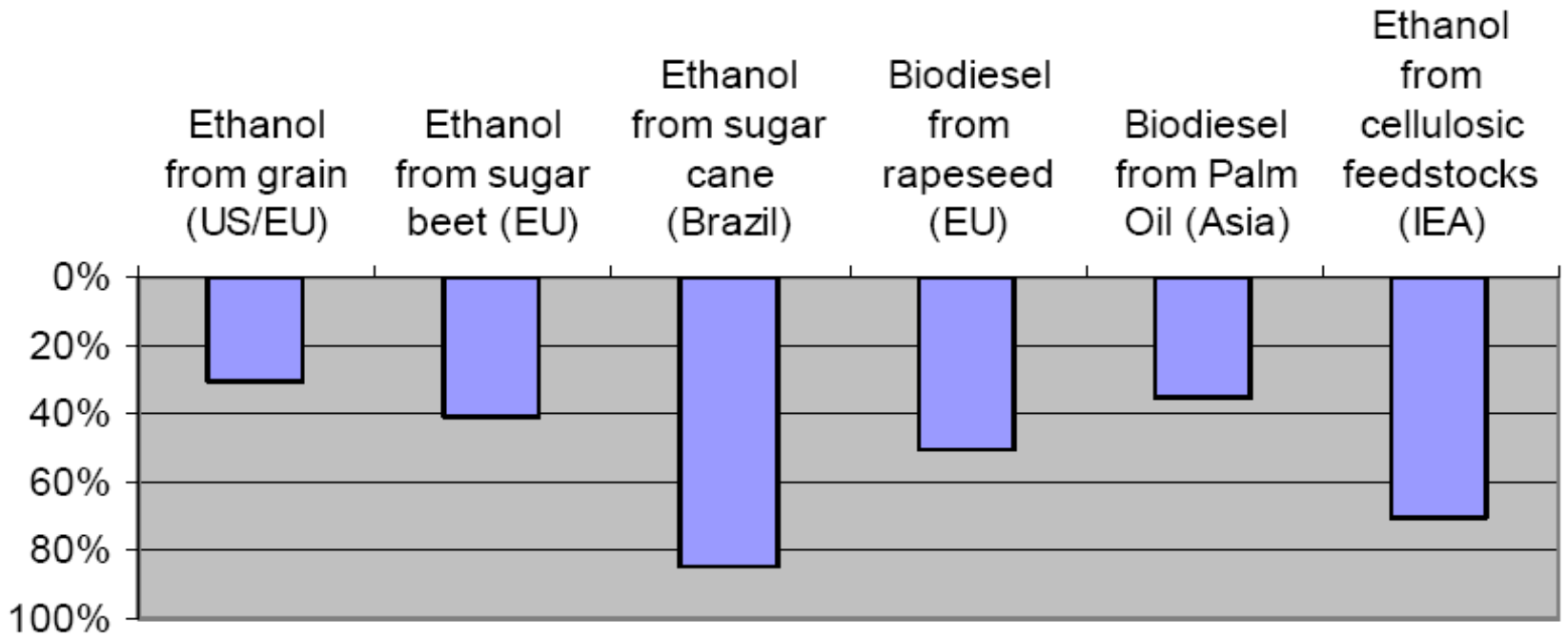
- Exhaustion of fossil energy resources
- Climate change and a need to reduce green house gas emissions
- Kyoto protocol
- EC strategy and directives to promote alternative fuels for transport
  - EU Biofuels Directive, 5.75% by 2010
  - EU Biofuels for Transport - Technology Platform: vision 25 % in 2030
  - EU Green Paper 2020: 10% natural gas, 8 % biofuels 2 % hydrogen
  - EU Biomass Action Plan (2005/628)
- Security of fuel supply and national raw materials, indigenous energy sources
- Need for raw materials not competing with food production

THE ERA OF RENEWABLES

- **Carbon dioxide is one of the major greenhouse gases**
- **Utilization of renewables should lead to a closed carbon dioxide cycle**
- **Renewables include agricultural and forest based raw materials and wastes**
- **According to the World Energy Council conversion of 5% of the world's biomass (a total of 13.5 billion tones) to cellulosic EtOH would meet 26% of the current energy needs (2007).**



GREENHOUSE GAS REDUCTIONS

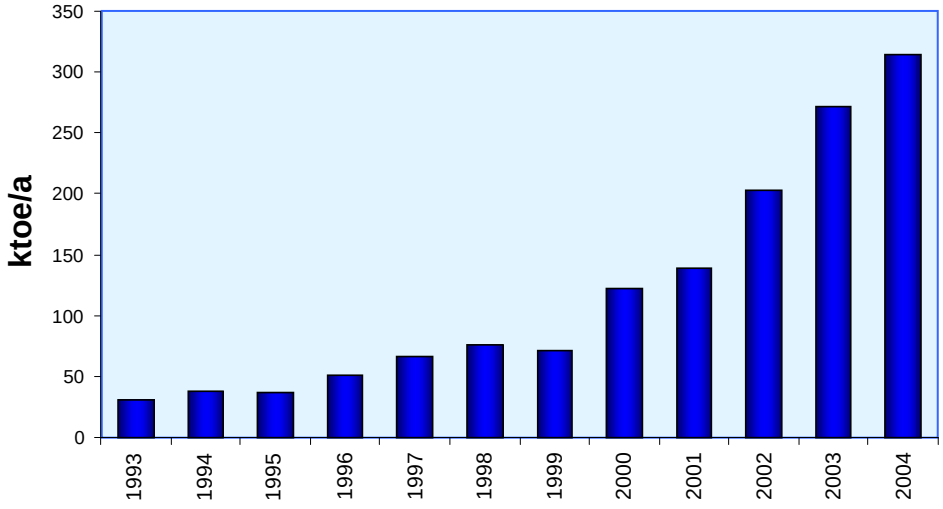


Doornbosch & Steenblick, OECD, 2007

Production trends of biofuels in the EU

Fuel ethanol production in EU, 1993-2004

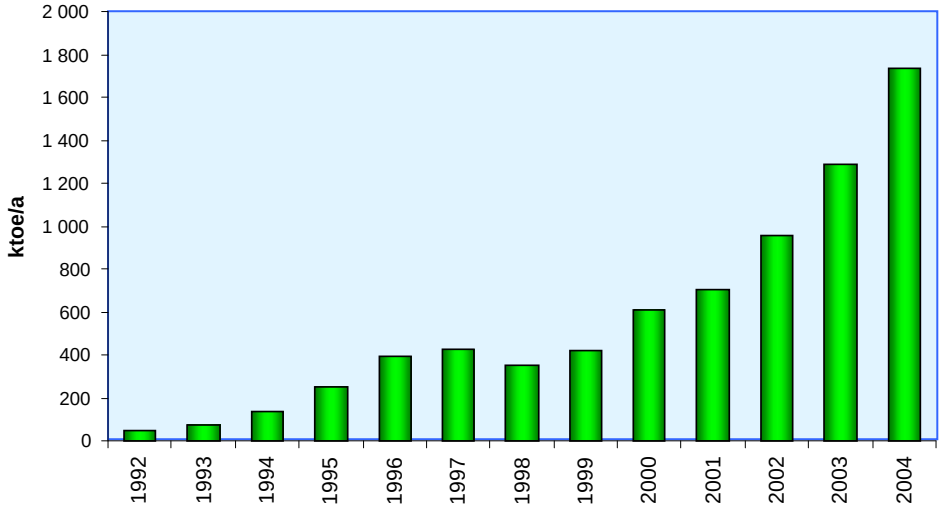
Ethanol tonne ~ 0.64 toe



source: System Solaires EurObserv'ER 2005 & http://europa.eu.int

Biodiesel production in EU, 1992-2004

Biodiesel tonne ~ 0.9 toe



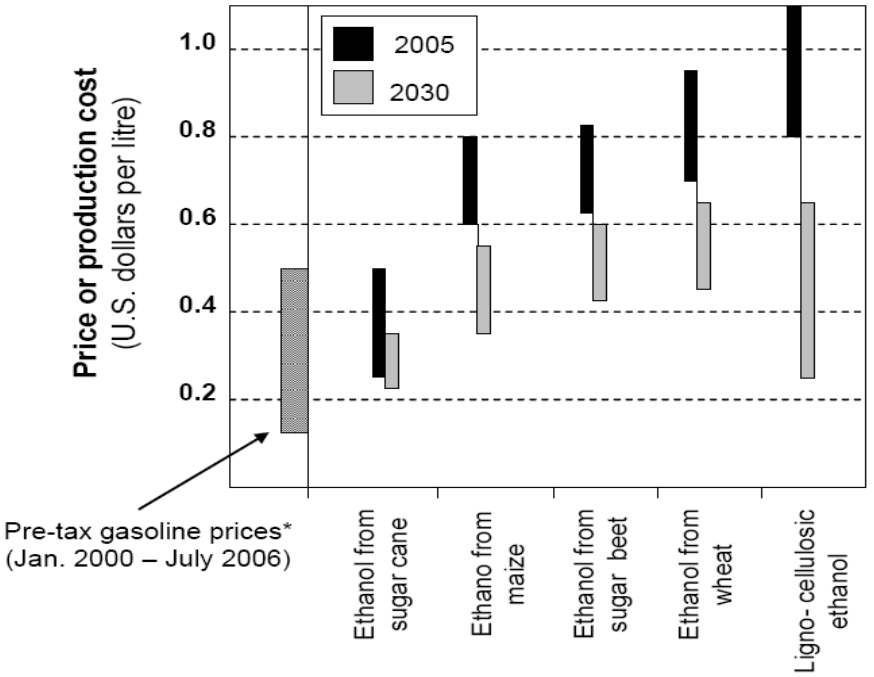
Source: European Biodiesel Board

Fast growth, but total amount still quite low!

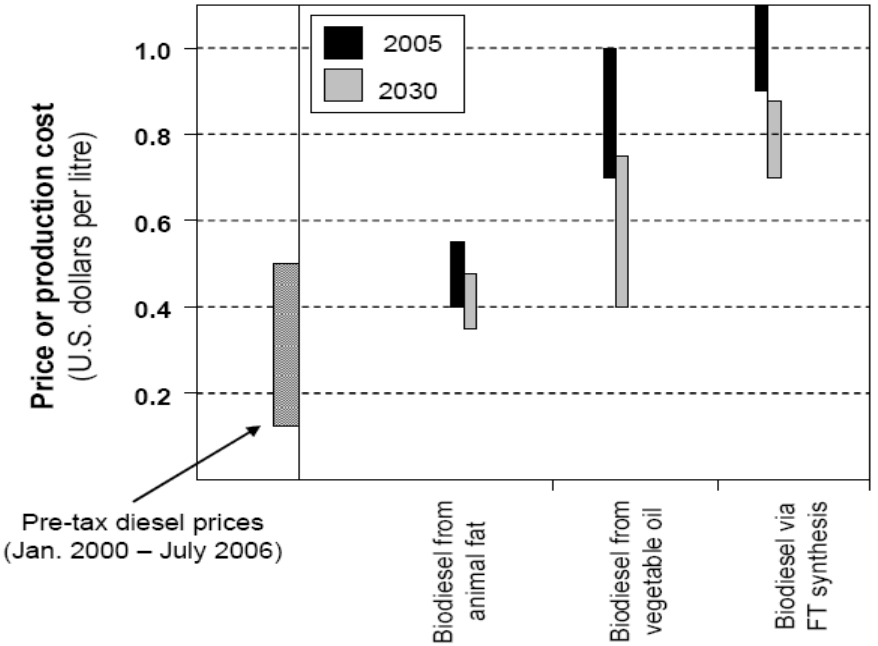
Source: EurObservER, System Solaires 2005, European Biodiesel Board

COST ESTIMATIONS FOR 2030

Ethanol



Biodiesel



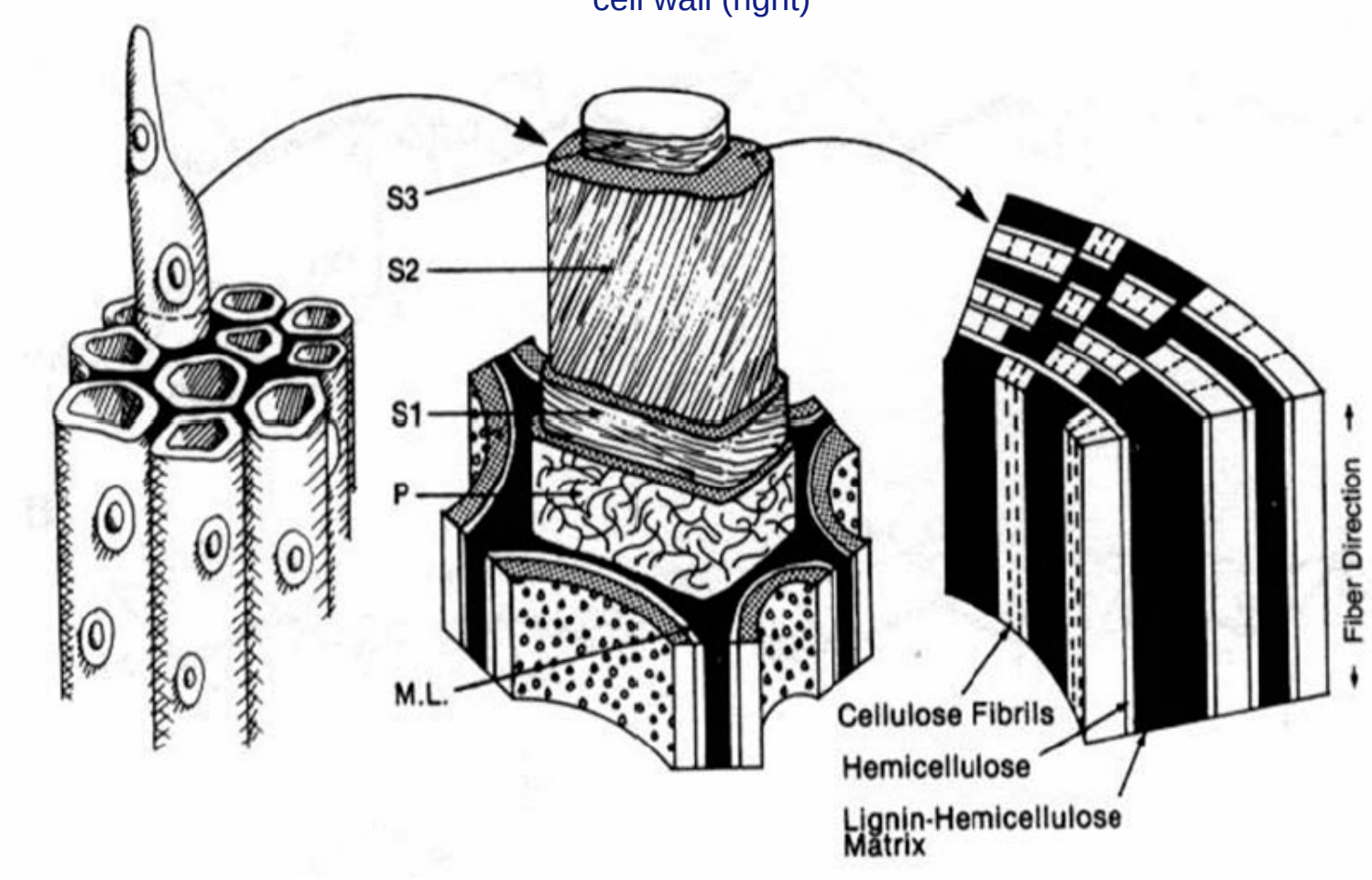
Doornbosch & Steenblick, OECD, 2007

Composition of various lignocellulosic biomass (%)

Raw material	Sugars		
	Hexoses	Pentoses	Lignin
Bagasse	33	30	29
Birch wood	40	33	21
Corn wastes	42	39	14
Nut shells	38	36	16
Barley straw	41	16	11
Pine wood	41	10	27
Rice straw	32	24	13
Wheat straw	30	24	18

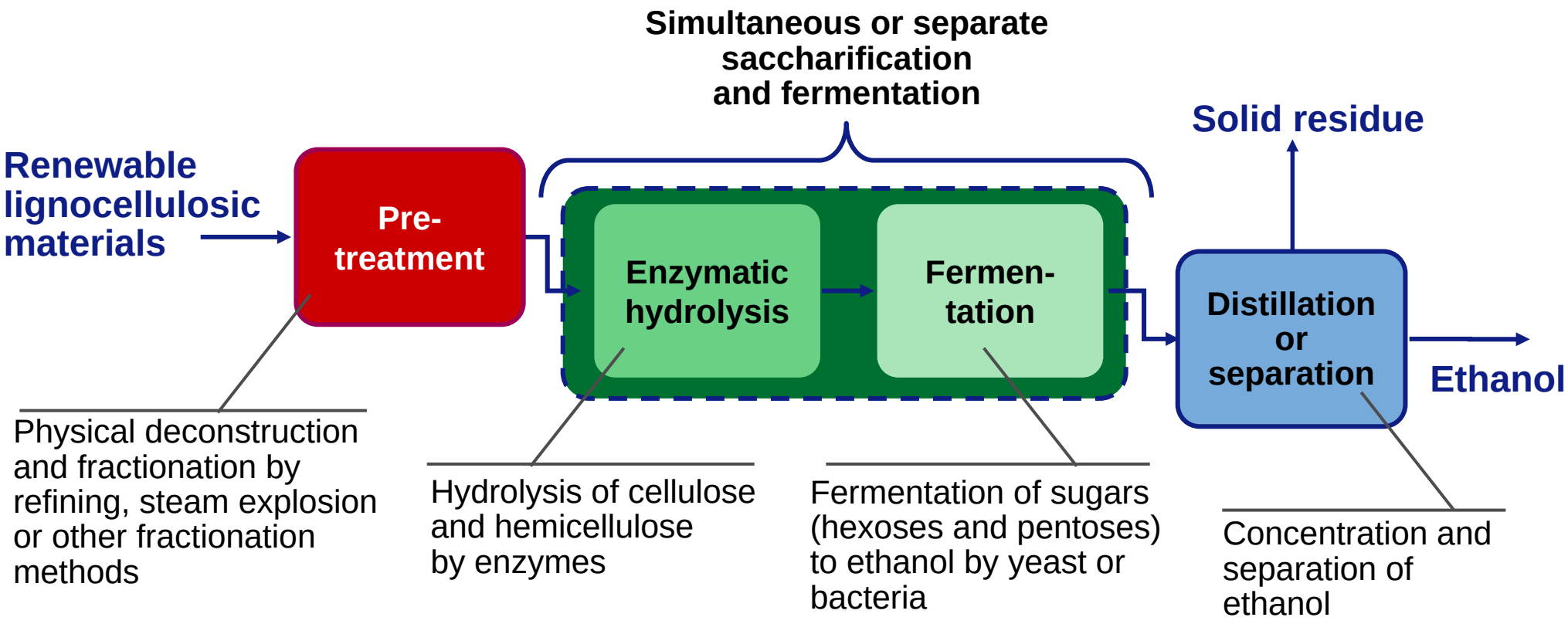
THE RAW MATERIAL - THE CHALLENGE

Diameter of each tracheid is approximately 30 µm (left), wood cell wall layers S1-S3: secondary cell wall layers, P: primary wall, M.L. middle lamella (middle) and lignin-carbohydrate complex of the secondary cell wall (right)



Adapted from Kirk and Cullen (1998).

MAIN PROCESS STEPS IN LIGNOCELLULOSE-TO-BIOETHANOL PROCESS



Enzymes participating lignocellulose hydrolysis

- **Cellulases**
  - Endo-β-1.4-glucanases, cellobiohydrolases, and β-glucosidases
  - Fungal cellulases e.g. *Trichoderma, Humicola, Acremonium*
  - Bacterial cellulases e.g. *Clostridium thrmocellum*
- **Hemicellulases**
  - Backbone degrading enzymes
  - Enzymes affecting on the side chains
  - β-xylosidases degradation of xylooligos
- **Lignin modifying enzymes**
  - Laccases
  - Peroxidases
  - H_2O_2 producing enzymes like aryl alcohol oxidase
- **Other helper enzymes/proteins**
  - Swollenin

Development of improved enzymes and enzyme mixtures and hydrolysis technologies

Enzyme properties

- Specific activity
- Thermal activity and stability
- End- product inhibition
- Non-specific binding

Enzymes for efficient hydrolysis

- Composition of cellulase mixture
- Role of additional enzymes (hemicellulses, ligninases)
- Efficient production hosts systems

Hydrolysis technologies

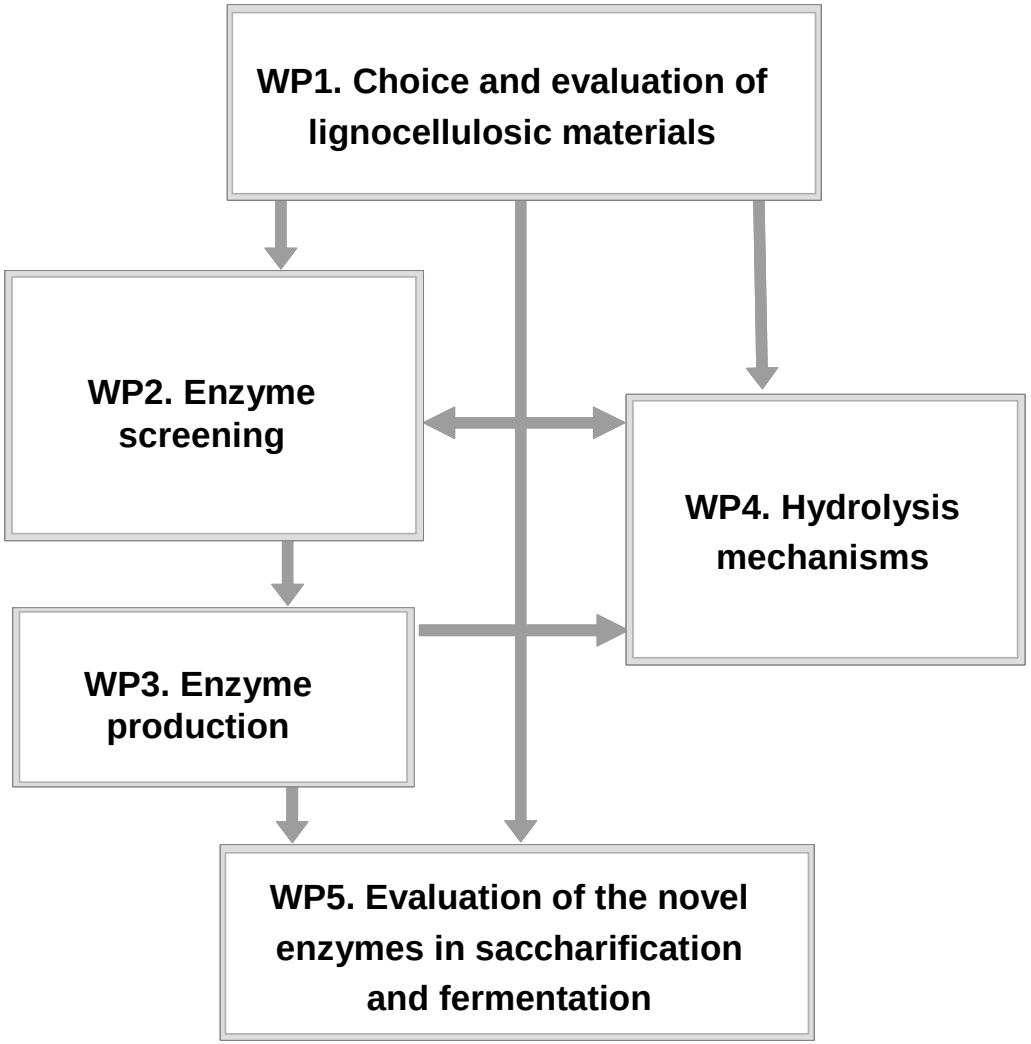
- Separate/simultaneous/stepwise
- Operational temperature
- Optimal use of enzymes - recycling

DISCO Targeted discovery of novel cellulases and hemicellulases and their reaction mechanisms for hydrolysis of lignocellulosic biomass

Aim

- to develop more efficient and therefore more cost-effective cellulosic and hemicellulosic enzymes to enhance the hydrolysis of pre-treated lignocellulosic biomass
- through the identification of novel cellulases and hemicellulases with high catalytic and synergistic activity and low affinity on lignin
- elucidation of enzymatic hydrolysis mechanisms focusing on the limiting structural factors and synergy between different cellulase and hemicellulase components
- to demonstrate the proof of concept with the cellulolytic enzymes in pilot scale using the most relevant European feedstock

Schematic diagram describing the main inter-relationships between the 5 technical workpackages in the DISCO project.



DISCO partnership

- Excellent combination of academic partners and industry from 7 different countries
- Totally 11 partners, from which 5 are industrial
- Expertise on lignocellulosic biomass and analyses, enzymology of lignocellulosic enzymes, enzyme discovery, enzyme production, pretreatment and hydrolysis technologies
- Whole value chain represented
- Dissemination of results: commercial and scientific exploitation