Biorefining of rapeseed crop

Bioreffinery Øresund

For sustainable Øresunds region

26th October

Lund

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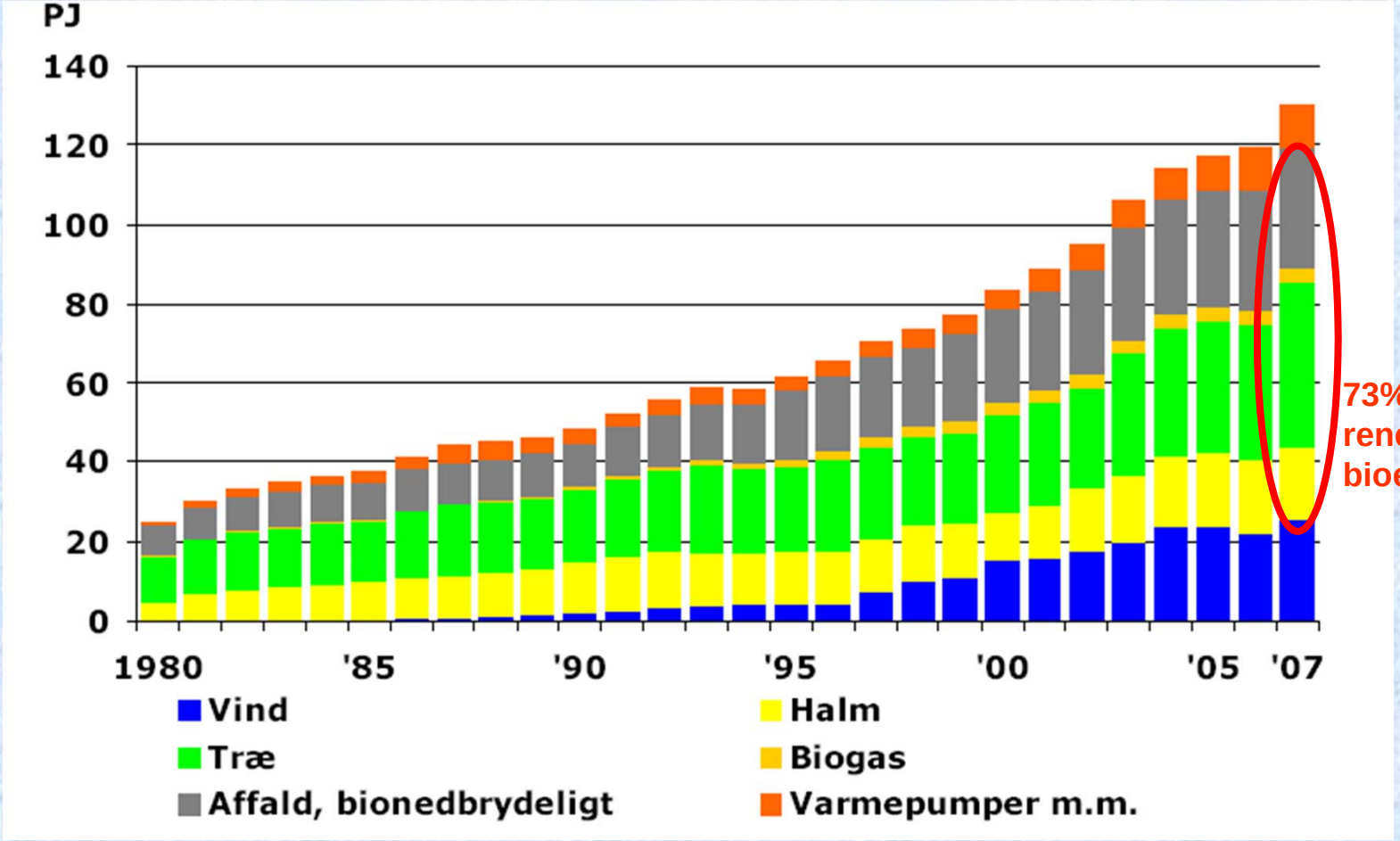
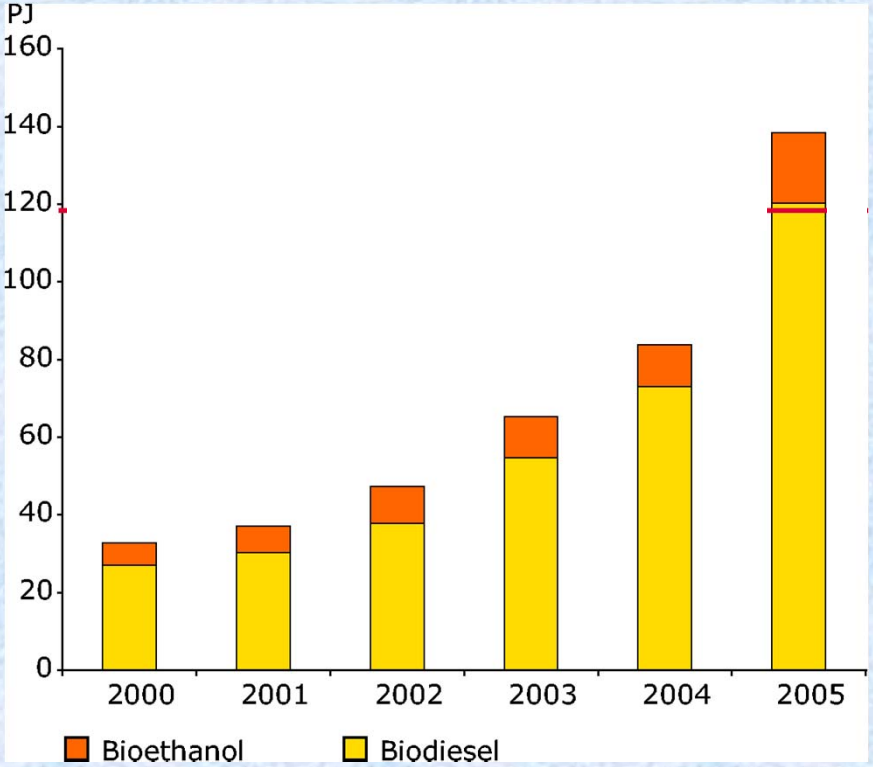
Renewable energy in Denmark



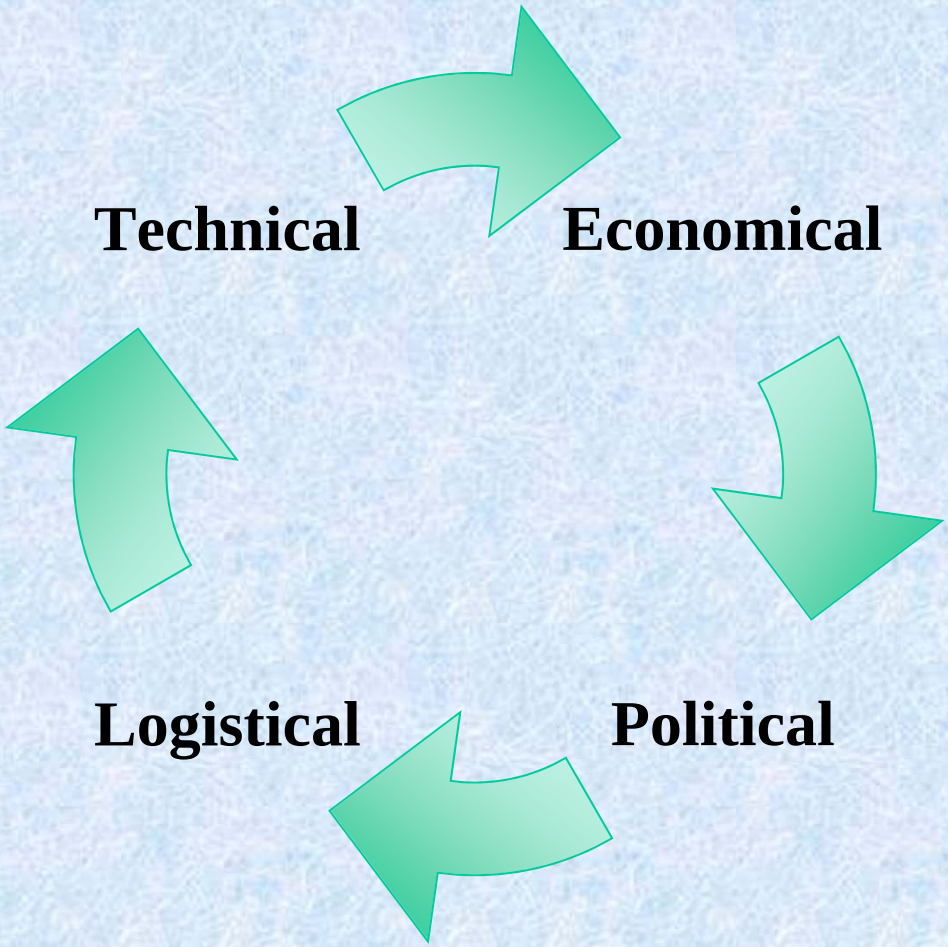
73% of the total renewable is bioenergy

Biofuels production in EU

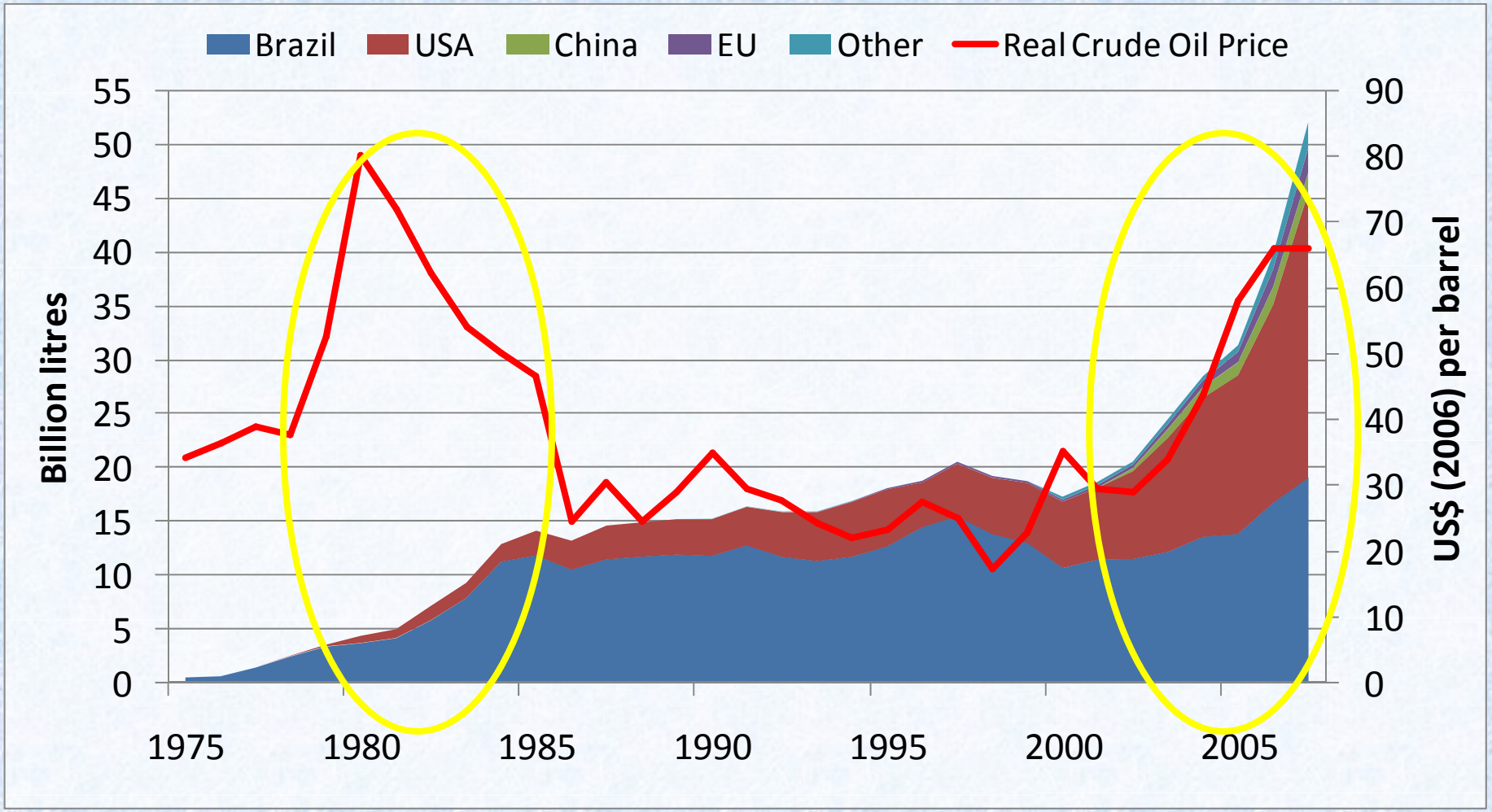


Source: EU-statistics

Interactions

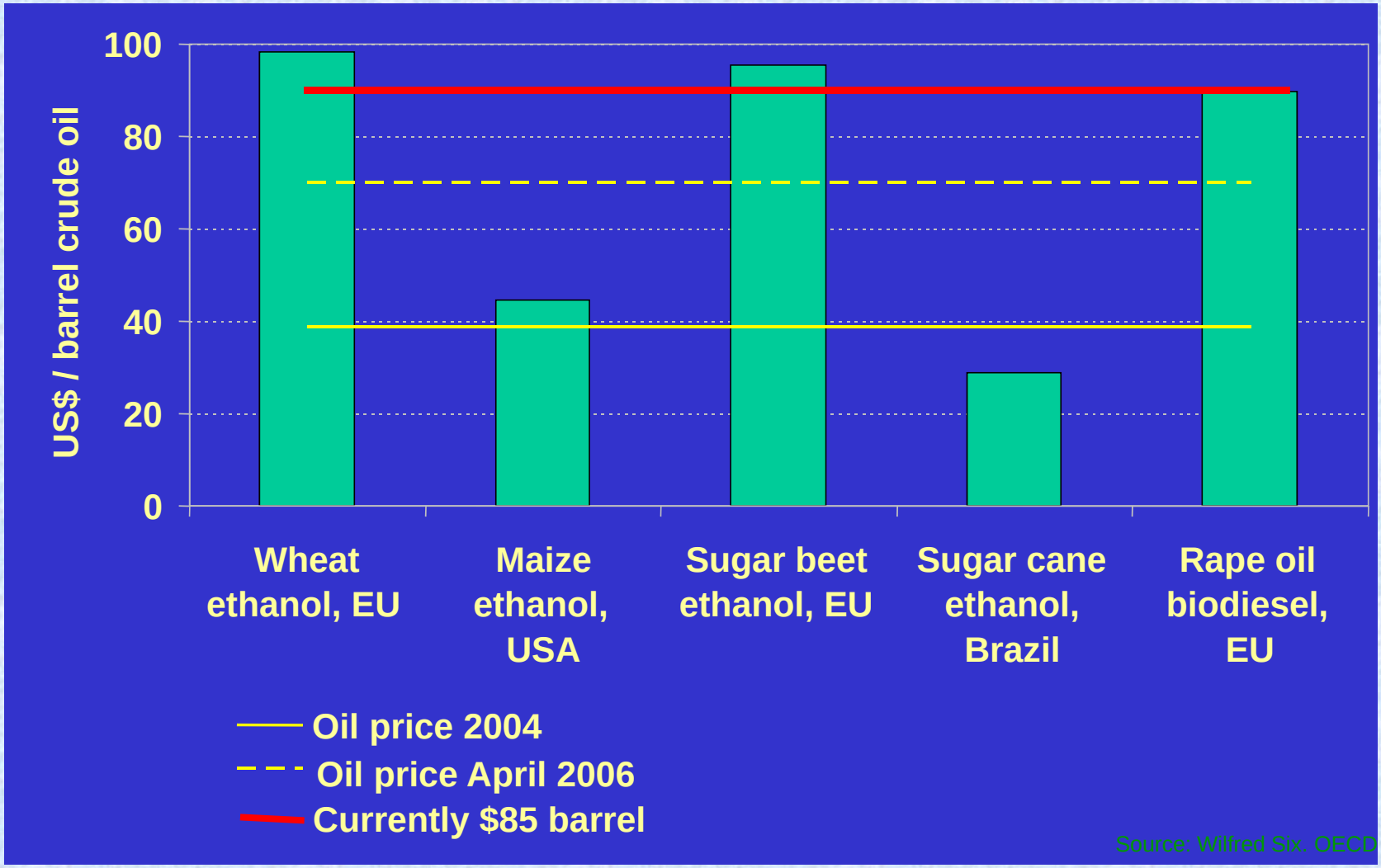


Changing interests in biofuels: Fuel ethanol production and crude prices



Source: F.O. Licht's , St. Luis Fed

Crude oil and bioenergy prices

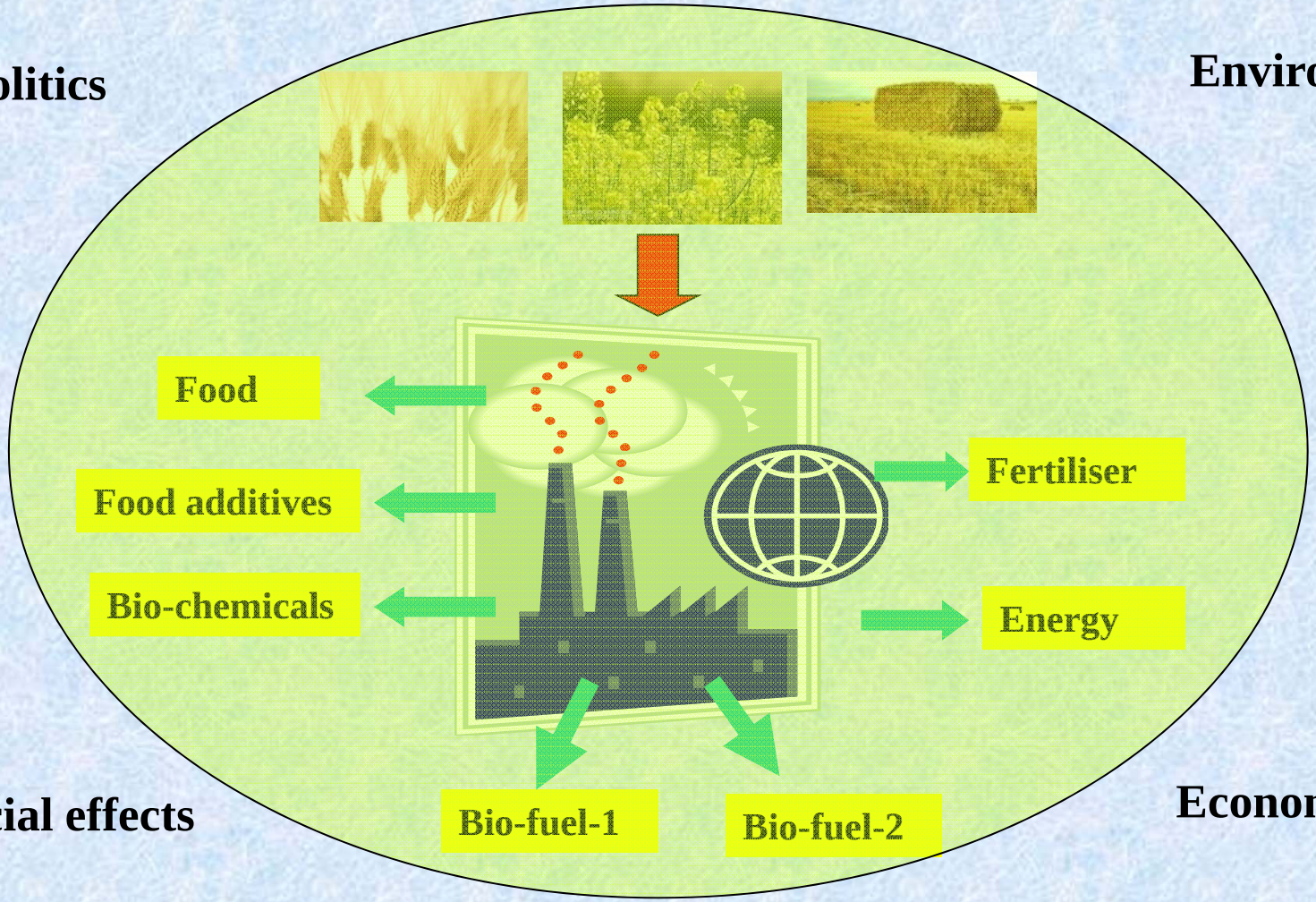


Source: Wilfred Six, OECD

Solutions

- Whole plant utilisation
- Residual biomass utilisation
- Multi-product process: Biorefineries
  - Food
  - Feed
  - Chemicals
  - Energy

What is a biorefinery?



Biorefinery definitions

- A biorefinery is a facility that integrates biomass conversion processes and equipment to produce multiple biofuels and products (NREL)
- A biorefinery is an overall concept of a processing plant, biomass feedstocks are converted and extracted into a spectrum of valuable products (US-DOE)
- Bioconversion to biomass into a variety of chemicals (Clark & Deswarte)
  - Phase I Biorefinery (1 feedstock -> 1 product)
  - Phase II Biorefinery (1 feedstock -> multiple products)
  - Phase III Biorefinery (multiple feedstocks -> multiple products)

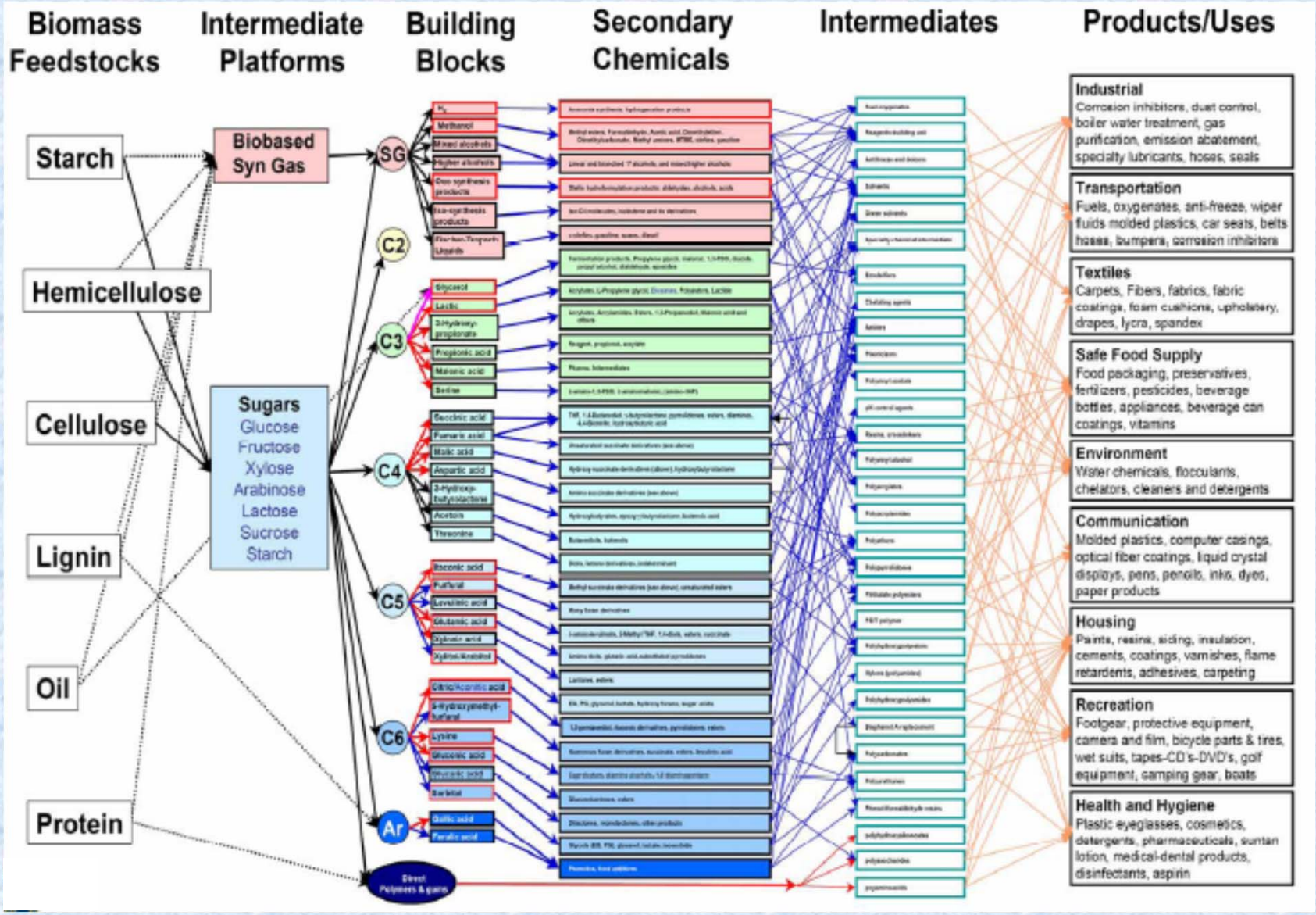
Utilisation routes for biomass

Food

Existing non- food:
- Animal Feed
- Additives
- Compost
- Energy

New Biobased Products
- Biobased materials
- Bio-based chemicals
- New Biofuels
- New Bioenergy

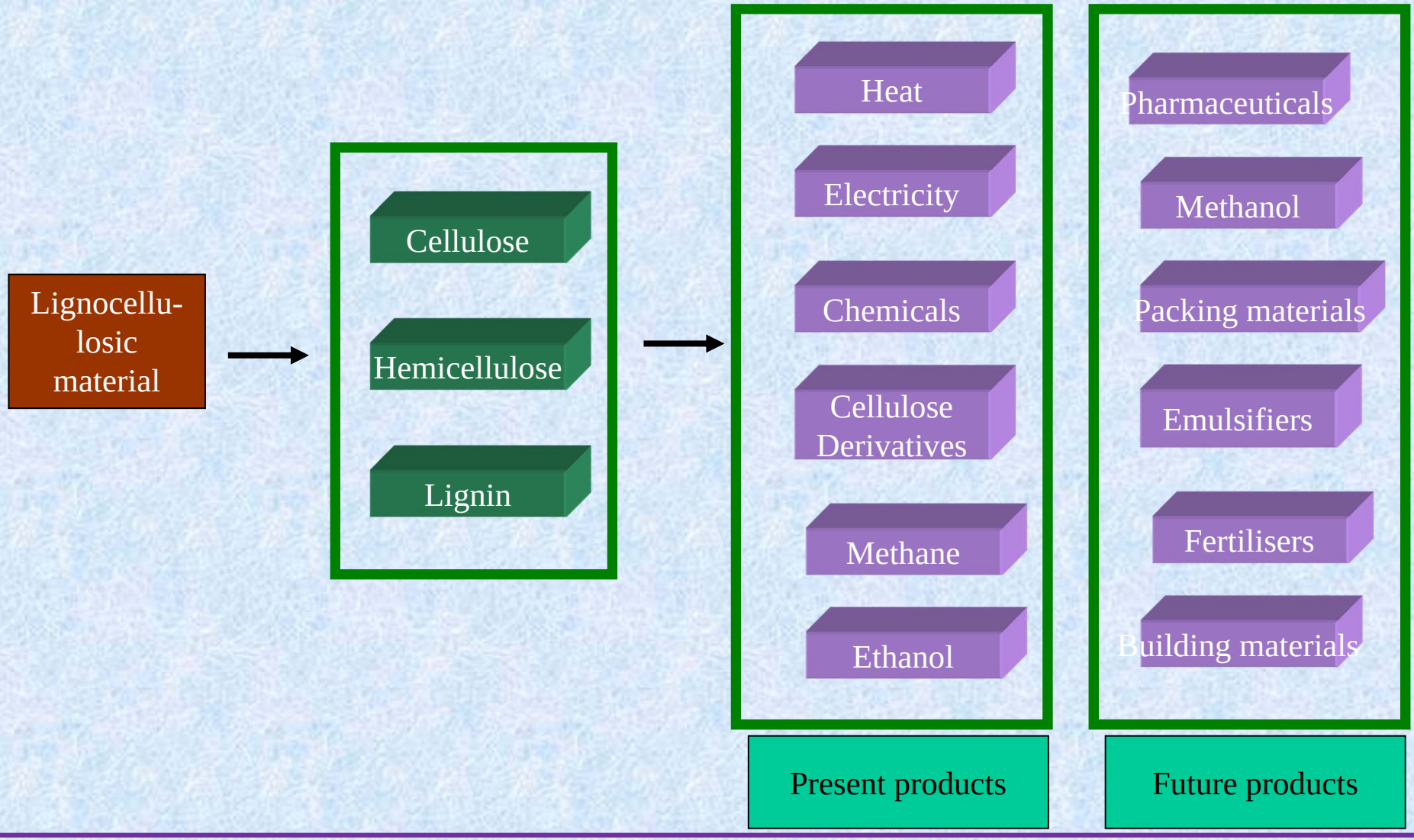
Potential products from biomass



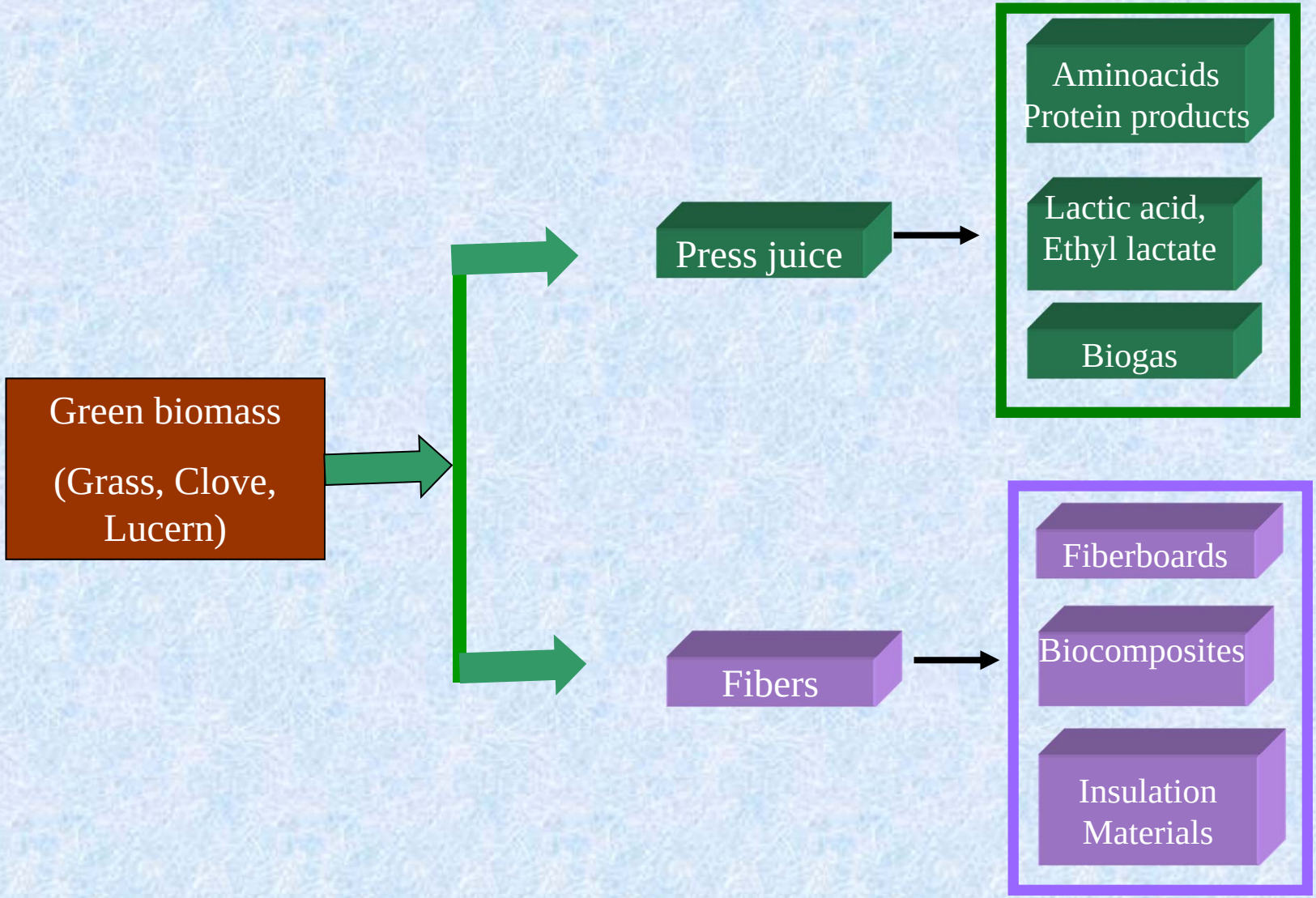
Types of biorefineries

- Lignocellulosic biorefinery
- Whole plant biorefinery
- Green biorefinery
- Oily biorefinery

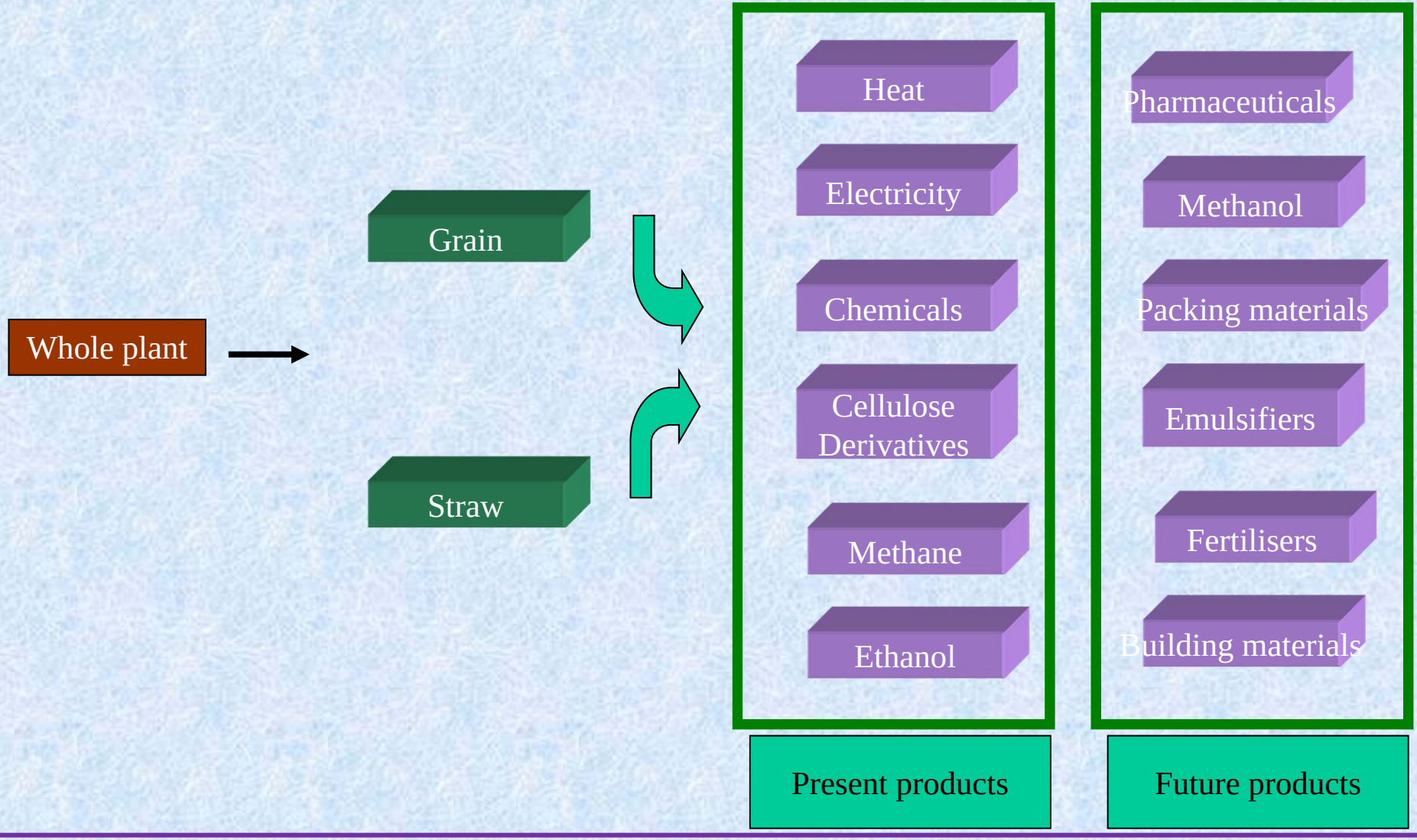
Lignocellulosic biorefinery



Green biorefinery



Whole crop biorefinery



Liberty – POET Emmetsburg

Whole plant
Grain + Cubs

→

- Ethanol
- Organic acids
- Proteins
- Animal feed

BioRef

Oilseeds

Straw

Enzymatic transesterification - continuous process

Biodiesel (RME or REE)

Byproducts: Biopesticides, glycerol, fatty acids animal feed

Straw pretreatment

Bioethanol

SSF C6 fermentation in membrane bioreactor

C5 fermentation to biohydrogen

Biohydrogen

Anaerobic digestion

Biogas

Fertiliser

System analysis, and evaluation

Key technological improvements for converison of lignocellulose to biofuels

Pretreatment

Loose lignocellulosic structure

Mixing

Enzymes

Hydrolysis

Hemicellulose

Glucose fermentation

Pentose fermentation to H2

Ethanol inhibition

Effluents

Hydolysis at high TS content

Effective – low cost process ➢ high solids content in biomass

Preferably > 20% TS in hydrolysed material

Problems with incorporation of enzymes and yeast

Hydrothermal pre-treatment of rapeseed straw

Solid fraction

Cellulose and lignin

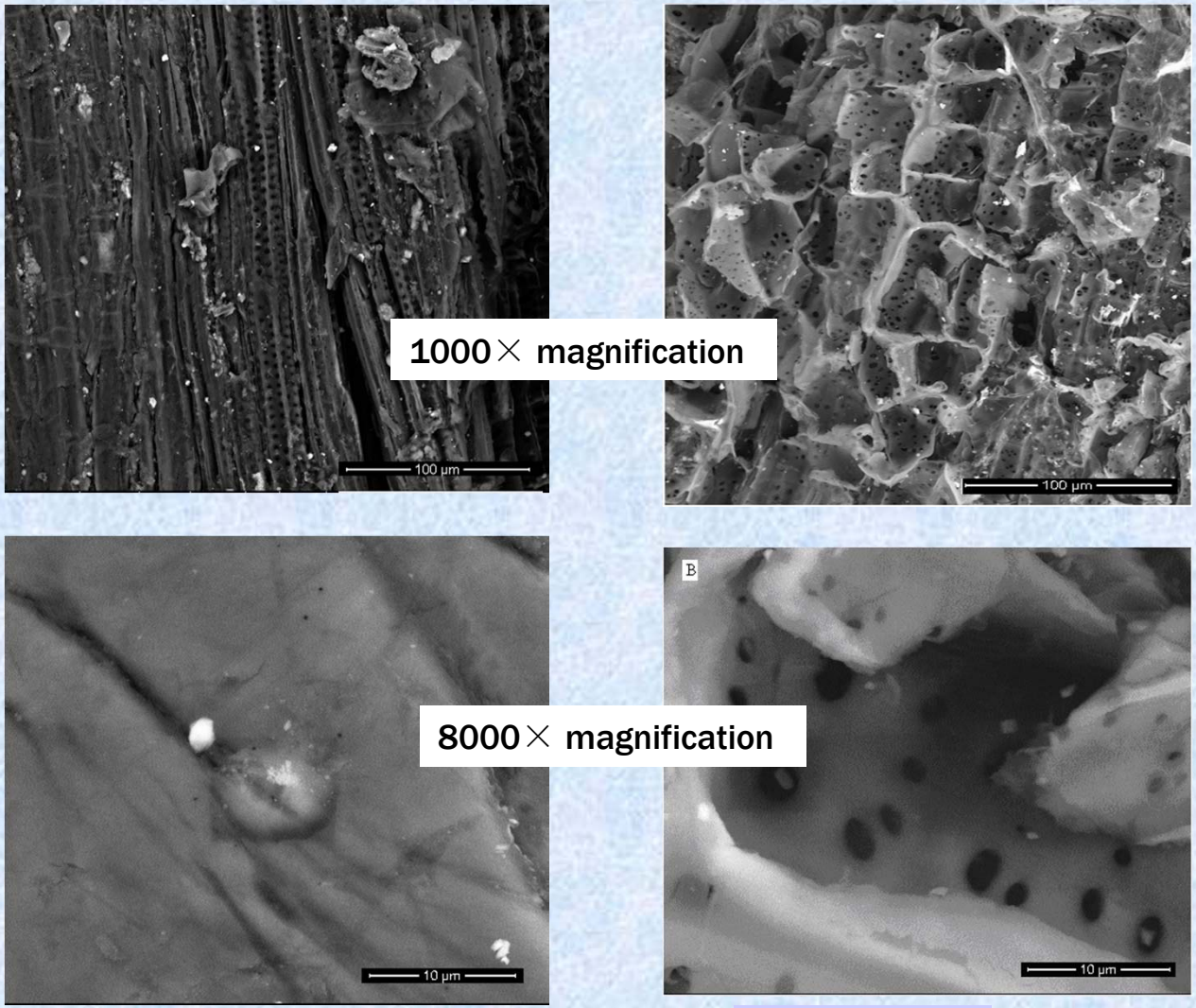
Liquid fraction

(inhibitors, hemicellulose,

and salts

Liquid fraction (hydrolysate)		**Solid fraction**	
Characteristics	*Value*[a]	*Characteristics*	*Value*[b]
Glucose	1.5	Cellulose	53.9
Xylose	11.1	Xylan	8.8
Arabinose	1.5	Arabinan	0.3
Total hemicellulose	12.6	Total Hemicellulose	9.1
TS(g/l)	27.9	Klason lignin	24.2
VS(g/l)	25.6	Ash	2.9
		Residual	9.9

Physical effect of hydrothermal pretreatment

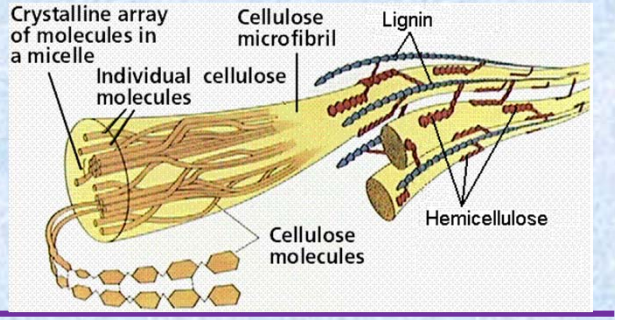


Hydrothermal pretreatment of rapeseed straw for bioethanol production

- Temperature (160, **180**, 190 °C)
- Reaction time (0, 5, 7.5, **10**, 15 min)
- Solid content (5, 10, 15, **20**, 30, 50%)
- Use of sulphuric acid as catalyst (0, 0.5, **1**%)
- Mixing time of sulfuric acid

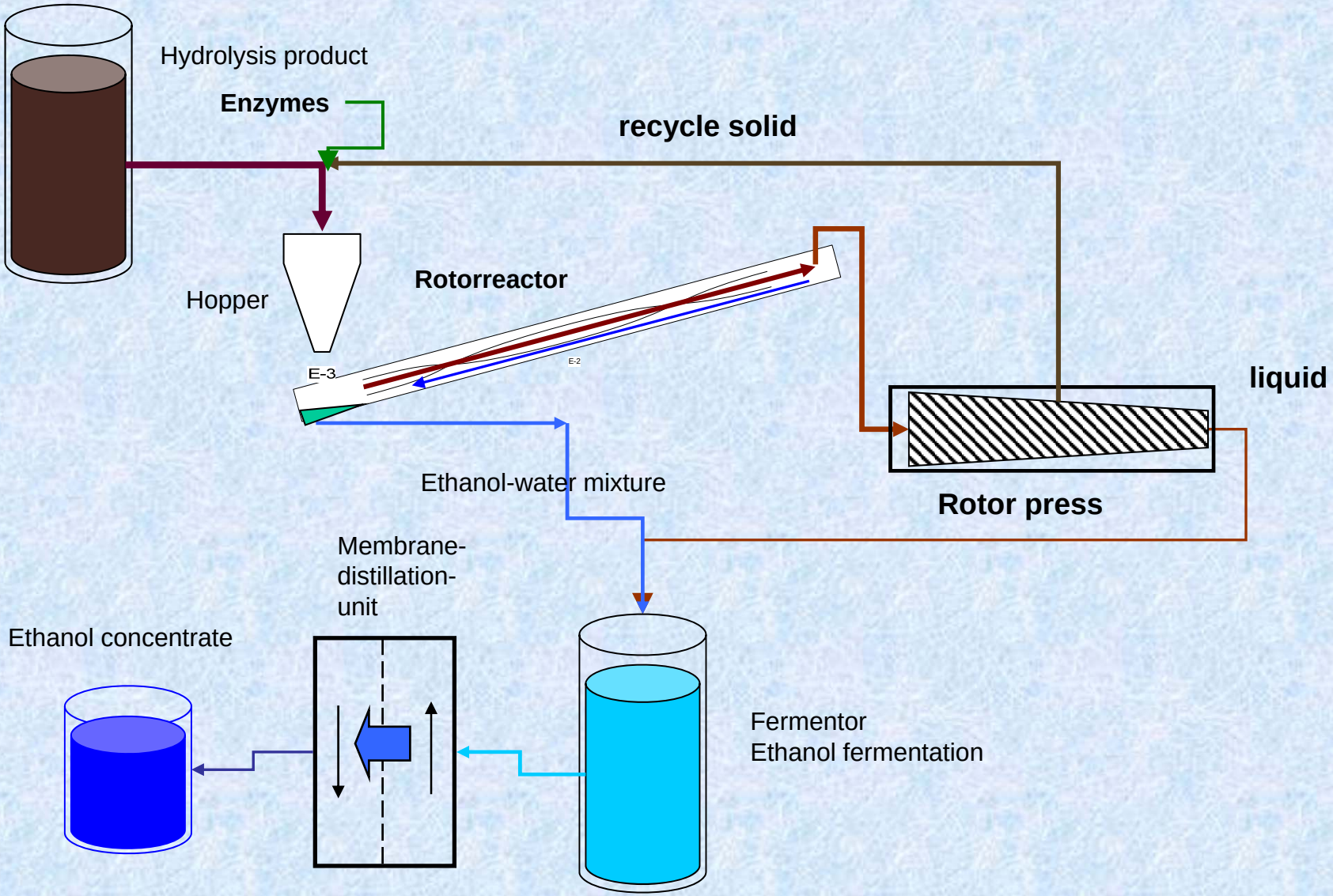
→ **>70% Ethanol yield based on the solid phase alone**

- ✓ **Maximization of sugar release (hemicellulose solubilization)**
- ✓ **Minimization of inhibitors formation (furfural, HMF)**
- ✓ **Maximization of ethanol production**

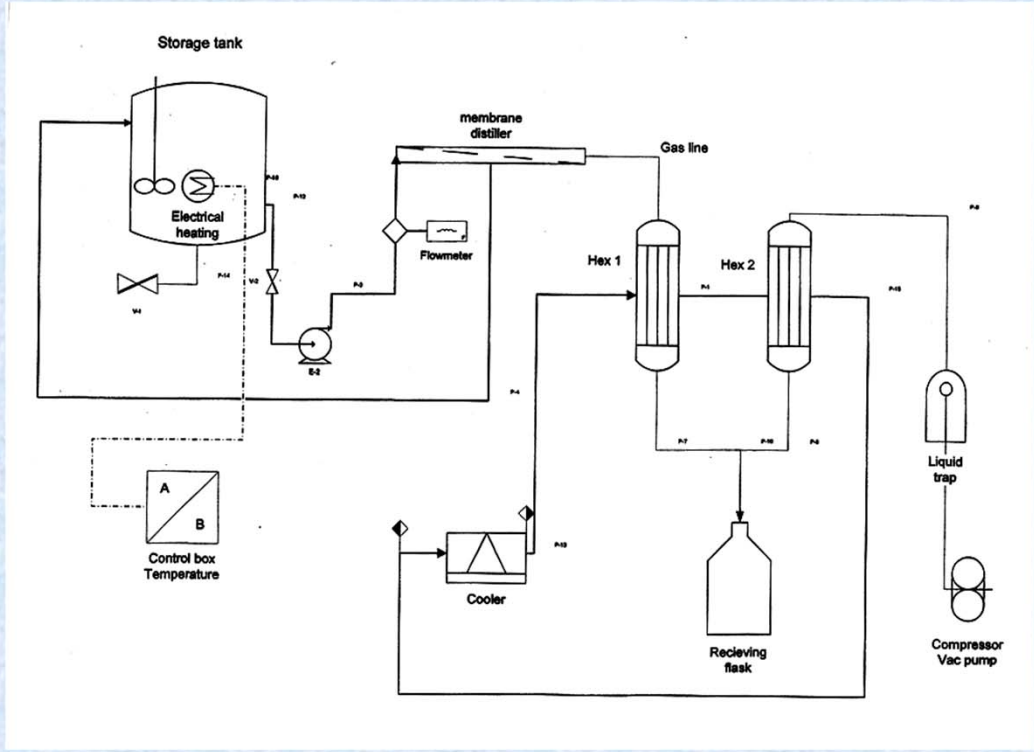


Efficient mixing of pretreated high TS material with enzymes

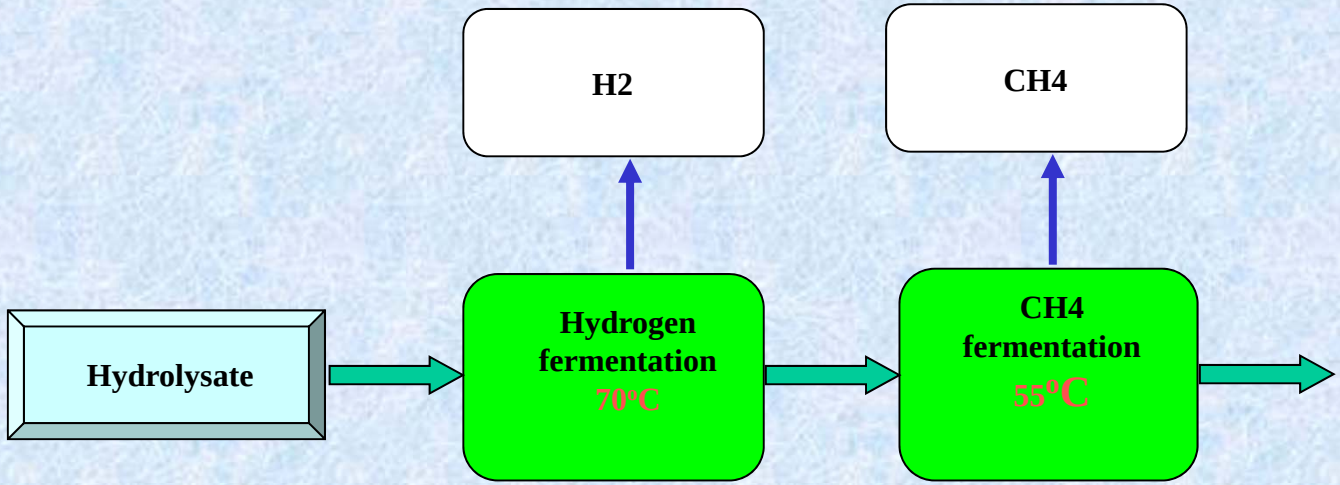
Flow-diagram sketch - SDU



Ethanol Fermentor with membrane distillation unit



Conversion of the liquid hydrolysate (pentoses) to Hydrogen and Methane in a two stage process



Converting straw hemicellulose (hydrolysate) to hydrogen and methane in a 2-stage anaerobic digestion system

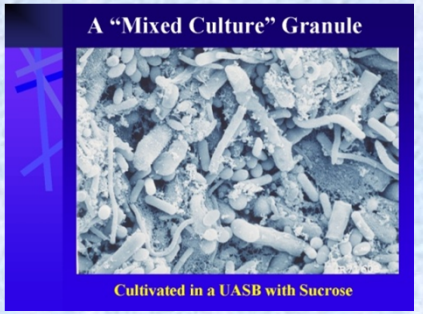
$H_2 + CO_2$

$CH_4 + CO_2$

Hydrolysate:25-30 %(V/V)

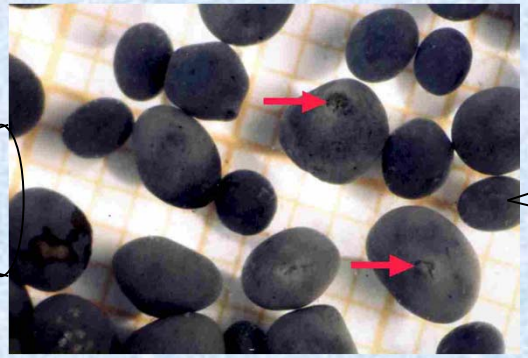
VFAs

Removed VFAs Effluent

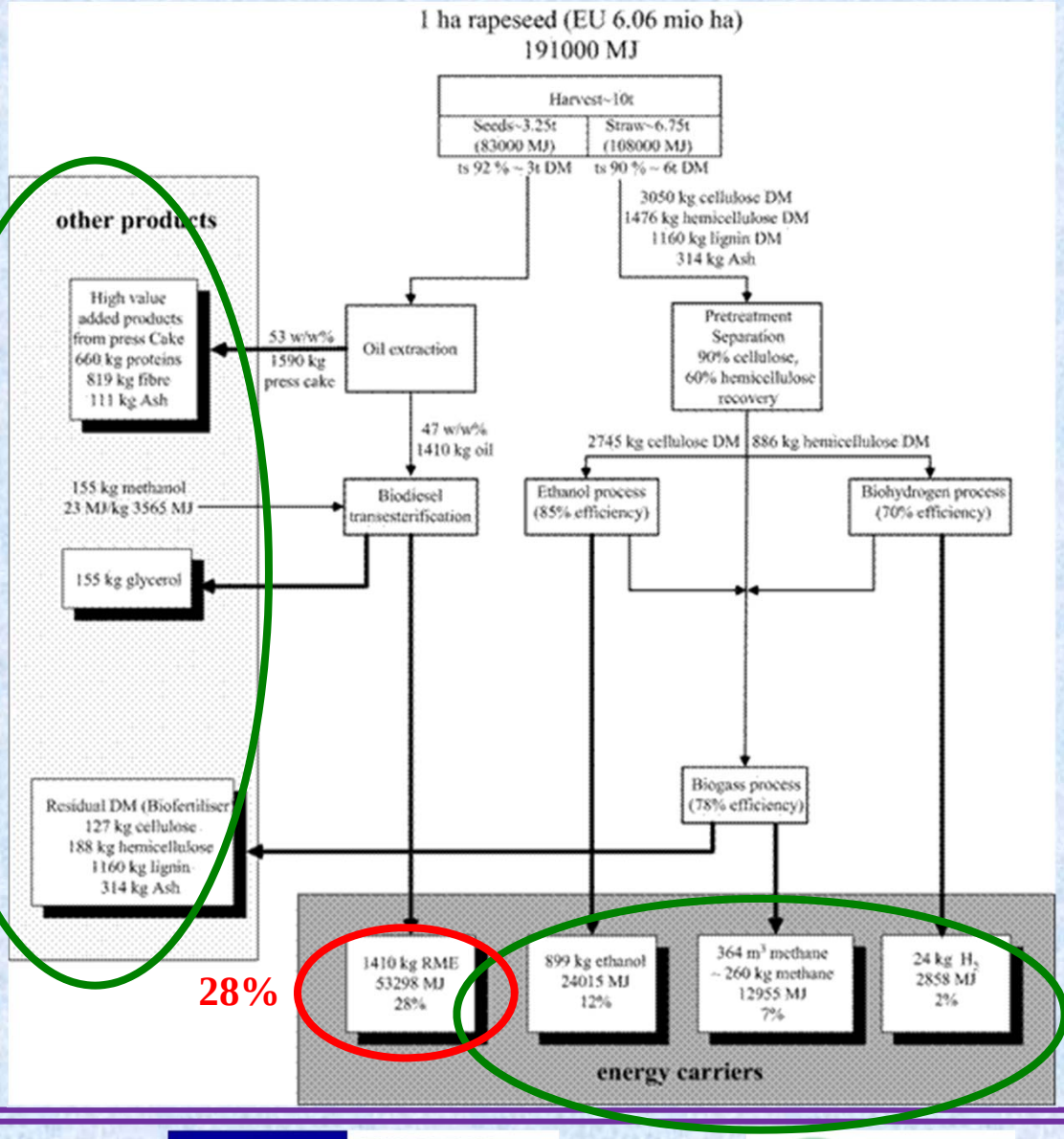


HRT (day)	**1**	**5.2 → 4.4 → 3.0 → 1.8 → 1.0 → 0.5**
Temperature (°C)	**70**	**55**

UASB reactors



Quantities of biofuels and biochemicals produced by the BioREF from 1 ha of rapeseed cultivation



Biorefineries

- Challenges
  - Pre-treatment of lignocellulosic biomass
  - Development of cheap and efficient enzymes
  - New microorganisms for bioconversion of all sugars
  - Effluents treatment

- Possibilities
  - Full utilisation of the biomass
  - New biomass based biochemicals
  - Improved overall economy
  - No-waste generating processes