What Future Biofuels in Australia ?

Bioethanol and Biodiesel Opportunities

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Global Biofuels (2005/6)

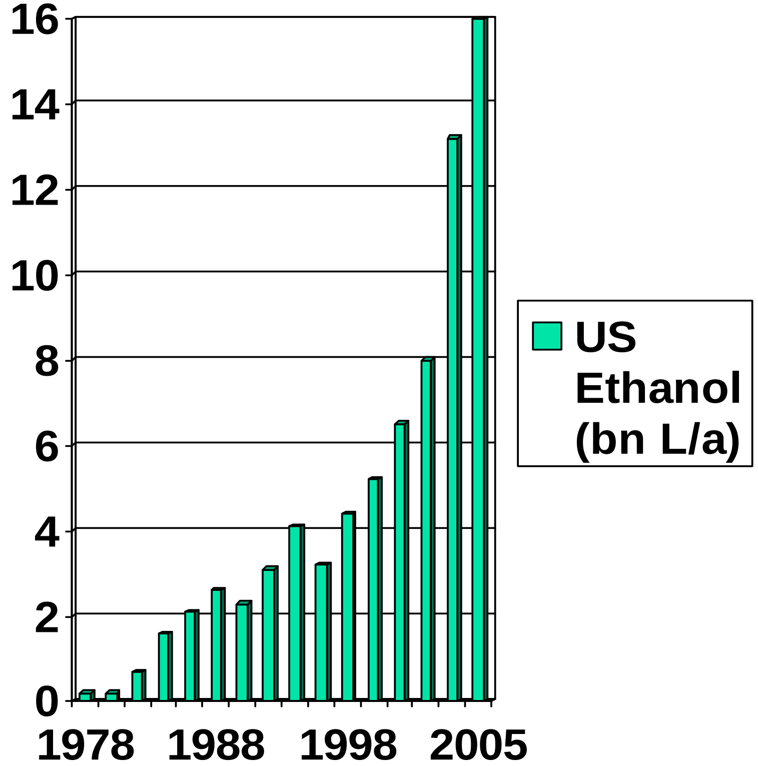
- Brazil:16.5 bn L/a ethanol from molasses, sugar cane juice, cassava

- US: 16 bn L/a ethanol from corn (20% total crop): 2.6% total US liquid fuels

- China: current 2 bn L/a ethanol (very large scale future plants projected)

- European Commission targets 2010 12 bn L/a (6% total liquid fuel)

- Australia : 120-150 m L/a: projected 350 m L/a by 2010 incl. biodiesel (approx 1% total liquid fuels)



Brazilian Ethanol Program

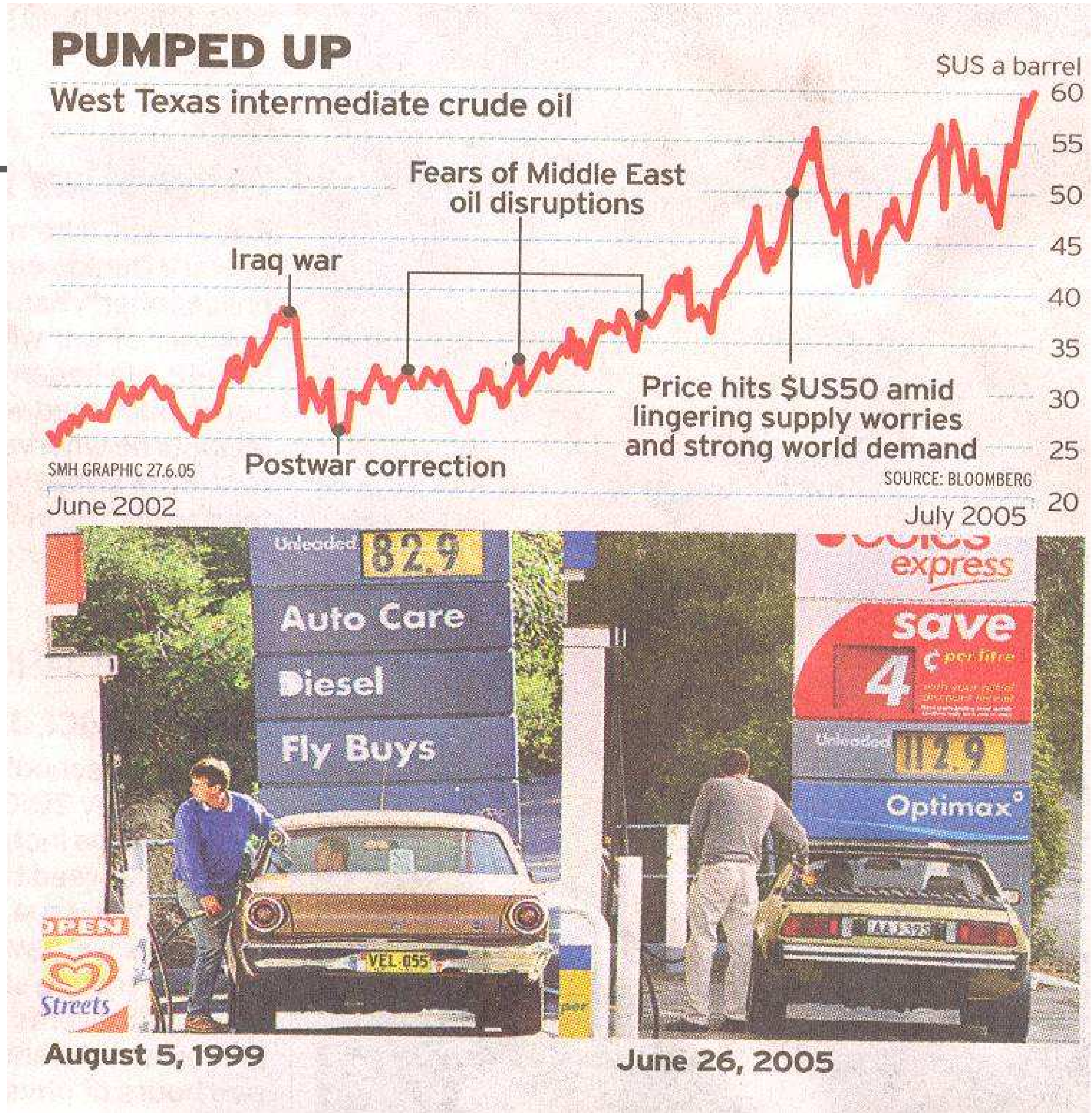
- Brazil produces 38% of world's sugar with total 59m t/a
- 28m t/a sugar converted to 16.5 bn L/a fuel ethanol
- Market share 15.7% of total liquid fuels
- Use of ethanol-based fuels originally mandated by the Brazilian Government in 1980s
- Production costs $US 0.15-0.20/litre with large scale fermentation and low cost batch technology
- Ethanol now a global commodity with significant exports from Brazil to the US and SE/NE Asia.

The European Solution

European Commission approval: 640 m litres surplus wine to biofuels

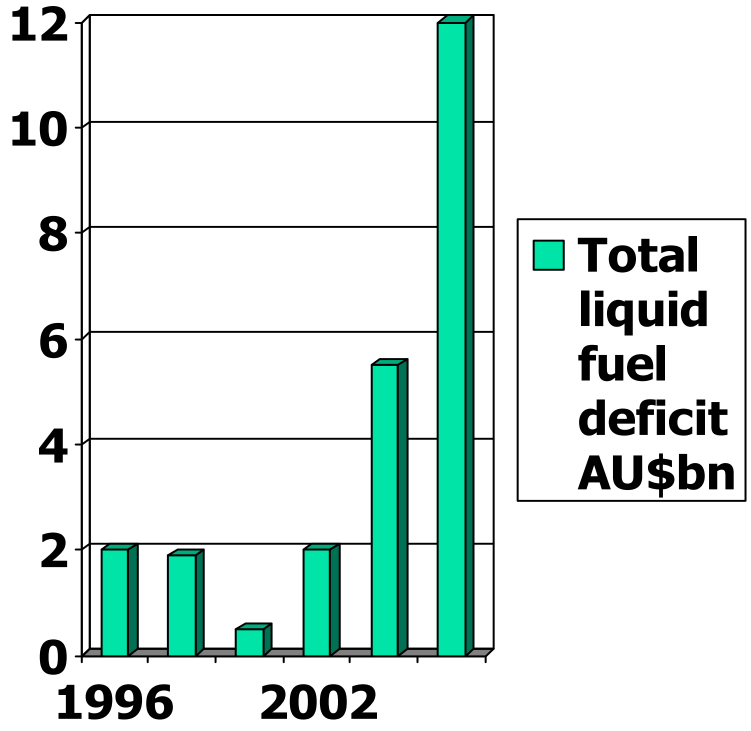
Key Drivers for Biofuels in Australia

- High price of oil and increasing oil imports ($12bn/a in 2005/6)
- Bio-security advantages (local production)
- Potential for significant regional economic development
- Biofuels based on renewable agricultural resources
- Reduced Greenhouse Gas emissions (CO2)
- Health benefits: reduced vehicle emissions including particulates (PM10)


PUMPED UP
West Texas intermediate crude oil
$US a barrel
60
55
50
45
40
35
30
25
20
Fears of Middle East oil disruptions
Iraq war
Postwar correction
Price hits $US50 amid lingering supply worries and strong world demand
SMH GRAPHIC 27.6.05
SOURCE: BLOOMBERG
June 2002
July 2005
Unleaded 82.9
Auto Care
Diesel
Fly Buys
express
save 4 c per litre
Unleaded 112.9
Optimax
August 5, 1999
June 26, 2005

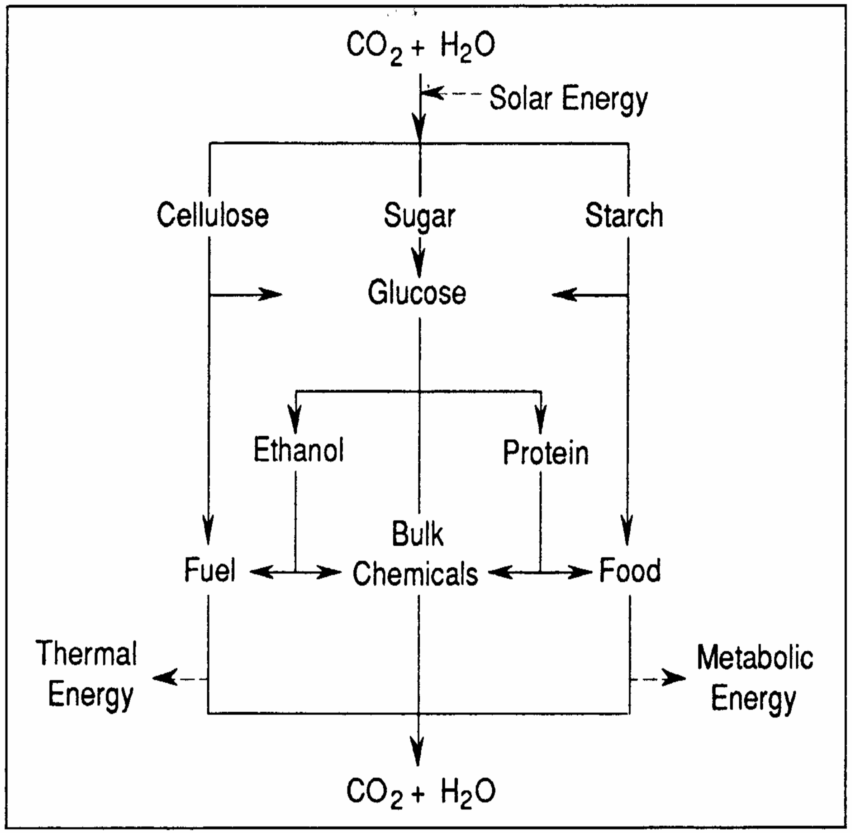
Australia's Increasing Liquid Fuel Deficit

- Deficit covers imports of gasoline, diesel and crude oil
- Significant recent increase due to increased demand and declining local production
- Deficit currently running at $12bn/a (2005/6)



Use of Renewable Resources : the Carbon Cycle

- Use of carbohydrate-based raw materials rather than those based on hydrocarbons
- Results in reduction in Greenhouse Gas (GHG) emissions
- Particular applications for commodity chemicals and biofuels (bioethanol)



Carbon cycle showing conversion of solar energy into thermal and metabolic energy

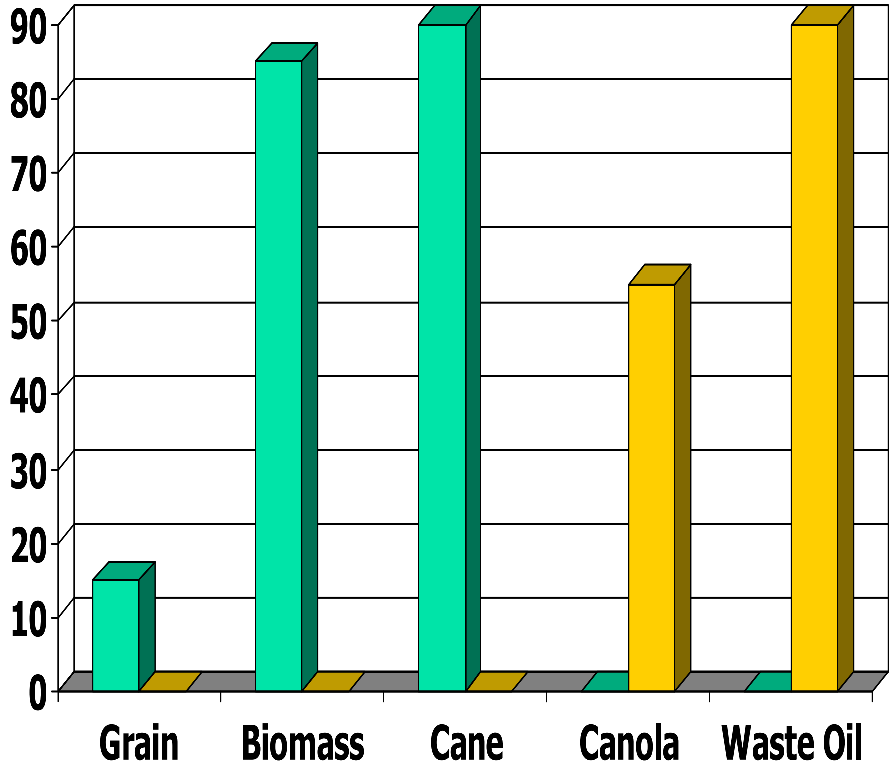
Greenhouse Gas Reductions

Biofuels Taskforce Report t the Prime Minister (2005)

"Consumption in 2010 of 350 ML biofuels (148ML ethanol and 202 ML biodiesel) would result in a total in total GHG emissions of approx 442,000 tonnes.

This reduction is estimated to comprise 107,000 tonnes from use of ethanol and 335,000 tonnes from use of biodiesel"

GHG Savings (%) compared to petrol or diesel (data from US Argonne National Lab)



AMA Submission to Biofuels Taskforce (2005)

- AMA supports interventions that reduce negative health impacts of emissions such as particulates, aromatic components and gaseous irritants (eg NO_2)

- AMA supports :
  -mandatory ethanol blends (10% in petrol; 20% in diesel)
  - reduction in highly toxic aromatics such as benzene in petrol
  - increased use of liquid petroleum gas (LPG) and compressed natural gas (CNG) in vehicles
  - installation of filters and gas-detoxification systems in vehicular tunnels in heavily populated cities

Key Issues in Australia

- Govt policies - State mandates of E5, E10 blends; carbon credits
  - excise tax removal on imported ethanol in 2011
  - reduced fuel tax concession (2011-2015)

- Land availability/additional inputs (water, fertilizers, pesticides)
  Risk of sustained drought conditions

- Limited opportunities for economies of scale

- Potential for lower cost non-food biomass crops

- Regulatory issues re GM crops/microbes for bioethanol production

- Support needed in Australia of oil and motor vehicle industries

Biodiesel

- Diesel blends with plant/animal oils (B2 to B100).
- Potential for cost reductions (per tonne: palm oil $350; used cooking oil $400; tallow $550; canola $900)
- Advantages: lower particulates (PM10) and GHG emissions, improved lubrication, higher flash point
- Other issues: meeting fuel standards, vehicle warrantees, cleaning of filters, higher gel point (tallow) - problems in colder climates
- Main producers: Germany 1920 ML/a; France 500 ML/a; US 290 ML/a;
- Australia: number of facilities including 110 ML/a from Tallow (BP)

Fuel Ethanol Production

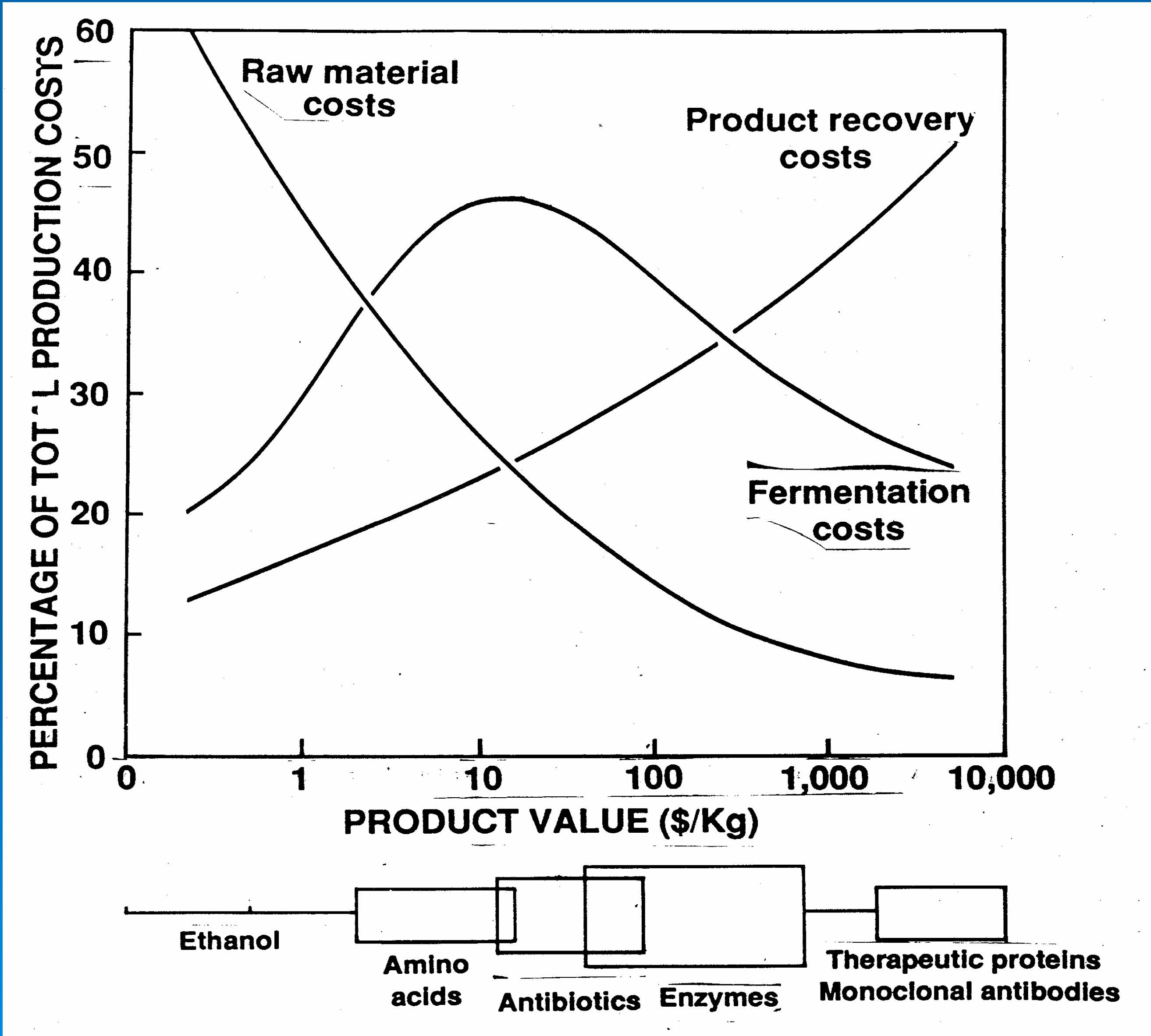
Traditional Processes : Fuel ethanol from sugars and starch hydrolysates

Ethanol from starch conversion plant

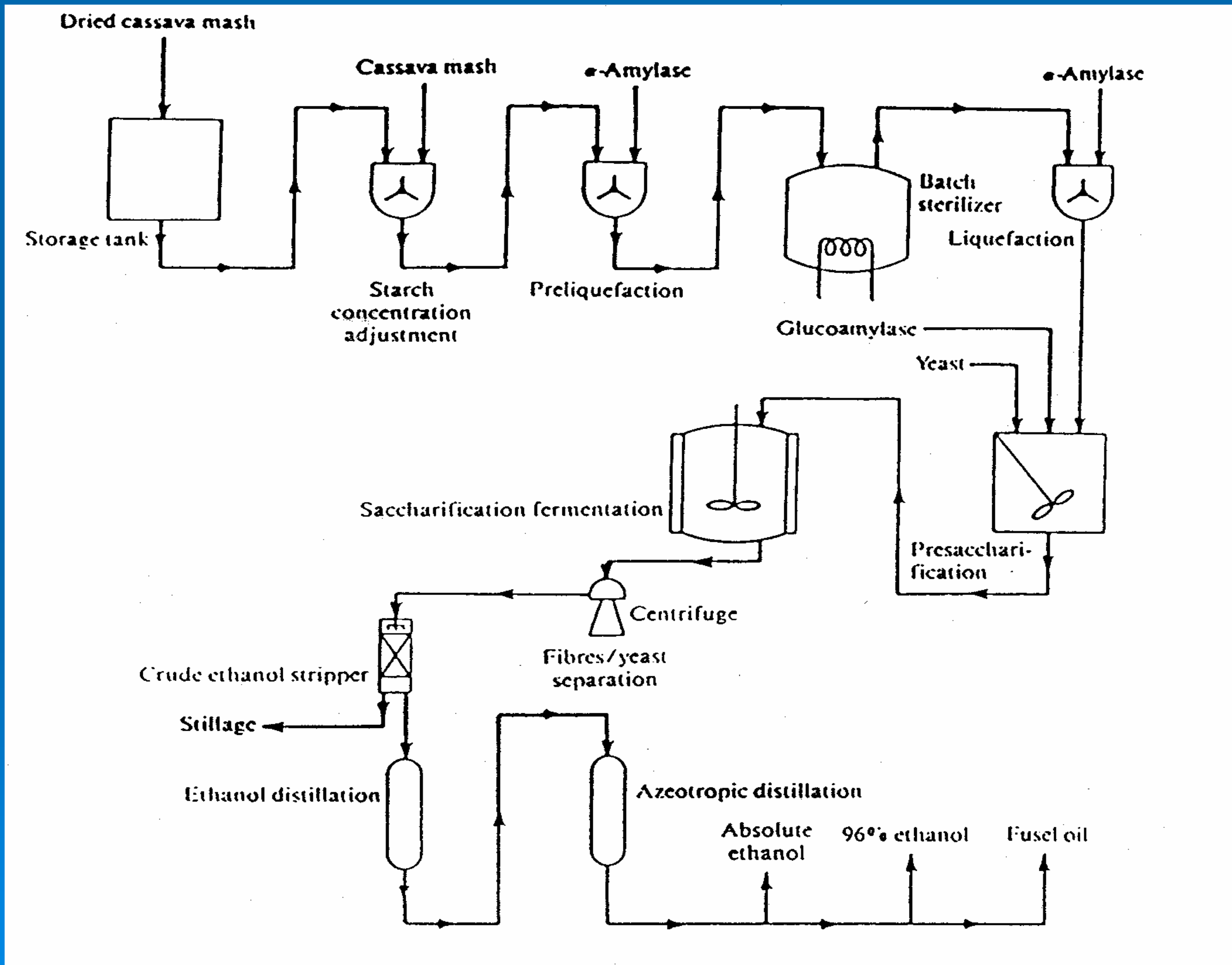
Main Sources of Raw Materials for Fermentation Processes

- Sugar cane, sugar beet etc main sources of sucrose usually as molasses ($50/tonne)
- Corn, wheat, cassava etc main sources of starch (enzymatic pre-treatment needed)
- Biomass/agricultural and forestry residues provide potential low cost substrates (opportunity cost $25-40 per tonne); however more complex pre-treatment and microbes needed.

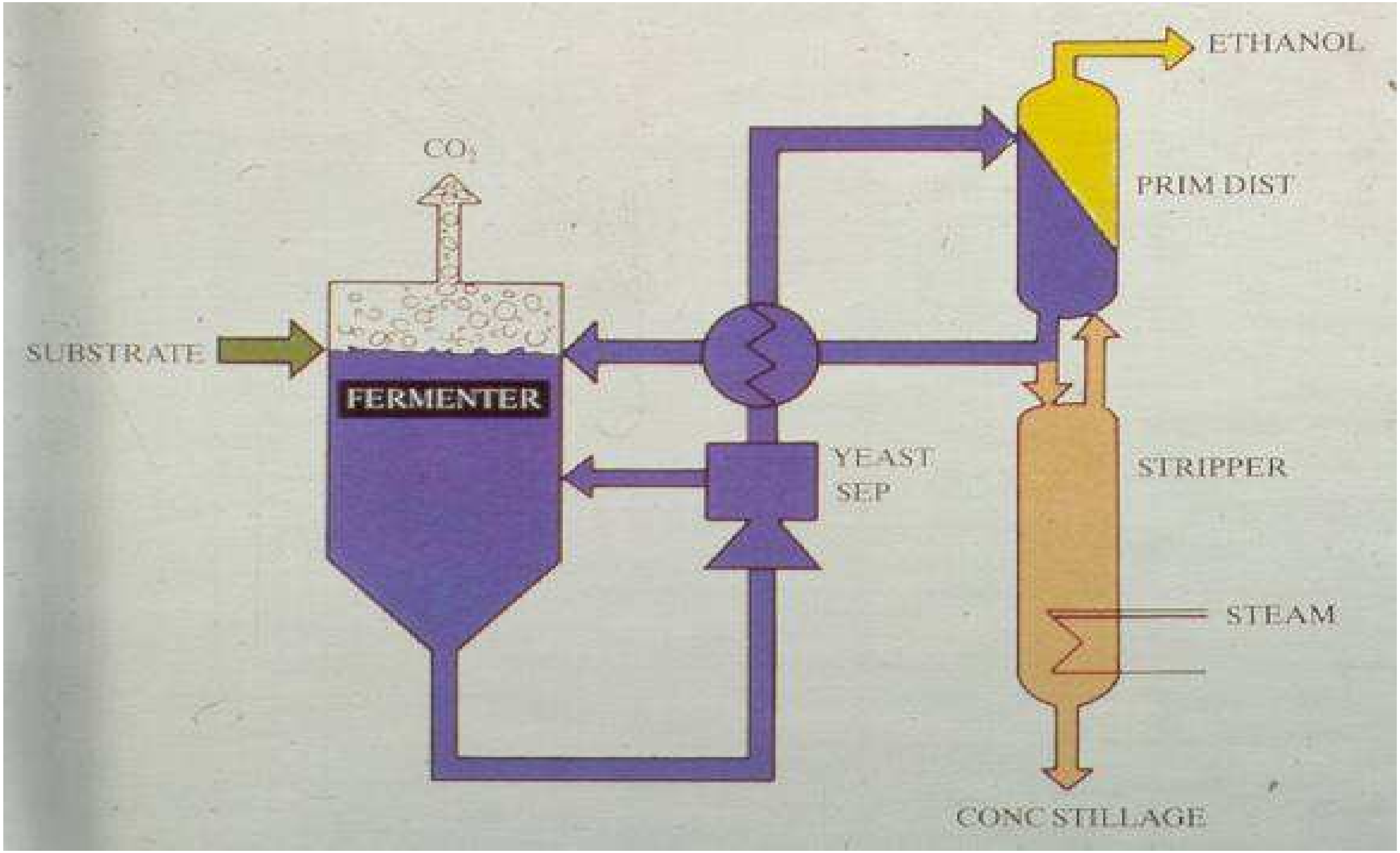
Factors affecting operating costs



Starch-Based Ethanol Process

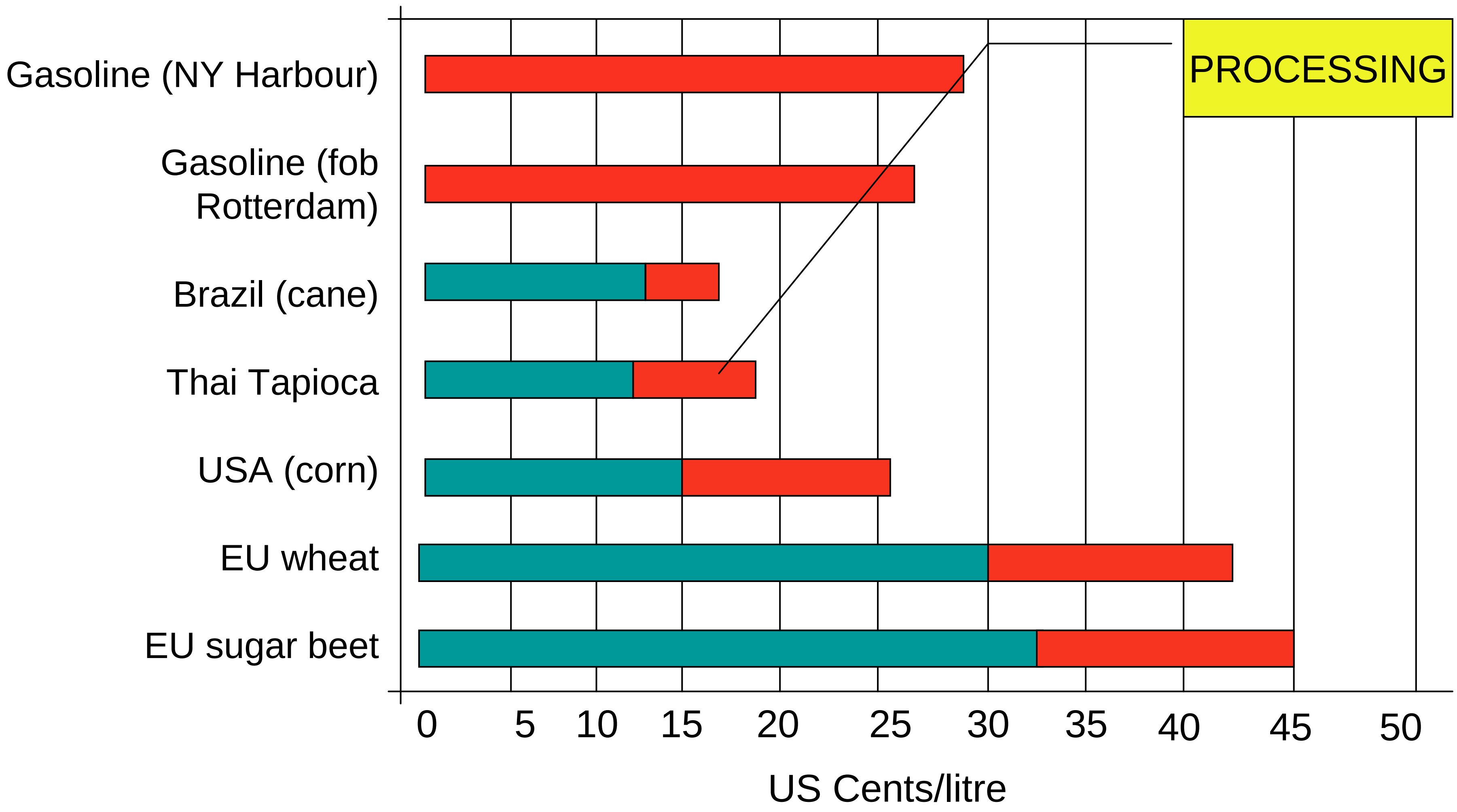


Industrial ethanol production cell recycle/vacuum fermentation



World Fuel Ethanol 2005

Costs of Production



New Technology : Ethanol from Biomass

- Biofuels Taskforce to PM (2005):

"Globally there is major investment in an emerging technology that can produce ethanol from lignocellulosic feedstock.

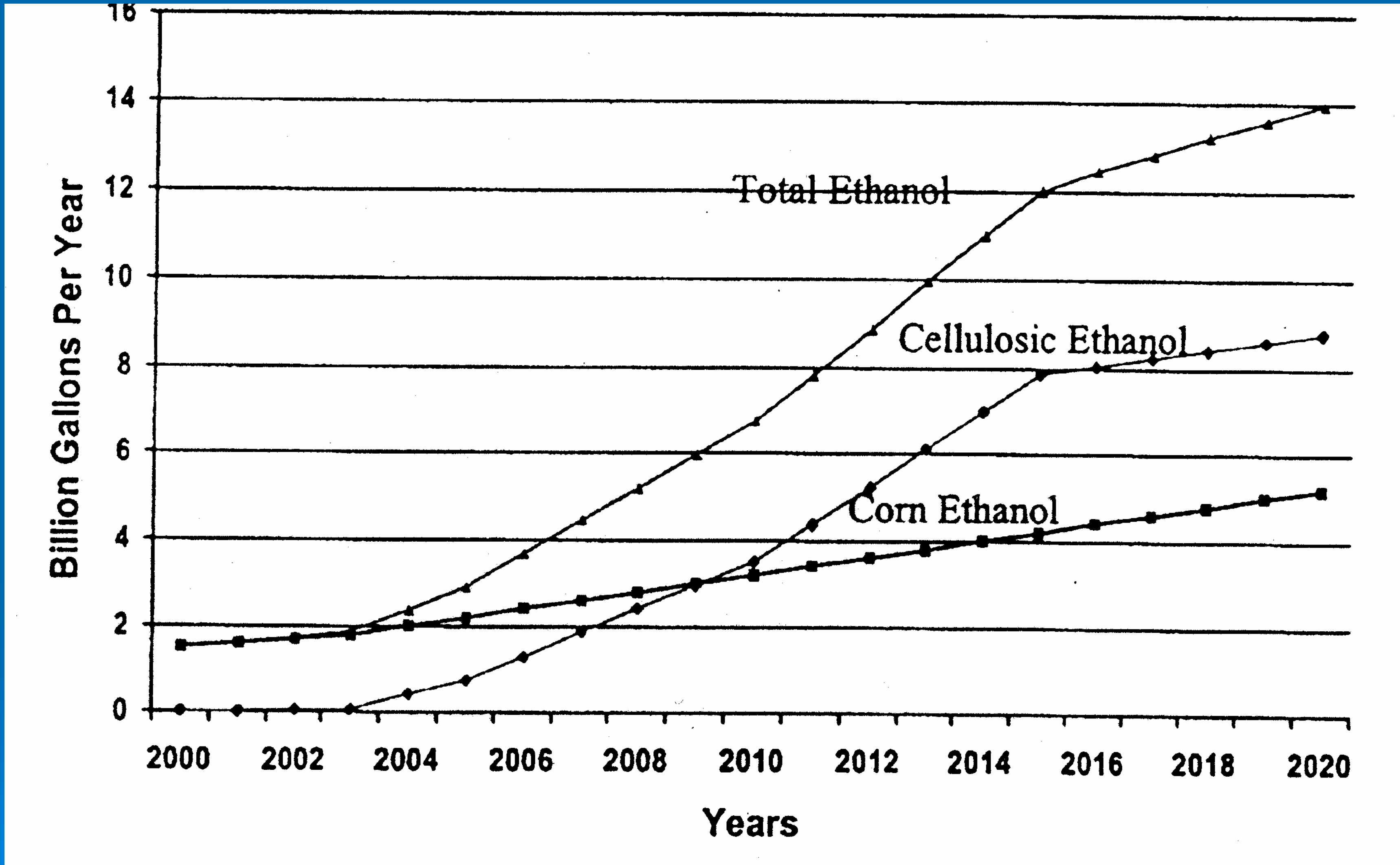
This could become commercially viable within the next five to ten years".

- US Department of Energy Secretary, Ray Orbach (Oct '06)

"30% biofuels replacement target by 2030".

Developing lignocellulosic crops for energy fuels could use less intensive production techniques & poorer quality land".

Projected Ethanol Production



Source: Mark Paster, Office of Biomass Program, US Department of Energy, 2002

Global R&D: Ethanol from Biomass

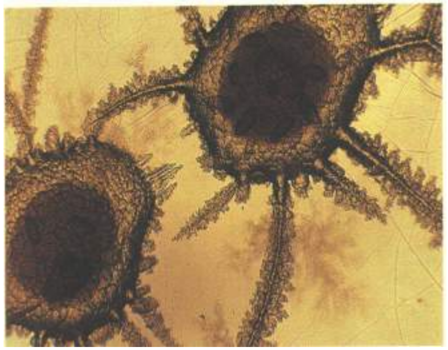
- Large scale pilot plant : Iogen (Canada) with Shell and PetroCanada 6 tonne/d wheat straw; 250 L/t ethanol

- Swedish group (Lund): 2 t/d softwood; 350L/t ethanol Production costs: $US 0.45-0.50/L based on 200,000 t/a plant

- Dupont/NREL/Diversa: $US 38m project to convert corn stover/cobs to ethanol. Starch used for higher value biopolymers

- Abengoa (Spain): pilot scale using wheat straw associated with grain to ethanol plant

Examples of Sustainable Bioprocesses (OECD Report 2001)



Cu leaching-low grade chalcopyrite

Use of *Thiobacillus* sp. Lower capital and operating costs . Reduced energy costs and sulphur dioxide emissions (BHP-Billiton)

Riboflavin (vitamin B2)

6 step chemical process replaced by single step with GM strain of *Bacillus subtilis* (Hoffmann LaRoche)

Ligno-cellulosics to fuel ethanol

Use of recombinant yeast with agricultural and forestry residues (Iogen and Shell Canada)

OECD Report on Sustainable Development (2001)

- Case studies : pharmaceuticals, bulk chemicals, food and feed, textiles, pulp and paper, minerals and energy
- General conclusion : for selected processes - cost savings, reduced energy inputs, better pollution control
- Greater potential for enhancement for bio-based processes compared to chemical ones (eg enzyme-based biocatalysts)

Technological Hurdles

- Cost effective pretreatment needed. Current options: size reduction, steam explosion, conc./dilute acid or alkali digestion, enzyme hydrolysis
- Enzyme (cellulase) costs significant - 20-fold cost reductions recently achieved (gene shuffling, protein engineering techniques)
- Recombinant microbes needed for fermentation of C5 (xylose, arabinose) & C6 (glucose) sugars. Hydrolysates may contain inhibitors
- By-product market needed for non-reactive lignin (15% total). Potential use in paints and adhesives

R&D Focus at UNSW

- Research group active at UNSW in Industrial Biotechnology over past decades

- Emphasis on high productivity fermentation processes for bioethanol/fine chemicals

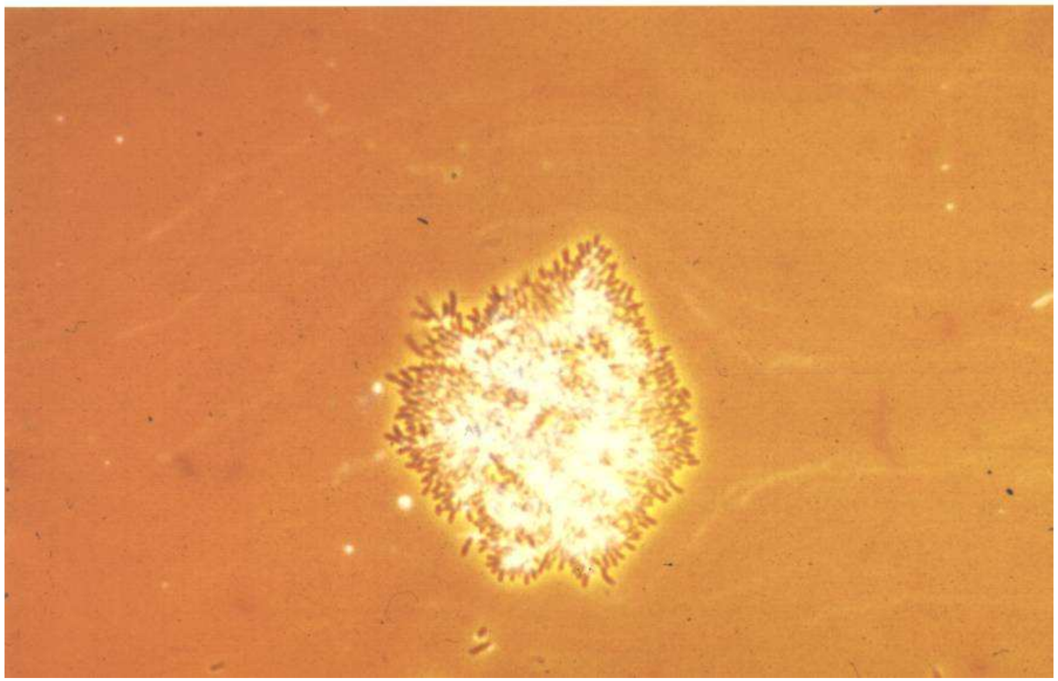
- R&D projects with Australian and overseas governments and industries

- Current collaboration with Dupont/NREL on pilot scale process for ethanol from residues from corn processing

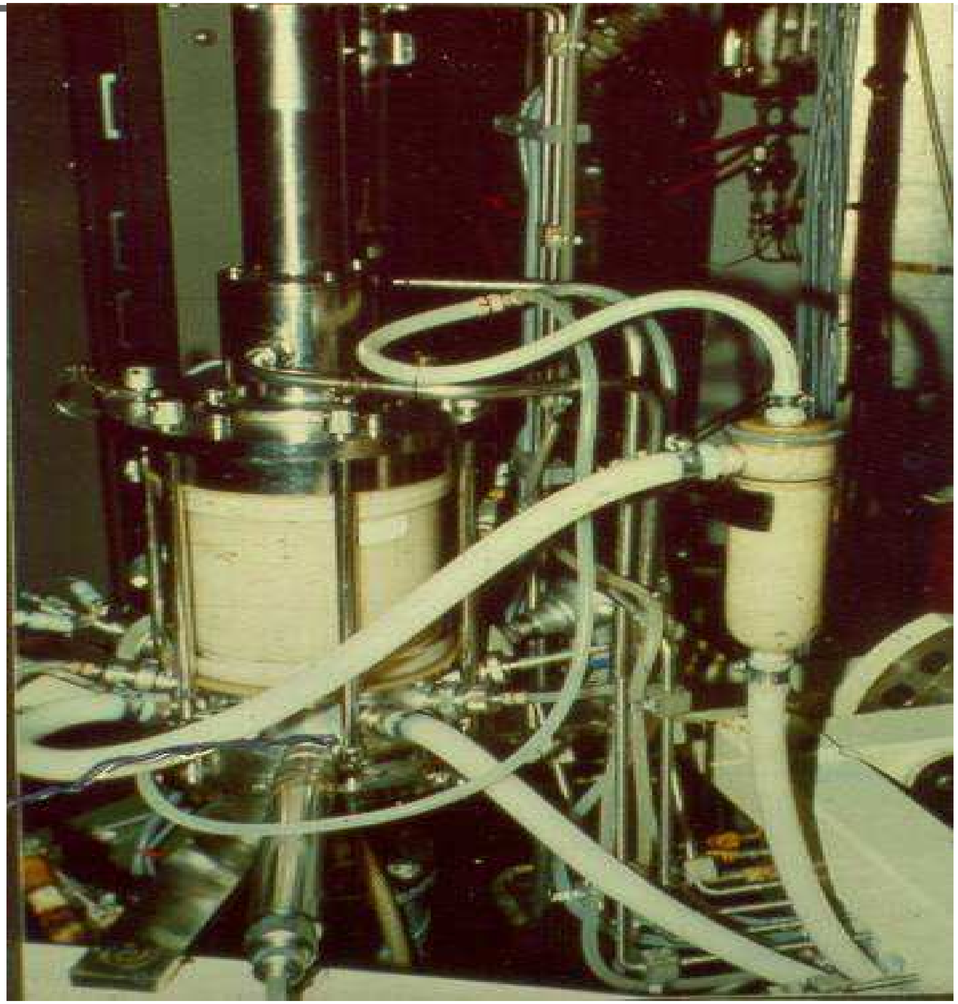
Electron microscope picture of *Zymomonas mobilis* (ZM4)

Flocculent Z.mobilis ZM401

- High productivity repeated batch fermentations achieved with flocculent cells



Continuous cell recycle process for high productivity fermentation



COMPUTER CONTROLLED FERMENTORS

100 LITRE

30 LITRE

Batch kinetics of rec *Z. mobilis*

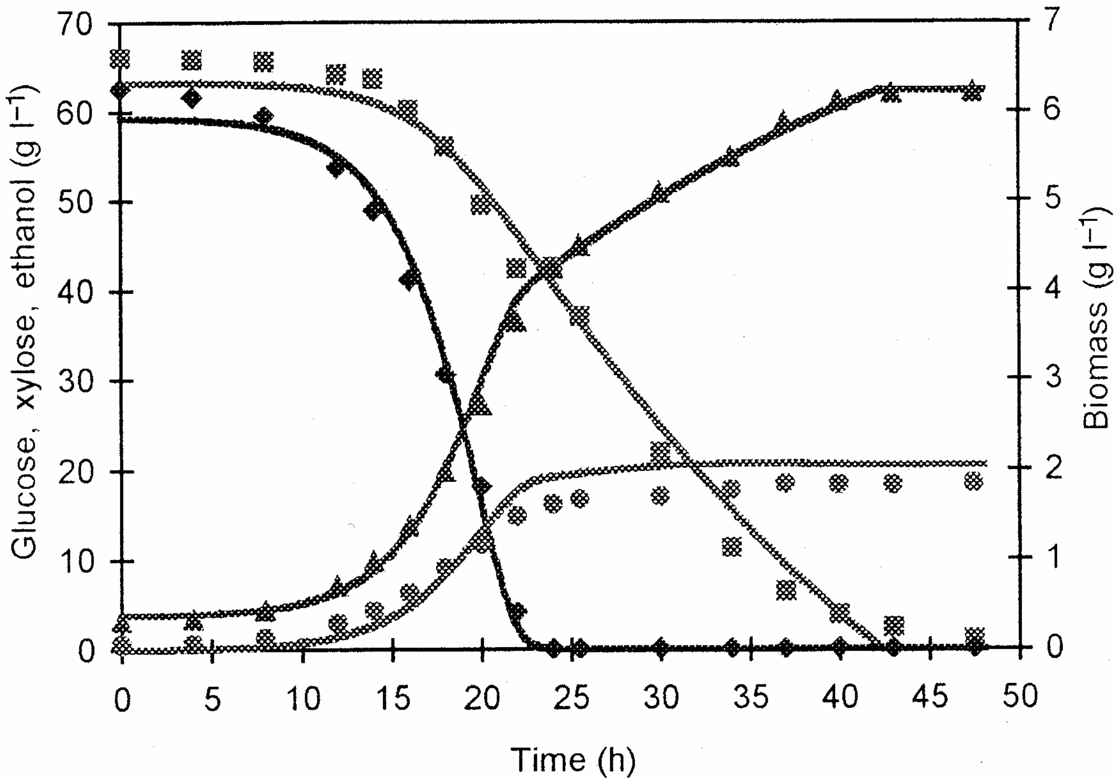
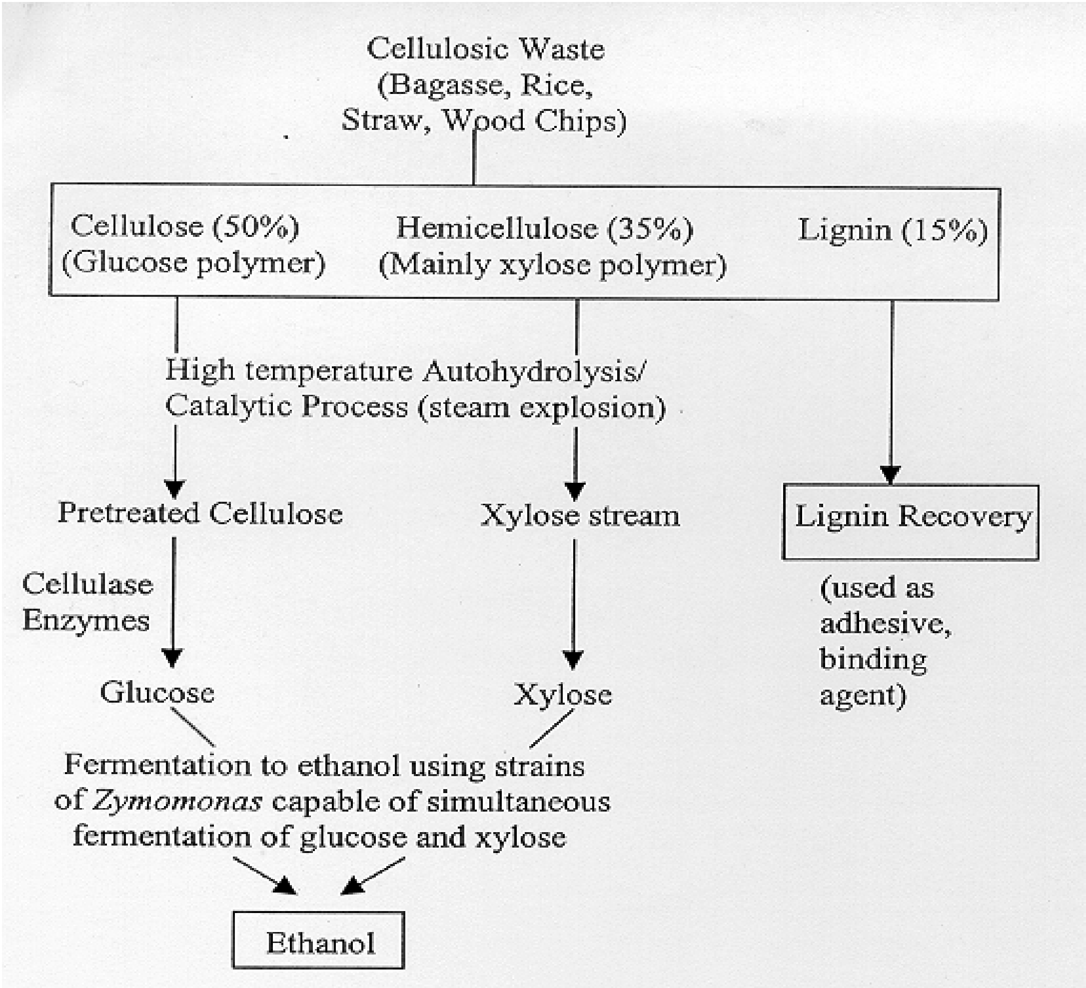


Fig. 3. Simulation of the mixed sugar system and experimental data for ZM4(pZB5) on 65 g l^{-1} glucose and 65 g l^{-1} xylose medium. ♦, Glucose; ■, xylose; ▲, ethanol; •, biomass.

Zymomonas-based process for conversion of lignocellulosics



Australian R&D : Pilot Scale lignocellulosics to ethanol

- Design and Feasibility Study: NSW State Forests, AGO, Manildra Starch (2000).

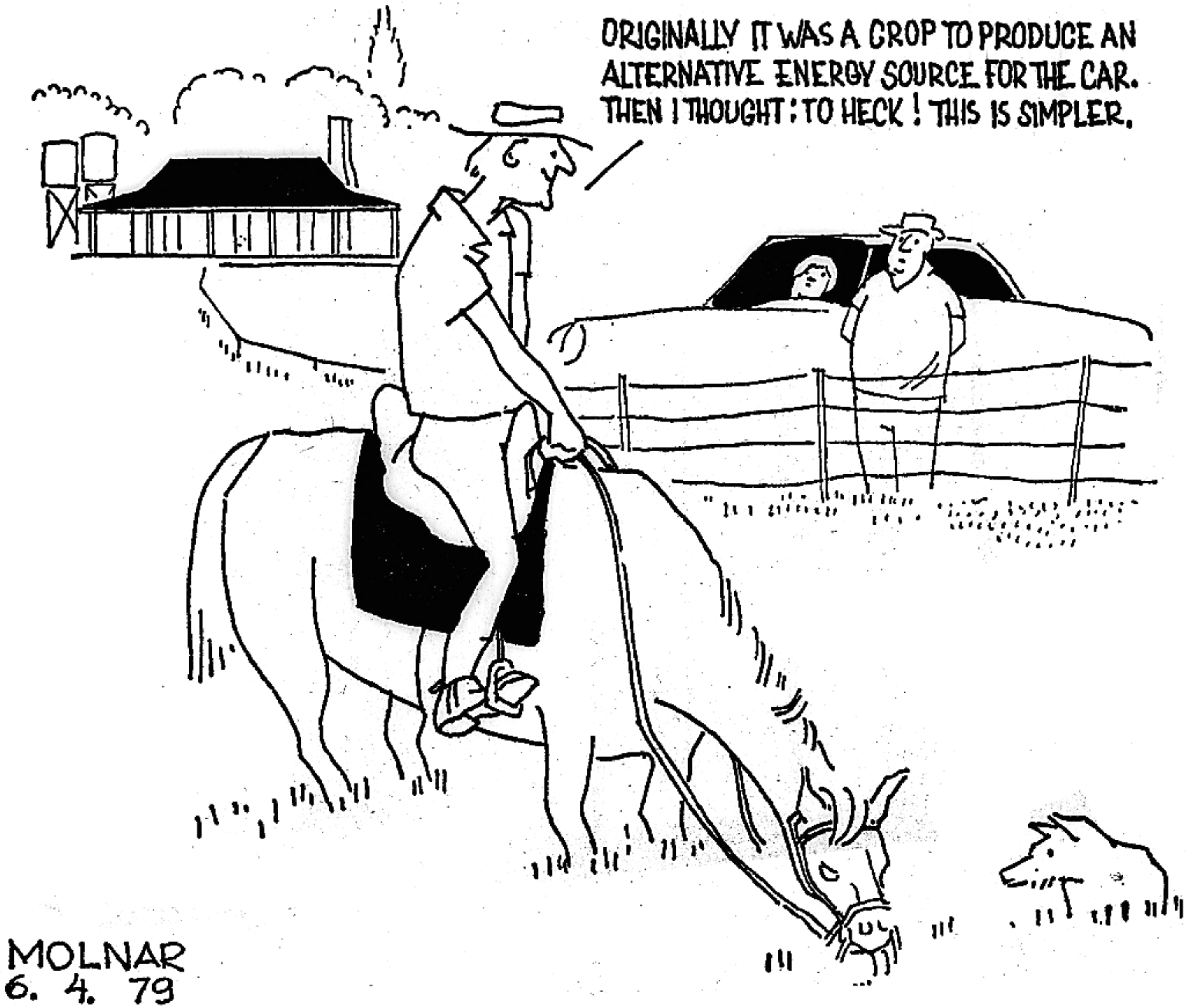
  Feedstock 2 t/d (wood chips); 350L/t ethanol.

  Estimated cost of pilot plant $A 16m.

- Biorefinery pilot plant : QUT/Mackay Sugar

  Conversion of bagasse to ethanol.

  Current funds: $A 3.1m from Queensland Govt. Further funds sought from Federal Govt., sugar industry


ORIGINALLY IT WAS A CROP TO PRODUCE AN ALTERNATIVE ENERGY SOURCE FOR THE CAR. THEN I THOUGHT: TO HECK! THIS IS SIMPLER.
MOLNAR
6. 4. 79

Dupont Integrated Corn Biorefinery (ICBR) : Biopolymers

- Joint venture with Tate and Lyle
- Production of 1,3 propandiol (PDO) as an intermediate for the biopolymer Sorona
- Use of genetically engineered *E.coli* for fermentation of hydrolysed corn starch
- Plant construction commenced early 2004.

Dupont Integrated Corn Biorefinery (ICBR) : Fuel Ethanol

- Lignocellulosic residues (stover, cobs) from corn
- DOE supported project ($A50m) in collaboration NREL/Diversa/Harvesting Companies
- Use of rec *Z.mobilis*
- Life Cycle Analysis re energy/water requirements

Opportunities in Australia: Integrated Biorefinery Concept

- Sugar industry: expanded fuel ethanol, higher value products (eg amino acids, enzymes, high value protein feed)
- Starch industry: higher value modified proteins, ethanol from starch/waste stream conversions
- Agro-forestry: trees for salinity control, for fuel ethanol and/or electricity co-generation. CSIRO Report : Beyond 2025: Transitions to a Biomass-Alcohol Economy (1999).

Four year old mallees grown in alleys for salinity control