Bioethanol

CE 521

Shinnosuke Onuki

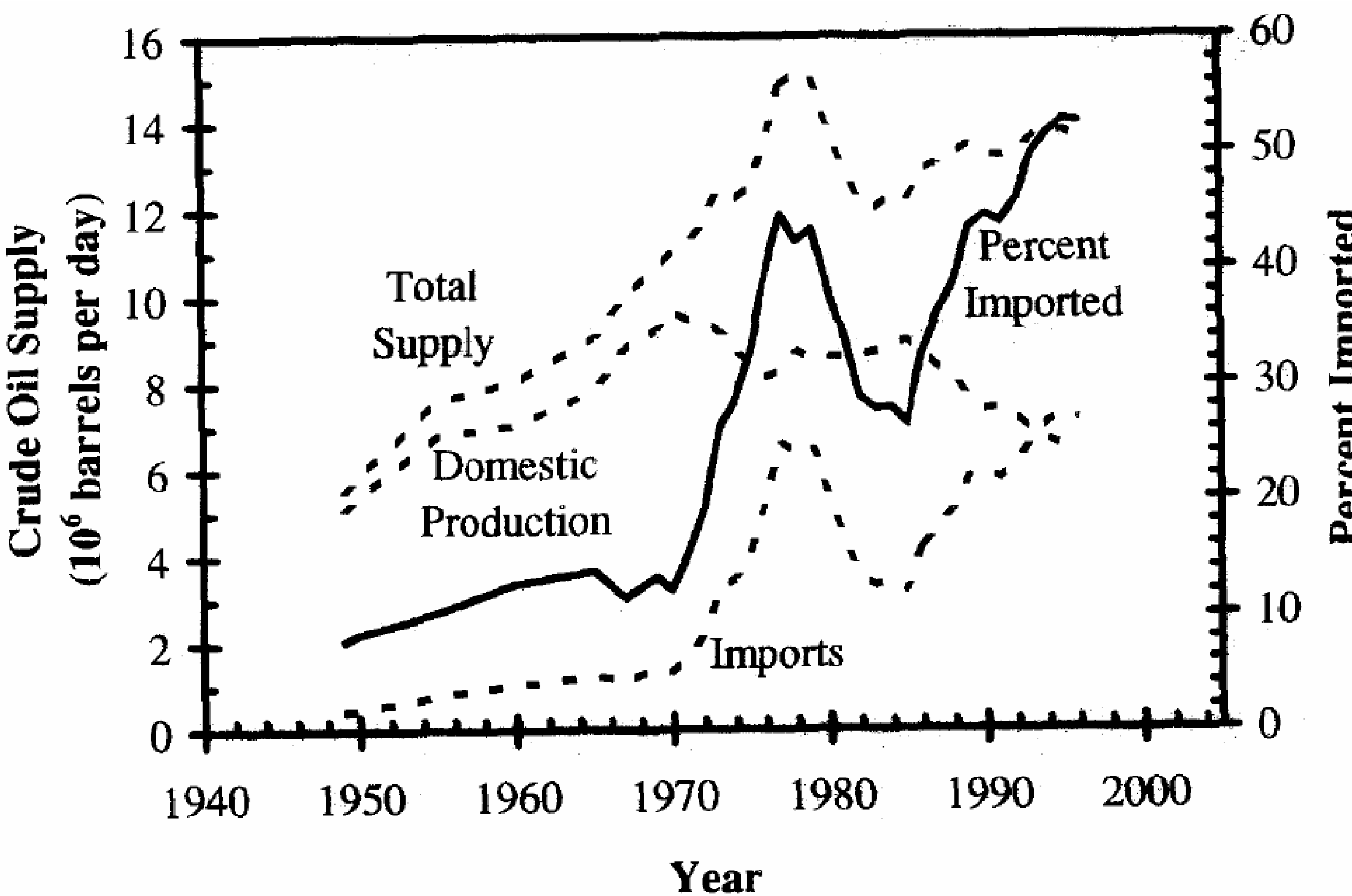
1. Introduction

Bioethanol

A biofuel produced by the fermentation of plants rich in sugar/starch

- ✓renewable resources
- ✓impact on air quality due to cleaner combustion
- ✓reduced net carbon dioxide (greenhouse gas) emissions
- ✓expanded market opportunity in the agricultural field
- ✓energy security: less dependence on crude oil
- ✓More than 90% of the bioethanol produced in the U.S. comes from corn

1. Introduction

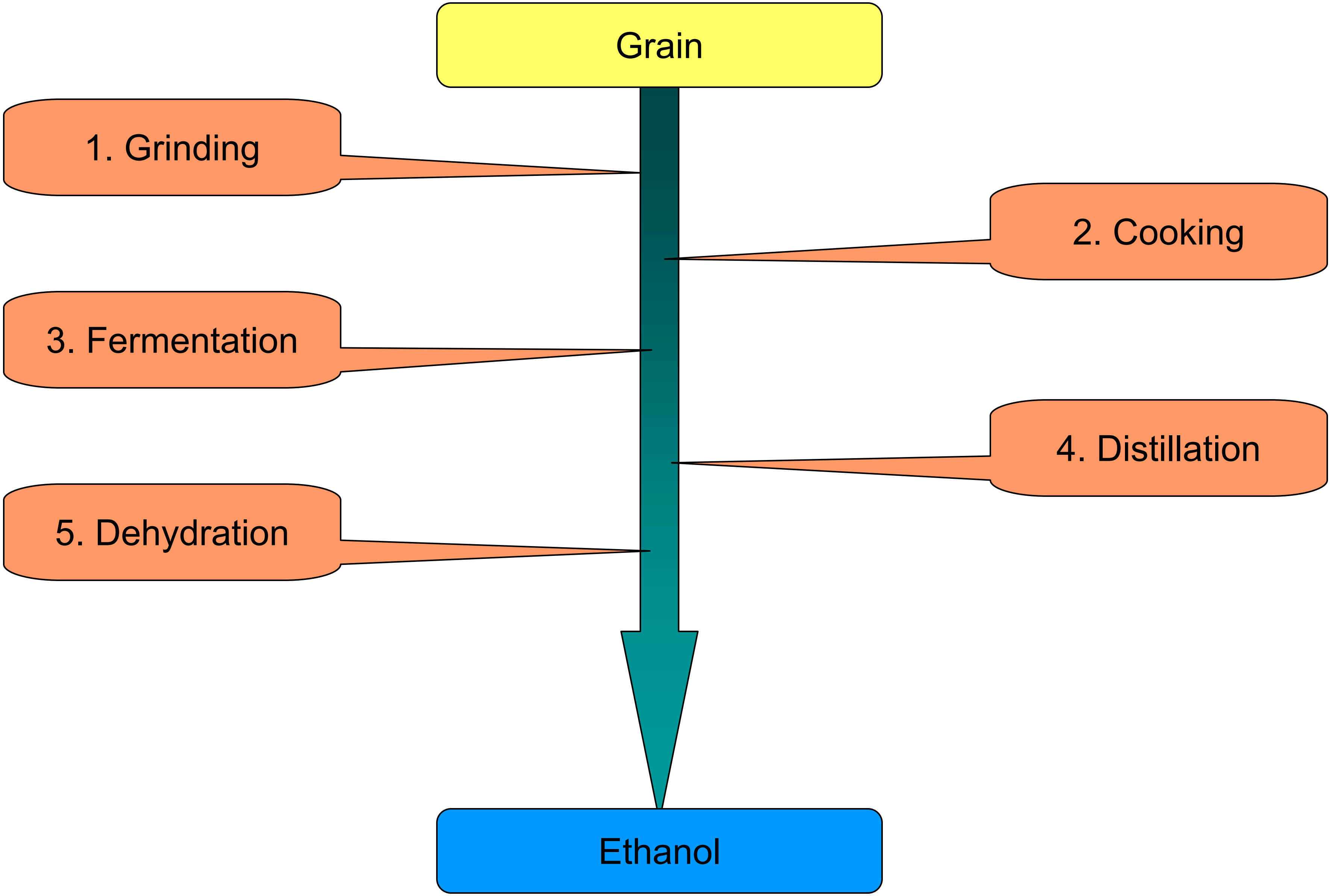


Imports as a percentage of total U.S. crude oil supply (McMillan,1996)

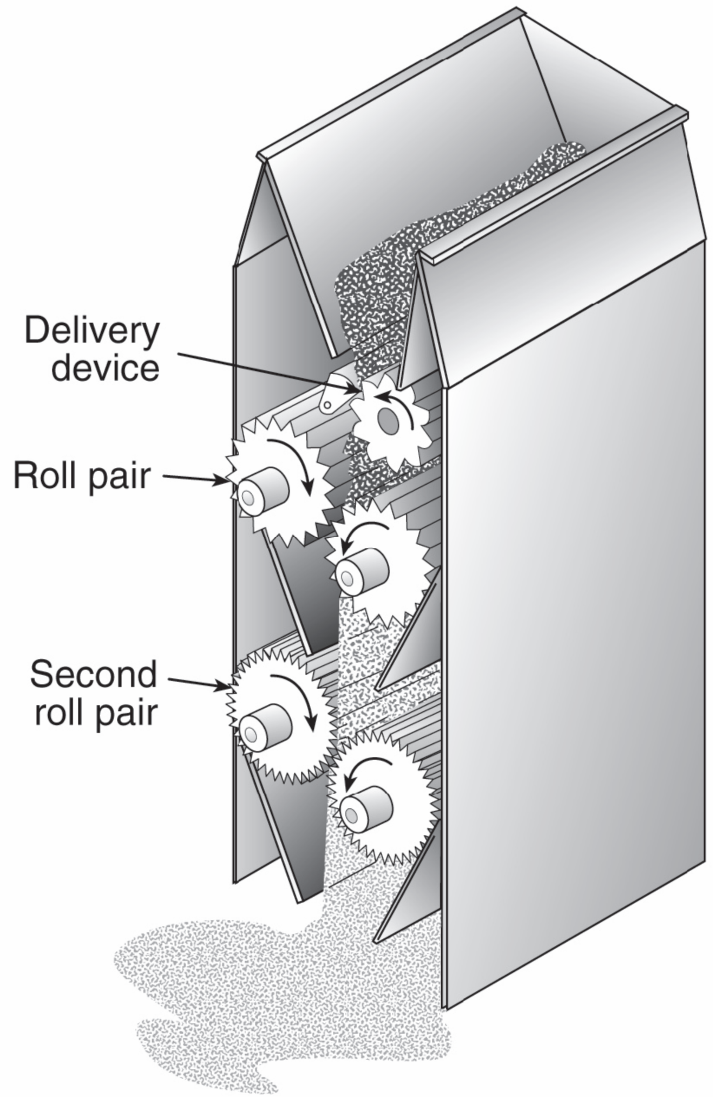
2. Outline

1. Production process
    1. Grinding
    2. Cooking
    3. Fermentation
    4. Stress management
    5. Distillation
    6. Dehydration
2. Lignocellulosic biomass
3. Immobilized Cell System
4. Energy Balance
5. Concerns

3. Production Process



3-1. Grinding



Roller mill (Kohl, 2003)

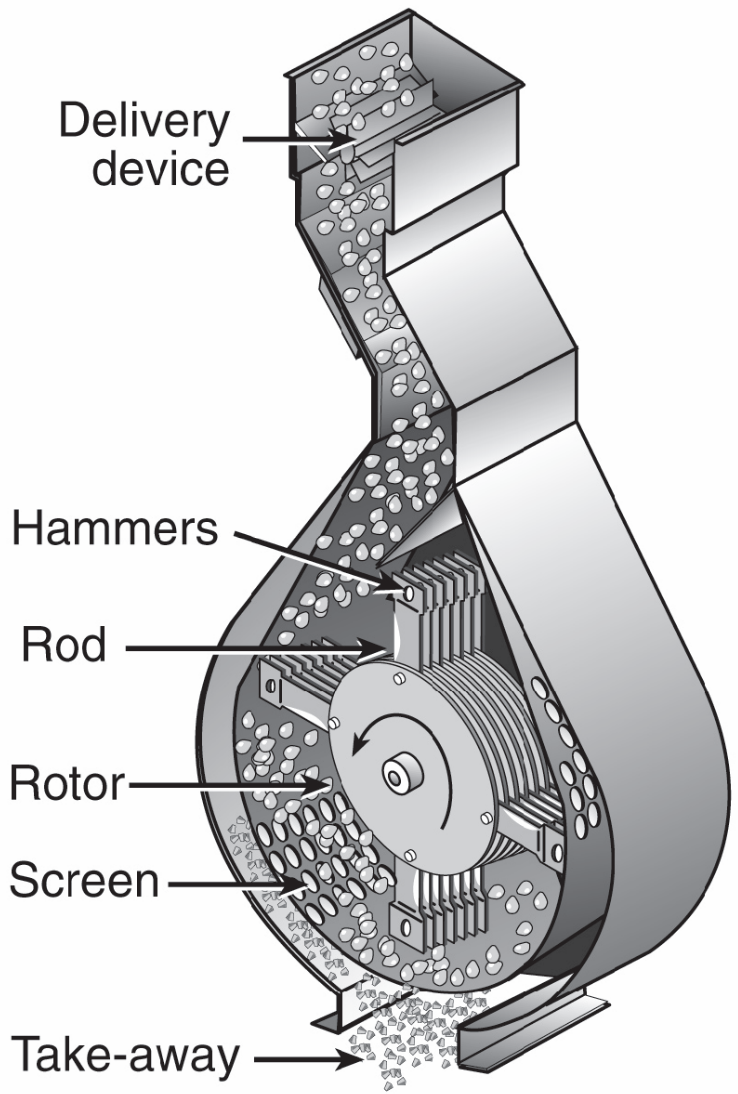
Advantage

- ✓Less energy consumption
- ✓Provide more uniform particles

Disadvantage

- ✓High set up cost
- ✓**High maintenance cost**
- ✓**Difficult to grind small grains**
- ✓**Difficult to grind hard shell grains**

3-1. Grinding



Hammer mill (Kohl, 2003)

Advantage

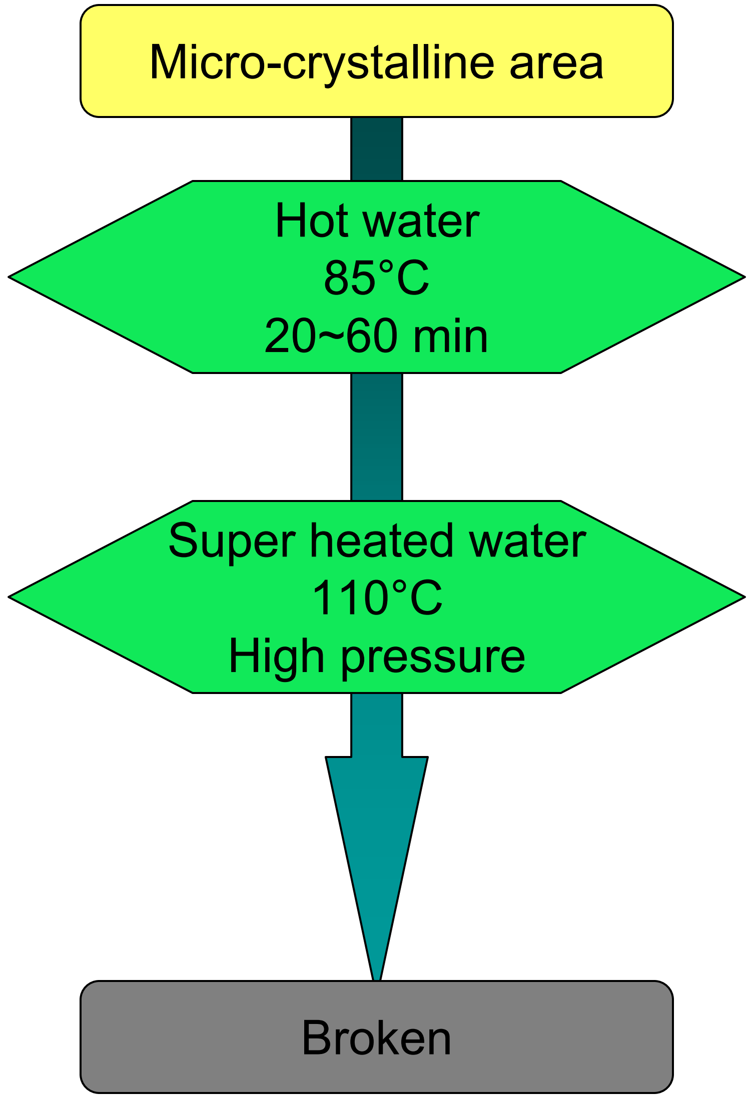
✓Less set up cost
✓**Less maintenance cost**
✓**Easier to grind small grains**
✓**Easier to grind hard shell grains**

Disadvantage

✓Higher energy consumption
(about twice as much)
✓Provide less uniform particles

3-2. Cooking

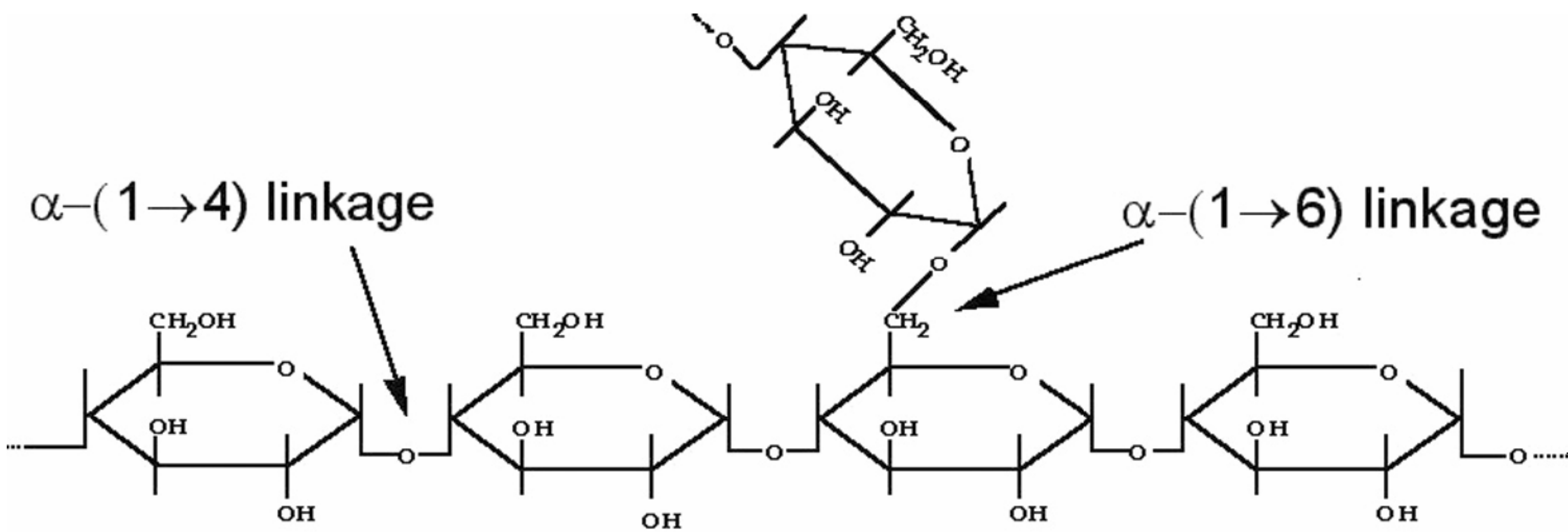
Hot water treatment



3-2. Cooking

Alpha-amylase

- ✓Liquefaction
- ✓Attack α-1,4 linkage
- ✓Convert Starch into Dextrin
- ✓endoenzyme
- ✓10 times faster than glucoamylase

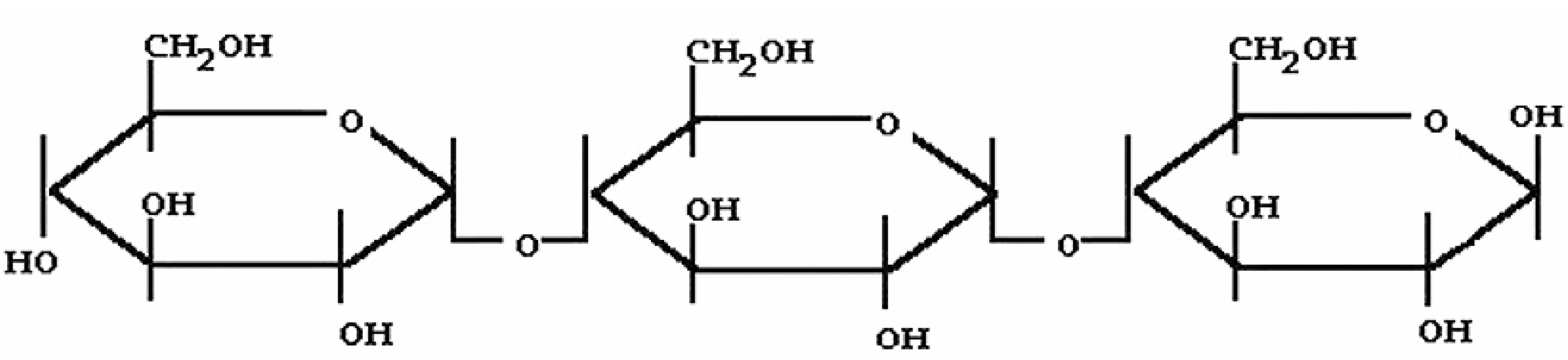


Starch (Kohl, 2003)

3-2. Cooking

Glucoamylase

- ✓Saccharification
- ✓exoenzyme
- ✓Attack α-1,4 and α-1,6 linkage
- ✓Convert Dextrin into Glucose

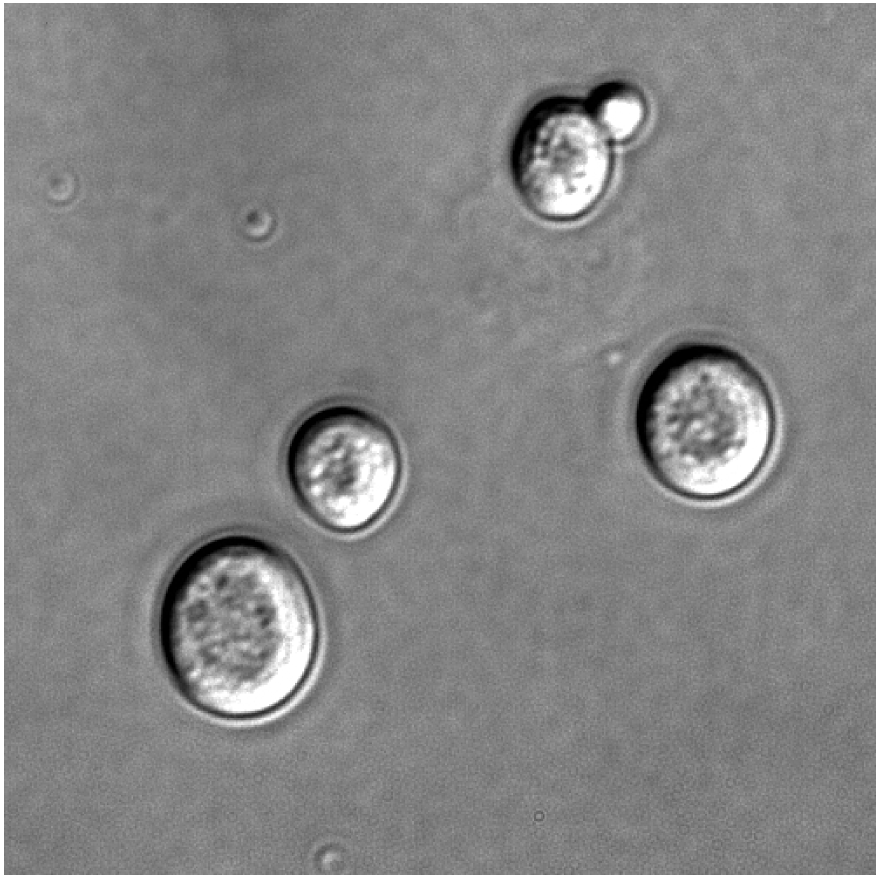


Dextrin (Kohl, 2003)

3-3. Fermentation

Yeast

- ✓Facultative anaerobic
- ✓Converts sugar into carbon dioxide and water in an aerobic environment
- ✓Converts sugar into carbon dioxide and ethanol in an anaerobic environment
- ✓Propagation tank



S. cerevisiae

3-4. Stress management

Temperature

- ✓Fermentation is exothermic
- ✓Cooling system is required

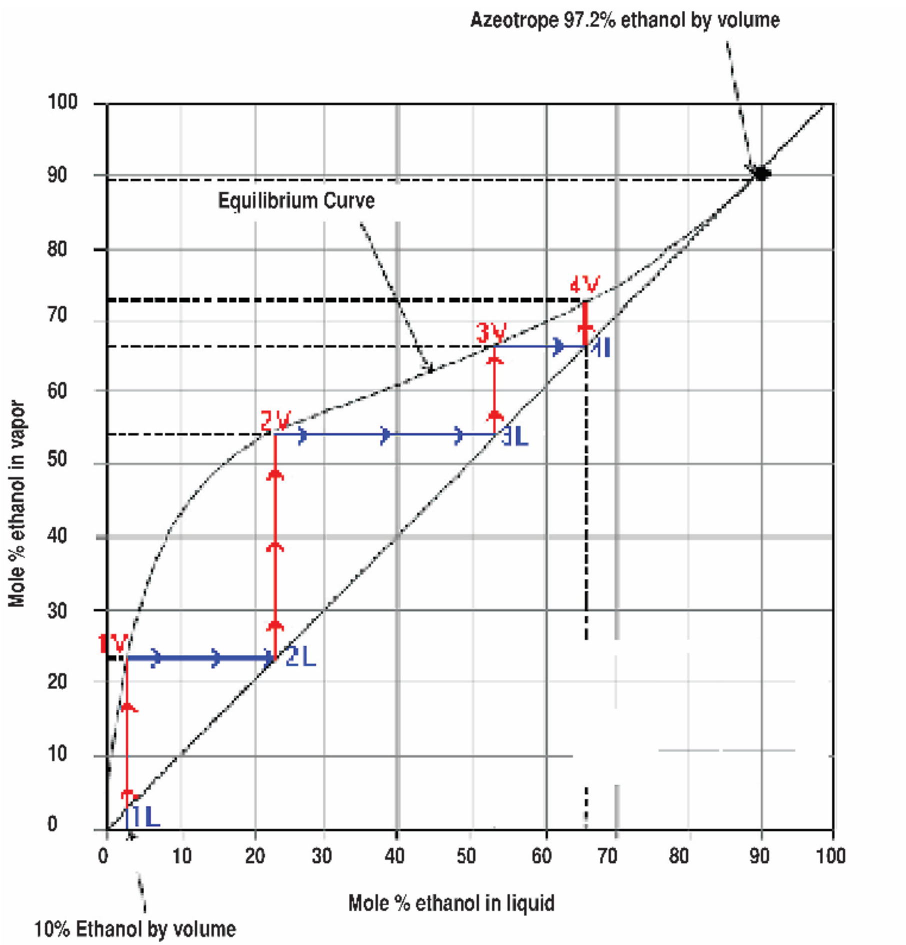
Concentrations of sugar and ethanol

- ✓Simultaneous increase in the both concentrations of sugar and ethanol should be avoided
- ✓The simultaneous saccharification and fermentation (SSF)

Lactic acid and Acetic acid

- ✓Byproducts produced by contaminated bacteria
- ✓Lactic acid: *lactobacilli* bacteria
- ✓Acetic acid: *acetobacter* bacteria
- ✓Close control is required

3-5. Distillation



Distillation step (Kohl, 2004)

✓Multiple vaporization and concentration
➡ It burdens on the cost
✓Initial concentration of ethanol is important

3-6. Dehydration

Azeotropic Distillation

- ✓Entrainer: benzene or cyclohexane
- ✓Strong intermolecular reaction between water and benzene
- ✓Complicated
- ✓Toxicity problem

Molecular sieves

- ✓Pore size of molecular sieves: 3 Ǻ
- ✓Ethanol: 4.4 Ǻ
- ✓Water: 2.8 Ǻ
- ✓High energy required to regenerate
- ✓Flammability of superheated ethanol

4. Lignocellulosic Biomass

Lignocellulosic biomass

- ✓Agricultural residue: bagasse, wheat straw, wheat husk, wooden waste
- ✓Pretreatment required: solubilization of cellulose, hemicellulose, and lignin

Pretreatment

- ✓Acid treatment
  - ✓Low cost
  - ✓High reaction
- ✓Alkaline treatment
  - ✓Be able to remove lignin without having big effects on the other parts
- ✓Thermal treatment
  - ✓Steam explosion
  - ✓Liquid hot water
- ✓Biological treatment

5. Immobilized Cell System

Immobilization

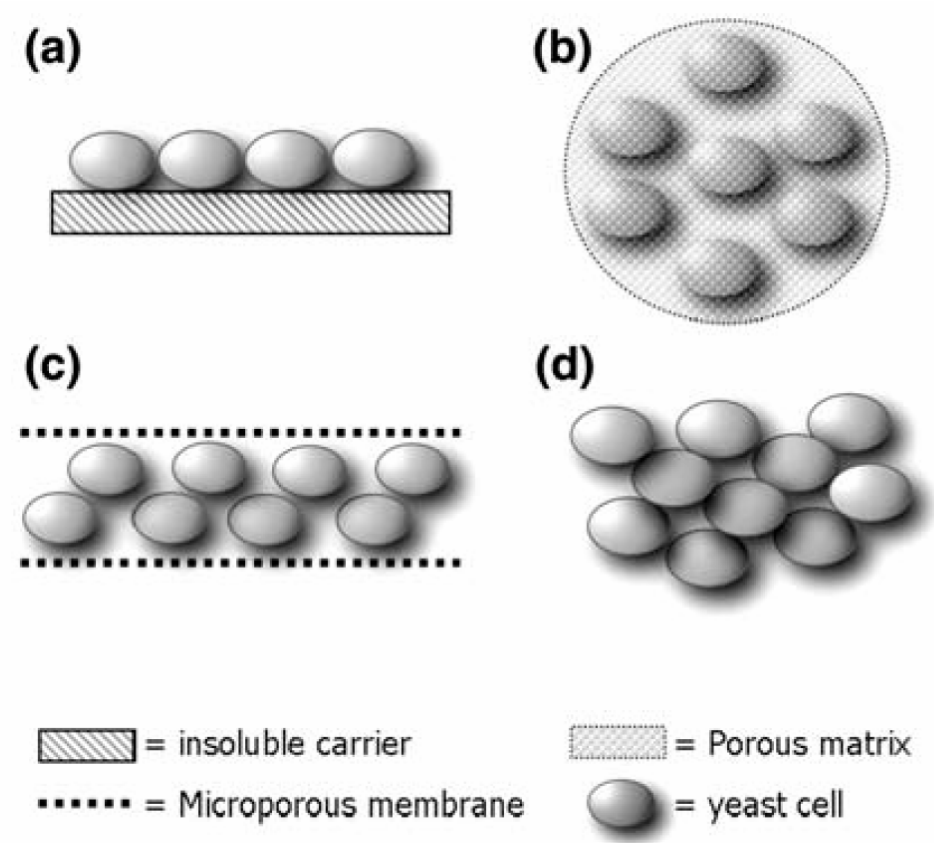
(a) attachment to a surface
(b) entrapment within a porous matrix
(c) containment behind a barrier
(d) self-agitation

Advantage

- ✓ Provide high density
- ✓ Enable high flow rate and short time operation

Disadvantage

- ✓ Affect on yeast: flavor, odor



Immobilization methods
(Verbalen et al., 2006)

6. Energy Balance

Energy balance of bioethanol (Shapouri et al., 1995)

Study/year	Corn yield	Nitrogen fertilizer application rate	Inputs for nitrogen fertilizer	Corn ethanol conversion rate	Ethanol conversion process	Total energy use	Coproducts energy credits	Net energy value
	bu/acre	lb/acre	Btu/lb	gal/bu	Btu/gal	Btu/gal	Btu/gal	Btu/gal
Pimentel (1991)	110	136.0	37,551	2.50	73,687 (LHV)	131,017	21,500	-33,517
Keeney and DeLuca (1992)	119	135.0	37,958	2.56	48,434 (LHV)	91,127	8,072	-8,431
Marland and Turhollow (1991)	119	127.0	31,135	2.50	40,105 (HHV)	73,934	8,127	18,324
Morris and Ahmed (1992)	120	127.0	31,000	2.55	46,297 (LHV)	75,297	24,950	25,653
Ho (1989)	90	NR	NR	NR	57,000 (LHV)	90,000	10,000	-4,000
This study (1995)	122	124.5	22,159	2.53	53,277 (HHV)	82,824	15,056	16,193
Average	113	129.9	31,961	NA	NA	NA	NA	2,373

Net energy value (NEV)

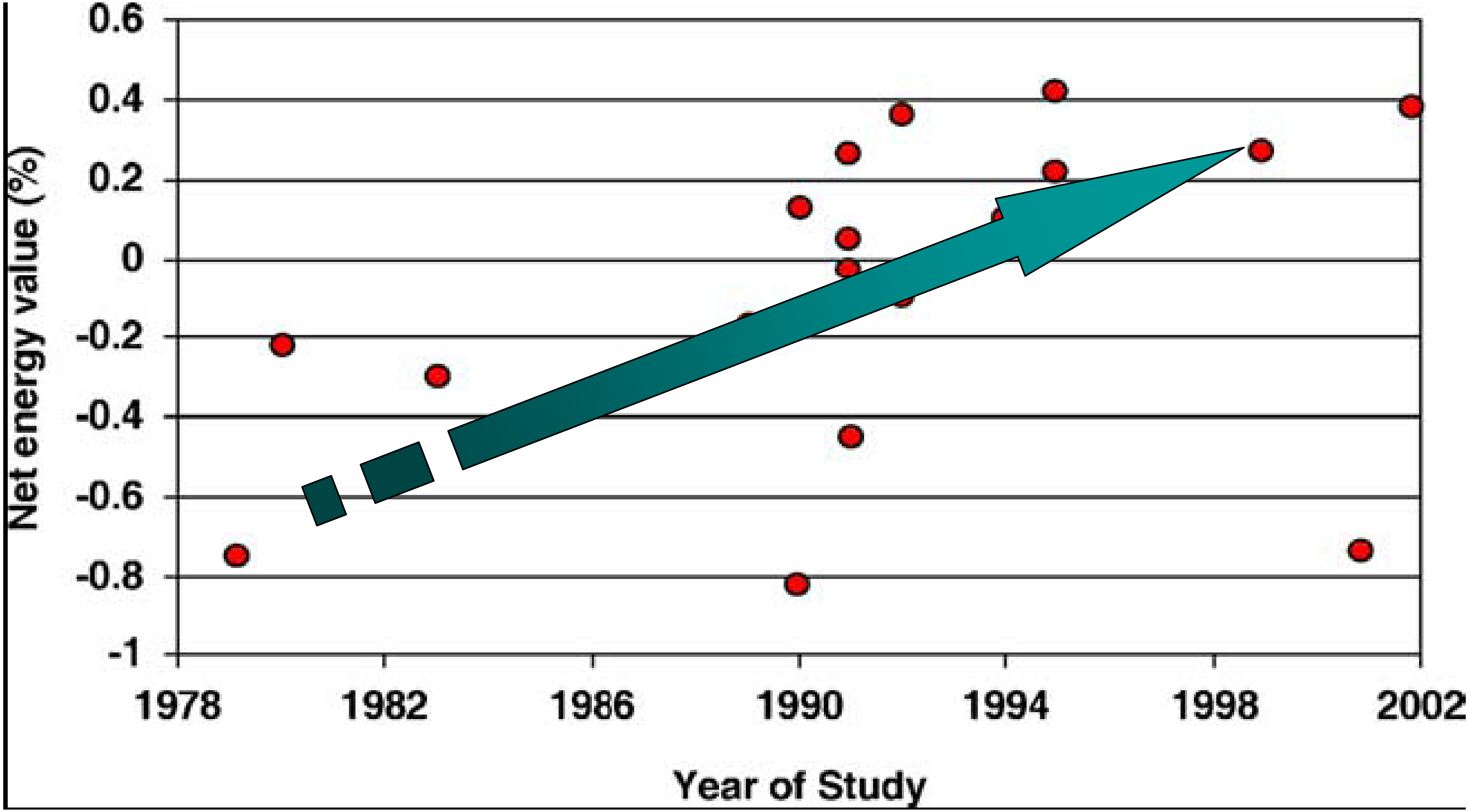
Energy converted into ethanol or its coproducts
minus energy used to produce ethanol

6. Energy Balance

Causes of discrepancies

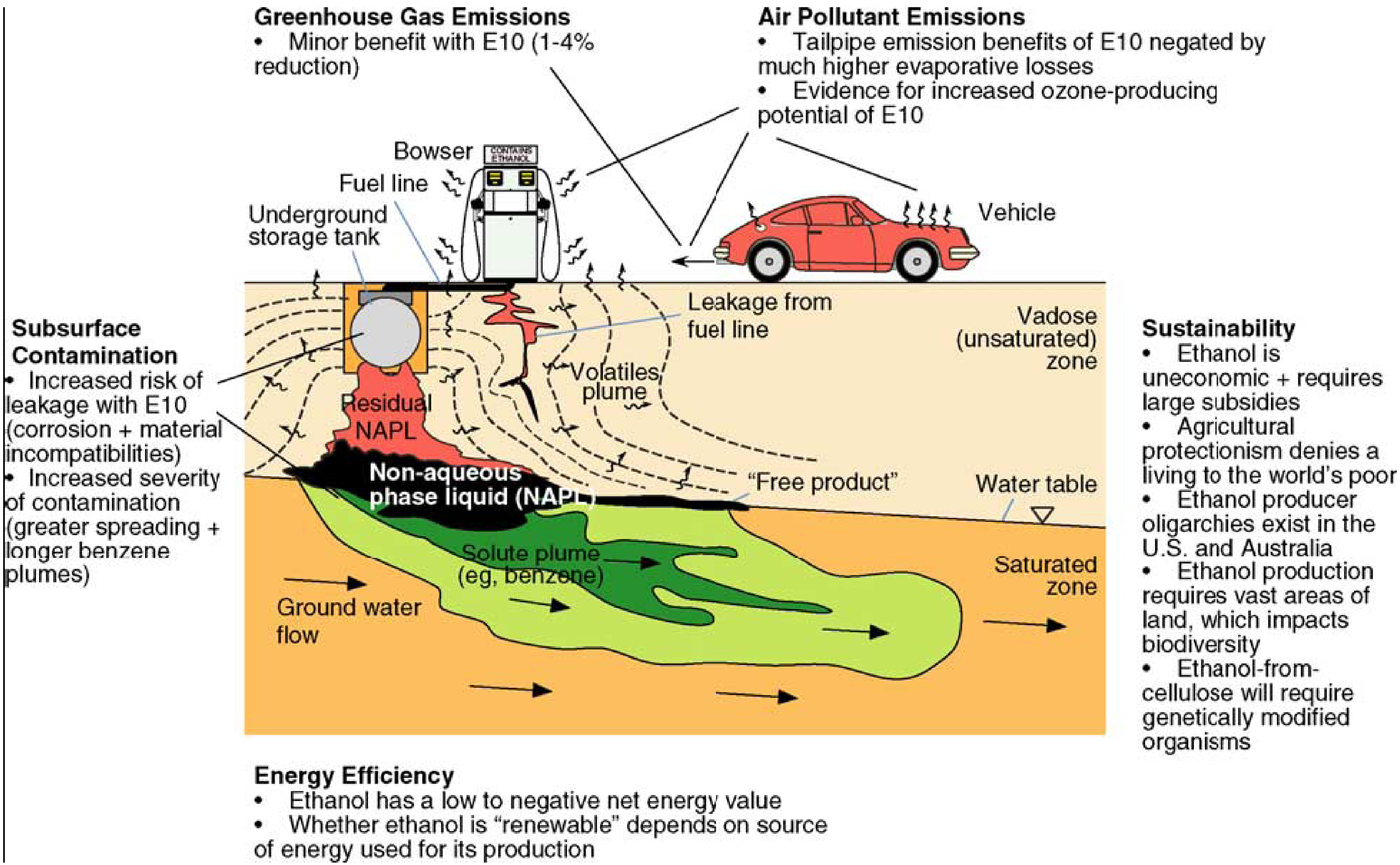
- ✓ Development of technologies
  - ✓ Corn yield
  - ✓ Fertilizer
    - ✓ Energy
    - ✓ Application rate
- ✓ Ethanol conversion
- ✓ Farm machinery
- ✓ Coproducts

6. Energy Balance



Change in NEV (Niven R.K., 2005)

7. Concerns



Environmental impacts of ethanol in gasoline (Niven R.K., 2005)

8. Conclusion

- ✓Many sophisticated techniques for production of bioethanol
- ✓Its energetic efficiency and environmental friendliness are still controversial.

Thank you