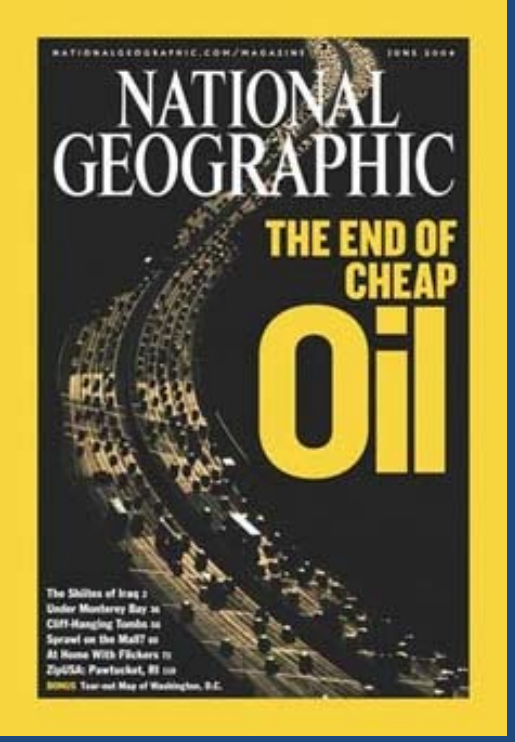

Use of Biocatalysis for Alternative Feedstocks to Produce Biofuels

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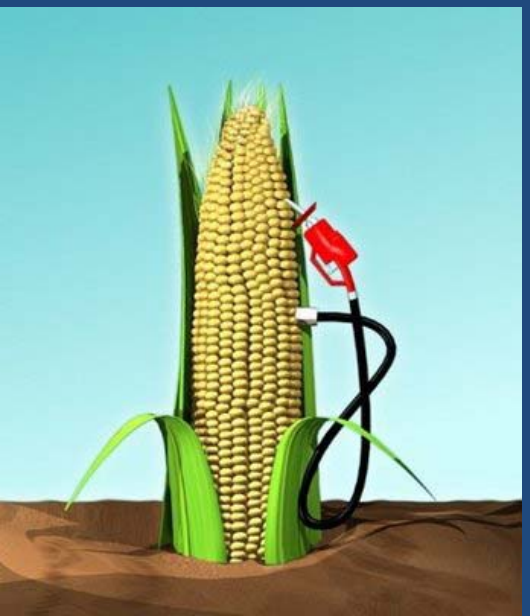


Overview

- Current Situation on Biofuels
  - Bioethanol
    - Problems with current feedstocks
    - Second Generation
  - Biodiesel
    - Problems with current feedstocks
    - Second Generation
  - Some Major Considerations of Biofuels
- Biocatalysis-Use of Microbes to make Products
- Waste Streams as Feedstock for Biofuels
  - Current research
- Future Plan of a Biofuel research facility at CSU Pueblo

Take Home Message

- Main problem: it must cost less than petroleum based fuels
- A number of different feedstocks for biofuels
  - All with problems of one sort or another
  - Biofuels are probably not sustainable in current format
- Alternative Feed stocks need to be studied
- Waste Streams as a partial source of feedstock
- Interdisciplinary team at CSU Pueblo working on development/improvement of Biofuels

What Aspects are Important in Alternative Energy?

- How does it fit into our current energy system?
- Baseline?
- Portability?
- Does it require conversion to other energy systems?
- Storage?
- Costs?
- Scale up and Sustainability?

Let's Look at Current Energy-Fossil Fuels

- Strong infrastructure to get energy to consumer
- Baseline
- Portability
- Storage
- Costs to start up not needed but rising prices for feedstock likely
- Problems with sustainability
  - Peak Oil?
  - Global Warming?

What about Bioenergy/Biofuel?

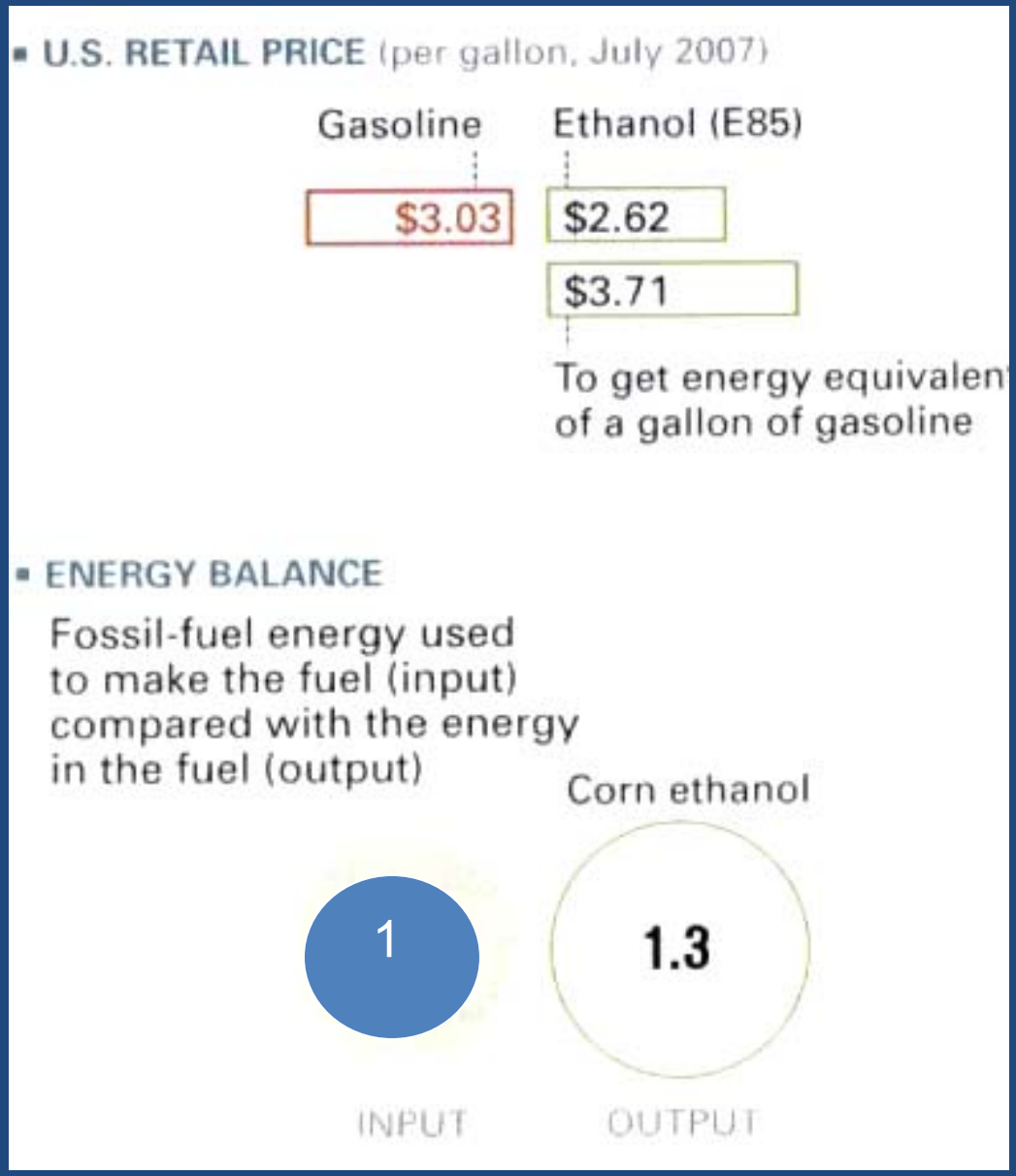
- Biodiesel and Bioethanol
- Fits into current infrastructure depending on fuel and system
- Baseline and Portability
- Costs
  - Startup is low
  - Feedstock is the main problem
  - Waste stream
- Scale up and sustainability are problems

Feedstock Problems with Biofuels

- Corn use for bioethanol
  - Cost high in fertilizer and input of energy in growth and harvest
  - High costs in actual feedstock
  - Lack of land for production of corn (without cutting out the other uses of corn).
- Oil for biodiesel from Soy and other feedstocks
  - Better but similar problems

Some Bioethanol Problems

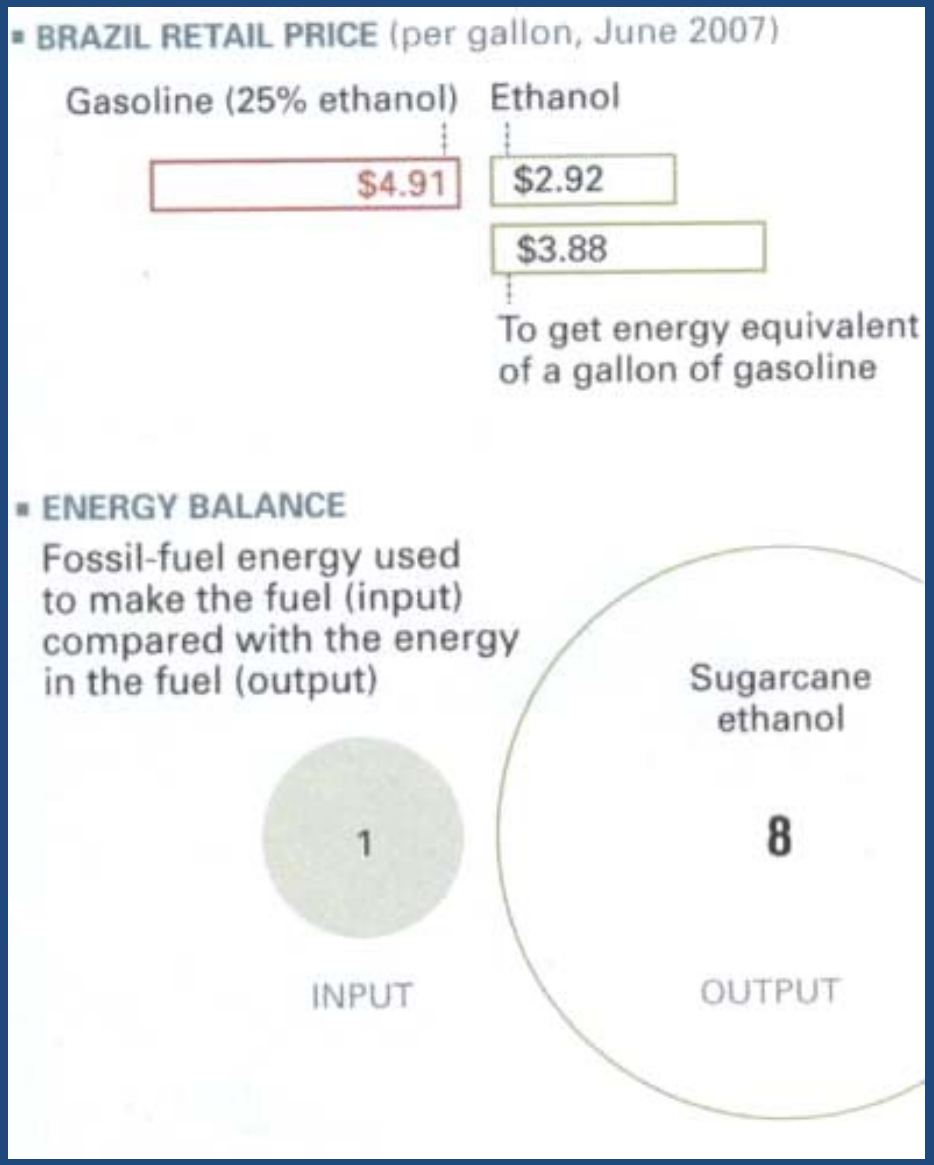
- This is based on corn
- Cost is roughly the same as gasoline to the consumer (higher right now)
- Low energy balance
- Problems with infrastructure



US Dept. of Energy, EPA

So how can Brazil do it? Different Feedstock

- Brazil uses sugarcane
- Higher energy Balance
- Easier to grow
- Why don't we do that?
  - Remember that is more of a tropical plant
- Different Engine that can run on anything between 100% Gasoline and 100% Ethanol



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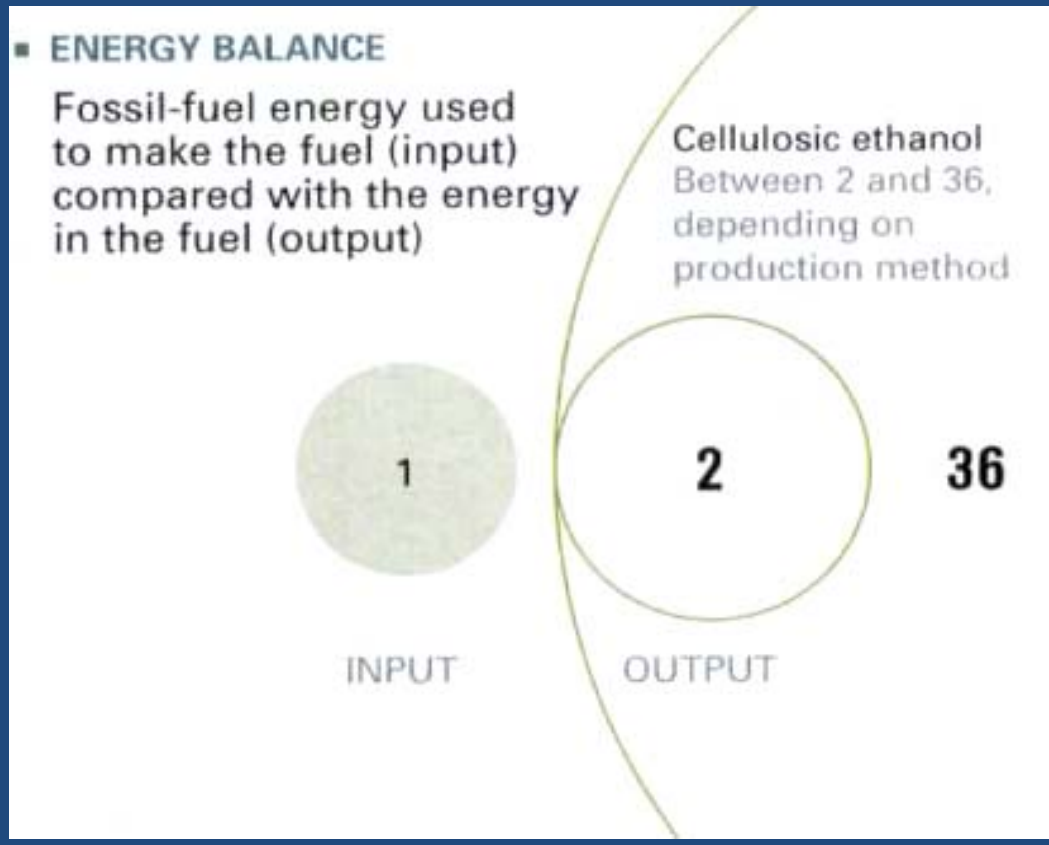
Why do we do Bioethanol, then?

- We had the technology
  - How long have people been making “Moonshine”?
- Do you want to spend Billions for the technology to make a consumable if you already have existing technology?
  - Only when you figure out it is not sustainable!!
- So Bioethanol is dead, right?!!

What about Cellulosic?

- Much better energy balance
- But I didn't put something in
  - It is more expensive right now to produce than grain or sugar cane.
- Improvements in technology needed



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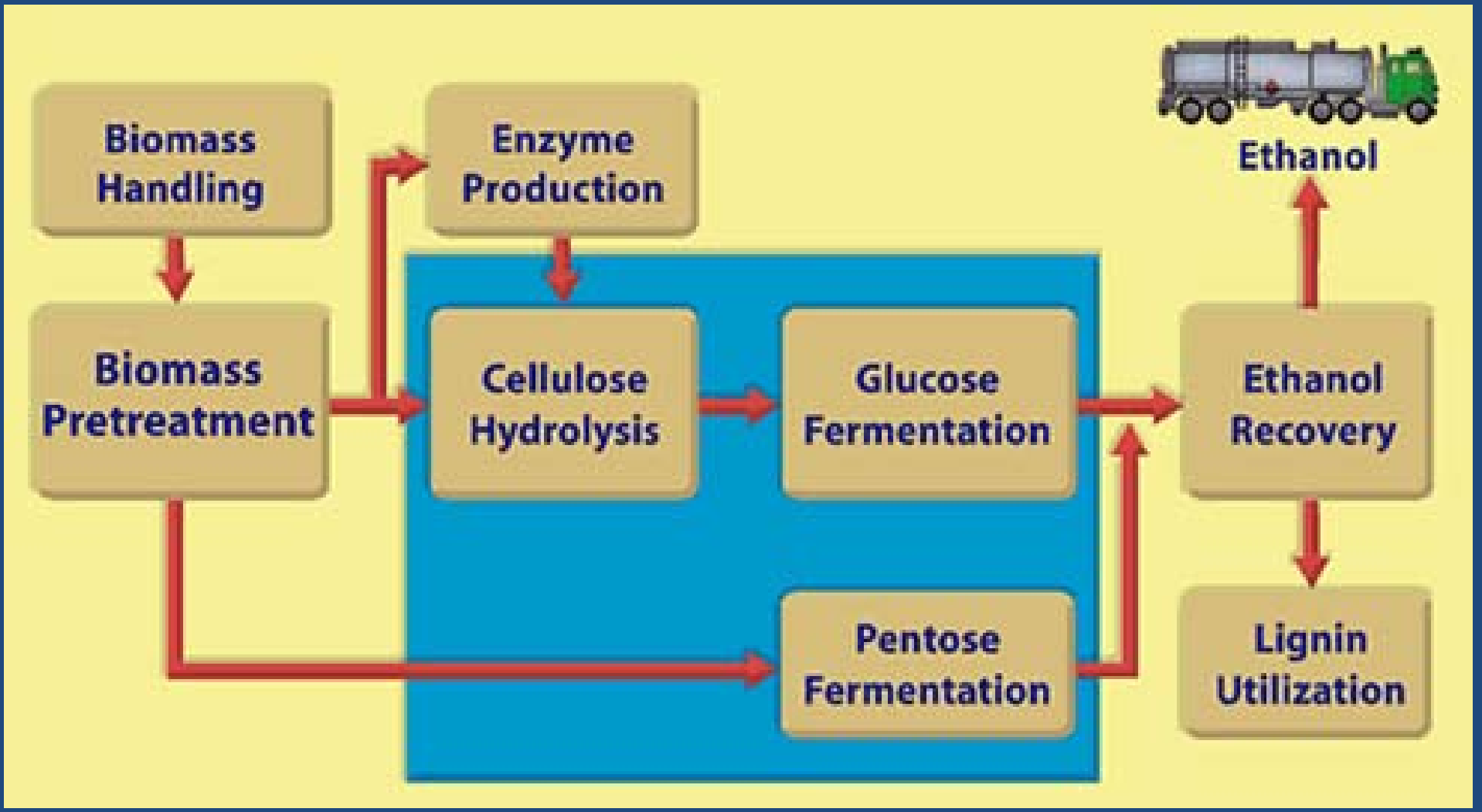
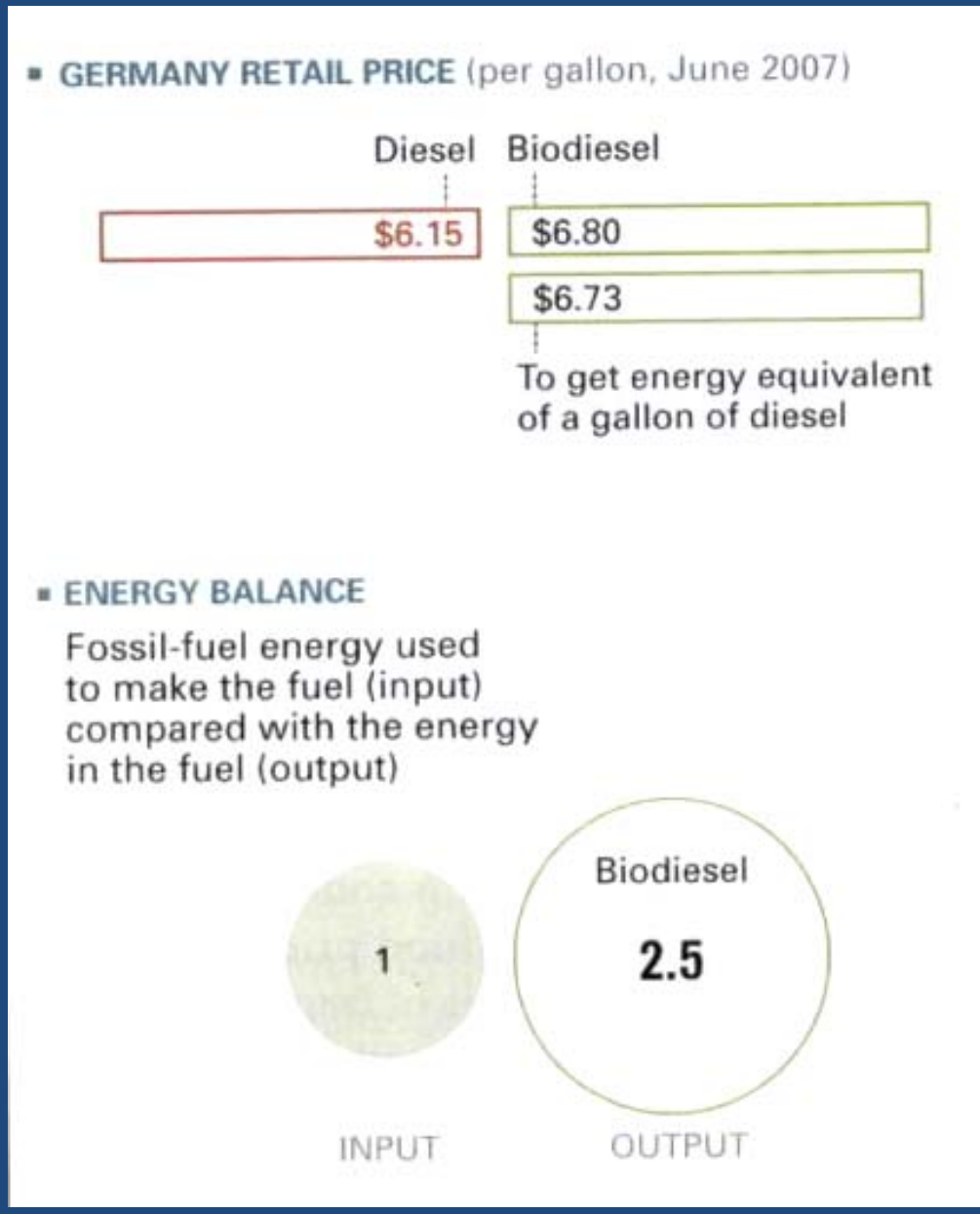
Additions onto Existing Ethanol Plants



Biodiesel

- Again a problem with feedstock?
  - Based on seed oil.
  - Better than grain alcohol but not by much.
- Again, we can't grow our way out of this one!!
- Is this out?



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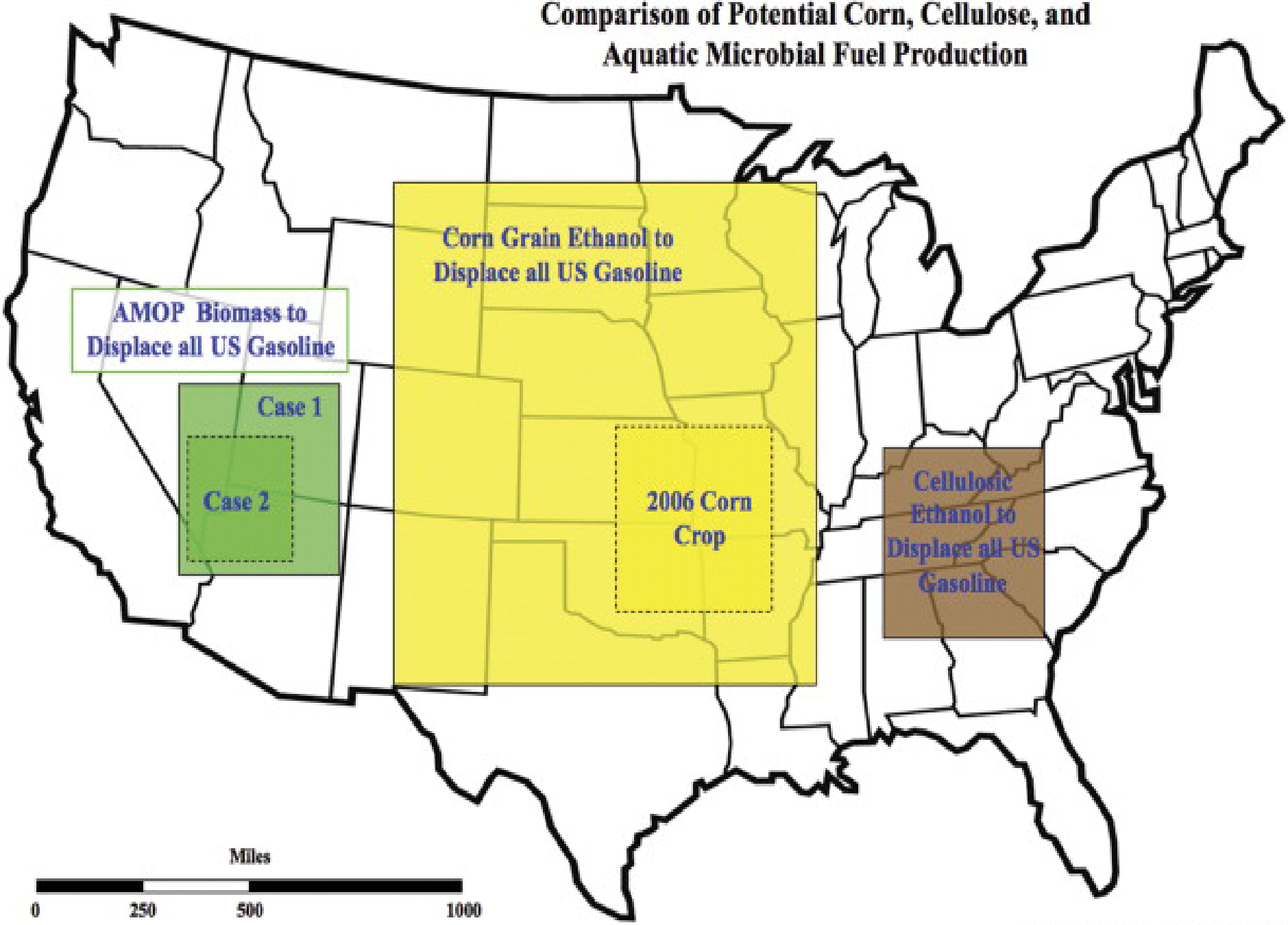
What about Algae?

- Many strains of Algae store energy as oil
- They can grow to much faster and at higher densities
  - more fuel per acre
- An attractive alternative feedstock for production of biodiesel

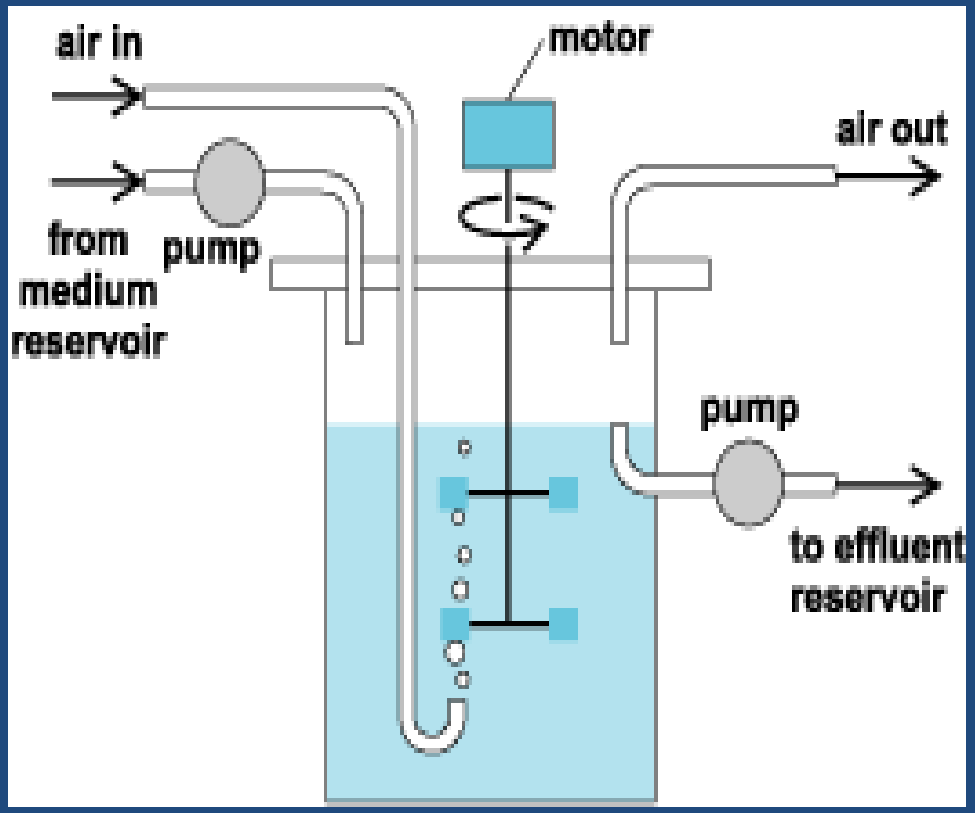

Comparison of Potential Corn, Cellulose, and Aquatic Microbial Fuel Production
Corn Grain Ethanol to Displace all US Gasoline
AMOP Biomass to Displace all US Gasoline
Case 1
Case 2
2006 Corn Crop
Cellulosic Ethanol to Displace all US Gasoline
Miles
0
250
500
1000
Current Opinion in Biotechnology

Biocatalysis

- Using Microbial ability to convert materials to products
  - Note that Bioethanol does this.
  - Algae to Biodiesel is also a type of biocatalysis
- Microbes can degrade a number of different chemicals to value added products
  - Bioremediation
  - Food processing

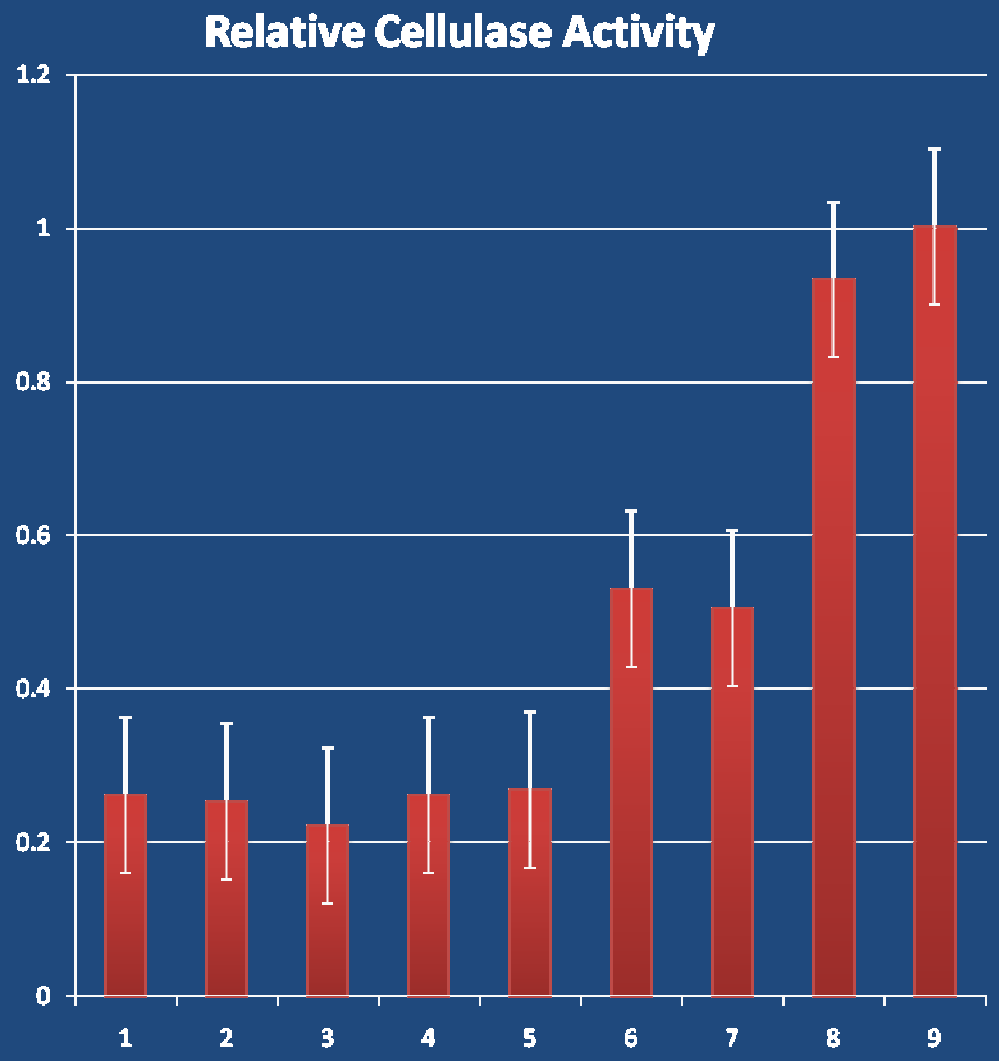
Improvement of Strains-Chemostat

- Continuous Culture system
- Flow rate will cause a dilution pressure on the organisms
- This can be used to improve biocatalytic function



Cellulase Project

- Study of Penicillium species producing cellulase
- Under chemostat condition using cellulose as primary energy and carbon source
- Improvement in the strain cellulase by 400+%



What about Waste streams as Feedstock for Biofuels?

- Most systems for Biofuels are based on growing crops specifically for energy
- If waste streams were used, some of the costs and impacts of biofuels would be decreased.

CSR Ethanol
Sarina Queensland Australia

- Molasses: a waste stream of sugar production
- $80 per tonne for molasses
- If converted to ethanol, $480 per tonne of molasses feedstock
- Fertilizer waste stream

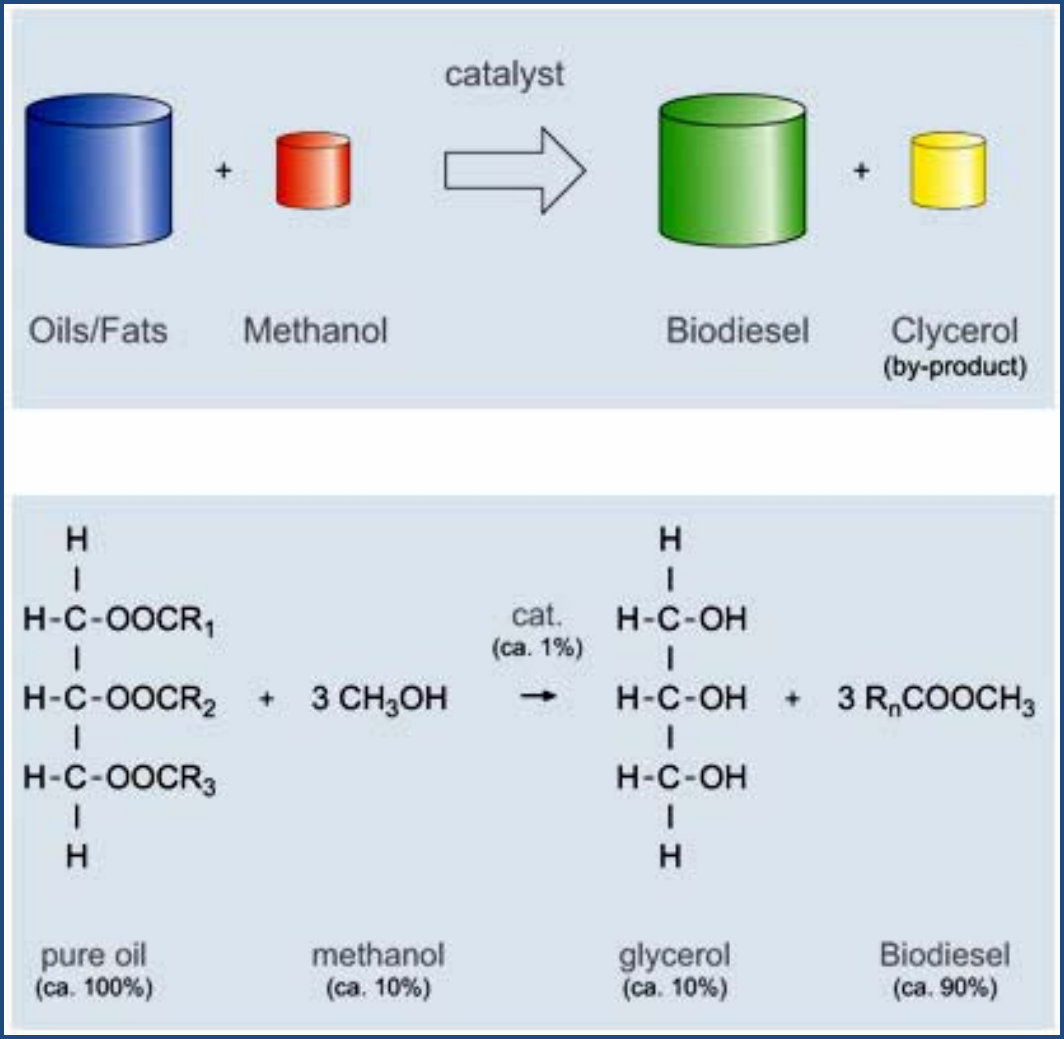
Use of Same Industrial Pad

- No feedstock shipment costs
- Lowers costs of Permitting
- Uses same physical plant requirements
  - Steam generation
  - Maintenance personnel
  - Use of physical plant during growing season

You can also use other waste

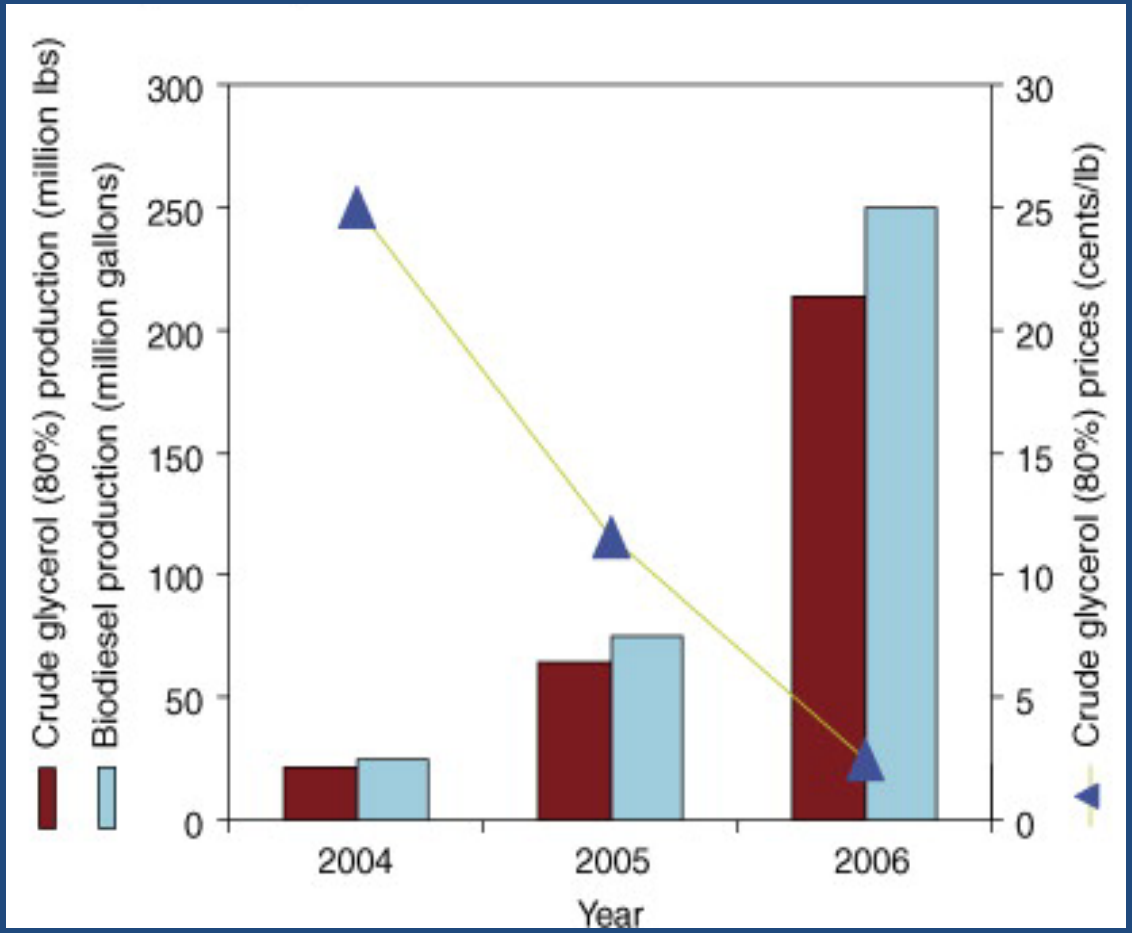
- These are orange peels from an orange juice plant
- These were once dried and sold as feed supplement but at a net loss
- These are being converted to ethanol and value-added other products

Waste from Biodiesel



- Biodiesel is made by trans-esterification using methanol as the alcohol.
- Depending on feedstock the alcohol is between 25-60% of raw materials cost
- A byproduct is glycerol

Waste from Biodiesel



- Glycerol is a major waste from a biodiesel process
- The market for glycerol is saturated and is being sent to landfills

Microbial Conversion of Glycerol to Ethanol?

$$C_3H_8O_3 \longrightarrow C_2H_6O + CO_2 + H_2$$

Glycerol — Ethanol — Carbon Dioxide — Hydrogen gas

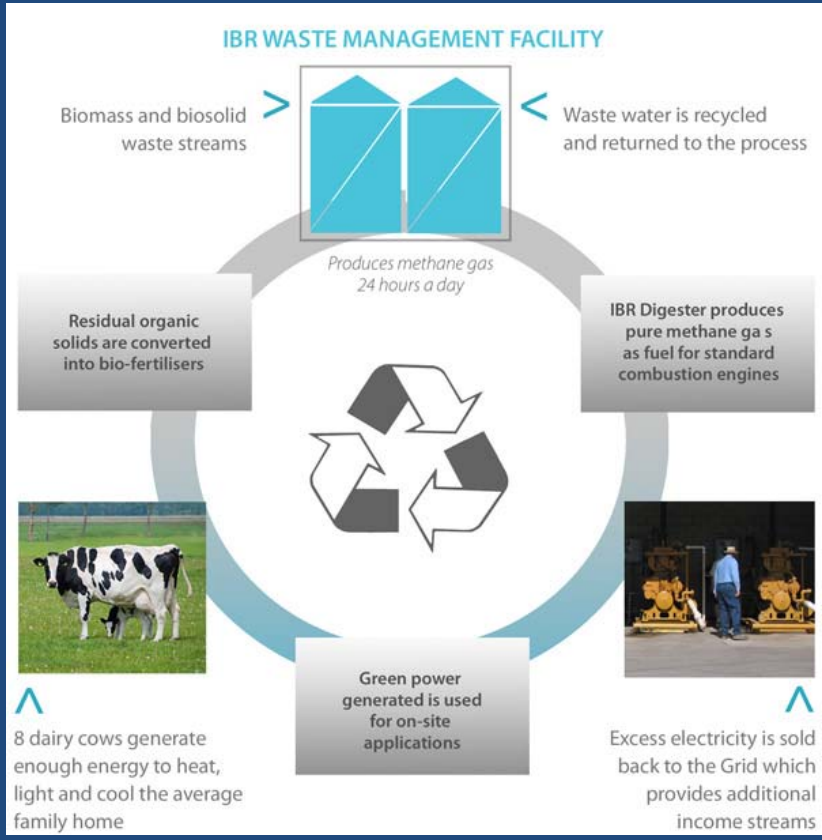
- The Ethanol can then be put into the process.
  - Cutting raw materials cost
  - Forming a partial closed loop
  - Use the glycerol (instead of landfill)
- This can be done with some microbes
- We currently have this conversion being done a small scale and are working on scale up to industrial levels.

Manure to Energy

- We are currently working with a feedlot owner that wants to convert manure to energy.
- Currently, the feedlot produces more than 100 tons of manure per day
  - Removal cost more than $250,000 per year

Anaerobic Digestion of Manure

- The manure can be used to create methane
  - This can be used as an energy source for the feedlots
  - Also, surplus electricity can be sent to the grid
- Waste from the Anaerobic Digester
  - Liquids are a high quality Fertilizer
  - Solids can possibly used in fiber products



www.bellwetheragriculture.com

Aspects we are currently studying

- Feedlot manure is different
  - Dairy manure is fresh
  - Feedlot manure is harvested on 180 to 300 day cycles
  - Fair amount of soil contamination is involved with feedlot manure
- How does this change methane production?
- Does this change during different times of the year?
- How does this affect anaerobic digestion system?

Interdisciplinary Team for Biofuel at CSU-Pueblo

- We hope to develop an alternative energy/biofuels research facility in the near future
- Faculty from many departments involved
  - Biology- D. Caprioglio and Vanden Heuvel
  - Chemistry- Dillon
  - Engineering- Fraser
  - Business-Wakefield

Plans for this Facility

- First aspect will be for Algae based fuels
- Module based growing system
- Aspects of this will be:
  - Biology and Chemistry in Improving Biocatalysis, Process Development, and Quality Control
  - Engineering in Developing/Improving Equipment for small to moderate size Biofuel production
  - Business involving coop development and economic development
- Currently seeking grant funding to start up

Goals for the Alternative Energy Facility

- Development of Research facility for student training and workforce development
- Development of local farmer co-op model
- Modular bioreactor system for production of feedstock
- Current model has the production of biodiesel at less than $2.00 per gallon (2009 dollars) (Wakefield)

Take Home Message

- Main problem: it must cost less than petroleum based fuels
- A number of different feedstocks for biofuels
  - All with problems of one sort or another
  - Biofuels are probably not sustainable in current format
- Alternative Feed stocks need to be studied
- Waste Streams as a partial source of feedstock

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Questions?
Hope I didn't go to fast

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