US Energy Mandates and the Promises of Biofuels

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THE 21ST CENTURY AMERICA'S CHALLENGES:

1- SECURE ENERGY FUTURE

2- DECREASED DEPENDENCE ON FOREIGN OIL

3- ECONOMIC GROWTH

4- SUSTAINABLE GROWTH

5- PROTECT THE ENVIRONMENT

6- PROTECT THE CLIMATE

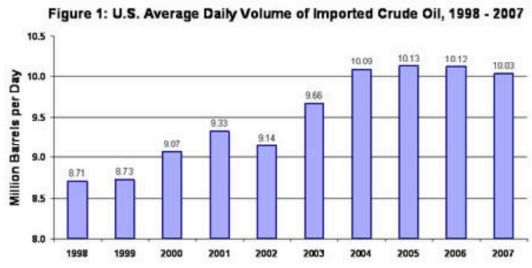
Reasons for Concern

- Increase in world population
- Increase demand for Energy World Wide
- Current dependency on fossil fuels
- Finite resources of fossil fuels
- Global Warming

US National Energy Challenge

- REDUCE OUR DEPENDENCE ON CRUDE OIL
- US ECONOMY IS TIED TO PETROLEUM PRODUCTS
- DANGER TO OUR NATIONAL SECURITY

US imports 2/3 of the oil needed for its economy



70% is required for transportation

US oil import bill:

2007…… $327 billion
2008…… should easily top $400 billion.

MORE IMPORTANTLY

- Domestic oil crude production is falling
- Conventional oil production could peak in the near future.

Several studies agree on these key issues:

1- Current trends in energy usage are not sustainable
2- Are a security risk
3- Strengthen National Energy Security by Reducing Dependence on Imported Oil

Americans are addicted to foreign oil
State of the Union Address, 2007

4- No single solution will secure the energy future
5- Biofuels can be part of the transportation energy.

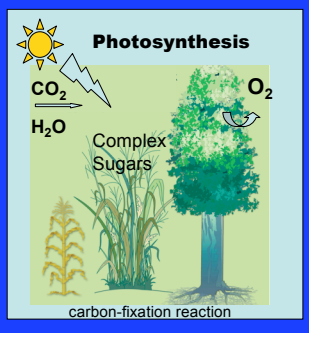
Biofuel: A fuel that is derived from biomass.
Biomass: any plant material that can be used as a source of energy

Promise of Biofuels

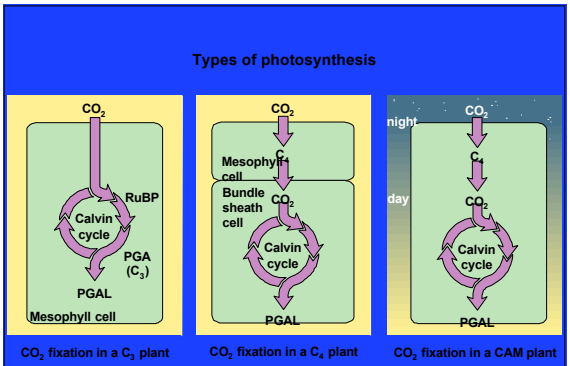
- **Strengthen Energy Security**
- **Assist Agricultural Industry**
- **Create Jobs**
- **Develop Local Economies**
- **Benefit the Environment**

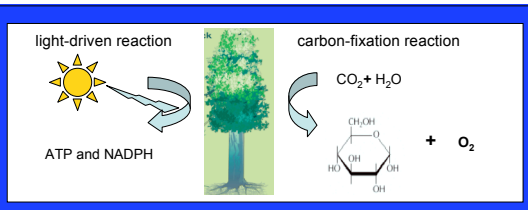
Plants Sustain Life on Earth

- Capture solar energy
- Maintain the 20.9% oxygen level
- Build, anchor and hold water in soil



$6CO_2 + 6H_2O$------ $C_6H_{12}O_6 + 6O_2$

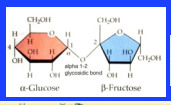




Biomass sugars that store glucose
- **Sucrose (glucose/fructose disaccharide)**
- **Starch (glucose polysaccharide)**
- **Cellulose (glucose polysaccharide)**

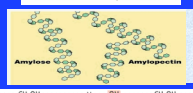
Composition of sugars that store glucose

Sucrose



α-1, 2 glycosidic linkage

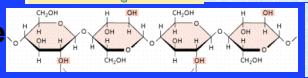
Starch



α-1,4 glycosidic linkages

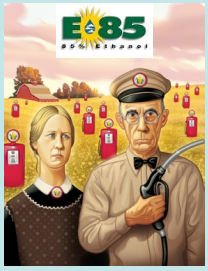
α-1,6 glycosidic linkages

Cellulose



β-1,4 glycosidic linkages

2007 Presidential Mandate



DEVELOP BIO-BASED FUELS
(i.e. Ethanol)

Fermentation is the basis of beer, wine and bread production using yeast

Saccharomyces cerevisiae (yeasts) is used for baking and brewing

- Originally isolated from the skins of grapes. There are many species and different strains.
- Each strain has different physiological and fermentative properties (impact on the type of wine or beer).
- Industrial production of ethanol also uses yeast

FERMENTATION IS A PROCESS LINKED TO GLUCOSE METABOLISM

Glucose Metabolism

$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$

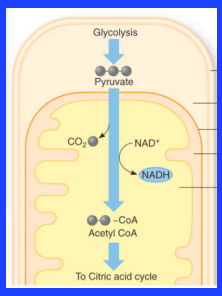
Reverse reaction of

Photosynthesis

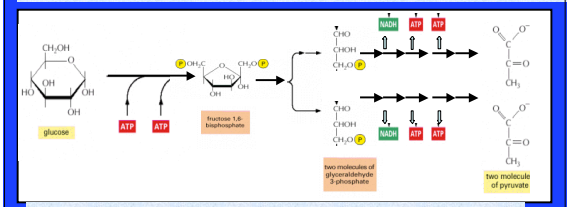
$6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$

Complete Glucose Metabolism involves 4 Chemical Pathways

1. Glycolysis
2. Generation of acetyl CoA
3. Citric acid cycle
4. Oxidative phosphorylation

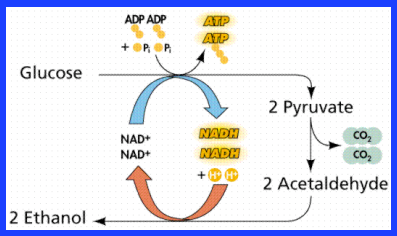


Incomplete Glucose metabolism involves 2 Pathways: Glycolysis & fermentation

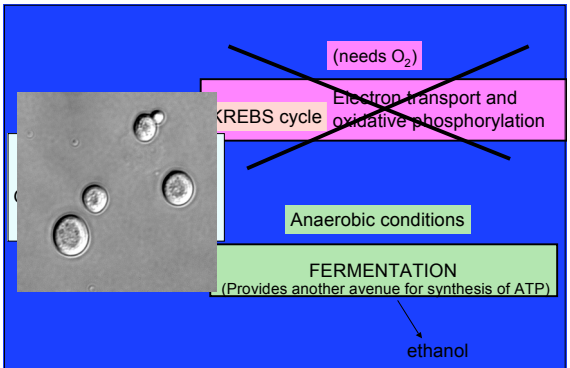


- Net gain of two molecules of ATP/glucose
- Net gain of two NADH molecules per glucose

Anaerobic fermentation

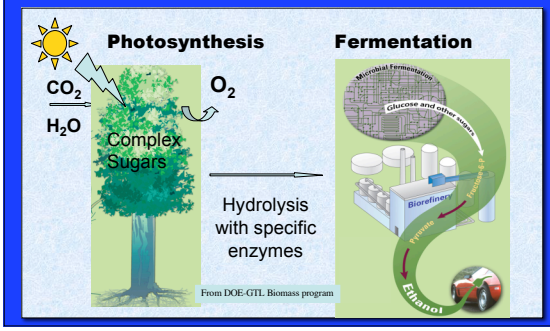


Fermentation regenerates NAD, & enables glycolysis to continue



Principles of conversion of plant biomass to ethanol:

- Break down complex plant sugars into simple sugars
- Convert them into ethanol by fermentation.



Why Ethanol?

- In 1896, Henry Ford built his first automobile, to run on pure ethanol.
- By 1920 gasoline became the motor fuel of choice.
- In 1988 ethanol was added to oxygenate gasoline and reduce smog (Gasoline blends).

US ENERGY MANDATES

In 2004 all gasoline sold in the US was required to carry 5.6% ethanol to replace the fuel methyl tertiary butyl ether, or MTBE, which was banned as pollutant of groundwater.

In 2005, The Energy Policy Act increased the mandate to blend gasoline with 10% of corn-ethanol.

In 2006 State of Union Address President Bush introduced a mandate to develop ethanol derived from cellulosic biomass.

In 2007 Congress passed an Energy Bill that raises the targets for ethanol production.

2008	9 billion gallons
2022	36 billion gallons
2050	250 billion gallons from cellulosic-ethanol

GOAL The 30 X 30 initiative

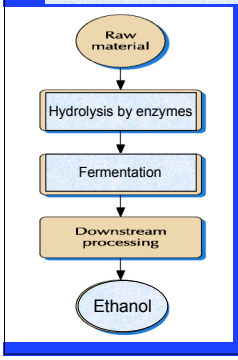
Replace 30% gasoline consumption with ethanol by 2030.

1 gal of gasoline = 1.4 gal of ethanol.

Consumption in 2007 ~ 42 Bgal gasoline/year.

Need to produce ~ 60 Bgal ethanol per year.

Biotechnology for Ethanol Production



- Collection & preparation of raw material
- Adding enzymes to generate glucose
- Adding yeast to ferment glucose & generate ethanol
- Recovery and purification from the medium or cell mass

Enzymes important to generate glucose units from sugar polymers used for ethanol production

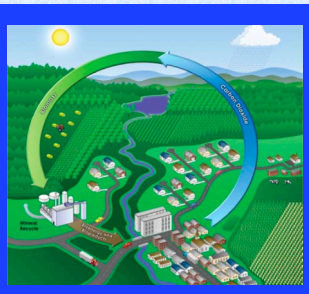
Sucrose: saccharase/ invertase

Starch: **α-amylase**, **β-amylase** **α 1,6 debranching** **α1,4-glycosidase**

Cellulose: **endoglucanases (+/-CBD)** **cellobiohydrolases (+/- CBD)** **β–1,4-glycosidase**

Benefit of Biofuels for Climate Change

Burning Biofuels from plant biomass should reduce net CO_2 emissions = carbon neutral



- When fossil fuels are consumed, carbon sequestered for millions of years is released into the atmosphere.
- When ethanol is used as biofuel, the CO_2 released by combustion is recaptured by photosynthesis & the production of new biomass
- A gallon of gasoline generates 19 pounds of CO_2
- A gallon of Ethanol 12.5 pounds of CO_2
- If 1.4 more ethanol to drive same distance CO2 for ethanol is ~17 pounds CO_2
- Moderate reduction of CO_2 emission per same distance traveled

1. What are the biomass resources of the United States capable of producing a sufficient & sustainable supply?
2. CORN GRAIN
3. CELLULOSE
4. Need to produce ~ 60 Bgal ethanol per year.

Current corn-grain yields are about 4.5 tons/acre.
In 2007, US planted 90.5 million acres of which only 15% of the corn harvested was used for ethanol:
~5.4 Bgal of ethanol

Corn stover can also be used for ethanol production

Corn stover is the most abundant agricultural residue in the US

Ethanol production from corn stover > 3 billion gallons per year

The US Energy Mandate Goal (30X30) is to displace 30% or more of the country's present petroleum consumption by 2030

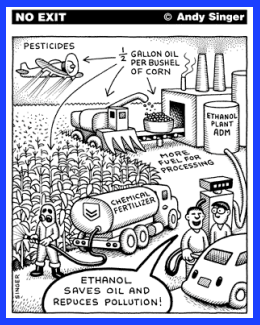
- Corn alone will not accomplish this goal even if production increases 50% (would yield 6.31%)

Other disadvantages of using corn….

•Ethanol production from Starch competes with food supply

•Grains are used for food

•Ethanol production from starch
•Is not sustainable
•Increase GHG



WHAT OTHER CROPS ARE BEING CONSIDERED

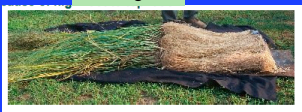
The "Ideal" Biomass Crop?	Corn	Short-Rotation Coppice*	Perennial Grass
C4 photosynthesis	★		★
Long canopy duration		★	★
Recycles nutrients to roots			★
Clean burning			★
Low input		★	★
Sterile (noninvasive)	N/A	(★)	*M.g.***
Winter standing		★	★
Easily removed	★		★
High water-use efficiency			★
No known pests or diseases			*M.g.*
Uses existing farm equipment	★		★

* Coppice is a grove of densely growing small trees pruned to encourage growth
** *Miscanthus giganteus*

Perennial crops and have many advantages:

- Use no fertilizer
- Need no planting
- Reduce soil erosion
- Increase C sequestration
- Improve water quality

Switchgrass



High root to top ratio

Carbon sequestration

Accomplishing the 30X30 goal would require approximately
1 billion dry tons of biomass feedstock per year

The two largest potential cellulosic biomass sources for this goal:

1) Forestland
2) Agricultural land after meeting food, feed, & export demands
3) A total of 1.3 billion dry tons per year of biomass potential

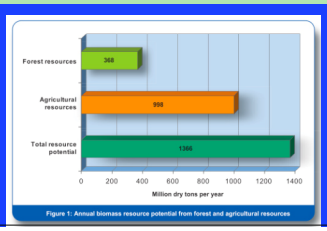
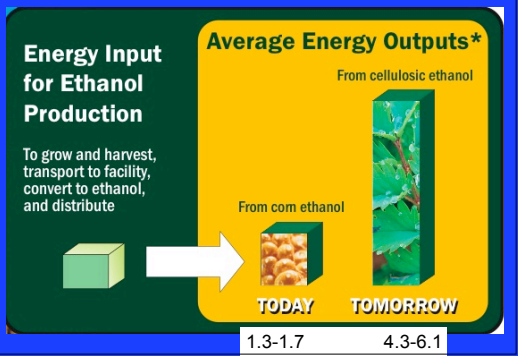
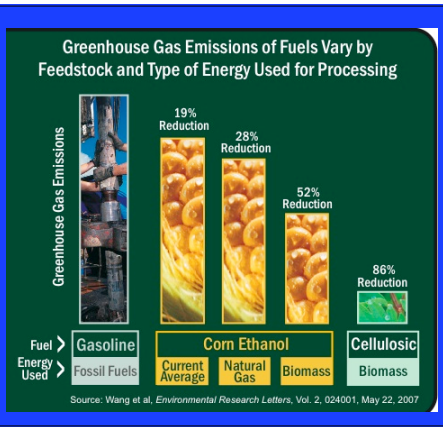


Figure 1: Annual biomass resource potential from forest and agricultural resources

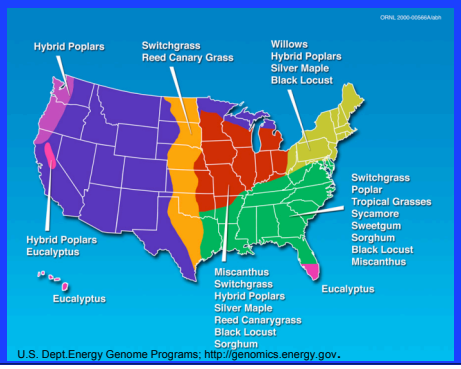
Cellulosic-ethanol from perennial grass yields more energy than corn-ethanol



1.3-1.7 4.3-6.1

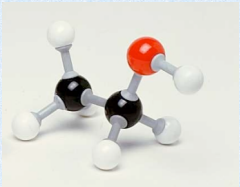


What should we grow and where in the US?



What is ethanol?

Alcohol (ethyl alcohol) (CH3CH2OH).

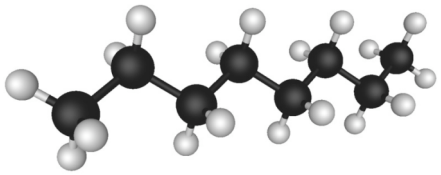


Energy of ethanol= Heat produced in combustion (*I.e.* Burning in the presence of Oxygen to form CO2 and H2O).

CH3 CH2 OH + 3O2 --> 2CO2 + 3 H2O + Heat

What is Gasoline?

- Hydrocarbon
-



Energy of gasoline= Heat produced in combustion

C8H18+ (25/2) O2 ----> 8 CO2 + 9 H2O + Heat

Basics of gasoline and ethanol.

GASOLINE Hydrocarbon	ETHANOL Alcohol
Density of gasoline = 3.0 kg/gallon	Density of ethanol = 3.5 kg/gallon
Combustion of one gallon of gasoline releases 44 kJ/g (kilojoules per gram).	Combustion of one gallon of ethanol releases 27 kJ/g
Freezing point, °F gasoline= -40	Freezing point, °F ethanol= -173.2

COMPARING COMBUSTION OF GASOLINE & ETHANOL

A. Combustion of gasoline [assuming it is pure octane (C8 H18) : 8C and 18 H.]

$C_8H_{18} + 25/2\ O_2 \longrightarrow 8\ CO_2\ (gas) + 9\ H_2O + Heat\ (44\ kJ/g)$

B. Balanced equation for combustion of ethanol (CH_3CH_2OH).

$CH_3CH_2OH + 3O_2 \longrightarrow 2CO_2\ (gas) + 3\ H_2O + Heat\ (27\ kJ/g)$

IN BOTH CASES THE COMBUSTION OR IGNITION GENERATES GAS & HEAT
HOT GAS EXPANDS AND GENERATE PRESSURE

How car engines work?

- A car engine is an internal combustion engine
- The engine converts gasoline into motion
- Gasoline is burned inside an engine

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