



Biofuels History and Review



Zephen Specht

24 March 2011

Energy Discussion Group



Outline

- Historical use of biofuels through the ages and competition with petroleum based fuels.
- Current usages of biofuels here in the United States.
- Analyzing different types of biofuels:
 - Ethanol and flex fuels
 - Biodiesel from vegetable oil
 - Biodiesel from algae
 - Energy derived from Biomass
- Listing the local companies that are working on biofuels.

Biofuels (general)

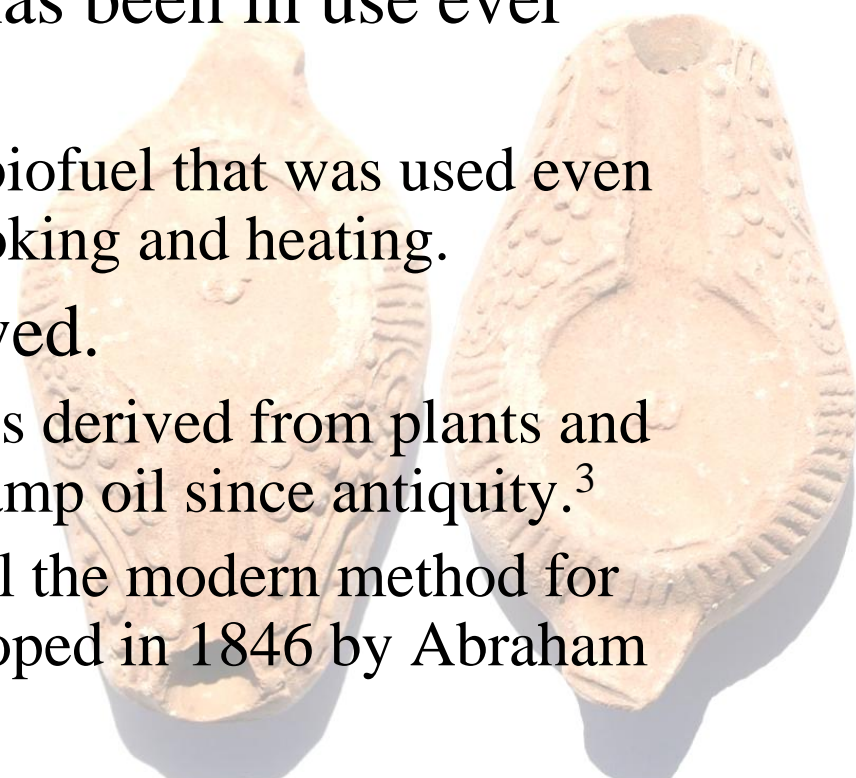
- **Biofuel** is defined as fuel derived from biological materials, including materials from organisms that died relatively recently and from the metabolic by-products of living organisms.^{1,2}
- In general, the term covers solid and liquid fuels as well as various biogases.
 - low nutrient input/high per acre yield crops
 - agricultural or forestry waste
 - other sustainable biomass feedstocks, including algae

1. Demirbas, A., *Applied Energy*, **2009**, 86 S108–S117.

2. Bungay H. R., *Science*, **1982**, 643-646.

Early Applications

- Biofuels in the solid form has been in use ever since man discovered fire.
 - Wood was the first form of biofuel that was used even by the ancient people for cooking and heating.
- Liquid biofuels soon followed.
 - Olive oil, as well as other oils derived from plants and animals, has been used for lamp oil since antiquity.³
 - Whale oil was also used until the modern method for refining kerosene was developed in 1846 by Abraham Gesner.⁴



3. Appolonia-Arsuf, Sussman V., **1983**, *The Samaritan Oil Lamps from Apolonia-*Arsuf*, TA 10, pp. 71-96.

4. Russell, L. S., **2003**, *A Heritage of Light: Lamps and Lighting in the Early Canadian Home*, University of Toronto Press.

Early Engines

- Several of the early automotive engines developed in the late 17th century utilized steam power ⁵
- By the 18th century gasoline or petrol-fueled engines were being invented.
- Rudolf Diesel is the German inventor of the diesel engine. He designed his diesel engine to run in peanut oil.⁶
- Henry Ford designed the Model T car which was produced from 1903 to 1926. This car was completely designed to use hemp derived biofuel as fuel.⁷

5. Eckermann, E., **2001**, *World History of the Automobile*, SAE Press.

6. Knothe G. *Inform*, **2001**, *12*, 103-1107.

7. New York Times, *Ford Predicts Fuel from Vegetation*, **Sept. 20, 1925**, p. 24.

World War II and Fuel Shortages

- During World War II, the high demand of biofuels was due to the increased use as an alternative for imported fuel.⁸
 - Germany developed the use of gasoline along with alcohol that was derived from potatoes (*Monopolin*).
 - Britain was the second country which came up with the concept of grain alcohol mixed with petrol (*Discol*).
- After WWII was over cheap oil from the gulf countries, as well as the Middle East, again eased off the pressure.



8. Nag, A., 2007, *Biofuels Refining and Performance*. New York, NY: McGraw-Hill.

Recent Fuel Shortages

- America has had several fuel shortages since the 1970's.⁹
 - 1973 oil crisis - caused by an OPEC (Organization of the Petroleum Exporting Countries) oil export embargo.
 - 1979 oil crisis - caused by the Iranian Revolution.
 - 1990 oil price shock - caused by the Gulf War.
- This lead many countries, including the U.S., to begin adding ethanol to their fuel.
- With the growing realization of the worlds environmental problems and critical instabilities in the Middle East, biofuels have become the center of attention of world governments.

9. Hammes, D., Wills, D. *The Independent Review*, **2005**, v. IX (n. 4), 501–511.

Biomass and the EIA

- **Biomass waste:** Organic non-fossil material of biological origin that is a byproduct or a discarded product. Biomass waste includes municipal solid waste from biogenic sources, landfill gas, sludge waste, agricultural crop byproducts, straw, and other biomass solids, liquids, and gases; but excludes wood and wood-derived fuels (including black liquor), biofuels feedstock, biodiesel, and fuel ethanol.¹⁰

10. U.S. Energy Information Administration; www.eia.doe.gov

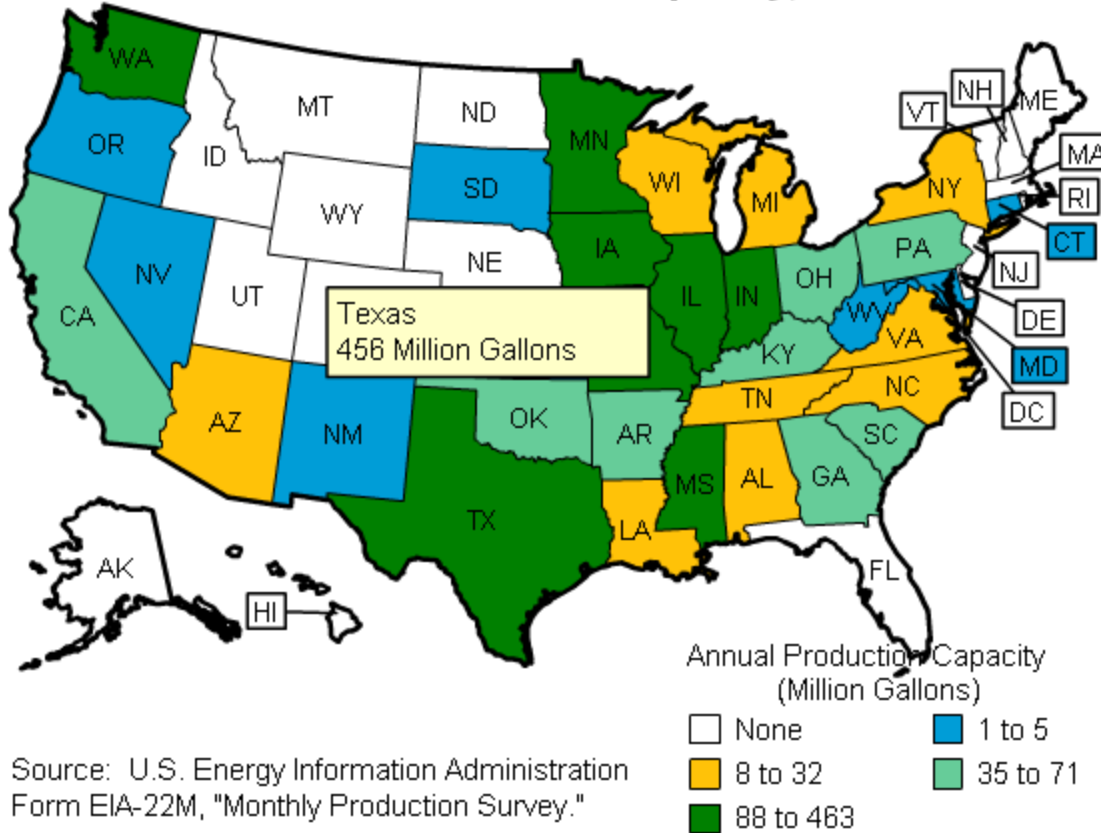


Specific Types of Biofuels

- **Biodiesel:** A fuel typically made from soybean, canola, or other vegetable oils; animal fats; and recycled grease.
- It can serve as a substitute for petroleum-derived diesel or distillate fuel.
 - For EIA reporting, it is a fuel composed of mono-alkyl esters of long chain fatty acids derived from vegetable oils or animal fats, designated B100, and meeting the requirements of ASTM (American Society for Testing materials) D 6751
- These are used primarily for transportation and do not include ethanol blended fuels.

Current Production of Biofuel for Energy by State

U.S. Biodiesel Production Capacity, 2009

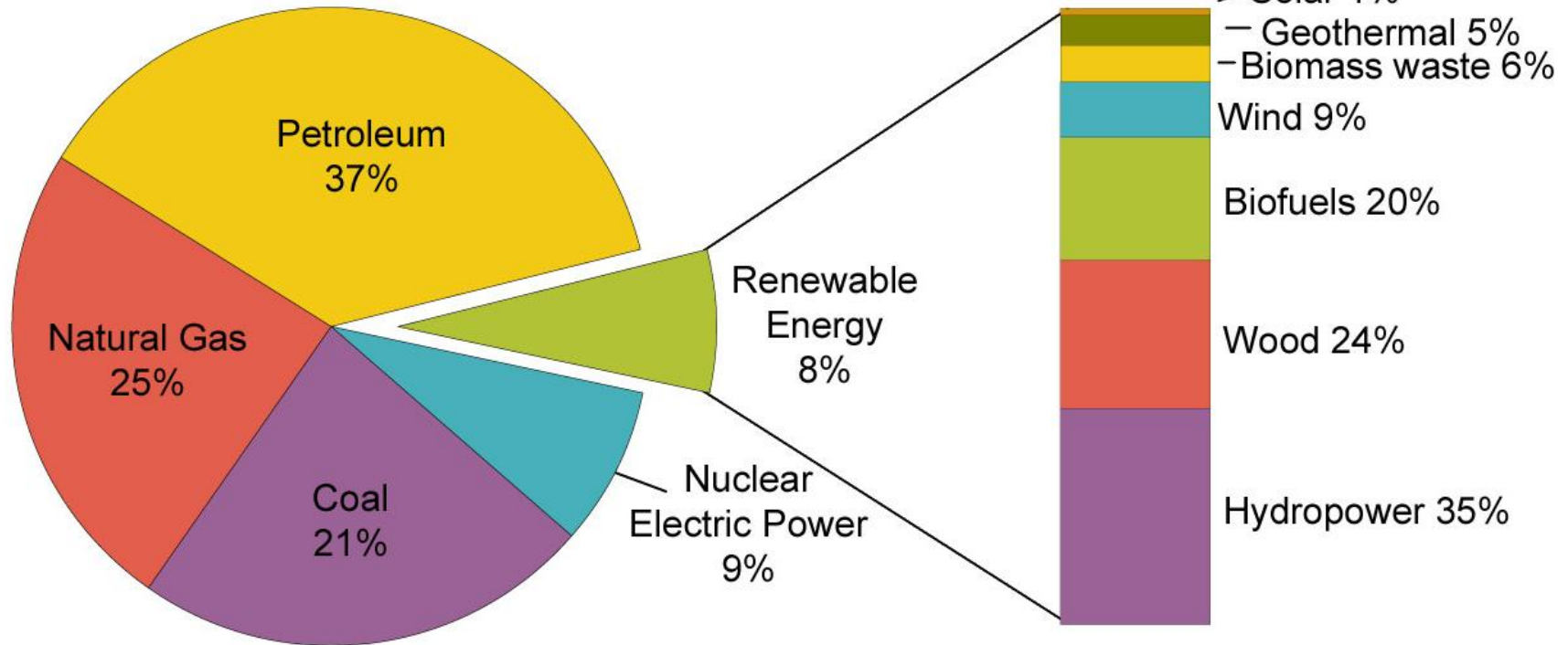


- As of 2009, the United States had 122 active biodiesel producers with total production capacity of 2 billion gallons.
- Monthly production was 61 million gallons
- Soybean oil was the largest feedstock input for 2009, followed by tallow and white grease respectively.
- Soybean oil used for production of 1.97 billion pounds.

U.S. Energy Consumption by Energy Source, 2009

Total = 94.578 Quadrillion Btu

Total = 7.744 Quadrillion Btu



Note: Sum of components may not equal 100% due to independent rounding.

Source: U.S. Energy Information Administration, *Annual Energy Review 2009*, Table 1.3, Primary Energy Consumption by Energy Source, 1949-2009 (August 2010).

- Renewable energy consumption increased by about 8% between 2008 and 2009, contributing about 8% of the Nation's total energy demand, and 10% of total U.S. electricity generation in 2009.

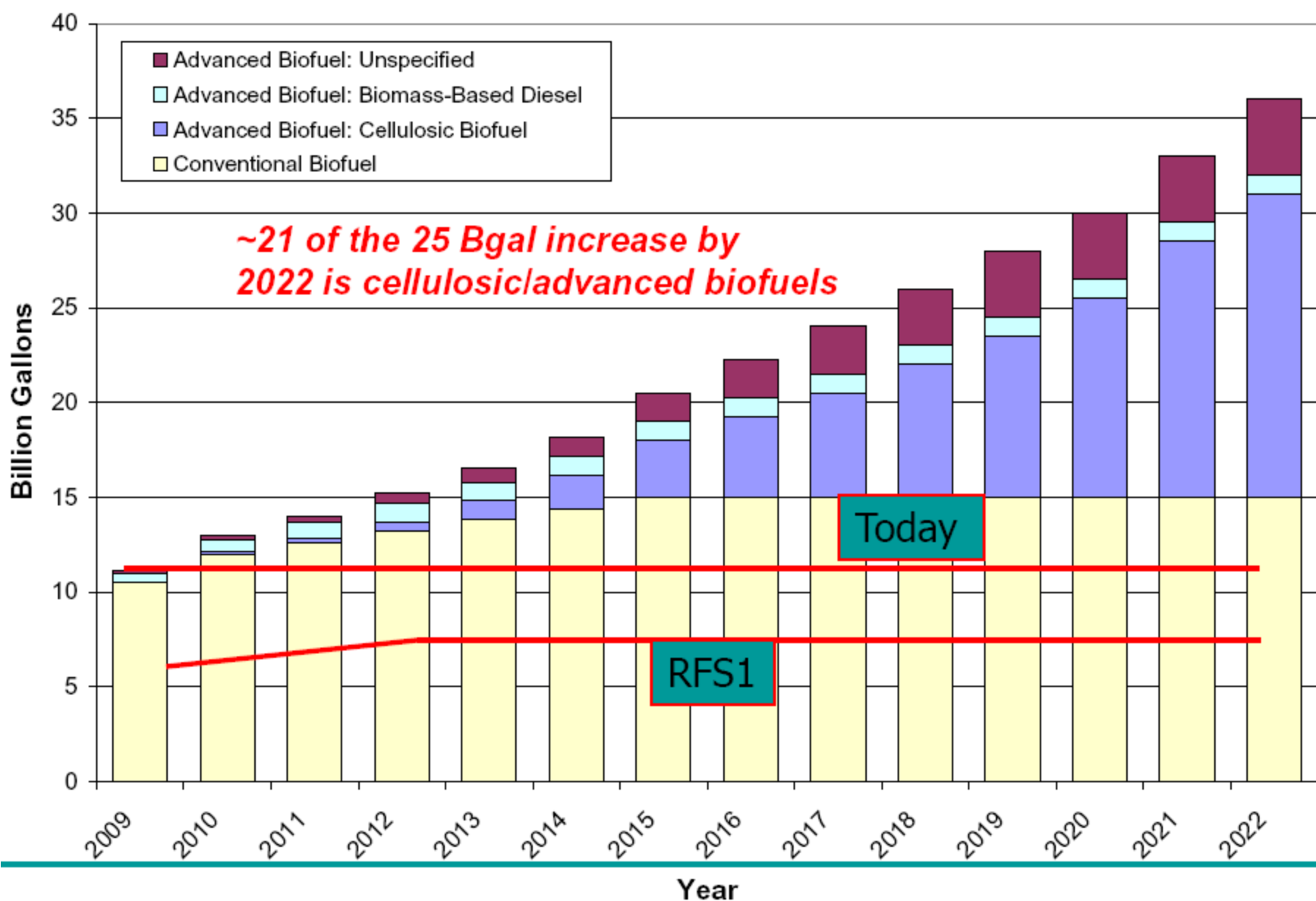
Most Renewable Energy Goes to Producing Electricity

- About 26% of renewable energy used was biomass consumed by industry for industrial applications (principally paper-making) by facilities producing only heat and steam.
- The largest share of the renewable-generated electricity in 2009 came from hydroelectric energy (66%), followed by wind (17%), wood (9%), biomass waste (4%), geothermal (4%), and solar (0.2%).¹¹

11. U.S. Energy Information Administration, *Annual Energy Review 2009*, Table 8.2a (August 2010).

The Energy Independence & Security Act

- RFS2 Rule and 2022 Projections
 - Significantly increased volumes of renewable fuel, from 11 billion gallons to 36 billion gallons by 2022.
 - Expanded from on road gasoline to on and off-road gasoline and diesel.
 - Separation of the volume requirements into four separate categories of renewable fuel: cellulosic biofuel, biomass-based diesel, advanced biofuel, total renewable fuel.
 - Changes to the definition of renewable fuels to include minimum lifecycle GHG reduction thresholds and grandfathering of volume from certain facilities.
 - Restrictions on the types of feedstocks that can be used to make renewable fuel, and the types of land that can be used to grow and harvest feedstocks.
 - Inclusion of specific types of waivers and EPA-generated credits for cellulosic biofuel.



12. Argyropoulos P., *National Renewable Fuel Standard Program –2010 and Beyond*, 2010 Energy Conference April 6 & 7, 2010, Office of Transportation and Air Quality, U.S. Environmental Protection Agency.

Biofuels on the International Level

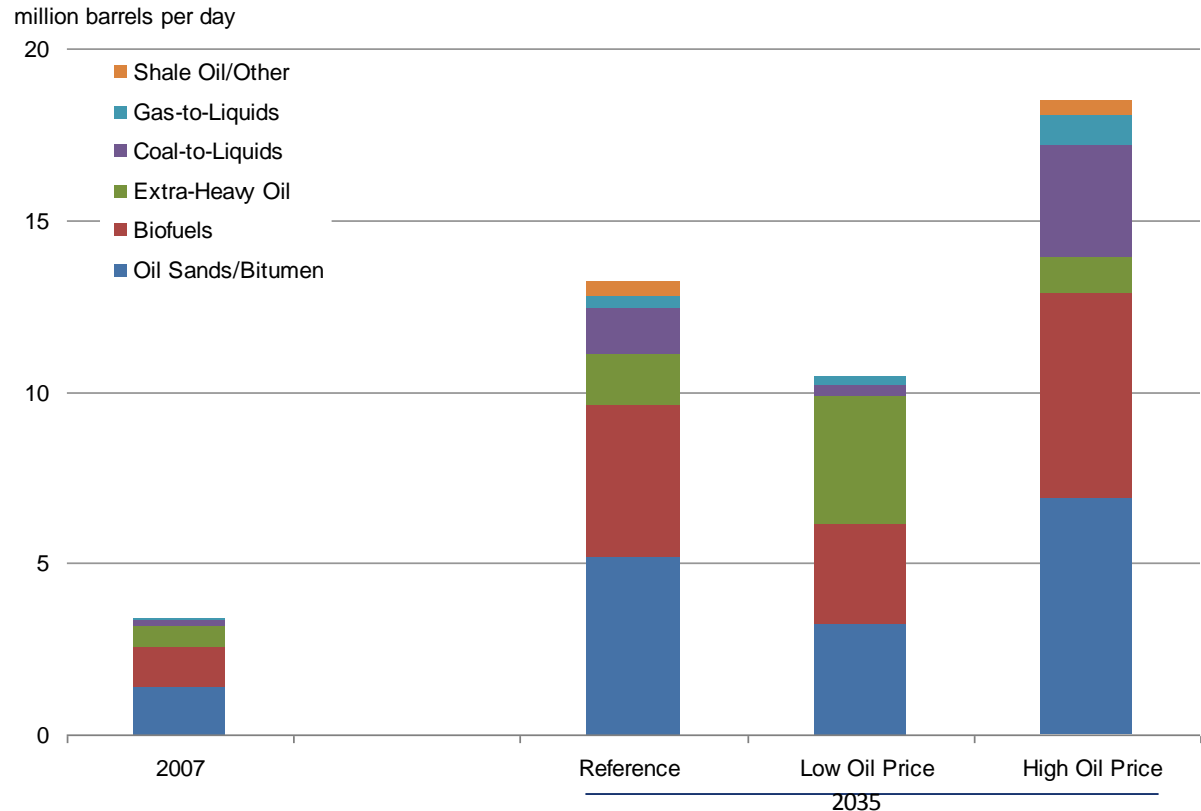
- There are international organizations such as IEA Bioenergy, established in 1978 by the Organisation for Economic Co-operation and Development (OECD) International Energy Agency (IEA), with the aim of improving cooperation and information exchange between countries that have national programs in bioenergy research, development and deployment.¹³
- The U.N. International Biofuels Forum is formed by Brazil, China, India, South Africa, the United States and the European Commission.
- The world leaders in biofuel development and use are Brazil, United States, France, Sweden and Germany.

13. Press Conference Launching International Biofuels Forum“, *United Nations Department of Public Information*. **March 2 2007**.

Projected Usage

- World liquids consumption in the IEO2010 Reference case increases from 86.1 million barrels per day in 2007 to 110.6 million barrels per day in 2035.¹⁴
- Unconventional liquids, at 12.9 million barrels per day, make up 12 percent of total liquids production in 2035.

Figure 30. World production of unconventional liquid fuels in three cases, 2007 and 2035



14. U.S. Energy Information Administration, *International Energy Outlook 2010, Liquid Fuels*, July 27 2010.

Three Main Types of Development

- Bioethanol, for flex fuel, is an alcohol made by fermenting the sugar components of plant materials
 - With advanced technology being developed, cellulosic biomass, such as trees and grasses, are also used as feedstocks for ethanol production.
- Biodiesel is made from vegetable oils, animal fats or recycled greases using transesterification.
- Biodiesel derived from alge, which is similar to that of vegetable and animal derived fuel.



Flex Fuel



- As a transportation fuel, ethanol can be used as a total or partial replacement for gasoline.¹⁵
- About 99% of the fuel ethanol consumed in the U.S. is added to gasoline in mixtures of up to 10% ethanol and 90% gasoline.
- The U.S. Environmental Protection Agency ruled in October 2010, that E15 can be used in cars and light trucks (only) of model year 2007 and newer without causing damage to the engine and fuel system.
- E85 is an alternative fuel that contains up to 85% ethanol. It is used mainly in the Midwest and South. Vehicles that use E85 are specially named as flexible fuel vehicles (FFV).

15. U.S. Department of Agriculture, *Bioenergy: Background – Ethanol*, **April 10 2010**.

National Renewable Energy Laboratory and Ethanol

- In a preliminary report released in October 2008, the NREL presented the results of the first evaluations of the effects of E10, E15 and E20 gasoline blends on vehicle durability.¹⁶
 - None of the vehicles displayed a malfunction indicator light as a result of the ethanol blend used
 - No fuel filter plugging symptoms were observed
 - No cold start problems were observed at 24°C (75°F) and 10°C (50°F) laboratory conditions
 - As expected, all test vehicles exhibited a loss in fuel economy proportional with the lower energy density of ethanol (E20, the average reduction in fuel economy was 7.7% when compared to E0)

16. West B., Knoll K., Clark W., Graves R., Orban J., Przesmitzki S., Theiss T. *Effects of Intermediate Ethanol Blends on Legacy Vehicles and Small Non-Road Engines, Report 1*, Oak Ridge National Laboratory and National Renewable Energy Laboratory, **2008**.

Ethanol Only Fuel

- Straight ethanol as an automotive fuel has been widely used in Brazil since the late seventies for neat ethanol vehicles.¹⁷
- Modifications are required for higher ratios of ethanol¹⁸

Required adjustments to gasoline engines to cope with different blends of ethanol fuel														
Ethanol blend	Carburetor	Fuel Injection	Fuel pump	Fuel pressure device	Fuel filter	Ignition system	Evaporative system	Fuel tank	Catalytic converter	Basic engine	Motor oil	Intake manifold	Exhaust system	Cold start system
≤ 5%	Any vehicle													
E5 to E10		Vehicles up to 15–20 years old												
E10 to E25	Specially designed vehicles									Vehicles up to 15-20 yrs old				
E25 to E85	Specially designed vehicles													
E85 to E100	Specially designed vehicles													
Modifications not necessary									Modifications probably necessary					

17. Voegele, E. *Sugarcane Economics*, March 2009, *Ethanol Producer Magazine*.

18. Josehp, "Sustainable biofuels: prospects and challenges, pp. 35-36" *The Royal Society*, 2008.

Biofuels From Vegetable Oil

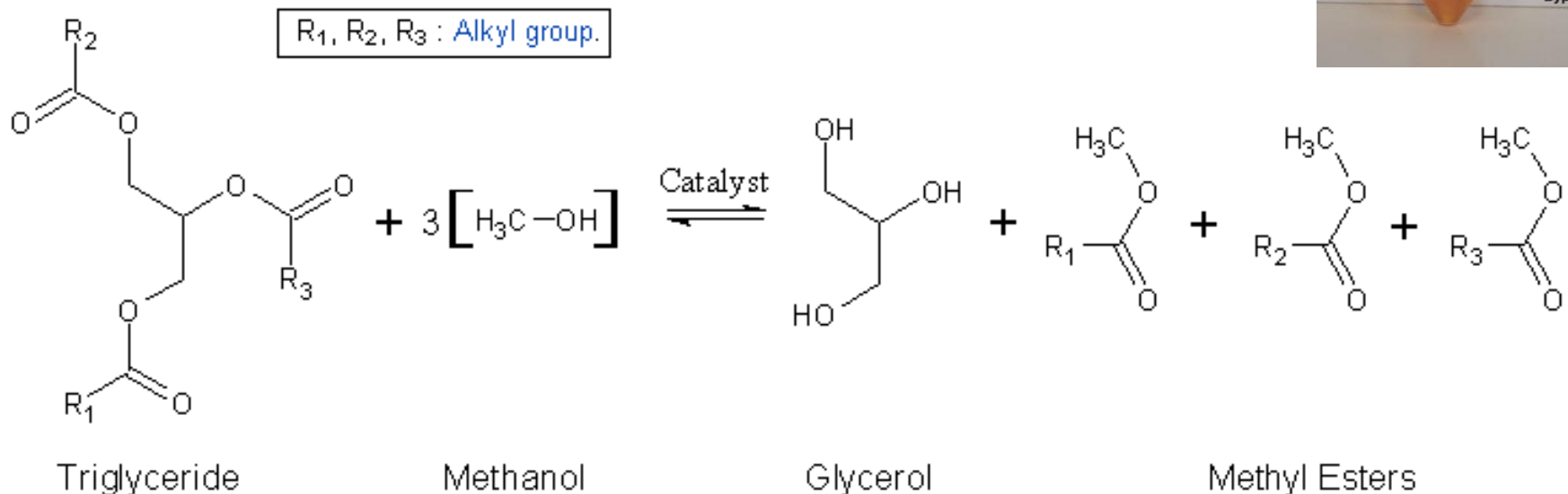
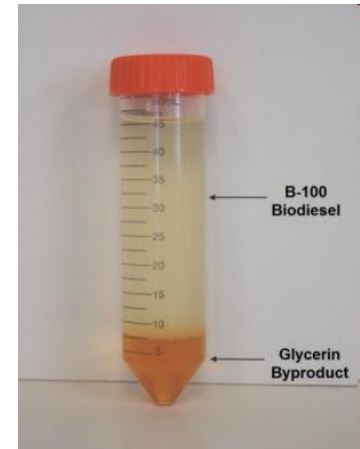
- Biodiesel from soy oil results, on average, in a 57% reduction in greenhouse gases compared to fossil diesel, and biodiesel produced from waste grease results in an 86% reduction.¹⁹
- However, for engines designed to burn diesel fuel, the viscosity of vegetable oil must be lowered to allow for proper atomization of the fuel
 - Otherwise incomplete combustion and carbon build up will ultimately damage the engine



19. EPA's Renewable Fuel Standards Program Regulatory Impact Analysis, **February 2010**.

Synthesis

- Animal and plant fats and oils are typically made of triglycerides which are esters containing three free fatty acids and the trihydric alcohol, glycerol.
- In the transesterification process, the alcohol is deprotonated with a base to make it a stronger nucleophile.
 - Ethanol or methanol are used typically to reduce foaming.
- The glycerol/alcohol layer is then separated from the fuel.



Efficiency and Economic Arguments

- There are various social, economic, environmental and technical issues with biofuel production and use, which have been discussed in the popular media and scientific journals.
- These include:
 - the "food vs fuel" debate
 - poverty reduction potential
 - carbon emissions levels
 - sustainable biofuel production
 - deforestation and soil erosion
 - loss of biodiversity
 - impact on water resources
 - energy balance and efficiency.



Biofuels From Algae

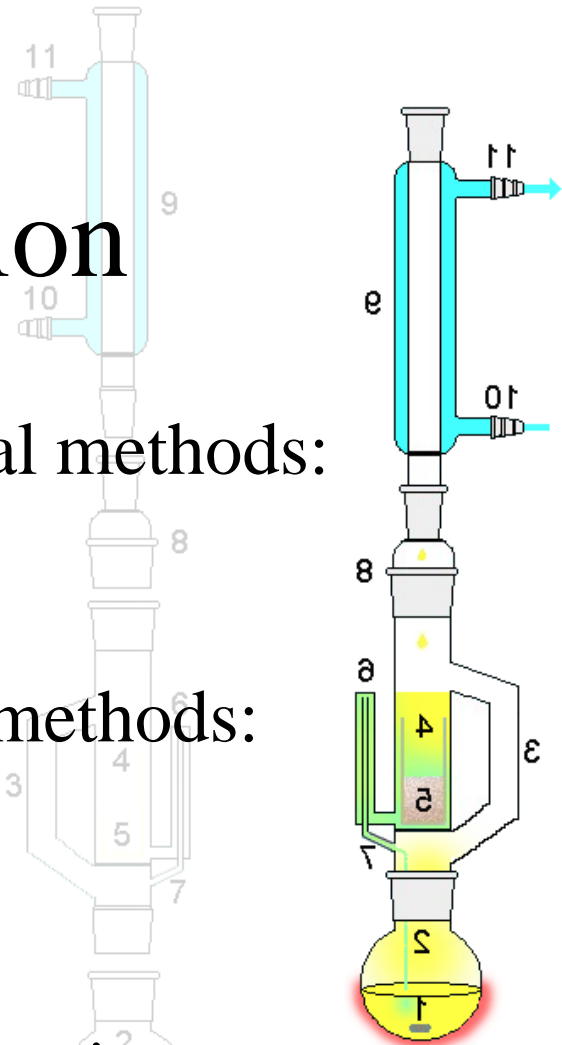
- Biofuel from algae offers three main advantages:²⁰
 - **Minimal land use** - Algae require much less land than traditional row crops, such as corn. In addition, algae can grow on non-arable, nutrient-poor land that won't support conventional agriculture.
 - **High yielding** - Algae grow quickly at a large scale and can potentially generate up to 50 times more the amount of oil per acre than row crops, like corn and soybeans, which produce vegetable oil.
 - **Non-competitive with agriculture** - Production of algae for biofuel doesn't require arable land needed for food production, fresh water for irrigation, or application of petroleum-based fertilizers.

Harvesting of Micro Algae

- Gathering algae consists of separating algae from the growing medium, drying, and processing it to obtain the desired product.
- Separating algae from its medium is known as harvesting and depends primarily on the type of algae.
- The high water content of algae must be removed to enable harvesting.
- The most common harvesting processes are:
 - flocculation
 - microscreening
 - centrifugation.

Algae Oil Extraction

- There are 2 main types of mechanical methods:
 - Expression/Expeller press
 - Ultrasonic-assisted extraction
- There are 3 main types of chemical methods:
 - Hexane Solvent Method
 - Soxhlet extraction
 - Supercritical fluid Extraction
- The oil is then chemically processed using an alcohol and catalyst to drive a transesterification reaction.



San Diego Business and Resources

- Biolight Harvesting, Inc
 - Carbon Capture Corporation
 - General Atomics
 - Life Technologies
 - LiveFuels Inc.
 - San Diego Center for Algae Biotechnology (SD-CAB)
 - Sapphire Energy
- 
- An aerial photograph of a large industrial facility, likely a biotechnology or energy production site. The foreground is dominated by two large, circular concrete tanks. The tank on the left contains a thick, brownish-orange slurry, while the tank on the right contains a clear, light blue liquid. Both tanks have long, white, vertical pipes extending into them. In the background, there are several large, white industrial buildings, a parking lot with a few vehicles, and a flat, open landscape under a clear sky.

SD-CAB Video

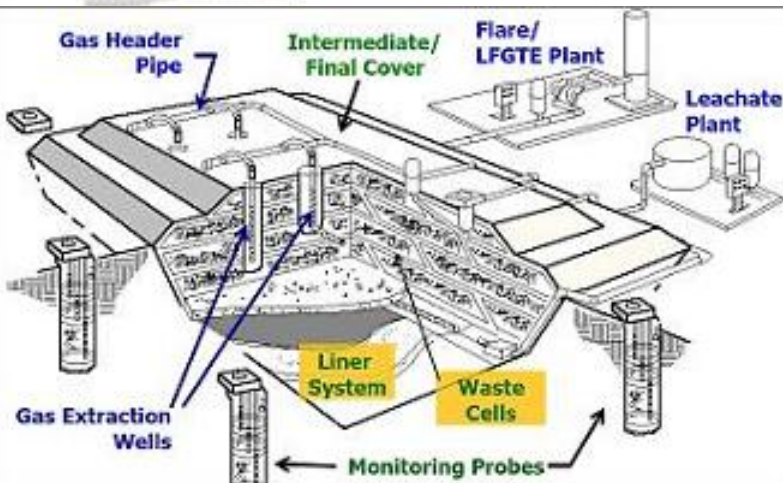
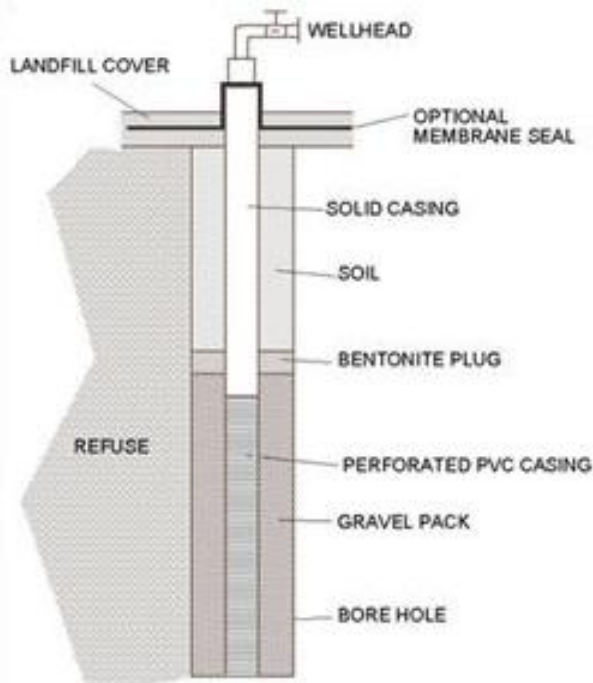


Alternative Biomass Fuels

- In addition to the three types of biofuels that have already been covered there are also three other biomass energy sources that you may find interesting.
 - Landfill gas
 - Gasification of biomass
 - Microbial electrolysis



Landfill Gas

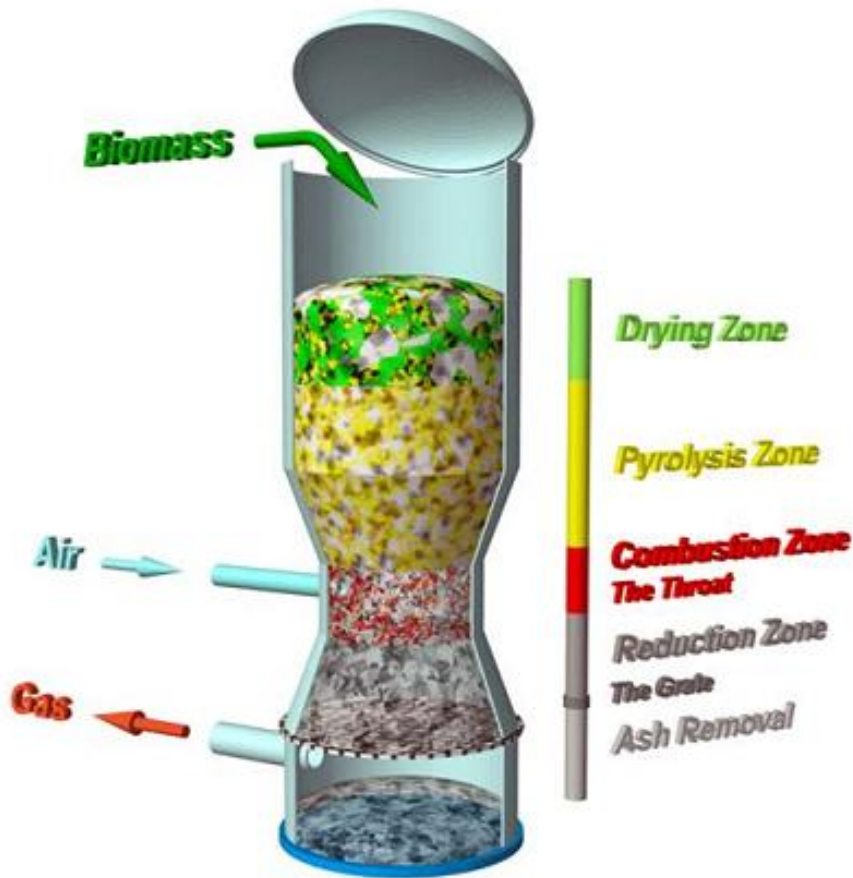


- 450 of the 2,300 landfills in the United States have operational landfill gas utilization projects as of 2007.^{21,22}
- Of the roughly 450 landfill gas projects operational in 2007, 11 billion kWh of electricity was generated and 78 billion cubic feet of gas was supplied to end users.

21. U.S. Environmental Protection Agency, *Landfill Gas Energy Basics*, LFG Energy Project Development Handbook, 16 Feb. **2009**.

22. U.S. Environmental Protection Agency, *Environmental Protection Agency LMOP: Benefits of Energy*, Web. 27 Nov. **2009**.

Biomass Gasification

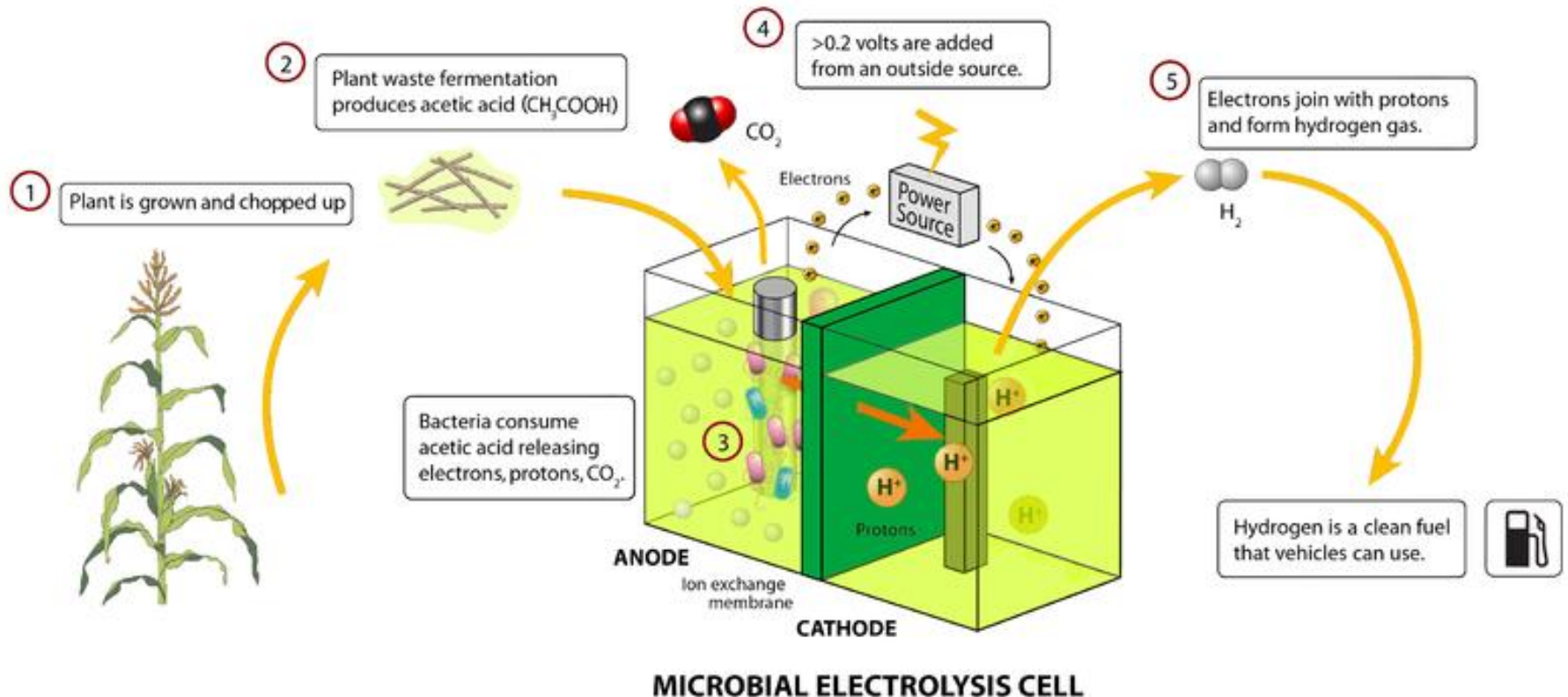


- Biomass gasifiers are of two kinds – updraft and downdraft. The efficiency of updraft gasifiers ranges from 80 to 90 per cent on account of efficient counter-current heat exchange between the rising gases and descending solids.
- However, the tars produced by updraft gasifiers imply that the gas must be cooled before it can be used in internal combustion engines.²³

23. Zafar S. “Woody Biomass Conversion Technologies”, *Alternative Energy and Fuels*, **October 6 2008**.

Microbial Electrolysis

- Highest hydrogen production rate reported is 17.8 m³/m³d, $E_{ap} = 1 \text{ V}$.¹³



Conclusions

- Biofuels have been, and will continue to be, an important part of our ever developing society.
- As a nation we have decided to try and double the amount of biofuels being produced by 2035.
- There is a lot of active research being done here in San Diego on alternative fuels, especially algae based biofuels.

Acknowledgments

- Jillian L. Blatti - UCSD
- Everyone in attendance