Biofuel: Synthesis and applications

DEFINITION OF TERMS

Fuels that have been extracted from plants and crops are known as biofuels.

A biofuel is a fuel that is produced through contemporary biological processes, such as agriculture and anaerobic digestion, rather than a fuel produced by geological processes such as those involved in the formation of fossil fuels, such as coal and petroleum, from prehistoric biological matter.

Introduction to Biofuels

Known petroleum reserves are limited and will eventually run out. Various studies put the date of the global peak in oil production between 1996 and 2035. Biomass energy technologies use waste or plant matter to produce energy with a lower level of greenhouse gas emissions than fossil fuel sources (Sheehan et al., 1998).

In developed countries there is a growing trend toward employing modern technologies and efficient bioenergy conversion using a range of biofuels, which are becoming cost competitive with fossil fuels (Puhan et al., 2005). The biofuel economy will grow rapidly during the 21st century. The biofuel economy, and its associated biorefineries, will be shaped by many of the same forces that shaped the development of the hydrocarbon economy and its refineries over the past century. President Bush spoke in his January 31, 2006 State of the Union address of producing biofuels by 2012 using “woodchips, stalks, and switchgrass” as the source of cellulosic biomass. These represent both existing and potential biomass resources. Due to the environmental merits of biofuel, its share in the automotive fuel market will grow rapidly in the next decade.

Various scenarios have put forward estimates of biofuel from biomass sources in the future energy system. In the most biomass-intensive scenario, by 2050 modernized biomass energy will contribute about one half of the total energy demand in developing countries (IPCC, 1997). The biomass-intensive future energy supply scenario includes 385 million ha of biomass energy plantations globally in 2050, with three quarters of this area established in developing countries (Kartha and Larson, 2000). The availability of biofuel resources is important for the electricity, heat, and liquid fuel market. There are two global biomass-based liquid transportation fuels that might replace gasoline and diesel fuel. These are bioethanol and biodiesel. Transport is one of the main energy-consuming sectors. It is assumed that biodiesel will be used as a fossil diesel replacement and that bioethanol will

be used as a gasoline replacement. Biomass-based energy sources for heat, electricity, and transportation fuels are potentially carbon dioxide neutral and recycle

the same carbon atoms. Due to the widespread availability of biomass resources,3biomass-based fuel technology can potentially employ more people than fossilfuel-based technology (Demirbas, 2006a). Demand for energy is increasing every

day due to the rapid growth of population and urbanization. As the major conventional energy sources like coal, petroleum, and natural gas are gradually depleted,

biomass is emerging as one of the promising environmentally friendly renewable

energy options.

The term biofuel refers to liquid or gaseous fuels for the transport sector that

are predominantly produced from biomass. It is generally held that biofuels offer

many benefits, including sustainability, reduction of greenhouse gas emissions,

and security of supply (Reijnders, 2006). A variety of fuels can be produced from

biomass resources including liquid fuels, such as ethanol, methanol, biodiesel, and

Fischer-Tropsch diesel, and gaseous fuels, such as hydrogen and methane. Biofuels are primarily used in vehicles but can also be used in engines or fuel cells for electricity generation.

There are several reasons why biofuels are considered relevant technologies by both developing and industrialized countries (Demirbas, 2006a). They include energy security, environmental concerns, foreign exchange savings, and socioeconomic issues related to the rural sector. Due to its environmental merits, the share of biofuel in the automotive fuel market will grow fast in the next decade (Kim and Dale, 2005; Demirbas and Balat, 2006). The advantages of biofuels are the following: (a) they are easily available from common biomass sources, (b) caırbon dioxide cycle occurs in combustion, (c) they are very environmentally friendly, and (d) they are biodegradable and contribute to sustainability (Puppan, 2002).

Various scenarios have led to the conclusion that biofuels will be in widespread use in the future energy system. The scenarios are to facilitate the transition from the hydrocarbon economy to the carbohydrate economy by using biomass to produce bioethanol and biomethanol as replacements for traditional oil-based fuels and feedstocks. The biofuel scenario produces equivalent rates of growth in GDP and per-capita affluence, reduces fossil energy intensities of GDP, and reduces oil imports. Each scenario has advantages whether in terms of rates of growth in GDP, reductions in carbon dioxide emissions, the energy ratio of the production process, the direct creation of jobs, or the area of biomass plantation required to make the production system feasible (Demirbas, 2006a).

The biggest difference between biofuels and petroleum feedstocks is oxygen content. Biofuels have oxygen levels of 10 to 45% while petroleum has essentially none, making the chemical properties of biofuels very different from those of petroleum. All have very low sulfur levels and many have low nitrogen levels.

Biomass can be converted into liquid and gaseous fuels through thermochemical and biological methods. Biofuel is a non-polluting, locally available, accessible, sustainable, and reliable fuel obtained from renewable sources (Vasudevan et al., 2005). Liquid biofuels fall into the following categories: (a) vegetable oils and biodiesels, (b) alcohols, and (c) biocrude and synthetic oils. Figure 2.1 shows the sources of the main liquid biofuels for automobiles. 6

MEANING OF BIOFUEL AND GENERATIONS OF BIOFUEL

A biofuel is a fuel that is produced through contemporary biological processes, such as agriculture and anaerobic digestion, rather than a fuel produced by geological processes such as those involved in the formation of fossil fuels, such as coal and petroleum, from prehistoric biological matter.

There are various social, economic, environmental and technical issues relating to biofuels production and use, which have been debated in the popular media and scientific journals. These include: the effect of moderating oil prices , 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 , rural social exclusion and injustice, shantytown migration, rural unskilled unemployment, and nitrogen dioxide (NO_2) emissions.

Biofuel generations

First-generation biofuels

"First-generation" or conventional biofuels are biofuels made from food crops grown on arable land. With this biofuel production generation, food crops are thus explicitly grown for fuel production , and not anything else. The sugar, starch, or vegetable oil obtained from the crops is converted into biodiesel or ethanol, using transesterification, or yeast fermentation. [6]

Second-generation biofuels

Main article: Second-generation biofuels

Second generation biofuels are fuels manufactured from various types of biomass . Biomass is a wide-ranging term meaning any source of organic carbon that is renewed rapidly as part of the carbon cycle. Biomass is derived from plant materials, but can also include animal materials.

Whereas first generation biofuels are made from the sugars and vegetable oils found in arable crops, second generation biofuels are made from lignocellulosic biomass or woody crops, agricultural residues or waste plant material (from food crops)[7]

This has both advantages and disadvantages. The advantage is that, unlike with regular food crops, no arable land is used solely for the production of fuel. The disadvantage is that unlike with regular food crops, it may be rather difficult to extract the fuel. For instance, a series of physical and chemical treatments might be required to convert lignocellulosic biomass to liquid fuels suitable for transportation.[8][9]

Third-generation biofuels

Main articles: Algaculture and Algae fuel

From 1978 to 1996, the US NREL experimented with using algae as a biofuels source in the "Aquatic Species Program". [10] A self-published article by Michael Briggs, at the UNH Biofuels Group, offers estimates for the realistic replacement of all vehicular fuel with biofuels by using algae that have a natural oil content greater than 50%, which Briggs suggests can be grown on algae ponds at wastewater treatment plants. [11] This oil-rich algae can then be extracted from the system and processed into biofuels, with the dried remainder further reprocessed to create ethanol. The production of algae to harvest oil for biofuels has not yet been undertaken on a commercial scale, but feasibility studies have been conducted to arrive at the above yield estimate. In addition to its projected high yield, algaculture — unlike crop-based biofuels – does not entail a decrease in

food production , since it requires neither farmland nor fresh water. Many companies are pursuing algae bioreactors for various purposes, including scaling up biofuels production to commercial levels. [12][13] Prof. Rodrigo E. Teixeira from the

University of Alabama in Huntsville demonstrated the extraction of biofuels lipids from wet algae using a simple and economical reaction in ionic liquids . [14]

Fourth-generation biofuels

Similarly to third-generation biofuels, fourth-generation biofuels are made using non-arable land. However, unlike third-generation biofuels, they do not require the destruction of biomass. This class of biofuels includes electrofuels. [15] and photobiological solar fuels. [16] Some of these fuels are

carbon-neutral .The conversion of crude oil from the plant seeds into useful fuels is called transesterification

Types of biofuels

The following fuels can be produced using first, second, third or fourth-generation biofuel production procedures. Most of these can even be produced using two or three of the different biofuel generation procedures.

Ethanol

Biologically produced alcohols , most commonly ethanol, and less commonly propanol and butanol, are produced by the action of microorganisms and enzymes through the fermentation of sugars or starches (easiest), or cellulose (which is more difficult). Biobutanol (also called biogasoline) is often claimed to provide a direct replacement for gasoline, because it can be used directly in a gasoline engine.Ethanol fuel is the most common biofuel worldwide, particularly in Brazil . Alcohol fuels are produced by fermentation of sugars derived from wheat, corn , sugar beets,

sugar cane , molasses and any sugar or starch from which

alcoholic beverages such as whiskey, can be made (such as

potato and fruit waste, etc.). The ethanol production methods used are enzyme digestion (to release sugars from stored starches), fermentation of the sugars, distillation and drying. The distillation process requires significant energy input for heat (sometimes unsustainable natural gas fossil fuel, but cellulosic biomass such as bagasse, the waste left after sugar cane is pressed to extract its juice, is the most common fuel in Brazil, while pellets, wood chips and also waste heat are more common in Europe) Waste steam fuels ethanol factory[18] – where waste heat from the factories also is used in the district heating grid.

Ethanol can be used in petrol engines as a replacement for gasoline; it can be mixed with gasoline to any percentage. Most existing car petrol engines can run on blends of up to 15% bioethanol with petroleum/gasoline. Ethanol has a smaller energy density than that of gasoline; this means it takes more fuel (volume and mass) to produce the same amount of work. An advantage of ethanol (CH_3CH_2OH) is that it has a higher octane rating than ethanol-free gasoline available at roadside gas stations, which allows an increase of an engine's compression ratio for increased thermal efficiency . In high-altitude (thin air) locations, some states mandate a mix of gasoline and ethanol as a winter oxidizer to reduce atmospheric pollution emissions.

Ethanol is also used to fuel bioethanol fireplaces . As they do not require a chimney and are "flueless", bioethanol fires [19] are extremely useful for newly built homes and apartments without a flue. The downsides to these fireplaces is that their heat output is slightly less than electric heat or gas fires, and precautions must be taken to avoid carbon monoxide poisoning.

Corn-to-ethanol and other food stocks has led to the development of cellulosic ethanol. According to a joint research agenda conducted through the US Department of Energy, [20] the fossil energy ratios (FER) for cellulosic ethanol, corn ethanol, and gasoline are 10.3, 1.36, and 0.81, respectively. [21][22][23]

Ethanol has roughly one-third lower energy content per unit of volume compared to gasoline. This is partly counteracted by the better efficiency when using ethanol (in a long-term test of more than 2.1 million km, the BEST project found FFV vehicles to be 1-26 % more energy efficient than petrol cars, but the volumetric consumption increases by approximately 30%, so more fuel stops are required).

With current subsidies, ethanol fuel is slightly cheaper per distance traveled in the United States.

Biodiesel

Biodiesel is the most common biofuel in Europe. It is produced from oils or fats using transesterification and is a liquid similar in composition to fossil/mineral diesel. Chemically, it consists mostly of fatty acid methyl (or ethyl) esters (FAMEs). Feedstocks for biodiesel include animal fats, vegetable oils, soy , rapeseed , jatropha, mahua , mustard , flax,

sunflower , palm oil , hemp , field pennycress , Pongamia pinnata and algae. Pure biodiesel (B100, also known as "neat" biodiesel) currently reduces emissions with up to 60% compared to diesel Second generation B100. [24]

Biodiesel can be used in any diesel engine when mixed with mineral diesel. In some countries, manufacturers cover their diesel engines under warranty for B100 use, although

Volkswagen of Germany , for example, asks drivers to check by telephone with the VW environmental services department before switching to B100. B100 may become more viscous at lower temperatures, depending on the feedstock used. In most cases, biodiesel is compatible with diesel engines from 1994 onwards, which use ' Viton ' (by DuPont) synthetic rubber in their mechanical fuel injection systems. Note however, that no vehicles are certified for using pure biodiesel before 2014, as there was no emission control protocol available for biodiesel before this date.

Electronically controlled ' common rail ' and ' unit injector' type systems from the late 1990s onwards may only use biodiesel blended with conventional diesel fuel. These engines have finely metered and atomized multiple-stage injection systems that are very sensitive to the viscosity of the fuel. Many current-generation diesel engines are made so that they can run on B100 without altering the engine itself, although this depends on the fuel rail design. Since biodiesel is an effective solvent and cleans residues deposited by mineral diesel, engine filters may need to be replaced more often, as the biofuel dissolves old deposits in the fuel tank and pipes.

It also effectively cleans the engine combustion chamber of carbon deposits, helping to maintain efficiency. In many European countries, a 5% biodiesel blend is widely used and is available at thousands of gas stations. [25][26] Biodiesel is also an oxygenated fuel , meaning it contains a reduced amount of carbon and higher hydrogen and oxygen content than fossil diesel. This improves the combustion of biodiesel and reduces the particulate emissions from unburnt carbon. However, using pure biodiesel may increase NOx -emissions[27]

Biodiesel is also safe to handle and transport because it is non-toxic and biodegradable, and has a high flash point of about 300 °F (148 °C) compared to petroleum diesel fuel, which has a flash point of 125 °F (52 °C). [28]

In the USA, more than 80% of commercial trucks and city buses run on diesel. The emerging US biodiesel market is estimated to have grown 200% from 2004 to 2005. "By the end of 2006 biodiesel production was estimated to increase fourfold [from 2004] to more than" 1 billion US gallons (3,800,000 m^3). [29]

In France, biodiesel is incorporated at a rate of 8% in the fuel used by all French diesel vehicles. [30] Avril Group produces under the brand Diester , a fifth of 11 million tons of biodiesel consumed annually by the European Union . [31] It is the leading European producer of biodiesel.

Vegetable oil

Straight unmodified edible vegetable oil is generally not used as fuel, but lower-quality oil has been used for this purpose. Used vegetable oil is increasingly being processed into biodiesel, or (more rarely) cleaned of water and particulates and then used as a fuel.

As with 100% biodiesel (B100), to ensure the fuel injectors atomize the vegetable oil in the correct pattern for efficient combustion, vegetable oil fuel must be heated to reduce its

viscosity to that of diesel, either by electric coils or heat exchangers. This is easier in warm or temperate climates.

MAN B&W Diesel, Wärtsilä, and Deutz AG , as well as a number of smaller companies, such as Elsbett, offer engines that are compatible with straight vegetable oil, without the need for after-market modifications.

Vegetable oil can also be used in many older diesel engines that do not use common rail or unit injection electronic diesel injection systems. Due to the design of the combustion chambers in indirect injection engines, these are the best engines for use with vegetable oil. This system allows the relatively larger oil molecules more time to burn. Some older engines, especially Mercedes, are driven experimentally by enthusiasts without any conversion, a handful of drivers have experienced limited success with earlier pre-"Pumpe Duse"

VW TDI engines and other similar engines with direct injection . Several companies, such as Elsbett or Wolf, have developed professional conversion kits and successfully installed hundreds of them over the last decades.

Oils and fats can be hydrogenated to give a diesel substitute. The resulting product is a straight-chain hydrocarbon with a high cetane number , low in aromatics and sulfur and does not contain oxygen. Hydrogenated oils can be blended with diesel in all proportions. They have several advantages over biodiesel, including good performance at low temperatures, no storage stability problems and no susceptibility to microbial attack

Bioethers

Bioethers (also referred to as fuel ethers or oxygenated fuels) are cost-effective compounds that act as octane rating enhancers."Bioethers are produced by the reaction of reactive iso-olefins, such as iso-butylene, with bioethanol." [47] Bioethers are created by wheat or sugar beet. [48] They also enhance engine performance, whilst significantly reducing engine wear and toxic exhaust emissions. Though bioethers are likely to replace petroethers in the UK, it is highly unlikely they will become a fuel in and of itself due to the low energy density. [49] Greatly reducing the amount of ground-level

ozone emissions, they contribute to air quality. [50][51]

When it comes to transportation fuel there are six ether additives: dimethyl ether (DME), diethyl ether (DEE), methyl teritiary-butyl ether (MTBE), ethyl ter -butyl ether (ETBE), ter -amyl methyl ether (TAME), and ter -amyl ethyl ether (TAEE). [52]

The European Fuel Oxygenates Association (EFOA) credits methyl Ttertiary-butyl ether (MTBE) and ethyl ter-butyl ether (ETBE) as the most commonly used ethers in fuel to replace lead. Ethers were introduced in Europe in the 1970s to replace the highly toxic compound. [53] Although Europeans still use bio-ether additives, the US no longer has an oxygenate requirement therefore bio-ethers are no longer used as the main fuel additive.

Biogas

Biogas is methane produced by the process of anaerobic digestion of organic material by anaerobes. [55] It can be produced either from biodegradable waste materials or by the use of energy crops fed into anaerobic digesters to supplement gas yields. The solid byproduct, digestate , can be used as a biofuel or a fertilizer.

Biogas can be recovered from mechanical biological treatment waste processing systems. Landfill gas , a less clean form of biogas, is produced in landfills through naturally occurring anaerobic digestion. If it escapes into the atmosphere, it is a potential greenhouse gas.

Farmers can produce biogas from manure from their cattle by using anaerobic digesters.

Solid biomass fuels

Examples include wood, sawdust , grass trimmings, domestic refuse, charcoal, agricultural waste , nonfood energy crops , and dried manure .

When solid biomass is already in a suitable form (such as

firewood), it can burn directly in a stove or furnace to provide heat or raise steam. When solid biomass is in an inconvenient form (such as sawdust, wood chips, grass, urban waste wood, agricultural residues), the typical process is to densify the biomass. This process includes grinding the raw biomass to an appropriate particulate size (known as hogfuel), which, depending on the densification type, can be from 1 to 3 cm (0.4 to 1.2 in), which is then concentrated into a fuel product. The current processes produce wood pellets , cubes, or pucks. The pellet process is most common in Europe, and is typically a pure wood product. The other types of densification are larger in size compared to a pellet and are compatible with a broad range of input feedstocks. The resulting densified fuel is easier to transport and feed into thermal generation systems, such as boilers.

Sawdust, bark and chips are already used for decades for fuel in industrial processes; examples include the pulp and paper industry and the sugar cane industry. Boilers in the range of 500,000 lb/hr of steam, and larger, are in routine operation, using grate, spreader stoker, suspension burning and fluid bed combustion. Utilities generate power, typically in the range of 5 to 50 MW, using locally available fuel. Other industries have also installed wood waste fueled boilers and dryers in areas with low-cost fuel. [58]

One of the advantages of solid biomass fuel is that it is often a byproduct, residue or waste-product of other processes, such as farming, animal husbandry and forestry. [59] In theory, this means fuel and food production do not compete for resources, although this is not always the case bioalcohols

Methanol is currently produced from natural gas , a non-renewable fossil fuel. In the future it is hoped to be produced from biomass as biomethanol . This is technically feasible, but the production is currently being postponed for concerns of Jacob S. Gibbs and Brinsley Coleberd that the economic viability is still pending. [32] The methanol economy is an alternative to the hydrogen economy , compared to today's

hydrogen production from natural gas.

Butanol (C_4H_9OH) is formed by ABE fermentation (acetone, butanol, ethanol) and experimental modifications of the process show potentially high net energy gains with butanol as the only liquid product. Butanol will produce more energy and allegedly can be burned "straight" in existing gasoline engines (without modification to the engine or car), [33] and is less corrosive and less water-soluble than ethanol, and could be distributed via existing infrastructures. DuPont and BP are working together to help develop butanol. E. coli strains have also been successfully engineered to produce butanol by modifying their amino acid metabolism .

Advantages of Biofuels

1. Cost Benefit: As of now, biofuels cost the same in the market as gasoline does. However, the overall cost benefit of using them is much higher. They are cleaner fuels, which means they produce fewer emissions on burning. Biofuels are adaptable to current engine designs and perform very well in most conditions. This keeps the engine running for longer, requires less maintenance and brings down overall pollution check costs. With the increased demand of biofuels, they have a potential of becoming cheaper in future as well. So, the use of biofuels will be less of a drain on the wallet.

2. Easy To Source: Gasoline is refined from crude oil, which happens to be a non-renewable resource. Although current reservoirs of gas will sustain for many years, they will end sometime in near future. Biofuels are made from many different sources such as manure, waste from crops and plants grown specifically for the fuel.

3. Renewable: Most of the fossil fuels will expire and end up in smoke one day. Since most of the sources like manure, corn, switchgrass, soyabeans, waste from crops and plants are renewable and are not likely to run out any time soon, making the use of biofuels efficient in nature. These crops can be replanted again and again.

4. Reduce Greenhouse Gases: Fossil fuels, when burnt, produce large amount of greenhouse gases i.e. carbon dioxide in the atmosphere. These greenhouse gases trap sunlight and cause planet to warm. The burning of coal and oil increases the temperature and causes global warming . To reduce the impact of

greenhouse gases , people around the world are using biofuels. Studies suggests that biofuels reduces greenhouse gases up to 65 percent.

5. Economic Security: Not every country has large reserves of crude oil. For them, having to import the oil puts a huge dent in the economy. If more people start shifting towards biofuels, a country can reduce its dependance on fossil fuels. More jobs will be created with a growing biofuel industry, which will keep our economy secure.

6. Reduce Dependance on Foreign Oil: While locally grown crops has reduce the nation's dependance on

fossil fuels, many experts believe that it will take a long time to solve our energy needs. As prices of crude oil is touching sky high, we need some more alternative energy solutions to reduce our dependance on fossil fuels.

7. Lower Levels of Pollution: Since biofuels can be made from renewable resources, they cause less pollution to the planet. However, that is not the only reason why the use of biofuels is being encouraged. They release lower levels of carbon dioxide and other emissions when burnt. Although the production of biofuels creates carbon dioxide as a byproduct, it is frequently used to grow the plants that will be converted into the fuel. This allows it to become something close to a self sustaining system.

Disadvantages of Biofuels

1. High Cost of Production: Even with all the benefits associated with biofuels, they are quite expensive to produce in the current market. As of now, the interest and capital investment being put into biofuel production is fairly low but it can match demand. If the demand increases, then increasing the supply will be a long term operation, which will be quite expensive. Such a disadvantage is still preventing the use of biofuels from becoming more popular.

2. Monoculture: Monoculture refers to practice of producing same crops year after year, rather than producing various crops through a farmer's fields over time. While, this might be economically attractive for farmers but growing same crop every year may deprive the soil of nutrients that are put back into the soil through crop rotation.

3. Use of Fertilizers: Biofuels are produced from crops and these crops need fertilizers to grow better. The downside of using fertilizers is that they can have harmful effects on surrounding environment and may cause water pollution . Fertilizers contain nitrogen and phosphorus. They can be washed away from soil to nearby lake, river or pond.

4. Shortage of Food: Biofuels are extracted from plants and crops that have high levels of sugar in them. However, most of these crops are also used as food crops.

Even though waste material from plants can be used as raw material, the requirement for such food crops will still exist. It will take up agricultural space from other crops, which can create a number of problems. Even if it does not cause an acute shortage of food, it will definitely put pressure on the current growth of crops. One major worry being faced by people is that the growing use of biofuels may just mean a rise in food prices as well.

5. Industrial Pollution: The carbon footprint of biofuels is less than the traditional forms of fuel when burnt. However, the process with which they are produced makes up for that. Production is largely dependent on lots of water and oil. Large scale industries meant for churning out biofuel are known to emit large amounts of emissions and cause small scale water pollution as well. Unless more efficient means of production are put into place, the overall carbon emission does not get a very big dent in it.

6. Water Use: Large quantities of water are required to irrigate the biofuel crops and it may impose strain on local and regional water resources, if not managed wisely. In order to produce corn based ethanol to meet local demand for biofuels, massive quantities of water are used that could put unsustainable pressure on local water resources.

7. Future Rise in Price: Current technology being employed for the production of biofuels is not as efficient as it should be. Scientists are engaged in developing better means by which we can extract this fuel. However, the cost of research and future installation means that the price of biofuels will see a significant spike. As of now, the prices are comparable with gasoline and are still feasible. Constantly rising prices may make the use of biofuels as harsh on the economy as the rising gas prices are doing right now.

Application nd synthesis

In this lab, we had multiple goals which we reached using a variety of experiments and analysis

techniques. We wanted to investigate the synthesis, ecotoxicity, and other characterizations of various

biofuels. We synthesized both biodiesel and ethanol; biodiesel by transesterifying waste cooking oil to combine triglyceride groups with alcohols, and ethanol by fermenting and distilling white grape juice.

We measured the ecotoxicities of these biofuels, along with 2-butanol and methanol, by analyzing the

effects of the biofuels on radish seed germination with respect to concentration. Finally, we analyzed

our biofuels by determining their densities, viscosities, and (perhaps most importantly) their heats of

combustion. We found that biodiesel was the least toxic of all the substances, and also had the

highest heating value, making a strong case for its use as a biofuel.16The first portion of our lab consisted of the synthesis of ethanol and biodiesel fuels. We synthesized

biodiesel using a reaction of triglycerides and alcohol, once with an acid catalyst and once with an

alkaline catalyst (Figure 1), a process known as transesterification. In our lab, we utilized wastecooking oil from Crossroads Dining for our triglycerides, and used both methanol (catalyzed basically

by NaOH) and propanol (catalyzed acidically by H_2SO_4) as our alcohols. After synthesis, we used

NaCl and $MgSO_4$ samples to remove water from the sample, and subsequently evaporated off the excess organic solvents to isolate the biodiesel. The major advantage to using this process was that it

is a comparatively easy way to synthesize biofuels using fairly common ingredients.

Ethanol, on the other hand, was synthesized in an extremely different manner. By applying yeast’s

ability to convert raw sugars into ethanol and carbon dioxide in an anaerobic environment (also

known as brewing or fermentation), we were able to create a solution containing a relatively high

percentage of ethanol (approximately 20 proof, where yeast begins to die out). The process by which

yeast turns common table sugar (sucrose) into ethanol is detailed in Figure 2. This process is

incredibly easy to operate, and in fact has been used by man for millenia. However, it is not by itself

a suitable process for producing high-purity ethanol; the resulting mixture contains mostly water,

with a small fraction ethanol and large amounts of grape juice and yeast impurities.

To isolate the ethanol to a much higher-purity state, filtration followed by distillation (Figure 3) of the filtrate is our process of choice, heating the mixture at a temperature of about 80°C such that only 95% pure ethanol vapors boil off and are condensed off in a separate container. Distillation is an

Global Biofuel Scenarios

Renewable resources are more evenly distributed than fossil and nuclear resources, and energy flows from renewable resources are more than three orders of magnitude higher than current global energy use. Today’s energy system is unsustainable because of uncompeting issues as well as environmental, economic, and geopolitical concerns that have implications far into the future (UNDP, 2000).

According to the International Energy Agency (IEA), scenarios developed for the USA and the EU indicate that near-term targets of up to 6% displacement of petroleum fuels with biofuels appear feasible using conventional biofuels, given available cropland. A 5% displacement of gasoline in the EU would require about

5% of available cropland to produce ethanol, while in the USA 8% would be required. A 5% displacement of diesel would require 13% of US cropland and 15%

in the EU. The recent commitment by the US government to increase bioenergy

threefold in 10 years has added impetus to the search for viable biofuels (IEA,

2004).

Dwindling fossil fuel stocks and the increasing dependency of the USA on imported crude oil have led to a major interest in expanding the use of bioenergy.

The EU has also adopted a proposal for a directive promoting the use of biofuels

with measures ensuring that biofuels would account for at least 2% of the market

for gasoline and diesel sold as transport fuel by the end of 2005, increasing in

stages to a minimum of 5.75% by the end of 2010 (Hansen et al., 2005). Biomass

can be converted into biofuels such as bioethanol and biodiesel and thermochemical conversion products such as syn-oil, bio-syngas, and biochemicals. Bioethanol

is a fuel derived from renewable sources of feedstock, typically plants such as

wheat, sugar beet, corn, straw, and wood. Bioethanol is a petroleum additive/substitute, and biodiesel is better than diesel fuel in terms of sulfur content, flash point, aromatic content, and biodegradability (Bala, 2005).

Figure 2.7 shows the alternative fuel projections for total automotive fuel consumption in the world. Hydrogen is currently more expensive than conventional energy sources. There are different technologies presently being applied to produce hydrogen economically from biomass. Biohydrogen technology will play a major role in the future because it can utilize renewable sources of energy (Nath and Das, 2003).

Hydrogen for fleet vehicles will probably dominate in the transportation sector in the future. To produce hydrogen via electrolysis and the transportation of liquefied hydrogen to rural areas with pipelines would be expensive. The production technology would be site specific and include steam reforming of methane and electrolysis in hydropower-rich countries. In the long run, when hydrogen is a very common energy carrier, distribution via pipeline is probably the preferred option. The cost of hydrogen distribution and refueling is very site specific. 20

Bukur, D.B., Nowicki, L., Manne, R.V., Lang, X. 1995. Activation studies with a precipitated

iron catalysts for the Fischer–Tropsch synthesis. J Catal 155:366−375

Cadenas, A., Cabezudo, S. 1998. Biofuels as sustainable technologies: perspectives for less

developed countries. Technol Forecast Social Change 58:83–103

Canakci, M., Van Gerpen, J. 2001. Biodiesel production from oils and fats with high free fatty

acids. Am Soc Agric Eng 4:1429−1436

Castro, F.B., Hotten, P.M., Ørskov, E.R. 1993. The potential of dilute-acid hydrolysis as a treatment for improving the nutritional quality of industrial lignocellulosic by products. Animal

Feed Sci Technol 42:39−53

Chmielniak, T., Sciazko, M. 2003. Co-gasification of biomass and coal for methanol synthesis.

Energy 74:393−403

Choudhary, T.V., Goodman, D.W. 2000. CO-free production of hydrogen via stepwise steam reforming of methane. J Catal 192:316−321

Davis, B.H. 2002. Overview of reactors for liquid phase Fischer–Tropsch synthesis. Catal Today 71:249−300

Demirbas, A. 1999. Fuel properties of charcoal derived from hazelnut shell and the production of briquets using pyrolytic oil. Energy 24:141−150

Demirbas, A. 2000. Mechanisms of liquefaction and pyrolysis reactions of biomass. Energy Convers Mgmt 41:633−646

Demirbas, A. 2002. Biodiesel from vegetable oils via transesterification in supercritical methanol. Energy Convers Mgmt 43:2349−2356

Demirbas, A. 2003. Biodiesel fuels from vegetable oils via catalytic and non-catalytic supercritical alcohol transesterifications and other methods: a survey. Energy Convers Mgmt 44:2093−2109

Demirbas, A. 2004. Hydrogen rich gas from fruit shells via supercritical water extraction. Int J

Hydrogen Energy 29:1237−1243

Demirbas, A. 2005. Biodiesel production from vegetable oils via catalytic and non-catalytic

supercritical methanol transesterification methods. Prog Energy Combust Sci 31:466−487

Demirbas, A. 2006a. Global biofuel strategies. Energy Edu Sci Technol 17:27−63.

Demirbas, A. 2006b. Biogas potential of manure and straw mixtures. Energy Sour 28:71−78

Demirbas, M.F. 2006c. Hydrogen from various biomass species via pyrolysis and steam gasification processes. Energy Sour A 28:245−252

Demirbas, A., Arin, G. 2002. An overview of biomass pyrolysis. Energy Sour 5:471−482

Demirbas, M.F., Balat, M. 2006. Recent advances on the production and utilization trends of biofuels: a global perspective. Energy Convers Mgmt 47:2371−2381

Demirbas, A., Gullu, D. 1998. Acetic acid, methanol and acetone from lignocellulosics by pyrpolysis. Edu Sci Technol 1:111−115

Difiglio, C. 1997. Using advanced technologies to reduce motor vehicle greenhouse gas emissions. Energy Policy 25:1173−1178

Dong, Y., Steinberg, M. 1997. Hynol—an economical process for methanol production from biomass and natural gas with reduced CO2 emission. Int J Hydrogen Energy 22:971−977

Dry, M.E. 1999. Fischer−Tropsch reactions and the environment. Appl Catal A General 189:185−190

Dry, M.E. 2002a. High quality diesel via the Fischer–Tropsch process-a review. J Chem Technol Biotechnol 77:43−50

Dry, M.E. 2002b. The Fischer–Tropsch process: 1950−2000. Catal Today 71:227−241.

Dry, M.E. 2004. Present and future applications of the Fischer−Tropsch process. Appl Catal A 276:1−3.

EC (European Commission). 2004. Promoting Biofuels in Europe. European Commission, Directorate -General for Energy and Transport, B-1049 Brussels, Belgium.

http://europa.eu.int/comm/dgs/energy_transport/index_en.html.

Encinar, J.M., Beltran, F.J., Ramiro, A., Gonzalez, J.F. 1998. Pyrolysis/gasification of agricultural residues by carbon dioxide in the presence of different additives: influence of variables.

Fuel Process Technol 55:219−233. 25

Ghadge, S.V., Raheman, H. 2006. Process optimization for biodiesel production from mahua

(Madhuca indica) oil using response surface methodology. Bioresour Technol 97:379−384.

Grassi, G. 1999. Modern bioenergy in the European Union. Renew Energy 6:985−990.

Gullu, D., Demirbas, A. 2001. Biomass to methanol via pyrolysis process. Energy Convers

Mgmt 42:1349−1356.

Haas, M.J., McAloon, A.J., Yee, W.C., Foglia, T.A. 2006. A process model to estimate biodiesel

production costs. Bioresour Technol 97:671−678.

Hall, D.O., Rosillo-Calle, F., Williams, R.H., Woods, J. 1993. Biomass for energy: supply prospects: Johansson, T.B., Kelly, H., Reddy, A.K.N., Williams, R.H. (eds.) Renewable Energy–for Fuels and Electricity. Island Press, Washington, D.C.

Hansen, A.C., Zhang, Q., Lyne, P.W.L. 2005. Ethanol–diesel fuel blends––a review. Technology

96:277−285.

Hao, X.H., Guo, L.J. 2002. A review on investigation of hydrogen production by biomass catalytic gasification in supercritical water. Huagong Xuebao 53:221−8 [in Chinese].

IEA (International Energy Agency). 2004. Biofuels for transport: an international perspective. 9,

rue de la Fédération, 75739 Paris, cedex 15, France. www.iea.org.

IPCC. 1997. Greenhouse Gas Inventory Reference Manual: Revised 1996 IPCC Guidelines for

National Greenhouse Gas Inventories, Report Vol. 3, p. 1.53, Intergovernmental Panel on

Climate Change (IPCC), Paris, France. www.ipcc.ch/pub/guide.htm.

Iwasa, N., Kudo, S., Takahashi, H., Masuda, S., Takezawa, N. 1993. Highly selective supported

Pd catalysts for steam reforming of methanol. Catal Lett 19:211−216.

Jager, B. 1998. Proceedings of the 5th Natural Gas Conversion Symposium, Taormina, Italy, September 1998.

Jin, Y., Datye, A.K. 2000. Phase transformations in iron Fischer–Tropsch catalysts during temperature-programmed reduction. J Catal 196:8−17.

Jothimurugesan, K., Goodwin, J.G., Santosh, S.K., Spivey, J.J. 2000. Development of Fe Fischer–Tropsch catalysts for slurry bubble column reactors. Catal Today 58:335−344.

Jun, K.W., Roh, H.S., Kim, K.S., Ryu, J.S., Lee, K.W. 2004. Catalytic investigation for Fischer–

Tropsch synthesis from bio-mass derived syngas. Appl Catal A 259:221−226.

Kapdi, S.S., Vijay, V.K., Rajesh, S.K., Prasad, R. 2005. Biogas scrubbing, compression and

storage: perspective and prospectus in Indian context. Renew Energy 30:1195−1202.

Kartha, S., Larson, E.D. 2000. Bioenergy primer: modernised biomass energy for sustainable

development, Technical Report UN Sales Number E.00.III.B.6, United Nations Development Programme, 1 United Nations Plaza, New York, NY 10017.

Kim, S., Dale, B.E. 2005. Life cycle assessment of various cropping systems utilized for producing: bioethanol and biodiesel. Biomass Bioenergy 29:426−439.

Kumar, A., Cameron, J.B., Flynn, P.C. 2005. Pipeline transport and simultaneous saccharification of corn stover. Bioresour Technol 96:819−829.

Larson, E. D, Jin H. 1999. In: Overend, R., Chornet, E. (eds.) Proceedings of the 4th Biomass

Conference of the Americas, Kidlington, UK, 29 August 1999, Elsevier, Amsterdam.

Lee, K.-W., Kim, S.-B., Jun, K.-W., Choi, M.-J. 2001. In: Williams, D.J., Durie, R.A., McMullan, P., Paulson, A.J., Smith, A.Y. (eds.) Proceedings of the 5th International Conference on

Greenhouse Gas Control Technology, Cairns, Australia, 13 August 2000, CSIRO.

Li, S., Krishnamoorthy, S., Li, A., Meitzner, G.D., Iglesia, E. 2002. Promoted iron-based catalysts for the Fischer–Tropsch synthesis: design, synthesis, site densities, and catalytic properties. J Catal 206:202−217.

MacLean, H.L., Lave, L.B. 2003. Evaluating automobile fuel/propulsion system technologies.

Energy Combust Sci 29:1−69.

Madras, G., Kolluru, C., Kumar, R. 2004. Synthesis of biodiesel in supercritical fluids. Fuel

83:2029−2033.

Maschio, G., Lucchesi, A., Stoppato, G. 1994. Production of syngas from biomass. Bioresour

Technol 48:119−126.

Matsumura, Y., Minowa, T. 2004. Fundamental design of a continuous biomass gasification

process using a supercritical water fluidized bed. Int J Hydrogen Energy 29:701−707.29