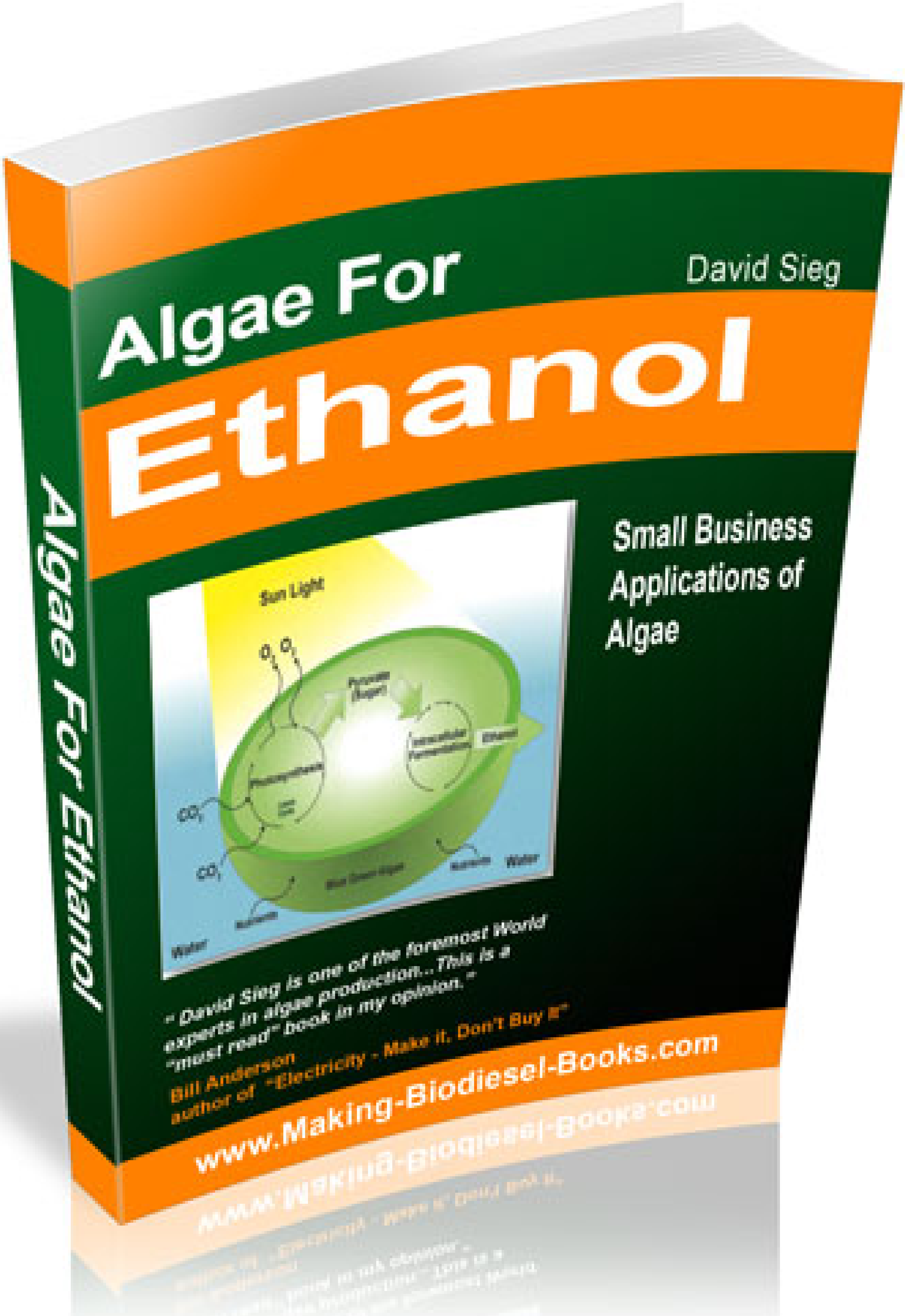
David Sieg
Algae For
Ethanol
Algae For Ethanol
Small Business
Applications of
Algae
Sun Light
Water
Nutrients
" David Sieg is one of the foremost World
experts in algae production...This is a
"must read" book in my opinion."
Bill Anderson
author of "Electricity - Make it, Don't Buy It"
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Rex Zeitman of Whitfield Consult, in South Africa, who is a longtime friend and client of mine. He has keep in touch with me over the years and generously supplied the photos and design of the small scale design. Rex can be contacted for algae to ethanol projects here: mailto:rex@process.co.za

http://www.process.co.za

The late Robert Warren, at http://ethanolpro.tripod.com/index.html for providing excellent open source material.

www.wikicommons.org for photos and illustrations except where indicated.

The National Renewable Energy Lab (NREL) and US Dept. of Energy (DOE) for the excellent work and documentation they make available to everyone. This is probably the greatest alternative energy resource on the planet.

Closed pond photos courtesy of Algae Venture Systems used with permission. Builders of quality covered open pond systems.

I'd also like to thank the following contributors for allowing me to use their pictures and text.

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Bruce Padula at www.efuel100.com

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Introduction

This book is about small scale algae to ethanol production in the United States. Ethanol is a contentious issue. Many feel that it is contributing to worldwide rise in the cost of food, and that growing food, to create fuel, is at best, a zero sum game. Whatever your opinion, or politics on the subject, algae sidesteps all these issues.

There are a lot of myths and misconceptions about ethanol in general, and algae's role in ethanol production in particular. These myths are perpetuated by the most part by heavily funded academic and industry interests of Mega-Oil.

> **Developing the next generation of biofuels is key to our effort to end our dependence on foreign oil and address the climate crisis – while creating millions of new jobs that can't be outsourced**
>
> — *Secretary of Energy Steven Chu at the White House ceremony on May 5, 2009, announcing $800 million in new biofuel research activities*

Small scale production of biofuels and transportation fuels in particular, threatens their power base. They have waged an on-going battle against biofuels for over 100 years. It is time to end their strangle-hold on our country and world.

Why use algae for ethanol?

- Algae can be grown on non-arable land not taking away from the productive farmland.
- Algae require fewer inputs than traditional sources.
- The EROI - Energy Returned is much higher than Energy Invested or required to produce algae ethanol.
- Making algae ethanol does not require a very complicated equipment or machinery to set it up.
- Algae ethanol plant does not use food crops.
- The alga to ethanol process produces many valuable by-products.
- A by-product of the fermentation process is CO2…a valuable component needed in maximizing algae production.
- You can press the oil from specific strains of algae to make biodiesel, and then use the left over biomass for ethanol…two transportation fuel products in one.

This book makes a number of assumptions about the reader. First, that you're considering either building or running a small scale algae to ethanol business. This isn't for the faint hearted. While it can certainly be done on very small or home scale, this book is more geared to small business sized production.

Second, it assumes you have some capital (money) to begin with. How much money necessary will be determined by your location and personal situation. Some money is required for upfront equipment and feedstock costs. I have however, given worksheets you can use to determine costs on your specific situation.

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Third, it assumes you are living in the US or a developed country. If you're living in a developing country, the basic principles will still apply however you'll need to adjust your expectations to your local conditions and background.

I've also included a lot of info about traditional ethanol feed stocks and production. I did this not to "pad" the book, but in reality you may want to start in a more traditional manner and add algae to the mix. In other situations you may want to add other feed stocks to your algae to boost production. In either event understanding traditional ethanol production is paramount.

This book is also designed to be a complete reference manual. It is, as far as I know, the only one of its kind available anywhere, at any price.

The need for small scale solutions

This book is part of an on-going series dedicated to using algae as a feedstock for various energy solutions. Part of the energy and food problem we now face is that a select few companies have the ability to hold the world's energy and food production hostage to their own profit goals.

Make no mistake, without energy, there is no food.

In order to break this energy strangle-hold, small, localized energy producers are critical and necessary.

In short, you.

If enough small scale and geographically located producers were to band together either as an independent organization or as an energy co-op this could effectively create enough competition in the market place to not only force prices down, but also break up the energy monopoly.

Don't expect the government to stand up and applaud your initiative. The energy industrial complex has long ago infiltrated every aspect of government. Instead, expect the opposite. Expect that they will hinder you at every step of the process. This is why it is also important to understand the process, and legally fulfill every obligation you're expected to fulfill. If you don't, *and that is what they expect*, you're just giving them reason to shut you down. Obey every law, but also use the same loop-holes and subsidies that Big-Oil uses. You play this game by beating them at their own game. I have tried to provide extensive documentation of both.

Working together we can profit, feed our families and country, even the world, heat or cool our homes, have more than enough transportation fuels, and end the endless oil wars, as well as break the energy strangle-hold on our country and world. Never forget, WE are the 99%. Standing together, we can make a difference. This, in the end, is what this book is about.

David Sieg
Dec. 2011
Des Moines, IA

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Forward

by Bill Anderson
author of "Electricity - Make it, Don't Buy It"
www.electricitybook.com

I first have to start out by saying... "I can't believe somebody didn't think of this earlier!" We already know that algae are one of the best sources for oil. Algae produces 100x more oil per acre than soybeans and 10x more oil per acres than the next best thing - jatropha. And now, David Sieg is telling us that you can make ethanol from the leftovers after you extract all the oil?! That's a lot of energy extracted from just one small acre of algae!

It's no secret that entire countries run on ethanol. Brazil is almost totally self-sufficient when it comes to its transportation energy needs. That's why they are called the Saudi Arabia of ethanol. Most of the vehicles in Brazil run on 100% ethanol or E100. They produce their ethanol from sugar cane and use the stalks to burn for heat in the distillation process. US ethanol producers mostly use corn as a feedstock which only produces about half the ethanol per acre that sugar cane does. US producers also use electricity or natural gas in the distillation process further diminishing the ROI. Heck... we can't even grow sugar cane in most of the US, so how are we going to compete?

Maybe algae are the answer! And David Sieg is the man with the answers to all your algae questions. He is one of the foremost World experts in algae production. He has written many books on the subject in recent years. Most of his subject matter was about algae for oil production. The oil could be extracted and used to make biodiesel. This oil production process in itself is 10x more efficient that the nearest source crop. Now we are learning from this new book, that you can take the byproduct of the oil production process and make another fuel to run our gas guzzling cars.

Did you know that if you buy a Flex Fuel Vehicle (FFV), it's good to go to run on E85 ethanol? A lot of cars manufactured today are FFVs. You may be driving one and not even know it. With the economy going as it is, and I expect it to get much worse before it gets better, you may want to seriously look into Made in America algae ethanol as a source for fuel in the near future. It just may turn out that you are still driving when others are parked in their driveway. This is a "must read" book in my opinion.

Sincerely,
Bill Anderson

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How to use this eBook

This book will give you an overview of how algae can be converted to ethanol. In an age where our natural resources such oil, natural gas and even coal are becoming increasingly harder to find, becoming more of a threat to the environment and with prices soaring out of control, algae can be a renewable resource that can create a more environmentally friendly future for our planet.

This book is a how to manual of algae to ethanol conversion. It is meant to allow investors and others just interested in the process to have a peek inside this new technology and potential gold mine industry. This is not a book on how to make ethanol in your bath tub; rather you will learn how it is done in plants and why this new technology is so important.

This book is set up to assist you in the following ways

- To thoroughly understand the algae to ethanol process as well as the fundamentals of alcohol fermentation.
- The different algal strain for Ethanol
- Where to buy algae strains.
- Build a home ethanol still for personal production.
- To thoroughly prepare you to successfully buy an ethanol still.
- To guide you through the process of building and setting up a small scale ethanol plant.
- To guide you in building and setting up a large scale ethanol plant.
- To help you understand the legal requirements related to ethanol production.
- To advise on the local and federal government tax breaks available to you to start.
- A resource guide to get most parts and equipement.
- Detailed reference sources to get further information.

In this book you will learn how algae can be used to create ethanol rather than feed stocks such as corn and sugar cane. This conversion of algae to Ethanol is possible by converting the starch (the storage component) and Cellulose (the cell wall component). In this book you will learn the process of how this is done. The science is relatively simple, the potential as a renewable resource is huge.

Feel free to contribute to futures editions by sharing your stories (Horror or success) with me anytime. Or if you just want to sound off. I love talking to my readers. You'll get a personal replay back. Email me here: dsieg@making-biodiesel-books.com

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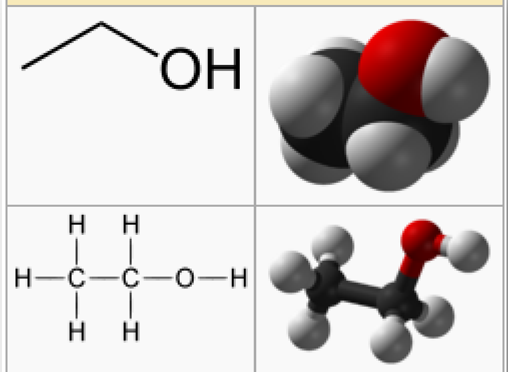
What is Ethanol?

In order for you to understand the process of conversion of algae to ethanol, you must first have an understanding of what Ethanol is. Ethanol, also called ethyl alcohol, pure alcohol, grain alcohol, or drinking alcohol. It is a volatile, flammable, colorless liquid. It is the ingredient found in alcoholic beverages. Ethanol is also used in thermometers, as a solvent, and as a fuel. In common usage, it is often referred to simply as alcohol or spirits.

Ethanol



Systematic name
Ethanol[1]

Other names
Absolute alcohol
Alcohol
Drinking alcohol
Ethyl alcohol
Ethyl hydrate
Ethyl hydroxide
Ethylic alcohol
Ethylol
Grain alcohol
Hydroxyethane
Methylcarbinol

For those with a scientific bent, Ethanol is a straight-chain alcohol, and its molecular formula is C_2H_5OH. Its empirical formula is C_2H_6O. An alternative notation is $CH_3–CH_2–OH$, which indicates that the carbon of a methyl group ($CH_3–$) is attached to the carbon of a methylene group ($–CH_2–$), which is attached to the oxygen of a hydroxyl group (–OH). It is a constitutional isomer of dimethyl ether. Ethanol is often abbreviated as EtOH, using the common organic chemistry notation of representing the ethyl group (C_2H_5) with Et.

Fermentation is a natural process and therefore it was one of the earliest organic reactions employed by humanity. There are records of the intoxicating effects of ethanol consumption dating back centuries. In modern times, ethanol intended for industrial use is also produced from ethylene. Ethanol has been used as a solvent of substances intended for human contact or consumption, including scents, flavorings, colorings, and medicines. In chemistry, it is both an essential solvent and a feedstock for the synthesis of other products. Ethanol has been used for many years as a fuel for heat and light, and more recently as a fuel for internal combustion engines.

Fossil fuels supply about 90% of the energy needs in the United States and other industrialized nations. Coal, oil, and natural gas are nonrenewable energy resources, and are being consumed rapidly. Alternative sources of energy include: solar, wine, biomass, hydroelectric, geothermal, nuclear, and tidal energy. Many of these alternative energy resources are renewable sources. They are replaced naturally, such as plant life; or are readily available, like sun and wind.

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History of Ethanol

We have used ethanol for centuries as the intoxicating ingredient of alcoholic beverages. Researchers have discovered dried residue on 9,000-year-old pottery found in China imply that Neolithic people consumed alcoholic beverages. The process is nothing new, and so the idea of creating ethanol for use in cars from algae is a very old process using new technology.

Although distillation was well known by the early Greeks and Arabs, the first recorded production of alcohol from distilled wine was by the School of Salerno alchemists in the 12th century. The first to mention absolute alcohol, in contrast with alcohol-water mixtures, was Raymond Lull.

In 1796, Johann Tobias Lowitz obtained pure ethanol by filtering distilled ethanol through activated charcoal. Antoine Lavoisier described ethanol as a compound of carbon, hydrogen, and oxygen, and in 1808 Nicolas-Théodore de Saussure determined ethanol's chemical formula. Fifty years later, Archibald Scott Couper published the structural formula of ethanol. It is one of the first structural formulas determined. The process of fermentation is from organic material is nothing new, just our understanding and application has grown over time.

Ethanol was first prepared synthetically in 1826 through the independent efforts of Henry Hennel in Great Britain and S.G. Sérullas in France. In 1828, Michael Faraday prepared ethanol by acid-catalyzed hydration of ethylene, a process similar to current industrial ethanol synthesis.

Here in the United States ethanol was used as lamp fuel as early as 1840, but a tax levied on industrial alcohol during the Civil War made this use uneconomical. The tax was repealed in 1906. Original Ford Model T automobiles ran on ethanol until 1908. That's right; the first cars in the world ran on ethanol, not fossil fuels. So what happened? With the advent of Prohibition in 1920, ethanol fuel sellers were accused of being allied with moonshiners, and ethanol fuel fell into disuse until late in the 20th century.

The use of ethanol as a fuel has grown since the late 1970s. It was first used as a gasoline extender because of oil shortages. In 1973, the Organization of Petroleum Exporting Countries (OPEC) caused gasoline shortages by increasing prices and blocking shipments of crude oil to the United States.

The OPEC action called attention to the fact that the United States was extremely dependent on foreign oil. The focus shifted once again to alternative fuels such as ethanol. At that time gasoline containing ethanol was called "gasohol". Later, when gasoline was more plentiful, ethanol-blended gasoline was introduced to increase the octane rating and the name "gasohol" was dropped in favor of names reflecting the higher octane levels. "E-10 Unleaded" and "super unleaded" are examples of names used today.

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We stand now in the 21st Century and we are returning to the idea of ethanol as a fuel and using renewable organic resources, and specifically algae in this current incarnation.

The current state of the ethanol industry is an important story in American manufacturing over the past quarter century. In 1980 the US was producing 175 million gallons of ethanol, but as of 2010 they were producing 13 billion gallons. In 1991, there were 35 plants producing 865 gallons of ethanol, most were from plant sources such as corn.

Two- thirds of capacity was accounted for by wet mill plants which had an average capacity of 16.5 MGY. Today there are well over 200 plants with an annual capacity of nearly 13.5 billion gallons. Dry mill plants account for more than 70 percent of capacity and most new ethanol plants are dry mills using grain as a feedstock or second generation plants designed to produce ethanol from Advanced Biofuel Feed stocks or cellulose.

Burning fossil fuels (oil, gasoline, and natural gas) produces carbon dioxide gas. Carbon dioxide is on the main greenhouse gases that contribute to global warming. Burning coal and gasoline also produces pollution that contributes to smog and acid rain.

Using renewable energy resources (solar, wind, biomass, geothermal, and hydropower) could help prevent global warming and reduce pollution and acid rain. Nuclear energy is also a renewable source; however, it requires storing radioactive waste created by nuclear power plants. The other alternative and renewable resource is ethanol. Ethanol burns cleaner than fossil fuels and is usually made from fermenting grains. In this book you will learn how algae can be fermented as well to create ethanol.

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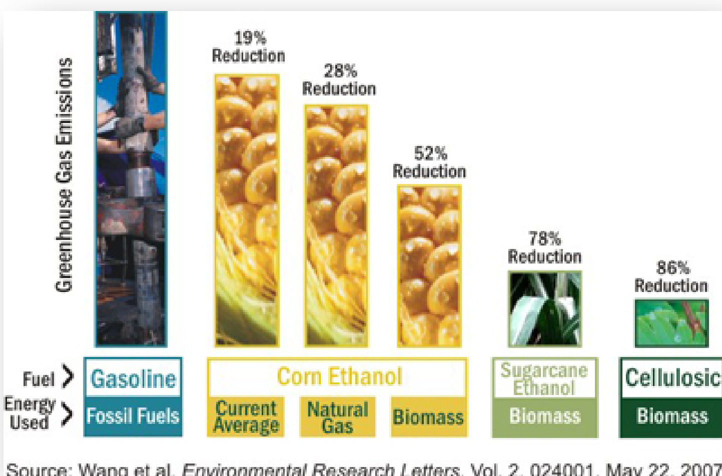
Ethanol myths

I don't need to get on a soap box or point any fingers about why there are so many untrue myths about ethanol. If people began using ethanol rather than fossil fuels for their energy needs, it does not take a rocket scientist to figure out which industry this might hurt, so it is little wonder why there are so many groups providing false information about the use of ethanol as a viable fuel source. Let us look at what the Department of Energy has to say on the subject of Ethanol. They are supposedly unbiased.

MYTH: In terms of emissions, ethanol pollutes the same as gasoline or more.

FACT: Ethanol results in fewer greenhouse gas (GHG) emissions than gasoline and is fully biodegradable, unlike some fuel additives.

- Today, on a life cycle basis, ethanol produced from corn results in about a 20 percent reduction in GHG emissions relative to gasoline. With improved efficiency and use of renewable energy, this reduction could be as much as 52 percent.
- In the future, ethanol produced from cellulose has the potential to cut life cycle GHG emissions by up to 86 percent relative to gasoline.
- Ethanol blended fuels currently in the market – whether E10 or E85 – meet stringent tailpipe emission standards.
- Ethanol readily biodegrades without harm to the environment, and is a safe, high-performance replacement for fuel additives such as MTBE.



In comparison to gasoline, ethanol made from cellulose and produced with power generated from biomass byproducts can result in an 86 percent reduction in greenhouse gas emissions.

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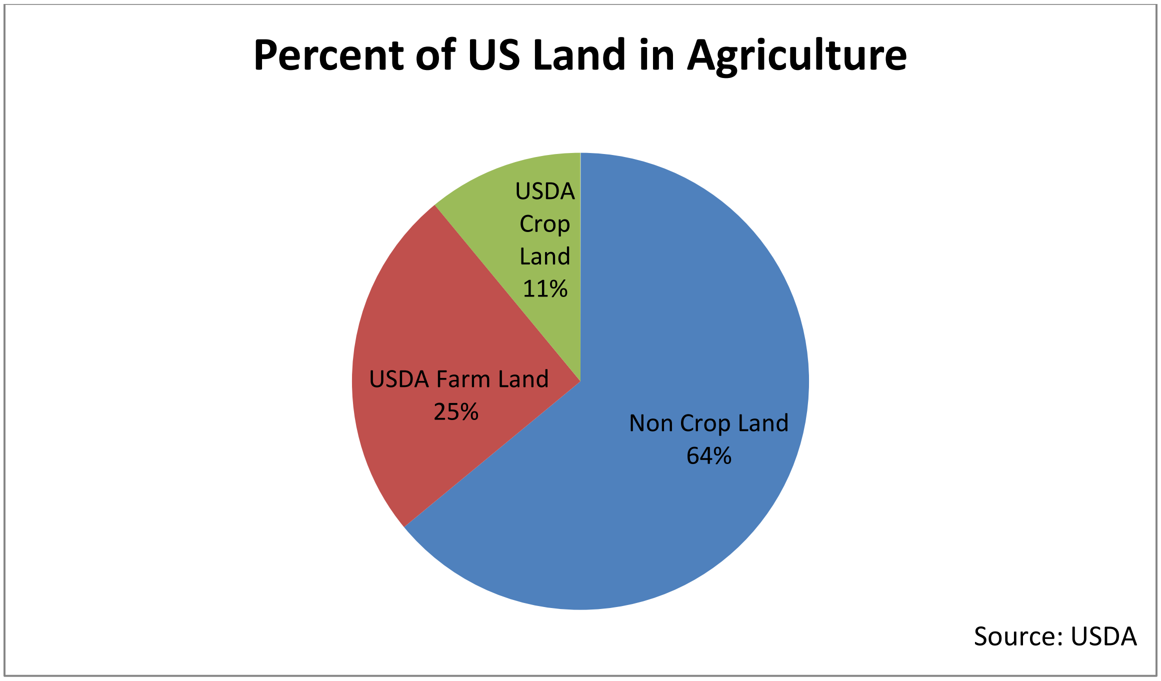
MYTH: Ethanol cannot be produced from corn in large enough quantities to make a real difference without disrupting food and feed supplies.

FACT: Corn is only one source of ethanol. As we develop new, cost-effective methods for producing biofuels, a significant amount of ethanol will be made from more abundant cellulosic biomass sources.

- Future ethanol will be produced increasingly from cellulose found in crop residues (e.g., stalks, hulls), forestry residues (e.g., forest thinning, wood byproducts), energy crops (e.g., switchgrass, sorghum), and sorted municipal wastes. Some promising energy crops grow on marginal soils not suited for traditional agriculture.
- A high-protein animal feed, known as Distiller's Dried Grains with Solubles (DDGS), is produced in the process of making ethanol from corn.
- The *Energy Independence and Security Act* of 2007 (EISA) requires use of 36 billion gallons of renewable transportation fuels in the U.S. by 2022. Of that quantity, 16 billion gallons must be cellulosic biofuels. Ethanol from corn is capped at 15 billion gallons.
- The U.S. Departments of Energy and Agriculture's *Billion-Ton Study* found that we can grow adequate biomass feed stocks to displace approximately 30 percent of current gasoline consumption by 2030 on a sustainable basis – with only modest changes in land use. It determined that 1.3 billion tons of U.S. biomass feedstock is potentially available for the production of biofuels – more than enough biomass to meet the new renewable fuel standard mandated by EISA.



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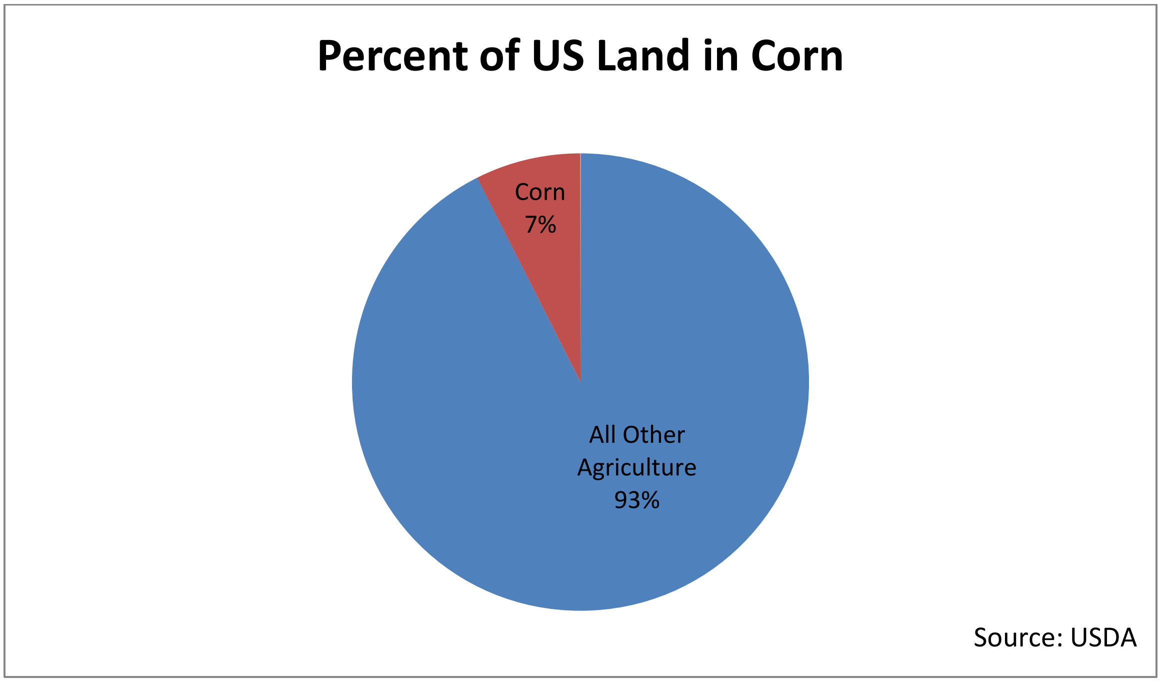

MYTH: More energy goes into producing ethanol than it delivers as a fuel.

FACT: In terms of fossil energy, each gallon of ethanol produced from corn today delivers one third or more energy than is used to produce it.

- Ethanol has a positive energy balance – that is, the energy content of ethanol is greater than the fossil energy used to produce it – and this balance is constantly improving with new technologies.
- Over the last 20 years, the amount of energy needed to produce ethanol from corn has significantly decreased because of improved farming techniques, more efficient use of fertilizers and pesticides, higher-yielding crops, and more energy-efficient conversion technology.
- Most studies that claim a negative energy balance for ethanol fail to take into account the energy contained in the co-products.

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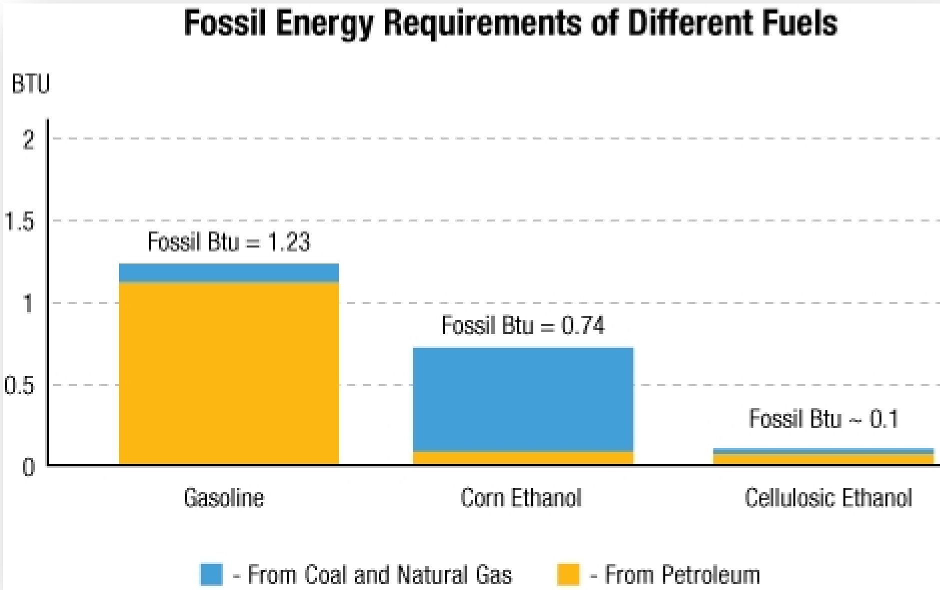

This graph shows how much fossil energy is required to provide 1 BTU of each fuel at the pump. The graph does not reflect energy derived from solar or other renewable sources used in the production of ethanol.

MYTH: Ethanol-gasoline blends can lower fuel economy and may harm your engine.

FACT: Ethanol blends in use today have little impact on fuel economy or vehicle performance.

- While ethanol delivers less energy than gasoline on a gallon-for-gallon basis, today's vehicles are designed to run on gasoline blended with small amounts of ethanol (10 percent or less) with no perceptible effect on fuel economy.
- Flex-fuel vehicles designed to run on higher ethanol blends (E85 or 85 percent ethanol) do experience reduced miles per gallon, but show a significant gain in horsepower.
- As a high-octane fuel additive and substitute for MTBE, ethanol enhances engine performance and adds oxygen to meet requirements for reformulated gasoline.

Race cars of the Indy Racing League benefit from the high performance characteristics of ethanol.

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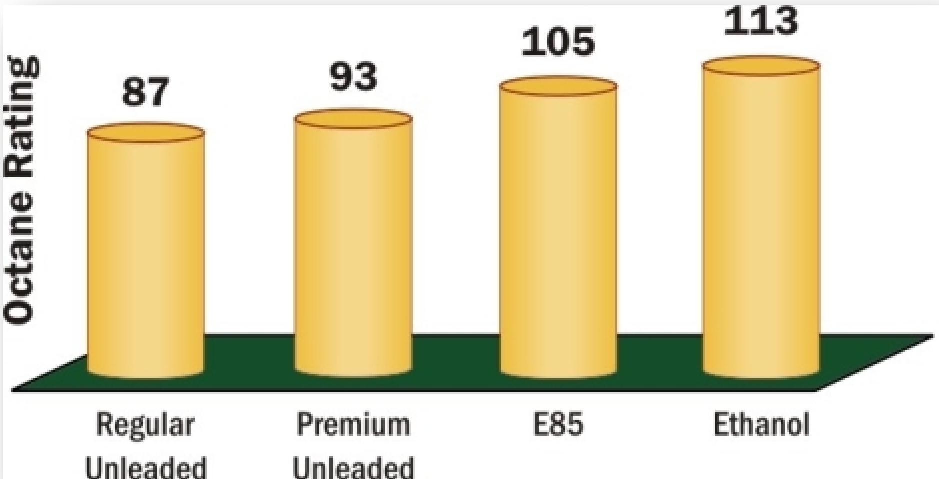

MYTH: Rainforests will be destroyed to create the new croplands required to meet food, feed, and biofuels needs, thus accelerating climate change and destroying valuable ecosystems.

FACT: Biofuels have the potential to significantly reduce global GHG emissions associated with transportation, but—as with all types of development—controls are needed to protect ecologically important lands.

- In Brazil and elsewhere, laws have already slowed deforestation, and for the past decade China has converted marginal croplands to grassland and forests to control erosion.
- Links between U.S. ethanol production and land use changes elsewhere are uncertain. We cannot simply assume that increases in U.S. ethanol production will lead to increased crop production abroad. Since 2002, during the greatest period of ethanol growth, U.S. corn exports increased by 60 percent and exports of Distiller's Dried Grains (DDGs) also increased steadily. In part, improvements in U.S. corn yield (about 1.6 percent annually since 1980) have enabled simultaneous growth in corn and ethanol production.
- Greenhouse gas emissions will decrease dramatically as biofuels of the future are increasingly made from cellulosic feed stocks and as the associated farming, harvesting, transport, and production processes increasingly use clean, renewable energy sources.

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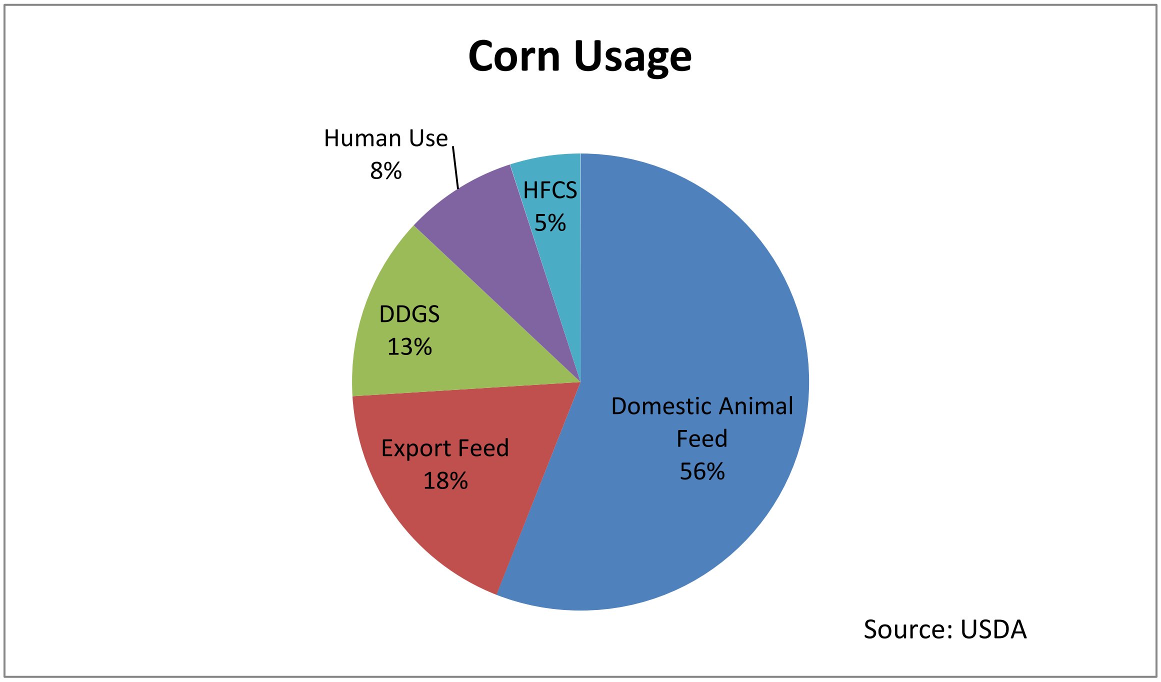
MYTH: Myth: It's Food vs. Fuel!

FACT: Only 8 percent of all corn grown in this country is eaten by humans. The rest is No. 2 yellow field corn, which is indigestible to humans and used in animal feed, food supplements and ethanol.



Specifically, a bushel of corn used for ethanol produces 1.5 pounds of corn oil, 17.5 pounds of high-protein feed called DDGS, 2.6 pounds of corn meal and 31.5 pounds of starch. The starch can be converted to sweeteners or used to produce 2.8 gallons of ethanol. DDGS displaces whole corn and some soybeans traditionally used in animal feed. The United States is a large exporter of DDGS to China and other countries.

Additionally, the food-versus-fuel debate has spurred significant research and development of second-generation biofuels like cellulosic ethanol that do not use food crops. Cellulosic ethanol is made from the "woody" structural material in plants that is unusable by humans. Unlike food crops, ethanol crops and cellulosic ethanol crops can grow in any soil that will sustain grass.

Researchers, including Argonne, are investigating using marginal land to grow ethanol crops. Studies from the U.S. Department of Energy suggest the United States has enough non-edible biomass to produce approximately 30 percent of our total transportation fuel requirements by 2030. That could go a long way toward easing our reliance on imported petroleum.

Taken together, the increase in crop yield and the use of marginal lands can enable us to produce food and fuels.

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Myth: Ethanol requires too much water to produce.

FACT: False. The amount of water used to make ethanol has declined dramatically. Today, producing one gallon of ethanol requires about 3.5 gallons of water. That's a little more than it takes to process a gallon of gasoline. Much of the criticism about ethanol's water requirements stem from the need to irrigate feedstock crops in drier climates. But most ethanol is produced from rain-fed crops grown in the Midwest.

In addition, ethanol is not carcinogenic and doesn't poison groundwater or the ocean. Ethanol rapidly biodegrades. Concerns over ethanol spills are muted by ethanol's low toxicity. In fact, you'll find ethanol in beer, bourbon and other happy-hour beverages you've probably consumed.

Myth: Cars get lower gas mileage with ethanol.

OK, this one's true. If you completely burn a gallon of gasoline and a gallon of E85, you'll get 25 percent less energy from the E85. Flex-fuel cars that run on gasoline and ethanol see 25 percent less mileage with ethanol. However, a gallon of ethanol costs approximately 17 percent less than that of a gallon of gasoline. In some, but not all, regions, the fuel-economy deficit is recovered by cheaper fuel costs. As the market grows and matures, production optimization would further drive down ethanol costs.

Research currently underway takes advantage of ethanol's characteristics in a fully optimized engine that could greatly reduce the energy deficit. Last year, for example, Delphi cut the fuel economy penalty by one-third — while simultaneously increasing power. Downsizing the engine, combined with cheaper E85, would result in cost savings to the consumer, potentially making E85 more favorable than gasoline. On the plus side, ethanol has a higher octane rating than gasoline so it can improve performance.

On a final note, it's important to take a step back and really look at our nation's energy position. Currently, the United States consumes 20 million barrels of oil per day, approximately a quarter of the world's total. Seventy percent of that petroleum is used for transportation.

To meet that demand, we import 65 percent of what we consume. Yet, there are a number of hidden costs associated with the use of petroleum. A study conducted in 2003 showed that the true cost of a gallon of gasoline (including all indirect costs) was $5.28 per gallon. Yet in 2003, the average pump price for a gallon of gasoline was only $1.50. One can imagine what the actual cost is today by factoring in such indirect costs.

We produce about 900,000 barrels of ethanol per day in the United States. That surpasses the volume of petroleum we import from Nigeria and is within striking distance of the amount that

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we import from Venezuela or Saudi Arabia. Ethanol is making a real contribution to our energy needs and reducing our dependence on imported petroleum.

Size and Structure of the US Ethanol Industry

According to the Renewable Fuels Association as of September 1, 2010 the U.S. ethanol industry was made up of 200 nameplate refineries with a total capacity of 13.544 million gallons per year (MGY).[7] Of these, 192 refineries were operational with an annual capacity of 12.9 MGY. An additional 12 plants were under construction or undergoing expansion. The location of these ethanol plants is illustrated in the graphic below.

Ethanol production is concentrated in the Midwest corn-belt states. The top ten ethanol producing states also are the nation's leading corn producers.

As ethanol production shifts to new feed stocks necessary to meet RFS targets (non-corn starch Advanced Biofuel feed stocks and cellulose), the geographic distribution of ethanol production is expected to expand with the Southeast, Mid-Atlantic, and Northwestern states experiencing the most significant growth as more wood and wood waste feed stocks are used to produce bioenergy..

The U.S. ethanol industry is relatively un-concentrated. Based on capacity data published by RFA, the largest 10 ethanol producers currently account for less than 50 percent of total industry output while the largest three firms account for about 32 percent of total production.
Local farmer ownership has been a hallmark of the U.S. ethanol industry but ownership of ethanol production also has changed. In 1991 the majority of ethanol plants and production were

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corporate owned and operated. Farmer-owned cooperatives accounted for a small share of ownership and production. As recently as five years ago nearly half of all ethanol plants were owned and operated by farmer cooperatives or limited liability companies (LLC). These plants account for 38 percent of total ethanol production. However, during the last several years there has been a substantial influx of non-farmer venture capital into the ethanol market and the share of farmer ownership has declined.

How Ethanol is Used

Typically ethanol is blended with gasoline to produce an oxygenated motor fuel. Ethanol is used to improve octane in conventional gasoline, to add oxygen to meet Clean Air Act requirements, and as an extender for gasoline. While ethanol adds octane to gasoline it has a lower energy content.

According to the Oak Ridge National Laboratories ethanol provides on average 75,700 Btu's per gallon compared to 115,000 for motor gasoline.[9] As a result, it takes 1.52 gallons of ethanol to provide the same energy as a gallon of gasoline. Since the majority of ethanol is sold as E10, a blend of 90 percent gasoline and 10 percent ethanol.

The impact of the energy loss to most drivers is negligible. The use of E85, a blend of 85 percent ethanol and 15 percent gasoline, also is increasing and will continue to grow as the number of flexible fuel vehicles and refueling stations expands. Since E85 is used in engines specifically designed to use higher blends of ethanol, the loss of energy is minimized.

Ethanol adds octane to gasoline and improves engine performance. Since an E-10 blend adds 2.5 points of octane, a consumer who uses E-10 benefits from a better quality gasoline. This characteristic also works to the advantage of gasoline refiners who can refine a sub-octane base to which ethanol is blended to provide an 87 octane regular gasoline.

The demand for ethanol is determined by economics, price, and government policy. In addition to octane, ethanol displaces more expensive petroleum. Ethanol is a substitute for hydrocarbons, and when crude oil prices increase, more ethanol is used to meet demand for gasoline.
Since ethanol is blended with gasoline, ethanol use closely follows gasoline use. Consequently, the largest ethanol markets are on the West and East coasts.

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Why Use Algae to Produce Ethanol?

Algae have a number of advantages over other land based crops when considering the algae to biofuels equation.

- Much greater productivity than their terrestrial cousins
- Non-food resource
- Use otherwise non-productive land
- Can utilize saline water
- Can utilize waste CO2streams
- Can be used in conjunction with waste water treatment
- An algal biorefinery could produce oils, protein, and carbohydrates
- Algal cultivation can be 50x more productive than traditional crops
- Potential for culture in areas not used for crop production
  - Desert land
  - Ocean

Co-products

- Co-products from the algae, (omega-3 oils) depending on strain, can bring as much as $3,000/ton USD
- Animal and Fish Feeds are currently selling for $2000/ton USD

Cost Considerations

- Can use wild algae for ethanol production = free algae inputs
- Raceway ponds are economical to build.
- Supporting mechanical infrastructure costs can be offset with solar energy inputs.

Wild algae

- Have to be fast growers to survive in nature
- Generally contain <10% oil (lipid)
- Generally contain high carbohydrate >50%
- Can be grown in open raceways without fear of contamination

Using Raceway Ponds

- Raceways are low cost installations ($75 000/ha)
- Raceways consume very little power (10 kW/ha)
- Starch to ethanol conversion plant is relatively expensive and energy intensive (distillation)

High oil producing algae

- Are slower growers than wild algae – double every 2-3 days
- Can be selected for maximum oil content – 50% not unusual
- Heed to be grown in protected environment – typically PBR's
- Most algae oil can be used for biodiesel production

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Photobioreactors (PBR's)

- Allow tight control of growing environment
- Optimise light usage
- Are capital intensive
- Are generally power intensive (300 kW/ha?)

Put simply, lipids in *algae* oil can be made into *biodiesel*, while the carbohydrates can be converted to *ethanol*. Algae are the optimal source for second generation bioethanol due to the fact that they are high in carbohydrates/polysaccharides and thin cellulose walls.

Bioethanol can be used as a biofuel which can replace part of the fossil-derived petrol. Currently bioethanol is produced by fermenting sugars, which in the case of corn are derived from hydrolyzing starch. Algae species starch contents over 50 percent have been reported. With new technologies, cellulose and hemicellulose can be hydrolyzed to sugars (Hamelinck *et al.*, 2005), creating the possibility of converting an even larger part of algal dry matter to ethanol.

Algae have some beneficial characteristics compared to woody biomass, the traditional target for this technology. Most notable is the absence of lignin in algae, making its removal needed for woody material redundant. Furthermore, algae composition is generally much more uniform and consistent than biomass from terrestrial plants, because algae lack specific functional parts such as roots and leaves.

Algal cell walls are largely made up of polysaccharides, which can be hydrolyzed to sugar. Another algae-specific technology for ethanol production is being developed, in which green algae are genetically modified to produce ethanol from sunlight and CO2 (Deng and Coleman, 1999). Ethanol production from or by algae has very interesting prospects, but is currently only in the preliminary phase of research. More development is needed to analyze a full-scale production system.

Today, ethanol is widely used and available in most areas of the United States. Ethanol is contained in over 15 percent of all gasoline sold in the United States. Ethanol-blended gasoline is, or has been, marketed by such companies as Exxon, Sunoco, Texaco, BP-Amoco, Mobil, ARCO, Super-America, Getty, Chevron, Union, Shell, and Phillips, as well as numerous independent marketers. Since 1978, American consumers have driven more than two trillion miles (80,000 trips around the world) on ethanol-blended gasoline.

More recently, the country has focused attention on other advantages of ethanol. One of these advantages is ethanol's ability to provide octane while replacing other environmentally harmful components in gasoline. Other studies suggest that using ethanol can slow global warming. And because ethanol is produced here in the United States, it reduces imports by replacing imported gasoline and crude oil. Reducing gasoline and crude oil imports reduces American dependence on foreign oil. According to a recent poll conducted by Research Strategy Management, 75 percent of American voters believe the country needs to do something to reduce its dependence on foreign oil.

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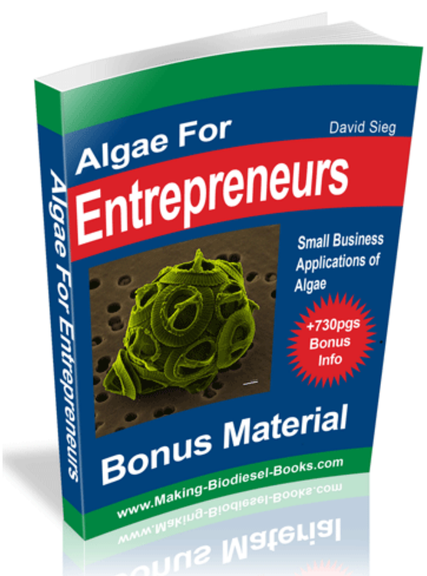

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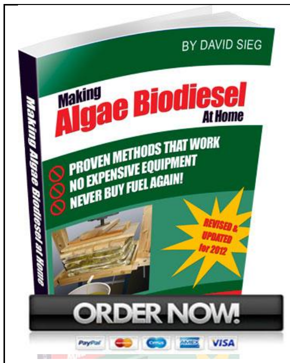

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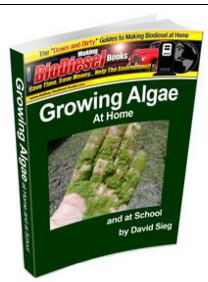

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About the Author

David Sieg, teacher, writer, consultant, and biofuels entrepreneur. David Sieg has done it all. Covering all aspects of algae biodiesel, algae biofuels, and alternative energy. He is also the Managing Director of International Biofuel Solutions, LTD. Thailand and President of Information Specialists, Corp., USA He currently lives in Des Moines, Iowa USA with his wife, Tram and Son, Lennon.

David Sieg consults on all areas of algae production on projects around the world. Contact him below to make your algae project a reality.

These reports were written with the intent of providing realistic, actionable, no BS, info on all aspects of the algae to production process. If you liked this book, we'd like to hear about it.

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