Biodiesel Engineering

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Fuel from the Fields

Joshua Tickell

Courtesy of Fred Greaves

Key Concepts
from Previous Chapters

- 2 Communicating the Solution (EDP)
- 7 Life Cycle Analysis
- 15 Temperature
- 15 Energy Transfer and Storage
- 17 Working Fluid
- 17 Pressure

My dad introduced me to the two greatest loves of my life: French fries and fast cars. I never could have known growing up that my two loves would take me so far—25,000 miles and counting.

My name is Joshua Tickell. I've spent two years driving across the United States in a van powered by biodiesel—fuel made from recycled French fry grease that I collected for free at McDonald's, Long John Silver's, and Burger King along my journey.

How did I get that idea? As I said, I've always loved driving and eating fast food. It wasn't until I got to college at New College in Sarasota, Florida, that I realized how much cars contribute to serious environmental and public health problems.

Most cars and trucks in this country burn diesel fuel or gasoline, which are both made from oil. Oil, along with natural gas and coal, is what's called a "fossil fuel." Fossil fuels are so-named because they formed hundreds of millions of years ago during the time of the dinosaurs. Most likely, these fuels started forming when dead and decaying plants collected in the bottom of swamps and waterways and, over time, were covered with sand and silt. That sand and silt eventually hardened into heavy layers of rock, which applied pressure on the decaying plant material. As centuries passed, high temperatures and pressure converted the plant matter to crude oil, coal, or natural gas.

Fossil fuels store a lot of energy, which they release when burned. But using fossil fuels has led to many problems. The burning of fossil fuels produces carbon dioxide and nitrous oxide gases. These gases trap energy from the sun and hold it near the Earth's surface—a phenomenon called the "Greenhouse Effect." Many scientists believe that our society's increased use of fossil fuels is raising the Earth's temperature. Some even predict that global warming will cause serious climate change and raise the sea level—both of which may have devastating effects on coastal cities and agricultural systems—sometime in the next century. According to the Environmental Protection Agency, the United States produces almost 6.6 tons of greenhouse gases per person every year, 82 percent of these gases resulting from burning fossil fuels to generate electricity or power our cars.

Extracting and transporting fossil fuels pose other serious problems. Because oil, natural gas, and coal are located deep under the Earth's surface, people must build complex systems of wells, mines, pipelines, and roadways—often in pristine environments—to extract them. Habitat loss and degradation in some of the most beautiful natural places on Earth are the results of collecting fossil fuels.

Likewise, transporting oil in cargo ships, large trains, and trucks has ruined habitats and endangered wildlife all over the world. In 1989, the Exxon Valdez dumped 11 million gallons of oil—the volume of about seven school gymnasiums put together—on the Prince William Sound ecosystem in Alaska. Biologists working to clean up the spill question whether or not the site will ever fully recover.

Engines of Change

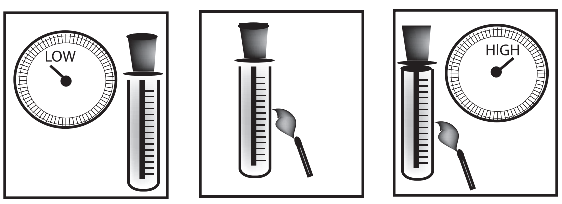
In college, I learned about the problems related to burning fossil fuels to power our cars and trucks. I wanted to find an alternative to using fossil fuels to power cars, but what?

When I was studying abroad in Europe my junior year in college, I found it. I was working on a farm in Germany when I noticed that the locals used a yellow liquid—biodiesel—to power their farm equipment. They didn't get their biodiesel from used French fry grease like I do now, though. Biodiesel can be made from any vegetable oil, such as soybean, corn, or sunflower oil. And it works in any kind of diesel engine. In fact, Rudolph Diesel, the inventor of the diesel engine, actually designed his engine to run on biodiesel fuel over 100 years ago.

So how is a car's engine designed to turn the wheels? The car engine is an internal combustion engine, which means fuel is burned inside the engine. Two main types of internal combustion engines are used in automobiles today: gasoline engines and diesel engines. Both engines take advantage of the relationship between temperature, pressure, and volume.

When gases are heated, they expand, taking up more volume. The diagram below shows what would happen if you capped a test tube with a balloon then used a candle to heat the air inside the test tube. As the air's temperature increases, its volume increases.

Say we corked the test tube instead of capping it with a balloon. In this case, the volume of the gas is fixed. When heated, the gas expands, but its volume cannot increase. Instead, the gas pressure increases as the temperature increases.



Temperature, pressure, and volume are related by the following equation, where P, V, and T stand for pressure, volume, and temperature. Because the quantity of air in the engine is a constant, you can use the following relationship to describe how the pressure and temperature are affected by the moving pistons in the combustion chamber:

$$P \alpha \frac{T}{V}$$

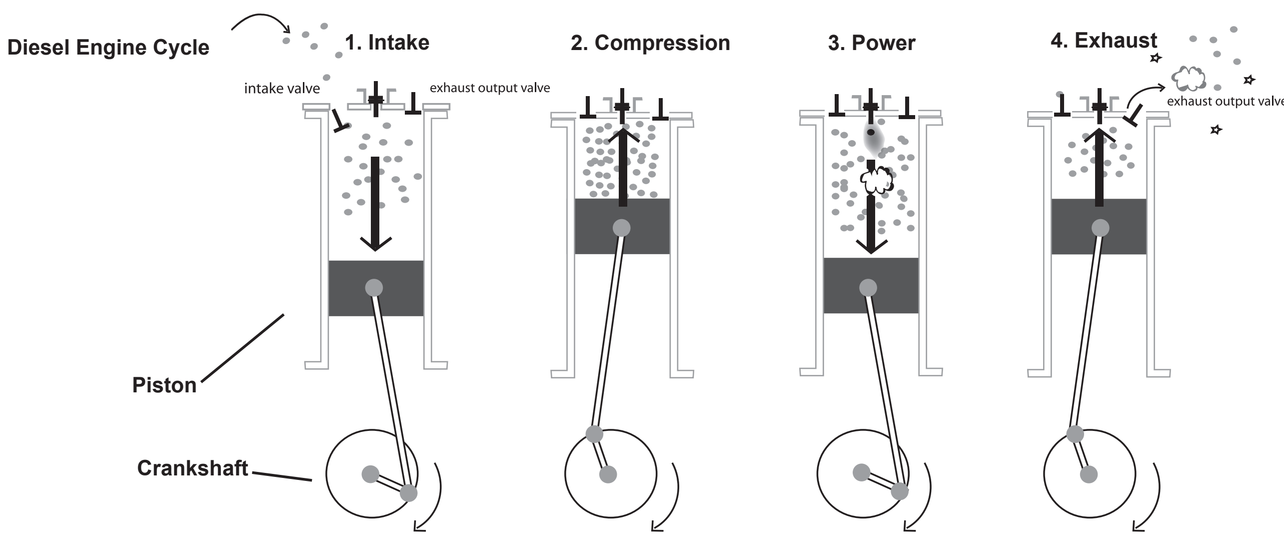
With this in mind, look at the diagram of a diesel engine cylinder below. This type of engine uses a four-stroke combustion cycle to convert the energy in diesel fuel into motion that rotates the engine crankshaft. As the crankshaft rotates, it positions each cylinder to complete an entire combustion cycle. The cycle is described in the following steps:

Intake Stroke
The piston is positioned at the top of the cylinder, and the intake valve opens. As the piston drops, air is drawn into the cylinder, called the "combustion chamber."

Compression Stroke
With the piston at the bottom, the intake valve closes and the piston pushes against the air inside of the cylinder, compressing it. As the volume of the chamber decreases, the pressure and temperature of the air inside the chamber increase.

Power Stroke
At the top of the stroke, fuel is injected into the hot, high-pressure air inside the chamber; it combusts immediately. The combustion spontaneously increases the chamber's pressure and temperature. The expanding gas pushes the piston down with great force. The linear motion of the piston is converted into rotational motion by the crankshaft.

Exhaust Stroke
As the piston rises a second time, the exhaust valve opens, and the smoke from the explosion exits the engine as exhaust.



Most car engines use multiple cylinders, which are connected to the crankshaft with connecting rods. The connecting rods are sequenced so that as one piston pushes downward, the turning crankshaft positions the other pistons up or down through a complete combustion cycle. The rapid, repeated cycling of multiple cylinders maintains the rotational motion of the crankshaft, which rotates the vehicle's wheels.

Gasoline versus Diesel

Diesel and gasoline engines have a few differences. One main difference is how the fuel-air mixture is ignited. As described above, a diesel engine compresses air, which raises its temperature and pressure. The engine injects fuel into the hot, high-pressure air, causing it to ignite. Gasoline engines, on the other hand, use spark plugs to ignite the pressurized fuel-air mixture in the cylinder. In this country, diesel engines power trains, large trucks, cargo ships, bulldozers, buses, and other heavy-duty vehicles because the engines can move the wheels of these heavier vehicles with greater force than a gasoline engine can. Gasoline engines won't run on diesel fuel or biodiesel, so don't try putting biodiesel in a gasoline engine!

Why do most American cars have gasoline engines? For one reason, diesel engines are hard to start in cold climates. And, historically, diesel engine exhaust has contained more soot and other pollutants than gasoline engine exhaust. Have you ever stood behind an idling bus or truck? If so, then you know that the fumes the vehicle emits have a strong, smoky smell. This exhaust arises from the incomplete combustion of the diesel fuel in the chamber. Soot blackens buildings and irritates people's lungs. States with pollution problems have taken measures to curb the number of diesel-powered vehicles on their roads. In recent years, California has placed limits on the sale and use of diesel vehicles.

Biodiesel works in a diesel engine the same way that diesel fuel does, but it doesn't produce nearly as much toxic soot. Recent life cycle analysis of biodiesel fuel made from the seeds of rape plants has found that biodiesel does not contribute to global warming. Yes, carbon gases are released to the atmosphere during the combustion of biodiesel, but biodiesel is a made from plants. When plants grow, they "breathe" in carbon dioxide and expel oxygen during photosynthesis. The plant essentially removes carbon from the atmosphere and uses it to grow.

Courtesy of Fred Greaves

The Veggie Van

The burning of 1,000 gallons of biodiesel fuel will release exactly as much carbon as one acre of plants will absorb from the atmosphere. As long as new crops are replanted after others have been harvested to make oil, the total amount of carbon in the atmosphere will not increase.

Where the Rubber Meets the Road

Doesn't biodiesel sound like a great solution? I thought so too! And I wanted to communicate my solution to the world. So I decided to drive across the country to promote biodiesel.

I bought a small diesel-powered camper van. My friends and I repainted it with wild, colorful pictures to make it highly visible. When people see my "Veggie Van," they can't miss it! I also built a special trailer to haul the equipment needed to convert waste cooking oil into useful biodiesel fuel. We named the trailer the "Green Grease Machine," and filled it with pumps, filters, vats, and all the equipment we needed to make the fuel. With this equipment, we could park behind McDonald's, pump out the waste cooking grease, put it through the Green Grease Machine, pour it into the Veggie Van's fuel tank, and drive away.

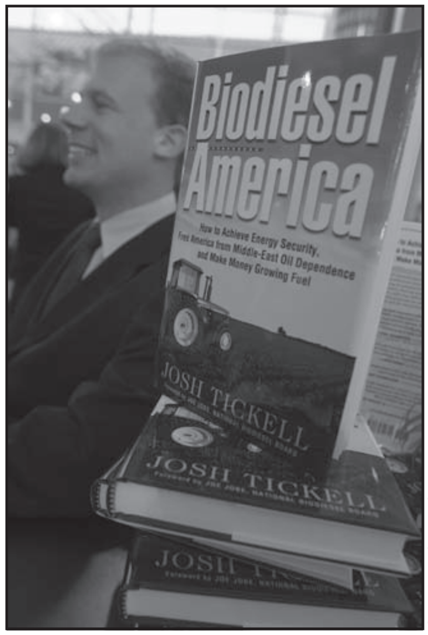
Courtesy of Fred Greaves

I'll never forget the first time I made my own biodiesel fuel using the Green Grease Machine. I drove around Sarasota collecting used oil from fast-food restaurants. Then some friends and I mixed the oil with alcohol and added a pinch of lye, a substance used to make soap. We stirred a large vat of the mixture using an old boat motor and let it sit over night. The next morning, we poured the concoction into the Veggie Van and hit the ignition. Did the homemade biodiesel power the Veggie Van? You bet it did! We've driven the Veggie Van across America twice, powered by old cooking grease!

People who follow the Veggie Van on the highway say the exhaust smells like French fries. (Is that why I'm always hungry?) Fast food gives me energy and the waste cooking grease gives the Veggie Van energy. If I have my way, more and more people will start using plant oil to fuel their cars. As I said before, about 1,000 gallons of useful vegetable oil can be produced from the plants grown on one acre of land every year. That's enough fuel to power a car for about 2,000 miles! And plants are a renewable resource, meaning we can grow them year after year. Fossil fuels, on the other hand, are non-renewable, meaning they won't replenish themselves.

One of my favorite things about biodiesel is that we can grow it right here on American soil. We don't have to buy it from other nations. Powering your car with biodiesel supports American farmers and boosts our national economy.

Because of the environmental and health effects of fossil fuels, I believe we must find cleaner sources of energy. My Veggie Van project is proof that it just takes a bit of thought to find solutions to the very serious energy challenges we face today. These solutions aren't always brand-new technologies. Biodiesel has powered engines for over a century. When it comes to finding a new way to fuel our cars, we may need to look no further than the frying pan.



Courtesy of Fred Greaves

Josh with his book, *Biodiesel America*

What's the Story?

1. What's the difference between a gas engine and diesel engine?

2 Give both an advantage and a disadvantage of a diesel engine over a gasoline engine.

Designing with Math and Science

3. What is the relationship between volume, temperature, and pressure that is useful for designing things with fixed-volume pistons?

4. What information would you need to know to determine the force with which the piston pushes the air during the second step of the diesel cycle? (Remember: the formula for pressure is in Chapter 17.)

5. What will happen to the pressure of the gas in the chamber as the volume of gas in the chamber expands in the third step?

Connecting the Dots

6. Whenever energy is transferred, some energy is always transferred to the environment. Where might a diesel engine transfer some energy to the environment?

What Do You Think?

7. Other engineers have tackled the problem of making more efficient cars. What are some new car technologies in development today that are designed to reduce the use of fossil fuels?