The University of Vermont's

Biodiesel Buses Project

They look and run like regular diesel buses, but smell like...french fries?

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About the Buses

Fall 2004 Update

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- From 2001-summer 2004 UVM experimented with biodiesel. The pure biodiesel fuel (B100) was stored 55-gallon drums in a building near the bus parking area. The B100 was transferred into smaller containers, poured by hand into the buses, and mixed 20% with petroleum diesel by driving the bus over bumps. Unfortunately, this fueling method is costly and labor intensive. UVM is currently looking for a better way to purchase, store, and handle biodiesel. As of October 2004, UVM has run out of its test biodiesel and is working towards establishing a fueling facility in partnership with local organizations.
- When using biodiesel, the fuel economy of the buses remained the same at 6 to 9 miles per gallon. In the summer of 2002 it was determined that the B20 biodiesel blend had performed adequately and starting in fall 2002 all seven CATS buses were fueled with B20.
- UVM is expecting to replace five diesel buses with Compressed Natural Gas buses in the next two years. This will be part of a project in cooperation with the City of Burlington, which will have a fueling station at the Department of Public Works. CNG burns cleaner than B20, though non-renewable.
- There will be three remaining diesel buses after the CNG bus purchase. The new diesel buses have an eight year life span, and are much cleaner than the old diesel buses (see analysis). One new bus was purchased in January of 2004, the other two will be delivered in the fall of 2004. This will put UVM buses in the diesel-or biodiesel - market for the next eight years barring significant, unexpected changes.
How did the project start?

- In 2001, UVM student Joshua Cabell, Environmental Studies student, proposed in his senior thesis that UVM test biodiesel in UVM’s CATS (Campus Area Transportation Service) buses. He suggested the idea to Michael Altman, UVM’s Transportation Manager, who was enthusiastic about the project and immediately began testing biodiesel in one of the buses.
- Starting in spring 2001 an 11-year old bus was run with 20% biodiesel, 80% petroleum diesel, or "B20." The performance of the bus was evaluated in all operating conditions to determine whether biodiesel was practical for more general use in the CATS fleet. In the summer of 2002 it was determined that the B20 biodiesel blend had performed adequately and starting in fall 2002 all seven CATS buses were fueled with B20. The student reaction to using B20 biodiesel blend has been very positive and will encourage further dialogue about using renewable fuel.
- Transportation and Parking Services thanks Joshua Cabell and the UVM Environmental Council for encouraging the use of biodiesel in the CATS bus fleet.

Fleet statistics:

- UVM uses an average of 11,000 gallons of diesel fuel per year in the bus fleet. This translates into 2,200 gallons of B100 to mix and fuel the buses for a year with B20.
- The buses travel 11,000 hours out of the year, exact mileage is unknown
- The buses make 600,000 passenger trips per year

What about using waste oil?

- UVM dining halls produce an average of 2,600 gallons (47 drums that contain 55 gallons when completely full) of waste vegetable oil per year which is currently recycled, but not for biodiesel production. UVM currently pays an average of $2,440 per year to dispose of waste vegetable oil at $52 per 55-gallon drum.
- The biodiesel used from 2001-2004 was from waste vegetable oil, from Dog River Fuels in East Montpelier, Vermont.
Why Use Biodiesel?

Renewable Fuel
Biodiesel can be made from domestically produced, renewable oilseed crops. If these crops are grown without the use of petroleum byproducts like artificial fertilizers, they do not contribute to any use of fossil fuels. When biodiesel is derived from reused vegetable oil or animal fat, it does not contribute to fossil fuel use and it utilizes waste products as well. Petroleum based fuels (fossil fuels), are not renewable.

Cleaner Burning
Over the course of its production and use, biodiesel produces approximately 80% less carbon dioxide emissions and almost 100% less sulfur dioxide. Combustion of 100% biodiesel provides a 90% reduction in total unburned hydrocarbons, and 75-90% reduction in aromatic hydrocarbons. The B20 blend reduces exhaust emissions in three important areas regulated by the Environmental Protection Agency (EPA):

- Total unburned hydrocarbons are reduced by 11%.
- Carbon monoxide is reduced 12.6%.
- Particulate matter (soot) is reduced 18%.

Biodiesel already meets the new EPA standards for low sulfur diesel fuel mandated for introduction in 2006.
Easy to Use

Biodiesel is the only alternate fuel that runs in any conventional, unmodified diesel engine. It can be stored anywhere that petroleum diesel is stored. It can be used alone or mixed in any ratio with petroleum diesel fuel. B20 is the most common blend (20% biodiesel, 80% petroleum diesel).

Extends Engine Life

Studies have shown that because biodiesel is more lubricating than petroleum diesel fuel, it can extend the life of diesel engines. Fuel consumption, auto ignition, power output, and engine torque are only slightly affected by biodiesel. However, it should be noted that long term effects of biodiesel on engines are still being studied and some biodiesel, when not properly produced and handled, has shown to cause engine problems.

Safe to Handle

Biodiesel is safe to handle and transport because it is as biodegradable as sugar, 10 times less toxic than table salt, and has a flash point of about 300°F compared with 125°F for petroleum diesel.
CATS Bus Fleet Analysis

<table>
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<th>Answer</th>
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<td>Does B20 reduce air emissions at UVM?</td>
<td>A study by Alison Donovan in 2002 modeled the emissions savings from the test bus using 20% biodiesel (B20). At the time the study was done there were 9 buses in the fleet and 5 out of the 9 buses were over 10 years old. The age of the B20 bus was 11 years. Because such a large percentage of B20 is petroleum diesel, there were insignificant reductions of emissions for the five pollutants regulated by federal environmental agencies (sulfur dioxide (SO₂), particulate matter (PM), nitrogen oxides (NOx), carbon monoxide (CO), and volatile organic compounds (VOC) is small). Using a computer model, Alison predicted pollution rates for the year 2003 with six different scenarios. The scenarios for the nine bus fleet were: 1) All buses operating on diesel 2) One 1992 bus operating on B20 3) All buses operating on B20 4) Old diesel buses replaced by model year 2002 buses 5) Old diesel buses replaced by model year 2002 buses operating on B20 6) Old diesel buses replaced by model year 2002 Compressed Natural Gas buses</td>
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<td>What is the best way to reduce emissions from the CATS buses?</td>
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<td>What are the emissions from B100?</td>
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The results are as seen in the following chart:

![Percent Emissions Reduction in Calendar Year 2003](chart.png)

The fleet was reduced to 7 buses in the summer of 2002 but this does not significantly change the data for the purpose of determining which scenario most reduces emissions.

**What is the best way to reduce emissions from the CATS buses?**

The chart above shows that using B20 in only 1 of the 9 buses did not significantly reduce emissions (less than 1%). In Alison's analysis, using B20 in all of the existing fleet would reduce emissions by 3.2% annually. Running new buses on B20, would reduce emissions by 18%. Using all model year 2002 buses on compressed natural gas would achieve a 58% reduction in emissions.

To learn more read Alison's study, UVM Bus Fleet Emissions Analysis.

**What are the emissions from B100?**

In June 2000 the United States Congress announced that biodiesel is the only alternative fuel that has been fully tested for health effects under Clean Air Act guidelines.

The studies concluded that burning biodiesel fuel instead of petroleum diesel reduces the ozone and smog forming potential of speciated hydrocarbon exhaust emissions 50%. Carbon monoxide emissions, contributors to smog and ozone formation, were also 50% less with
biodiesel instead of petroleum diesel.

Particulate matter, a contributor to respiratory diseases, is 30% lower with biodiesel. Emissions of hydrocarbons that cause local smog and ozone, is 95% lower. Emissions of aromatic compounds are also significantly lower. Most PAHs emissions are between 75 to 85% lower. NPAHs emissions are 90% lower. Both PAHs and NPAHs are suspected carcinogens. Emissions of sulfur oxides and sulfates, which contribute to acid rain, are eliminated.

However one problem remains, emissions of nitrogen oxides are increased 5% with B100. Using B20, Nitrogen oxides increase 1%. Nitrogen oxides are contributors to acid rain and are Vermont's biggest air pollutant. They are caused by the combustion of any fuel in the presence of oxygen. More research is needed to find ways to reduce nitrogen oxide emissions from biodiesel, but since it is a result of the combustion process, there are limits to the amount of reductions.

The release of carbon dioxide and other greenhouse gases contributes to climate change. Neat (100%) biodiesel can reduce carbon dioxide emissions by 78%. This is due to the "closed carbon cycle." Carbon dioxide is still released from burning neat biodiesel but it is also absorbed by plants grown and harvested to make biodiesel. It is not a literal emission reduction, but a balance or closing of the global carbon cycle. If the total amount of carbon absorbed by the crops grown to produce biodiesel were equal to the amount emitted by burning the fuel, it would be considered a Carbon Neutral Fuel (CNF).

In contrast to biodiesel, petroleum-based fuels, or fossil fuels, are derived from carbon reserves that have been sequestered, or stored, deep in the earth for millions of years. Burning fossil fuels puts carbon into the atmosphere that had been sequestered for millions of years.
Making Biodiesel

How UVM Gets Biodiesel

UVM tested locally made biodiesel from Dog River Alternative Fuels in Berlin, Vermont. However, this company no longer supplies UVM, and the university is currently looking for a "Road Grade" biodiesel supplier. There are limited suppliers in the Vermont region, especially those that can supply ASTM standard biodiesel and pre-mixed B20 fuel.

The Biodiesel Industry

Biodiesel fuel can be made from new or used vegetable oils and animal fats. All are non-toxic, biodegradable, renewable resources. Approximately half the biodiesel industry makes biodiesel from animal fat. The animal fats industry sells fat to be made into biodiesel at quite a low cost because it is a low value byproduct of meat production and other processes. The other half of the industry is using vegetable oils. Soy oil is more expensive than animal fat but it is the least expensive vegetable oil for making biodiesel. The soy industry has promoted commercial production of biodiesel due to excess production capacity, product surpluses, and declining prices. Prices for soy oil are currently subsidized by the government to assist farmers, who produce a surplus.

Some other vegetable oil sources are palm oils, rapeseed (canola oil), flaxseed (linseed oil), sunflower oil, oil extracted from algae, hemp oils, and other various plants. Although these plant based oils can be prohibitively expensive, it should be noted that various waste vegetable oils from restaurants and stores can be free, or can make money if stores pay to remove it.
most currently do). Also, plant crops that are currently grown for biodiesel often use large amounts of petroleum in their production (from artificial fertilizers, biocides, cultivation materials, and machinery use). Reusing waste oil does not increase the use of these products.

The biodiesel industry is not large enough to supply the nation with fuel. Currently, it has the capacity to supply 1.9 billion gallons of biodiesel. The Department of Energy is developing a new, low cost biodiesel oil made from spicy mustard seeds that could add another 5-10 billion gallons of biodiesel to the fuel supply. Supply could also increase with other technological innovations as well, so predictions are hard to establish. If producers steadily grow in the coming years, it could be a significant source of fuel in America, as it is in some other countries.

**How Biodiesel Is Made**

Biodiesel can be made using several different techniques. In the most common process, oil is first filtered and heated to remove water and contaminants. Separately, a pure alcohol such as ethanol or methanol is mixed with a catalyst (usually sodium hydroxide or potassium hydroxide) in a contained reaction. Then these are added to the filtered oil and agitated or stirred for a specified amount of time. The oil molecules are broken apart and reformed into esters and glycerol, which separate into layers in the settling/mixing tank. They are then removed from each other and purified. These are the two main byproducts of the process. Fatty acid (m)ethyl esters are more simply referred to as "biodiesel" when they are use for fuel. The glycerin is subsequently sold for soap production or other various uses.
Resources and links

Alternative Fuels Data Center
http://www.eere.energy.gov/afdc/
Offers general information about biodiesel, standards, codes and legislation, training safety, supply information and links for papers, publications and presentations on biodiesel and other alternative fuels.

US Department of Energy
http://www.eere.energy.gov/biomass/
Provides information about the Biofuels for Sustainable Transportation program, research and technology, and biofuels issues.

Grassroots biodiesel information:  
www.veggievan.org
Learn about the Veggie Van's cross country trip, discuss biodiesel in the discussion forum, get information about hands-on workshops.

National Biodiesel Board
www.biodiesel.org
The official site for the National Biodiesel Board. Offers many resources: factsheets, buying information, reports and databases.
UVM Transportation and Parking Services
www.uvm.edu/tps
More information about transportation at the University of Vermont.

Vermont Biofuels Association
http://www.vermontbiofuels.org/
For info on the status of biodiesel and other biofuel use in Vermont. This site contains links to local producers, relevant political news, and general information about biodiesel in Vermont.

Vermont Biodiesel Workshop
http://www.aot.state.vt.us/planning/Biodiesel.htm
Official website of the 2004 state sponsored workshop. All of the speaker's presentations are accessible and downloadable.