An ASABE Meeting Presentation

Paper Number: 074145

Using Biogas as a Fuel for Trucks and Tractors

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Written for presentation at the
2007 ASABE Annual International Meeting
Sponsored by ASABE
Minneapolis Convention Center
Minneapolis, Minnesota
17 - 20 June 2007

Abstract. Anaerobic digestion on the farm has been promoted for decades as an effective method to reduce pollution and produce fuel. However, because of the cost and the problems associated with anaerobic digestion of animal manures and the lack of return on the investment, there are relatively few digesters being installed in the United States. Most of the biogas produced by anaerobic digestion is used to generate electricity. Grid interconnect agreements require lengthy negotiations and are difficult to finalize. Usually the electrical rates received are below the cost of production because equipment for electrical generation is expensive to install and expensive to maintain. By showing that biogas can easily be used as a fuel in trucks and/or tractors, anaerobic digestion would be more attractive especially on smaller facilities.

High fuel prices are starting to have a significant impact on the economic viability of farms. If farmers could produce there own fuel in the form of biogas the pay back time on an anaerobic digester system could be reduced significantly. This would also encourage the installation of more pollution preventing anaerobic digester systems.

With the help from a Rural Development (USDA), grant, Utah State University has been operating a 1996 Chevy ¾ ton truck on biogas produced by their Induced Blanket Reactor (IBR) anaerobic digester. This presentation will report on the trucks performance over the past 8 months comparing the use of biogas with gasoline and natural gas. Data includes horse power tests, oil sampling, and emissions tests.

Keywords. Biofuel, Renewable energy, Biogas, Green Power, Anaerobic Digestion, Biomethane

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Introduction

In his 2006 State of the Union address, President Bush outlined the Advanced Energy Initiative (AEI) to help free America's dependence on foreign sources of energy. The President has set a national goal of replacing more than 75% of our oil imports from the Middle East by 2025. These goals for energy independence were reemphasized again in the 2007 State of the Union address. The best way to break the addiction to foreign oil is through new technology.

Anaerobic digestion on the farm has been promoted for decades as one of a group of effective methods to reduce pollution and produce renewable fuels (Anonymous, 2005). However, to-date, there are relatively few digesters being installed in the United States. Two major reasons for the limited number of anaerobic digesters on animal feeding operations in the United States are:

1. The high failure rate of installed digesters and
2. The minimum or no return on the investment.

The first problem of digester unreliability has been a focus of research and development at Utah State University (USU) for many years. The result of this research was the development of the high rate anaerobic digester called The Induced Blanket Reactor (IBR). However, because most of the biogas produced by anaerobic digestion in general is used to generate electricity, there is little support to solving the second problem of economics. Anaerobic digesters are expensive to build and commodity priced electrical generation is not producing enough revenue to achieve a decent rate of return on the investment. Not only is electrical generation equipment expensive to install and to operate, but negotiating contracts for in-putting electricity into the power grid can be time consuming and very frustrating. If a farmer or other captive fleet operators could use biogas as a fuel for their automobiles, farm equipment, and building heating, the pay back time on the anaerobic digester could be cut in half. This would encourage the installation of these pollution preventing digester systems.

Background:

For the past three years Utah State University has been performing research with an anaerobic digester called an Induced Blanket Reactor (IBR) that is located on an 1000 cow dairy in West Weber, Utah. The IBR system has a hydraulic retention time (HRT) of 5 to 8 days. A conventional pit digester has a HRT time of 20 to 30 days (Lusk 1998).

To treat waste at a high rate, anaerobic digesters (AD) must have some means of retaining the slow growing anaerobic bacteria. The principle of operation of the IBR is to capture solids in an enclosed vessel, thus creating an enriched environment for the bacteria. The IBR system includes a septum near the top of the tank. As methanogenic bacteria eat the waste, gas bubbles form which make the bacteria float. The bacteria and attached solids float to the top hit the septum which separates the gas from the bacteria. The bacteria and the uneaten solids sink, thus they are retained and the cycle starts over again. The gas escapes through a hole in the septum.

The invention causes a sludge blanket or bed to form in the lower portion of the bioreactor vessel. Under the right circumstances, this sludge bed becomes mostly living bacteria. This means that wastewater can be treated much faster and more efficiently in this anaerobic bioreactor compared to others. In experiments on a pig farm, a small version of the IBR created a sludge blanket and sped up anaerobic treatment of pig waste by 4-6 times over commonly used AD methods.

The invention also makes it easy for an inexperienced operator to manage an anaerobic digester without having to know much about how it works. A programmable logic controller or microprocessor will run the system. The controller calls a trained professional if a key parameter is out of a defined range. Additionally, it is very simple to put information (pH, temperature, flow rates in and out, biogas production) that sensors are gathering, on the internet so that authorized persons can use a password to monitor, or even make changes to the system remotely.

The IBR system is a smaller unit, compared to current anaerobic digesters on the commercial market with a given throughput. The IBR has the potential to treat high COD waste also. Waste streams with up to 20% COD or 200,000 mg/L have been successfully treated. It is also able to treat waste streams high in protein and/or carbohydrates and/or lipids. The IBR can also be easily scaled. It can accommodate a 120,000 sow operation or be reduced in size and cost to operate on a small farm or for a small food processor.

A biogas compressor system called a Fuel Maker was used to compress the biogas into high pressure storage tanks (3000 lbs.). The technology for the Fuel Maker system has been used with natural gas by gas companies for many years. Questar Gas (our local gas company) operates most of their service vehicles with natural gas. Questar Gas has successfully used low quality well-head gas in their service trucks in Wyoming. Comparably the natural gas provided by Questar Gas has about a 900 BTU per cubic foot value and the biogas from the IBR system is approximately 700 BTU'S per cubic foot of gas.

Research Structure

A 1996 Chevrolet ¾ ton truck was purchased from Questar Gas, the natural gas supplying company. The vehicle's engine was retro fitted by the company to operate with gasoline and compressed natural gas (CNG). Because of the CNG components on the engine, the vehicle will be able to function with biogas as a fuel source. Due to the high levels of hydrogen sulfide in the biogas that would eventually poison the catalytic converter, the catalytic converters on the vehicle's exhaust system were removed to provide consistent emission data through the testing period.

Baseline tests on the vehicle were performed using gasoline and CNG as the fuel source before the biogas was used. The tests that were performed included a horse power test completed on a dynamometer and an emission test performed at a Environmental Protection Agency (EPA) vehicle emission testing location. Samples of the vehicles motor oil were sent out for testing and analysis to see if there was any unusual wear on the engine when using biogas as a fuel. At the completion of each of the set mileage intervals the testing was conducted and comparisons were made for the three fuel sources (Gasoline, CNG, and Biogas). The vehicle was driven 4,000 miles using biogas as a fuel source.

Horse power analysis was used to determine if unconditioned biogas (sour gas) could provide adequate power for the vehicle to function properly. Horsepower analysis also gave a comparison of the power performance of each of the three different types of fuels.

The emissions test determined how the unconditioned biogas emissions would affect the environmental air quality compared to gasoline and CNG fuels. There was also a question as to whether or not biogas with its current components would be environmentally safe for use as a fuel source for light duty vehicles.

The motor oil samples were used to check metal and sulfur content. Samples were taken of clean motor oil, oil from the engine after 500 miles using gasoline, and then taken while the vehicle was powered by unconditioned biogas. Elevated levels of metals in the motor oil could show excess wear and corrosion of the engine. Elevated sulfur levels could indicate excessive contamination of the oil.

The demonstration of successfully using biogas in farm vehicles could eventually provide the foundation to expand to conditioned biogas from municipal waste treatment systems and landfills for use in city buses and/or fleet vehicles. Several Utah cities are presently producing biogas by using anaerobic digestion in their waste treatment systems.

Data:

The data is represented in the following graphs and tables. Performance data includes horse power and torque. The emissions data includes carbon dioxide, carbon monoxide, NOx and oxygen in the emissions from the truck using the various types of fuel.

Performance Data:

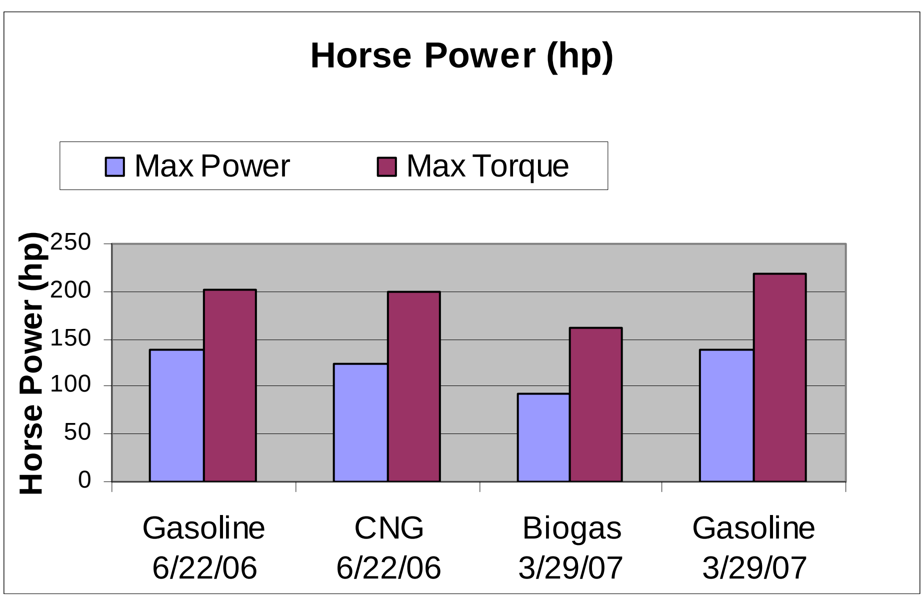
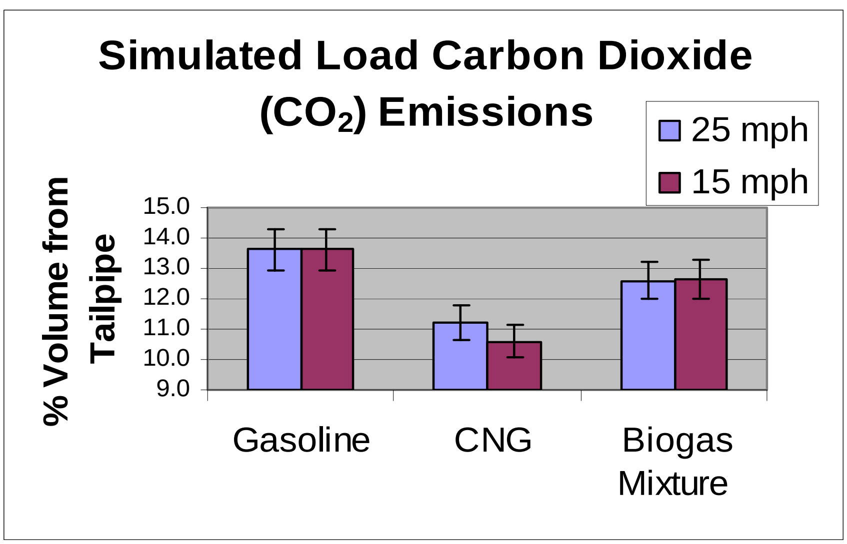


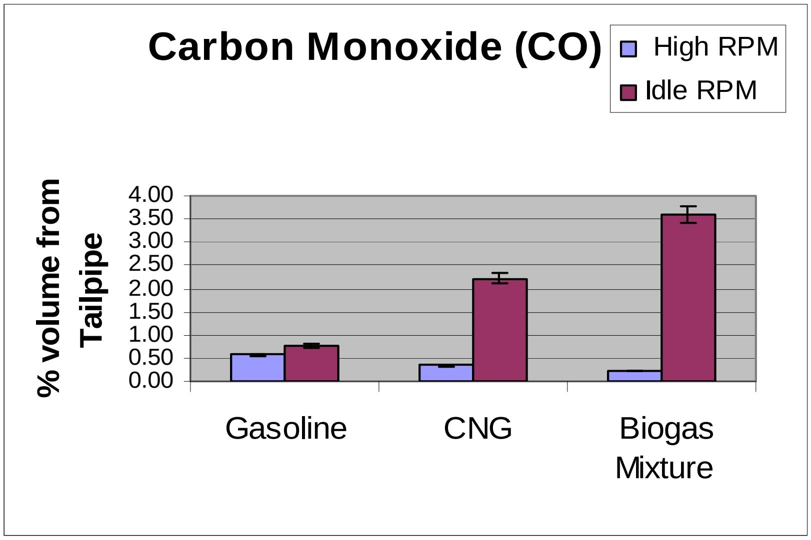
Table 1. Comparison data between each fuel source

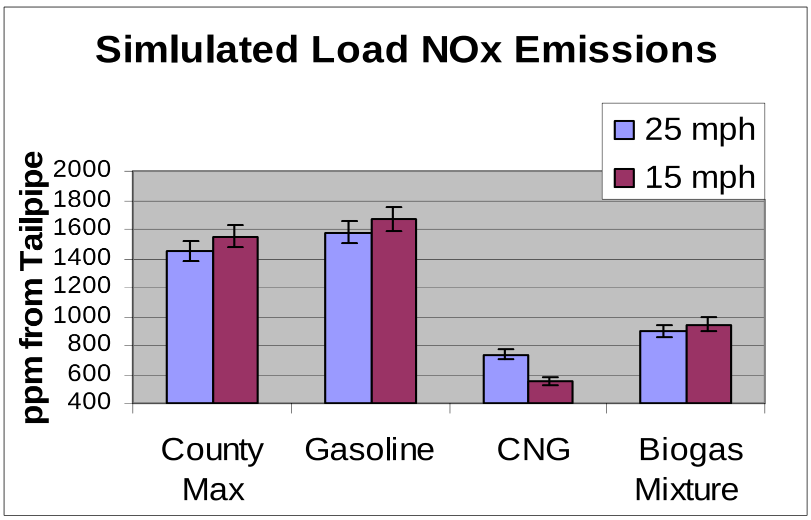
Performance Data								
Date	6/22/06	6/22/06	3/29/07	3/29/07	6/22/06	6/22/06	3/29/07	3/29/07
	Gasoline	CNG	Biogas	Gasoline	Gasoline	CNG	Biogas	Gasoline
	Max Power				Max Torque			
RPM	3911	3603	3009	4155	2966	3228	3009	3073
MPH	84	78	42.2	58.2	64	70	42.2	43.1
Power (hp)	139	123	92.5	138.9	202	199	161.4	218.7

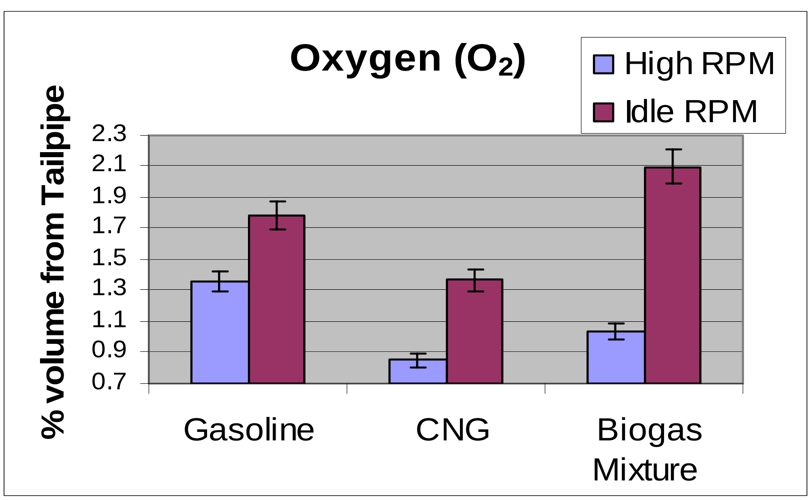
	Gasoline	CNG	Biogas	Gasoline	Gasoline	CNG	Biogas	Gasoline
	Max Power Difference				Max Torque Difference			
Power (hp)	0	-11.5%	-33.7%	-0.4%	0	-1.6%	-25.4%	7.5%

Emissions Data:




Carbon Monoxide (CO)
High RPM
Idle RPM
% volume from Tailpipe
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
Gasoline
CNG
Biogas Mixture


Simlulated Load NOx Emissions
25 mph
15 mph
ppm from Tailpipe
2000
1800
1600
1400
1200
1000
800
600
400
County Max
Gasoline
CNG
Biogas Mixture


Oxygen (O_2)
High RPM
Idle RPM
% volume from Tailpipe
2.3
2.1
1.9
1.7
1.5
1.3
1.1
0.9
0.7
Gasoline
CNG
Biogas Mixture

Conclusions:

This study has shown that unconditioned biogas can be used in farm vehicles but that there is a significant loss of power when compared to using natural gas or gasoline. Analysis of oil tests indicated that over the 8 months of using biogas there was no significant extra wear on the engine. The lower level carbon monoxide at a high RPM and then the much higher levels at a low RPM was somewhat of a surprise.

None of the EPA emissions testing stations were capable of measuring sulfur emissions. The sulfur in the biogas may have affected the accuracy of these tests or may have had an actual affect on the levels of CO, CO_2 and NOx emissions. This will need farther study. The major decrease in horsepower, which was very evident in the performance of the truck, was do to the CO_2 content. The 30% CO_2 in the Biogas reduced the horsepower ratings proportionately. It is anticipated that our next level of research will be with conditioned biogas where all of the water, all of the H_2S and all of the CO_2 is removed leaving only the methane as a fuel.

Energy costs are taking a larger portion of the farm budget. In some cases, these costs amount to more than 50% of the budget (USDA 2006). Being able to produce your own fuel could be the difference between a profit or a loss in the farming industry.

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