Powering a vehicle with Waste Vegetable Oil – Sep 2011

Abstract

A waste vegetable oil (WVO) conversion on a vehicle, Diesel Opel 1.7, model 2002, is researched, designed and built. The installation consists of a secondary tank, heat exchanger, solenoid valve and 5 way chamber. This modification is an add-on to the engine. The installation was done in Sep 2006 and the vehicle has traveled 113,000km, on the WVO system, without damage to the engine. The consumption and power difference, as compared to running on diesel, is negligible. The WVO is collected from restaurants and pre-filtered to 5 micron, using filter socks. This conversion is not recommended for vehicles with the following distribution injector pumps; CAV, Lucas, Stanadyne, RotoDiesel or Delphi.

1. Introduction

Petroleum oil will eventually run out. What other fuel alternatives are there?

In 1895, Dr. Rudolf Diesel developed the first diesel engine to run on vegetable oil. He demonstrated his engine at the World exhibition in Paris, in 1900 and used peanut oil to fuel his engine.

Vegetable oil can be harvested from many plants like soybeans, sunflower seeds and canola seeds. Vegetable oil plants absorb more carbon dioxide from the air during their growing cycle than what they release when the oil is burned. This means that vegetable oil does not produce excess carbon dioxide in the atmosphere. This is referred to as carbon neutral.

An added benefit, is your vehicle's emissions will be reduced. There is no sulphur content in vegetable oil. This eliminates the first major carcinogen associated with diesel fuel.

Clean or recycled vegetable oil from restaurants can be used and there is about 54 million litres available in South Africa annually. (Biophile 2006, issue 10, pg 34)

2. Biodiesel or WVO conversion?

Before one can use vegetable oil as a fuel, one requires a diesel vehicle and you need to reduce the vegetable oil's viscosity.

To reduce the vegetable oil's viscosity, there are two options.

The first is to use biodiesel, which is vegetable oil that goes through the transesterification process (similar to saponification or soap making). A methyl ester of vegetable oil is obtained and has similar properties to diesel fuel. Biodiesel can be used on diesel engines without modification to the engine.

The process of making biodiesel in your garage, will require a mini plant, consisting of a 150 litre vessel, electric pump, two empty 220 litre drums, methonal, potassium hydroxide and some basic laboratory equipment. If you plan to do this yourself, caution needs to be exercised. Methanol and potassium hydroxide are dangerous chemicals.

The second option is to use WVO or pure straight vegetable oil. Figure 1 is a diagram of the installation done on an Opel Corsa 1.7D vehicle.

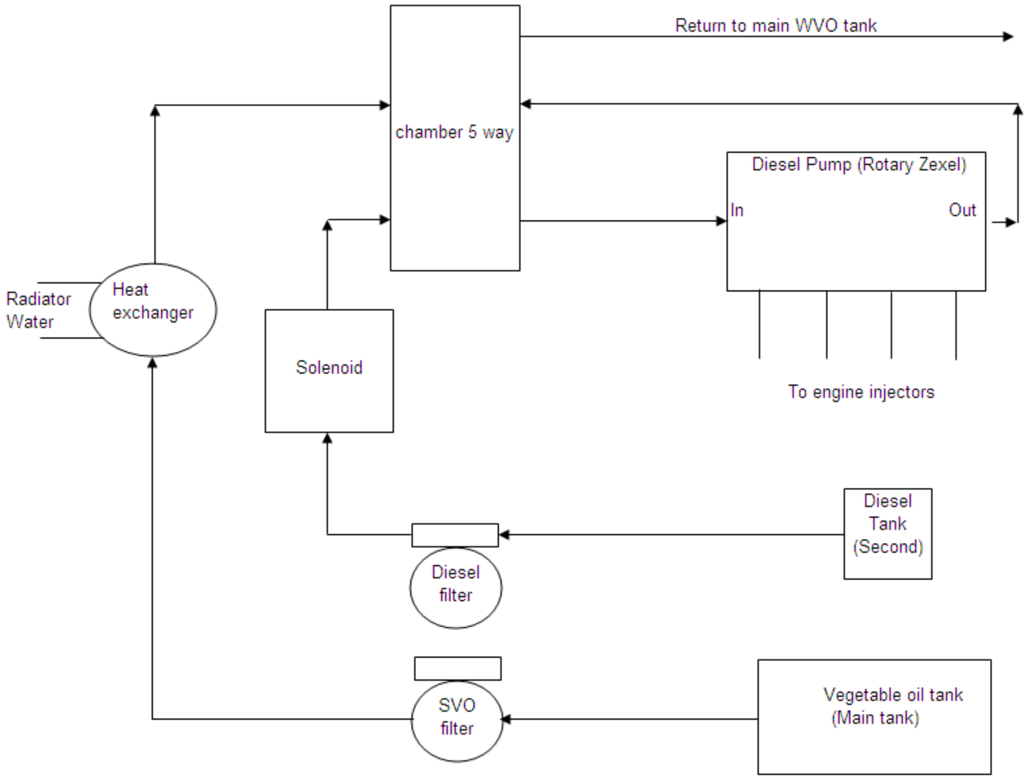


Figure 1 – Diagram of the 2 tank system

This system requires a modification to the engine and is a two tank, heat fuel system. The vehicle's diesel tank and filter will supply diesel fuel to the engine at start up and shut down. After starting, radiator fluid will transfer heat from the engine to the new installed heat exchanger, in the vegetable fuel system. This heat exchanger heats the vegetable oil in the fuel lines. Once it is sufficiently hot, the heat will reduce the viscosity of vegetable oil. One then switches off the diesel supply (by cutting the power to the solenoid) and the diesel pump will suck WVO, which then supplies the injectors. The hot, lower viscosity WVO, is then able to be atomized, in the combustion chamber.

When one arrives at the destination and the vehicle is going to be switched off for a period long enough for the fuel to cool, the vegetable oil must be removed from the fuel system, and replaced with diesel for the next start up. One, therefore, needs to switch over to diesel, typically 5km before arriving at the destination.

3. Sourcing the WVO conversion components.

3.1 Secondary Tank

Fuel is used from this tank at startup and when you approach the end of your destination. A sealed tank, from 20lt to 40lt will be suitable. In this case, an empty paraffin 20lt tank, obtained at the local fuel garage, was used. See figure 2. One could also use a fuel jerry can or manufacture a custom made stainless steel tank. This tank was installed in the bin of the light delivery vehicle (LDV) and strapped tightly.

Figure 2 – Diesel tank

A breather pipe and fuel line is "soldered" to the tank, using Q-bond. The new diesel fuel line is strapped to the underside of the vehicle, with cable ties. See figure 3.

The previous diesel line, now carries the WVO fuel.

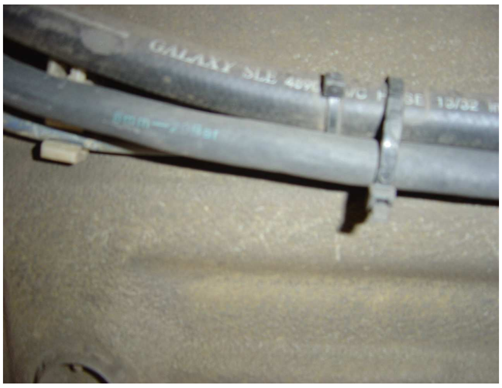


Figure 3 – Diesel & vegetable oil lines

3.2 Heat exchanger

The heat exchanger was made by a local fabricator. It is designed to heat the vegetable oil using the radiator water (typically 70-90 degrees Celsius). See diagram below.

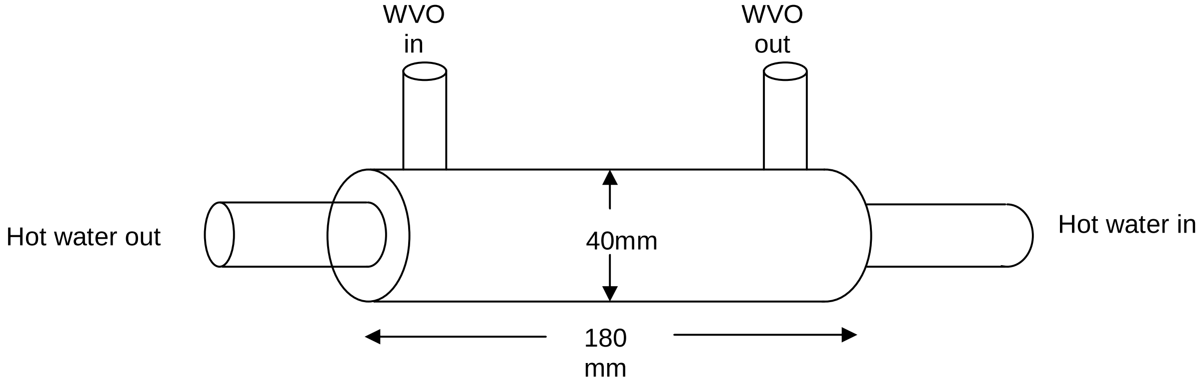


Figure 4 – Heat exchanger

It is made out of aluminium and measures 180mmL x 40mmD. The flow of the WVO, follows a spiral path and gets hot in the process.

The heat exchanger is connected in parallel to the radiator water system. This is done by installing a T piece to both supply and return of the hot water lines. The tie in, is done on the heater side of the thermostat, not the radiator side. This way, hot coolant is available much quicker, before the thermostat opens.

The heat exchanger was fitted behind the engine block, close to the injector pump. This way, hot fuel has a shorter distance to travel and will have less time to cool down as it approaches the injector pump.

The heat transfer of this unit, is very effective, as the flow rate of WVO is a maximum of 2.5ml/s. (See section 3.3 for calculation).

The injector pump and individual injectors, once hot, also assist in heating the vegetable oil.

One could also have used an electric heater. But this will cause unnecessary strain on alternator and battery. The hot coolant is readily available, and is therefore, an efficient use of energy.

3.3 Solenoid valve

A 12V DC 1/8" port size, normally closed, 2 way general purpose solenoid valve, was used. See figure 5. The solenoid is energised only when diesel fuel is required, which is at startup (until engine gets hot) and as you approach the end of the destination. The rest of the time, the solenoid is normally closed when operating on WVO. In this way, the life of the solenoid is extended.

Viton seals were chosen, instead of the NBR (nitrile-butylene elastomer), as viton is a more durable material and is able to withstand much higher temperatures.

The 12V solenoid voltage tolerances are +10% and -5%, and has a coil resistance of 26ohm. The battery voltage when the vehicle is running, was measured at 14V and the solenoid was getting very hot. The solenoid can tolerate temperatures of 155 degrees Celsius. To prolong the lifespan of the solenoid, a suitable resistor was connected in series. Using Ohm's law, 0.46A is the maximum permissible current.
(*I=V/R=12V/26ohms=0.46A.*)
To limit this current, a 5ohm resistor connected in series, is sufficient.
(14V=0.45y+0.45x26ohm, therefore y=5ohm). A 1W resistor is suitable.
($P=I^2R$=0.45Ax0.45Ax5ohm=1W).

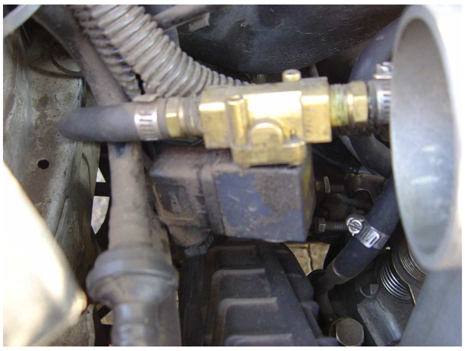


Figure 5 - Solenoid

A toggle switch was installed on the lower right side of the dash board with an LED. See figure 6. In WVO mode the LED is off and in Diesel mode, the LED is on. The +12v was connected to the ignition system allowing current to the solenoid only if the ignition is switched on. This will provide a fail safe mode if one forgets to switch over to the "off – vegetable oil mode", when the engine is switched off. To adjust the brightness, a 500 ohm variable resistor was connected in series to the LED.

Figure 6 – Switching over

To calculate the maximum flow rate through the valve, the average consumption per second was calculated. The vehicle's average consumption is 1 litre per 16km. Assuming a 1hr traveling time at 120km per hour, the engine will have consumed *120km/16km per litre = 7.5lt per hour*. Therefore, the flow rate per second is *7.5lt/3600x1000 = 2.1ml/s*. The valve used has an orifice diameter of 2.3mm and a Kv(m3/hr) of 0.14m3/hr or 39ml/s. The valve size is, therefore, sufficient.

<u>3.4 Chamber 5 way</u>

This inexpensive chamber or vessel, eliminates the use of additional solenoids. See figure 7. The engine's diesel injector pump, the heart of the loop, sucks fuel from the path of least resistance (either vegetable oil from the main tank or diesel from the secondary tank). So if the solenoid valve is open, the injector pump will rather suck diesel, as it is less viscous, even though, the WVO line is available. Once power is switched off to the solenoid valve, the valve will close and the injector pump has no choice but to suck from the WVO line.

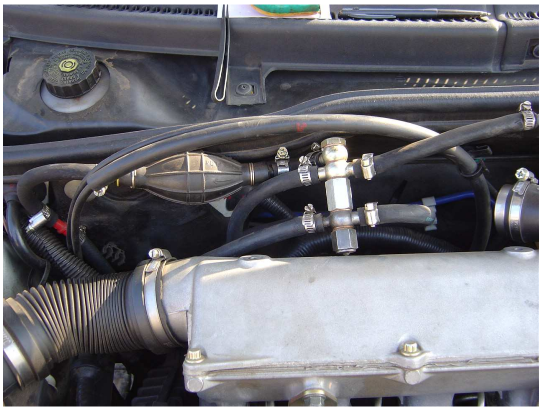


Figure 7 – Chamber 5 way

The injector pump (rotary type) is able to suck the WVO without the assistance of an inline booster pump. On other vehicles, a booster pump may be required.
The uppermost leg, is the return to the main tank. A one way hand pump is installed to remove any air from the loop.

The chamber is made up of various banjo parts that are bolted together. These parts can be obtained at any supplier of hydraulic accessories.

Mixing of the two fuels, is no problem.

The diesel tank height is higher than the main WVO tank. When the diesel line is open, fuel will leak into the WVO line, due to pressure differences and this depletes the diesel fuel quicker. To eliminate this, one could install another solenoid to block the flow. An easier, cheaper option, is to install the WVO line, higher than the incoming diesel line. The one way hand pump is also pointed upward to prevent diesel fuel leaking into the main tank return line.

3.5 Fuel lines

Fuel lines made of rubber, degrade over time with vegetable oil use. According to www.greaseworks.org , viton fuel lines are the ideal material to use. I was unable to obtain it and therefore used normal fuel line, which will need to be replaced, in perhaps 3 years.

3.6 WVO pre-filtering.

The existing engine diesel fuel filter, will filter out particles of size 5-10 microns. If the WVO is not pre-filtered, the filter will get blocked soon. Figure 8 shows the pre-filtering system.

Filter socks of 5 micron were used and will clean about 10 drums or 2000lt of WVO. Try to obtain reasonably clean oil. One should get oil that has fried fish and/or chips. WVO originating from chicken friers, has a higher viscosity, due to the animal fat, and this blocks the filter much sooner.

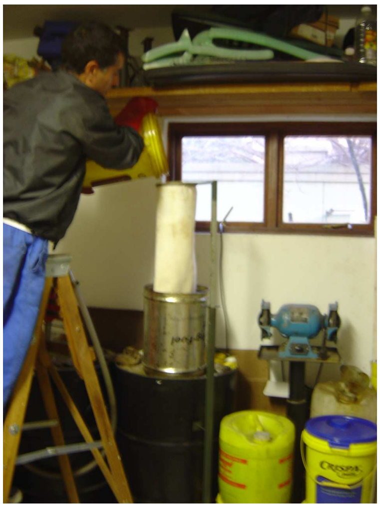


Figure 8 – Pre-filtering

An old oil can with its bottom cut out, can be used as a wide funnel. When pouring into the filter sock from the original container, don't pour the bottom sediments, instead pour them into a separate container and allow to settle, for your next filtering session. This way, the filter sock will last you much longer.

Cleaning of the filter sock, can be done by spraying diesel on the inside using a garden sprayer.

4. The cost of Installation – prices @ Aug 2006.

The parts were sourced locally, but one can order the conversion kit directly from www.elsbett.com or www.greaseworks.org .

Description	Supplier	Contact	Amount
Heat exchanger	Cirrus	082 876 5923	R 600
Solenoid	Siraco	011 450 2515	R 460
Hose and fittings	Vee's pipes and fittings cc	011 334 4412	R 870
5 way chamber	Dipasa	082 356 6862	R 350
Primer bulb hand pump	Boating International	011 452 8280	R 50
LED, switch, resistor	AP Electronics	011 624 2944	R 20
Pre-filtering			
Filter sock	Eaton Filtration	011 791 4331	R 40
Hand Drum pump	Corro pump & equipment	011 392 1800	R 400
210lt grade A tight head drum x 3	Enviro drum recyclers	011 902 7355	R 360
Stand	Scrap		R 50
Total			**R 3,200**

5. Running

If the engine is idling on pure WVO, the engine tends to "hunt" slightly. If the engine revolutions are increased slightly, the "hunting" diminishes and disappears completely at higher revs. This is due to the injectors not able to atomise the WVO completely. To correct this, one needs to get special extensions to the injectors, which can be imported from www.elsbett.com in Germany. Alternatively, one can dilute the WVO mixture slightly, by switching over to diesel supply. This is done especially in town driving. One could also increase the opening pressure of the injectors by 5 to 10 bar. This was not done, as it will force the injector pump to work harder and may cause more wear and tear on the injector pump.

The idle rest volume screw on the injector pump was increased by 1/16 of a turn. This allows slightly higher volume of fuel to go through the injector pump to compensate for the higher viscosity of the WVO. If one turns the adjustment screw too much, the engine becomes inefficient and will also smoke excessively.

The conversion is best suited for longer distance traveling, as switching over to diesel is done less frequently.

Figure 9 – Filling her up

6. Conclusion and Recommendations

This research, engineer, procure and construct project, showed that it is practical and possible, to use an alternative, renewable, more environmentally friendly fuel, made from waste vegetable oil. The vehicle used, was an Opel Corsa 1.7 diesel, year 2002.

At lower engine revs, the engine does "hunt" (irregular idling), due to poor atomizing of the vegetable oil at the lower revs. To eliminate this, one can install extensions and/or modify the injectors. These extensions can be obtained from www.elsbett.com. They also sell one tank systems. One could also increase the opening pressure of injectors, but in the long term, this may cause damage to the injector pump. In this installation, the idling revs were set higher, and I switch over to diesel fuel, when doing stop/start, town driving.

The long term effect of vegetable oil, on the injector pump is still unknown. It is suspected, that due to the more viscous nature of vegetable oil, even when heated, more wear and tear will result on the delicate parts of the injector pump.

It is recommended that one changes the engine oil, every 7500km.

In warmer areas, the heat exchanger will not be necessary.

Performance and economy between diesel and vegetable oil fuel are similar. You will feel no difference besides one – the exhaust fumes, smell of fries!

The conversion is best suited for longer distance traveling, as switching over to diesel is done less frequently.

The parts were sourced locally, but one can obtain the complete kit from www.elsbett.com

There are other documented cases of vehicles having done over 100,000km on WVO.

This conversion is not recommended for vehicles with the following distribution injector pumps; CAV, Lucas, Stanadyne, RotoDiesel or Delphi.

Investigation into the more modern diesel engines, fitted with common rail and unit injector system, still needs to be done. See Appendix 8.1, for more info.

7. References and useful websites.

Biophile 2006, issue 10, pg 34

www.greaseworks.org
www.elsbett.com

8. Appendices

8.1 Diesel engines

(from www.rodbowen.co.uk/daniel/dieselengines.htm)

This page provides some basic information about diesel engines relevant to their conversion to running on straight vegetable oil (SVO). It also includes details on how to find and identify fuel injector pumps.

There are now at least four types of widely used diesel engines; these are distinguished by the way the fuel injection system works. The four types are described here:

Indirect injection (IDI)

In these engines fuel is not injected directly into the top of the cylinder, it is sprayed indirectly via a combustion chamber or swirl chamber which adjoins the top of cylinder; hence the name indirect injection. It is in this pre chamber that the majority of fuel combustion takes place. The fuel injection pump used on these engines times a single injection of fuel into each combustion chamber in turn. This timed injection is synchronised via the timing belt or chain of the vehicle. Two kinds of fuel injection pump are commonly used with this type of engine: rotary or inline pumps. These two types can be distinguished by the location of the injection pipe outlets on the pump. With rotary pumps the outlets are arranged in a square, or circular configuration at the side of the pump. Where as on an inline pump the outlets tend to be in a line on the top of the pump. Engines of the indirect design are in fact the best for converting to run on SVO provided they have suitable pumps, and because of this many can be fitted with Elsbett one tank conversions.

Direct injection (DI)

In these engines the fuel is injected directly into the cylinder where the combustion takes place. This increases the amount of energy from the combustion converted to motion making vehicles with these engines more efficient than the above. Direct injection engines can use similar injector pumps to those used in the IDI systems giving timed single injections of fuel to each cylinder in turn synchronised by a timing belt. Certain types of these engines which have not progressed on to common-rail direct injection or unit injection can be converted with an Elsbett one tank system.

Common-rail direct injection (CDI)

In these types of diesel engines fuel is also injected directly in to the cylinders of the engine, however the fuel injection pumping system is different to the above. With common rail direct injection the main fuel pump does not pump to each cylinder in turn. Instead it pumps fuel at pressure into a "common rail" which is a common pipe, resilient to high fuel pressures which branches off to each injector. Computer operated valves then control when the fuel injection into the cylinder occurs rather than the timing of the pump. This allows the pressure at which the fuel is injected into the cylinders to be increased, which creates a better combustion of the fuel. Better combustion leads to better fuel efficiency and also lower unburnt or partially burnt emissions. Some manufacturers refer to this type of engine as high-pressure direct injection (HDI). These systems currently can only be converted with two tank conversion systems as they have to start up on diesel. The two tank kits are also not of the conventional type as additional pumps need to be fitted to these systems.

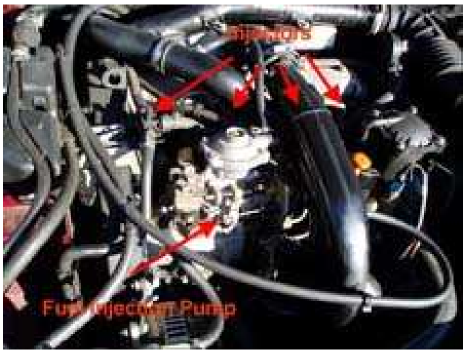
Unit Injection (UI)

This is the injection system design used on the most modern diesel vehicles although the idea has been around for some time. Fuel again is directly injected into the cylinder of the engine. However in this system the injector, which injects the fuel into the cylinder and the pump which creates the necessary pressure to allow this are combined into one unit. Therefore each cylinder has its own pump. In Volkswagen - Audi engines they call this system Pumpe-Düse which translated means pump injector. Currently these engines cannot be converted with an Elsbett one tank system and like the CDI engines require special two tank conversion systems.

Locating a fuel injector pump

This is a beginners guide to locating your fuel injector pump. It intended for vehicle owners who have IDI engines or DI engines which do not fall into the CDI or UI category.

Often the first thing that needs to be done before it is possible to get a good view of the engine is to remove the engine cover, if one is fitted. This can often be unbolted quite easily. Once you can get a good view of the engine it should be possible to see a row of injectors with various pipes attached to them running along the length of the upper part of the engine. These are often in a similar location to where the spark plugs would be on a petrol engine. The pipes that go in to the very ends of the injectors are the injector supply pipes and these can be followed back to find the fuel injector pump. If the fuel injection pump is rotary in design then the injector pipes will come out in a square or circular group from the side of the pump. If engine has an inline pump then the injector pipes will come out of the pump in a row across the top of it. The location of the fuel injector pump on an IDI Peugeot/Citroen engine can be seen here. The fuel injector pump is not always located in such a convenient position at the front of the engine for viewing. On Vauxhall Corsa diesel engines the pump is hidden on the opposite side of the engine. In such cases a mounted mirror is often needed to increase the ease with which the pump can be examined.



Fuel pump identification

Here are some pointers in distinguishing Bosch and CAV/Lucas pumps. These are often the two types of pump that need to be differentiated on European manufactured cars.

The standard Bosch rotary pump for a four cylinder indirect injection diesel can be distinguished by having the Bosch name and symbol cast in to the aluminium body of the pump. These pumps usually have "made in Germany" in the cast as well. The fuel supply enters the pump at the opposite end to the injection outlets.

The equivalent CAV/Lucas pump can be identified by the presence of a blue shiny plate with the CAV/Lucas insignia on it. On these pumps the fuel supply enters at the opposite end to the Bosch pump and at the same end as the injection outlets.

Article on emissions comparison of WVO vs diesel