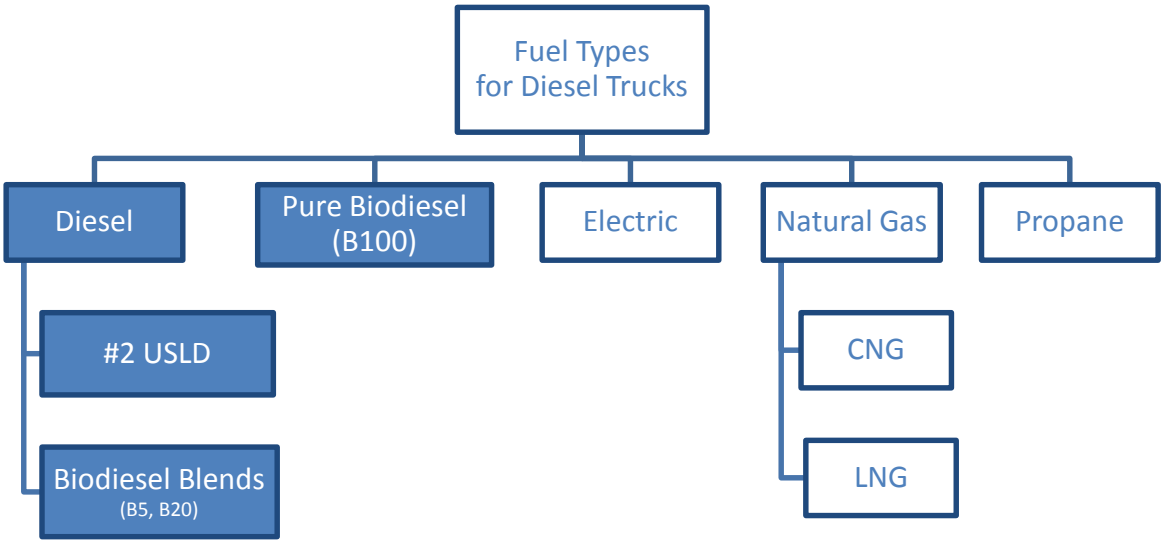
Alternative Fuel and Engine Types Overview

Defining Optimus' Solution

Fleet operators these days have to wade through an "information forest" as they assess the best path forward for reducing fuel costs and emissions, while addressing sustainability and domestic sourcing guidelines. At Optimus we like to keep things simple, so we provide the following overview of alternative fuel types and engine types to help you understand how Optimus relates to other solutions.

Alternative Fuel Types

There are many different types of alternative fuels these days that are being used in medium- and heavy-duty diesel trucks, making it confusing for fleet operators to understand their options, much less the pros and cons of each. The following chart organizes fuel types to make it much easier to understand. Fuels highlighted in blue are compatible with the Optimus Vector system.



Segmentation of fuel types is difficult due to lack of standard terminology or taxonomy across industries, countries, standards committees, regulatory bodies, etc. For instance, with some regulatory organizations and companies, "advanced biofuels" include "biodiesel" regardless of whether or not the fuel is blended with diesel. For others, "biodiesel" is considered a diesel blend (e.g. B5, B20) and "advanced biofuels" refer primarily to pure, non-petroleum, sustainable fuels. At Optimus, we try to keep things clear, referring to non-petroleum-based biofuels as "pure" biofuel.

Advanced biofuels, such as pure biodiesel, are derived from plant oil or animal-fat feedstocks. Such oils come from distillers' corn oil (a by-product of ethanol refining), soybean oil, algae, recycled cooking oil, etc.

When making pure biodiesel, the pre-processed oils are put through a trans-esterification process that involves adding chemicals and chemically changing the molecular structure of the oil. More information on Biofuels can be found in the Biofuels Overview located in the Resources section of the website.

CNG, or compressed natural gas, is a fossil-based fuel that is extracted from deep within the earth's surface, typically via a process known as fracking. The natural gas is collected, processed, and stored under pressure in specially certified transmission and storage systems. CNG usually has to be pumped at independent fueling stations by trained and certified operators who transfer the gas to a truck's large fuel tanks under high pressure. Affordable fueling stations usually require overnight periods, using time-fill technology.[1]

LNG, or liquefied natural gas, is a fossil-based fuel that is similar to CNG, but is transferred in a liquid state under high pressure and cryogenic temperatures (−238 °F). LNG fueling is provided at special fueling stations by trained and certified operators who transfer the gas to a truck's large fuel tanks while using special gloves, protective clothing, and masks. Fueling times for private fleets are similar to diesel[2].

Electric vehicles, both new and retrofitted, are being used in a wide variety of fleet applications. The retrofits for medium- and heavy-duty vehicles are typically bolt-on hybrid systems that work in harmony with the diesel fueling system. Charging of the batteries is usually done by the engine via regenerative braking in which case no changes to the fueling infrastructure are required.

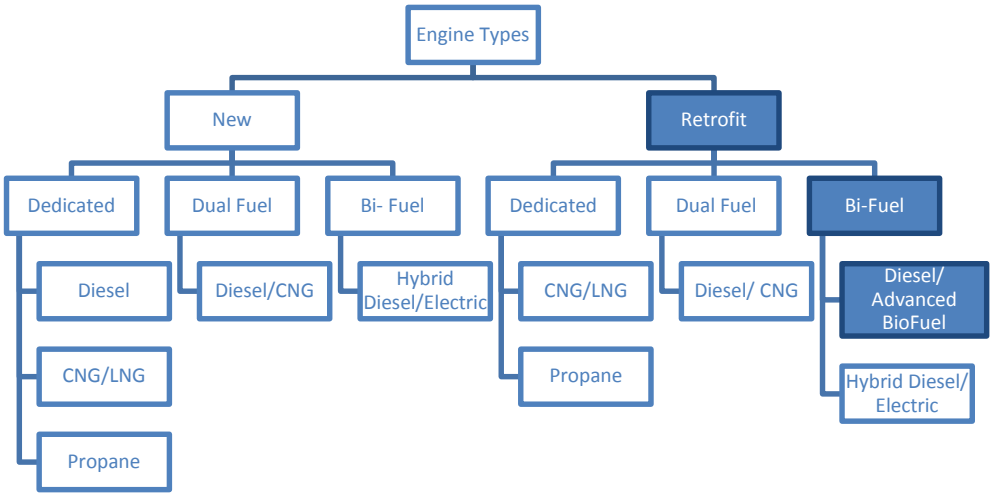
Propane is another alternative fuel produced as a byproduct from natural gas production or coal refining. Propane retrofits are only available for light-duty vehicles including pick-up trucks and small buses.

Now let's look at the alternative fuel engine types and approaches that are available for some of the alternative fuel types discussed above.

[1] http://www.afdc.energy.gov/fuels/natural_gas_infrastructure.html#cost
[2] Ibid.

Alternative Fuel Engine Types

There are many different ways fleet operators can use alternative fuels in medium- and heavy-duty diesel trucks these days, making it confusing understand implementation options, much less the pros and cons of each. The following chart organizes approaches to engines, both new engines and those that are converted via retrofits to make it much easier to understand.



New engines that support alternative fuel solutions are those that are integrated with the vehicle when the vehicle is sold. Some engine manufacturers perform the integration themselves while others contract with third-party vendors. New engines tend to be dedicated solutions.

Retrofits, on the other hand, are provided in one of three approaches. When a vehicle runs on a dedicated fuel system, the original engine is replaced with a new or used engine that uses one fuel type. In the other two cases – dual fuel or bi-fuel -- two fuel types are supported. Dual fuel means that the engine is using both fuels at the same time. Bi-fuel means that the engine can use one OR the other fuel but not both at the same time. Optimus Technologies is currently the only U.S. provider of bi-fuel solutions that use diesel or advanced biofuel for medium- and heavy-duty vehicles.

Fuel Comparison

The following pages provide an overview of some common alternative fuels these days and a comparison of traits that relate to the return on investment and emissions performance. In the end, one will realize that advanced biofuels provide the best option for those seeking to reduce fuel costs and emissions for their current and future fleets through conversion and retrofit solutions.

Alternative Fuel Comparison

Out of the five primary fuel types listed in the diagram above, there are three alternative fuels fleet operators primarily consider for their medium- and heavy-duty trucks – advanced biofuel, CNG, and

biodiesel blends. Of the remaining categories, LNG is very expensive to employ and cumbersome to implement. Also, propane and hybrid electric conversion systems are usually offered for light-duty vehicles only. A comparison of the most common alternatives is provided in the following table:

Table 1

	Traits	Advanced Biofuel	Biodiesel Blends	CNG
Fuels	**Description**	Biofuel is a fuel derived from plant or animal oils. B100 is considered an advanced biofuel.	Blend of diesel and biodiesel. Various blends of increasing biofuel content, typically offered as B5 or B20.	CNG (compressed natural gas) has no nationwide/industry-wide fuel quality standard in place.[3]
	Energy Density relative to Diesel	No loss of power or MPG relative to diesel.	Relatively the same.	1:4[4] Requires much larger fuel tanks per vehicle.
	Fuel Price	Relatively inexpensive domestic, sustainable, renewable fuel source – can be up to 25% *less* expensive than diesel.	Relatively expensive, fossil-fuel source – up to 2-5% *more* expensive than diesel.	Inexpensive domestic, fossil-fuel source – up to 50% *less* expensive than diesel.
	Fuel Availability	Available primarily via private or fleet-based systems.	Available at most truck fuel stops (in low blend levels).	Available primarily via private or fleet-based systems.
	Traits	**Advanced Biofuel**	**Biodiesel Blends**	**CNG**
	Engine and Fuel System Compatibility	Can be used in current diesel engines and fuel systems with minor modifications.	B5 and B20 work in current diesel fuel systems and engines.	Major modifications required to engines and fuel systems.

[3] http://www.nrcan.gc.ca/sites/oee.nrcan.gc.ca/files/pdf/transportation/alternative-fuels/resources/pdf/roadmap.pdf

[4] http://www.eia.gov/todayinenergy/detail.cfm?id=9991
http://arewetoast.com/energy-content-of-selected-fuels.html

		B100 requires minor modifications.		
Conversion Systems	**Costs for Engine Conversion**	Relatively inexpensive -- ~$10k per engine.	No cost.	Relatively expensive -- ~$70k per engine.
	Emissions Performance	Significant emissions reductions. Depends on fuel source and conversion system performance, but typically fewer emissions than diesel, with 38% fewer particulates, 8% less NO_x and 13% less CO_x.	Addresses some level of emissions needs. Depends on fuel source and blend level. For B20, 12% fewer particulates, 2% increased NO_x and 12% less CO_x.[5]	Moderate emission reductions. Depends on conversion system performance; but, typically 10% fewer particulates, 0% less NO_x, and 695% increase in CO_x.[6] Methane emissions (CH_4) can increase 100% over diesel.[7]
	Maintenance Implications Relative to Diesel	Minor. Requires periodic fuel filter change.	Relatively none for B5 and B20. Some extra filter changes and tank cleaning possible during beginning due to biodiesel solvent properties.	Increased in most respects: spark plugs need to be inspected often as well as the fuel storage cylinders. Oil changes less often. Fleet technicians require training on CNG.
Fueling Stations	**Fueling Station Compatibility**	Can be used in current fueling stations with minor modifications (Heating elements used in tanks and fuel pumps). Same modifications for B100.	B5 and B20 work in current diesel fueling stations.	Requires a new fueling station.
	Traits	**Advanced Biofuel**	**Biodiesel Blends**	**CNG**

[5] http://www.biodiesel.org/docs/ffs-basics/emissions-fact-sheet.pdf?sfvrsn=4
[6] http://greet.es.anl.gov/
[7] http://www.research.psu.edu/events/expired-events/naturalgas/documents/trans-fuels-position-paper.pdf

	Fueling Time Relative to Diesel	The same as diesel.	The same as diesel.	Can be substantially longer. For fleets, typically configured for overnight timeframes.
	Fueling Regulations Relative to Diesel	The same as diesel or less in some states/municipalities.	The same as diesel.	Significant impact. Requires certifications and training for operators and mechanics.
	Costs for Fueling Stations	Relatively inexpensive -- $10-140k per station. Can retrofit current diesel systems or install portable systems.	No cost.	Very expensive -- $1-6M per station.[8] Requires special certifications.

With all of the data provided in Table 1, one can quickly analyze the relative pros and cons of each solution as summarized in Table 2.

[8] http://www.afdc.energy.gov/pdfs/47919.pdf

Table 2

Benefits	Advanced Biofuel	Biodiesel Blends	CNG
Reduces fuel expenses (% reduction from diesel price)	10-25%	n/a	~50%
Conversion costs per vehicle (as a % of CNG Conversion Costs)	~10-15%	n/a	100%
Conversion costs per fueling station (as a % of CNG Conversion)	~2-10%	n/a	100%
Reduction of greenhouse gas emissions	~-70 to -100%	~16%[9]	~8 to 30%
Enables domestically produced fuels	X	X	X
Ease of implementation/operation	X	X	-
Average Financial Payback (varies based on fuel use and other factors)	~1yr	n/a	~3-5yrs

Conclusion:

For fleet operators who need to reduce fuel costs and emissions for their current fleets, advanced biofuel is a better alternative fuel option versus CNG, much less any other alternative fuel. And while the technology has been available in Europe for decades, no company in the US market has focused on developing a rugged, high performance solution for medium- and heavy-duty trucks – until now. Optimus Technologies was founded in 2010 with the vision of helping fleet operators with a viable alternative fuel option for their fleets. With Optimus, fleet operators have new options to meet their goals of reducing fuel costs and emissions.

[9] http://www.biodiesel.org/reports/19980501_gen-388.pdf