Land of Enchantment

Clean Cities Coalition

Propane Autogas, the lowest cost and maintenance mid-sized transit fuel available.

You may not know propane, a.k.a autogas, as a transportation fuel, or a motor fuel that your grandparents put in the farm pick-up or tractor. Propane is a domestically-produced gaseous fuel that is currently the most efficient alternative fuel and mid-duty transit bus option – based on fuel cost and life-cycle – compared to gasoline, ethanol (E85) and diesel. Propane is the fastest-growing alternative fuel used in over 15,000 school buses, thousands of shuttle and mid-duty transit buses. It has a stellar safety record and the lowest greenhouse and "smog" controlled tailpipe gases for mid-sized transit buses. Autogas engine technology is proven by millions of miles, operating on systems designed by companies like Roush Clean Tech – think Roush/Ford racing – and others, certified to strict emissions and reliability standards.

Propane is a non-toxic, safe, easy to fuel on-site alternative to off-site refueling, such as retail outlets; mobile (on-road) refueling is also an option with propane autogas; employing propane delivery trucks. Propane can be stored indefinitely and doesn't require hazardous spill containment like gasoline and diesel and eliminates pilferage. Another alternative fuel used in light transit is E85 Ethanol (flex-fuel), which is actually 70% corn-sourced ethanol and not widely available rural New Mexico. Note: Ethanol E85 is sold like gasoline but has roughly 30% less energy in a gallon and blended in gasoline to reduce carbon monoxide (CO) emissions (E10 unleaded).

Between 2017 and 2019, Land of Enchantment Clean Cities Coalition (LOECC) compared the fuel economy of four identically-sized and powered mid-sized transit buses operating on alternative fuels and conventional unleaded gasoline. The analysis was equated using 38,500 miles per year and average fuel costs (with and without incentives), comparing four identical buses and engines, each operating on different fuels – at similar service duty-cycles.

The data were collected from North Central Regional Transit District (NCRTD) and reported to U.S. DOE for alternative fuel data collection in 2018 and 2019 (and early 2020). All fuel comparison data was verified for accuracy using engine manufacturer, U.S. Environment Protection Agency (EPA), U.S. Department of Energy (DOE), and national fleet studies.

When working with alternative transportation fuels, one must understand some basic differences. For example, compressed natural gas is a gas and never a liquid so we compare its energy value to gasoline (or diesel) gallons, resulting in a fair comparison . Propane is also considered a gaseous fuel but remains liquid under pressure in the storage tank and into the engine, where is vaporizes like gasoline. A gallon of propane has approximately 73% energy value of gasoline so we adjust to that to compare the two fuels. For example, on propane the bus got 7 mpg. But if that is equated to gasoline gallon equivalence (GGE), the bus would get 9.44 mpg. Ethanol (E85) contains

approximately 70% ethanol (alcohol) with the remaining 30% being gasoline. So a gallon of ethanol goes about ¾ of the distance that a gallon of gasoline would take you (or 76% energy content compared to a gallon of gasoline).

A summary of lifetime costs based on equal mileages, identical mid-sized buses (Ford E350 chassis) and fuel equivalents. Note: Propane and CNG receive a federal cash-back "tax credit/rebate" for any entity dispensing propane or natural gas. Propane dispensers are the easiest on-site fueling option for transit operators. A summary of performance and costs follows:

Note: GGE refers to Gasoline Gallon Equivalent based on confirmed energy values for gasoline, see below.	Gasoline Cost of bus $75,000 (grant percentage funding not included)	Propane/LPG/Autogas Cost of Bus $100,000 (grant percentage funding not included)	CNG Cost of bus $125,000 (grant percentage funding not included)	Ethanol E85 Cost of bus $75,000 (grant percentage funding not included)	Electric Cost of bus $250,000 ($175,000 assuming 30% grant funding)
Annual Miles	38,500	38,500	38,500	38,500	38,500
Years Operated	7	7	7	7	7
Total Lifetime Bus	269,500	269,500	269,500	269,500	269,500
Fuel Economy (mpg)	9.24 GGE 10.23 DGE	7 mpg LPG (or 9.65 mpg GGE and 10.68 DGE)	9.58 GGE 10.88 DGE (San Juan Basin natural gas dispensed)	9.21 GGE 10.19 DGE	@2.15 kWh per mile (or 15.67 mpg GGE or 17.51 DGE)
Gallons Used Annually per bus	4166	5,500 LPG gallons (or 4,015 GGE)	4,019 GGE	5,697 (E85 gallons)	N/A
Gallons Used Total per Bus – Lifetime	29,167	38,500 LPG gallons (28,368 GGE)	28,133	39,879	N/A

Fuel Price / Gallon	$1.80	$1.19 (or $0.83 per gallon with federal tax rebate)	$2.35 $/GGE ($1.11 – 1.16 DGE fleet price)	$1.73	34 kWh/GGE * $0.155/kWh = $5.25/GGE
Preventative Maintenance Oil and filter changes	$2,238	$2,238	$2,238	$2,238	$800
Lifetime Fuel & Maintenance Costs combined	$54,739 (used as baseline cost)	$48,053 (or $34,193 with tax/credit rebate)	$68,347 (or $34,578 with fleet fuel pricing)	~~$~~71,229	~~$~~91,092 (maintenance cost estimated at $800 for drive-train related fluids and filters)
Lifetime engine-operation Savings	$0	$6,686 (or $20,546 with tax/credit rebate)	$13,608 (or $20,161 with fleet fuel pricing)	$16,490	$36,353
Cost per Mile	$0.20	$0.18 (or $0.13 with tax credit/rebate)	$0.27 (or $0.13 per mile with fleet pricing)	$0.26	$0.34 (based on $0.155/ kWh & 2.15kWh/mile)
Annual GHG	59.7 short tons	49.5 short tons	51.7 short ton (-15.5 short tons using animal-waste sourced renewable natural gas)	36.8 short tons	8.7 short tons Note: Battery manufacturing emissions are not taken into account.

As noted in the table above. Propane and CNG receive a federal tax rebate of $0.36 per gallon propane and $0.50 per gallon CNG -- dispensed. If a number of buses were dedicated to refueling with propane on-site, a propane fuel provider will install a dispenser at no cost and set a price for fuel on a 1-3 year basis. Likewise, one known fuel provider offers $5,000 or more cash support per propane bus. The transit property would then be able to apply for the $0.36 per gallon “tax credit/rebate” from the federal government and the discount rebate from the fuel provider for upfront bus cost. (This

applies to public and tax-exempt entities as well as private companies; the IRS Congressional Alternative Fuels Tax Credit was reauthorized in December 2020.) Note: Compressed natural gas refueling is expensive for small transit operators to install on-site and often not an option if natural gas pipelines are not in proximity to the property.)

Also, while E85 contains roughly 70% renewable feedstock (corn-based), a lot of non-renewable energy is invested in the growing and distillation of corn to make ethanol. This is calculated into the Green House Gas (GHG) numbers in the table above. Also, natural gas and propane can be made from renewable sources and is a growing industry that makes propane and CNG the most "carbon-negative" fuels available, with carbon index numbers much lower than even renewable energy produced electricity. Calculations of electric vehicle GHG based on renewable sources are not readily available due to lack of electric-grid related data. Consequently, this and other nuanced details related to renewable fuel feedstocks are not fully discussed in this article but worth further investigation as we strive for low-and no-carbon alternative fuels.

For more information, contact Land of Enchantment Clean Cities at
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Footnotes

Alternative fuels as described by U.S. Department of Energy (DOE) include: natural gas (CNG & LNG), propane (LPG/autogas), hydrogen, ethanol and electric. Land of Enchantment Clean Cities Coalition has represented New Mexico since 1994, assisting fleets with CNG and propane vehicles and related infrastructure

E85 fuel economy estimates came out 20 to 25 percent lower than gasoline (Edmunds E85 vs. Gasoline Comparison Test)
https://www.edmunds.com/fuel-economy/e85-vs-gasoline-comparison-test.htm

Because of **ethanol's** lower energy content, FFVs operating on **E85** get roughly15% to 27% fewer miles per gallon than when operating on regular **gasoline**, depending on the **ethanol** content. Regular **gasoline** typically contains about 10% **ethanol** so 1.32 gallons of E85 has the same amount of energy as one gallon of conventional gasoline.(US EPA – Fuel Economy
https://www.fueleconomy.gov/feg/ethanol.shtmlHow are GGE and DGE values determined?

Energy content is measured in British thermal units (Btus) per gallon of fuel, and is often referred to as the lower heating value of the fuel. To calculate GGE and DGE, the energy content of one gallon of gasoline or diesel is divided by the energy content of the comparison fuel. For example, conventional gasoline has an energy content of 116,090 Btus per gallon, while propane has an energy content of 84,250 Btus per gallon. As such, 1.38 gallons of propane has the same amount of energy as one gallon of conventional gasoline.

The table below displays the energy content, GGE, and DGE values of conventional and alternative fuels derived from U.S. Department of Energy data. The fuel prices are not current to New Mexico 2020 data.

Fuel	Energy Content*	Quantity of Fuel in 1 GGE	Quantity of Fuel in 1 DGE
Gasoline	116,090 Btu/gallon	1.00 gallon	1.11 gallon
Low Sulfur Diesel	128,488 Btu/gallon	0.90 gallon	1.00 gallon
Biodiesel (B20)	126,700 Btu/gallon	0.92 gallon	1.01 gallon
Biodiesel (B100)	119,550 Btu/gallon	0.97 gallon	1.07 gallon
Compressed Natural Gas (CNG)	923 Btu/cubic foot (ft^3) or 20,160 Btu/lb	125.77 ft^3 or 5.76 lb	139.21 ft^3 or 6.37 lb
Liquefied Natural Gas	21,240 Btu/lb	5.47 lb	6.05 lb
Ethanol (E100)	76,330 Btu/gallon	1.52 gallon	1.68 gallon
Ethanol (E85)**	88,258 Btu/gallon	1.32 gallon	1.46 gallon
Electricity***	3,414 Btu/kilowatt hour (kWh)	34.00 kWh	37.64 kWh
Propane	84,250 Btu/gallon	1.38 gallon	1.53 gallon
Hydrogen	288.88 Btu/ft^3 or 51,585 Btu/lb	401.86 ft^3 or 2.25 lb	444.78 ft^3 or 2.49 lb

* Lower heating value. Source for CNG and hydrogen (Btu/ft^3): Transportation Energy Data Book, Edition 35. Source for remaining values: Alternative Fuels Data Center (AFDC) Fuel Properties.

** E85 that is sold in the United States today actually contains, on average, approximately 70% ethanol. Therefore, E85 energy content calculated as [(.70) x (E100 energy content)] + [(.30) x (gasoline energy content)]

*** Electric vehicles are more efficient (on a Btu basis) than combustion engines, which should be taken into account when calculating and comparing miles per GGE (see below).

The values in the table above can help standardize fuel amounts for comparisons. For example, if you have 10,000 ft^3 of CNG, you can determine the equivalent number of GGEs by dividing by 125.77 ft^3 to get 79.5 GGE. Similarly, to determine the number of DGEs, you would divide by 139.21 ft^3 to get 71.83 DGE.

How are GGE and DGE used to compare fuel prices?

Fuel prices can be represented in dollars per GGE or DGE for consistency in pricing between fuels. For that reason, the Clean Cities Alternative Fuel Price Report shows prices on an energy-equivalent basis (Table 3 in recent reports). If values for price per GGE or DGE are not available, you can do the

calculation on your own. For instance, if one gallon of E85 is $2.04, you would multiply by 1.32 (see table above) to find that this price equates to $2.69 per GGE after adjusting for energy content.

http://nhcleancities.org/2017/04/can-compare-energy-content-alternative-fuels-gasoline-diesel/