

Allegheny County Sanitary Authority Alternative Fuels Analysis Report

Prepared for:

Alternative Fuels Technical Assistance Program

Pennsylvania Department of Environmental Protection

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By:



Wilson Engineering Services, PC
902 Market Street • Meadville, PA 16335
(814) 337-8223

www.wilsonengineeringservices.com

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1.0 EXECUTIVE SUMMARY

Fleet Description

ALCOSAN operates a fleet of over 130 vehicles, ranging from sedans for passenger transportation to heavy-duty trucks for hauling waste. Most vehicles are parked overnight at the plant, though some are taken home by the drivers. Vehicles are replaced on an as needed basis, typically once they reach 100,000 miles or are over 10 years old. Table ES1 summarizes the vehicles and their use.

Table ES1 – Vehicles and Usage

Vehicle Use	Leaves Plant?	Gasoline		Diesel		Total Vehicle Count
		Vehicle Count	Average Annual Fuel Use per Vehicle	Vehicle Count	Average Annual Fuel Use per Vehicle	
Regional Conveyance	Yes	27	735	14	757	41
Tri-Axle Dump Truck ¹	Yes	0	-	12	1,091	12
Industrial Waste	Yes	9	522	0	-	9
Scholastic Outreach	Yes	5	146	0	-	5
Maintenance	No	19	178	3	556	22
Security	No	5	212	0	-	5
Wet Weather Program	Yes	4	633	1	148	5
Misc. In-Plant Use	No	35	189	0	-	35

Note 1: Two of the tri-axle dump trucks are specialty service vehicles, a boom truck and a roll-off truck.

Alternative Fuel Options and Vehicle Types

Table ES2 lists the properties and costs of the various fuels evaluated.

Table ES2 – Fuel Cost Comparison

Fuel Type	Unit of Measure	Units per GGE	Units per DGE	Cost per Unit without Taxes	Cost Per GGE without Taxes	O+M Costs Per GGE	Cost Per GGE Overall
Gasoline ¹	gal	1	1.13	\$2.23	\$2.23	\$0.000	\$2.23
Diesel ²	gal	0.89	1	\$2.37	\$2.10	\$0.000	\$2.10
Biodiesel (B100) ³	gal	0.95	1.08	\$2.98	\$2.84	\$0.000	\$2.84
Biodiesel (B20) ⁴	gal	0.90	1.01	\$2.50	\$2.25	\$0.000	\$2.25
CNG (offsite) ⁵	GGE	1	1.13	\$1.44	\$1.44	\$0.000	\$1.44
CNG (onsite) ⁶	therm	1.27	1.43	\$0.60	\$0.76	\$0.174	\$0.93
Propane ⁷	gal	1.35	1.53	\$1.69	\$2.29	\$0.010	\$2.30
Electric ⁸	kWh	9.10	10.27	\$0.08	\$0.69	\$0.000	\$0.69

Note 1: Gasoline cost is based on a delivery in May 2018.

Note 2: Diesel cost is based on a delivery in May 2018.

Note 3: B100 biodiesel cost is based on the Clean Cities Alternative Fuel Price Report for January 2018 in the Central Atlantic region¹.

Note 4: B20 biodiesel cost is based on a June 2018 price quote from Export Fuel.

Note 5: CNG offsite cost is based on current street price quoted by American Natural, minus \$0.576/gal state tax, and minus \$0.183/gal federal tax.

Note 6: CNG onsite cost is from People's Gas Equitable Division tariff GSS effective April 10, 2018. O+M costs are for a time fill station.

Note 7: Propane cost is based on an estimated price for a 1 year fixed price contract with Progas, assuming 5-10 propane vehicles. Propane supplier will provide onsite fueling station at no cost to ALCOSAN as part of this contract.

Note 8: Electric cost is based on Duquesne Light Company GM-Medium Commercial tariff and the Price to Compare effective March 1, 2018 through May 31, 2018, with metered demand > 25 kW. Electric cost includes fixed fees, assuming 5 electric vehicles. Electric GGE calculation is specific to the Nissan Leaf and includes a battery charging efficiency of 85%.

New vehicles can be purchased and then upfitted to utilize CNG or propane without affecting the OEM warranty. Upfit costs for an F-150 is estimated at \$10,000.

Compressed natural gas (CNG) vehicles store natural gas onboard in high pressure tanks. The CNG is used in a conventional spark ignition engine. Propane vehicles store liquid propane in a tank onboard the vehicle, and likewise utilize the propane in a spark ignition engine.

Biodiesel blends up to B20 can be utilized in diesel engines with no changes required to the vehicle. Diesel vehicles can also be upfitted with technologies that will allow for blends up to B100 to be used. Cost for upfit of a medium or heavy truck is estimated at \$12,000.

Fueling Station Capital Costs

Several potential options require or have as an option an onsite fueling station, however, there is very limited footprint available within the plant to install a fueling station. There are local public CNG stations within ALCOSAN's service area, which if used would avoid capital costs, but the cost of fuel at this station would be higher than if the CNG were dispensed by a fueling station owned by ALCOSAN. A time fill CNG fueling station capable of serving 5 vehicles would be expected to cost about \$60,000.

¹ https://www.afdc.energy.gov/uploads/publication/alternative_fuel_price_report_jan_2018.pdf

Funding from the AFIG program could be utilized to fund 50% of these costs, however, ALCOSAN would be limited to vehicles with a GWVR of 10,000 or less.

Biodiesel blends of up to B20 can be utilized in the same fuel tank which stores conventional diesel, with no upgrades required. Fuel tanks storing higher blends must provide means for cold weather protection of the fuel. A new fuel tank for B100 biodiesel would be expected to cost between \$50,000 and \$70,000.

Economic Analysis

Table ES3 presents the costs, savings, and simple payback of a scenario in which 5 light trucks from the regional conveyance department are replaced with CNG, propane, or hybrid vehicles. The total gasoline usage of these 5 trucks is 4,087 gallons per year. An onsite time-fill CNG option is also shown.

Table ES3 – Capital Costs, Savings, and Simple Payback for 5 Light Trucks

Option	Capital Cost	Assumed Grant Funding	Net Capital Cost With Grants	Fuel Cost Savings	Simple Payback With Grants (years)	Simple Payback Without Grants (years)
CNG Offsite	\$50,000	\$50,000	\$0	\$3,237	0	15
CNG Onsite	\$110,000	\$80,000	\$30,000	\$5,316	6	21
Propane ¹	\$50,000	\$50,000	\$0	(\$265)	-	-
Hybrid	\$55,000	\$27,500	\$27,500	\$1,824	15	30

Note 1: Based on the expected fuel use of 5 vehicles, the propane price does not offer savings over conventional fuels. Pricing may change if ALCOSAN can commit to more propane use.

ALCOSAN can utilize B20 biodiesel in its diesel fleet without any operational changes or infrastructure costs to reduce emissions. Table ES4 presents the fuel costs to switch to a higher blend of biodiesel, 20%. B20 biodiesel is generally equivalent in price to diesel, ±\$0.10. The total diesel usage of the 30 diesel vehicles is 23,230 gallons per year. This would reduce ALCOSAN's greenhouse gas emissions by 87 metric tons, annually.

Table ES4 – Fuel Costs for B20 Biodiesel

Description	Current Fuel Cost	Alternative Fuel Cost	Maintenance Increase	Total Cost
B20 Biodiesel	(\$55,023)	\$58,913	\$0	\$3,890

Note 1: A positive value in the Total line indicates a net increase in costs.

Table ES5 presents the costs, savings, and simple payback of a scenario in which the 5 scholastic outreach vehicles are switched to electric vehicles. These vehicles are highly visible, traveling to schools within the area, providing education on water, public health, and the environment to students. Due to low annual mileage, this option does not provide a payback, however, it may provide the opportunity to further the scholastic outreach division's goals of education on public health and environmental issues.

Table ES5– Capital Costs, Savings, and Simple Payback for Scholastic Outreach Vehicles

Option	Capital Cost	Assumed Grant Funding	Net Capital Cost With Grants	Fuel Cost Savings	Simple Payback With Grants (years)	Simple Payback Without Grants (years)
Electric Vehicles	\$70,000	\$23,000	\$47,000	\$1,122	42	62

Emissions

Alternative fuel vehicles have the potential to improve the emissions profile of the fleet, both in criteria pollutants and greenhouse gas emissions.

The CO₂ reductions of utilizing alternative fuels are well understood. Compared to E10 gasoline, on an energy equivalent basis, natural gas provides a 14% reduction in CO₂ emissions, and propane provides a 2% reduction in CO₂ emissions. Compared to B2 diesel, on an energy equivalent basis, B20 biodiesel provides a 17% reduction in CO₂ emissions. EVs provide CO₂ emissions benefits as a function of the CO₂ emissions of the grid power which they utilize. Based on the generation mix available in western Pennsylvania, the CO₂ emissions benefits of EVs are at least as good as natural gas, and could potentially be greater if power was sourced from renewable generation.

Natural gas and propane engines are available which have been demonstrated to be lower in certain criteria pollutants, such as NO_x, which is a precursor to smog. EVs produce no tailpipe emissions, but they do contribute to emissions at power plants, which are highly regulated. When considering purchase of alternative fuel vehicles, fleet owners should request emissions data for the specific vehicles (or electric power generation) being considered, rather than relying on a blanket assumption that all alternative fuel vehicles are cleaner than modern gasoline and diesel vehicles.

Conclusions

- Switching to a B20 biodiesel blend for the diesel fleet can provide significant greenhouse gas reductions for minimal cost impact
- Vehicle upfits for alternative fuels are not viable without the AFIG program
- Offsite CNG fueling would provide immediate cash flow at current fuel prices
- Onsite CNG fueling provides the most fuel savings based on current economics
- EV developments may offer an opportunity in the near future

2.0 INTRODUCTION

Allegheny County Sanitary Authority (ALCOSAN) is a municipal authority with a wastewater treatment plant located in Pittsburgh, and serves 83 municipalities within Allegheny County. ALCOSAN manages a fleet of service, hauling, plant maintenance, and administrative vehicles. This report evaluates which vehicles in ALCOSAN's fleet are most suited towards replacement with alternative fuel vehicles, and provides economic analysis and discussion of the most viable options.

3.0 FLEET DESCRIPTION

3.1 USAGE AND COST

ALCOSAN operates a fleet of over 130 vehicles, ranging from sedans for passenger transportation to heavy-duty trucks for hauling waste. Some vehicles are used solely within the plant, while others routinely travel outside of the plant. ALCOSAN services a land area of 309 square miles. A map of the service area is provided in Figure 1. Naturally, vehicles routinely traveling outside of the plant have higher annual mileage and use more fuel than those that stay within the plant. The majority of all vehicles are parked overnight at the plant. These vehicles are not kept at a central location however, most are parked at their respective department buildings or work areas. Currently, there are only 11 vehicles that are taken home with the driver overnight.

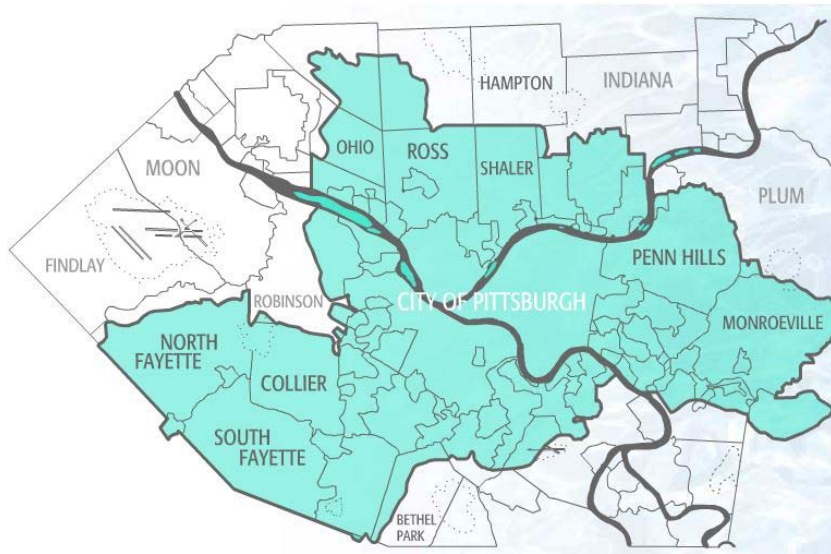


Figure 1: Map of ALCOSAN Service Area

ALCOSAN provided a fleet listing with mileage current to calendar year ending 2017. This data included vehicle make, model, year, fuel type, 2017 fuel mileage and fuel consumption, as well as the total vehicle mileage. Vehicles were also classified by their department or end use. A summary of the vehicle usage by end use is presented in Table 1. The Regional Conveyance vehicles and Tri-Axle Dump Trucks use the most fuel per vehicle. Regional Conveyance vehicles are approximately 2/3rd gasoline and 1/3rd diesel, while the dump trucks are all diesel vehicles.

Table 1 – Vehicles and Usage

Vehicle Use	Leaves Plant?	Gasoline		Diesel		Total Vehicle Count
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Regional Conveyance	Yes	27	735	14	757	41
Tri-Axle Dump Truck ¹	Yes	0	-	12	1,091	12
Industrial Waste	Yes	9	522	0	-	9
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Security	No	5	212	0	-	5
Wet Weather Program	Yes	4	633	1	148	5
Misc. In-Plant Use	No	35	189	0	-	35

Note 1: Two of the tri-axle dump trucks are specialty service vehicles, a boom truck and a roll-off truck.

A summary of the vehicle counts by class for each department is presented in Table 2. The vehicles classes with the most annual mileage and fuel consumption are the tri-axle dump trucks, regional conveyance light and medium trucks, and the industrial waste cargo vans. Generally, the medium and heavy trucks are diesel vehicles, while the rest run on gasoline.

Table 2 – Vehicle Count by Vehicle Class

Vehicle Use	Vehicle Count					
	Sedan	SUV	Cargo Van	Light Truck	Medium Truck	Heavy Truck
Tri-Axle Dump Truck						12
Regional Conveyance		3	3	23	10	2
Industrial Waste		1	8			
Scholastic Outreach		5				
Maintenance			4	14	4	
Security		3		2		
Wet Weather Program				4	1	
Miscellaneous Plant	11	9	9	6		

Note 1: Light trucks consist of F-250 or similar model trucks and smaller.

Note 2: Medium trucks consist of F-450 or similar model trucks.

Note 3: Heavy trucks consist of trucks with a GCWR of 26,001 and greater, including Mack trucks.

ALCOSAN has its own fueling station on site, near the maintenance building. The fuel station consists of one 10,000 gallon tank, evenly split between two chambers for gasoline and diesel. Space for a second fueling station at this site is very limited, and in general, space within the plant is limited. ALCOSAN does own a small piece of property, which is used for overflow parking a few times per year, and is less than ½ mile from the plant.

3.2 REPLACEMENT SCHEDULE

ALCOSAN manages the replacement of its vehicles on an as needed basis. Vehicles are generally replaced once they reach 100,000 miles or reach 10 – 12 years of age, especially if they are vehicles that leave the plant on a regular basis. A scatter plot showing the age and mileage of the fleet by end use is

presented in Figure 2. This plot shows there to be several regional conveyance vehicles with high mileage. The fleet of 10 tri-axle dump trucks are being steadily replaced, two at-a-time, every two years.

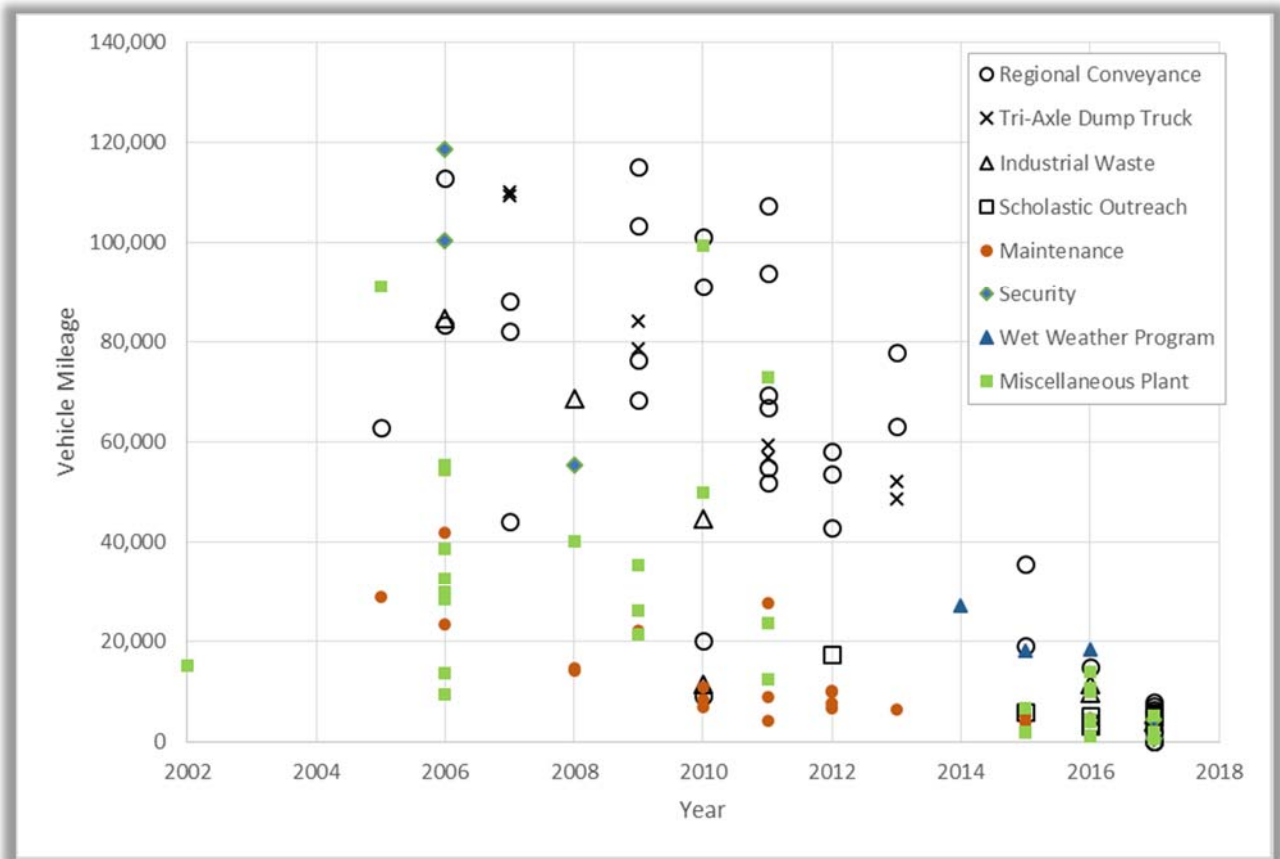


Figure 2 – Age and Mileage of Fleet

4.0 ALTERNATIVE FUELS, COSTS, AND INCENTIVES

Appendix A provides an overview of alternative fuels and fueling stations.

4.1 VEHICLE AVAILABILITY

Depending on the vehicle type, there are several ways to procure an alternative fuel vehicle. Light and medium duty CNG or propane vehicles are not available from the factory as CNG or propane. However, Ford has a network of Qualified Vehicle Modifiers (QVMs) who are certified by Ford to provide alternative fuel upfits to specific models of Ford vehicles which have the gaseous fuel prep package. In some cases, the local Ford dealer coordinates with the factory and a QVM installer to produce an appropriate vehicle to the customer's specifications. In other cases, the customer can purchase a vehicle as a gasoline vehicle with the gaseous fuel prep option, and then they can work with a local QVM upfitter to have the vehicle modified. Alternatively, there are manufacturers of alternative fuel systems who are not QVMs, especially for CNG and propane vehicles. Ford only permits their QVM manufacturers to develop upfits for Ford vehicles, and this restriction may prompt manufacturers to avoid the QVM program so that they can develop systems for a greater range of vehicles. Installers often

offer both QVM and non-QVM upfits. In the case of Ford, QVMs are only able to offer upfit kits for engines which Ford provides with the gaseous prep package. However, non-QVM kits are available for other Ford vehicles that do not offer the gaseous prep option, such as the Explorer or Fusion. Both QVM and non-QVM upfits are available with EPA and/or CARB (California Air Resources Board) certification. Although Pennsylvania is a "CARB state" (meaning that new vehicles must meet CARB emissions limits), there is an exception for alternative fuel vehicles allowing certification by either EPA or CARB.² Upfits which lack final EPA and/or CARB approval are not legal in PA and should be avoided. Federal law requires that auto manufacturers honor vehicle warranties even if aftermarket engine equipment has been installed, as long as that equipment has passed EPA emissions testing. Therefore, non-QVM upfits will not void the vehicle's warranty.

Several heavy duty truck manufacturers market trucks with natural gas engines direct from the OEM. Notably, Mack offers the Cummins Westport ISX12 G engine in its Pinnacle truck series. The upfit cost for a CNG truck in this class can range from \$50,000 to \$70,000, including engine and fuel tank upgrades.

Bi-fuel systems are generally recommended for applications where the vehicle may spend an extended amount of time in a location where CNG or propane fueling stations are not available. In the case of ALCOSAN, the daily mileage is limited and the vehicles return to a common location every night, so the option for bi-fuel vehicles is not necessary. Even if the needed range is available from the CNG or propane storage tank, a bi-fuel upfit can be an advantage because in these cases the vehicles use gasoline at startup to warm up the engine, and then the vehicles switch to propane or CNG. This ensures a smooth startup.

Costs for CNG and propane upfits can vary from approximately \$5,000 for a non-QVM upfit of a Ford Taurus sedan to as high as \$20,000 for a QVM CNG upfit of a Ford E-450 shuttle bus. For the same vehicle, a propane upfit will commonly be 10-20% cheaper than a CNG upfit, because propane is stored at a lower pressure and requires smaller tanks due to its higher energy density.

Most diesel engines can operate on biodiesel blends up to B20 (20% biodiesel, 80% conventional diesel) with no changes required to the vehicle (biodiesel can have a solvent effect within the engine, initially requiring frequent changing of the fuel filter). Technologies also exist that will allow diesel vehicles to operate on any blend of biodiesel up to B100. Optimus Technologies, which is based out of Pittsburgh, is one supplier of such technology, and provides EPA-approved systems focused on the medium and heavy truck classes. With their system, a second fuel tank or dual fuel tank is installed, carrying both conventional diesel and biodiesel. The engine is started on conventional diesel, utilizing waste heat from the engine to warm the biodiesel fuel tank. Once the biodiesel comes up to temperature, the system can then switch to run on 100% biodiesel. The system operates without any needed input from the operator. Installed costs this system are approximately \$12,000.

Electric vehicles are widely available as passenger vehicles, but have limited commercialization as medium duty and heavy duty vehicles due to the steep cost of large battery packs. Two different manufacturers are offering an electric full size cargo van (based on the Ford Transit or RAM Promaster), and the upfit cost is approximately \$65,000 (base vehicle cost is about \$30,000).

2

<http://www.depgreenport.state.pa.us/elibrary/GetDocument?docId=7557&DocName=POLICY%20ON%20CLEAN%20ALTERNATIVE%20FUEL%20CONVERSION%20SYSTEMS.PDF%20>

4.2 INFRASTRUCTURE COSTS

4.2.1 Biodiesel

There are no publicly available biodiesel fueling stations within the ALCOSAN service area. Utilizing biodiesel would require an onsite fueling station. A biodiesel fueling station would mostly be functionally and spatially identical to a conventional fueling station. For B99/B100 blends, consideration must be given to warming the tank, often accomplished with an electric heating element, to allow the biodiesel to flow properly. Biodiesel has a higher viscosity, and can begin to gel in cold weather. B20 blends generally can be treated in the same manner as conventional diesel.

If an existing fuel tank and infrastructure are in place and available to be converted to biodiesel, then infrastructure costs can be minimized. Conversion of an existing tank for B100 biodiesel would cost approximately \$10,000. Installation of a new fuel tank for a B100 biodiesel would depend on site conditions and tank size. A 5,000 gallon tank could be expected to cost \$50,000 to \$70,000.

4.2.2 CNG

For CNG vehicles, ALCOSAN would have the option of fueling at an existing retail fast fill CNG station, or constructing their own time fill or fast fill CNG station. Fueling at a retail station would incur no infrastructure costs. The retail CNG stations are able to sell fuel without the normal state or federal fuel taxes if they have an exemption certificate on file for a particular fleet customer. The PA Department of Revenue also has a system for annually refunding state tax paid on motor fuels.

There are three publicly available fast fill CNG stations within ALCOSAN's service area. A station owned by American Natural is located 4 miles southwest of the plant. This CNG station can provide approximately 7-8 GGE/minute, which is comparable to a conventional gas pump. The two others are owned by EQT in the Strip District, approximately 4 miles east of the plant, and by Giant Eagle in Crafton, approximately 3 miles southwest of the plant. A map showing the CNG fueling stations is presented in Figure 3. For reference, the University of Pittsburgh Medical Center operates an employee transit fleet which utilizes both the American Natural CNG station on the South Side, as well as the EQT CNG station in the Strip District.

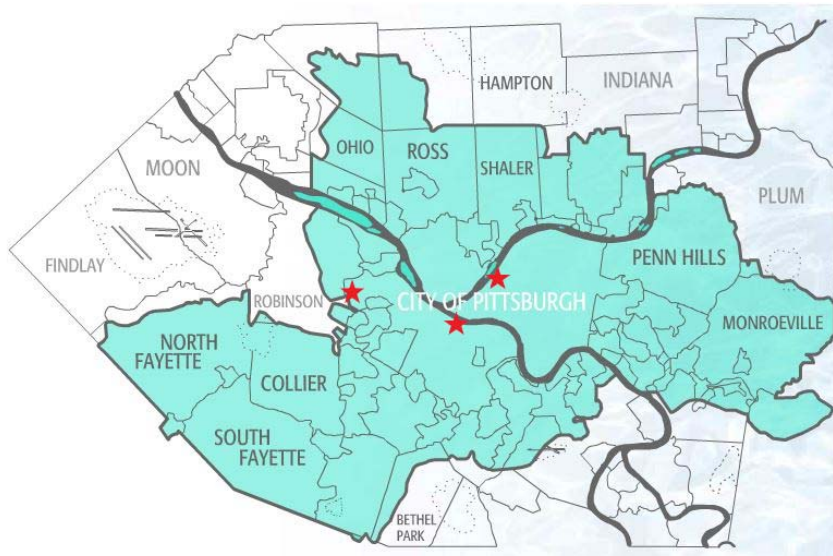


Figure 3: Public CNG Fueling Stations

Installation of its own onsite fast fill or time fill station would carry considerable infrastructure costs. Fast fill stations are significantly more expensive than time fill stations, because of the larger compressors required, as well as the necessary on-site high pressure storage. However, with ALCOSAN's limited footprint available for a new fueling station and lack of a centralized overnight parking area within the plant, installation and operation of a large time fill station would be difficult. A small time fill fueling station designed to serve 5 vehicles is estimated to cost \$60,000.

4.2.3 Propane

A propane fueling station could be installed in a relatively small area at the ALCOSAN plant, requiring a minimum of site work. A station which could supply about 10 vehicles would require one 1,000 gallon tank and a single dispenser. Construction of this station would require an electrical branch circuit capable of operating the dispenser pump and associated equipment. The cost of this station would be approximately \$20,000-\$30,000. WES discussed this potential project with Progas, a local propane supplier, and Progas indicated that they would be willing to provide tanks and fuel dispensers at no charge, including installation, in order to secure an exclusive propane supply contract. ALCOSAN would be responsible for site preparation, supplying power to the dispenser, and installing crash protection bollards as needed. The cost for this ancillary site work is estimated at \$10,000.

4.2.4 Electricity

Each EV would require a dedicated Level II EVSE (Electric Vehicle Supply Equipment, see Appendix A for details) to allow for overnight charging. This would require minimal site modification, except that parking spaces would have to be set aside for the EVs. EVSE costs, including installation, are estimated at \$2,000 to \$4,000 per charging station. Site work to provide a new electrical service and distribution cabinet is estimated at \$2,000 to \$10,000, and can vary considerably depending on the location. If EVSEs can be installed on the wall of a building with electrical service supplied from within the building, installation costs will be reduced, compared to a case where the EVSEs are located in a parking lot area.

An EV would require at least 8 hours to fully charge, which would generally take place overnight. However, with typical usage patterns of the EVs, there would normally be battery charge remaining at the end of each day, thus the time to recharge would be reduced. The charger for this application would likely be a Level II EVSE rated for 6 kW, which requires a 240 V circuit with a 30 A breaker.

4.3 FUEL COSTS

Table 3 lists the properties and costs of the various fuels evaluated. The units GGE and DGE mean Gasoline Gallon Equivalent and Diesel Gallon Equivalent, respectively, and are equal to the amount of energy in a gallon of gasoline or a gallon of diesel fuel. As a government entity, ALCOSAN is exempt from state and federal fuel excise taxes. As of May 2018, ALCOSAN's gasoline price was \$2.23 per gallon, and the diesel price was \$2.37 per gallon.

The price of B100 listed in the table below is based on the Clean Cities Alternative Fuel Price Report for January 2018, in the Central Atlantic region. Note that this price indicates a cost increase over conventional diesel. Price information was requested from fuel suppliers with the ability to serve ALCOSAN, however, was not obtained due to the closing of a biodiesel plant which supplies the area. Price history was obtained from the City of Pittsburgh, which has run a fleet of trash trucks on B100 biodiesel. Their cost of B100 biodiesel was \$2.09 per gallon as of December 2017. With available technology, ALCOSAN could convert its fleet of medium and heavy trucks to B100 biodiesel, but this would not provide a savings based on the pricing presented below, and is not considered.

Table 3 – Fuel Cost Comparison

Fuel Type	Unit of Measure	Units per GGE	Units per DGE	Cost per Unit without Taxes	Cost Per GGE without Taxes	O+M Costs Per GGE	Cost Per GGE Overall
Gasoline ¹	gal	1	1.13	\$2.23	\$2.23	\$0.000	\$2.23
Diesel ²	gal	0.89	1	\$2.37	\$2.10	\$0.000	\$2.10
Biodiesel (B100) ³	gal	0.95	1.08	\$2.98	\$2.84	\$0.000	\$2.84
Biodiesel (B20) ⁴	gal	0.90	1.01	\$2.50	\$2.25	\$0.000	\$2.25
CNG (offsite) ⁵	GGE	1	1.13	\$1.44	\$1.44	\$0.000	\$1.44
CNG (onsite) ⁶	therm	1.27	1.43	\$0.60	\$0.76	\$0.174	\$0.93
Propane ⁷	gal	1.35	1.53	\$1.69	\$2.29	\$0.010	\$2.30
Electric ⁸	kWh	9.10	10.27	\$0.08	\$0.69	\$0.000	\$0.69

Note 1: Gasoline cost is based on a delivery in May 2018.

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Note 6: CNG onsite cost is from People's Gas Equitable Division tariff GSS effective April 10, 2018. O+M costs are for a time fill station.

Note 7: Propane cost is based on an estimated price for a 1 year fixed price contract with Progas, assuming 5-10 propane vehicles. Propane supplier will provide onsite fueling station at no cost to ALCOSAN as part of this contract.

Note 8: Electric cost is based on Duquesne Light Company GM-Medium Commercial tariff and the Price to Compare effective March 1, 2018 through May 31, 2018, with metered demand > 25 kW. Electric cost includes fixed fees, assuming 5 electric vehicles. Electric GGE calculation is specific to the Nissan Leaf and includes a battery charging efficiency of 85%.

4.4 OPERATION AND MAINTENANCE COSTS

Gaseous-fuel such as natural gas and propane can result in reduced engine deposits and cleaner engine oil, compared to gasoline. Biodiesel and biodiesel blends can have a solvent-like effect on engine deposits or residues in the fuel lines or tank, and can release these requiring frequent fuel filter changes, initially. EVs with no combustion engine completely eliminate the need for oil changes. However, the engine is only one component of a vehicle and so the maintenance for tires, brakes, suspension, drivetrain, electrical, and steering is largely unchanged.

Major repair facilities for CNG vehicles must include specific protections against combustible gases near the ceiling, eliminate open flames on heating appliances, and provide adequate ventilation. Major repair is considered body work, welding, engine overhaul, or fuel system work. Minor repair facilities and storage facilities are not subject to as stringent of requirements, but instead have the same requirements as diesel maintenance facilities.⁴ If ALCOSAN selects CNG as a fuel, initially it may be best to outsource major repair to an appropriately equipped facility (or perform maintenance outdoors), until ALCOSAN has acquired enough vehicles to warrant the investment in upgrading its own

³ https://www.afdc.energy.gov/uploads/publication/alternative_fuel_price_report_jan_2018.pdf

⁴ <http://www.government-fleet.com/channel/green-fleet/article/story/2014/11/upgrading-a-maintenance-facility-for-cng.aspx>

maintenance facility. Depending on the layout of the maintenance facility, the upgrades could be targeted at a portion of the facility only, which would then be designated as the CNG major repair area. This would avoid the need to upgrade the entire facility, and light maintenance on CNG vehicles could still be performed in all areas of the maintenance facility. In this report, no capital cost allowances have been made for maintenance facility upgrades.

EVs in particular present a strong case for a reduction in maintenance expense, especially for light duty vehicles. However, EVs are relatively new to the vehicle class under consideration for ALCOSAN, and therefore it is too early to quantify the potential O&M savings, while considering the uncertainty of battery replacement costs.

For the purposes of this report, it is assumed that operation and maintenance costs will be unchanged for alternative fuel vehicles, compared to the existing fleet.

4.5 GRANTS AND INCENTIVES

4.5.1 Alternative Fuels Incentive Grant

The Alternative Fuels Incentive Grant (AFIG) is administered by the Pennsylvania Department of Environmental Protection (DEP), and provides grant funding for the purchase or conversion of alternative fuel vehicles, or the purchase and installation of alternative fuel infrastructure. The grant program is currently accepting new applications for the 2018 cycle.

The details of this grant program for vehicle purchase are as follows:

- Vehicle funding applies to new or retrofitted vehicles.
- Hybrid vehicles which utilize regenerative braking are eligible, even if they are fueled only by gasoline or diesel.
- For new CNG, LNG, propane, biodiesel vehicles using a blend greater than B20, electric vehicles with a battery system capacity equal to or greater than 20 kWh, and hydrogen fuel cell vehicles, applicants may request 100% of the incremental cost of the vehicle up to \$40,000 per vehicle.
- For electric vehicles with a battery system capacity between 10 kWh and 20 kWh, applicants may request 75% of the incremental cost of the vehicle up to \$20,000 per vehicle.
- For existing CNG, LNG, propane, and biodiesel vehicles using a blend of B20 or greater, which are retrofitted with these alternative fuel systems, and for electric vehicles with a battery system capacity of less than 10 kWh, applicants may request 50% of the incremental cost up to \$20,000 per vehicle.
- Maximum request for all vehicles combined can be no greater than \$300,000.
- Applicants can receive AFIG funding in consecutive years, but an initial grant project must be completed prior to any grant application in a subsequent year.
- Vehicles which receive funding from Driving PA Forward cannot also receive AFIG funding.

The details of this grant program for fleet fueling infrastructure are as follows:

- Grant funding is limited to 50% of the cost of a fleet fuel station, with a maximum grant of \$500,000.
- Fleet refueling projects require a minimum of 10 vehicles using the refueling station, owned by a single entity, 26,000 GVWR or less.
- When funds for purchase of alternative fuel vehicles are also requested, the overall maximum grant award is \$600,000.

4.5.2 Driving PA Forward (Volkswagen Environmental Mitigation Trust Agreement)

The Commonwealth of Pennsylvania has received approximately \$118 million from two Volkswagen settlements, which will be administered by DEP in a program called Driving PA Forward. The plans for how to spend this money were announced in May 2018, but applications for funding will not be accepted until mid-2018. The overall goal will be to fund diesel-source NOx reductions and EV charging infrastructure. ALCOSAN may be able to leverage these funds specifically for replacing diesel vehicles.

4.5.3 Alternative and Clean Energy Program

The Alternative and Clean Energy Program (ACE) provides financial assistance in the form of grant and loan funds for the development of alternative and clean energy projects in the Commonwealth of Pennsylvania. Businesses, nonprofit organizations, economic development organizations, and political subdivisions are eligible to apply. The program provides funding for building efficiency upgrades, alternative energy projects, and manufacturing of alternative energy fuels and products.

The maximum grant amount for a CNG or LNG fueling station which is accessible to the public is \$2,000,000 or 40% of the project cost, whichever is less. The maximum grant amount for a CNG or LNG station which is not accessible to the public is \$2,000,000 or 25% of the project cost. Propane fueling stations and EVSE infrastructure are not specifically addressed. The maximum combination of grants and loans from the ACE program is \$5,000,000 or 50% of the project cost, whichever is less.

AFIG and ACE grants are generally not awarded to the same project.

4.5.4 Diesel Emissions Reduction Act (DERA) Grant

The EPA administers the Diesel Emissions Reduction Act (DERA) grant program which provides grants to fleets which operate diesel vehicles to repower or add additional emissions controls to existing diesel engines. Regional, state, local, or tribal entities are eligible to participate. Eligible vehicles include school buses and Class 5 through Class 8 heavy duty trucks. Vehicle replacements are funded at 25% (or at 35% if the engine is certified to CARB's Optional Low-NOx Standards), however, these replacements must be done electively and the funding is not available for vehicles that would have been replaced anyway within 3 years. Alternative fuel conversions are funded at 40%.

4.5.5 Federal EV Tax Credit

The Federal EV Tax Credit applies to all-electric as well as plug-in hybrid vehicles, and the amount is based on the battery capacity. The base amount of the credit is \$2,500, and if the vehicle has a battery capacity greater than 5 kWh, \$417 is added to the credit for each battery kWh above 5. For example, a vehicle with a 7 kWh battery would be eligible for a credit of \$2500 + \$417 * 2, which is \$3,334. The maximum amount of the credit is \$7,500 (this is achieved for all EVs with a battery capacity of 17 kWh or greater).

The credit can only be applied to tax owed in the year that the vehicle was purchased, and therefore, nonprofit and government entities cannot directly claim this credit. However, the credit does have provisions which allow the seller of the EV to take the credit. The seller is not required to pass on the amount of this credit to the buyer, but the seller must disclose to the buyer the tentative amount of the credit. In some cases, it may not be feasible for a seller to take the credit, because they may not have sufficient tax liability to be offset by the credit. This could especially be the case with manufacturers who exclusively market EVs, but it could also occur at other dealers depending on how they have structured their business units. EV Smart Fleets had published a report on strategies for capturing the federal EV

tax credit, which outlines how public agencies have successfully leveraged this credit to reduce fleet acquisition costs.⁵

4.5.6 Alternative Fuel Infrastructure Tax Credit (Expired)

This federal incentive expired at the end of 2017. It has been extended retroactively in the past, and may be extended in the future. This tax credit provides 30% of the funding for a natural gas, propane, electricity, E85, or blended diesel fueling facility, up to \$30,000. Tax exempt and government entities may be able to structure an agreement with a private fuel station developer so that the fuel station is able to take the tax credit and pass the savings on to the host entity.

4.5.7 Alternative Fuel Excise Tax Credit (Expired)

This federal incentive expired at the end of 2017. It has been extended retroactively in the past, and may be extended in the future. This tax credit provides a refund of \$0.50 per GGE for natural gas, propane, and liquefied hydrogen fuels. To be eligible for the credit, an entity must be liable for paying the federal excise tax on the applicable alternative fuels. This is generally the case if the alternative fuels are dispensed from a fueling station which is owned by the entity, but is not the case if the alternative fuels are purchased from a retail dispensing station not owned by the entity. In ALCOSAN's case, this tax credit would apply (if it was extended) to an onsite time fill CNG station, or an onsite propane station, but it would not apply to purchases of fuel at the American Natural CNG station, for example.

4.5.8 Biodiesel Income Tax Credit (Expired)

This federal incentive expired at the end of 2017. It has been extended retroactively in the past, and may be extended in the future. This incentive provides an income tax credit of \$1.00 per gallon for biodiesel delivered to vehicles from a vehicle owner's private filling station. If biodiesel is purchased at a retail station, the station owner is able to claim the credit. Because ALCOSAN has no income tax liability, ALCOSAN would be unable to take advantage of this credit if it built its own biodiesel fueling station. However, if an independently owned fueling station was identified which could supply ALCOSAN's vehicles with biodiesel, the potential credit to the station owner could factor into the price negotiations.

5.0 ECONOMIC ANALYSIS

Three scenarios are presented to evaluate the costs and savings of transitioning to an alternative vehicle fleet. The first shows a scenario in which 5 Regional Conveyance light trucks would be converted to an alternative fuel. The second shows a scenario in which ALCOSAN would switch from conventional diesel (B2) to a B20 biodiesel blend. The third shows a scenario in which the 5 Scholastic Outreach vehicles could be replaced with electric vehicles.

5.1 5 REGIONAL CONVEYANCE VEHICLES

Table 4 presents the added capital cost estimates for transitioning 5 light trucks from the regional conveyance department to an alternative fuel. The light truck class includes the Chevrolet Silverado, GMC Sierra and the Ford F-150 and F-250 model trucks. As these trucks are replaced, new trucks can be purchased or upfitted with alternative fuel options. Currently 6 of these vehicles are slated for replacement within the next 2 to 3 years. The upfit cost of a light truck is estimated at \$10,000 for CNG or propane, and \$11,000 for an electric hybrid with regenerative braking.

A CNG option with an onsite time-fill fueling station is also shown. Note that in order to receive AFIG grant funding for a fleet fueling station, at least 10 CNG vehicles would be required. However, for

⁵ <http://evsmartfleets.com/materials/capturing-the-federal-ev-tax-credit-for-public-fleets/>

vehicle classes with a GVWR up to 10,000 lbs, ALCOSAN can qualify for the Workplace, Home, or Intermediary Refueling option under AFIG. This funding would pay for half of the infrastructure costs for an onsite fueling station. A time-fill CNG station designed to serve 5 vehicles would require minimal footprint for a small compressor, fuel dryer, and buffer tank, with fueling posts installed at each parking spot.

Table 4 – Capital Cost Estimates for 5 Light Trucks

Description	CNG Offsite	CNG Onsite	Propane	Hybrid
Vehicle Upfits	\$50,000	\$50,000	\$50,000	\$55,000
AFIG Vehicle Funding	(\$50,000)	(\$50,000)	(\$50,000)	(\$27,500)
Fueling Station	\$0	\$60,000	\$0	\$0
AFIG Fuel Station Funding	\$0	(\$30,000)	\$0	\$0
Total Cost With Grants	\$0	\$30,000	\$0	\$27,500
Total Cost Without Grants	\$50,000	\$110,000	\$50,000	\$55,000

The average annual fuel usage of the 23 light trucks in the regional conveyance department was 817 gallons of gasoline for 2017. Thus, the 5 light trucks under consideration for conversion use a total of 4,087 gallons of gasoline per year. CNG and propane options would replace the entire gasoline usage of the 5 vehicles, while a hybrid vehicle would provide a fuel reduction of approximately 20%.

Table 5 presents the fuel costs and savings for the 5 light trucks. Note that propane does not offer savings over conventional fuel. Because the propane supplier would supply the propane fuel tank, propane pricing is based on overall use. Were more vehicles to be converted to propane, a more competitive price could be obtained.

Table 5 – Fuel and Maintenance Costs for 5 Light Trucks

Description	Current Fuel Cost	Alternative Fuel Cost	Fuel Not Offset	Maintenance Increase	TOTAL
CNG Offsite	(\$9,122)	\$5,885	\$0	\$0	(\$3,237)
CNG Onsite	(\$9,122)	\$3,806	\$0	\$0	(\$5,316)
Propane	(\$9,122)	\$9,387	\$0	\$0	\$265
Hybrid ²	(\$9,122)	\$0	\$7,298	\$0	(\$1,824)

Note 1: A positive value in the Total line indicates a net increase in costs.

Note 2: Hybrid vehicle fuel use assumes 20% fuel savings.

Table 6 presents the costs, savings, and simple payback for the 5 light trucks with CNG and propane.

Table 6 – Capital Costs, Savings, and Simple Payback for 5 Light Trucks

Option	Capital Cost	Assumed Grant Funding	Net Capital Cost With Grants	Fuel Cost Savings	Simple Payback With Grants (years)	Simple Payback Without Grants (years)
CNG Offsite	\$50,000	\$50,000	\$0	\$3,237	0	15
CNG Onsite	\$110,000	\$80,000	\$30,000	\$5,316	6	21
Propane ¹	\$50,000	\$50,000	\$0	(\$265)	-	-
Hybrid	\$55,000	\$27,500	\$27,500	\$1,824	15	30

Note 1: Based on the expected fuel use of 5 vehicles, the propane price does not offer savings over conventional fuels. Pricing may change if ALCOSAN can commit to more propane use.

With the CNG options for 5 light trucks, ALCOSAN would reduce its CO₂ emissions by 4 metric tons annually. With the hybrid option, ALCOSAN would reduce CO₂ emissions by 6 metric tons, annually. Emissions are discussed further in Section 6.0.

5.2 B20 BIODIESEL

ALCOSAN has a fleet of 30 diesel vehicles and has the opportunity to significantly reduce the emissions from these vehicles by utilizing a higher blend of biodiesel fuel. Currently, all diesel sold in the state of Pennsylvania must contain at least 2% biodiesel (B2). ALCOSAN could utilize a B20 biodiesel (20% biodiesel, 80% petrodiesel) in its diesel fleet, at no significant cost increase or performance difference. This would simply require purchasing a different diesel fuel blend. Historical price information provided by the Clean Cities Alternative Fuel Price Report, published by the U.S. Department of Energy, has shown historical B20 biodiesel prices to be equivalent to petrodiesel, plus or minus about \$0.10 per gallon. B20 biodiesel contains about 1% to 2% less energy per gallon than conventional diesel, requiring a small increase in fuel use.

The vast majority of diesel OEM's now approve B20 for use in their engines and state formally that B20 biodiesel will not void parts or workmanship warranties, provided that the fuel meets the appropriate ASTM standards. This includes all of the diesel vehicles operated by ALCOSAN manufactured in 2011 or later. Older diesel vehicles can still use B20 biodiesel, however, no warranty guarantees have been provided by the manufacturer. Note that increased fuel filter replacement may be required initially, particularly with older vehicles.

Because this scenario simply involves switching fuels, there are no capital costs required. The annual diesel usage of the fleet of 30 diesel vehicles is approximately 23,230 gallons.

Table 7 presents the fuel costs for the diesel fleet with B20 biodiesel. The price of B20 biodiesel is slightly higher than current diesel price, based on a price quote from June 2018, and a May 2018 delivery price of diesel to the site. A portion of this cost increase may be explained by the time difference in price information, as diesel prices in the region have risen \$0.10 per gallon over this time period according to EIA information.

Table 7 – Fuel and Maintenance Costs for B20 Biodiesel

Description	Current Fuel Cost	Alternative Fuel Cost	Maintenance Increase	Total Cost
B20 Biodiesel	(\$55,023)	\$58,913	\$0	\$3,890

Note 1: A positive value in the Total line indicates a net increase in costs.

By utilizing a B20 biodiesel blend, ALCOSAN would reduce its CO₂ emissions by 39 metric tons annually. Emissions are discussed further in Section 6.0.

5.3 ELECTRIC VEHICLES FOR SCHOLASTIC OUTREACH

ALCOSAN operates a fleet of 5 scholastic outreach vehicles, which travel to local schools. The role of this division is to educate students about water, public health, the environment and career opportunities in science, technology, engineering and math fields. While annual mileage of these vehicles is low, these vehicles have a high degree of visibility within the community, and an electric vehicle may provide the scholastic outreach division with an opportunity to demonstrate environmentally friendly technologies. These vehicles are also kept at the same location overnight, allowing for a charging station to charge vehicles overnight.

The existing scholastic outreach vehicles are not expected to be replaced in the near term, however, with this option it is assumed that these vehicles might be traded in or passed to another division with need of vehicle replacement. Trade-in values for the scholastic outreach division's Chevrolet Equinoxes

are estimated to range from \$10,000 to \$14,000. A trade-in value of \$12,000 per vehicle is assumed. Table 8 presents the capital cost estimates for this option. Electric vehicle pricing is based on the 2018 Nissan Leaf, and is estimated to be \$30,500. This price is offset by the value of the trade-in, federal EV tax credit, valued at up to \$7,500, and the incremental upfit costs funded by AFIG. Note that government entities cannot directly claim the federal EV tax credit, however, the credit does have provisions which allow the seller to take the credit.

Table 8 – Capital Cost Estimates for Scholastic Outreach Vehicles

Description	EV
Electric Vehicle Cost ¹	\$152,500
Existing Vehicle Trade-in Value ²	(\$60,000)
AFIG Vehicle Funding/ Federal EV Tax Credit ³	(\$60,500)
Charging Station	\$15,000
AFIG Charging Station Funding ⁴	\$0
Total Cost With Grants	\$47,000
Total Cost Without Grants	\$107,500

Note 1: Electric vehicle cost assumes a base price of \$30,500.

Note 2: Trade-in value is assumed to be \$12,000 on average for the existing vehicles, and is based on Kelly Blue Book trade-in value.

Note 3: The incremental cost funded by AFIG is based on the 2018 Nissan Sentra, estimated at \$18,400. Note that because this option requires ALCOSAN to switch vehicle classes, AFIG may not choose to fund the entire incremental cost.

Note 4: AFIG funding for infrastructure requires a minimum of 10 vehicles, and therefore is not applicable.

The average annual fuel usage of the 5 scholastic outreach vehicles was 146 gallons of gasoline for 2017. Thus, the 5 vehicles under consideration for conversion use a total of 729 gallons of gasoline per year. Table 9 presents the fuel costs and savings for the alternative fuel option for the scholastic outreach vehicles.

Table 9 – Fuel and Maintenance Costs for Scholastic Outreach Vehicles

Description	Current Fuel Cost	Alternative Fuel Cost	Maintenance Increase	TOTAL
Electric Vehicles	(\$1,627)	\$506	\$0	(\$1,122)

Note: A positive value in the Total line indicates a net increase in costs.

Table 10 presents the costs, savings, and simple payback for the alternative fuel option for the scholastic outreach vehicles.

Table 10 – Capital Costs, Savings, and Simple Payback for Scholastic Outreach Vehicles

Option	Capital Cost	Assumed Grant Funding	Net Capital Cost With Grants	Fuel Cost Savings	Simple Payback With Grants (years)	Simple Payback Without Grants (years)
Electric Vehicles	\$70,000	\$23,000	\$47,000	\$1,122	42	62

By replacing the scholastic outreach vehicles with electric vehicles, ALCOSAN would reduce its CO₂ emissions by over 1 metric ton annually. Emissions are discussed further in Section 6.0.

6.0 EMISSIONS

6.1 CO₂ EMISSIONS

Table 11 lists the CO₂ emissions of the various fuels under consideration in this report.

Table 11 – CO₂ Emissions from Vehicle Fuels

Fuel (unit)	lb CO ₂ per unit volume	lb CO ₂ per GGE
Gasoline E10 (gal)	17.4	17.4
Diesel B2 (gal)	21.7	19.2
B100 Biodiesel (gal)	0.0	0.0
B20 Biodiesel (gal)	17.7	15.9
Gasoline E10 Hybrid (gal)	17.4	17.4
Natural Gas (Mcf)	119.9	15.0
Propane (gal)	12.6	17.0
Electricity (kWh)	1.4	15.5

Note 1: Gasoline, Natural Gas, and Propane data are from Instructions for Form EIA-1605, Voluntary Reporting of Greenhouse Gases, April 25, 2007. Gasoline emissions are for a 10% Ethanol blend. Electricity data is from 2014v2 EPA eGrid data for subregion RFCW, using value for Total Output Emission Factor (baseload). Electricity emissions include EPA estimated line losses of 4.97%.

It is important to note that the CO₂ emissions from electricity reported in Table 11 are based on the default mix of power generation in western Pennsylvania. The CO₂ emission of an EV could be drastically reduced if an owner were to exercise their option of supplier choice to purchase “green” power for charging the EV.

6.2 CRITERIA POLLUTANTS

6.2.1 California Air Resources Board (CARB) Data

Table 12 lists the pollutant emissions from a new heavy duty Ford vehicle.

Table 12 – Ford E-450 Emissions

Fuel	BHP	NMHC	NOx	CO	PM	HCHO
Gasoline	305	0.05	0.16	3.70	0.001	0.000
Diesel	330	0.02	0.15	0.50	0.010	0.002
CNG	305	0.05	0.12	1.70	n/a	0.010
Propane	305	0.07	0.13	3.30	0.001	0.001

Note: BHP = brake horsepower, NMHC = non-methane hydrocarbon, PM = particulate matter, HCHO = formaldehyde. Pollutant values are expressed in units of grams per brake horsepower-hour.

Note: Gasoline and Propane data are from MY2018 E-450 6.8L gasoline CARB executive order test results. Diesel data are from MY2018 6.7L diesel CARB executive order test results. CNG data are from E-450 6.8L gasoline MY2017 CARB executive order test results.

Fiat Chrysler Automotive (FCA) produces a bifuel gasoline/CNG version of the RAM 2500 pickup truck. This vehicle is experiencing production problems and lacks support from FCA, and therefore it should not be considered for purchase. However, the emissions test results for this vehicle are of interest. Table

13 presents a selection of the test results for the city driving cycle federal test protocol simulating the useful life of the vehicle, from the model year 2018 CARB Executive Order.

Table 13 – RAM 2500 CNG/Gasoline Emissions

Fuel	NMOG+NOx (g/mi)	CO (g/mi)	NOx (g/mi)	HCHO (mg/mi)	PM (g/mi)
CNG	0.0796	0.65	0.066	0.7	n/a
Gasoline E10	0.1755	1.00	0.092	n/a	n/a

Note: NMOG = non-methane organic gas, HCHO = formaldehyde, PM = particulate matter.

Test results for model year 2016 Ford F-250 and F-350 are available from CARB for multiple upfitters and fuel types. Table 14 presents a selection of the test results for the city driving cycle federal test protocol simulating the useful life of the vehicle, from applicable model year 2016 CARB Executive Orders.

Table 14 – Ford F-250 and F-350 Engine Emissions

Upfitter	Engine Disp. (L)	Fuel	NMOG ¹ (g/mi)	CO (g/mi)	NOx (g/mi)	HCHO (mg/mi)	PM (g/mi)	Notes
Ford OEM	6.2	E85	0.0880	2.00	0.100	1.0	n/a	Class MDV4
Ford OEM	6.2	Gasoline	0.0500	2.50	0.100	n/a	n/a	Class MDV4
Ford OEM	6.7	Diesel	0.0578	0.30	0.200	7.4	0.01	Class MDV4
Ford OEM	6.2	E85	0.1020	2.40	0.100	7.0	n/a	Class MDV5
Ford OEM	6.2	Gasoline	0.0490	3.10	0.100	n/a	n/a	Class MDV5
Ford OEM	6.7	Diesel	0.0461	0.70	0.300	7.3	0.01	Class MDV5
Impco	6.2	CNG	0.0015	1.17	0.020	0.0	n/a	Class MDV4
Westport	6.2	CNG	0.0090	1.95	0.061	n/a	n/a	Class MDV4 and MDV5
LandiRenzo	6.2	CNG	0.0380	2.23	0.100	n/a	n/a	Class MDV4

Note 1: Diesel tests report results as NMHC rather than NMOG. NMHC results have been converted to NMOG using a factor of 1.07 NMOG/NMHC⁶.

Note: NMHC = non-methane hydrocarbon, NMOG = non-methane organic gas, HCHO = formaldehyde, PM = particulate matter.

6.2.2 Low NO_x Technology

NO_x refers to oxides of nitrogen which generally take the form of NO, NO₂, N₂O, and N₂O₂. NO_x is produced when nitrogen is exposed to high temperatures in a combustion process.⁷ NO_x is regulated because it reacts with VOCs (volatile organic compounds) in the atmosphere to produce ozone, which is a respiratory irritant.

The current limit for NO_x in heavy duty diesel engines is 0.20 grams per brake horsepower hour (g/bhp-hr). This limit was phased in from 2007-2010.⁸ CARB has proposed voluntary low-NOX standards of 0.10, 0.05, and 0.02 g/bhp-hr. So far, several commercially available engines have been certified to meet these standards, and these are listed in Table 15.

⁶ Conversion Factors for Hydrocarbon Emission Components. US EPA. 2005.

<https://19january2017snapshot.epa.gov/www3/otaq/models/nonrdmdl/nonrdmdl2005/420r05015.pdf>

⁷ Nitrogen Oxides (NO_x), Why and How They Are Controlled. US EPA. 1999.

<https://www3.epa.gov/ttnecat1/dir1/fnoxdoc.pdf>

⁸ <https://www.dieselnet.com/standards/us/hd.php>

Table 15 – Low NO_x Engines

Manufacturer	Engine	Fuel Type	Standard Met (g/bhp-hr)	Test Result (g/bhp-hr)	Emissions with Diesel (g/bhp-hr)
Cummins Westport	8.9L ISL G	Natural Gas	0.02	0.01	n/a
Cummins Westport	8.9L L9N	Natural Gas	0.02	0.01	0.16
Cummins Westport	11.9L ISX12N	Natural Gas	0.02	0.01	0.19
Roush Cleantech	Ford 6.8L	Propane	0.05	0.01	0.08
Roush Cleantech	Ford 6.8L	Natural Gas	0.10	0.04	0.08
Cummins Westport	6.7L ISB6.7 G	Natural Gas	0.10	0.08	0.19
Cummins Westport	6.7L B6.7N	Natural Gas	0.10	0.08	0.15

Note: Data are from CARB Executive Orders.

6.2.3 Discussion

Alternative fuel vehicles are required to meet the same emissions standards as conventional fuel vehicles. However, CNG and propane have the potential to provide significant emissions reductions when used in specially tuned engines. Due to the wide variety of engine technologies available, fleet managers should critically evaluate emissions claims, especially when applied to a specific fuel across the board. Emissions benefits are best substantiated by emissions test results for the specific vehicle model being considered for purchase. These test results should be requested from the OEM and/or upfitters as part of a solicitation for quote.

6.3 EV EMISSIONS

EVs have zero tail pipe emissions, but do contribute to power plant emissions, depending on how the electricity is sourced. The CO₂ emissions for electricity assume that charging takes place at night, rather than during peak hours, and this allows for the use of base load power which has a reduced carbon intensity. Although power plants do emit pollutants, they do so in a carefully regulated way. Most power plants are sited so that they minimize impacts on communities, whereas internal combustion engine vehicles deposit emissions disproportionately in densely populated areas where the pollutants are the most likely to result in health risks.

7.0 CONCLUSIONS AND RECOMMENDATIONS

ALCOSAN has a large number of vehicles and relatively low annual mileage per vehicle. This limits the savings which can be achieved on a per vehicle basis. The options in this report have targeted the vehicles which are reported to have larger annual mileages, the vehicles servicing the regional conveyance system. The report also looks at no-cost fuel switching to reduce emissions from diesel vehicles.

Publicly available CNG fuel is cheaper than gasoline by about 35%. With the low annual mileage of the fleet, however, normally converting to CNG would not be viable. However, with the AFIG grant potentially covering 100% of the upfit cost of a new vehicle and a few public CNG filling stations located within the service area, CNG vehicles could provide immediate cash flow for ALCOSAN. Conversion of the regional conveyance fleet to CNG as they are replaced is the best project in terms of economics, if grant funding can be obtained.

ALCOSAN can also significantly reduce its greenhouse gas and pollutant emissions by utilizing a higher biodiesel blend fuel. By utilizing a B20 biodiesel blend, ALCOSAN can reduce its CO₂ emissions by over 80 metric tons, annually, at little to no cost.

This study evaluated the options based on current usage patterns and preferred vehicle types. With the lack of a centralized overnight parking area and limited footprint available, EV options for the regional conveyance and industrial waste fleets are difficult. ALCOSAN does have a small fleet of 5 scholastic outreach vehicles that do share an overnight parking area, in which a charging station could be built. These vehicles are highly visible, traveling to schools within the area, providing education on water, public health, and the environment to students. Due to low annual mileage, this option does not provide a payback, however, it may provide the opportunity to further the scholastic outreach division's goals of education on public health and environmental issues.

Due to rapidly advancing options in EVs, and potential grants from Driving PA Forward, ALCOSAN should revisit available EV options in the near future. A low-cost, short-range EV appropriate for the scholastic outreach vehicles would be ideal for ALCOSAN due to the short distances traveled. Current trends in EV development are towards increasing range, which is not what ALCOSAN needs in this case. However, it is expected that as the EV market becomes more developed, there will be more options so that ALCOSAN would not need to spend excess money on range that is never going to be used. EVs may be the best long term solution for ALCOSAN for certain vehicle classes, because they would provide the best emissions reduction and would result in long term maintenance cost reductions. It is expected that as the EV market becomes more developed, there may be more options that will fit ALCOSAN's needs.

7.1 NEXT STEPS

- Work with fuel suppliers to understand the potential, if any, cost impacts of switching to B20 biodiesel.
- Work with fuel suppliers to develop cost estimates for B100 biodiesel.
- Evaluate the convenience of local options for CNG vehicle service, keeping in mind that minor repairs can still be done in house. One potential service provider would be Fyda Freightliner in Canonsburg, PA.
- Monitor the Driving PA Forward Grant Program rules for potential project funding as an alternative to AFIG.

Appendix A – Discussion of Alternative Fuel Vehicles and Fueling Stations

A.1 Compressed Natural Gas

A.1.1 CNG Vehicles

Compressed Natural Gas (CNG) powered vehicles are designed to have similar range and performance to their gasoline or diesel fueled counterparts, but they do have a few components that are distinctly different. Similar to a gasoline engine, natural gas is injected into the cylinder and a spark is used to ignite it. Some automakers have produced dedicated CNG vehicles, but in most cases, including with Ford, the OEMs do not produce CNG vehicles, but instead provide a “gaseous fuel prep” option which makes certain engine modifications on a gasoline powered vehicle to allow for future installation of an aftermarket CNG fuel system by a vehicle upfitter. Ford’s gaseous fuel prep option includes hardened valves, valve seats, pistons, and rings, because natural gas has a higher combustion temperature than gasoline. Without the gaseous fuel prep option, a gasoline engine would still be able to be converted to CNG, but it could suffer accelerated wear.

The other major component that is different than a gasoline powered vehicle is the CNG storage tank. Instead of a steel or plastic tank that contains a liquid fuel, CNG tanks are steel or composite cylinders that are designed to withstand the impact of a collision while containing the CNG at pressures up to 3,600 psig. To protect the CNG tanks during a collision, they are typically provided with a steel cover or mounted between the structural members of the vehicle frame. In the case of bi-fuel vehicles, where the liquid fuel tank is left in place, the CNG tanks are typically mounted in the cargo area of the vehicle, which decreases the usable cargo space. This is also sometimes necessary to achieve an acceptable range for the CNG vehicle. An exception to this mounting technique is the full size transit bus where the tanks are mounted on the roof of the vehicle.

In order to ensure the safety and integrity of the CNG fuel tanks, tank inspections by a qualified technician are required every 3 years or 36,000 miles, whichever comes first. Additionally, tanks have a useful life of 15-25 years, and this is clearly labeled on each tank in the form of an expiration date⁹. Figure 4 shows an example tank label, for a tank with a 20 year useful life span.

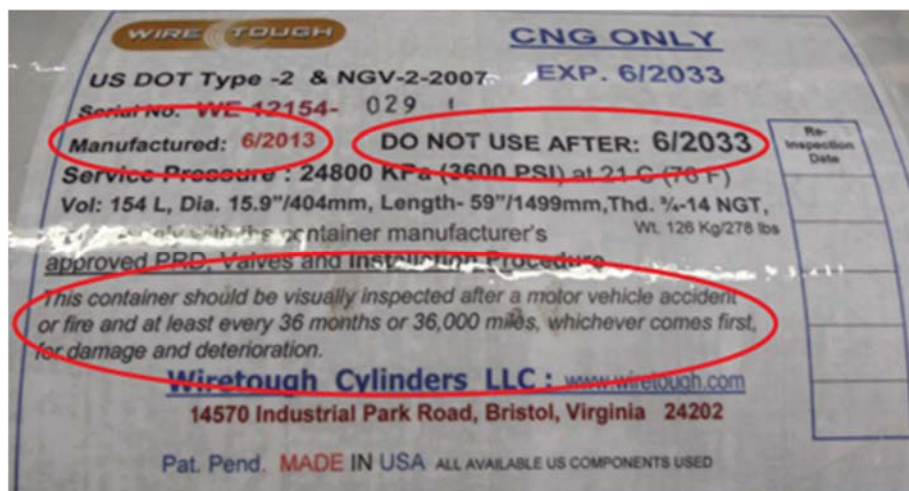


Figure 4 – Example CNG Tank Label

Image credit: U.S. Department of Energy

⁹ https://www.afdc.energy.gov/vehicles/natural_gas_cylinder.html

A vehicle with a CNG fuel system can still be serviced by mechanics with no special CNG training, as long as they don't work on the fuel system. For example, the vast majority of vehicle maintenance does not involve the CNG system, including spark plugs, lights, tires, brakes, transmission, engine oil, air filter, and exhaust.

Unlike gasoline and diesel vapors, natural gas is lighter than air. This property generally requires some ventilation modifications to maintenance facilities where CNG fuel systems are serviced. This ensures that any releases of natural gas are safely dispersed and do not come into contact with ignition sources. Natural gas does not present any environmental ground or surface water contamination hazards, as gasoline does, should it leak out of a tank during storage or fueling.

A.1.2 Time Fill CNG Fueling Stations

Natural gas is distributed in a network of pipelines owned and maintained by utility companies, natural gas producing companies, or other entities. Although large transmission lines can operate at higher pressures (up to 1,500 psi), distribution lines typically operate at much lower pressures (60 psi or less), thus requiring compression of the natural gas for vehicle fueling. A connection to a gas distribution line and a compressor are common to all types of fueling stations. CNG is measured in GGE (Gasoline Gallon Equivalent), where 1 GGE is 5.66 lb. of CNG, which has an equivalent amount of energy as 1 gallon of gasoline.

Time fill stations include a gas dryer, compressor, temperature compensation panel, and high pressure CNG distribution system as shown in Figure 5. These stations are commonly called time fill stations because the system requires an extended period of time, which is usually in the 8-10 hour range, to complete vehicle fueling. This fueling time makes the system most suitable for fleets that are stored in a single location at the end of each day and parked until the next morning. The gas dryer removes excess moisture from the natural gas to prevent complications from freezing of critical fuel delivery components onboard the vehicle. Several different dryer designs are available; however, the most common uses a regenerative desiccant bed. The desiccant absorbs the moisture from the natural gas while the compressor is in operation and then the desiccant is dried or "regenerated" when the compressor is not in operation. Some models are equipped with two separate beds that alternate so that one bed is always available for gas drying while the other regenerates.

The second main component in a time fill station is the compressor. Like the dryer, there are several different compressor configurations available depending on the pressure of the gas supply and the requirements of the fleet. All natural gas compressors require multiple stages of compression to prevent the natural gas and the compressor from reaching excessive temperatures and to maintain an optimum level of efficiency. A reciprocating compressor is typically used for CNG compression. Power for the compressor is provided by a large electric motor (approximately 50 HP), but can be operated by an engine powered by natural gas or other fuels where electricity is not available. The size of the compressor is determined by the size of the fleet, type of vehicles being fueled, the amount of natural gas to be delivered, and the amount of time available for refueling.

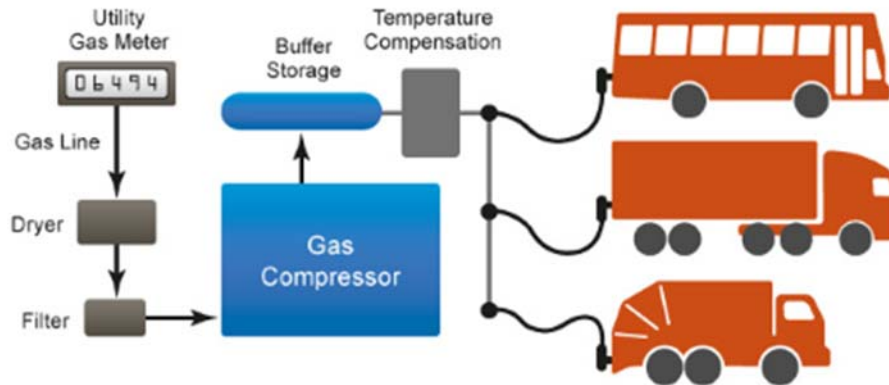


Figure 5 – Time Fill Station Diagram

Image credit: U.S. Department of Energy

During normal operation of the time fill system, the compressor operates continuously, to slowly bring all the connected vehicles up to 3,600 psi. Each vehicle has a check valve on its tank, and thus, CNG flows first to the vehicle with the lowest CNG tank pressure. Eventually, the pressure in all of the vehicles will equalize and the compressor will power off once the pressure is brought up to 3,600 psi.

A.1.3 Fast Fill CNG Fueling Stations

Fast fill stations are similar to slow fill stations in equipment configuration. The main differences include high pressure CNG storage and a larger CNG compressor. The larger compressor (typically around 200 HP), and compressed gas storage allows the station to operate similarly to a gasoline fueling station where fueling time is in the range of 5 to 10 minutes per vehicle. Figure 6 shows the general layout of a fast fill station.

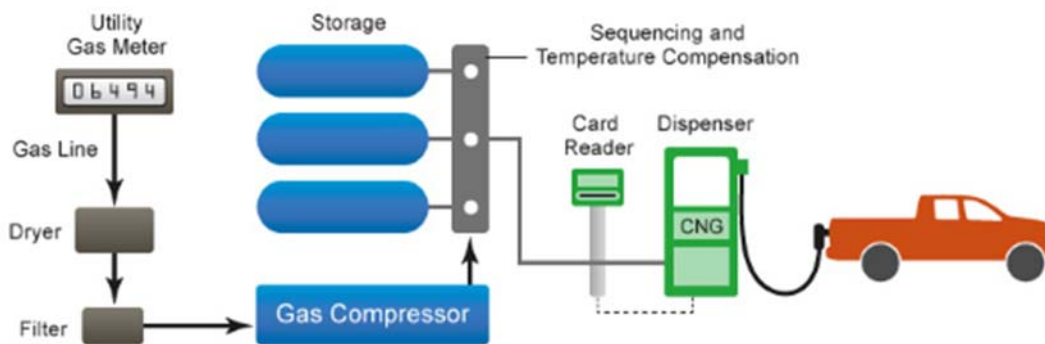


Figure 6 – Fast Fill Station Diagram

Image credit: U.S. Department of Energy

There are three fueling station configurations that are common. The first configuration uses what is commonly known as buffer storage. This configuration is used where the fast fill station is serving a fleet of large vehicles like a transit bus fleet (100 GGE capacity or larger). To provide the 5 to 10 minute fueling time, the compressor charges the buffer storage when vehicles are not being fueled. This provides a reservoir of CNG that is ready to be transferred to an empty CNG vehicle without compression. Once the buffer storage is depleted, the compressor continues to provide CNG to meet the 5 to 10 minute fueling time. However, if additional empty vehicles arrive for fueling, the fueling time is likely to increase because the compressed gas will flow to the vehicle that is less full, similar to the

slow fill station. This results in the first vehicle being forced to wait for the second to be fueled until its tank reaches a similar pressure, then both buses are filled to capacity simultaneously.

To overcome this issue, the industry developed a second type of storage known as cascade storage. In this arrangement, natural gas is compressed and stored in three separate tanks at three separate pressures during fueling instead of a single tank as is done in buffer storage. When a vehicle is fueled, only one tank is discharged until the pressure in the vehicle and that tank are equalized. Then, the next tank discharges until the vehicle is filled or a second equalization pressure (higher than the first) is reached. If the vehicle is still not full to capacity, a third tank discharges to a third discharge pressure equal to the vehicle's fully charged pressure, which is usually 3,600 psi. A set of sequencing valves control the flow of CNG out of the three storage tanks to maintain the low, medium, and high discharge pressures and to meet the fueling station demand. A priority fill system directs the flow of CNG into the tanks from the compressor to maintain the low, medium, and high discharge pressures as well. This system allows the station to fill multiple vehicles simultaneously while ensuring that they are completely full.

An alternative to cascade storage uses a second compressor to provide the additional pressure required to fill vehicles to capacity simultaneously. Instead of using the bank of three storage tanks, a single storage tank is combined with a second compressor. Gas is compressed from the supply pressure to 3,250 psi in the first compressor. From there, it flows either to storage, or to the second compressor that increases the pressure to 3,600 psi. Since the second compressor is not increasing the pressure as much as the first, it can supply CNG to meet the 5 to 10 minute fueling time. This is true of the first compressor as well, since it only compresses the natural gas to 3,250 psi.

Figure 7 shows an example of a publicly accessible fast fill CNG station.



Figure 7 – CNG Fueling Station at Philadelphia Airport

Image Credit: Clean Energy Fuels

A.2 Propane

A.2.1 Propane Vehicles

Propane is a gas at room temperature and atmospheric pressure, but is stored and combusted as a liquid in vehicular applications. Unlike natural gas, which can only be liquified under cryogenic conditions, propane is easily liquefied and stored at around 150 psi. One gallon of liquid propane has approximately 84% of the energy of a gallon of gasoline.

Like CNG vehicles, a propane vehicle is generally ordered from the OEM with a gaseous fuel prep package, and then receives a propane fuel system by an OEM-qualified third party upfitter. This results in the full vehicle warranty being honored by the manufacturer.

Propane is slightly less complicated than CNG in terms of vehicle modifications and maintenance. Because propane is a liquid, and can be stored at relatively low pressure compared to CNG, the fuel tanks are less expensive, and can hold relatively more fuel. Like gasoline and diesel vapors, propane gas is heavier than air, and thus there are fewer modifications required for maintenance garages where propane vehicles are serviced. As with natural gas vehicles, the vast majority of maintenance doesn't touch the fuel system, and so servicing a propane vehicle is much like servicing a gasoline vehicle.

A.2.2 Propane Fueling Stations

Propane is distributed via transmission pipelines, railcar, and truck. For end users, propane is almost always delivered by tanker truck, and is stored in liquid form in onsite tanks. In heating applications, propane vapor is removed from the top of the tanks, and is used in gas burners, but for vehicle applications, liquid propane is pumped from the bottom of the tank under pressure into vehicle tanks.

Because propane is stored as a liquid at each site, a large compressor is not required as with a CNG fuel station. Instead, a small electric pump is used to transfer the liquid. Onsite tank storage is usually sized to store approximately 1-2 weeks of usage. Figure 8 shows a general diagram of a propane fueling station, and Figure 9 is a photo of a simple propane fueling station for a fleet, with a single dispenser.

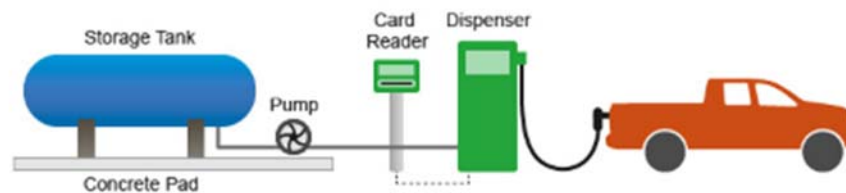


Figure 8 – Propane Fueling Station Diagram

Image credit: U.S. Department of Energy



Figure 9 – Propane Fueling Station at Customer Site

Image Credit: Pennsylvania Department of Environmental Protection

Although propane is stored as a liquid, it becomes a gas at atmospheric pressure, and thus does not pose a threat to land or water contamination should a leak or spill occur during storage or fueling.

A.3 Electricity

A.3.1 Electric Vehicles

Currently, there are several manufacturers who are marketing all-electric vehicles. The Chevrolet Bolt and Nissan Leaf are two examples of such vehicles. Cost of vehicles can be expected to increase with increase in driving range. The Nissan Leaf offers a range of 150 miles while the Chevrolet Bolt offers a range of 238 miles. Both of these vehicles would offer sufficient range for the needs of ALCOSAN.

A.3.2 Electric Charging Stations

There are 3 classes of EV charging equipment: Level I, Level II, and DC Fast Charge.

- Level I charging uses a standard 120 V AC receptacle, and can charge a vehicle at a rate of up to 1.9 kW.
- Level II charging operates on 240 V AC, and can charge a vehicle at a rate of up to 19.2 kW, although the majority of Level II chargers provide only 6.6 kW. An example is shown in Figure 10.
- DC Fast Charge operates at rates exceeding 20 kW. In the past, there have been several incompatible versions of this charging type. The Tesla Supercharger is one example of this. However, the current trend is towards standardization of this charging type, because this is the type of charger that is preferred to be implemented alongside major highways all across the country.



Figure 10 – Level II Fleet Charging Stations

Image Credit: U.S. Department of Energy Idaho National Laboratory

The column-mounted units shown in Figure 10 are referred to as Electric Vehicle Service Equipment (EVSE). The EVSE is connected to the AC power supply and provides a charging cable with the proper connector to interface with the vehicle's charging port. The EVSE is able to turn on and off the flow of power to the vehicle, and communicates with the vehicle to ensure that power will only flow when the vehicle is properly connected and in need of charging. If the charging cable is disconnected, or the vehicle experiences an error, the power to the charging cable will be turned off for safety.

In addition to propulsion, EVs use the battery for climate control and auxiliary features, and the use of these will affect the range. Many EVs have the option of warming or cooling the vehicle while it is still connected to the EVSE. This will utilize grid power rather than battery power, and optimizes the use of the batteries.

A.4 Hybrid Technologies

A.4.1 Regenerative Braking

When a vehicle slows down, rather than dissipating that energy as heat in the brake pads and rotors, the energy is captured by an electric motor and battery. This technique is employed by hybrids and pure EVs. In some cases, rather than an electric motor, the system consists of a hydraulic motor coupled to the drive shaft, and a hydraulic accumulator which is able to deliver and receive energy to and from the regenerative drive motor.

Unlike an EV, which must store enough charge in the battery pack to propel the vehicle the entire distance traveled, the accumulators in a hybrid vehicle with regenerative braking only have to store the amount of energy equal to bringing the vehicle from full speed to a dead stop. When the vehicle moves forward again, that energy stored in the accumulator is released in concert with the torque from the engine, and helps to bring the vehicle back up to speed. At that point, the accumulator is empty, and ready to start the cycle again. Therefore, a relatively small battery is required compared to a pure EV.

A hybrid regenerative braking upfit is available for the Ford F Series trucks as an upfit from a Ford QVM. This QVM claims that the system can reduce vehicle fuel usage by up to 20%. The actual performance will vary, and depends on the drive cycle of the vehicles. If a vehicle has many stops and starts, performance will be improved, compared to a vehicle with mostly highway driving.

A.4.2 Gasoline Electric Powertrain

Many hybrid vehicles have a powertrain which is designed to be powered primarily by an electric motor, with the capability to link directly to the engine when necessary. Normally, the engine powers a generator which charges the battery as needed, and the battery is used to power the electric motors which drive the vehicle. This configuration allows the engine to operate in a way that optimizes efficiency, rather than maximizing power output or horsepower. In a conventional vehicle, the engine experiences a wide range of loads and speeds, and this range results in reduced efficiency. A hybrid electric drive system uses the engine at its optimal efficiency point to top off the battery as needed.

A.4.3 Plug In Hybrids

A plug in hybrid has a larger battery pack to allow the vehicle to operate in an extended EV only range. Additionally, a plug in hybrid is able to obtain energy from an electric utility as well as from gasoline, compared to a non plug in hybrid which obtains all of its energy from gasoline. These features result in increased fuel cost savings, and decreased emissions. Examples of plug in hybrids are the Ford Fusion Energi, Toyota Prius Prime, and Chrysler Pacifica Hybrid.