Pittsburgh Public Schools
Alternative Fuels Analysis Report

Prepared for:

Alternative Fuels Technical Assistance Program

Pennsylvania Department of Environmental Protection

June 1, 2018

By:

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1.0 EXECUTIVE SUMMARY

Fleet Description

Pittsburgh Public Schools operates a fleet of 95 service and administrative vehicles. PPS does not own or operate any school buses. Most of the vehicles are stored at PPS's Service Center on the South Side. The fleet ranges in age up to 15+ years. Table ES1 summarizes the vehicles and their usage.

Table ES1 – Vehicles and Usage

			Diesel		Gasoline		
Vehicle Type	**Vehicle Description**	**Average Assumed MPG**	**Vehicle Count**	**Average Gallons Per Vehicle Per Year**	**Vehicle Count**	**Average Gallons Per Vehicle Per Year**	**Total Vehicles**
E-150	Van	12			8	287	8
E-350	Van	9			22	656	22
Sprinter	Van	18	3	687			3
Transit	Van	14			2	458	2
Transit Connect	Van	20			4	124	4
Uplander	Van	17			3	167	3
Expedition	SUV	13			3	520	3
Explorer	SUV	15			14	454	14
F-350 [1]	Truck	9	1	296	9	501	10
F-450 [2]	Truck	10	2	404	1	235	3
F-550 [3]	Truck	7	2	1,017	5	358	7
F-650	Truck	8	6	813			6
F-750	Truck	7	5	758			5
FL-60	Truck	8	2	942			2
M-6500	Truck	8	2	205			2
Ranger	Truck	16			1	159	1
TOTALS			**23**		**72**		**95**

Note 1: Assumptions are F-350 Diesel 10 MPG, F-350 Gasoline 9 MPG.
Note 2: Assumptions are F-450 Diesel 10 MPG, F-450 Gasoline 9 MPG.
Note 3: Assumptions are F-550 Diesel 8 MPG, F-550 Gasoline 7 MPG.

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	$1.94	$1.94	$0.000	$1.94
Diesel[2]	gal	0.89	1	$2.09	$1.85	$0.000	$1.85
CNG (offsite)[3]	GGE	1	1.13	$1.44	$1.44	$0.000	$1.44
CNG (onsite)[4]	therm	1.27	1.43	$0.71	$0.90	$0.179	$1.08
Propane[5]	gal	1.35	1.53	$1.40	$1.89	$0.010	$1.90
Electric[6]	kWh	10.66	12.04	$0.08	$0.85	$0.000	$0.85

Note 1: Gasoline cost is based on a delivery in April 2018.
Note 2: Diesel cost is based on a delivery in April 2018.
Note 3: 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 4: 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 5: 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 PPS as part of this contract.
Note 6: Electric cost is based on Duquesne Light Company tariff GM effective May 29, 2018 and 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 a cargo van vehicle and includes a battery charging efficiency of 85%.

New vehicles can be purchased and then upfitted to utilize CNG or propane fuel without affecting the OEM warranty. Upfit costs for a Ford Transit cargo van are estimated at $12,000 for CNG, $11,000 for propane, $65,000 for battery electric, and $15,000 for hybrid. Upfit costs for a Ford F-750 food delivery truck are estimated at $14,000 for CNG and $12,000 for propane.

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.

The hybrid-electric vehicle has a regenerative braking system added. This braking system captures and stores the energy dissipated by braking, and uses an electric motor to assist the gasoline engine during accelerations using the stored energy.

Electric vehicles (EV) are plug in vehicles with batteries and electric motors. These can also be duel fuel vehicles that use internal combustion engines for greater range. Significant advances in EVs are expected in the near future however at the present time EV vehicles in the classifications used by PPS have a limited availability. In the near future it is likely that EVs that could fit the needs of the school police will be available and may offer an alternative fuel vehicle opportunity.

Fueling Station Capital Costs

Several options require or have as an option an onsite fueling station. There is a local CNG station, 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 fuel station owned by PPS.

A CNG fueling station capable of filling vehicles overnight would cost between $150,000 and $750,000, depending on the size of the CNG fleet. A propane fueling station would be provided by the propane supplier, but would require a propane fuel supply contract. This is included in the cost of propane listed in Table ES2. Additional site work required to install the propane station would cost about $10,000. An electric vehicle charging station for 10 vehicles would cost approximately $25,000.

Economic Analysis

Table ES3 presents the costs, savings, and simple payback of a scenario where 10 new alternative fuel cargo vans were purchased. The total gasoline usage of these 10 vans is 6,263 gallons/year.

Table ES3 – Capital Costs, Savings, and Simple Payback for 10 Cargo Van Option

Option	Capital Cost	Assumed Grant Funding[1]	Net Capital Cost With Grants	Fuel Cost Savings	Simple Payback With Grants (years)	Simple Payback Without Grants (years)
CNG Offsite	$120,000	$120,000	$0	$3,283	0	37
CNG Onsite	$320,000	$220,000	$100,000	$5,661	18	57
Propane Onsite	$120,000	$110,000	$10,000	($390)	-	-
Electricity	$675,000	$312,500	$362,500	$7,129	51	95
Hybrid	$150,000	$75,000	$75,000	$2,547	29	59

Note 1: Assumed grant funding reflects AFIG grant only in a single year.

Table ES4 presents the costs, savings, and simple payback of a scenario where 10 new alternative fuel food trucks (F-650, F-750, and FL-60) were purchased. The total diesel usage of these 10 trucks is 8,570 gallons/year of diesel.

Table ES4 – Capital Costs, Savings, and Simple Payback for 10 Food Truck Option

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	$140,000	$140,000	$0	$4,399	0	32
CNG Onsite	$390,000	$265,000	$125,000	$8,255	15	47
Propane Onsite	$130,000	$120,000	$10,000	($1,557)	-	-

Emissions

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

The CO_2 reductions of utilizing alternative fuels are well understood. Compared to E10 gasoline, on an energy equivalent basis, natural gas provides a 14% reduction in CO_2 emissions, and propane provides a 2% reduction in CO_2 emissions. Compared to B2 diesel, on an energy equivalent basis, natural gas provides a 22% reduction in CO_2 emissions, and propane provides a 11% reduction in CO_2 emissions. EVs provide CO_2 emissions benefits as a function of the CO_2 emissions of the grid power which they utilize. Based on the generation mix available in western Pennsylvania, the CO_2 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

- Projects are not viable without the AFIG program
- Annual usage per vehicle is insufficient to justify an onsite CNG fueling station
- Offsite CNG fueling is the best option based on current economics
- EV developments may offer an opportunity in the near future

2.0 INTRODUCTION

Pittsburgh Public Schools (PPS) is the second largest school district in Pennsylvania, and serves approximately 25,000 students[1] at 54 schools[2]. PPS owns and manages a fleet which is made up of service and administrative vehicles, but not school buses. This report evaluates which vehicles in the PPS 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

The land area served by PPS is only 55.3 square miles[3], and fleet vehicles rarely have a need to leave the district territory. The PPS fleet does not include any school buses; these are owned and operated by subcontractors. PPS provided a fleet listing with mileage current to 10/27/2017. The data included vehicle make, model, year, fuel type, mileage on odometer, assumed miles per gallon, and assumed gallons per year consumption. The gallons per year consumption was calculated from the odometer reading, year of vehicle, and assumed miles per gallon. The miles per gallon assumptions were reviewed by WES and modified based on data published by fuelly.com for similar vehicles. Table 1 lists the vehicles and assumed fuel usage by type.

[1] https://www.pghschools.org/domain/1297

[2] https://www.pghschools.org/domain/17

[3] https://en.wikipedia.org/wiki/Pittsburgh_Public_Schools

Table 1 – Vehicles and Usage

Vehicle Type	Vehicle Description	Average Assumed MPG	Diesel		Gasoline		Total Vehicles
			Vehicle Count	Average Gallons Per Vehicle Per Year	Vehicle Count	Average Gallons Per Vehicle Per Year	
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Note 3: Assumptions are F-550 Diesel 8 MPG, F-550 Gasoline 7 MPG.

Vehicles are stored at 3 locations:

- Service Center, 13th and Muriel St, Pittsburgh, PA 15203
- South Annex, #8 Sarah Street, Pittsburgh, PA 15203
- Administration Building, 341 South Bellefield Ave, Pittsburgh, PA 15213

The Explorers and Expeditions are utilized by the school police, and are stored at the South Annex and the Administration Building. These vehicles are used to transport officers to various schools, as well as to patrol neighborhoods near schools. All other vehicles are stored at the Service Center.

PPS operates its own fueling station at the Service Center. There are two storage tanks, one for gasoline and one for diesel, sized at 10,000 gallons each. These tanks are used to fuel the fleet of 95 vehicles shown in Table 1, as well as backup generators and landscaping equipment.

As a school district, PPS is exempt from state and federal taxes, including state and federal fuel excise taxes. As of April 2018, PPS's gasoline price was $1.94/gal, and the diesel price was $2.09/gal.

3.2 Replacement Schedule

Figure 1 shows the breakdown by age and mileage of the vehicles in the fleet.

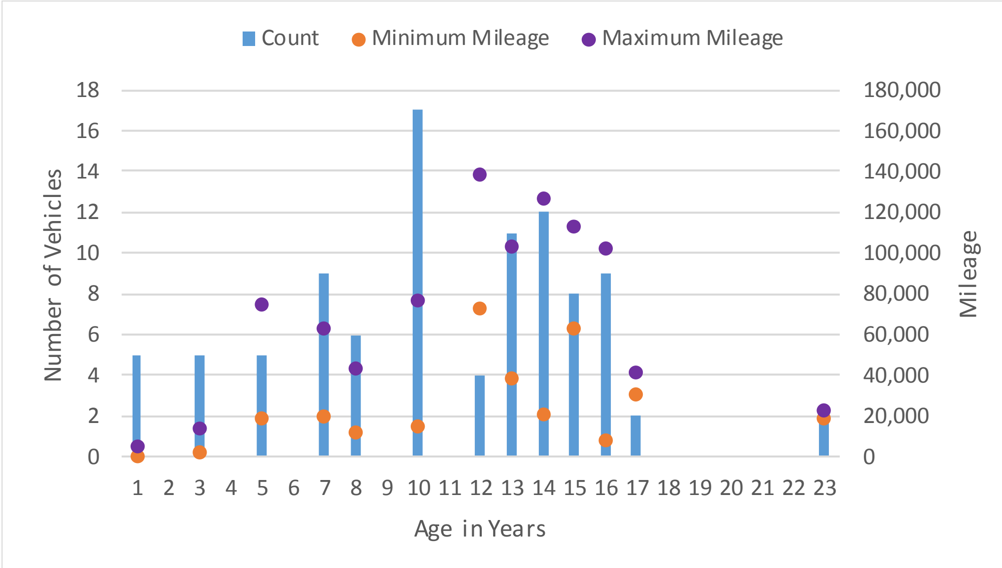

Figure 1 – Age and Mileage of Fleet

Vehicles are replaced or upgraded as needed. Based on the data in Figure 1, a 15 year cycle is typical.

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. There are currently no CNG or propane vehicles available from the factory as CNG or propane. 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.[4] 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

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

equipment has passed EPA emissions testing. Therefore, non-QVM upfits will not void the vehicle's warranty.

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 PPS, 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.

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).

4.2 Infrastructure Costs

4.2.1 CNG

There is a publicly available fast fill CNG station owned by American Natural located 1 mile west of the Service Center. This CNG station can provide approximately 7-8 GGE/minute, which is comparable to a conventional gas pump. There are 3 additional CNG stations in the region, one in the Strip District which is owned by EQT, one at the Giant Eagle distribution center in Crafton, and one in Harmar Township which is also owned by American Natural. Although these two additional sites are farther away from the Service Center, the one in the Strip District or the one in Crafton may be convenient depending on the route driven, and these would provide backup fueling options. The UPMC employee transit fleet utilizes both the American Natural CNG station on the South Side, as well as the EQT CNG station in the Strip District.

For CNG vehicles, PPS would have the option of fueling at an existing retail fast fill CNG station, or else constructing their own time fill or fast fill CNG station at the Service Center. 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.

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. Based on PPS's usage patterns, a time fill station would be appropriate, and would be sized to fuel all of PPS's CNG vehicles overnight in 8-10 hours. Depending on the number of vehicles being fueled at once, a time fill station would cost from $150,000 to $750,000.

4.2.2 Propane

A propane fueling station could be installed in a relatively small area at the PPS base, 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. PPS 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.

4.2.3 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 remote area of a parking lot.

An EV would require at least 8 hours to fully charge, which would generally take place overnight. However, the usage patterns of the PPS fleet are such that the EVs would normally have 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.

There is the potential that the EVSEs could be utilized by school employees or the general public when not in use by the PPS fleet. Since police vehicles spend extended time at school buildings, this is a potential location for charging stations should the school police fleet choose EVs in the future. Many EVSE units have built in billing systems which would allow PPS to properly account for employee, public, and fleet charging usage. Allowing public usage of these chargers during the day could improve the competitiveness of any grant funding applications submitted by PPS for this type of project, and would also provide a valuable community service or employee benefit.

4.3 Fuel Costs

Table 2 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.

Table 2 – 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	$1.94	$1.94	$0.000	$1.94
Diesel[2]	gal	0.89	1	$2.09	$1.85	$0.000	$1.85
CNG (offsite)[3]	GGE	1	1.13	$1.44	$1.44	$0.000	$1.44
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Propane[5]	gal	1.35	1.53	$1.40	$1.89	$0.010	$1.90
Electric[6]	kWh	10.66	12.04	$0.08	$0.85	$0.000	$0.85

Note 1: Gasoline cost is based on a delivery in April 2018.
Note 2: Diesel cost is based on a delivery in April 2018.
Note 3: 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 4: 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 5: 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 PPS as part of this contract.
Note 6: Electric cost is based on Duquesne Light Company tariff GM effective May 29, 2018 and 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 a cargo van vehicle 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. Similarly, 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[5]. If PPS selects CNG as a fuel, initially it may be best to outsource major repair to an appropriately equipped facility (or perform maintenance outdoors), until PPS has acquired enough vehicles to warrant the investment in upgrading its own 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 PPS, and therefore

[5] http://www.government-fleet.com/channel/green-fleet/article/story/2014/11/upgrading-a-maintenance-facility-for-cng.aspx

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. PPS may be able to leverage these funds specifically for replacing diesel vehicles. There is also the potential that these funds could support a project for a public or semi-public EV charging station.

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[6].

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

[6] http://evsmartfleets.com/materials/capturing-the-federal-ev-tax-credit-for-public-fleets/

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 PPS'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.

5.0 ECONOMIC ANALYSIS

Two scenarios are presented to evaluate the costs and savings of transitioning to an alternative vehicle fleet. The first scenario shows a scenario with 10 cargo vans being converted to alternate fuels, while the second scenario is for 10 food service trucks.

5.1 10 CARGO VANS

According to the fleet data, the E-350 cargo vans on average have the highest gasoline consumption of any vehicle type in the PPS fleet. Therefore, these vans are used to determine whether utilizing an alternative fuel to replace gasoline vehicles makes sense. Table 3 presents the capital cost estimates for this option. The upfit cost of a cargo van is estimated at $12,000 for CNG, $11,000 for propane, $65,000 for battery electric, and $15,000 for hybrid. The number 10 was selected because this is the minimum number of vehicles required by the AFIG grant in order to receive funding for an onsite fueling station.

Table 3 – Capital Cost Estimates for 10 Van Option

Description	CNG Offsite	CNG Onsite	Propane Onsite	Electricity	Hybrid
Vehicle Upfits	$120,000	$120,000	$110,000	$650,000	$150,000
AFIG Vehicle Funding	($120,000)	($120,000)	($110,000)	($300,000)	($75,000)
Fueling Station	$0	$200,000	$10,000	$25,000	$0
AFIG Fuel Station Funding	$0	($100,000)	$0	($12,500)	$0
Total Cost With Grants	**$0**	**$100,000**	**$10,000**	**$362,500**	**$75,000**
Total Cost Without Grants	**$120,000**	**$320,000**	**$120,000**	**$675,000**	**$150,000**

Notes: AFIG funding for vehicles is limited to $300,000 per year for the EV option. AFIG funding for the Hybrid option is 50% of upfit cost because the battery on this vehicle is 1.8 kWh. Since the propane fueling station is assumed to be provided by the propane supplier, the AFIG funding does not cover the site preparation costs.

Table 4 lists the current annual fuel usage for 10 average Ford E-350 cargo vans, and the comparable consumption of alternative fuels for those 10 vans.

Table 4 – Fuel Requirements for 10 Van Option

Option	Existing Fuel Usage (GGE)	Proposed Alternative Fuel Usage[1] (GGE)	Proposed Gasoline Not Offset (GGE)
CNG Offsite	6,563	6,563	0
CNG Onsite	6,563	6,563	0
Propane Onsite[2]	6,563	6,891	0
Electricity	6,563	6,563	0
Hybrid[3]	6,563	0	5,250

Note 1: Changes in fuel usage based on proposed onsite and offsite fueling locations compared to current onsite fueling are assumed to be negligible.
Note 2: Propane vehicle fuel use assumes 5% increase in fuel equivalent due to reduced fuel economy.
Note 3: Hybrid vehicle assumes 20% fuel savings.

Table 5 presents the fuel costs and savings for the 10 van option.

Table 5 – Fuel and Maintenance Costs for 10 Van Option

Description	CNG Offsite	CNG Onsite	Propane Onsite	Electricity	Hybrid
Current Fuel Cost	($12,734)	($12,734)	($12,734)	($12,734)	($12,734)
Alternative Fuel Cost	$9,451	$7,073	$13,124	$5,605	$0
Gasoline Not Offset	$0	$0	$0	$0	$10,187
Maintenance Increase	$0	$0	$0	$0	$0
TOTAL	**($3,283)**	**($5,661)**	**$390**	**($7,129)**	**($2,547)**

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

Table 6 presents the costs, savings, and simple payback for the 10 van option.

Table 6 – Capital Costs, Savings, and Simple Payback for 10 Van Option

Option	Capital Cost	Assumed Grant Funding[1]	Net Capital Cost With Grants	Fuel Cost Savings	Simple Payback With Grants (years)	Simple Payback Without Grants (years)
CNG Offsite	$120,000	$120,000	$0	$3,283	0	37
CNG Onsite	$320,000	$220,000	$100,000	$5,661	18	57
Propane Onsite	$120,000	$110,000	$10,000	($390)	-	-
Electricity	$675,000	$312,500	$362,500	$7,129	51	95
Hybrid	$150,000	$75,000	$75,000	$2,547	29	59

Note 1: Assumed grant funding reflects AFIG grant only in a single year.

5.2 10 Food Service Trucks

Table 7 presents the added capital cost estimates for transitioning 10 food service trucks to alternative fuels. These trucks are among the diesel F-650, F-750, and FL-60 trucks listed in Table 1. The upfit cost of a food truck is estimated at $14,000 for CNG and $12,000 for propane.

Table 7 – Capital Cost Estimates for 10 Food Truck Option

Description	CNG Offsite	CNG Onsite	Propane Onsite
Vehicle Upfits	$140,000	$140,000	$120,000
AFIG Vehicle Funding	($140,000)	($140,000)	($120,000)
Fueling Station	$0	$250,000	$10,000
AFIG Fuel Station Funding	$0	($125,000)	$0
Total Cost With Grants	**$0**	**$125,000**	**$10,000**
Total Cost Without Grants	**$140,000**	**$390,000**	**$130,000**

The average annual fuel usage of a food truck is 857 gallons of diesel (this includes four F-650, four F-750, and two FL-60 trucks). Table 8 lists the current fuel usage for the 10 food trucks, and the comparable consumption of alternative fuels.

Table 8 – Fuel Requirements for 10 Food Truck Option

Option	Fuel Unit	Fuel Usage[1]
Existing Diesel Fuel Usage	DGE	8,570
CNG Offsite[2]	GGE	10,643
CNG Onsite[2]	GGE	10,643
Propane Onsite[3]	GGE	11,175

Note 1: Changes in fuel usage based on proposed onsite and offsite fueling locations compared to current onsite fueling are assumed to be negligible.
Note 2: CNG vehicle fuel use assumes 10% increase in fuel equivalent due to reduced fuel economy compared to diesel.
Note 3: Propane vehicle fuel use assumes 5% increase in fuel equivalent due to reduced fuel economy compared to CNG.

Table 9 presents the fuel costs and savings for the 10 food truck option.

Table 9 – Fuel and Maintenance Costs for 10 Food Truck Option

Description	CNG Offsite	CNG Onsite	Propane Onsite
Current Fuel Cost	($19,724)	($19,724)	($19,724)
Alternative Fuel Cost	$15,325	$11,469	$21,282
Gasoline Not Offset	$0	$0	$0
Maintenance Increase	$0	$0	$0
TOTAL	**($4,399)**	**($8,255)**	**$1,557**

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 10 food truck option.

Table 10 – Capital Costs, Savings, and Simple Payback for 10 Food Truck Option

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	$140,000	$140,000	$0	$4,399	0	32
CNG Onsite	$390,000	$265,000	$125,000	$8,255	15	47
Propane Onsite	$130,000	$120,000	$10,000	($1,557)	-	-

6.0 EMISSIONS

6.1 CO_2 EMISSIONS

Table 11 lists the CO_2 emissions of the various fuels under consideration in this report.

Table 11 – CO_2 Emissions from Vehicle Fuels

Fuel	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
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 CO_2 emissions from electricity reported in Table 11 are based on the default mix of power generation in western Pennsylvania. The CO_2 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/NMHC[7].
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, NO_2, N_2O, and N_2O_2. NO_X is produced when nitrogen is exposed to high temperatures in a combustion process[8]. 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[9]. CARB has proposed voluntary low-NOX standards of 0.10, 0.05, and 0.02 g/bhp-hr. So far, four commercially available engines have been certified to meet these standards, and these are listed in Table 15.

Table 15 – Low NO_X Engines

Manufacturer	Engine	Model Year	Fuel Type	Standard Met (g/bhp-hr)	Test Result (g/bhp-hr)	Emissions with Diesel (g/bhp-hr)
Cummins Westport	8.9L ISL G	2016 and later	Natural Gas	0.02	0.01	n/a
Cummins Westport	6.7L ISB6.7 G	2017	Natural Gas	0.10	0.08	0.19
Roush Cleantech	Ford 6.8L	2016	Natural Gas	0.10	0.04	0.08
Roush Cleantech	Ford 6.8L	2017	Propane	0.05	0.03	0.08

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

[7] Conversion Factors for Hydrocarbon Emission Components. US EPA. 2005. https://19january2017snapshot.epa.gov/www3/otaq/models/nonrdmdl/nonrdmdl2005/420r05015.pdf

[8] Nitrogen Oxides (NOx), Why and How They Are Controlled. US EPA. 1999. https://www3.epa.gov/ttncatc1/dir1/fnoxdoc.pdf

[9] https://www.dieselnet.com/standards/us/hd.php

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 CO_2 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

PPS 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, such as the cargo vans and food trucks.

Based on the price comparison for fuels, for the vehicle options available to PPS, CNG is clearly the cheapest fuel available. Because of the low annual mileage, normally this project would not be viable. The fact that the AFIG grant could potentially cover 100% of the upfit cost of a new vehicle, and the Service Center's proximity to the American Natural CNG fast fill station located on the South Side, CNG vehicles can provide immediate cash flow for PPS. As shown by the Simple Payback Without Grants column in Table 6 and Table 10, this project does not make sense without the generous AFIG grant funding for vehicle upfits. Conversion of one or more food delivery trucks to CNG is the best project for PPS if grant funding can be obtained.

It is unlikely that the savings from CNG could justify the cost to upgrade PPS's vehicle maintenance center to perform major repairs. While the project does provide cash flow for PPS if a grant pays for the upfit cost of the vehicle, overall the project does not make sense from a purely economic standpoint. However, compared to a diesel truck, a CNG truck would be quieter and have less emissions.

This study evaluated the options based on current usage patterns and preferred vehicle types. Due to rapidly advancing options in EVs, and potential grants from Driving PA Forward, PPS should revisit available EV options in the near future, especially for the school police fleet. PPS could provide opportunities for community service by offering charging stations that could be accessed by PPS and the public. Because of PPS's urban setting, EVs are likely to be the best long term solution for PPS, because they would provide the best emissions reduction and would result in long term maintenance cost reductions. A low-cost, short-range EV appropriate for cargo usage would be ideal for PPS due to the short distances between schools. Current trends in EV development are towards increasing range, which is not what PPS needs. However, it is expected that as the EV market becomes more developed, there will be more options so that PPS would not need to spend excess money on range that is never going to be used.

7.1 NEXT STEPS

- Monitor the Driving PA Forward Grant Program rules for potential project funding as an alternative to AFIG.

- 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.
- Consider installing EV charging stations at schools using funding from Driving PA Forward, to allow for charging of personal vehicles. A network of charging stations at various schools would make it easy to add EVs to the fleet in the future.

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 date[10]. Figure 2 shows an example tank label, for a tank with a 20 year useful life span.

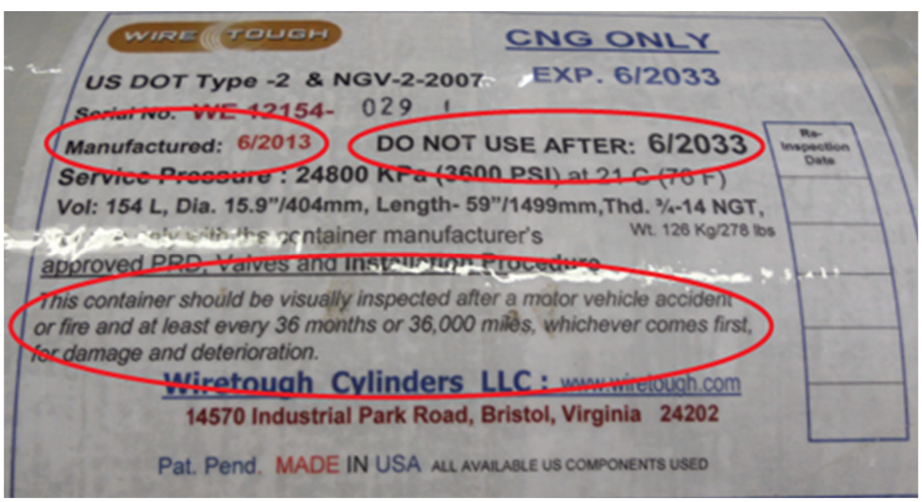

Figure 2 – Example CNG Tank Label

Image credit: U.S. Department of Energy

[10] 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 3. 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.

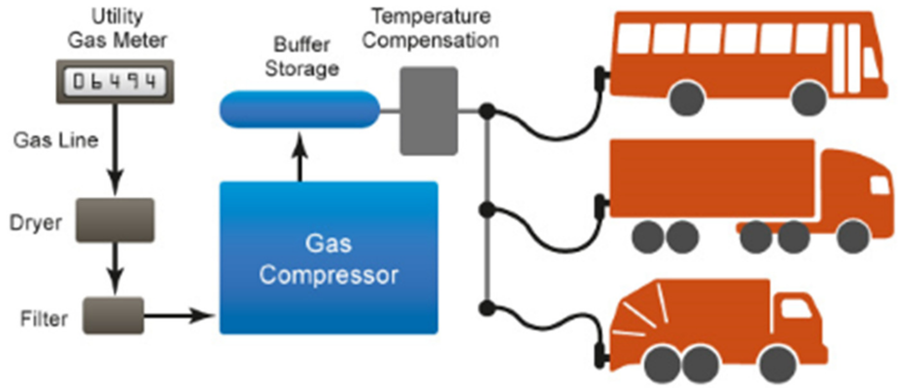

Figure 3 – Time Fill Station Diagram

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 4 shows the general layout of a fast fill station.

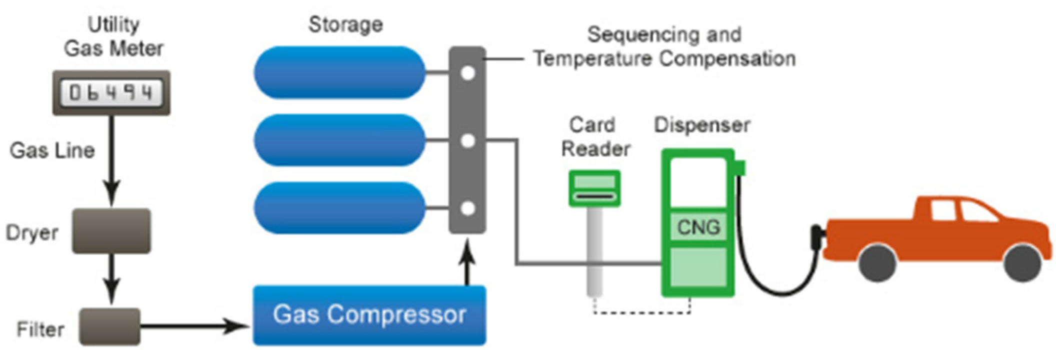

Figure 4 – Fast Fill Station Diagram

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

Figure 5 – 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 6 shows a general diagram of a propane fueling station, and Figure 7 is a photo of a simple propane fueling station for a fleet, with a single dispenser.

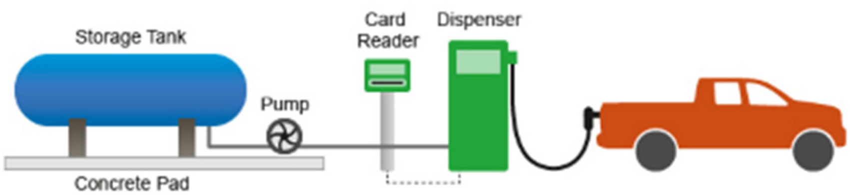

Figure 6 – Propane Fueling Station Diagram

Image credit: U.S. Department of Energy

Figure 7 – 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 a couple manufacturers who are marketing all-electric cargo vans. The range of the EV vans considered would be about 80 miles, depending on the route.

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 8.
- 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 8 – Level II Fleet Charging Stations

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

The column-mounted units shown in Figure 8 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.