Township of Lower Merion
Alternative Fuels Analysis Report

image courtesy Township of Lower Merion

Prepared for:

Alternative Fuels Technical Assistance Program

Pennsylvania Department of Environmental Protection

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1.0 EXECUTIVE SUMMARY

Fleet Description

The Township of Lower Merion is located in the Philadelphia suburbs and operates a fleet of 197 vehicles. The fleet includes trash trucks, recycling trucks, plow dump trucks, pickup trucks, law enforcement SUVs and sedans, administrative vehicles, and construction equipment. The law enforcement and administrative vehicles are generally stored at the administration building, while the other vehicles are stored at the public works complex. Table ES1 summarizes the vehicles and their usage.

Table ES1 – Vehicles and Usage

	Diesel		Gasoline		
Vehicle Type	**Vehicle Count**	**Average Gallons Per Vehicle Per Year**	**Vehicle Count**	**Average Gallons Per Vehicle Per Year**	**Total Vehicles**
Bucket[1]	7	915			7
Dump[2]	23	949	1	1,594	24
Offroad[3]	23	340	1	362	24
Pickup	5	603	24	826	29
Police Sedan			14	333	14
Sedan			7	355	7
SUV			54	1,313	54
Sweeper[4]	4	418	2	109	6
Trash[5]	16	2,694			16
Unknown	3	37	2	0	5
Van	2	287	9	306	11
TOTALS	**83**		**114**		**197**

Note 1: Bucket trucks are generally medium duty, Class IV or larger vehicles
Note 2: Dump trucks are used for snow plowing in the winter.
Note 3: Offroad vehicles include construction and landscaping equipment.
Note 4: Sweeper vehicles include street sweepers, leaf collection, and jet trucks.
Note 5: Trash trucks include trash and recycling trucks.

Alternative Fuel Options and Vehicle Types

For comparing economics when converting gasoline vehicles to propane or natural gas, generally gas gallon equivalents (GGE) are equal. When converting diesel vehicles to propane or natural gas the economics of alternative fuel needs to be adjusted for differences in mileage as a diesel engine will get better miles per gallon than an equivalent engine converted to propane or natural gas. Table ES2 lists the properties and costs of various fuels, compared on a gasoline gallon equivalent basis. Table ES3 lists the properties and costs of various fuels, compared on a diesel gallon equivalent basis.

Table ES2 – Fuel Cost Comparison Based on Gasoline

Fuel Type	Unit of Measure	Units per GGE	Cost per Unit without Taxes	Cost Per GGE without Taxes	O+M Costs Per GGE	Cost Per GGE Overall
Gasoline[1]	gal	1	$2.12	$2.12	$0.00	$2.12
Diesel[1]	gal	0.89	$2.25	$1.99	$0.00	$1.99
CNG (offsite)[2]	GGE	1	$1.59	$1.59	$0.00	$1.59
CNG (time fill)[3]	therm	1.27	$0.61	$0.78	$0.23	$1.01
CNG (fast fill)[3]	therm	1.27	$0.61	$0.78	$0.33	$1.11
Propane[4]	gal	1.35	$1.35	$1.83	$0.00	$1.83
Electric[5]	kWh	10.66	$0.10	$1.07	$0.00	$1.07

Note 1: Gasoline and diesel costs are current as of May 21, 2018.
Note 2: CNG offsite cost is based on current retail price at VNG's CNG station as of May 18, 2018, minus $0.576/GGE state tax, and minus $0.183/GGE federal tax.
Note 3: CNG onsite cost is from PECO tariff MV-F effective December 8, 2017, and PECO Gas Service Price to Compare effective March 1, 2018 through May 31, 2018. Cost does not include the fixed distribution charge of $34/month.
Note 4: Propane cost is based on an estimated price for a 1 year fixed price contract with a local propane supplier, assuming 10 propane vehicles. Propane supplier will provide onsite fueling station at no cost to the customer as part of this contract.
Note 5: Electric cost is an estimate, and will vary depending on whether the vehicles are charged peak or off peak hours. Electric GGE calculation is derived from a comparison to a gasoline vehicle and includes a battery charging efficiency of 85%.

Table ES3 – Fuel Cost Comparison Based on Diesel

Fuel Type	Unit of Measure	Units per DGE	Cost per Unit without Taxes	Cost Per DGE without Taxes	O+M Costs Per DGE	Cost Per DGE Overall
Gasoline[1]	gal	1.13	$2.12	$2.39	$0.00	$2.39
Diesel[1]	gal	1	$2.25	$2.25	$0.00	$2.25
CNG (offsite)[2]	GGE	1.13	$1.59	$1.80	$0.00	$1.80
CNG (time fill)[3]	therm	1.43	$0.61	$0.88	$0.26	$1.14
CNG (fast fill)[3]	therm	1.43	$0.61	$0.88	$0.37	$1.25
Propane[4]	gal	1.53	$1.35	$2.06	$0.00	$2.06
Electric[5]	kWh	12.04	$0.10	$1.20	$0.00	$1.20

Note 1: Gasoline and diesel costs are current as of May 21, 2018.
Note 2: CNG offsite cost is based on current retail price at VNG's CNG station as of May 18, 2018, minus $0.576/GGE state tax, and minus $0.183/GGE federal tax.
Note 3: CNG onsite cost is from PECO tariff MV-F effective December 8, 2017, and PECO Gas Service Price to Compare effective March 1, 2018 through May 31, 2018. Cost does not include the fixed distribution charge of $34/month.
Note 4: Propane cost is based on an estimated price for a 1 year fixed price contract with a local propane supplier, assuming 10 propane vehicles. Propane supplier will provide onsite fueling station at no cost to the customer as part of this contract.
Note 5: Electric cost is an estimate, and will vary depending on whether the vehicles are charged peak or off peak hours. Electric GGE calculation is derived from a comparison to a gasoline vehicle and includes a battery charging efficiency of 85%.

Fueling Station Capital Costs

Several options evaluated require or have as an option an onsite fueling station. There is a retail CNG station near the township, but the location is not convenient, and this station would only be used as a backup in emergencies.

A time fill CNG fueling station capable of filling vehicles overnight would cost between $250,000 and $350,000, for a fleet of 10-20 vehicles. A comparable fast fill station would cost $500,000 to $600,000. A propane fueling station could 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 and Table ES3. Additional site work required to install the propane station could cost about $5,000 to $10,000 depending on the site. An electric vehicle charging station for up to 10 vehicles would cost approximately $20,000 to $40,000, depending on the cost to provide the electrical service to the charging station.

Economic Analysis – Trash Trucks

Based on Table ES1, the trash trucks have the highest average fuel usage. The trash truck fleet is made up of 2 mini trash trucks and 14 large trash trucks. In order to most effectively leverage the available incentive programs, a proposed conversion project would be done in two phases. Phase 1A would convert the 2 mini trash trucks and 8 pickup trucks. Phase 1B would covert 5 trash trucks, with additional trash trucks converted each subsequent year, until the entire trash truck fleet has been converted.

As part of Phase 1A, a CNG or propane fueling station would be provided. The cost of a time fill CNG station is estimated at $300,000, and the cost of a fast fill CNG station is estimated at $500,000. A propane fueling station would be provided by the propane supplier.

The upfit costs would be $12,000 for a medium duty pickup truck, $20,000 for a mini trash truck, and $30,000 for a large trash truck.

Table ES4 presents the costs, savings, and simple payback of the combined Phases 1A and 1B scenario which include 2 mini trash trucks, 8 medium duty pickup trucks, and 5 large trash trucks. CNG offsite is provided to demonstrate savings if the township was willing to use an existing fast fill station in the area. No value is assigned for the inconvenience of using the offsite fast fill station. Propane is not considered for these options because it is not a viable fuel for heavy duty Class 8 trucks.

Table ES4 – Capital Costs, Savings, and Simple Payback for 8 Pickups and 7 Trash Trucks

Option	1A Capital Cost	1B Capital Cost	Assumed 1A Grant Funding	Assumed 1B Grant Funding	Net Capital Cost With Grants	Annual Fuel Cost Savings	Simple Payback With Grants (years)	Simple Payback Without Grants (years)
CNG Offsite	$136,000	$150,000	($136,000)	($150,000)	$0	$8,355	0	16
CNG Time Fill	$436,000	$150,000	($286,000)	($150,000)	$150,000	$25,006	6	17
CNG Fast Fill	$636,000	$150,000	($386,000)	($150,000)	$250,000	$22,145	11	29

Note: Assumed grant funding reflects two AFIG grants over two consecutive years.

As additional trash trucks are converted to CNG, the simple payback will improve slightly, as long as the trash truck upfits can be fully or partially funded by grant dollars.

Economic Analysis – Law Enforcement SUVs

The 10 SUVs with the highest fuel usage in 2016 and 2017 had an average annual gasoline consumption of 2,412 gallons. All of the SUVs with the highest use are the Ford Explorer, which are assumed to be used for police patrol. Ford does not offer the option for the Explorer as a gaseous prep package and upfits to CNG or propane by a qualified vehicle modifier (QVM). However upfits for these vehicles are available from non QVM suppliers for an estimated cost of $5,500 per vehicle. A CNG time fill station at the administration building is budgeted at $250,000, while a CNG fast fill station at the administration building is budgeted at $500,000. Because these vehicles are used for multiple shifts, a CNG fast fill station or a propane station would be the most appropriate. CNG offsite is provided to demonstrate savings if the township was willing to use an existing fast fill station in the area. No value is assigned for the inconvenience of using the offsite fast fill station. Table ES5 presents the results of this analysis.

Table ES5 – Costs, Savings, and Payback Analysis for 10 Explorers

Option	Capital Cost	Assumed Grant Funding	Net Capital Cost With Grants	Annual Fuel Cost Savings	Simple Payback With Grants (years)	Simple Payback Without Grants (years)
CNG Offsite	$55,000	($55,000)	$0	$12,760	0	4
CNG Time Fill	$305,000	($180,000)	$125,000	$26,797	5	11
CNG Fast Fill	$555,000	($305,000)	$250,000	$24,385	10	23
Propane	$55,000	($55,000)	$0	$7,072	0	8

Economic Analysis – Hybrid Electric Vehicles

The township's five Ford Fusions average 351 gallons per year. These are assumed to be used as police patrol cars initially, and then when they are retired from law enforcement service, they are used as administrative vehicles. The Ford Fusion is offered in both hybrid (Fusion Hybrid) and plug in hybrid (Fusion Energi) models, in addition to the standard gasoline model. Ford produces pursuit rated versions of the Fusion and Fusion Hybrid, and a "special service" (non pursuit) version of the Fusion Energi plug in hybrid. Upfit costs of $5,000 and $10,000 respectively are estimated for the hybrid and plug in hybrid models compared to a base gasoline model. Table ES6 shows the economics for both types of cars. As a plug in hybrid, the Fusion Energi requires a charging station, and a cost of $30,000 is included for the installation of 10 charging stations.

Table ES6 – Capital Costs, Savings, and Payback Summary for 10 Sedans

Option	Capital Cost[1]	Assumed Grants and Incentives[2]	Net Capital Cost With Grants	Annual Fuel Cost Savings	Simple Payback With Grants (years)	Simple Payback Without Grants (years)
Fusion Hybrid	$50,000	($25,000)	$25,000	$3,922	6	13
Fusion Energi	$130,000	($105,070)	$24,930	$4,340	6	30

Note 1: Capital costs include estimated upfit costs only and do not include the base price of the vehicle which is equivalent to the price of the gasoline only version. If the charging station is funded at a rate greater than 50% (potentially with Driving PA Forward), then the simple payback of the Fusion Energi option will be shortened.

Note 2: Grants and incentives include 50% coverage of upfit costs by AFIG for both vehicle types (batteries are less than 10 kWh), and capture of $4,007 federal tax credit for the Fusion Energi.

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, natural gas provides a 14% reduction in CO_2 emissions, and propane provides a 2% reduction in CO_2 emissions. Compared to B2 diesel, 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 estern 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.

CNG engines are generally quieter than diesel engines. This can be an important consideration for heavy duty trucks such are garbage trucks which operate frequently in residential areas.

Conclusions

- Converting both the trash trucks and the police SUVs would provide the best economics for a CNG project if a single fast fill station could be constructed which meets the needs of both of these segments of the fleet. The township should consider whether an appropriate site exists for this station.
- Consider conversion of some police patrol cars to propane as a pilot project. The upfits are inexpensive and the fueling station can be provided by the propane supplier, making the project economics fairly easy to predict. The township should contact several local propane suppliers for a site assessment of the administration building to determine where a propane tank and dispenser could be located.
- The Ford Fusion hybrid and plug in hybrid should be considered for any future purchases of police sedans, as these will provide a good return on investment as long as the annual miles driven is relatively high. The police department should consider whether officers would be willing to drive the Fusion patrol cars rather than Ford Explorers on the high mileage routes. This would provide good return on a hybrid or plug in hybrid purchase.

2.0 INTRODUCTION

The Township of Lower Merion is a suburb of Philadelphia with a population of approximately 58,000 people and an area of 24 square miles.[1] The township owns and manages a fleet which is made up of administrative, service, construction, refuse, law enforcement, and public safety vehicles. This report evaluates which vehicles in the township'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

The township provided a list of fleet vehicles as well as fuel reports for 2016 and 2017. The fuel reports list each fill-up for each vehicle. Miles traveled data was not available. Table 1 lists the vehicles and average fuel usage by type.

Table 1 – Vehicles and Usage

	Diesel		Gasoline		
Vehicle Type	**Vehicle Count**	**Average Gallons Per Vehicle Per Year**	**Vehicle Count**	**Average Gallons Per Vehicle Per Year**	**Total Vehicles**
Bucket[1]	7	915			7
Dump[2]	23	949	1	1,594	24
Offroad[3]	23	340	1	362	24
Pickup	5	603	24	826	29
Police Sedan			14	333	14
Sedan			7	355	7
SUV			54	1,313	54
Sweeper[4]	4	418	2	109	6
Trash[5]	16	2,694			16
Unknown	3	37	2	0	5
Van	2	287	9	306	11
TOTALS	**83**		**114**		**197**

Note 1: Bucket trucks are generally medium duty Class 4 or larger.
Note 2: Dump trucks are used for snow plowing in the winter.
Note 3: Offroad vehicles include construction and landscaping equipment.
Note 4: Sweeper vehicles include street sweepers, leaf collection, and jet trucks.
Note 5: Trash trucks include trash and recycling trucks.

Vehicles are stored at 3 locations:

- Robert J. Koegel Public Works Complex, 1300 N Woodbine Ave, Penn Valley, PA 19072
- Township Administration Building, 75 East Lancaster Ave, Ardmore, PA 19003
- Facilities Electric Shop

The trash trucks and maintenance vehicles are based out of the public works complex where onsite gasoline and diesel fueling pumps are available. These vehicles are generally used 5 days a week and

[1] http://www.lowermerion.org/government/about-lower-merion/a-brief-history

parked at the complex during evening hours. The police department is located at the administration building, and police vehicles are based from this location. A gasoline fueling station with a single dispenser is located at the administration/police building. The police vehicles are used around the clock. A small number of service vehicles are also stored at the facilities electric shop, but these vehicles are fueled at either the public works complex or the administration building.

3.2 Fuel Costs

Table 2 lists the fuel costs provided by the township for the past 2 years. These amounts include all fuel dispensed at the public works complex as well as the administration building, for all onroad and offroad uses.

Table 2 – Historical Annual Fuel Costs

	Gasoline			Diesel		
Year	Volume (gal)	Cost	Unit Cost ($/gal)	Volume (gal)	Cost	Unit Cost ($/gal)
2016	140,496	$191,483	$1.36	115,759	$165,010	$1.43
2017	136,684	$220,980	$1.62	97,353	$177,174	$1.82
Current Price	n/a	n/a	$2.12	n/a	n/a	$2.25
AVERAGE	**138,590**	**$206,231**		**106,556**	**$171,092**	

As a municipality, the township is exempt from state and federal fuel excise taxes. As of May 21 2018, the township's gasoline price was $2.12/gal, and the diesel price was $2.25/gal. This current pricing will be used for economic comparisons with alternative fuels.

3.3 Age and Replacement Schedule

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

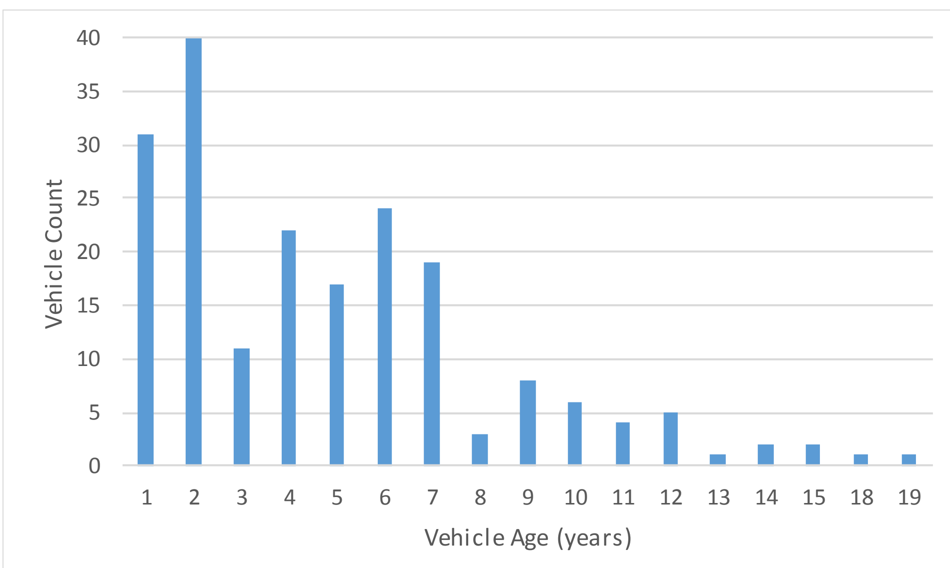

Figure 1 – Age of Fleet

Vehicles are replaced or upgraded as needed. The estimated useful life spans of vehicles as estimated by township fleet staff are shown in Table 3.

Table 3 – Vehicle Useful Life by Type

Useful Life (years)	Vehicle Count										
	Bucket	Dump	Offroad	Pickup	Police Sedan	Sedan	SUV	Sweeper	Trash	Unknown	Van
3					1	1	25				
5					1		5			2	1
6							10		2		
7					3		1				
8		3	2	18	1		5				2
9		4		1					4		
10	6	14	12	9	8	5	7	5	5	2	6
11						1		1	5		
12	1	1	5	1							
13		2	1								
14							1				
15			2								1
16			1								1
20			1							1	

Note: Useful life is based on years of life starting with a new vehicle.

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.[2] Upfits which lack final EPA and/or CARB approval are not legal in PA and should be

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

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.

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 this case, the daily mileage is limited and the vehicles return to a common location every night, so there is no reason to select bi-fuel vehicles.

CNG vehicles are available from sedans all the way up to Class 8 heavy duty trucks. The low energy density of CNG compared to diesel makes it difficult to use in long-haul applications, but this would not apply to the township. Long haul trucks are sometimes equipped with Liquefied Natural Gas (LNG) systems, but these are more expensive and would not be necessary for the township's purposes. Propane vehicles are available from sedans up through medium duty trucks. Propane is not used as a fuel for heavy duty trucks such as tractor trailers or garbage trucks.

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. There have been some pilot projects for all-electric garbage trucks in the past year, but this technology is currently too expensive and experimental for the township to consider. Two different manufacturers are offering an electric full size cargo van (based on the Ford Transit and RAM Promaster), and the upfit cost is approximately $65,000 (base vehicle cost is about $30,000).

4.2 Fueling Infrastructure

4.2.1 CNG

There are no publicly available CNG fast fill stations in the township, however, there are three public CNG stations within a few miles of the township, as shown in Figure 2.

Figure 2 – Public CNG Station Locations

Image Credit: Google Maps

For CNG vehicles, the township 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 public works complex or the administration building. Fueling at a retail station would incur no infrastructure costs, however it would be inconvenient as vehicles would have to leave the township and traffic conditions could cause delays. 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.

Fast fill stations are more expensive than time fill stations, because of the larger compressors required, as well as the necessary on-site high pressure storage. Slow fill stations work well when vehicles return to the same location and remain out of use for several continuous hours which is the case for the public works complex but not for the police cars at the administration building. Based on the township's usage patterns, a fast fill station will be considered for the administration building, and both fast fill and time fill stations will be considered for the public works complex. Capital costs for these stations will be discussed later in this report.

Lower Merion School District has two fast fill CNG stations in the township which are used to fuel their school bus fleet. If the township were to construct their own fueling station(s), there is the potential that the township and school district could work out a mutually beneficial cooperative agreement that would allow access in the case of equipment failure or emergency.

4.2.2 Propane

A propane fueling station could be installed in a relatively small area at the public works complex or the administration building parking lot, and would require only minor site work to provide electrical service. A station which could supply 10-20 vehicles would include 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. With a larger propane vehicle fleet, onsite storage of 4,000-6,000 gallons would be appropriate, since the standard propane delivery truck can carry about 3,500 gallons. WES discussed this potential project with two local propane suppliers, and both indicated that they would be willing to provide a tank and fuel dispenser at no charge, including installation, in order to secure an exclusive propane supply contract.

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 budgeted 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, in most cases EVs normally have battery charge remaining at the end of each day, thus the actual 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 dedicated 240 V circuit with a 30 A breaker.

There is the potential that the EVSEs could be utilized by employees or the general public when not in use by the township fleet. The administration building would be an ideal place to offer public EV charging, as it is located in Ardmore's business district, and currently provides public parking spaces. Many EVSE units have built in billing systems which would allow the township 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 the township for this type of project, and would also provide a valuable community service or employee benefit.

4.3 Fuel Costs

Table 4 lists the properties and costs of various fuels, compared on a gasoline gallon equivalent basis. Table 5 lists the properties and costs of various fuels, compared on a diesel gallon equivalent basis. The units GGE and DGE mean Gasoline Gallon Equivalent and Diesel Gallon Equivalent, and are equivalent to the amount of energy in a gallon of gasoline or a gallon of diesel fuel, respectively.

Table 4 – Fuel Cost Comparison Based on Gasoline

Fuel Type	Unit of Measure	Units per GGE	Cost per Unit without Taxes	Cost Per GGE without Taxes	O+M Costs Per GGE	Cost Per GGE Overall
Gasoline[1]	gal	1	$2.12	$2.12	$0.00	$2.12
Diesel[1]	gal	0.89	$2.25	$1.99	$0.00	$1.99
CNG (offsite)[2]	GGE	1	$1.59	$1.59	$0.00	$1.59
CNG (time fill)[3]	therm	1.27	$0.61	$0.78	$0.23	$1.01
CNG (fast fill)[3]	therm	1.27	$0.61	$0.78	$0.33	$1.11
Propane[4]	gal	1.35	$1.35	$1.83	$0.00	$1.83
Electric[5]	kWh	10.66	$0.10	$1.07	$0.00	$1.07

Note 1: Gasoline and diesel costs are current as of May 21, 2018.
Note 2: CNG offsite cost is based on current retail price at VNG's CNG station as of May 18, 2018, minus $0.576/GGE state tax, and minus $0.183/GGE federal tax.
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Note 4: Propane cost is based on an estimated price for a 1 year fixed price contract with a local propane supplier, assuming 10 propane vehicles. Propane supplier will provide onsite fueling station at no cost to the customer as part of this contract.
Note 5: Electric cost is an estimate, and will vary depending on whether the vehicles are charged peak or off peak hours. Electric GGE calculation is derived from a comparison to a gasoline vehicle and includes a battery charging efficiency of 85%.

Table 5 – Fuel Cost Comparison Based on Diesel

Fuel Type	Unit of Measure	Units per DGE	Cost per Unit without Taxes	Cost Per DGE without Taxes	O+M Costs Per DGE	Cost Per DGE Overall
Gasoline[1]	gal	1.13	$2.12	$2.39	$0.00	$2.39
Diesel[1]	gal	1	$2.25	$2.25	$0.00	$2.25
CNG (offsite)[2]	GGE	1.13	$1.59	$1.80	$0.00	$1.80
CNG (time fill)[3]	therm	1.43	$0.61	$0.88	$0.26	$1.14
CNG (fast fill)[3]	therm	1.43	$0.61	$0.88	$0.37	$1.25
Propane[4]	gal	1.53	$1.35	$2.06	$0.00	$2.06
Electric[5]	kWh	12.04	$0.10	$1.20	$0.00	$1.20

Note 1: Gasoline and diesel costs are current as of May 21, 2018.
Note 2: CNG offsite cost is based on current retail price at VNG's CNG station as of May 18, 2018, minus $0.576/GGE state tax, and minus $0.183/GGE federal tax.
Note 3: CNG onsite cost is from PECO tariff MV-F effective December 8, 2017, and PECO Gas Service Price to Compare effective March 1, 2018 through May 31, 2018. Cost does not include the fixed distribution charge of $34/month.
Note 4: Propane cost is based on an estimated price for a 1 year fixed price contract with a local propane supplier, assuming 10 propane vehicles. Propane supplier will provide onsite fueling station at no cost to the customer as part of this contract.
Note 5: Electric cost is an estimate, and will vary depending on whether the vehicles are charged peak or off peak hours. Electric GGE calculation is derived from a comparison to a gasoline vehicle and includes a battery charging efficiency of 85%.

It is important to note that these tables compare the fuels on an energy equivalent basis, and do not take into account engine characteristics and other features which may result in differences in thermal efficiency when used in a vehicle engine. For example, a spark ignition engine is assumed to be 10% less efficient (10% lower miles per gallon) than a diesel engine in the same vehicle, due to the higher compression ratio of a diesel engine. Spark ignition engines include gasoline, CNG, and propane.

4.4 Operation and Maintenance Costs

Gaseous fuels 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.[3] If the township selects CNG as a fuel, initially it may be best to outsource major repair to an appropriately equipped facility (or perform maintenance outdoors), until the township 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.

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

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.

EVs in particular present a strong case for a reduction in maintenance expense, especially for light duty vehicles. For heavy duty vehicles, EV technology is relatively new, 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. Non-plug-in hybrid vehicles generally have a small onboard battery bank or hydraulic accumulator.
- 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 overall plans for how the funds will be spent were announced in May 2018, but applications for funding and/or rebates will not be accepted until mid-2018. The overall goal will be to fund diesel-source NOx reductions and EV charging infrastructure. Projects funded through this program could include replacement of heavy duty diesel trucks, and installation of public and semi-public EV charging stations.

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 (which do not owe income tax) 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[4].

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

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. In the township's case, this tax credit would apply (if it was extended) to an onsite time fill or fast fill CNG station, or an onsite propane station, but it would not apply to purchases of fuel at the regional VNG or Clean Energy CNG stations, for example.

5.0 ECONOMIC ANALYSIS

The township currently operates its fleet out of two facilities, each of which already has conventional fueling infrastructure. These two facilities serve very different purposes, and therefore the fleets which are based out of these facilities are considered independently.

5.1 TRASH TRUCKS

The 16 diesel trash and recycling trucks have the greatest fuel consumption of any vehicle type. Table 6 lists the trash truck descriptions, fuel usage, and costs of fuel. For the purposes of this analysis, the trash and recycling trucks will be referred to simply as trash trucks.

Table 6 – Trash Truck Fleet, Fuel Usage, and Cost

Vehicle Number	Description	Annual Fuel Usage (gal/year)	Annual Fuel Cost ($/year)
5955	International 20 Cy Trash truck w/Plow	3,728	$7,269
5950	International 20 Cy Trash Truck	3,265	$6,366
5944	International 20 Cy Recycle	3,183	$6,206
5956	International 20 Cy Trash truck w/Plow	3,115	$6,073
5954	International 20 Cy Trash Truck	3,044	$5,935
5943	International 20 Cy Recycle	3,024	$5,897
5946	International 20 Cy Recycle	2,987	$5,824
5953	International 20 Cy Trash Truck	2,945	$5,742
5949	International 20 Cy Trash Truck	2,740	$5,343
5952	International 20 Cy Trash Truck	2,583	$5,036
5945	International 20 Cy Recycle	2,429	$4,737
5947	International 20 Cy Recycle	2,302	$4,488
5948	International 20 Cy Trash truck w/Plow	2,129	$4,151
5962	Dodge 5500 Mini Packer Trash	2,036	$3,970
5951	International 20 Cy Trash truck w/Plow	2,018	$3,936
5961	Dodge 5500 Mini Recycle	1,579	$3,080
TOTAL		**43,104**	**$84,053**

Note: Annual fuel usage listed is an average of 2016 and 2017 diesel fuel usage for each truck.

Overall average usage for a trash truck is 2,694 gallons per year. The 14 large trash trucks average 2,821 gallons per year, while the two mini trash trucks average 1,807 gallons per year.

The cost to upfit a 20 cubic yard trash truck with a CNG system, compared to a standard diesel truck, is approximately $30,000-$35,000. The cost to upfit one of the mini trash trucks is estimated to be approximately $15,000-20,000.

Propane is not a viable fuel for heavy duty trucks such as the 20 yard trash trucks, but it would be available as an upfit for the mini trash trucks and the medium duty pickups. Therefore, propane is considered as a fuel for these smaller trucks, but not for the large trash trucks.

5.1.1 Phase 1A

It is important to note that the AFIG grant will provide funding for an onsite fueling station only if 10 vehicles with a GVWR of less than 26,000 lbs. are able to utilize it. Of the trash truck fleet, only the two mini trash trucks (Dodge 5500) meet this requirement.

Initially, the township would replace the two mini trash trucks with comparable CNG trucks and also purchase 8 Ford F-350 pickups to replace existing pickup trucks which are used for maintenance and snow plowing. This would provide the fleet of 10 vehicles needed for 50% AFIG funding of the CNG fueling station.

Table 7 shows the current and projected fueling costs for the two mini trash trucks, while Table 8 shows the current and projected fueling costs for 8 F-350 pickups. For the onsite CNG options, the fuel costs include operation and maintenance of the filling station as shown in Table 4 and Table 5.

Table 7 – Fuel Cost Comparison for 2 Mini Trash Trucks

Description	CNG Offsite	CNG Time Fill	CNG Fast Fill	Propane
Current Fuel Avoided Cost	($8,134)	($8,134)	($8,134)	($8,134)
Alternative Fuel Cost	$7,142	$4,530	$4,979	$8,201
Maintenance Cost Increase	$0	$0	$0	$0
Annual Cost Difference	**($991)**	**($3,604)**	**($3,155)**	**$67**

Note: Based on average diesel usage of 1,807 gal/year for the two mini trash trucks. Alternative fuel cost takes into account 10% reduction in efficiency of the CNG engine versus the diesel engine. The additional fuel and time needed to access the offsite fuel station are not accounted for.

Table 8 – Fuel Cost Comparison for 8 F-350 Pickup Trucks

Description	CNG Offsite	CNG Time Fill	CNG Fast Fill	Propane
Current Fuel Avoided Cost	($14,013)	($14,013)	($14,013)	($14,013)
Alternative Fuel Cost	$10,516	$6,670	$7,331	$12,075
Maintenance Cost Increase	$0	$0	$0	$0
Annual Cost Difference	**($3,497)**	**($7,343)**	**($6,682)**	**($1,938)**

Note: Based on average pickup truck gasoline usage of 826 gal/year from Table 1. The additional fuel and time needed to access the offsite fuel station are not accounted for.

Because of the relatively small difference between the diesel and gasoline prices and the price at the nearest retail CNG station (east of the township across the Schuylkill River), offsite CNG does not provide significant savings. However, the distance alone to this CNG station is a major factor in the consideration of the offsite CNG option due to the traffic involved, but it is still important to consider as a backup fueling site.

The Ford F-350 is available with the gaseous fuel prep option and can be upfitted for CNG or propane using a QVM kit. The CNG tank would reside in the front 2' of the bed and be protected by a heavy duty metal shroud. The CNG option costs approximately $12,000 more than the base gasoline model. Considering the township's fleet, this would be a mid-size pickup truck, and could be useful for snow plowing, towing trailers, and general maintenance.

The onsite CNG fueling station could be a time fill or a fast fill station. A time fill station would have a lower cost, but would require more land area as the trucks would need to park outside overnight in order to be fueled. A fast fill station would be convenient, as trucks could be filled at any time, but it would have a higher cost. Either type of station would be constructed to provide the capacity needed to supply the entire trash truck fleet as well as some additional CNG vehicles.

Table 9 lists the capital costs for vehicle acquisition and fuel station construction in the first year, which is termed Phase 1A. The vehicle costs shown reflect the increased costs of a CNG or propane vehicle compared to a conventional fuel vehicle. The township would be responsible for covering the base cost of each vehicle in the amount equal to what the township would have spent on a comparable conventional fuel vehicle.

Table 9 – 1A Capital Cost and Grant Summary for 10 Medium Duty Vehicles

Description	CNG Offsite	CNG Time Fill	CNG Fast Fill	Propane
F-350 upfit (qty. 8)	$96,000	$96,000	$96,000	$96,000
RAM 5500 upfit (qty. 2)	$40,000	$40,000	$40,000	$40,000
Fueling Station	$0	$300,000	$500,000	$0
AFIG Vehicle Funding	($136,000)	($136,000)	($136,000)	($136,000)
AFIG Fuel Station Funding	$0	($150,000)	($250,000)	$0
Total Cost Without AFIG	**$136,000**	**$436,000**	**$636,000**	**$136,000**
Total AFIG Grant	**($136,000)**	**($286,000)**	**($386,000)**	**($136,000)**
Total Cost With AFIG	**$0**	**$150,000**	**$250,000**	**$0**

Table 10 shows the costs, savings, and simple payback for the options.

Table 10 – 1A Costs, Savings, and Payback Analysis for 10 Medium Duty Vehicles

Option	Capital Cost	Assumed Grant Funding	Net Capital Cost With Grants	Annual Fuel Cost Savings	Simple Payback With Grants (years)	Simple Payback Without Grants (years)
CNG Offsite	$136,000	($136,000)	$0	$4,488	0	30
CNG Time Fill	$436,000	($286,000)	$150,000	$10,947	14	40
CNG Fast Fill	$636,000	($386,000)	$250,000	$9,837	25	65
Propane	$136,000	($136,000)	$0	$1,871	0	73

Because the CNG offsite and propane options with AFIG require no additional capital investment beyond the base costs of the vehicles, they provide immediate cash flow. However, the savings are modest and in the case of the offsite CNG option may be negated by the inconvenience of fueling at a station which is outside the township. The onsite time fill CNG option with AFIG provides a 14 year simple payback. At first glance, this may seem to be longer than the useful life of the vehicles. However, the key item is the fueling station, which should have at least a 20 year useful life. As CNG vehicles wear out, new ones can be obtained which will utilize the same fueling station. The other important consideration is that Phase 1A is designed to provide the township with some initial experience with CNG vehicles and an onsite CNG fueling station which will allow the township to further expand their CNG fleet in the future in order to increase the savings and achieve an acceptable payback.

5.1.2 Phase 1B

In Phase 1B, the township would start to replace the 20 cubic yard trash truck fleet with new CNG trash trucks, starting with 5 trash trucks. Funding for this project could come from AFIG or it could come from Driving PA Forward. The specific funding levels in Driving PA Forward for replacement of heavy duty diesel trucks have not yet been disclosed, but for a government owned fleet they have the potential to be as good as or better than the incentive levels of AFIG.

Table 11 shows the current and projected fueling costs for a group of 5 trash trucks which will be Phase 1B. As previously mentioned, propane is not an available fuel for Class 8 heavy duty trucks.

Table 11 – Fuel Cost Comparison for 5 Trash Trucks

Description	CNG Offsite	CNG Time Fill	CNG Fast Fill
Current Fuel Avoided Cost	($31,732)	($31,732)	($31,732)
Alternative Fuel Cost	$27,865	$17,673	$19,424
Maintenance Cost Increase	$0	$0	$0
Annual Cost Difference	**($3,868)**	**($14,059)**	**($12,308)**

Note: Based on average diesel usage of 2,821 gal/year. Alternative fuel cost takes into account 10% reduction in efficiency of the CNG engine versus the diesel engine. The additional fuel and time needed to access the offsite fuel station are not accounted for.

Phase 1B capital costs are only for upfit of the 5 trash trucks, and thus total $150,000. This assumes that an adequate fueling station was constructed in Phase 1A. Current AFIG incentive levels would potentially cover 100% of this cost. Table 12 shows the costs, savings, and simple payback for the CNG options of Phase 1B.

Table 12 – 1B Costs, Savings, and Payback Analysis for 5 Trash Trucks

Option	Capital Cost	Assumed Grant Funding	Net Capital Cost With Grants	Annual Fuel Cost Savings	Simple Payback With Grants (years)	Simple Payback Without Grants (years)
CNG Offsite	$150,000	($150,000)	$0	$3,868	0	39
CNG Time Fill	$150,000	($150,000)	$0	$14,059	0	11
CNG Fast Fill	$150,000	($150,000)	$0	$12,308	0	12

5.1.3 Combination of Phases 1A and 1B

Phases 1A and 1B should also be evaluated economically as a single project, even though they are spread over 2 years. Table 13 develops the simple payback for this scenario.

Table 13 – 1A and 1B Combined Costs, Savings, and Payback Analysis for 15 Medium and Heavy Duty Vehicles

Option	1A Capital Cost	1B Capital Cost	Assumed 1A Grant Funding	Assumed 1B Grant Funding	Net Capital Cost With Grants	Annual Fuel Cost Savings	Simple Payback With Grants (years)	Simple Payback Without Grants (years)
CNG Offsite	$136,000	$150,000	($136,000)	($150,000)	$0	$8,355	0	16
CNG Time Fill	$436,000	$150,000	($286,000)	($150,000)	$150,000	$25,006	6	17
CNG Fast Fill	$636,000	$150,000	($386,000)	($150,000)	$250,000	$22,145	11	29

In order to replace the entire fleet of large trash trucks, Phase 1B would have to be repeated 2 more times. If these CNG upfit costs were also covered by AFIG or other grants, then the simple payback would be reduced even more compared to what is shown in Table 13.

5.2 LAW ENFORCEMENT

The top 10 SUVs with the highest fuel usage had an average annual gasoline consumption of 2,412 gallons for 2016 and 2017 (maximum 3,429, minimum 2,039). All of the SUVs with the highest use are the Ford Explorer.

A company called CNG Interceptor provides CNG and propane upfit services specifically for law enforcement and public safety vehicles. The upfit cost for either fuel is $4,900 (Ford Explorer or Taurus). For the purposes of this analysis, a cost of $5,500 per vehicle will be assumed in order to cover the cost of shipping the vehicles through the upfit facility in Indianapolis. CNG and propane conversions for vehicles of this type are generally in the $5,000 to $10,000 range. The CNG Interceptor upfit is a non-QVM upfit, and the Ford Explorer and Taurus are currently not available with the gaseous fuel prep option from the factory. Because Ford does not offer the gaseous fuel prep for these vehicles, there are no QVM upfit options. Figure 3 shows a propane tank mounted in the storage area of a Ford Explorer.

Figure 3 – Propane Tank Behind Rear Seat of Ford Explorer

Note: Image courtesy CNG Interceptor.

Table 14 shows the fuel costs for 10 Explorers, based on an average fuel usage of 2,412 gallons per SUV.

Table 14 – Fuel Cost Comparison for 10 Explorers

Description	CNG Offsite	CNG Time Fill	CNG Fast Fill	Propane
Current Fuel Avoided Cost	($51,137)	($51,137)	($51,137)	($51,137)
Alternative Fuel Cost	$38,377	$24,340	$26,752	$42,433
Maintenance Cost Increase	$0	$0	$0	$0
Annual Cost Difference	**($12,760)**	**($26,797)**	**($24,385)**	**($8,704)**

Table 15 shows the capital costs for each fuel type for the 10 Explorers.

Table 15 – Capital Costs for 10 Explorers

Description	CNG Offsite	CNG Time Fill	CNG Fast Fill	Propane
Explorer (qty. 10)	$55,000	$55,000	$55,000	$55,000
Fueling Station	$0	$250,000	$500,000	$0
AFIG Vehicle Funding	($55,000)	($55,000)	($55,000)	($55,000)
AFIG Fuel Station Funding	$0	($125,000)	($250,000)	$0
Total Cost Without AFIG	**$55,000**	**$305,000**	**$555,000**	**$55,000**
Total AFIG Grant	**($55,000)**	**($180,000)**	**($305,000)**	**($55,000)**
Total Cost With AFIG	**$0**	**$125,000**	**$250,000**	**$0**

Table 16 presents the simple payback for each option.

Table 16 – Costs, Savings, and Payback Analysis for 10 Explorers

Option	Capital Cost	Assumed Grant Funding	Net Capital Cost With Grants	Annual Fuel Cost Savings	Simple Payback With Grants (years)	Simple Payback Without Grants (years)
CNG Offsite	$55,000	($55,000)	$0	$12,760	0	4
CNG Time Fill	$305,000	($180,000)	$125,000	$26,797	5	11
CNG Fast Fill	$555,000	($305,000)	$250,000	$24,385	10	23
Propane	$55,000	($55,000)	$0	$7,072	0	8

Note that the estimated useful life of these vehicles is 3 years, although these vehicles may be repurposed after the initial 3 years of law enforcement use. Project paybacks which significantly exceed the useful life of the vehicles give the appearance that the projects are not viable. As with the trash truck projects, the cost of the onsite CNG fueling stations is a large portion of the CNG project cost, and the onsite stations have a longer useful life than the vehicles.

5.3 Electric Vehicles

The township's fleet includes 21 sedans which include vehicles such as the Impala, Edge, Fusion, Taurus, Prius, and Crown Victoria. Besides the Prius, these vehicles are assumed to be obtained first for police service, and after they are retired from police service, they are used as administrative vehicles.

The Ford Fusion is offered in both hybrid (Fusion Hybrid) and plug in hybrid (Fusion Energi) models, in addition to the standard gasoline model. Ford produces pursuit rated versions of the Fusion and Fusion Hybrid, and a "special service" (non pursuit) version of the Fusion Energi plug in hybrid.

The township's five Ford Fusions average 351 gallons per year. Table 17 analyzes the potential fuel savings for a single Fusion sedan based on this average fuel usage.

Table 17 – Comparison of Hybrid and Plug in Hybrid Police Sedans to Gasoline Base Case

Vehicle	Gasoline Usage (gal/year)	Electric Usage (kWh/year)	Annual Gasoline Cost	Annual Electric Cost	Total Annual Cost	Cost Savings Compared to Gasoline
Fusion	351	0	$745	$0	$745	n/a
Fusion Hybrid	166	0	$353	$0	$353	$392
Fusion Energi	83	1,347	$176	$135	$311	$434

Note: EPA combined estimate for Fusion Police Interceptor is 18 mpg. Ford estimates that the Fusion Hybrid Police Responder will be rated at 38 mpg. Fusion Energi fuel usage is based on the assumption of 50% gasoline miles and 50% electric miles, with 38 mpg on gasoline and 0.36 kWh/mile on electricity (includes charger efficiency of 85%).

Table 18 shows the capital costs for both options based on a project of 10 Fusion hybrid or plug in hybrid sedans. 10 vehicles are used in this project example because that is the minimum number needed to obtain AFIG funding for the charging station for the Fusion Energi option. The Fusion Hybrid does not require a charging station. There is the possibility that the Driving PA Forward program could be used to cover the cost of the charging station, and thus the project would not be subject to the AFIG minimum number of 10 vehicles.

Table 18 – Capital Costs and Incentives for 10 Police Sedans

Description	Fusion Hybrid	Fusion Energi
Vehicle Upfit Cost (qty. 10)	$50,000	$100,000
Charging Station	$0	$30,000
AFIG Vehicle Funding	($25,000)	($50,000)
EV Federal Tax Credit	$0	($40,070)
AFIG Fuel Station Funding	$0	($15,000)
Total Cost Without Incentives	**$50,000**	**$130,000**
Total AFIG and Fed. Tax Credit	**($25,000)**	**($105,070)**
Total Cost With Incentives	**$25,000**	**$24,930**

Note: See section 4.5 for discussion of the EV tax credit.

Table 19 presents the simple payback for each option.

Table 19 – Sedan Capital Costs, Savings, and Payback Summary

Option	Capital Cost[1]	Assumed Grants and Incentives[2]	Net Capital Cost With Grants	Annual Fuel Cost Savings	Simple Payback With Grants (years)	Simple Payback Without Grants (years)
Fusion Hybrid	$50,000	($25,000)	$25,000	$3,922	6	13
Fusion Energi	$130,000	($105,070)	$24,930	$4,340	6	30

Note 1: Capital costs include estimated upfit costs only and do not include the base price of the vehicle which is equivalent to the price of the gasoline only version. If the charging station is funded at a rate greater than 50% (potentially with Driving PA Forward), then the simple payback of the Fusion Energi option will be shortened.
Note 2: Grants and incentives include 50% coverage of upfit costs by AFIG for both vehicle types (batteries are less than 10 kWh), and capture of $4,007 federal tax credit for the Fusion Energi.

It is important to note that the simple payback with grants are equal for both projects, however, at the end of the useful life of the vehicles, the Fusion Energi option will have paid for an EV charging station which can then be used for the next round of vehicles, whether they be plug in EVs or pure battery EVs.

6.0 EMISSIONS

6.1 CO_2 EMISSIONS

Table 20 lists the CO_2 emissions of the various fuels under consideration in this report.

Table 20 – 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)	0.9	9.3

Note: 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 RFCE, using value for Total Output Emission Factor (baseload). Electricity emissions include EPA estimated line losses of 4.97%, and assumed EV charging efficiency of 85%.

It is important to note that the CO_2 emissions from electricity reported in Table 20 are based on the default mix of power generation in eastern Pennsylvania. The CO_2 emissions 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 21 lists the pollutant emissions test results for a new heavy duty Ford vehicle.

Table 21 – 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 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 22 presents a selection of the test results for the city driving cycle federal test protocol simulating the useful life of the vehicle. These results were obtained from the model year 2018 CARB Executive Order.

Table 22 – 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 23 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 23 – 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 g NMOG/g NMHC[5].
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[6]. 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[7]. 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 24.

Table 24 – 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.

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

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

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

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 designed 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 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

7.1 CNG

The township currently has several segments of the fleet which would be good candidates for conversion to alternate fuels when considered with currently available incentives. A limiting factor in the evaluated projects is that the fleet is split into two locations which have been proposed with separate fueling stations for the CNG options. Since the cost of the fueling station is the largest upfront cost for a CNG project, this limits the potential savings compared to what could be achieved if all vehicles used a single fast fill station. The township should consider whether space could be allocated near the administration building for a fast fill station which could be utilized by trash trucks, medium duty pickup trucks, snow plows, and police vehicles.

The trash truck fleet shows the potential for savings when taking into account incentives for vehicle upfits, but when considered without upfit incentives, there is little to no economic benefit. For example, annual savings of $2,812 per trash truck when filled at a time fill station (Table 11) provide an 11 year simple payback on the $30,000 trash truck upfit cost, assuming that the time fill station has already been paid for. The CNG project does show savings if vehicles can be upfitted using incentives, but if the incentives become unavailable in the future, subsequent purchases of CNG vehicles likely could not be justified, even with an existing CNG fueling station, unless the cost of the CNG upfits decreases, or the cost of diesel increases. The reason for this is that the township's trash trucks simply do not consume enough diesel fuel to allow for significant savings without help from incentives.

Even if the economics are marginal, the township could still benefit from a CNG trash truck fleet due to the reduced engine noise (compared to diesel) and reductions in emissions in neighborhoods.

The Ford Explorers used by the township police department have fuel usage comparable to the trash trucks. However, the reduced upfit costs of these vehicles results in an acceptable payback period for the CNG options, even without incentives for upfitting vehicles. This means that as long as a major portion of the fueling station can be funded by incentives, the police fleet could justify purchase of CNG upfitted vehicles as an alternative fuel fleet without needing an incentive for each vehicle purchase.

7.2 Propane

Propane upfits can provide some savings for light duty and medium duty vehicles, and this fuel requires a minimum of site work and capital investment. The propane supplier can install and manage the fuel station, and no garage upgrades are required for servicing propane vehicles as long as the garage meets code for gasoline and diesel maintenance. Although this option would provide very little savings, it would still displace gasoline and diesel, and could result in reduced pollutant and CO_2 emissions in the township. If the federal Alternative Fuel Excise Tax Credit is extended (it is currently expired), the economics of propane (and CNG) would be significantly enhanced during the time that the tax credit is available.

Because the propane upfits for these Explorers are bi-fuel, and the propane dispensing equipment would be owned by the propane supplier, the project could be ended at any point in the future and the parking lot space could be easily reclaimed.

7.3 Electricity

Due to rapidly advancing options in EVs, and potential grants from AFIG and Driving PA Forward, the township should seriously consider plug in hybrid and pure EV options for their light duty vehicles. In the next few years there will probably be several electric SUVs on the market, however, it is not likely that these would be appropriate for general law enforcement use.

The hybrid and plug in hybrid vehicles show a good potential for savings if driven enough miles. The township should investigate whether their dealer can help them capture the federal EV tax credit on the purchase of plug in hybrid EVs. If the township cannot capture this credit, then the plug in hybrid option probably does not make economic sense unless the annual mileage can be significantly increased.

The township should consider installing an EV charging station at the administration building which could be utilized by the general public. In 2016, Pennsylvania had 0.71 registered plug in EVs per 1,000 people,[8] which is equivalent to 41 EVs in Lower Merion Township. There are funds allocated in the Driving PA Forward program specifically for EV charging stations. This would assist private citizens in adopting EV technology, encourage the use of low or non-emitting transportation in downtown Ardmore, and give the township the opportunity to transition to EVs at some point in the future.

7.4 Next Steps

The following items are suggestions for future investigation by the township:

- Monitor the Driving PA Forward Grant Program rules for potential project funding
- Investigate availability of a convenient location for constructing a fast fill station where both police SUVs and trash trucks can refuel. The police SUVs and trash trucks offer the greatest savings potential due to fuel use if the costs of the fueling station can be spread over more fuel savings.
- While propane conversions on light duty vehicles offers modest fuel cost savings it comes with minimal investment in fueling infrastructure. Consider conversion of some police patrol cars or lighter duty trucks to propane as a pilot project. The township could contact several local propane suppliers for a site assessment of the administration building to determine where a propane tank and dispenser could be located.
- The Ford Fusion hybrid and plug in hybrid should be considered for any future purchases of police sedans, as these will provide reasonable return on investment as long as the annual

[8] https://www.energy.gov/eere/vehicles/articles/fotw-1004-november-20-2017-california-had-highest-concentration-plug-vehicles

mileage is relatively high. The police department should consider whether officers would be willing to drive the Fusion patrol cars rather than Ford Explorers on the high mileage routes. This would provide good payback on a hybrid or plug in hybrid purchase.

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 could 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 due to the lower energy density. An exception to this mounting technique is the full size transit bus or trash truck where the tanks can be 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[9]. Figure 4 shows an example tank label, for a tank with a 20 year useful life span.

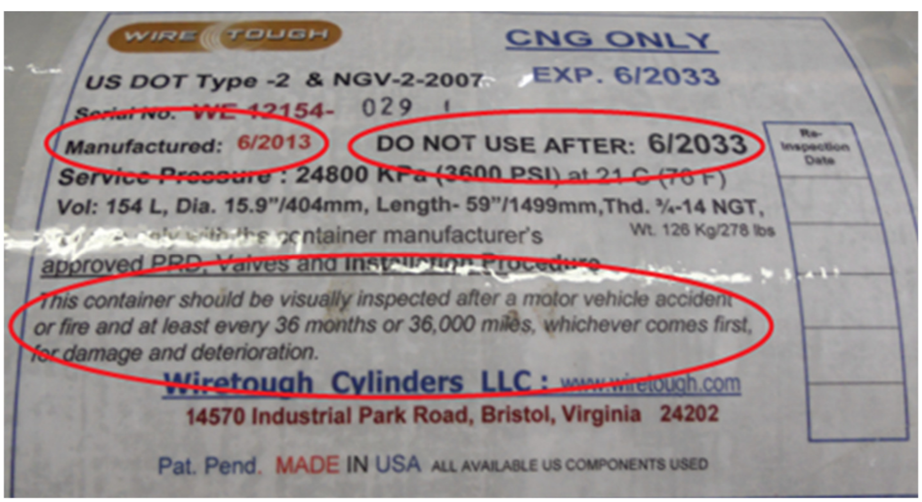

Figure 4 – Example CNG Tank Label

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.

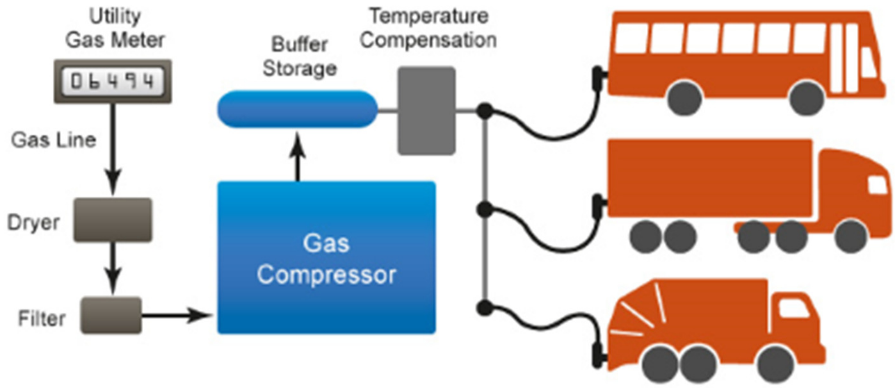

Figure 5 – Time Fill Station Diagram

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.

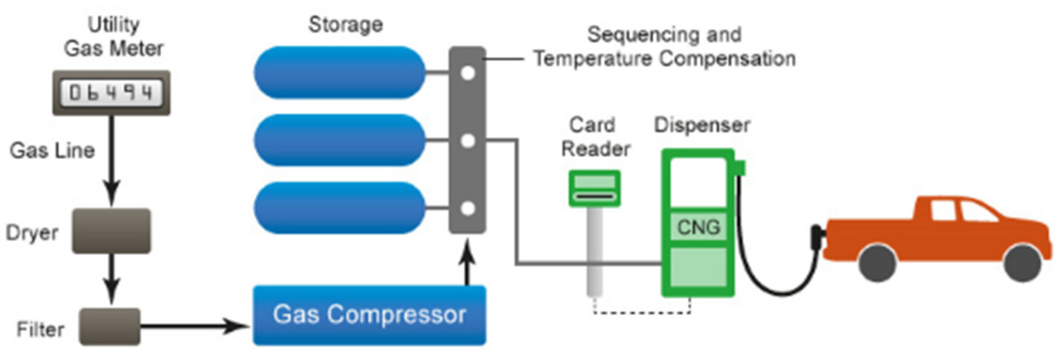

Figure 6 – Fast Fill Station Diagram

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 often able to be 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 to no 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.

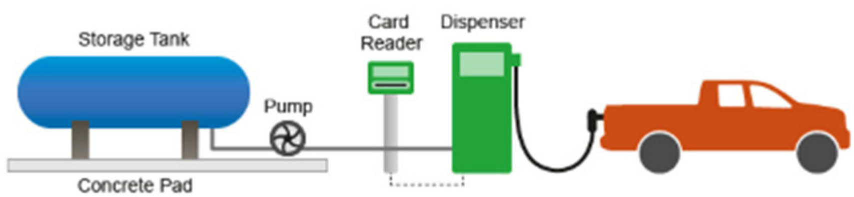

Figure 8 – Propane Fueling Station Diagram

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

Passenger sedans are commonly available as electric vehicles (EVs), but larger vehicles including SUVs, cargo vans, and trucks have only recently become commercially available. The cost of small EVs is competitive with gasoline vehicles, especially with current incentives, but larger EVs are not cost effective, because they require large and expensive battery packs. Currently, there are a couple manufacturers who are marketing all-electric cargo vans with a range of 50-100 miles.

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.