Community Transit of Delaware County
Alternative Fuels Analysis Report

Prepared for:

Alternative Fuels Technical Assistance Program

Pennsylvania Department of Environmental Protection

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1.0 EXECUTIVE SUMMARY

Fleet Description

Community Transit of Delaware County (CTDC) is a private nonprofit shared ride service which serves all of Delaware County, Pennsylvania. CTDC operates a fleet of 47 buses which are built on the Ford E-350 and E-450 chassis, and are fueled by gasoline. The average fleet bus uses 4,767 gallons of gasoline per year. The buses operate 5-6 days per week, and average statistics for a day of operation are 91 miles and 16.7 gallons of gasoline, for an average fuel economy of 5.4 miles per gallon (based on estimated annual mileage for vehicles ending on December 31, 2017).

The fleet ranges in age up to 10 years. CTDC purchases approximately 5 new buses each year, and retires a corresponding number of old buses. All buses are based at a common location every night.

Alternative Fuel Options and Vehicle Types

Table ES1 lists the properties and costs of the various fuels evaluated.

Table ES1 – Fuel Cost Comparison

Fuel Type	Unit of Measure	Units per GGE	Cost per Unit without Taxes	Cost Per GGE without Taxes	Federal Taxes Per GGE	O+M Costs Per GGE	Cost Per GGE Overall
Gasoline[1]	gal	1	$2.02	$2.02	$0.184	$0.000	$2.20
CNG (offsite)[2]	GGE	1	$1.79	$1.79	$0.183	$0.000	$1.97
CNG (onsite)[3]	therm	1.27	$0.61	$0.78	$0.183	$0.182	$1.14
Propane[4]	gal	1.35	$1.30	$1.76	$0.183	$0.010	$1.95
Electric[5]	kWh	8.46	$0.08	$0.70	$0.000	$0.000	$0.70

Note 1: Gasoline cost is fleet average for March 2018.
Note 2: CNG offsite cost is quoted by Clean Energy, assuming 5 CNG buses utilize the station.
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. O+M costs are for a time fill station.
Note 4: Propane cost is based on a quote for a 1 year fixed price contract with a propane supplier, assuming 5 propane buses. Propane supplier will provide onsite fueling station at no cost to CTDC as part of this contract.
Note 5: Electric cost is based on PECO tariff GS with Night Service rider and Price to Compare effective March 1, 2018 through May 31, 2018. Electric cost includes fixed fees, assuming 5 electric buses. Electric GGE calculation is specific to an E-450 vehicle and includes a battery charging efficiency of 85%.

New Ford E-450 vehicles can be purchased then upfitted at a qualified vehicle modifier (QVM) to utilize CNG or propane fuel carrying the full factory warranty. Upfitted Ford E-450 vehicles are evaluated in this report compared to the base case of the current gasoline powered E-450 bus. Table ES2 provides the upfit costs for each of these fuel types.

Table ES2 – Upfit Costs by Fuel Type

Fuel Type	Upfit Cost[1]
Gasoline	$0
CNG	$20,000
Propane	$18,000
Electric	$175,000
Hybrid-Electric	$15,800

Note 1: Upfit costs are specifically for new E-450 vehicles with upfit performed by a Ford QVM.

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 is a standard gasoline powered bus which has a regenerative braking system added. This braking system captures and stores the energy dissipated by braking, and uses a motor to assist the gasoline engine during accelerations using the stored energy.

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 CTDC.

A CNG fueling station capable of filling buses overnight would cost between $150,000 and $750,000, depending on the size of the CNG fleet. A propane fueling station would have no capital cost, and 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 ES1. Alternatively, a propane fueling station could be constructed by CTDC for a cost of $20,000 to $30,000. An electric vehicle charging station for 10 buses would cost approximately $50,000.

Economic Analysis

Table ES3 provides a summary of the fuel usage of a scenario where 10 new alternative fuel vehicles were purchased.

Table ES3 – Fuel Requirements for 10 Vehicle Option

Option	Existing Fuel Usage (GGE)	Proposed Alternative Fuel Usage[1] (GGE)	Proposed Gasoline Not Offset (GGE)	Overall Fuel Savings (GGE)
CNG Offsite	47,666	47,666	0	0
CNG Onsite	47,666	47,666	0	0
Propane Onsite	47,666	47,666	0	0
Electricity[2]	47,666	42,037	5,629	0
Hybrid[3]	47,666	0	38,133	9,533

Note 1: Changes in fuel usage based on proposed onsite and offsite fueling locations compared to current offsite fueling locations are assumed to be negligible.
Note 2: Due to limited range, the EV option is not able to replace 100% of the fuel usage of the average gasoline-powered bus.
Note 3: Hybrid vehicle fuel use assumes 20% fuel savings.

Table ES4 presents the costs, savings, and simple payback for the 10 vehicle option.

Table ES4 – Capital Costs, Savings, and Simple Payback for 10 Vehicle 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	$200,000	$200,000	$0	$11,011	0	18
CNG Onsite	$350,000	$275,000	$75,000	$50,593	1.5	7
Propane Onsite	$180,000	$180,000	$0	$12,005	0	15
Electricity	$1,800,000	$325,000	$1,475,000	$63,098	23	29
Hybrid	$158,000	$79,000	$79,000	$21,011	4	8

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

Grants and incentives for purchasing and operating alternative fuel vehicles and economics of transitioning the entire fleet to alternative fuels are discussed in Section 5 of the report.

Conclusions

- Propane and offsite CNG provide some fuel cost savings, and positive cash flow with the AFIG program,
- Onsite CNG fueling is the best option based on current economics for both cash flow and simple payback, even without grant funding,
- Electric vehicles are not appropriate right now, but they may be the best option both economically and environmentally in 5-10 years.

2.0 INTRODUCTION

Community Transit of Delaware County (CTDC) is a private nonprofit corporation which provides shared-ride transportation to residents of Delaware County. Most of the riders served by CTDC are seniors or individuals with disabilities who are not well-served by conventional means of public transportation. CTDC also transports riders to Philadelphia and bordering counties, on request and as capacity permits. Delaware County covers 191 square miles and is the third smallest county in the Commonwealth of Pennsylvania by area, but is the fifth largest by population.

3.0 FLEET DESCRIPTION

3.1 USAGE AND COST

CTDC operates a fleet of 47 handicap-accessible gasoline fueled buses. These buses are built on the Ford E-350 and E-450 chassis and cab, with a GVWR of 14,050 lbs. CTDC provided data ending on December 31, 2017, which listed each vehicle, the date that it was put into service, the vehicle's operating days per week, and the vehicle's odometer reading. CTDC also provided overall fuel usage data for the period July 1, 2015 through June 30, 2016, and individual vehicle fuel and cost data for March 2018.

Service is generally provided from 6:00 AM to 6:00 PM Monday through Saturday. Trips are scheduled from 2 weeks to 1 day in advance, although dispatchers are able to dynamically reallocate rides during the day in order to optimize service. Table 1 shows the average vehicle usage by vehicle type.

Table 1 – Average Vehicle Usage

Vehicle Type	Average Operating Days per Vehicle per Week	Average Miles per Operating Day	Average Miles per Vehicle per Year
E-350	5.7	83	24,398
E-450	5.4	94	26,146
AVERAGE	**5.5**	**91**	**25,588**

Table 2 shows annual fuel usage and cost for the one year period provided by CTDC. Both the fleet and the non-fleet buses utilize CTDC's fleet fueling account at local gas stations. The non-fleet buses are owned and operated by outside contractors, but are contracted by CTDC and thus are permitted to use the fleet fueling contract. Because the non-fleet buses are not owned by CTDC, they are outside the scope of this study.

Table 2 – Annual Fuel Usage

Date Range	Description	Gasoline Used (gal.)
7/1/2015 - 6/30/2016	47 Fleet Buses	224,030
	Non-Fleet Buses	193,691
TOTAL		**417,721**

As a nonprofit, CTDC is exempt from state taxes, including state fuel excise taxes, but is liable for federal fuel excise taxes. CTDC's fleet fueling account is set up to charge the full price at the pump, and then the state taxes are refunded later. For March 2018, the average price at the pump was $2.78/gal. Without the state fuel tax of $0.576/gal., CTDC's effective current gasoline price is $2.20/gal. The general practice is for each driver to refuel their bus at the end of their shift. Refueling in the middle of a shift is undesirable, as it would impact the timeliness of service.

The March 2018 fueling data indicated that the fleet buses used 14,926 gal., which is 80% of the amount predicted by Table 2, assuming that each month of the year has an equal number of miles driven. This data also indicates that only 43 buses out of 47 were utilized in March. Seasonal variations in demand for services may have caused the low number of gallons used in March. Because the data shown in Table 2 encompasses a larger span of time, it is more appropriate to use for analysis.

Based on Table 1 and Table 2, the average fleet bus uses 4,767 gallons of gasoline per year. Average statistics for a day of operation are 91 miles and 16.7 gallons of gasoline, for an average fuel economy of 5.4 miles per gallon (based on estimated annual mileage for vehicles ending on December 31, 2017).

3.2 Replacement Schedule

Figure 1 shows the breakdown by age of the buses in the fleet. It is the practice of CTDC that buses are not retired until new vehicles are purchased.

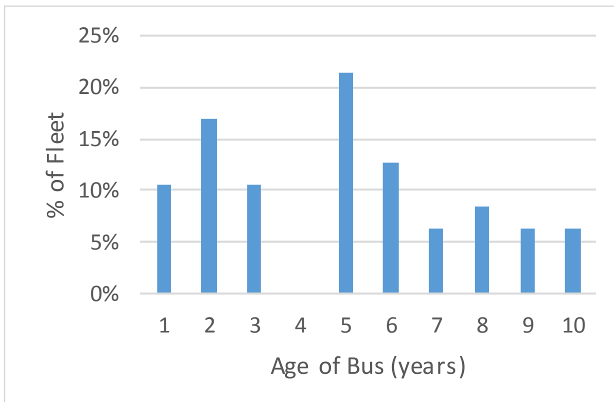

Figure 1 – Age of Fleet as of 12/31/2017

CTDC receives grant funding annually for replacement of old vehicles. However, this funding source is limited to replacing only the oldest vehicles in the fleet, and cannot be used to electively upgrade or replace other vehicles in the fleet. The funding will not cover alternative fuel upfit costs, but rather, assumes a like-for-like replacement. Figure 2 plots the average mileage of the vehicles as a function of age.

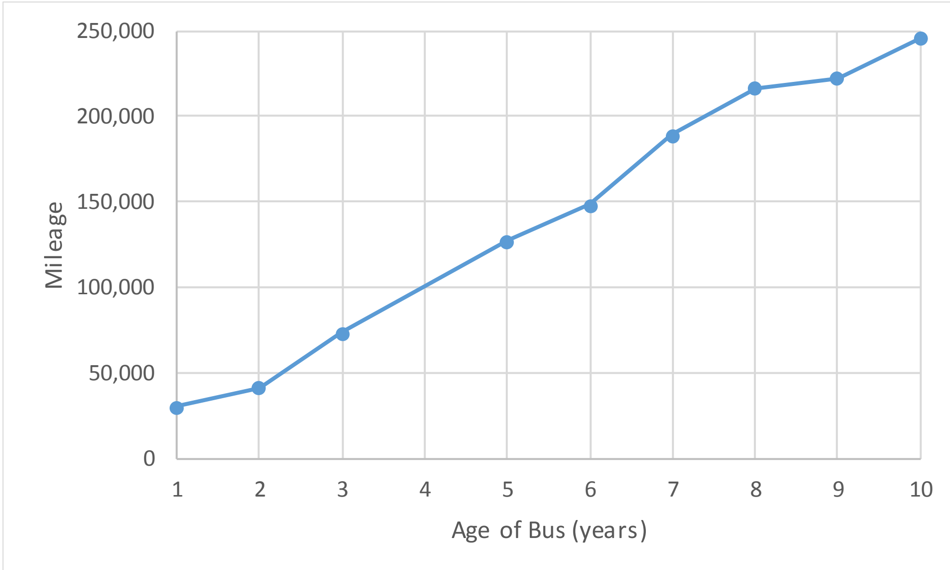

Figure 2 – Age and Mileage of Vehicles as of 12/31/2017

For 2018, 5 buses are scheduled for replacement.

4.0 ALTERNATIVE FUELS, COSTS, AND INCENTIVES

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

4.1 Vehicle Costs

CTDC's cost for a gasoline powered Ford E-450 shuttle bus with appropriate trim and accessibility features is approximately $75,000. Table 3 lists budget costs for upfitting a single new vehicle with an alternative fuel system. Thus, the total price of the new vehicle would be $75,000 plus the amount listed in Table 3.

Table 3 – Upfit Costs by Fuel Type

Fuel Type	Upfit Cost[1]
Gasoline	$0
CNG	$20,000
Propane	$18,000
Electric[2]	$175,000
Hybrid-Electric[3]	$15,800

Note 1: Upfit costs are specifically for new E-450 vehicle with upfit performed by a Ford QVM.
Note 2: Range of electric vehicle is approximately 80 miles.
Note 3: Hybrid-Electric vehicle utilizes regenerative braking and is powered by gasoline.

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. These vehicles are then eligible for the standard factory warranty on the entire vehicle, including the CNG fuel system. In most cases, the local Ford dealer will coordinate with the factory and a QVM to produce an appropriate vehicle to the customer's specifications. The QVMs work closely with the customer's local Ford Dealer as well as the factory to ensure that the alternative fuel system is appropriately installed. The QVMs in turn provide training to the Ford dealer to allow the dealer to perform all standard and necessary maintenance, service, and warranty work for the entire vehicle, including the CNG fuel system.

Additionally, there are manufacturers and upfitters of alternative fuel systems who are not QVMs, especially for CNG and propane vehicles. These non-QVM upfits are generally cheaper (Table 3 shows QVM costs), but can vary in quality and performance. The non-QVM upfitters are not audited by Ford, and in some cases may not have access to the dealer and factory relationships enjoyed by the QVMs. Both QVM and non-QVM upfits are available with EPA and/or CARB (California Air Resources Board) certification, and thus are legal for use in the Commonwealth of Pennsylvania[1]. However, upfits which lack final EPA and/or CARB approval are not legal in PA and should be avoided.

The Ford E-450 shuttle bus platform has broad support from Ford's alternative fuel QVMs, and is available with multiple types of fuels, as shown in Table 3. Although bi-fuel systems have been and are currently available on the market, there are currently no bi-fuel systems recommended by a QVM for the current model of the E-450. 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 CTDC, the vehicles would be able to refuel every night, so the option to operate on gasoline is not necessary.

4.2 INFRASTRUCTURE COSTS

4.2.1 CNG

There is a publicly available fast fill CNG station owned by Clean Energy located near the Philadelphia airport, approximately 5 miles from the CTDC headquarters. This CNG station is equipped with two 250 HP compressors which can provide approximately 8 GGE/minute. In the case of an E-450 bus, the fill time would be approximately 3 minutes. A photo of the station is provided in Figure 3.

Figure 3 – "Wally Park" CNG Fueling Station at Philadelphia Airport

Image Credit: Clean Energy Fuels

There are 3 additional Clean Energy CNG stations in the region, one near the King of Prussia Mall, one in Plymouth Meeting, and one in Camden, NJ. The BP station at 2901 Abbotsford Avenue in Philadelphia also sells CNG, and this station is owned by VNG. Although these 4 additional sites are outside of the county, they may be convenient depending on the route driven, and provide backup fueling options. Figure 4 shows the CNG station locations relative to the CTDC base.

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

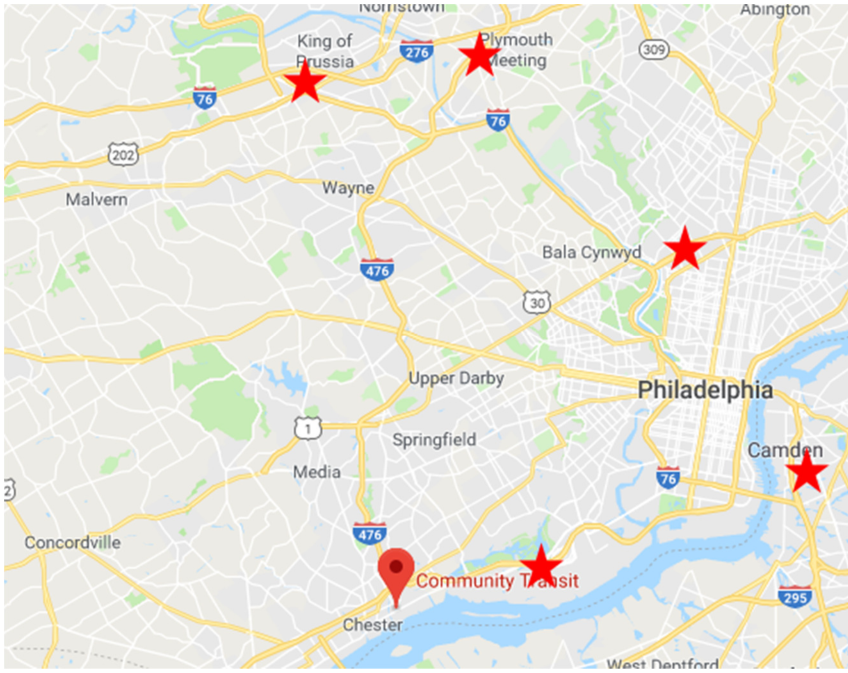

Figure 4 – CTDC Base and CNG Station Locations

Image Credit: Google Maps

For CNG vehicles, CTDC 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 base. Fueling at a retail station would incur no infrastructure costs. Clean Energy is 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. Clean Energy provides fleet discounts which are able to be negotiated based on volume.

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 CTDC's usage patterns, a time fill station would be appropriate, and would be sized to fuel all of CTDC'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. However, because CTDC does not own the property where the vehicles are stored, installation of costly infrastructure may not be appropriate.

4.2.2 Propane

A propane fueling station could be installed in a relatively small area at the CTDC base, requiring minimum site work. A station which could supply 5 buses would require 2-4 1,000 gallon tanks, and a single dispenser. Sizing the onsite storage at 4,000 gallons would be preferable to improve the economics of delivery, as standard propane trucks are sized in the range of 3,000-3,500 gallons. 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 two local propane suppliers, and both 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.

As an alternative to a fueling station sited at the base, there is a propane fueling station located at the Park & Jet facility which is approximately 2 miles east of the base. This fueling station is jointly used by

Park & Jet, Colonial Airport Parking, and Tinicum Township. The ownership details of this station are unclear, but it is likely that CTDC could work out an arrangement to allow for fleet fueling at this station.

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 $4,000 per vehicle. Site work to provide a new electrical service and distribution cabinet is estimated at $10,000.

An EV bus would require at least 8 hours to fully charge, which would generally take place overnight. The charger for this application would likely be a Level II EVSE rated for 19.2 kW, which requires a 240 V or 208 V circuit with a 100 A breaker. The rate of charge for the EV bus would be approximately 13 miles per hour of charging. Charging during the day would not be appropriate, even if DC Fast Charging was available.

Because of the consistent usage pattern of the buses which makes it only necessary to charge them at night, there is the potential that the EVSE at the CTDC base could be utilized by employees or the general public during the day (such as by employees at nearby businesses). Many EVSE have built in billing systems which would allow CTDC 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 CTDC for this type of project, and would also provide a valuable community service or employee benefit.

4.2.4 Hybrid-Electric

Hybrid vehicles which utilize regenerative braking require no special fueling equipment, as all energy is harvested from the vehicle’s movement. Additional discussion of this vehicle type can be found in Appendix A.

4.3 FUEL COSTS

Table 4 lists the properties and costs of the various fuels evaluated.

Table 4 – Fuel Cost Comparison

Fuel Type	Unit of Measure	Units per GGE	Cost per Unit without Taxes	Cost Per GGE without Taxes	Federal Taxes Per GGE	O+M Costs Per GGE	Cost Per GGE Overall
Gasoline[1]	gal	1	$2.02	$2.02	$0.184	$0.000	$2.20
CNG (offsite)[2]	GGE	1	$1.79	$1.79	$0.183	$0.000	$1.97
CNG (onsite)[3]	therm	1.27	$0.61	$0.78	$0.183	$0.182	$1.14
Propane[4]	gal	1.35	$1.30	$1.76	$0.183	$0.010	$1.95
Electric[5]	kWh	8.46	$0.08	$0.70	$0.000	$0.000	$0.70

Note 1: Gasoline cost is fleet average for March 2018.
Note 2: CNG offsite cost is quoted by Clean Energy, including a discount off retail which assumes that 5 CNG buses utilize the station.
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. O+M costs are for a time fill station.
Note 4: Propane cost is based on a quote for a 1 year fixed price contract with a propane supplier, assuming 5 propane buses. Propane supplier will provide onsite fueling station at no cost to CTDC as part of this contract.

Note 5: Electric cost is based on PECO tariff GS with Night Service rider and Price to Compare effective March 1, 2018 through May 31, 2018. Electric cost includes fixed fees, assuming 10 electric buses. Electric GGE calculation is specific to an E-450 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. Additionally, while there is a strong market for servicing of alternative fuel vehicles, even in the Philadelphia region, many auto mechanics do not have the training or facilities for performing maintenance on these fuels systems, although they are qualified for servicing the other systems on these vehicles. However, working with a Ford dealer and a QVM will enable CTDC to secure an appropriate service center locally.

EVs in particular present a strong case for a reduction in maintenance expense. However, EVs are relatively new to the vehicle class under consideration for CTDC, 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 not accepting new applications, but it will be reopened later this year.

The details of this grant program for vehicle purchase are as follows (this includes modifications from 2017 which are expected to be announced soon):

- 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.

The details of this grant program for fleet fueling infrastructure are as follows (based on 2017 solicitation):

- 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 Volkswagen Environmental Mitigation Trust Agreement

The Commonwealth of Pennsylvania has received approximately $118 million from two Volkswagen settlements, which will be administered by DEP. The plans for how to spend this money have not yet been finalized, but the overall goal will be to fund diesel-source NOx reductions. DEP anticipates that a grant program will be available in the third quarter of 2018, which will focus on implementation of fast charging along highways and community charging at workplaces and other daily parking areas. While CTDC does not have any diesel vehicles which can be directly targeted with these trust funds, there is the potential that CTDC could still receive funding for a project, especially if it is related to EVs.

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 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.

4.5.5 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 CTDC'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 Clean Energy CNG station near the airport, for example.

If this tax credit were to be reauthorized, CTDC would realize approximately $2,383 per year for each propane or natural gas vehicle in the fleet.

5.0 ECONOMIC ANALYSIS

Two scenarios are presented to evaluate the costs and savings of transitioning to an alternative vehicle fleet. The first scenario assumes that only 10 vehicles are purchased, while the second scenario assumes that 100% of the fleet is converted to the alternative fuel.

5.1 10 VEHICLES

Table 5 presents the capital cost estimates for the 10 vehicle option. 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 5 – Capital Cost Estimates for 10 Vehicle Option

Description	CNG Offsite	CNG Onsite	Propane Onsite	Electricity	Hybrid
Vehicle Upfits	$200,000	$200,000	$180,000	$1,750,000	$158,000
AFIG Vehicle Funding	($200,000)	($200,000)	($180,000)	($300,000)	($79,000)
Fueling Station	$0	$150,000	$0	$50,000	$0
AFIG Fuel Station Funding	$0	($75,000)	$0	($25,000)	$0
Total Cost With Grants	**$0**	**$75,000**	**$0**	**$1,475,000**	**$79,000**
Total Cost Without Grants	**$200,000**	**$350,000**	**$180,000**	**$1,800,000**	**$158,000**

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 these vehicles are 1.8 kWh.

Table 6 lists the current fuel usage for 10 average buses, and the comparable consumption of alternative fuels for those 10 buses.

Table 6 – Fuel Requirements for 10 Vehicle Option

Option	Existing Fuel Usage (GGE)	Proposed Alternative Fuel Usage[1] (GGE)	Proposed Gasoline Not Offset (GGE)	Overall Fuel Savings (GGE)
CNG Offsite	47,666	47,666	0	0
CNG Onsite	47,666	47,666	0	0
Propane Onsite	47,666	47,666	0	0
Electricity[2]	47,666	42,037	5,629	0
Hybrid[3]	47,666	0	38,133	9,533

Note 1: Changes in fuel usage based on proposed onsite and offsite fueling locations compared to current offsite fueling locations are assumed to be negligible.
Note 2: Due to limited range, the EV option is not able to replace 100% of the fuel usage of the average gasoline-powered bus.
Note 3: Hybrid vehicle fuel use assumes 20% fuel savings.

Table 7 presents the fuel costs and savings for the 10 vehicle option.

Table 7 – Fuel and Maintenance Costs for 10 Vehicle Option

Description	CNG Offsite	CNG Onsite	Propane Onsite	Electricity	Hybrid
Current Fuel Cost	($105,056)	($105,056)	($105,056)	($105,056)	($105,056)
Alternative Fuel Cost	$94,045	$54,463	$93,050	$29,552	$0
Gasoline Not Offset	$0	$0	$0	$12,406	$84,045
Maintenance Increase	$0	$0	$0	$0	$0
TOTAL	**($11,011)**	**($50,593)**	**($12,005)**	**($63,098)**	**($21,011)**

Table 8 presents the costs, savings, and simple payback for the 10 vehicle option.

Table 8 – Capital Costs, Savings, and Simple Payback for 10 Vehicle 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	$200,000	$200,000	$0	$11,011	0	18
CNG Onsite	$350,000	$275,000	$75,000	$50,593	1.5	7
Propane Onsite	$180,000	$180,000	$0	$12,005	0	15
Electricity	$1,800,000	$325,000	$1,475,000	$63,098	23	29
Hybrid	$158,000	$79,000	$79,000	$21,011	4	8

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

5.2 ENTIRE FLEET (47 VEHICLES)

Table 9 presents the capital cost estimates for transitioning the entire fleet to alternative fuels. Because EVs are not able to achieve the average daily miles driven, they are not viable for a total fleet replacement at this time.

Table 9 – Capital Cost Estimates for Entire Fleet Option

Description	CNG Offsite	CNG Onsite	Propane Onsite	Electricity	Hybrid
Vehicle Upfits	$940,000	$940,000	$846,000	n/a	$742,600
AFIG Vehicle Funding[1]	($300,000)	($300,000)	($300,000)	n/a	($300,000)
Fueling Station	$0	$750,000	$0	n/a	$0
AFIG Fuel Station Funding	$0	($300,000)	$0	n/a	$0
Total Cost With Grants	**$640,000**	**$1,090,000**	**$546,000**	**n/a**	**$442,600**
Total Cost Without Grants	**$940,000**	**$1,690,000**	**$846,000**	**n/a**	**$742,600**

Note 1: AFIG funding is limited to $300,000 for vehicle conversions, and $600,000 overall per project, per year.

Because total replacement of CTDC's fleet in a single year is not likely, these scenarios are intended to demonstrate the general economics of a gradual fleet conversion with no or limited grant funding. The grant funding shown in Table 9 is a maximum AFIG award for a single year. This simulates the case where significant competition for AFIG funding results in CTDC receiving an amount over the course of 2-3 years, equal to the maximum annual award of $300,000 for vehicle upfits and $300,000 for a fueling station, and then not in subsequent years.

Table 10 lists the current fuel usage for the entire fleet, and the comparable consumption of alternative fuels for the entire fleet.

Table 10 – Fuel Requirements for Entire Fleet Option

Option	Existing Fuel Usage (GGE)	Proposed Alternative Fuel Usage[1] (GGE)	Proposed Gasoline Not Offset (GGE)	Overall Fuel Savings (GGE)
CNG Offsite	224,030	224,030	0	0
CNG Onsite	224,030	224,030	0	0
Propane Onsite	224,030	224,030	0	0
Electricity	224,030	n/a	n/a	n/a
Hybrid[2]	224,030	0	179,224	44,806

Note 1: Changes in fuel usage based on proposed onsite and offsite fueling locations compared to current offsite fueling locations are assumed to be negligible.
Note 2: Hybrid vehicle fuel use assumes 20% fuel savings.

Table 11 presents the fuel costs and savings for the entire fleet option.

Table 11 – Fuel and Maintenance Costs for Entire Fleet Option

Description	CNG Offsite[1]	CNG Onsite	Propane Onsite[1]	Electricity	Hybrid
Current Fuel Cost	($493,762)	($493,762)	($493,762)	n/a	($493,762)
Alternative Fuel Cost	$433,171	$255,976	$428,590	n/a	$0
Gasoline Not Offset	$0	$0	$0	n/a	$395,010
Maintenance Increase	$0	$0	$0	n/a	$0
TOTAL	**($60,591)**	**($237,786)**	**($65,172)**	**n/a**	**($98,752)**

Note 1: Alternative Fuel Costs assume 2% reduction in price for offsite CNG and propane due to increased purchase volume, compared to the costs listed in Table 4.

Table 12 presents the costs, savings, and simple payback for the entire fleet option.

Table 12 – Capital Costs, Savings, and Simple Payback for Entire Fleet 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	$940,000	$300,000	$640,000	$60,591	11	16
CNG Onsite	$1,690,000	$600,000	$1,090,000	$237,786	5	7
Propane Onsite	$846,000	$300,000	$546,000	$65,172	8	13
Electricity	n/a	n/a	n/a	n/a	n/a	n/a
Hybrid	$742,600	$300,000	$442,600	$98,752	4	8

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

6.0 EMISSIONS

Table 13 lists the CO_2 emissions of the various fuels under consideration in this report.

Table 13 – CO_2 Emissions from Vehicle Fuels

Fuel	lb. CO_2 per Unit Volume[1]	lb. CO_2 per GGE	Annual CO_2 Reduction per Vehicle (tonnes)[3]
Gasoline E10 (gal)	17.4	17.4	-
Hybrid E10 (gal)[2]	17.4	17.4	8
Natural Gas (Mcf)	119.9	15.0	5
Propane (gal)	12.6	17.0	1
Electricity (kWh)	0.9	7.4	22

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 RFCE, using value for Total Output Emission Factor (baseload). Electricity emissions include EPA estimated line losses of 4.97%.
Note 2: Hybrid emissions reduction is based on assumed fuel savings of 20%.
Note 3: 1 tonne = 1,000 kg (2,205 lbs.).

Table 14 lists the pollutant emissions from a new Ford E-450 vehicle.

Table 14 – Vehicle Pollutant Emissions

Fuel	BHP	NMHC	NOx	CO	PM	HCHO
Gasoline	305	0.05	0.16	3.70	0.001	0.000
CNG	305	0.05	0.12	1.70	-	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 CARB executive order test results. CNG data are from MY2017 CARB executive order test results.

Alternative fuel vehicles are required to meet the same emissions standards as conventional fuel vehicles. CNG and propane demonstrate emissions reductions for both NOx and CO. With the exception of formaldehyde in these test results, CNG is equal to or better than gasoline.

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 DISCUSSION OF OPTIONS

Community Transit has the opportunity to transition its fleet to alternative fuel or more efficient vehicles in order to reduce operating costs, improve regional air quality, and reduce greenhouse gas emissions. This report has presented four alternative fuel options which are able to be upfitted onto a new E-450 bus, ensuring that CTDC customers enjoy the same level of service and comfort. Community Transit's fleet has several strengths which make transitioning to alternative fuel vehicles attractive. These aspects include:

- a consistent vehicle type,
- relatively high annual miles driven and fuel use per vehicle,
- storage of vehicles at a common site every night,
- access to pipeline natural gas, as well as a range of competitive local fuel providers,
- local access to qualified service dealers

Electric vehicles, which have recently become available in this size class, provide the greatest fuel cost savings compared to gasoline, but the capital cost of upfitting the vehicles is an order of magnitude greater than for the other options. Therefore, this option is not appropriate unless additional EV-specific incentives become available. Additionally, the range of currently available EV buses is slightly less than the average mileage driven by the CTDC vehicles, and therefore these EVs would not be appropriate for a full fleet replacement until battery technology has advanced.

Compressed natural gas and propane vehicles both have reasonable upfit costs, which fit well into current incentive programs. Natural gas is an abundant fuel produced locally in Pennsylvania. The economics for these fuels are largely dependent on the fueling scheme selected. A public fast fill CNG station is located nearby, requiring CTDC to invest nothing in a fuel station, but the expected price that CTDC could negotiate for this fuel would provide minimal savings compared to gasoline. Without incentive funding, the fuel savings from offsite CNG fueling would not recoup the upfit cost of the CNG bus.

Installation of a propane fueling station at the CTDC site would provide slightly more savings, and this propane fueling station could be paid for either by the propane vendor or by CTDC. Onsite propane fueling would likely be more convenient for drivers compared to fueling at an offsite gasoline or CNG station. However, without incentive funding, the fuel savings from onsite propane fueling would not recoup the upfit cost of the propane bus.

An onsite time fill CNG station would provide the best economics, because CTDC would purchase the gas directly from the utility as it was needed, but this would require a larger investment in fueling infrastructure. Because CTDC currently leases space for bus storage and administrative offices, constructing fueling infrastructure may appear questionable.

With AFIG funding, the simple payback of an onsite CNG station is attractive enough to justify the investment within as little as 3 years, assuming that 5 vehicles are acquired per year with AFIG funding. Therefore, lack of ownership of the site does not in and of itself spoil the economics of this option. Even if CTDC only uses a time fill station for 5 years, and then abandons the site, this option is still attractive. However, there is the possibility that the length of CTDC's remaining lease could be a factor in the scoring of a request for funding for an onsite fuel station.

An onsite propane fueling station requires only a small amount of electricity for the transfer pump, and thus could easily be powered by a propane backup generator should there be a power outage. In the event of a regional disaster where utility power is lost, and gasoline stations are not able to pump gas, CTDC would be able to refuel the propane buses using whatever propane was available in storage. This resiliency could prove especially helpful, since many of CTDC's clients are especially vulnerable in cases of large scale power outages or disasters. In Atlantic City after Hurricane Sandy, a local CNG minibus fleet played an important role in evacuating residents[2]. These buses were supplied with fuel by a Clean Energy fast fill station which was equipped with a mobile backup generator during and after the storm. The buses were able to access CNG fuel without interruption. The siting of the Clean Energy station near

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[2] https://www.energy.gov/energysaver/articles/face-hurricane-sandy-cng-vehicles-shuttle-people-safety

the Philadelphia airport is significant, because in the case of a large scale power outage, airport infrastructure is considered critical, and would be preferentially serviced by utility crews when restoring power. Thus, even if CTDC constructed a time fill station onsite, CTDC would still be able to fuel at the Clean Energy station during an emergency.

Hybrid vehicles which capture energy from braking are another viable option. These vehicles would not require any special fueling infrastructure, and CTDC could potentially obtain partial funding of these vehicles through incentive programs. The hybrid system reduces fuel usage by up to 20%, according to manufacturer data. The fuel usage reduction is highly dependent on the drive cycle of these vehicles, but the community shared ride use case is expected to provide good performance in this regard, compared to a vehicle which is used predominantly for highway driving. If CTDC is interested in this option, it is recommended that the manufacturer be consulted to provide further analysis of CTDC's typical drive cycles, in order to more accurately determine the potential fuel savings.

7.2 Next Steps

The AFIG grant offers generous incentives for the upfit costs of alternative fuel vehicles. When CTDC acquires a new vehicle, that vehicle could essentially be delivered as a CNG or propane vehicle with no out of pocket cost increase to CTDC. Both CNG fueling (offsite near the airport) and propane fueling (onsite, provided by propane supplier) are viable fueling strategies which require little to no investment. Therefore, a gradual transition to alternative fuels could be accomplished with only a few vehicles per year, providing positive cash flow from day 1.

An important consideration is whether the AFIG incentives will increase or decrease in the future. This year, the AFIG incentive is significantly increased, because last year the AFIG program only paid for 1/2 of the upfit cost, compared to this year where it will pay for up to 100% depending on the vehicle type. Realistically, if CTDC embarks on a fleet conversion project, the AFIG funding may be available for a few years at the beginning, and then the AFIG funding may not be available, due to changes in the program, or competition from other organizations for this funding. Therefore it's prudent to consider the "Simple Payback Without Grants" column of Table 8 and Table 12, to determine whether any of these options really make sense without an incentive. Without the AFIG funding, the onsite CNG and the hybrid-electric vehicles are the options which stand out. However, there is no downside to having a fleet made up of some alternative fuel vehicles, and some gasoline vehicles, if funding for upfits is no longer available at some point in the future.

The AFIG program is currently closed until later this year, but if CTDC is purchasing vehicles immediately, it may make sense to order these as gasoline vehicles, but with the gaseous fuel prep option. This would allow them to be upfitted at some point in the future when funding was available. The AFIG program would only pay 50% of this upfit cost, since the vehicles would not be new at the time of upfit, compared to 100% of the upfit cost if the vehicles were new. However, if the upfit was performed on 1 year old vehicles, there would still be a net benefit over the life of the vehicle.

The 10 vehicle scenario was used as a base case since this is the number of vehicles needed to activate AFIG funding for an onsite fueling station. However, CTDC's funding mechanism for replacement vehicles makes it unlikely that 10 vehicles could be purchased in a single year. Therefore, in the first year, CTDC could apply for AFIG funding to upfit 5 CNG buses, and CTDC would fuel these at the Clean Energy CNG station. Then in year 2, CTDC could apply for funding to upfit 5 more buses, and at the same time, apply for funding to cover 50% of an onsite time fill station.

Current trends in the clean transportation industry are towards electric vehicles. Compared to other alternative fuels and to conventional fuels, EVs have the potential to significantly reduce both CO_2 and pollutant emissions. While EV options for medium duty vehicles are currently sparse, the medium-duty class will probably have several good EV options in the next 5 years, which may meet CTDC's needs. While the prices of EVs are still high compared to conventional vehicles, costs are expected to decline as battery technology advances, and as automakers increase production capacity. Future incentive programs are likely to preferentially target EVs, compared to other alternative fuels.

7.3 SUMMARY

- Propane and offsite CNG provide some fuel cost savings, and positive cash flow with the AFIG program,
- Onsite CNG fueling is the best option based on current economics for both cash flow and simple payback, even without grant funding,
- Electric vehicles are not appropriate right now, but they may be the best option both economically and environmentally in 5-10 years.

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 would 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 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. Because of the high CNG storage pressure and the potential for severe damage in a collision, the storage tanks can be a large percentage of the cost of the vehicle conversion to CNG.

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[3]. Figure 5 shows an example tank label, for a tank with a 20 year useful life span.

[3] https://www.afdc.energy.gov/vehicles/natural_gas_cylinder.html

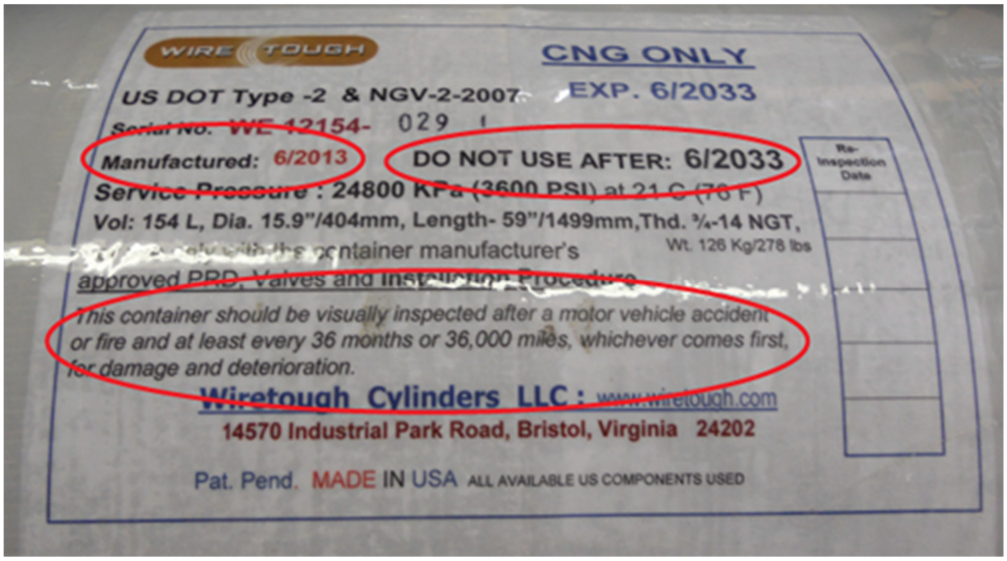

Figure 5 – Example CNG Tank Label

Image credit: U.S. Department of Energy

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 6. 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.

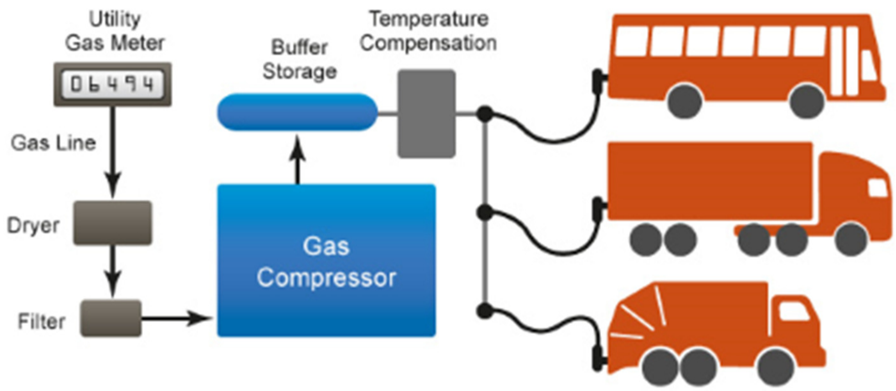

Figure 6 – Time Fill Station Diagram

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 7 shows the general layout of a fast fill station.

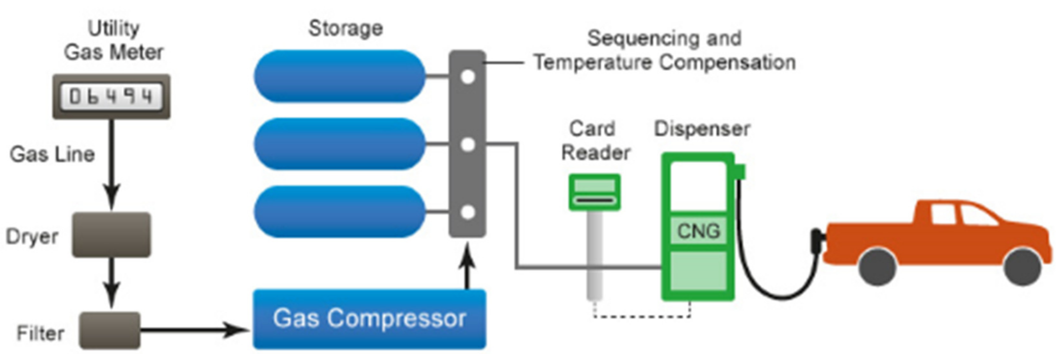

Figure 7 – Fast Fill Station Diagram

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

Figure 8 – "Wally Park" 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 9 shows a general diagram of a propane fueling station, and Figure 10 is a photo of a simple propane fueling station for a fleet, with a single dispenser.

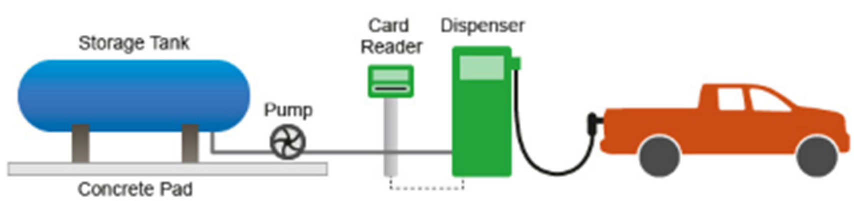

Figure 9 – Propane Fueling Station Diagram

Image credit: U.S. Department of Energy

Figure 10 – 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

Electric vehicles (EVs) are commonly available as passenger vehicles, but are relatively new to this size class. Currently, there are a couple manufacturers who are marketing all-electric shuttle buses. The range of an EV bus would be 75-85 miles, depending on the route. Therefore, the use of these buses by CTDC would require special routing to ensure that they did not run out of charge. Additionally, the requirement to operate these vehicles on shorter routes could reduce the amount of gasoline offset. However, if EV-specific incentives on the capital cost of these vehicles were available, EV buses could still be a good investment, although they would not be appropriate for replacement of 100% of the bus fleet. As EV technology for medium-duty and heavy-duty vehicles matures, there will likely be options available in the future to allow for replacement of vehicles which require a longer range.

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 11.
- 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 11 – Level II Fleet Charging Stations

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

The column-mounted units shown in Figure 11 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 Hybrid Regenerative Braking

For this vehicle size class, the predominant hybrid technology employed is 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 a regenerative braking system. EVs use this system, but it can also be employed in hybrid fossil fuel vehicles. For hybrids, the system consists of an electric or hydraulic motor coupled to the drive shaft, and an accumulator which is able to deliver or 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.

The Ford F-450 with hybrid electric regenerative braking and a 1.8 kWh battery is available as an upfit from a Ford QVM. The 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. Actual savings can be measured by a data logger which can be installed as part of the upfit. The data logger meters the energy absorbed and delivered by the regenerative braking system, and calculates the fuel savings.