ALTERNATIVE FUEL VEHICLES STUDY

for the
Metropolitan Government of Nashville and Davidson County
Department of General Services
Office of Fleet Management

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Getting the word out on alternative fuel vehicles and clean transportation

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QUALIFICATION

This report reflects 2014 petroleum pricing (about $3.37 for gasoline and $3.82 for diesel, per gallon) before the significant reductions in crude oil prices. Therefore, potential fuel savings presented do not reflect current prices, and the break-even periods indicated are far more optimistic than current prices would dictate.

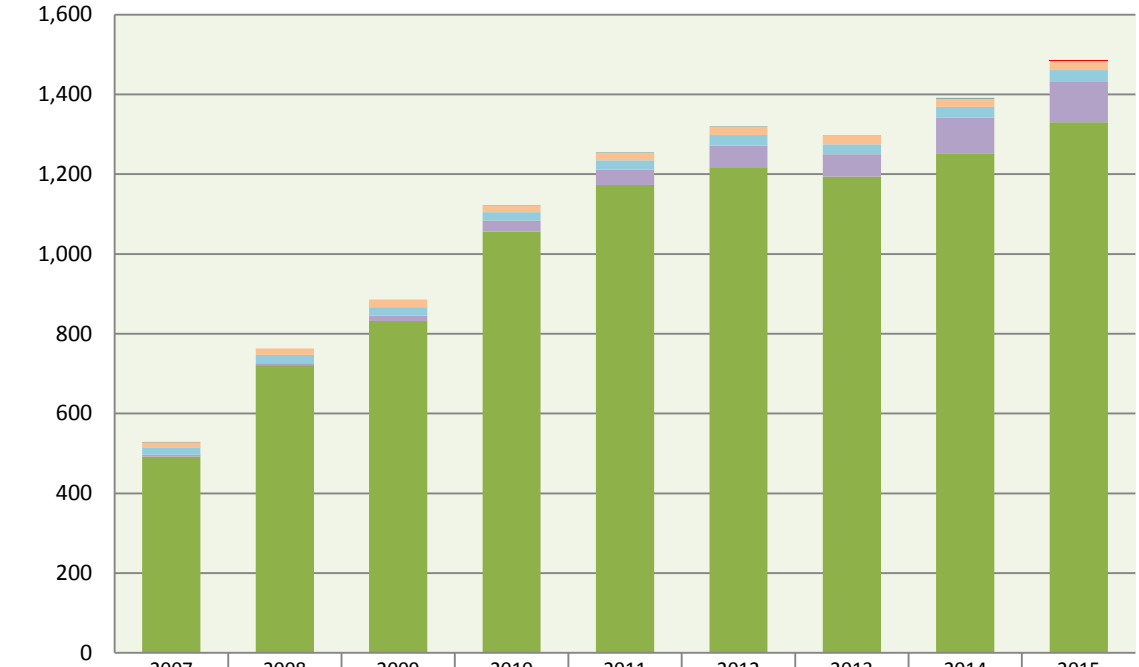
Gasoline and diesel supplies from U.S. resources are strong and prices may remain low through next year.

Introduction

The Department of General Services, Office of Fleet Management is at the vanguard of metropolitan government's sustainability initiatives. Concern about greenhouse gas emissions, foreign oil dependency, and costs will continue guiding the Office of Fleet Management's on-going efforts to examine, test, and appropriately implement the use of various fuels and alternative fuel vehicles.

The Metropolitan Government of Nashville and Davidson County (Metro) fleet currently includes: flex-fuel vehicles; B5 biodiesel compatible trucks, tractors, mowers and carts; gas hybrid and electric cars; liquefied petroleum gas (LPG/propane) units; and, a compressed natural gas truck.

Metro Green Fleet 2007 – 2015



	2007	2008	2009	2010	2011	2012	2013	2014	2015
CNG									1
BATTERY	1			1	1	1	1	1	1
ELECTRIC	13	16	19	16	19	21	21	21	23
PROPANE	18	21	21	21	23	26	25	27	28
HYBRID	5	5	14	28	39	56	56	91	103
FLEX	492	721	832	1,056	1,173	1,216	1,194	1,251	1,330

This report reviews an array of practical, cogent considerations and details steps for advancing General Services' strategic commitment to sustainability, reduced petroleum consumption, and cost containment.

Objectives

A cost-benefit analysis of alternative fuel vehicles must include a range of disparate factors that are, in many instances, elusive, conflicting, or unsettled in terms of data and quantification. Nevertheless, this report offers the following for improved, more transparent decision making:

- a review of fuel and vehicle options;
- a profile of existing, local infrastructure supporting alternative fuels;
- an assessment of costs associated with alternative fuel vehicles;
- an overview of potential benefits associated with vehicle choices; and
- a strategy for meeting sustainability targets while recognizing that fleet procurement decisions are significantly budget driven and largely rest on initial investment and anticipated total cost of ownership.

Data and Methodology

Resources supporting this examination include interviews with original equipment manufacturers (OEMs), up-fitting/conversion companies, fuel system suppliers, vehicle dealers, Clean Cities coordinators, and fleet managers, as well as information collected about experiences with alternative fuel vehicles by other municipalities. Reviewed resources also consist of material at manufacturer and dealer Internet sites and in industry, association, and U.S. Department of Energy publications.

Data detailed about greenhouse gas emissions and fuel consumption was derived, in part, from the EPA Office of Transportation and Air Quality model for the fuel economy and emissions standards. Information about maintenance and fueling safety standards, training, and certification was collected from the Natural Gas Vehicle Institute, the Propane Education & Research Council, the National Fire Protection Association, and the National Institute for Automotive Service Excellence (ASE). Additionally, the in-depth North Carolina Alternative Fuels Feasibility Study (2012) provides additional underpinning for this study as well as a foundation for alternative fuel vehicle considerations.

Report exhibits cite analysis factors used for determining grams and metric tons of greenhouse gas emissions, along with savings in gallons of fuel consumed and fuel expenses.

Current Fleet

The Office of Fleet Management (OFM) is responsible for ensuring that safe, reliable vehicles are available, accessible, and efficiently used for Metro business. OFM oversees the procurement, maintenance, and repair of a large and diverse fleet serving several departments including Public Works, Water Services, Parks, Police, Sheriff, Fire, Health, Public Library, and Assessor of Property.

OFM is also responsible for the provision of fuel to operate the Metro fleet. OFM's fuel program affords access to Metro-owned bulk fuel sites as well as retail stations where employees may obtain fuel for Metro vehicles and equipment on a transactional basis from local, commercial vendors accepting payment through Metro's fuel card vendor.

Fleet Units

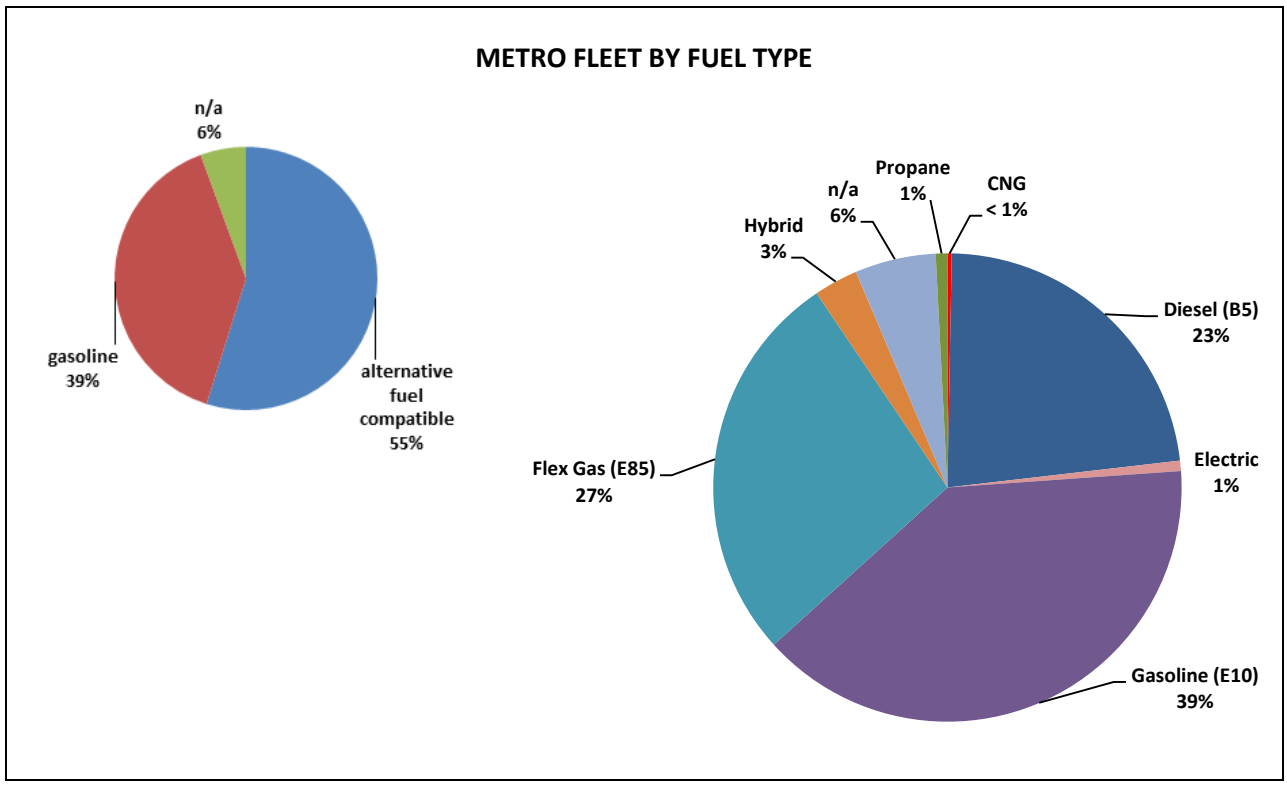
Metro's fleet is composed of a broad range of vehicles and equipment types including, but not limited to, large specialty vehicles, boats, towed trailers, small equipment, work trucks, and general purpose sedans. The following table details a late 2014 snapshot of Metro fleet units by class code and further delineates the units by fuel compatibility.

FLEET UNITS BY CLASS (alternative fuel compatible units are shaded)

Class	Fuel Type	Vehicle/Equipment Description	Count
1G/Flex	Gas (E10)	general purpose sedans, pickups, station wagons, and vans-3/4 ton rating or lower	1,035
1D	Biodiesel (B5)	general purpose pickups, vans-3/4 ton rating or lower	10
1CNG	CNG	general purpose sedans, pickups, station wagons, and vans-3/4 ton rating or lower	0
1E	Electric	general purpose sedans, pickups, station wagons, and vans-3/4 ton rating or lower	3
1H	Hybrid	general purpose sedans, pickups, station wagons, and vans-3/4 ton rating or lower	103
1P	Propane	general purpose sedans, pickups, station wagons, and vans-3/4 ton rating or lower	0
2	Gas/Flex (E85)	police patrol/pursuit sedans	861
3	Gas/Flex (E85)	general purpose trucks, pickups, flat bed or single axle dump trucks 10,000 - 17,950 GVW	47
3	Biodiesel (B5)	general purpose trucks, pickups, flat bed or single axle dump trucks 10,000 - 17,950 GVW	132
4	Gas/Flex (E85)	general purpose trucks, pickups, flat bed or single axle dump trucks 17,950 - 26,000 GVW	14
4	Biodiesel (B5)	general purpose trucks, pickups, flat bed or single axle dump trucks 17,950 - 26,000 GVW	86
5	Biodiesel (B5)	general purpose vehicles with 26,001 GVW or higher (excluding specialty units)	109
6	Gas (E10)	specialty units — solid waste collection (rear, side, and front compaction) trucks, sweepers, vacuums, truck mounted cranes, articulated grapples, aerial bucket devices	1
6	Biodiesel (B5)	specialty units — solid waste collection (rear, side, and front compaction) trucks, sweepers, vacuums, truck mounted cranes, articulated grapples, aerial bucket devices	132
6CNG	CNG	specialty units — solid waste collection (rear, side, and front compaction) trucks, sweepers, vacuums, truck mounted cranes, articulated grapples, aerial bucket devices	1
7	Gas (E10)	fire trucks, aerial trucks	1

FLEET UNITS BY CLASS (alternative fuel compatible units are shaded)			
Class	**Fuel Type**	**Vehicle/Equipment Description**	**Count**
7	Biodiesel (B5)	fire trucks, aerial trucks	1
8	Gas (E10)	emergency response ambulances, rescue, hazmat trucks	2
8	Biodiesel (B5)	emergency response ambulances, rescue, hazmat trucks	35
9	Gas (E10)	construction graders, backhoes, loaders, dozers, compactors, scrapers, pavers, milling machines, and other similar "heavy" equipment	2
9	Biodiesel (B5)	construction graders, backhoes, loaders, dozers, compactors, scrapers, pavers, milling machines, and other similar "heavy" equipment	48
10	Gas (E10)	grounds skid steer, forklift, generators, air compressors and other similar equipment	25
10	Biodiesel (B5)	grounds skid steer, forklift, generators, air compressors and other similar equipment	59
10	Electric	grounds skid steer, forklift, generators, air compressors and other similar equipment	7
10	Propane	grounds skid steer, forklift, generators, air compressors and other similar equipment	23
11	Gas (E10)	grounds tractors with mowers including right-of-way and high volume	24
11	Biodiesel (B5)	grounds tractors with mowers including right-of-way and high volume	1
12	n/a	grounds trailers of all sizes and types	123
13	n/a	heavy equipment trailers of all sizes and types	66
14	Biodiesel (B5)	buses of all sizes and types	47
15	Gas (E10)	boats of all sizes and types	17
15	Biodiesel (B5)	boats of all sizes and types	3
16	Gas (E10)	police motorcycles	27
17	Biodiesel (B5)	grounds tractors only (no attachments)	55
18	Gas (E10)	grounds self-propelled industrial mowers, all-terrain vehicles, utility vehicles, golf carts	112
18	Biodiesel (B5)	grounds self-propelled industrial mowers, all-terrain vehicles, utility vehicles, golf carts	37
18E	Electric	grounds self-propelled industrial mowers, all-terrain vehicles, utility vehicles, golf carts	7
18P	Propane	grounds self-propelled industrial mowers, all-terrain vehicles, utility vehicles, golf carts	3
19	Gas (E10)	grounds golf course reel mowers including towed attachments (not greens mowers)	10
19	Biodiesel (B5)	grounds golf course reel mowers including towed attachments (not greens mowers)	13
19E	Electric	grounds golf course reel mowers including towed attachments (not greens mowers)	1
20	Gas (E10)	grounds golf course greens and tee mowers	20
20	Biodiesel (B5)	grounds golf course greens and tee mowers	1
21	Gas (E10)	grounds powered and non-powered equipment and attachments	56
21	Biodiesel (B5)	grounds powered and non-powered equipment and attachments	4
21E	Electric	grounds powered and non-powered equipment and attachments	6
21P	Propane	grounds powered and non-powered equipment and attachments	1
		TOTAL	**3,371**

OFM plans and executes vehicle acquisitions to maintain a cutting-edge fleet in support of metropolitan government's business and to foster environmental and sustainability goals. At the time of review, about fifty-five percent of the fleet vehicles and equipment are alternative fuel compatible units.



Fuel Consumption

OFM's fuel sites stock E10 gasoline and B5 biodiesel, and about half the fuel consumed by Metro vehicles is pumped at these sites. In FY 2014, approximately 1.5 million gallons of transportation fuel was pumped at the Metro-owned sites and the remaining fuel consumed was from retail filling stations. It is projected that Metro will consume approximately 3.1 million gallons of fuel in FY 2015— about 1.5 million gallons pumped at Metro-owned fuel sites plus another 1.6 million gallons bought from retail stations.

Fuel Alternatives

Fossil fuel use is seen as a leading air pollution culprit and is probably the only one of several greenhouse gas sources that is realistically disposed to impact by metropolitan government. Further, according to the U.S. Energy Information Administration, about thirty-three percent of petroleum consumed in the United States (in 2013) was imported from foreign countries (albeit the lowest level since 1985) and about fifty percent of the crude oil processed in U.S. refineries was imported.

The fuel used by Metro's fleet is clearly a major factor determining the extent to which Metro achieves goals to reduce harmful vehicle emissions and dependency on foreign oil. In this equation, fuel types are variables for manipulation toward achieving desired ends.

Gasoline (E10)

Gasoline is a refined petroleum product derived from crude oil. Almost all retail gasoline contains a small amount of ethanol (ten percent or less). The resulting mixture of ninety percent gasoline and ten percent ethanol is known as E10. E10 gasoline is the most common, motor vehicle fuel.

Ethanol (E85)

Ethanol is derived from plant-based feed stocks such as corn, sugar, or similar organic materials. According to the U.S. Energy Information Administration, the vast majority of domestic ethanol production occurs in mid-western states, and the primary feed stock for this ethanol is corn. Ethanol is produced through fermentation and distillation. A blend of eight-five percent ethanol and fifteen percent gasoline is commonly sold as E85. E85 is available at seven retail locations in Davidson County.

Ethanol contains less energy per volume than gasoline, and the E85 blend can have up to twenty-five percent less energy per gallon than regular E10 gasoline. Therefore, the price of E85 must be proportionally less to achieve the same mileage per dollar.

E85 compatible vehicles are commonly referred to as "flex-fuel" vehicles, and can run on any gasoline blend with up to eighty-five percent ethanol. Several major vehicle manufacturers offer flex fuel capability as a no-cost option on a full range of vehicle types.

Diesel

Diesel is a refined petroleum product created from crude oil through a process called fractional distillation. In accordance with federal regulations, all diesel sold in the United States for highway use is now ultra-low sulfur diesel (ULSD) that contains no more than fifteen parts per million of sulfur. Limiting sulfur in diesel permits more effective after-treatment of exhaust products and reduces negative environmental effects.

Diesel and diesel-powered vehicles are widely available. Diesel is currently the dominant fuel used by commercial trucking and heavy duty vehicles.

Biodiesel (B5 and B20)

Biofuel is produced from one or more of several different feed stocks such as vegetable oils (*e.g.*, soy, rapeseed, canola, sunflower, *etc.*), animal fats, waste cooking oil, and oil from algae. The primary feedstock for domestic biofuel is soy oil extracted from soybeans through a crushing process. Approximately seventy-five percent of domestic biofuel production occurs in mid-west states. Production is affected by weather conditions because of the agricultural products content.

Biodiesel is a blend of petroleum diesel and biofuel and is labeled according to the percentage of biofuel it contains. A B5 designation indicates that the biodiesel is a blend containing five percent biofuel, and B20 biodiesel contains twenty percent biofuel. Biodiesel is safe, biodegradable, and produces less air pollutants than regular diesel (including a fifteen percent reduction in carbon dioxide emissions). Fuel economy between diesel and biodiesel blends is comparable (within a five percent range). Biodiesel is available at seven retail locations in Davidson County (as well as at Metro's bulk fuel sites).

Nearly all newly built, diesel-powered vehicles are manufacturer approved to operate on B5 biodiesel, and light, medium, and heavy duty truck manufacturers offer a range of B20 capable, diesel-powered products.

Propane

Propane (also known as liquefied petroleum gas or LPG) is a byproduct of natural gas processing and crude oil refining. Because it is naturally odorless and colorless, an odorant is added for safety reasons. Propane (typically used as a heating or cooking fuel) is not commonly sold as a motor fuel.

As a transportation fuel, propane is stored in an on-board cylinder pressurized to approximately 250 pounds per square inch (PSI). Propane powered vehicles are available in dedicated propane only and bi-fuel (propane & gasoline or diesel) configurations. Dedicated engines have only one fuel storage and delivery system. Bi-Fuel vehicles have a separate fuel storage systems allowing the vehicle to operate on either propane or a conventional fuel. Bi-Fuel configurations offer more flexibility and range.

A few OEMs offer a limited range of propane powered vehicles direct from the factory (*e.g.*, Ford Crown Victoria, F250, F350 trucks, Silverado, GMC Sierra trucks, and Ford E-Series passenger vans). Additionally, there are several OEM-approved, third party firms that perform propane conversions of gasoline and diesel powered vehicles.

Compressed Natural Gas (CNG)

Natural Gas, a mixture of methane and other hydrocarbon gases, is typically found in areas that also produce crude oil, and the vast majority of natural gas consumed in the United States is domestic. Like propane, because natural gas is odorless and colorless, an odorant is added to for safety purposes. Compressed Natural Gas (CNG) is natural gas compressed into a pressurized storage container (an integral component of CNG vehicles).

Like propane, CNG is not widely available. A few manufacturers offer a limited range of CNG powered vehicles direct from the factory. Additionally, there are OEM-approved, third party firms that perform conventional vehicle conversions.

Electricity

Electricity is used in powering three types of automotive engine technology: gas hybrid, electric hybrid, and electric vehicles.

Gas hybrids must have access to gasoline refueling infrastructure because all energy for locomotion is generated by an internal combustion engine. These hybrids only use a secondary electric drive train to supplement the engine and improve fuel economy. Gas hybrids do not have to be plugged-in. Gas hybrid vehicle examples are the Honda Insight, Toyota Prius, or Ford Fusion.

Electric hybrids can operate for short distances (approximately 40 miles) on battery power alone. If the battery is depleted during normal operation or the driver demands more power (*e.g.*, higher speed) than the electric drive train can produce, the electric hybrid engages a gas-fueled, internal combustion engine to power the wheels and run a generator. Batteries in electric hybrids are primarily recharged by plugging the vehicle into a specially configured electrical outlet. The Chevrolet Volt, Toyota Plug-in Hybrid Prius, and Ford Fusion Energi are electric hybrid vehicles.

Electric vehicles have battery packs capable of powering travel in the 100-mile range on a single charge. They do not have an internal combustion engine to supplement or recharge their batteries. To replenish their batteries, electric vehicles must have access to charging stations. The Nissan Leaf and Mitsubishi i-MiEV are examples of these vehicles.

Electric hybrid and electric vehicles both depend on externally generated electricity. Local electricity from the TVA system is generated from various energy sources (including solar, wind, hydroelectric, nuclear, and coal)— some of which are clean energy sources and some are not.

Hydraulic Power

Hydraulic hybrid vehicles (HHVs) use two sources of power— a regular, internal combustion engine and a hydraulic motor. These vehicles have high pressure hydraulic fluid vessels called accumulators that are used to store pressurized fluid. The hydraulic drive uses the pressurized fluid to help drive the wheels and vehicle momentum to re-pressurize the hydraulic fluid. Energy normally lost in braking helps power the vehicle through a process that converts kinetic energy into potential energy. As a result of the "regenerative braking," HHVs are ideal where stop-and-go traffic is common and when vehicle duties require frequent stops.

Retrofitting vehicle platforms like shuttle buses, delivery vehicles, and work trucks with hydraulic hybrid drive systems is available from several sources. HHVs do not pose unique fueling needs and do not appear to have additional infrastructure requirements.

Infrastructure

Fleet conversion to alternative fuel vehicles is an investment— an outlay of funds with the expectation of future reward. It is critical to evaluate options based on total cost of ownership in "return on investment" calculations. Along with acquisition cost, total cost of ownership accounts for the costs of infrastructure and other related implementation and operational resources. The ready availability of refueling infrastructure is a fundamental requirement that must exist commercially or be built and operated. Additionally, garaging, maintenance, and service needs of alternative fuel vehicles (which could require extensive modifications to existing garages or the construction of a new facility for maintaining selected vehicles) must be accommodated and included in total cost of ownership calculations.

Propane

Fueling Sites. There are six public, propane fueling stations in Davidson County. Fueling sites used for propane are similar to those for gasoline and diesel. Propane is brought to the site by a transport truck and put into onsite storage, usually above ground. Fuel providers and fleets typically place propane dispensers alongside gasoline and diesel dispensers.

While the limited number of local, retail stations could pose an infrastructure issue, the installation of propane dispensers is relatively low cost. A basic propane fueling station could be installed for approximately $28,000. This price would include a motor, electric connection, and 1,000 gallon skid tank (capable of filling 50 vehicles assuming 20 gallon tanks). The installation of an 18,000 gallon tank could cost approximately $120,000. While propane autogas dispenser technology works with most modern fuel tracking systems, these prices do not include the cost or ability to track fuel usage.

Propane dispenser installation is significantly less expensive than infrastructure for other alternative fuels. Further, it is possible to avoid a major portion of propane fueling infrastructure costs. Propane vendors provide and install dispenser infrastructure at a substantial discount in return for a contract to supply the fuel for some extended period. Others offer a no cost option for installing a fueling site at a fleet facility.

Propane fueling stations are installed with minimal site preparation, improvements, and permitting. Propane infrastructure can be installed in areas where other fuels cannot and has fewer compliance requirements than conventional fuels. Nevertheless, safety guidelines— like the National Fire Prevention Association's NFPA 58 Vehicular Liquefied Petroleum Gas Code, which applies to the design and installation of propane facilities— must be considered when developing infrastructure.

A propane refueling station typically has similar electricity requirements and associated operational costs as gasoline and diesel stations.

Service Facilities. Garage requirements for propane vehicle maintenance and service are similar to those for and internal combustion engines and present similar safety issues for the maintenance shop workforce. Facility ventilation requirements for propane are the same as those

for gasoline and diesel fuel. This includes ventilation for all workspaces including floor areas, pits, below-grade areas, and subfloors. There is no need for modifications to the building or building design, and special propane detection equipment is not required for repair garages and maintenance facilities.

Propane maintenance bays would require site inspections by the building code and fire departments. Additionally, propane-powered vehicles may require special software for service technicians conducting vehicle inspections, and a few unique tools may necessary to service the vehicles.

Compressed Natural Gas

Fueling Sites. Since there are only four commercial CNG stations in Davidson County, fueling infrastructure would be an issue in CNG vehicle consideration.

Multiple factors result in vastly differing projections for CNG fueling site installation costs. A major variable is that a CNG fueling site can be built with time-fill or fast-fill dispensers. Time-fill fueling facilities (requiring several hours to refuel a vehicle) cost less to build, but would result in equipment down-time and additional costs if multiple CNG vehicles are in service. Further, installation costs vary by market and equipment used and depend significantly upon the natural gas source (an underground storage tank or existing pipelines).

A 2014 U.S. Department of Energy study found that onsite CNG fueling station installation costs falls in the expansive range of $45,000 to $600,000 per site (summary details below).

Costs Associated With Compressed Natural Gas Vehicle Fueling Infrastructure*

Cost Estimate	Fueling Site Description
$45,000 to $75,000	CNG station, 8 standard cubic feet per minute (SCFM) or 4 gasoline gallon equivalent (GGE) per hour compressor, 3,780 SCF storage, 2-5 lbs. per square inch (PSI) inlet gas pressure, single-hose dispenser, serving up to four light vehicles per day with 10 GGE
$35,000 to $50,000	CNG station, 8 SCFM or 4 GGE per hour compressor, 3,780 SCF storage, 2-5 PSI inlet gas pressure, two dispensers, able to serve up to two utility trucks with 20 GGE each night
$400,000 to $600,000	CNG station, 40 -75 SCFM (19-24 GGE per hour) compressor, 5-15 PSI inlet gas pressure, 16,250 SCF storage (129 GGE), one single-hose metered dispenser, able to fuel 9-16 work trucks fueling up to 12 GGE per day
$250,000 to $500,000	CNG station, 20-50 SFCM (10-24 GGE per hour) compressor, 5-10 PSI inlet gas pressure, 10 dual-hose posts, time-fill panel with a 10-hour fueling window, able to fuel 5-10 refuse vehicles up to 20 GGE per night or 15-20 sedans/pickups up to 7 GGE per night

* www.afdc.energy.gov/uploads/publication/cng infrastructure costs.pdf

These Department of Energy estimates do not include expenses associated with unusually complicated installations, permitting issues, or other factors that could increase the total project cost, and they do not include the installation and cost of a fuel management (usage tracking) system that Metro would also require. The Department of General Services estimates that it would be realistic to assume a cost of more than $1.2 million (not including the cost of land where the facility would be built) for the construction of a CNG fueling site properly configured to accommodate a moderate level of Metro business.

In addition to the price to build CNG fueling infrastructure, the costs to operate, maintain, and eventually replace the equipment are essential for determining true cost. The high capacity electricity demands of CNG compressors result in substantial, additional, on-going power costs. CNG station operating costs also include inspections, unique maintenance and associated costs including parts, oil, and filters. An estimate for servicing a fast-fill compressor station is $1,500 per month.

Service Facilities. CNG poses unique safety issues for maintenance and repair shops because the natural gas rises in the event of a leak instead of pooling on the ground like the liquid fuel that traditional, gasoline and diesel vehicle maintenance shops are designed to accommodate. To make a garage safe for CNG vehicles, it must be evaluated and modified to safely accommodate lighter-than-air fuel and comply with regulations and code requirements pertaining to CNG vehicle maintenance facilities.

Primary considerations for CNG vehicle maintenance and repair facilities will determine the necessary investment. Considerations include:

- ventilation, heating, lighting, electrical, and mechanical systems;
- building envelope and internal structure; and
- potential ignition sources.

It is particularly important to have an expert to engineer a proper ventilation system. Measures include methane detectors, a supplemental exhaust system, and exhaust fans over the maintenance bays. Sealed combustion, catalytic or infrared heaters with a temperature below 800 degrees are appropriate heating systems for a CNG vehicle maintenance facility. No potential source of ignition (including lighting and electrical equipment) that could create a spark able to ignite natural gas may be located or mounted in a maintenance area within eighteen inches from the ceiling and up. Costs for garage upgrades vary dramatically, depending on the size, age, and current configuration of the facility.

Electric Vehicle Infrastructure

Electric vehicle charging stations are located all over Davidson County, and several are located at Metro facilities (libraries, fire stations, and office buildings). In 2012, Nashville ranked third in a listing of ten top cities for public electric vehicle charging stations (www.zdnet.com/article/10-top-cities-for-public-electric-vehicle-charging-stations/). While there may be ample resources, more dedicated sites for charging Metro vehicles could be necessary if Metro expands the use of electric hybrid and electric units.

The Department of General Services recently added four charging stations at the Fulton campus, and specifically dedicated some stations to Metro vehicles, some to Metro employee vehicles, and some for public use. The total installation cost for the stations (each one able to charge two vehicles at a time) was $44,390. The cost to operate charging stations, primarily limited to the cost of electricity, is expected to be minimal.

Special maintenance facility conditions are not necessary, and current, Metro garages are adequate for servicing hybrid and electric vehicles. However, the tools necessary to service these vehicles differ from those for internal combustion engines vehicles, are not commonly available at Metro service facilities, and would represent an additional cost if the vehicles are serviced in-house.

Maintenance Resources

The Department of General Services operates extensive maintenance facilities at its light and heavy vehicles and equipment shops where the service staff maintain ASE Blue Seal Recognition. However, the skills necessary for traditional vehicles and currently held by Metro mechanics are not always the same as the expertise required by alternative fuel vehicle service and repair.

- Propane vehicles are similar to those powered by gasoline and diesel, but would require some specialized training and support of technicians.
- CNG vehicle tanks and cylinders are extremely different from traditional, liquid fuel tanks, and vehicle maintenance would require more investment in staff training than other types of alternative fuel vehicles. Routine work on these vehicles would necessitate that Metro garages be CNG-certified.
- Hybrid and electric vehicle maintenance requires special maintenance expertise that current service staff would have to build through experience and specialized training. Until such skills are developed internally, a local dealer network experienced in warranty-covered service is critical.
- Hydraulic hybrid vehicles would be somewhat new to fleet personnel in terms of the hydraulic system, however hydraulic hybrid vehicles are found to require less maintenance than other vehicles, especially for brake issues and replacements.

The following table summarizes training/certification programs and associated costs per employee by selected vehicle types.

ALTERNATIVE FUEL VEHICLE TRAINING PROGRAMS AND CERTIFICATIONS			
Vehicle Fuel/Power Type	**Training/Certification**	**Organization**	**Cost Per Employee**
Propane	NFPA 58: Liquefied Petroleum Gas Code	National Fire Protection Association	$54.50 (NFPA codes & standards)
Propane	online maintenance technician training	Roush CleanTech	part of supplier agreement
Propane	technician course and training	Propane Education & Research Council with National Alternative Fuels Training Consortium	may be free program through clean cities coalitions
Propane, CNG, Hydrogen, and Liquefied Natural Gas	NFPA 30A: Code for Motor Fuel Dispensing Facilities and Repair Garages	National Fire Protection Association	$42 (NFPA codes & standards)
CNG	technician and fleet operations safety training	Natural Gas Vehicle Institute (NGVi) *	$495 (with early registration)
CNG	fuel system inspector training	NGVi	$795 (with early registration)

ALTERNATIVE FUEL VEHICLE TRAINING PROGRAMS AND CERTIFICATIONS			
Vehicle Fuel/Power Type	**Training/Certification**	**Organization**	**Cost Per Employee**
CNG	heavy vehicle maintenance and diagnostics training	NGVi	$1,695 (with early registration)
Hybrid and Electric	Light Duty Hybrid/Electric Vehicle Specialist (L3)	National Institute for Automotive Service Excellence (ASE)	$70 for certification test
* NGVi is currently the only natural gas vehicle industry training provider to earn ASE accreditation.			

Dealer Support

Regardless of the alternative fuel vehicle type, the quality of Metro's ownership experience will largely depend upon a local dealer network skilled in warranty-covered service. OFM currently works with Ford and General Motors dealers in the region that provide manufacturer warranty and extended service contract coverage of propane, natural gas, hybrid, and plug-in hybrid vehicles. Golden Circle Auto Group in Jackson, Tennessee offers propane-powered vehicles and warranty service, along with other Ford alternative fuel and hybrid vehicles. OFM also works with Ford of Murfreesboro, GM of Murfreesboro, and Freeland Chevrolet on drop-ship vehicle deliveries and maintenance, and these vendors all have experience with alternative fuel vehicles.

Fuel Savings

The purchase price of alternative fuel vehicles is, to varying degrees, more (often significantly more) than their internal combustion engine counterparts. However, regardless of the fuel type, proponents claim the investment "pays for itself" with fuel savings, and with ever constricting budgets, anticipated savings is often the impetus for government implementation of alternative fuel vehicles.

Alternative fuel vehicles typically do result in fuel savings (*e.g.*, CNG prices have ranged between $2.15 and $2.29 in gasoline gallon equivalents (GGE) at local stations while the price for gasoline has been over $3 per gallon). Some alternative fuel vehicles may even reduce maintenance costs (potential maintenance cost savings is not readily available). Therefore alternative fuel vehicles can offer an opportunity to recoup the premium paid for these vehicles versus the cost of a traditional vehicle. Nevertheless, the payback on investment is varied and contingent upon multiple market conditions. Further, new traditional fuel vehicles, with MPG ratings higher than the vehicles they would replace, also offer fuel savings opportunities (without a premium with which to break-even). Inasmuch, it is important to definitively determine the "payback" that Metro deems acceptable— in terms of break-even period, total long term savings or cost, environmental impact, *etc*.

The upcharge/savings break-even periods by vehicle fuel types indicated below are conservatively based on potential fuel cost savings.

BREAK-EVEN PERIODS FOR SELECTED ALTERNATIVE FUEL VEHICLES

Vehicle	Premium	Fuel Savings	Maintenance Savings	Payback Period
Gasoline — Pursuit Package Sedan	n/a	$1,023	no estimate	n/a
Hydraulic Hybrid — 18 YRD Sanitation Truck	$75,000	$1,500	$12,000	5.5 years
Electric Hybrid — Mid-Size Sedan	$9,265	$900	$300	7.7 years
Propane — Full-Size Pickup Truck	$11,000	$1,100	no estimate	10 years
CNG (bi-fuel) — Full-Size Pickup Truck	$9,500	$700	no estimate	13.6 years

Analysis Factors:

- These Hydraulic hybrid trucks would be about 40% to 45% more fuel efficient than trucks currently in the fleet. Average miles per gallon for these trash trucks currently in the fleet is about 12 MPG.
- Gallons of diesel fuel saved per year for each hydraulic trash truck: 450 gallons.
- Gallons of diesel fuel per year saved by 25 hydraulic hybrids: 11,250 gallons.
- Ford Fusion Energi plug-in hybrid has an 88 combined city/highway miles per gallon equivalent (MPGe) rating. The standard gasoline-engine Fusion has a 29 combined MPG rating.
- Electricity cost for vehicles recharged by the grid at $0.10/kWh and traveling less than 40 miles a day would be around $1.40 a day.
- New Interceptor sedans are 20% more fuel efficient than previous Crown Victoria models.
- Gasoline saved per Interceptor sedan per year based on 30,000 miles per car per year: 341 gallons @ $3.

It will take a minimum of 5.5 to 13.5 years of regular use (depending upon the vehicle type) for fuel cost savings to break-even with the extra cost to buy alternative fuel vehicles. Municipal and other government fleets around the country incur similar upcharge/savings break-even periods on alternative fuel vehicles.

Greenhouse Gas and Carbon Footprint

A greenhouse gas (GHG) is a gas in Earth's atmosphere that absorbs and emits radiation and impacts Earth's temperature. The primary greenhouse gases are water vapor, carbon dioxide, methane, nitrous oxide, and ozone.

The main sources of GHG emissions are fossil fuel use, deforestation, livestock farming, synthetic fertilizer use, and industrial processes. The popular culture expression, "carbon footprint," has become the terminology used in discourse about the total amount of multiple greenhouse gases produced by a particular entity (*i.e.*, a factory, local government, household, *etc.*).

One of the greenhouse gases, carbon dioxide (or CO_2), has become the *de facto*, U.S. standard for measuring and reporting on vehicle emissions. Perhaps it is because, in the past 250 years, the amount of carbon dioxide in Earth's atmosphere has increased by forty percent (and is largely attributed to the combustion of carbon-based fossil fuels). Accordingly, almost all emissions data for vehicles pertains to carbon dioxide emissions.

Alternative Fuel Vehicles

In comparison with traditional vehicles, alternative fuel vehicles of all types offer lower CO_2 emissions.

CO_2 EMISSION REDUCTION BY ALTERNATIVE FUEL VEHICLE

Vehicle	Miles Per Year	CO_2 Reduction	
		Grams Per Vehicle	Tons Per Vehicle
Hydraulic Hybrid Trash Truck	12,000	4,581,000	4.58
Ford Interceptor sedan with EcoBoost	30,000	2,806,514.6	2.80
Propane-Fueled Ford F-Series Truck	15,000	2,221,750	2.20
CNG-Fueled Half-Ton Truck	15,000	2,777,188	2.70
Electric Hybrid Ford Fusion Energi	15,000	2,618,910	2.62

Analysis Factors:

- Data follows an EPA Office of Transportation and Air Quality model for passenger and commercial vehicle emissions standards.
- Hydraulic hybrid trash truck is compared to diesel-engine trash truck for mileage and emissions.
- Ford Interceptor sedan is compared to Ford Crown Victoria sedan.
- Propane and natural gas pickup trucks are compared to gasoline-engine pickups.
- Ford Fusion Energi plug-in hybrid is compared to Ford Fusion standard gasoline-engine model.
- EPA estimates CO_2 emissions from diesel and gasoline are 10,180 grams and 8,887 grams, per gallon respectively.

However, the total effects of alternative fuels are not easily determined, and analysis is confounded by the fact that some data and literature relating to alternative fuels are conflicting and suggest that some environmental benefits could be overstated. The best choices among alternatives are not as clear with full consideration of all greenhouse gases. Indeed, available data leaves the suitability of some alternative fuel vehicle choices unsettled.

In particular, the greenhouse gas, methane (or CH_4) is of special concern. Methane is reported to have a global warming potential at least twenty times greater than CO_2. Vehicles that are powered by natural gas products (propane and CNG) have low CO_2 emissions compared with those using other fuels, and thus, appear to offer cleaner alternatives. On the other hand, natural gas is about ninety-five percent methane, and emissions of the gas occur when propane or CNG is combusted to create energy. Further, methane emissions from natural gas powered vehicles are greater than those from traditional fuel vehicles of similar technology and age— methane emissions from light duty, CNG-powered automobiles are, on average, more than twenty times greater than from a gasoline vehicle. Additionally, pre-combustion leaks of methane during natural gas extraction and delivery pose a problem. Research has indicated that, if methane leaks are considered, natural gas contributes more to global warming than the combustion of oil or coal.

Choices about alternative fuels are also complicated by the fact that greenhouse gases are not only produced by standard gasoline and diesel engines but also by alternative fuel vehicles. Even electric power is generated from other primary sources of energy. Depending upon its energy source (*e.g.*, solar, wind, hydroelectric, tidal, geothermal, nuclear, coal, natural gas, or petroleum), electricity may be clean energy or can be responsible for significant GHG emissions. The primary energy sources for manufacturing alternative fuel vehicle components (*e.g.*, batteries) as well as the production and transport of the fuel itself also obscures the impact of alternative fuel vehicles on the environment.

Traditional Fuel Vehicles

In addition to alternative fuel vehicles, new, traditional fuel vehicles offer reductions in both greenhouse gas emissions and fuel consumption. For a number of years growing concern about greenhouse gases and air quality in general as well as fuel economy have driven change in the automotive industry. Evolving, federal air pollution and fuel consumption standards continually result in both a reduction of GHG emissions and improved mileage.

The data below shows GHG emissions reductions for four types of vehicles powered by gasoline or diesel.

GHG EMISSIONS - Reduction By Traditional Vehicle Type*

Fuel	Sedan	Van	Light Duty Truck	Light Duty Diesel Truck
E10 Gasoline / Diesel	7%	12%	4%	4%

* New, 2012 model compared to 2005 model of the same type (2012 North Carolina alternative fuels study, pp.30-32).

Alternative Vehicle Options

Both alternative fuel vehicles and new fuel efficient technologies are available to help meet both Metro's sustainability goals and OFM's obligation to provide safe, efficient vehicles meeting user agency needs. However, alternative fuels pose different infrastructure challenges and investment costs, and considerations are complicated by volatile market reductions in the cost of gasoline and diesel.

It is, at least, clear that alternative fuel vehicles can foster sustainability by reducing carbon dioxide emissions and oil consumption. It is also true that some alternative fuel vehicle options are better suited for particular purposes, and some are not available for all vehicle types and uses. With Metro's fleet of vehicles with widely differing uses and functionality, it is imperative that fleet improvements pair the best solution(s) with vehicle duty while considering infrastructure requirements and total costs.

Propane, hybrid, and electric sedans and utility trucks are the alternative fuel vehicles most commonly available and attractive in terms of cost and savings potential. These alternative vehicles have been used in the public sector for various duties and appear to be viable alternatives from a business perspective. At current vehicle prices and traditional fuel cost, long term savings could accrue from currently available propane and electric vehicle technology, but it would likely be insignificant.

Hydraulic hybrid trash trucks also have higher acquisition costs. However, with respect to environmental goals and other factors, Metro would be prudent to include new trash trucks with hydraulic hybrid systems in the fleet. Laboratory tests of a hydraulic hybrid UPS vehicles showed a sixty to seventy percent improvement in city fuel economy, more than forty percent lower CO_2 emissions, fifty percent lower hydrocarbon emissions, and sixty percent lower particulate matter emissions in comparison with traditional trucks (www.epa.gov/region9/air/hydraulic-hybrid/). The low cost to manufacture combined, reduced brake maintenance costs, and significantly increased fuel efficiency can result in vehicle lifetime savings and make hydraulic hybrid trash trucks one of the best green technology investments for fleets.

Conclusions

Given current technology and costs, decisions to add alternative fuel vehicles to Metro's fleet are founded on:

- reducing emissions in support of sustainability goals; and
- reducing foreign oil dependency through lower consumption and domestic fuels.

Although anticipated savings tends to be a major impetus for considering alternative fuel vehicles, the purchase price of these vehicles is considerably greater than their gasoline and diesel counterparts. Alternative technologies offer varying degrees of savings, however it will take six to fourteen years of regular use for fuel savings to compensate just for the extra cost to buy the vehicles. Further, the real cost of alternative fuel vehicles includes related infrastructure costs, maintenance costs, as well as the operational costs for additional, infrastructure. Financial considerations do not appear to justify broad implementation of alternative fuel vehicles by Metro at this time.

To maintain an ever-evolving, leading edge fleet available for Metro business, it is practical for the Department of General Services, Office of Fleet Management to continue current, strategic practices in putting alternative fuel vehicles into service. An action plan to methodically acquire and put alternative fuel units into service for the purpose of reducing GHG emissions and dependency on foreign oil is reasonable and responsible. Toward that end, the following recommendations are detailed.

B20 Biodiesel

- ❖ Confirm the extent to which current fleet units are B20 biodiesel compatible.
- ❖ Require B20 biodiesel compatibility in appropriate new vehicle procurement specifications.

OFM already stocks B5 biodiesel at Metro bulk fuel sites, and transitioning to the use of and possibly stocking B20 biodiesel would build on OFM efforts to develop a greener fleet.

Vehicle Replacement Cycle

- ❖ Continue OFM annual, vehicle replacement reviews using appropriate standards to identify vehicles for replacement.
- ❖ Increase the annual, capital budget for fleet acquisitions to afford the replacement of all vehicles indicated by OFM's annual vehicle review and replacement benchmarks.
- ❖ Eliminate SUVs from the fleet in favor of less expensive sedans and pick-up trucks.
- ❖ Strictly limit "assigned" vehicles in favor of shared vehicles.

OFM vehicle replacement standards are designed to achieve the best value for Metro by minimizing total cost of ownership and maximizing years of service, and they serve as an

objective guide for annual fleet procurements. Because evolving, federal air pollution and fuel consumption standards result in notable improvements in both emissions and fuel economy, the routine replacement of fleet units with new, gasoline and diesel units (offering advanced technology and engineering) is an efficient, cost effective means to achieve both environmental and conservation objectives.

Vehicle Replacements

Current Fleet Unit Description	Replacement Recommendation
class 2 — gasoline-powered, flex fuel police patrol/pursuit sedans and SUVs	gasoline-powered, flex fuel police patrol/pursuit sedans and SUVs (Ford Interceptor)
class 6 — diesel-powered specialty rear, side, and front load solid waste collection/compaction units, sweepers, vacuums, truck mounted cranes, articulated grapples, bucket devices	hydraulic hybrid (diesel) trash trucks (Parker Hannifin RunWise)
class 3 — gasoline and diesel-powered general purpose trucks, pickups, flat bed or single axle dump trucks 10,000 - 17,950 GVW	propane-powered pickup trucks (Roush CleanTech F-Series)
class 1 — gasoline-powered, flex fuel general purpose sedans, pickups, station wagons, and vans-3/4 ton rating or lower	plug-in hybrid general purpose sedans (Ford Fusion Energi)
class 1 — gasoline-powered, flex fuel general purpose sedans, pickups, station wagons, and vans-3/4 ton rating or lower	CNG bi-fuel-powered general purpose sedans (Chevrolet Impala)

The upfront costs and substantial time before fuel savings will afford the extra cost of an alternative fuel vehicle make selecting the right vehicle types critical to cost containment. The recommended schedule for acquiring the first two types of vehicles listed above (classes 2 and 6) is to do so when funding is available and replacements of the subject vehicle types are indicated by OFM's annual fleet review and according to established replacement standards.

The recommended schedule for adding the final three vehicle types (classes 1 and 3) to the fleet is to do so when funding is available for additional fleet vehicles of the type or when replacements of the subject vehicle types are indicated by OFM's annual fleet review, and in either instance, limiting fleet-wide alternative fuel vehicle additions to one or two of each type annually.

The recommended vehicle types and schedule should enable Metro service staff to garner experience with selected alternative technologies while limiting the need for ancillary investment. It will also give time for the further improvement of alternative fuel vehicle options, growth of the commercial alternative fuel infrastructure, as well as the clarification of environmental benefits and costs related to certain types of alternative fuel vehicles.