NCHRP 20-65 Task 72: Small System Alternative Fuel Strategies

Guidance Document
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Small System Alternative Fuel Strategies

Guidance Document

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Abstract

This guidance document supplies small urban and rural transit agencies to educate them on alternative fuels, know which fuels could be successful at their agency, and provide a tool to estimate the lifecycle costs of converting to alternative fuels. This report documents the surveys and interviews with small urban and rural transit agencies about their experiences implementing alternative fuels, what are the major barriers to implementation, and identify tools and guidance to break through those barriers. The surveys showed many agencies has investigated alternative fuels but eventually did not implement them. The follow-on interviews with a selection of these agencies found that refueling infrastructure, grant funding and vehicle availability were major hurdles to implementing alternative fuels. As part of this project, a lifecycle analysis tool was developed to help agencies compare the economic and environmental costs and benefits of implementing alternative fuels and run scenarios for planning the transition to alternative fuels. A simple user guide for the tool is included in this document. This guidance document includes descriptions of the various alternative fuels and a matrix to help an agency select which alternative fuels could work the best for them and necessitate further detailed investigation. The document also includes case studies of transit agencies that have successfully implemented alternative fuels and recommendations for State Departments of Transport (DOTs) to facilitate and enhance the adoption of alternative fuels.

1 Overview

1.1 Purpose

Many transit agencies are under increasing pressure to transition to alternative fuels for many reasons: decision-makers, community residents, and transit riders, in some areas are demanding transit that is more environmentally friendly; some agencies may see opportunities to reduce operational costs by switching to alternative fuels; and all agencies are subject to emission reduction goals and regulations. Federal National Ambient Air Quality Standards (NAAQS)[1] call for transit agencies to consider alternative fuels to reduce pollutants such as nitrogen oxides (NOx) and diesel particulate matter (DPM). Some states and regions, including California, Oregon and the Northeast States for Coordinated Air Use Management (NESCAUM), have developed or are considering low-carbon or clean fuel standards. These regulations incentivize the transition to alternative fuels by monetizing reductions in greenhouse gas (GHG) emissions. Currently the list of states and regions implementing and investigating these programs is limited. Some regional and local governments also have plans and policies to improve air quality or reduce greenhouse gas GHG emissions.

Another key issue for small and rural systems looking to purchase alternative fuels is limited resources. Frequently small and rural agencies have limited funds to purchase conventional technologies, let alone to cover the initial costs that are necessary to shift to alternative fuels. To try new technologies, small systems frequently rely on a patchwork of state and federal grant funding to cover capital costs, including FTA Section 5311[2] funds (Formula grants for rural regions, as well as training and assistance programs, Statewide Transportation Improvement Program (STIP) grants and funding, and any other funding source that can be available. A few states have dedicated funding sources that can support alternative fuel purchases, such as California's Hybrid Vehicle Incentive Program (HVIP) and California and Oregon's incentives for alternative fuel purchases that reduce GHG emissions. In the absence of dedicated resources like these, few federal or state grant programs are available to help agencies purchase vehicles, install infrastructure or pay for increased fuel costs. Furthermore, small agencies often have limited staff who can help analyze different alternative fuel options.

This project produced a toolkit which includes a lifecycle analysis took and this guidance document to help agencies identify which alternative fuels and technologies can best be implemented for their system based on factors such as:

[1] National Ambient Air Quality Standards

[2] FTA Section 5311 program https://www.transit.dot.gov/funding/grants/rural-transportation-assistance-program-5311b3

- Relevant environmental regulations and air quality issues
- Service characteristics (e.g., ridership, service type, terrain)
- Availability of different fuel stocks and associated infrastructure or maintenance facilities
- Available funding sources

The toolkit developed for this project includes:

- This guidance document identifying decision-making processes and best practices for addressing the issues above.
- A spreadsheet tool to help agencies quantify the potential benefits, both economic and environmental from converting to an alternative fuel.

Quantitative (within the tool) and qualitative (within this document) guidance to help agencies understand how quickly they can change over their fleet or what portion of their fleet they should eventually convert to alternative fuels. The tool and guidance document developed in this project focused on alternative fuels and did not include conventional fueled hybrid vehicles. There have been inconsistent experiences with new and converted paratransit and cut-away hybrid vehicles.

1.2 Project Purpose and Overview

A survey titled *Small Systems Alternative Fuel Strategies* was administered by ICF via Survey Monkey and email (pdf version of survey). The goal of the survey was to collect information on which small and rural transit agencies have implemented or investigated alternative fuels and identify those systems for more detailed interviews. In the follow-up interviews, ICF gathered detailed information about the systems' motivations, processes, successes, and challenges in exploring alternative fuels. ICF also used the survey to determine any major trends and consistent challenges for systems in implementing alternative fuels and how they related to fleet size, fuel access, and availability of funding.

Summary of the Small and Rural System Alternative Fuel Survey

ICF collected and analyzed responses from 40 small urban and rural transit systems. The survey questionnaire was sent to over 700 small systems out of which 230 emails were undeliverable. This is an 8.5% response rate from those agencies that received the email. While the response rate was low, the responses we did receive were varied in agency size, type and fuels investigated or implemented.

Exhibit 1 shows that while many transit agencies have investigated biodiesel, CNG, propane and electricity, the most implemented fuels are biodiesel and CNG. We believe the high electricity number is from agencies considering diesel hybrid buses as "electric." Hybrid buses do not use electricity as an alternative fuel, they use diesel more efficiently.

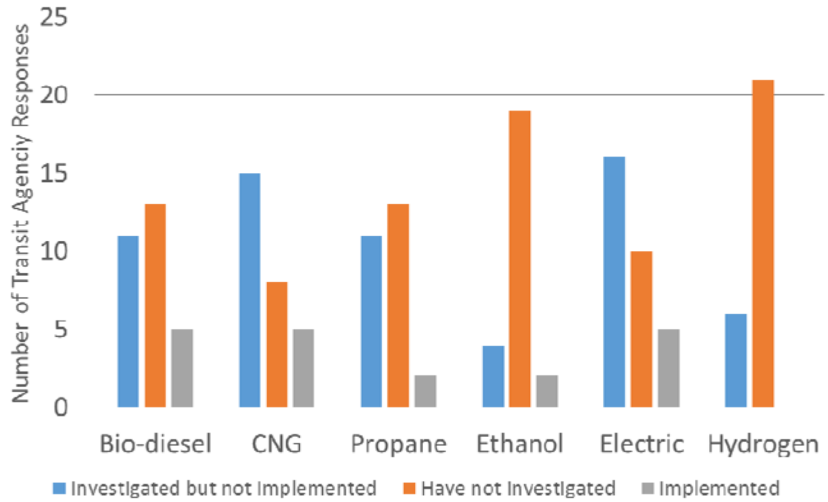

Exhibit 1: Survey Responses by Fuel Type

Key findings from the survey for why fuels were investigated by not implemented included: (1) refueling infrastructure availability, (2) lack of available funding, and (3) maintenance issues and costs associated with different fuels

Summary of the Interview Results

From the agencies that responded to the surveys, ICF developed an initial list of 10 agencies to interview. After receiving comments from the NCHRP 20-65-72 Committee, ICF modified the list of agencies to interview that are shown in the table below. The 10 agencies interviewed, shown it the table below, represent diverse fleet types and sizes including body-on-chassis (BOC)/cutaways, vans, transit buses and paratransit fleet. An example of a BOC/cutaway bus is shown in Exhibit 2. Of the agencies interviewed, three (3) are 100% BOC/Cutaway fleets (Danville, Rainbow and Estuary); two (2) are almost all cutaways or vans (Greeley and Big Sky) and two (2) agencies have paratransit vehicles making up 50% of their fleet (Las Cruces, Grand Forks Cities). The diversity of fleets resulted in a diversity of input and findings related to alternative fuel vehicles, technologies, funding and deployment.

Exhibit 2: BOC/Cutaway Bus

Table 1: Transit Agency Interview List

Agency	System Type	State	Fleet Vehicles		
			Transit Bus	BOC/Cutaway	Van
Cache Valley Transit District	Urban	Utah	26	8 paratransit	
City of Las Cruces/ RoadRUNNER Transit	Urban	New Mexico	19		20 paratransit
Danville Transit System	Urban	Virginia		24	
Grand Forks Cities Area Transit	Urban	North Dakota	6	5	11
Greeley Evans Transit	Urban	Colorado	2	17 + 9 paratransit	
Roaring Fork Transportation authority	Rural	Colorado	100+		24
Town of Snowmass Village	Rural	Colorado	19	10	
Rainbow Rider Transit	Rural	Minnesota		35	
Estuary Transit District	Rural	Connecticut		16	
Big Sky Transportation District	Rural	Montana	2	8	7

ICF gathered detailed information from these interviews about the systems' motivations, processes, successes, and challenges in exploring alternative fuels that are summarized below. The following key finding have been divided into three categories:

- Overall issues that were relevant to both rural and small urban agencies
- Findings mainly relevant to rural agencies
- Findings mainly relevant to urban agencies

Overall Issues

During the interviews, both small urban and rural agencies raised a number of concerns associated with alternative fuel deployment including:

- Maintenance costs
- Refueling Infrastructure accessibility
    - Property/site size
    - Fuel costs
- Limitation of alternative fuel vehicles on available procurement contracts and lack of availability of funding and/or limitations to existing funding sources

  - In the follow up interviews, ICF received additional supporting materials such as FTA funding denial letters[3] on vehicle procurement/"piggybacking"[4] (eg: for Town of Snowmass) that enforces the requirement for all agencies related to contracting/procurement compliance for the use and distribution of federal funds through FTA.
- Fuel throughput and vehicle turnover including limited driving range and retirement cycles

In terms of implementation or investigation of specific alternative fuels or technology, urban and rural agencies show a similar willingness to consider electric and/or hybrids. For agencies who have investigated electric technologies, vehicle cost is a significantly more important issue than infrastructure and maintenance while infrastructure and maintenance costs are the main issues for CNG.

A common theme that emerged was that there is a desire and awareness that they could/should consider alternative fuels but they were unsure how to proceed, resources to utilize or what type of fuel/technology they should consider.

Rural Agencies

The availability of vehicle technologies and funding are the key issues for alternative fuel deployment at rural agencies. Vehicles are procured with state and federal funding, but the availability to purchase an alternative fuel can be limited depending on how an agency procures vehicles. Consortiums such as the Colorado Mountain Purchasing Consortium[5] (eg: Roaring Fork Transit Authority and Town of Snowmass in Colorado) put out bids containing alternative fuel vehicles and increase access for rural agencies who are part of one. Rural agencies not part of consortiums procure vehicles through their state and are limited to the vehicles available, which often do not include alternative fuel options. Estuary Transit (CT) has been part of a consortium that allows procurement of CNG, propane and hybrid vehicles.

Previously agencies that were not part of a consortium could "piggyback" on other contracts to gain access to purchasing alternative (and conventional) fuel vehicles, but agencies note that piggybacking is not as easy as it used to be and is being eliminated by FTA due to questionable procurement practices. Rural agencies also indicate that new infrastructure needs are a main barrier to alternative fuel implementation. For example, some agencies are unable to construct

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[3] FTA Region VIII letter on piggybacking, April 2017 available in pdf

[4] FTA requirement https://www.transit.dot.gov/funding/procurement/bppm-procurement-object-types-special-considerations#BM6_3_

[5] Colorado Mountain Purchasing Consortium http://www.bing.com/search?q=Colorado+Mountain+Purchasing+Consortium&src=IE-TopResult&FORM=IETR02&conversationid

an onsite station or unwilling to fuel their fleet at a publically available station nearby. These are among many reasons rural agencies prefer to use liquid fuels over gaseous fuels. Also, many rural agencies do not have their own maintenance facilities and staff and must outsource to local private maintenance facilities, or share maintenance staff and facilities with other city and county fleets. It can be infeasible to either provide training and facility upgrades or find trained maintenance locations when you are a rural transit agency that outsources or shares maintenance.

Funding availability is still the main issue for alternative fuel implementation. Agencies like Big Sky have indicated concerns including fueling costs, one-way driving distance per tank, and cost issues especially with CNG and propane. However, they are open to implementing electric buses for their fleet if they had lower incremental costs.

Small Urban Agencies

Most agencies are supportive of CNG but they note that there are issues with fueling offsite along with added costs that are burdensome. There are mixed perceptions and results about the use of biodiesel including being more expensive than gasoline and issues with clogging filters but another agency reported better mileage with biodiesel. Unique to small urban over rural agencies is continued interest in implementing and continuing investigation with electric buses. Some of the noted benefits include reduced maintenance and operations costs, decreased ground level emissions and occasionally lower fueling costs. Some of the noted benefits include lower maintenance and fueling costs.

Danville Transit System has successfully begun the implementation of LPG in their fleet in Virginia. Maintenance issues with their diesel particulate traps was listed as the major reason for considering expansion of the fleet with LPG buses. However, a challenge with LPG buses on fixed route service is lower mileage due to the lower energy density of LPG. Similar to rural agencies, limited local funding and dependence on federal funds is a major hurdle to implementing alternative fuels.

2 Alternative Fuels

The following sections provide a detailed review of the alternative fuels options for small urban and rural transit agencies and summary of the operational advantages and disadvantages, and environmental benefits.

2.1 Review of Alternative Fuel Options

Biodiesel

Description

Biodiesel is a renewable fuel made by reacting animal or vegetable fats with alcohol. Approximately 70% of the nation's biodiesel is produced in the Midwest, where soybean oil is the dominant biodiesel feedstock.[6] Biodiesel is also produced from waste oils and fats including tallow and used cooking oil which reduces the environmental impact of the fuel.

Most biodiesel is used in low-level blends, usually as 5% or 20% biodiesel blended with conventional diesel (referred to as B5 or B20, respectively). B20 is the highest blend of biodiesel commonly used in the United States as it provides good cold-weather performance, is generally cost effective, and can be used in most engines without modification. Fifty percent (B50) and pure biodiesel (B100) are available in the marketplace and can be used in some engines without modification, although equipment changes may be necessary in other engines.

Uses and Applications

In contrast to most other alternative fuels, biodiesel does not require a specific alternative fuel vehicle. Depending on the blend level, biodiesel can be used in most conventional diesel vehicles. High-level blends tend to have a solvent effect that cleans a vehicle's fuel system and releases deposits accumulated from previous petroleum diesel use. Once released, these deposits may initially clog filters and require filter replacement in the first few tanks of high-level biodiesel blends. As such, vehicle operators should consult their vehicle and engine warranty statements before using biodiesel, particularly before using biodiesel blends higher than B5.

Biodiesel can have a limited shelf life due to factors such as contamination and exposure to air, extreme temperatures, and additives. Shelf life issues are a greater concern with higher blends.

[6] U.S. Energy Information Administration, 2012, "Monthly Biodiesel Production Report: May 2012," http://www.eia.gov/biofuels/biodiesel/production/

Proper fuel management can dramatically extend biodiesel's shelf-life to a year or more, which is on par with conventional diesel.

A majority of the biodiesel used in the United States is consumed by commercial fleets and government entities, including transit agencies, waste haulers, and school districts. Information from the American Public Transportation Association suggests that 7.4% of public transit buses in the U.S. use biodiesel.[7]

Most heavy-duty diesel engine manufacturers state that using up to B20 will not void engine warranties. Many fleets have successfully used B50 to B99 blends for several years or more.[8] In 2008, the American Society for Testing and Materials adopted biodiesel standards for blends up to B20 and for B99.

Renewable Diesel

Description

Renewable diesel is produced from the same feedstocks as biodiesel using a more energy intensive hydrotreating process, creating a product that is 100% fungible with diesel. Renewable diesel meets the same ASTM specifications as ultra-low sulfur diesel (ULSD) and therefore does not have any blend limitations. The largest worldwide producer of renewable diesel is Neste Oil with production facilities in Singapore and Europe. One the main feedstocks for renewable diesel produced by Neste is palm oil. The use of palm oil has been linked to significant greenhouse gas emissions and environmental impacts. It is very important to understand the feedstock for renewable diesel when sourcing the fuel and quantifying environmental benefits compared to diesel. Facilities are being built in the United States including Diamond Green in Louisiana.

Uses and Applications[9]

Renewable diesel, similar to biodiesel, does not require an alternative fuel vehicle. But unlike biodiesel, it does not have any blend limitations, issues with solvency, and can be used in any current and future diesel engine. Use of renewable diesel will not void engine warranties at any blend level.

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[7] American Public Transportation Association, "Public Transportation Industry Is a Green Industry," April 16, 2015. http://www.apta.com/mediacenter/pressreleases/2015/Pages/150416_Earth-Day.aspx

[8] California Energy Commission, 2009, "Investment Plan for the Alternative and Renewable Fuel and Vehicle Technology Program," http://www.energy.ca.gov/2009publications/CEC-600-2009-008/CEC-600-2009-008-CMF.PDF

[9] Renewable Diesel Picture Source - http://www.greencarreports.com/news/1098913_tesla-gigafactory-update-vw-tests-renewable-diesel-chevy-cruze-hybrid-todays-car-news

Natural Gas

Description

One-quarter of the energy used in the United States is produced by natural gas. With plentiful reserves bolstered by newly accessible gas in shale formations, natural gas is a reliable, primarily domestic source of clean-burning fuel. Advances in hydraulic fracturing technologies have provided access to large volumes of natural gas from shale formations. In addition, natural gas can be derived from biogas, which is produced through anaerobic digestion of organic matter in biomass waste materials.

Natural gas in compressed (CNG) or liquefied (LNG) form is used as a transportation fuel. The high octane number of natural gas makes it suitable for spark ignition (gasoline) engines with some modifications. Heavy-duty natural gas vehicles are also available. Some use spark ignition natural gas systems, while others use high-pressure direct injection in a compression ignition (diesel) cycle.

CNG is stored onboard a vehicle in cylinders pressurized at 3,000–3,600 pounds per square inch (psi). A CNG-powered vehicle has a similar fuel economy to a gasoline vehicle on a gasoline gallon equivalent (GGE) basis, with a GGE equal to approximately 5.66 pounds of CNG. CNG is used in light-, medium-, and heavy-duty vehicles.

Purifying natural gas and super-cooling it to -260°F creates LNG. Because it must be kept at cold temperatures, LNG is stored in double-walled, vacuum-insulated pressure vessels. Liquid is more dense than gas (CNG), so LNG is beneficial for vehicles that require a longer driving range—as more energy can be stored by volume in an LNG tank. A gallon of LNG has approximately 66% of the energy in a gallon of diesel; consequently, a diesel gallon equivalent (DGE) equals approximately 1.5 gallons of LNG.

A new and growing source of CNG and LNG is biomethane, commonly referred to renewable natural gas (RNG). The main source of RNG is landfill biogas that is cleaned up to pipeline specifications and injected into the intrastate pipeline system. The production and use of RNG is incentivized through the federal Renewable Fuel Standard (RFS) and additionally through state programs and regulations such as the California Low Carbon Fuel Standard (LCFS)[10] and the Oregon Clean Fuels Program (CFP)[11]. With the recent contract signed by the Los Angeles County Metropolitan Transportation Authority (LA Metro), almost 90% of all CNG and LNG used in the state of California will come from RNG.

[10] California ARB Low Carbon Fuel Standard https://arb.ca.gov/fuels/lcfs/lcfs.htm

[11] Oregon Clean Fuels Program http://www.oregon.gov/deq/aq/programs/Pages/Clean-Fuels.aspx

RNG achieves significant greenhouse gas emission reductions (upwards of 60-70% when compared to diesel) while traditional fossil natural gas reduces greenhouse gas emissions only 10-20% depending on LNG vs CNG. Since RNG is transported through the common carrier pipeline and is accounted for via displacement, RNG and fossil natural gas are interchangeable when considering refueling infrastructure and vehicles.

Uses and Applications

Natural gas can be used in virtually all types of on-road vehicles. There are three different types of natural gas vehicles (NGVs):

- Dedicated, which run only on natural gas
- Bi-fuel, which use either natural gas or gasoline
- Dual-fuel, which run on natural gas and use diesel for ignition assistance

Dual-fuel vehicles are traditionally limited to largest heavy-duty vehicles (HDVs). There are limited applications for dual-fuel in transit applications. Dedicated NGVs tend to demonstrate better performance and produce lower emissions than bi-fuel vehicles. Because dedicated NGVs have only one fuel tank, they weigh less than bi-fuel NGVs and offer more cargo capacity.

Although extra storage tanks can increase the range of an NGV, the additional weight and reduced space may decrease the amount of cargo or passengers the vehicle can carry.

For light-duty uses, the last NGV previously available from an original equipment manufacturer (OEM) was the CNG Honda Civic which production was stopped in early 2016. More models are available for medium-duty truck and van applications. For example, a 2013 GMC Savana cargo van is available in a CNG version.[12] Many of the other on-road NGVs in use today are conversions.

Among transit buses, natural gas has been the dominant alternative fuel. Approximately 16,000[13] natural gas transit buses are in operation nationwide, or 23%[14] of the national bus fleet.

[12] http://www.gmc.com/savana-cargo-van.html

[13] https://www.afdc.energy.gov/data/10302, Calendar year 2015

[14] National Transit Database 2014, Table 17 – Energy Consumption. 23% includes Bus, Bus Rapid Transit, Commuter Bus, Demand Response and Vanpool. https://www.transit.dot.gov/ntd/data-product/2015-annual-database-energy-consumption

Propane

Description

Liquefied petroleum gas (LPG) is commonly referred to as propane. *Autogas* is another term specific to propane used in transportation. Propane turns into a colorless, odorless liquid when stored under pressure inside a tank. As pressure is released, the liquid propane vaporizes and turns into a gas, which is used for combustion. Propane presents no threat to soil, surface water, or groundwater. Additionally, propane has a high octane rating which allows for increased vehicle power and performance.

Nearly all U.S. propane supply is produced in North America either as a by-product of natural gas processing or by crude oil refining. Pipelines, railroads, barges, trucks, and tanker ships are used to ship propane from its points of production to bulk distribution terminals. Trucks are filled at the terminals, and propane dealers then distribute propane to end users, which include retail fuel sites.

Uses and Applications[15]

Propane is mainly used in light-duty pick-up trucks, taxis, medium-duty vans, and heavy-duty school and transit buses. Propane is well suited for spark ignition engines, and gasoline engines can be converted relatively easily to use propane. The high octane rating of propane (104–112 compared to 87–92 for gasoline), combined with low carbon and oil contamination characteristics, results in engine life that can last up to two times longer than a gasoline engine. Propane can be stored onboard a vehicle as a liquid at a low pressure—between 100 and 200 psi, allowing for refueling times comparable to gasoline refueling.

The cruising speed, power, and acceleration of propane vehicles are similar to those of gasoline-powered vehicles. Propane has approximately 73% the energy content of gasoline per gallon; therefore, the typical range of a light duty vehicle equipped with a 20-gallon tank is approximately 250 miles. Driving range can be increased by adding additional storage tanks; however, the added weight displaces payload and passenger capacity.

Because few propane vehicles are offered by OEMs, propane normally requires conversion of a gasoline vehicle. Companies providing propane conversions include Bi-Phase Technologies, CleanFuel USA, Icom North America, IMPCO Technologies, and Roush CleanTech.

[15] Picture Source: https://ngtnews.com/laketran-touts-new-propane-autogas-fueling-station-public-bus-fleet

Propane has a niche among transit fleets and can also be well suited to off-road applications such as forklifts, commercial mowers and other grounds maintenance equipment, and airport ground support equipment.

Electricity

Description

Electricity can be used to power all plug-in electric vehicles (PEVs), which include battery electric vehicles (BEVs, which run exclusively on electricity) and plug-in hybrid electric vehicles (PHEVs, which can run both on electricity and other fuels, typically gasoline). Electricity can also power fixed guideway transit applications such as heavy rail (e.g. Bay Area Rapid Transit, Los Angeles Metro), light rail (e.g. Sacramento Regional Transit), and trolleys (San Diego Metro). All PEVs draw electricity from off-board electrical power sources (i.e., the electrical grid) and store the electricity as chemical energy in onboard batteries. In a BEV, the battery powers an electric motor. PHEVs also have an electric motor that uses energy stored in a battery, as well as an internal combustion engine (ICE) that can run on petroleum or alternative fuel depending on the vehicle design. All PHEVs commercialized at scale today use electricity and gasoline.

Note that PEVs differ from conventional hybrid-electric vehicles, which typically use regenerative braking to charge a small on-board battery that can power the vehicle during idling and low speeds. There are many diesel-electric hybrid transit buses currently in service. These vehicles cannot be charged using an external power source.

PEVs are charged by plugging into charging equipment, often known as electric vehicle supply equipment (EVSE). Electric vehicle supply equipment is generally categorized in terms of its level, a term that refers to the range of current or voltage at which the equipment is designed to support the charging of the vehicle. Charging times vary and can range from 15 minutes to 20 hours or more, depending on factors such as battery size and type, and the type of charging equipment used. AC level 1 EVSE supports conductive charging at current levels up to 16 amperes (A), at voltage levels of 120 alternating current volts (VAC), common in standard outlets. AC level 2 EVSE supports conductive charging at current levels between 12 and 80 A, using 208 to 240 VAC circuits. A third type or level of equipment, known as DC fast charge (sometimes referred to as DC level 3), uses direct current. This type of equipment enables charging at much higher current, and has a rated power in the order of 50kW. DC fast charging equipment uses a charger included in the equipment, while level 1 and 2 use the charger in the vehicle. DC fast chargers require a different connector, for which a standard is currently being developed in the United States. In addition, inductive charging uses an electromagnetic field to transfer electricity. Charging equipment using inductive charging has been used since the 1990s, but conductive charging has been the dominant mode in the current large-scale commercialization of PEVs. It is possible to use inductive charging in wireless charging systems. This technology has had limited but successful deployments at transit agencies including Long Beach Transit, Monterey-Salinas Transit, and Antelope Valley Transit Authority.

As of the date of this writing, there were 16,100 EV charging stations installed and reported across the country, with a total of over 43,000 outlets.[16]

Uses and Applications

The cumulative sales of PEV in the United States grew to over 640,000 by the time of this writing. PEV sales in 2016 alone amounted to almost 160,000, with 72,800 PHEV and 86,700 BEV. There currently are 32 different models of PEVs offered in the market. The focus of large auto manufacturers is heavily on the light-duty vehicle market. PEVs currently make up 1.13% of all U.S. LDV sales in June 2017.[17]

There are some medium-vehicle (MDV) and heavy-duty vehicle (HDV) plug-in models commercially available including transit buses from Proterra, BYD, GreenPower, and New Flyer.

2.2 Summary of Advantages and Disadvantages

Below is a summary of the operational advantages and disadvantages and the environmental benefits of each potential alternative fuel for rural and small urban transit agencies.

[16] https://www.afdc.energy.gov/locator/stations/

[17] http://www.hybridcars.com/may-2014-dashboard/

Table 2: Summary of Operational Advantages and Disadvantages by Alternative Fuel

Alternative Fuels	Operational Advantages	Operational Disadvantages	Environmental Benefits
Biodiesel	• Use of existing vehicles • Immediate implementation • Limited to no additional maintenance training or facility upgrades	• Biodiesel can act as a solvent requiring increased filter replacement for a limited time after implementation • Staged implementation will require additional storage and refueling infrastructure • Limited shelf life of biodiesel • Potential engine warranty issues • At high blends, cold weather temperature issues • Increased fuel price compared to diesel	• Reduces diesel consumption • Reduces GHG Emissions (feedstock dependent)
Renewable Diesel	• Use of existing vehicles • Immediate implementation • Meets ASTM specification for diesel so no engine warranty or increased maintenance issues	• Staged implementation will require additional storage and refueling infrastructure • Increased fuel price compared to diesel	• Reduces diesel consumption • Reduces GHG Emissions (feedstock dependent)
Natural Gas	• Elimination of maintenance issues around diesel emission control devices • Less volatile and lower fuel costs compared to diesel	• Training of maintenance staff for CNG vehicles • Facility upgrades for CNG vehicle maintenance • Either use of local public station or require new private station onsite	• Reduces diesel consumption • Reduces GHG Emissions (significant reductions from RNG use) • Reduces NOx and PM emissions
Propane	• Elimination of maintenance issues around diesel emission control devices • Lower fuel prices (when taking into account energy density) compared to diesel	• Training of maintenance staff for propane vehicles • Facility upgrades for propane vehicle maintenance • Either use of local public station or require new private station onsite	• Reduces diesel consumption • Reduces NOx and PM emissions
Electricity	• Reduced operations and maintenance costs • Potential lower per mile fuel costs, minimizing demand charges important	• Training of maintenance staff for electric buses • Potential facility updates for electric bus maintenance and battery storage • Installation of potentially high cost charging infrastructure • Battery capacity and charging issues at cold weather temperatures	• Reduces diesel consumption • Reduces GHG Emissions • Eliminates tailpipe emissions

3 Guidance for Selecting Alternative Fuels

3.1 Key Consideration

When a transit agency is considering switching to an alternative fuel, there are key considerations that need to be weighed to determine if an alternative fuel will be successful. The following table identifies the key consideration and why they are important when considering switching to an alternative fuel. The following section will assist agencies in navigating the key consideration to narrow the list of fuels for a more detailed analysis.

Table 3: Key Considerations when Evaluating Alternative Fuels

Key Consideration	Why it is important
Federal, State and Local Regulations	Federal, State and Local regulations could incentive or even require the use of alternative fuels or technologies to minimize emissions. These regulations could make it difficult to switch to fuels that do not reduce emissions and potentially provide funding for the switch to alternative fuels.
Fuel Availability	The location of a transit agency in relation to natural gas pipelines or other distribution infrastructure could lead to serious barriers (i.e. increased costs) for implementation. Investigate whether these barriers exist prior at the onset of the process.
Infrastructure Availability	Some transit agencies have limitations for constructing new refueling infrastructure. Therefore, implementation of alternative fuels will be limited to those with local public refueling (i.e. a local public CNG refueling station) or using existing infrastructure.
Fuel Throughput	Maximizing fuel throughput is incredibly important for the economics of a new private refueling station. Stations are sized for maximum annual throughput and underutilization of infrastructure while the fleet is being converted can have a significant effect on the economics. Low throughput can make it difficult to implement alternative fuels with costly refueling infrastructure (i.e. CNG).
Vehicle Availability	For transit agencies who are restricted to their state's procurement contracts, certain alternative fuels cannot be implemented if dedicated alternative fuel vehicles (e.g. natural gas, propane, electricity) are not available for purchase.
Fuel, Operations and Maintenance Costs	Each rural and small urban transit agency has unique circumstances for fuel, operations and maintenance costs. It is important if local or state level fuel procurement contracts include alternative fuels like propane. Also, some agencies outsource or share maintenance services/staff/costs and these staff will need to be trained in how to maintain alternative fuel vehicles.
Climate and Topography	There are limitations to certain alternative fuels based on climate and topography. Some of these limitation (i.e. CNG at high altitudes, biodiesel

Key Consideration	Why it is important
	in cold temperatures) have been overcome either with newer vehicle technologies (CNG at high altitudes) or season blending variations or use of renewable diesel (biodiesel in cold temperatures). It is important to investigate each fuel for any limitation and contact agencies utilizing the fuel and technology in similar climates for real world experiences.

A potential solution to transit agency concerns over alternative fuel vehicle operations and maintenance is educating agencies and maintenance staff by developing and coordinating workshops and demonstrations. These workshops could provide “hands-on” opportunities for fleet operators, managers and maintenance staff to operate and see the vehicles and discuss with other transit agencies that have successfully implemented the vehicles.

In addition, agencies who are limited to vehicle purchases from their state procurement contract should consider and investigate joining a consortium. The Colorado Mountain Purchasing Consortium is an example of 10 similar climate and topographical transit agencies joining together to increase their purchasing power and their access to alternative fuel vehicles. Their most recent request for proposals (RFP) included both CNG and LPG dedicated vehicles.[18]

3.2 Alternative Fuel Selection Matrix

The matrix below provides guidance on the selection of alternative fuels with brief descriptions of each fuel for all the key considerations identified in the previous section. These descriptions are meant to be a guide since each agency will have its own unique considerations. Please utilize the lifecycle analysis tool in tandem with this document during the alternative fuel evaluation process.

[18] http://www.eaglecounty.us/OpenEagleCounty/Documents/CMPC_14_BOC_RFP_Solicitation_Part_1_3_1_14/

Table 4: Guidance for Each Fuel on the Key Considerations

Key Considerations	Limitations or Potential Barriers	Biodiesel	Renewable Diesel	Natural Gas	Propane	Electricity
Federal, State and Local Regulations	Criteria Pollutant (NOx, VOC, PM) Emissions	Biodiesel does displace diesel and diesel PM but it does not reduce NOx, a precursor to ozone	Renewable diesel does displace diesel and diesel PM but it does not reduce NOx, a precursor to ozone	Natural gas reduces NOx and diesel PM emission, but does not decrease VOC emissions.	Propane slightly reduces NOx and reduces diesel PM emission, but does not decrease VOC emissions.	Electricity from battery electric vehicles eliminates tailpipe emissions
	Greenhouse Gas Emissions	Biodiesel does reduce GHG emissions	Renewable diesel does reduce GHG emissions	Fossil natural achieves small GHG reductions; Renewable natural gas has significant GHG reductions	Propane achieves small GHG reductions	Electricity has significant GHG reductions
Fuel Availability		In general, there are limited issues with biodiesel availability, contact your fuel distributor to confirm	In general, there are limited issues with renewable diesel availability, contact your fuel distributor to confirm	Pipeline access can be a barrier to natural gas implementation, trucking in LNG is more expensive and reduces fuel price savings	In general, there are limited issues with propane availability, contact your fuel distributor to confirm	In general, there are limited issues with electricity availability, contact your local utility to confirm
Infrastructure Availability	Space limitations	A full fleet transition does not require additional space, biodiesel blends can use existing infrastructure with minor upgrades and cleaning prior to the transition	Renewable diesel is fungible with conventional diesel and can utilize existing infrastructure with minimal to no upgrades	If space is insufficient for an onsite station, a local public or private station must be available for implementation of CNG	If space is insufficient for an onsite station, a local public or private station must be available for implementation of propane	For overnight charging, the infrastructure must be onsite and for in-route charging, there must be a location where charging can occur, (e.g. transit center)
Fuel Throughput	Small Fleet with Limited Throughput	Little to no limitations with implementing biodiesel; utilizes existing vehicles and,	Little to no limitations with implementing renewable diesel; utilizes existing	If a new station is required, a small fleet with limited throughput can make the economics difficult	Propane stations are less expensive and more modular compared to CNG allowing for smaller	For overnight charging, the size of the fleet is less of an issue; the economics of in-route charging

Key Considerations	Limitations or Potential Barriers	Biodiesel	Renewable Diesel	Natural Gas	Propane	Electricity
		with upgrades, existing infrastructure	vehicles and existing infrastructure		fleet and throughput conversion.	favor larger fleets and fuel throughput
Vehicle Availability	Limited Vehicles on State Procurements	Utilizes existing and available vehicles	Utilizes existing and available vehicles	CNG dedicated vehicles may not be available on state procurement contracts	Propane dedicated vehicles may not be available on state procurement contracts	Electric vehicles are not yet available on state procurement contracts, but mainly through grant or other funding programs like Lo-No – FTA 5339
Fuel, Operations and Maintenance Costs		Biodiesel acts as a solvent and increases maintenance costs in the short term after implementation	No maintenance or operations changes from diesel	CNG has similar maintenance costs to diesel but could require upgrades to maintenance facilities and staff training. CNG does not require diesel particulate traps or other diesel specific emission control devices	Propane has similar maintenance costs to gasoline but could require upgrades to maintenance facilities and staff training. Propane does not require diesel particulate traps or other diesel specific emission control devices	Electric buses do not require traditional combustion engine maintenance but training and battery storage capabilities at the maintenance facility will be required.
Climate and Topography	Cold Weather, Hot Weather, Mountains	Biodiesel can have issues at low temperatures with gelling, blend levels could be seasonally adjusted	Renewable diesel has no issues with climate and topography	Through successful implementation in the US Rocky Mountains, CNG successfully operated in cold and hot weather and mountainous terrain	Propane does not have climate or topographical limitation, only potential onboard fuel storage limitations	In cold climates battery storage issues have been seen

3.3 Staged Implementation of Alternative Fuels

The goal when balancing implementation of alternative fuels with fleet turnover is maximizing the throughput of new refueling infrastructure and utilizing the full useful life of the current vehicles in the fleets. Also, the availability of funds is key for how many vehicles can be initially transitioned.

Staged implementation needs to be considered when transitioning to alternative fuels that require dedicated vehicles. Switching to biodiesel or renewable diesel does not require staging and may only require slight upgrades to refueling infrastructure. Once that is complete, all diesel vehicles can begin use. For natural gas and propane, when new vehicles are purchased, how many, and the size of refueling infrastructure are importance considerations.

Propane is more straightforward to stage the transition because the refueling infrastructure is less expensive and modular. For propane, a station can be built to meet the needs of the first stage of the fleet transition and additional storage tanks can be installed to meet future needs. Before implementation, it will be necessary to confirm the future station location can accommodate the full fleet transition. The refueling station implementation can be in stages as conventional vehicles are retired, new propane vehicles are purchased, and additional propane is required.

Natural gas requires additional forethought when implementing a staged fleet transition. The economies of scale for a CNG station limit staged infrastructure implementation like propane. The costs and availability of funds for a CNG station can limit construction to one station and compressor to accommodate the entire fleet for most rural and small urban transit agencies. The availability of funding, age of the existing vehicles, and access to local public or private CNG stations will determine how many vehicles are initially converted and when the station is built.

If a local CNG station exists, fleet transition can proceed until the fleet size is sufficient for its own station. If there are no local CNG stations, the window for transitioning the fleet to full implementation will need to be condensed to maximize throughput of the station and the return on investment of station. This can be done by extending the life of older vehicles until newer vehicles need to be replaced. This will increase the initial amount of vehicles converted. The lifecycle analysis tool developed through this NCHRP task can be used to model various staged vehicle implementation scenarios and compare the cost and net present value (NPV) for each.

In the near term, the availability of grant funding will determine the timing and implementation of electric transit vehicles. Once the technology costs decrease and their use becomes ubiquitous, a similar approach to propane or CNG can be employed depending on the charging infrastructure.

4 User Guide – Alternative Fuel Assessment Tool

The following section serves is a guide to running and utilizing the results of the Alternative Fuel Assessment Tool that was developed as part of this project. The following subsections correspond the initial data entry section on the *Inputs* tab of the tool with a final subsection on understanding the results from the *Output* tab. For this tool, the only values, formulas or cells that should be changed are on the *Inputs* tab. The yellow, brown and green tabs are to be left unchanged since they contain necessary constants, formulas, and background data for the tool to operate properly. These tabs are not hidden or locked so the user can, if they desire, review and trace the data and formulas, and their sources. There are brief instructions on how to operate the tool on the *Inputs* tab shown in the figure below.

Instructions

All data elements in this worksheet are required to conduct the alternative fuel assessment.
To facilitate completion of the data elements, drop-down menus and default values have been included as part of the tool's design.
Users may conduct the assessment based on the default values or based on user-defined values.
User inputs on the 'Inputs' tab are marked either required or optional. See Legend.
Tabs ('Constants' through 'Overview') highlighted in these colors do not require user input. These tabs include reference data tied to 'Inputs' and 'Output' tab.
The 'Inputs' tab consists of five sections numbered 1-5 for required/optional user input to run the tool.

Exhibit 3. Brief Tool Instructions on the *Inputs* Tabs

4.1 Small System Transit Agency Fleet Location

In this section, the user will input the name of the agency and the city and state where it is located. Entering the state is extremely important for the operation of the tool. The state determines which set of background fuel price data is utilized by the model for the analysis.

4.2 Vehicle Use

The vehicle use section is where the user inputs the total vans, BOC and transit buses in the fleet in cells B24 – B26. The default values for annual vehicle miles traveled (VMT), miles per gallon (mpg) or vehicle life are shown in cells C24-26, E24-26 and G24-26. In cells D24-26, F24-26 and H24-26, the user has the option to enter fleet specific annual VMT, mpg or vehicle life for each of the three vehicle types to make the results more representative of the specific transit agency being analyzed.

4.3 Fuel Use

Conventional Fuel

In this section, the user should identify which conventional fuel is the baseline fuel for each vehicle type. For transit bus, diesel is the only option for baseline fuel since a cost was not available for new gasoline transit buses. Default current conventional fuel prices are provided in cells B39-40. The user has the option to provide their own diesel fuel price to refine the results.

Regional fuel price trends from the EIA Annual Energy Outlook are applied to the current fuel prices (either default or user-defined) to estimate future fuel prices.

Alternative Fuel

In this section, the user identifies the alternative fuel for the analysis. If biodiesel is selected, the user has the choice to adjust the incremental cost from the default $0.05/gallon over the price diesel. If electricity is selected, the user needs to select a charging option – in-route or overnight charging. In-route charging is where charging occurs mid-route or at the end of routes and during the course of the day. Buses that use this type of charging usually have smaller batteries and in-route charging is required to sustain the charge all day. The electrical load for in-route charging is significantly higher than overnight charging so charging can occur in 15-20 minutes instead of hours. Overnight charging is a lower load charging where the bus plugs in overnight and is fully charged at the beginning of the day. Because of the higher load, in-route charging is more expensive to install and can have higher electricity costs from the increased demand charges.

4.4 Purchase Schedule

This section is for detailing the purchase schedule to replace conventional fueled vehicles with alternative fueled vehicles. New alternative fueled vehicles replacing alternative fueled vehicles that reached the end of their useful life are not included in this table. The calculations on the *Annual Vehicle Costs* tab account for the replacement of alternative fueled vehicles with new alternative fueled vehicles. First the user enters the start year for vehicle replacements and then for each year enters the amount of conventional fuel vehicles that will be replaced with alternative fuel vehicles. If user attempts to enter transit bus conversions to propane or E85, an error message will appear since there are no E85 or propane transit buses available for sale. Only vans and BOC can be converted to propane.

4.5 Cost Estimation Parameters

The user is able to adjust the default discount rate of 2%. The discount rate reflects the opportunity cost of alternative uses of money meaning the relative value of money today versus money in the future. A discount rate of 2% means that money one year from now is valued 2% less than the same amount of money today. This results in the costs in the future being discounted when compared to costs today. The higher the discount rate, the lower the value that is placed on future costs. The discount rate is utilized to quantify the Net Present Value (NPV) results on the *Output* tab. The discount rate is compounded annually and applied to the corresponding future costs. NPV sums the future discounted costs with the current costs to determine the aggregate costs for conventional or alternative fuels over the analysis period. In this case the analysis period is 10 years.

4.6 Output Results

The output results tab includes a set of tables detailing the economic analysis from converting to alternative fueled vehicles in the following sections.

NPV of 10-Year Costs

This section includes a figure and table of the NPV cost over the 10-year analysis period. This is the main output of the tool and comparison between conventional and alternative fuels. The difference between the conventional fuel and alternative fuel NPV costs over the analysis period is the overall costs or savings from converting to an alternative fuel. The costs include vehicles, stations, fuels and, operations and maintenance costs for vehicles and stations. Only the costs for the quantity of vehicles entered in the "Purchase Schedule" are accounted for in the analysis.

Alternative fuels that result in minimal cost increases or cost savings could be good options for implementation and should result in a more in-depth investigation. More in-depth investigations should focus on the key considerations in Sections 3.1 and 3.2 of this guidance document. The individual values for vehicles, station, operations and maintenance, and fuel allow for the user to see which values are the major drivers for costs or savings and where attention should be focused when performing the more in-depth analysis.

Annual Capital Investment

The summary table includes the vehicle and station costs that would be incurred each year over the analysis time period. This table includes the costs of purchasing vehicles that replace both conventional and alternative fueled vehicles. This allows the user to know when to expect capital expenditures from implementing alternative fuel and how they compare to conventional fuels.

Annual Operating/Fuel Costs

The summary table includes annual station and vehicle operations and maintenance costs and fuel costs for both conventional and alternative fuels. The user can see here how costs change over time and whether cost savings are increasing or decreasing over time.

Annual Baseline Emissions, Alternative Fuel Emissions and Emission Reductions

The summary table in this section includes the annual emissions for both conventional and alternative fueled vehicles and the annual emission reductions for NOx, VOC, PM and GHGs.

5 Case Studies for Best Practices in Implementing Alternative Fuels at Small Systems

5.1 Danville Transit System, Virginia

Alternative Fuel Implemented: Propane

Best Practice: Successful phased approach to infrastructure planning and vehicle fleet transition to propane. DTS recognized the excessive operation and maintenance costs, and down time from their diesel fleet and took advantage of switching to an alternative fuel that significantly reduced those costs.

DTS is a small urban transit service for the greater Danville, Virginia area in South-Central Virginia along the North Carolina border. The system provides 50% fixed route and 40% demand response services and 10% of its services are dedicated to the disadvantaged. The DTS fleet is composed of 100% BOC/cutaways. Currently, the system includes two propane buses and plans to expand its propane fleet by 33% or more by end of the year. In the next 5 years, the majority of its fleet will be powered by propane. The buses in the DTS fleet do not last more than five or six years and they have to look to different funding sources for vehicle procurement in addition to securing funding for refueling infrastructure.

The City council's enquiry about alternative transportation strategies and a recommendation from the Public Works Director, motivated DTS to explore alternative fuels with an emphasis on propane and CNG. Maintenance issues with diesel particulate traps was a major reason DTS expanded the fleet of propane buses. However, a challenge with the propane buses on a fixed route service is lower mileage due to the lower energy density of propane and the pump at the propane station often ran out of fuel. To address this issue, DTS is currently planning to develop a new LPG refueling station that is located across from the transfer center that stages demand response and fixed route buses. This planned refueling station would be equipped with a 2,000 gallon underground tank and will be primarily used by Danville Transit bus operators.

The majority of the funding for vehicle procurement comes from federal resources (80%) and state transit funds (16%). The city contributes 4% of funds to cover the extra costs of propane conversion. The return on investment is evaluated from highly subsidized federal rebates equaling $0.50 per gallon, which helps keep the cost of LPG lower than diesel.

5.2 Greeley Evans Transit, Colorado

Alternative Fuel Implemented: CNG

Best Practice: Access to alternative fuel vehicles from being part of a consortium. GET was resourceful in finding a variety of funding mechanisms to procure their vehicles and fuels.

Greeley Evans Transit (GET), in Colorado, is a small urban transit system that services the city of Greeley, Evans and Garden City. The GET fleet is composed of almost all BOC/cutaways that run on diesel and two 35' Gillig transit buses that run on CNG. There are plans underway to replace the entire fixed route diesel BOCs with low floor CNG buses. Factors that initiated GET to explore alternative fuels include air quality benefits, emissions control, and ability to stay on track with their capital replacement schedules due to additional grant funding opportunities.

GET is part of a consortium called the Colorado Mountain Purchasing Program[19]. This joint procurement effort, was started to gain greater purchasing power for smaller agencies on bus purchases. Federal funding sources such as the FHWA's Congestion Mitigation Air Quality (CMAQ)[20] program have played a significant role in GET's ability to fund its capital replacement schedule. Other state grant programs, including the Department of Local Affairs (DOLA) Alternative Fuels Funding Program[21] and Northern Colorado Clean Cities' Regional Air Quality[22] grants are available but have not been utilized by GET. The CNG buses are currently refueling at the local Spark natural gas station.

In addition to implementing CNG, GET has investigated paratransit propane vans which have the benefits of lower upfront costs and the ability to fuel onsite. One barrier that has prevented implementation is the shorter vehicle life compared to Gillig buses

[19] Colorado Mountain Purchasing Consortium http://www.eaglecounty.us/OpenEagleCounty/Documents/CMPC_14_BOC_RFP_Solicitation_Part_3_Revised_4_25_14/

[20] FHWA, CMAQ https://www.fhwa.dot.gov/environment/air_quality/cmaq/index.cfm

[21] DOLA Alt Fuel Funding Program https://www.codot.gov/programs/planning/documents/stac-archives/2014-stac/august-2014/alt-fuels-colorado-program-table

[22] Northern Colorado Clean Cities funding resources http://northerncocleancities.org/resourcesfunding.html

5.3 Big Sky Transportation District, Montana

Alternative Fuel Implemented: Biodiesel

Best Practice: Thoroughly exploring alternative fuels including contacting and communicating with various manufacturers and other transit agencies for best practices to successfully implement alternative fuels.

Big Sky Transportation (Skyline) is a small rural transit system located in Big Sky Montana and services the city of Big Sky and its local recreation areas and ski resort, in addition to express routes linking Big Sky to Bozeman, MT. Skyline's fleet is composed of 90% BOC/cutaways and vans and two transit buses. Skyline has implemented biodiesel and is considering implementation of electric and propane buses in the future. The implementation of these additional alternative fuels will depend upon the results from further detailed investigation. Major concerns for alternative fuel implementation in this area include fueling and infrastructure costs, fuel-capacity and distance, maintenance, and weather.

Vehicles are procured through state funding sources and biodiesel is procured through a local distributor. The biodiesel blends include B10-B20. The B20 blend requires more filter changes but Big Sky had no major issues with biodiesel other than higher and inconsistent prices.

In the state of Montana, all rural FTA 5311 applications go through the state for procurement of vehicles. In Montana almost all transit services are demand response and the state DOT plays a major role in rural transit systems' push for alternative fuels. Big Sky Transportation is seeking potential additional funding for electric buses through the Volkswagen settlement[23].

[23]Volkswagen Clean Air Act Settlement https://www.epa.gov/enforcement/volkswagen-clean-air-act-civil-settlement

6 Recommendations for State DOTs and the Federal Agencies

Based on the surveys and interviews with small urban and rural transit agencies, the two main recommendations for State DOTs and federal agencies to increase the adoption of alternative fuels are workshops and demonstrations, and increased vehicle availability.

Many small urban and rural transit agencies are concerned, with their limited resources and dependent population they serve, to “experiment” with alternative fuels. It is important that fleet managers, vehicle operators and maintenance staff have the chance meet and discuss with other transit agencies that have successfully implemented these fuels to confirm that fuel could be successfully implemented at their agency and feel comfortable spending precious resources on more expensive vehicles and/or infrastructure. Also, these workshops should include demonstrations and ride-and-drives so vehicles operators and maintenance staff can drive and touch the vehicles and refueling equipment.

The follow-on to making transit agency staff comfortable with alternatives is having these vehicles available for purchase either on state procurement contracts or other forms of group purchasing. If these vehicles cannot be available on state procurement contracts, state DOTs should investigate and encourage the creation of consortiums or other forms of group purchasing that can increase the availability of alternative fuel vehicles to small urban and rural transit agencies. Federal agencies should work with state DOTs to find creative solutions where agencies are not restricted to the vehicles on the state procurement contracts and still be eligible for federal funding.

Appendix A: NCHRP 20-65 Task 72 Survey

NCHRP 20-65-72: Small Systems Alternative Fuel Strategies

This survey is due by Monday, March 6, 2017, 11:59 PM PST.

If you have any questions or concerns, please do not hesitate to contact Jeffrey Rosenfeld, Manager at E: Jeffrey.Rosenfeld@icf.com; Ph 408-216-2818 or Neha Ganesh, Associate at E: Neha.Ganesh@icf.com; Ph: 415-677-7118

Thank you and we look forward to your participation.

1. Please provide your contact information.

Agency Name:

Address:

Website:

Respondent Name (First, Last):

Title:

Telephone:

Email:

May we contact you?

2. Please indicate the size of your revenue vehicle fleet (transit-buses, trains, other).

[Total number and type of vehicles]

3. What type of fuel(s) or technologies does your agency operate? Please select all that apply.

Please note: The following questions apply to revenue vehicle fleet only.

- [ ] Bio-diesel
- [ ] CNG
- [ ] LPG (Propane)
- [ ] Ethanol
- [ ] Hybrid-Electric
- [ ] Hydrogen
- [ ] Diesel
- [ ] Gasoline
- [ ] Other

Other (please specify):

4. Please indicate whether the following fuels were implemented, investigated but not implemented or have not been investigated.

	Select
Bio-diesel	
CNG	
LPG (Propane)	
Ethanol	
Electric	
Hydrogen	
Other	

Other (please specify)

5. Please indicate the corresponding year the fuel was implemented

	Year implemented	N/A
Bio-diesel		
CNG		
LPG (Propane)		
Ethanol		
Electric		
Hydrogen		
Other		

Other (please specify)

6. Refueling infrastructure: Please enter the number of fueling stations for each applicable fuel type.

7. For each fuel type, if not currently implemented, is there potential to switch? Please specify.

8. For those alternative fuels that your system has investigated but not implemented, please describe why (for example: fuel costs and availability, accessibility to refueling infrastructure, lack of information/resources, lack of funding).

9. What information or resources would be helpful for further investigation of alternative fuels? Please indicate whether your agency has used outside consultants or inside technical expertise to assist in the process.

3

10. What funding sources did you draw upon to cover the up-front costs of switching to different fuels? Please specify.

11. Please share any additional information that might be helpful.

Appendix B: NCHRP 20-65 Task 72 Survey Summary Memo

Memorandum

To: NCHRP 20-65-72 Committee

From: Jeff Rosenfeld and Neha Ganesh, ICF

Date: April 2017

Re: NCHRP 20-65-72: Small Systems Alternative Fuel Strategies-Survey Summary Memo

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Survey

A survey titled *Small Systems Alternative Fuel Strategies* was administered by ICF from February 2017 through March 2017 via Survey Monkey and email (pdf version of survey). ICF collected and analyzed responses from 40 small urban and rural transit systems. The survey questionnaire was sent to over 700 small systems out of which 230 emails were undeliverable. This is an 8.5% response rate from those agencies that received the email. While the response rate was low, the responses we did receive were varied in agency size, type and fuels investigated or implemented.

The goal of this survey was to collect information on which small and rural transit agencies have implemented or investigated alternative fuels and identify those systems for more detailed interviews. In the follow-up interviews, ICF will look to gather detailed information about the systems' motivations, processes, successes, and challenges in exploring alternative fuels. ICF is also using the survey to determine any major trends and consistent challenges for systems in implementing alternative fuels and how they relate to fleet size, fuel access, and availability of funding. The survey results will be included in the guidance document as an appendix.

Key Findings:

Fuel/Technology

Of those small systems surveyed:

- **Biodiesel:** 5 agencies have implemented and 11 have investigated
- **CNG**: 5 agencies have implemented and 15 have investigated
- **LPG (Propane):** 2 agencies have implemented and 11 have investigated
- **Ethanol:** 2 agencies have implemented and 4 have investigated
- **Hydrogen:** 6 agencies have investigated and 21 agencies have neither investigated nor implemented. No agency has implemented Hydrogen.
- **Electric:** 5 agencies have implemented Hybrid/EV technology and 10 have investigated.

Main reasons indicated for why fuels were investigated but not implemented

- Refueling Infrastructure accessibility
- Lack of availability of funding
- Maintenance issues and costs associated with different fuels

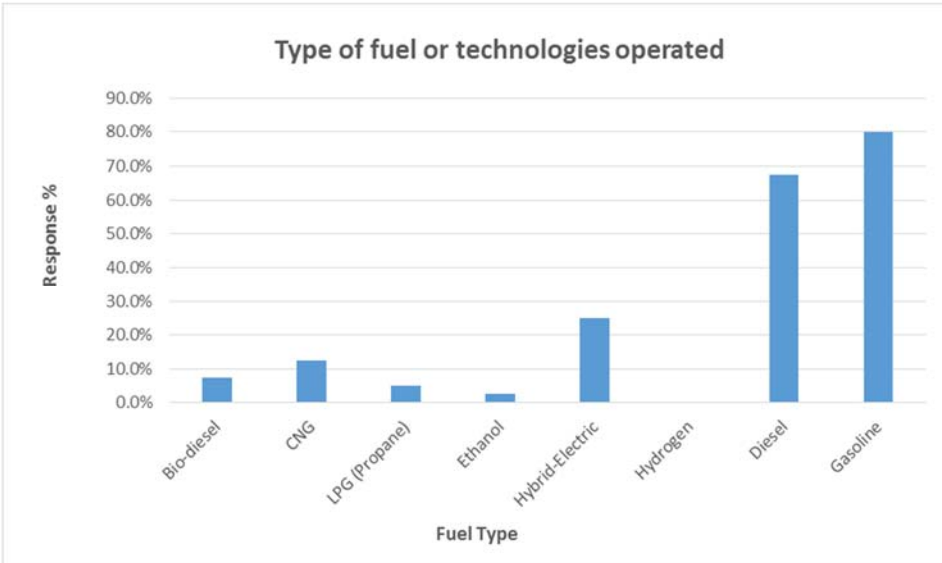

Figure 2. Type of Fuel or Technology operated at various small systems

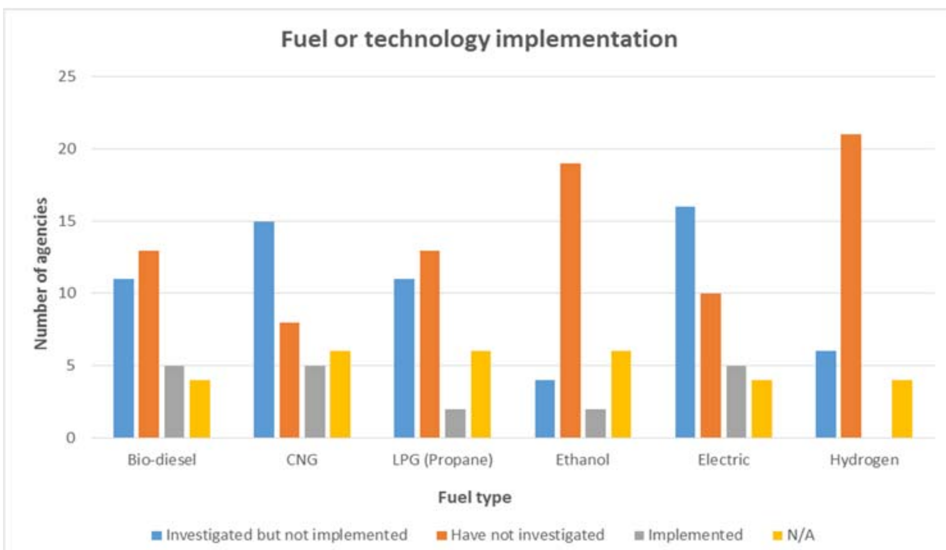

Figure 1. Type of Fuel or Technology either implemented, investigated but not implemented or have not investigated by various small systems

Major Funding resources identified

- Various federal and state transit funds including
    - Congestion Mitigation and Air Quality Improvement Program (CMAQ), Department of Local Affairs Energy Impact Mitigation grants

    - CNG implementation
- FTA No-Low Grant, 5307
    - Bio-diesel, hybrid-electric vehicle implementation
- American Recovery and Reinvestment Act (ARRA)
    - Implementation of Hybrid technology

In general, we will seek to identify any specific sources of funding for the implementation of particular alternative fuels during our interview process.

State DOTs

ICF also surveyed and collected responses from six State DOTs to help identify additional systems that use state procurement for alternative fuel implementation. We have reviewed these responses and included the small systems identified in our survey. Of those identified and contacted through this step, we received only one response from Rainbow Rider in Minnesota.

Literature Review

ICF reviewed resources from the National Transit Database[24], Transportation Research Board (TRB)[25] and American Public Transportation Association (APTA)[26] and a number of key studies published by the Small Urban and Rural Transit Center of the Upper Great Plains Transportation Institute (UGPTI)[27] at the North Dakota State University. Conversations and communication with North Dakota State helped guide the survey process and selection of candidates for interview. ICF contacted Jeremy Mattson from UGPTI via email and telephone conference for guidance on contact information for small systems and to gather more information on the UGPTI research on alternative fuel use by small systems.

- Mattson, Jeremy. *Use of Alternative Fuels and Hybrid Vehicles by Small Urban and Rural Transit Systems*, DP-250. North Dakota State University, Fargo: Upper Great Plains Transportation Institute, 2012.
    - This study sought to identify those small systems that have implemented either Bio-diesel, E85, CNG, propane and hybrid-electric vehicles and analyze the reasons, benefits and deterrents associated with each fuel implemented. This study used survey-feedback methods to collect and analyze results.
    - For most agencies, fuel-costs, mileage and infrastructure were the main deterrents to implementation of an alternative fuel while positive reasons indicated for adopting an alternative fuel and/or hybrids include emission reductions, energy dependence concerns, political derivatives and improving

[24] Federal Transit Administration, NTD website: https://www.transit.dot.gov/ntd

[25] The Transportation Research Board: http://www.trb.org/Main/Home.aspx

[26] APTA: http://www.apta.com/Pages/default.aspx

[27] UGPTI, Small Urban and Rural Transit Center: http://www.surtc.org/

public perception. A majority of the systems indicated that they were “very satisfied” with CNG and Hybrid implementation followed by E85 and Bio-diesel.

- Del Peterson and Jeremy Mattson: *Biodiesel Use in Fargo-Moorhead MAT Buses*, Upper Great Plains Transportation Institute, 2008.
    - This study reviews the state of biodiesel across various transit agencies in the U.S. and presents an overview of the use of biodiesel in the Fargo-Moorhead region.
    - Performance of biodiesel in cold weather, decrease in fuel economy and maintenance costs are among the major deterrents in the use of biodiesel across many agencies
    - The Fargo-Moorhead Metro Area Transit (MTA), a small urban system explored bio-diesel in 2005 and has had success using different blends including B5, B2 (in some cold weather months) and B20. It is noted that riders tend to use this bio-diesel transit service more as they perceive that use of Bio-diesel causes lower emissions and lower environmental impact and provides support to local farmers. The study encourages the analysis between ridership and alternative fuel usage.

Other key studies covering vehicle procurement practice in public transportation[28] and classification of small urban and rural agencies[29] were reviewed.

Next Steps

ICF will interview up-to 10 small systems- both urban and rural in the month of April. We recommend selecting those agencies that have either implemented or investigated one or more alternative fuels, based on the survey responses. In addition to interviewing the following agencies, we will review an ICF authored energy reduction study for Lake Transit Authority[30]. ICF will also review Simi Valley Transit (CNG implementation). We will include these reviews as part of the full literature review in Task 4. We request the panel’s feedback on the interview candidates and questions proposed below.

Interview Candidates

ICF proposes the following 10 systems to interview. According to the responses we received we have identified a higher number of small urban systems.

[28] http://www.ugpti.org/pubs/pdf/DP246.pdf

[29] http://www.ugpti.org/pubs/pdf/DP212.pdf

[30] http://laketransit.org/wp-content/uploads/2015/05/ICF_Lake-Transity-Energy-Use-Reduction-Plan_010316.pdf

Agency Name	System Classification	State	Biodiesel	CNG	LPG(Propane)	Ethanol	Electric	Hydrogen
Cache Valley Transit District	Urban	Utah	Investigated but not implemented	Investigated but not implemented	Investigated but not implemented	Have not investigated	Investigated but not implemented	Have not investigated
City of Las Cruces/RoadRUNNER Transit	Urban	New Mexico	Investigated but not implemented	Investigated but not implemented	Have not investigated	Have not investigated	Investigated but not implemented	Have not investigated
City of Santa Clarita	Urban	California	Investigated but not implemented	Implemented	N/A	N/A	Investigated but not implemented	Investigated but not implemented
Danville Transit System	Urban	Virginia	Investigated but not implemented	Investigated but not implemented	Implemented	Investigated but not implemented	Investigated but not implemented	Investigated but not implemented
Duluth Transit Authority	Urban	Minnesota	Implemented	Investigated but not implemented	-	-	Implemented	-
Grand Forks Cities Area Transit	Urban	North Dakota	Investigated but not implemented	N/A	N/A	Implemented	N/A	Investigated but not implemented
Greeley Evans Transit	Urban	Colorado	Have not investigated	Implemented	Investigated but not implemented	Have not investigated	Investigated but not implemented	Have not investigated
Lane Transit District	Rural	Oregon	Investigated but not implemented	Investigated but not implemented	Investigated but not implemented	Have not investigated	Implemented	Investigated but not implemented
Roaring Fork Transportation authority	Rural	Colorado	Implemented	Implemented	Have not investigated	Implemented	Investigated but not implemented	Have not investigated
Town of Snowmass Village	Rural	Colorado	Investigated but not implemented	Investigated but not implemented	Investigated but not implemented	Investigated but not implemented	Investigated but not implemented	Have not investigated

Interview Questions

Potential interview questions are listed below. Note that we anticipate asking only a select few questions from this list identifying most important topics for each system based on fuel, funding and other issues ultimately collating all the relevant information to use toward developing the guidance tool.

General

1. What initially motivated you to explore alternative strategies?
2. What fuels did you look into using, and what were the advantages and disadvantages of each?
3. What funding sources did you draw upon to cover the up-front costs of switching to different fuels?
4. How did you procure fuels, vehicles, and equipment?
5. Have there been unanticipated benefits or challenges to adopting alternative fuels?
6. Looking back, is there anything that you wish you would have known when you began looking into alternative fuels?
7. What tools or guidance might help you or your peers make better decisions about alternative fuels in the future?

Agency Specific

1. Cache Valley Transit District
    - Please describe the process your agency will undertake to transition to a CNG fleet- in the survey you mentioned it is due to legislative pressure.
    - What resources will you seek/utilize?

2. City of Las Cruces/RoadRUNNER Transit
    - Please explain the agency's plan to switch to all-electric.
    - Will paratransit vehicles also be included in this transition?

3. City of Santa Clarita
    - Please describe the successes and challenges with CNG implementation.
    - What are some other fuels your agency will consider investigating?
    - What are the funding sources available to you/will seek to implement additional fuels or expand your CNG fleet?
    - Please provide detail on CNG refueling costs for the vehicles your agency operates

4. Danville Transit System
    - Please describe the successes and challenges with LPG implementation. Please provide detail about your agency's bio-diesel and CNG fuel investigation. What funding sources did you draw upon?

5. Duluth Transit Authority
    - Please provide information on the fleet mix-percentage of vehicles that run on bio-diesel and ethanol
    - What are some of the successes and challenges in ethanol fuel implementation?

6. Grand Forks Cities Area Transit

- Please describe the successes and challenges of your agency's efforts in ethanol implementation? It is indicated that your agency is a relatively smaller system with 11 buses and 11 paratransit vans- how many of these run on ethanol? Are there plans to expand your fleet to include electric buses and also investigate bio-diesel implementation?

7. Greeley Evans Transit
    - What are some of the challenges your agency faces with CNG implementation?
    - Please provide any details about refueling infrastructure and other costs

8. Lane Transit District
    - Please provide more information on the Lo-No grant for procuring additional electric buses
    - Among the other fuels indicated as investigated but not implemented which one seems more likely to be implemented in the near future and why

9. Roaring Fork Transportation Authority
    - Describe the successes and challenges your agency has faced in implementing bio-diesel and CNG
    - It is indicated that your agency has investigated electric buses. What is the percentage of your fleet that will run on bio-diesel, CNG and electric?
    - What are some funding sources your agency has drawn upon?

10. Town of Snowmass Village
    - When does your agency plan to potentially switch to CNG?
    - Does your agency have all the required tools ready to transition to CNG fleet? If not, what are the resources needed?
    - In the survey you indicated that your agency had investigated but not implemented Biodiesel and Ethanol. Could you please provide more detail?
    - Roaring Fork Transportation Authority also a rural transit system in Aspen, Colorado has implemented Biodiesel, CNG and Ethanol. Would you consider them a stakeholder/resource to help with exploring implementation of these fuels?]

Appendix C: NCHRP 20-65 Task 72 Interview Summary Memo

Memorandum

To: NCHRP 20-65-72 Committee

From: Jeff Rosenfeld and Neha Ganesh, ICF

Date: June 2017

Re: NCHRP 20-65-72: Small Systems Alternative Fuel Strategies Interview Summary and Proposed Toolkit Memo (Task 2)

Interviews

Shortly following the survey process in the months of February and March 2017, ICF developed a list of 10 agencies to interview that were included in the Task 1 Survey Summary. After receiving comments from the NCHRP 20-65-72 Committee, ICF modified the list of agencies to interview. ICF removed City of Santa Clarita, Duluth Transit Authority and Lane Transit and replaced them with Rainbow Rider, Estuary Transit and Big Sky. The three new agencies are all rural. Rainbow and Estuary are wholly BOC/cutaways fleets and Big Sky is almost 90% BOC/cutaway and vans. ICF conducted interviews with the identified 10 small urban and rural system agencies from March to May 2017. Of the 10 agencies interviewed, 5 are urban and 5 are rural. The 10 agencies interviewed varied in fleet size, type and fuels investigated or implemented. ICF gathered detailed information from these interviews about the systems' motivations, processes, successes, and challenges in exploring alternative fuels that are summarized below.

The dual purpose of this memo is to: (1) provide key findings from the interviews highlighting the barriers and challenges associated with deploying alternative fuels for small system operators; and (2) identify what tools should be developed and information included it the guidance document to help guide these systems to assess alternative fuels for their fleet.

The agencies interviewed, shown it the table below, represent diverse fleet types and sizes including BOC/cutaways, vans, transit buses and paratransit fleet. Of the agencies interviewed, 3 are 100% BOC/Cutaway fleets (Danville, Rainbow and Estuary); 2 are almost all cutaways or vans (Greeley and Big Sky) and 2 agencies have paratransit vehicles making up 50% of their fleet (Las Cruces, Grand Forks Cities). The diversity of fleets resulted in a diversity of input and findings related to alternative fuel vehicles, technologies, funding and deployment.

Agency	System	Region	Fleet type		
			Transit bus	BOC/cutaway	Van
Cache Valley Transit District	Urban	Utah	26	8 paratransit	
City of Las Cruces/RoadRUNNER Transit	Urban	New Mexico	19		20 paratransit
Danville Transit System	Urban	Virginia		24	
Grand Forks Cities Area Transit	Urban	North Dakota	6	5	11
Greeley Evans Transit	Urban	Colorado	2	17 + 9 paratransit	
Roaring Fork Transportation authority	Rural	Colorado	100+		24
Town of Snowmass Village	Rural	Colorado	19	10	
Rainbow Rider Transit	Rural	Minnesota		35	
Estuary Transit District	Rural	Connecticut		16	
Big Sky Transportation District	Rural	Montana	2	8	7

Key Findings:

During the interviews, both small urban and rural agencies raised a number of concerns associated with alternative fuel deployment including:

- Maintenance costs
- Refueling Infrastructure accessibility
  - Property/site size
  - Fuel costs
- Limitation of alternative fuel vehicles on available procurement contracts and lack of availability of funding and/or limitations to existing funding sources
  - In the follow ups, ICF received additional supporting materials such as FTA funding denial letters[31] on vehicle procurement/"piggybacking
  - "[32] (eg: for Town of Snowmass) that enforces the requirement for all agencies related to contracting/procurement compliance for the use and distribution of federal funds through FTA.
- Fuel throughput and vehicle turnover including limited driving range and retirement cycles

In terms of implementation or investigation of specific alternative fuels or technology, electric and/or hybrids are comparable in their willingness to consider these technologies, to both urban and rural agencies. For agencies who have investigated electric technologies, vehicle cost is a significantly more important issue than infrastructure and maintenance while infrastructure and maintenance costs are the main issues for CNG.

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[31] FTA Region VIII letter on piggybacking, April 2017 available in pdf

[32] FTA requirement https://www.transit.dot.gov/funding/procurement/bppm-procurement-object-types-special-considerations#BM6_3_

A common theme that emerged was that there is a desire and awareness that they could/should consider alternative fuels but they were unsure how to proceed, resources to utilize or what type of fuel/technology they should consider. A combined tool and guidance document was considered to be helpful to assess current implementation or explore the possibility of switching to an alternative fuel fleet.

Rural

The availability of vehicle technologies and funding are the key issues for alternative fuel deployment at rural agencies. Vehicles are procured with state and federal funding, but the availability to purchase an alternative fuel can be limited depending on how an agency procures vehicles. Consortiums such as the Colorado Mountain Purchasing Consortium[33] (eg: Roaring Fork Transit Authority and Town of Snowmass) put out bids containing alternative fuel vehicles and increase access for rural agencies who are part of one. Rural agencies not part of consortiums procure vehicles through their state and are limited to the vehicles available, which often do not include alternative fuel options. Estuary Transit (CT) has been part of a consortium that allows procurement of CNG, propane and hybrid vehicles.

Previously agencies that were not part of a consortium could "piggyback" on other contracts to gain access to purchasing alternative (and conventional) fuel vehicles, but agencies note that "piggybacking is not as easy as it used to be"[34]. Rural agencies also indicate that new infrastructure needs are a main barrier to alternative fuel implementation. For example, some agencies are unable to construct an onsite station or unwilling to fuel their fleet at a publically available station nearby. These are among reasons to prefer to use liquid fuels over gaseous fuels. Also, many rural agencies do not have their own maintenance facilities and staff and must outsource to local private maintenance facilities, or share maintenance staff and facilities with other city and county fleets. It can be infeasible to either provide training and facility upgrades or find trained maintenance locations when you are rural transit agency that outsources or shares maintenance.

Funding availability is still the main issue for alternative fuel implementation. Agencies like Big Sky have indicated concerns including fueling costs, VMT per tank, and cost issues especially with CNG and propane. However, they are open to implementing electric buses for their fleet if they had lower incremental costs.

Urban

The following are key findings for small urban systems:

- Most agencies are supportive of CNG but they note that there are issues with fueling offsite along with added costs that are burdensome.
- There are mixed perceptions about the use of biodiesel- more expensive than gasoline, issues with clogging filters. One agency noted that better mileage with biodiesel was a plus.

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[33] Colorado Mountain Purchasing Consortium http://www.bing.com/search?q=Colorado+Mountain+Purchasing+Consortium&src=IE-TopResult&FORM=IETR02&conversationid

[34] Interview with David Peckler, Transportation Director, Town of Snowmass Village, Colorado

- There is continued interest in implementing and continuing investigation with electric buses. Some of the noted benefits include lower maintenance and fueling costs.
- The agency most positive about implementation of LPG in their fleet is Danville Transit System in Virginia. Maintenance issues with their diesel particulate traps was listed as the major reason for leaning toward expansion of the fleet with LPG buses. However, a challenge with the LPG buses on the fixed route service is lower mileage due to the lower energy density of LPG.
- Limited local funding and dependence on federal funds

Toolkit Development

The goal of this project is to develop a toolkit to assist smaller transit agencies in implementing and analyzing the costs and benefits of alternative fuels. The toolkit with include quantitative resources and a guidance document to assess the impacts of deploying alternative fuels and overcoming challenges and barriers to implementation. The interviews identified successes and challenges towards implementing alternative fuels which provided input into the development of the toolkit.

Based on the interviews with small urban and small rural agencies, ICF recommends developing a spreadsheet tool to estimate lifecycle costs from implementing alternative fuels including quantification of environmental and emissions benefits. The tool will included a formal output sheet and provide a summary of information on the different types of funding available and the benefits of alternative fuels. During the interviews a recommendation was made to have a formal output sheet that would contain the necessary information for funding applications.

The following are suggested inputs for the spreadsheet tool that will estimate lifecycle costs from implementing different alternative fuels (biodiesel, CNG, LPG, electricity and E85):

- Costs: infrastructure, maintenance, fleet/bus procurement, fueling
  - Will look at the increased incremental costs of fueling infrastructure and vehicles and fuel costs increases (e.g. biodiesel) or savings
- Fleet: type, size, service (urban vs. rural)
  - Size of fleet conversion or throughput necessary to fully utilize new infrastructure
  - Will have default values for annual VMT, MPG, etc based on service type and vehicle size
- Fuel/technology: type, lifecycle emissions during transit applications[35] and associated GHG emissions/criteria pollutant data, mileage
- Phase in of the alternative fuel fleet
- Funding sources by region/urban, rural; federal/state; local

The guidance document will accompany the spreadsheet tool. The guidance document will help transit agencies identify which alternative fuels have the greatest chance of success for their circumstances and where to focus their time and available resources for in-depth analyses. ICF is planning on developing a matrix-style decision process that walks transit agencies through a series of questions to identify the barriers and challenges of each fuel for the that specific agency and determine which fuels will likely have the lower lifecycle costs and greatest change for success. The guidance document will also identify

[35] APTA Protocol/ICF work for TCRP H 53: Tools for Sustainable Transit

funding sources and provide recommendations for agencies considering alternative fuels such as joining a consortium.

Next Steps

ICF is in the process of gathering resources for the toolkit and guidance document. ICF aims to have a draft tool compiled in mid-July and have the guidance document drafted at end of July or early August.