Developing a Natural Gas-Powered Bus Rapid Transit Service: A Case Study

George Mitchell
National Renewable Energy Laboratory

NREL is a national laboratory of the U.S. Department of Energy
Office of Energy Efficiency & Renewable Energy
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Technical Report
NREL/TP-5400-64756
November 2015

Contract No. DE-AC36-08GO28308

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List of Acronyms

BRT	bus rapid transit
CARB	California's Air Resources Board
CASTA	Colorado Association of Transit Authorities
CNG	compressed natural gas
DGE	diesel gallon equivalent
FTA	Federal Transit Administration
GHGs	greenhouse gasses
GMF	Glenwood Maintenance Facility
kW	kilowatt
MPG	miles per gallon
NESCAUM	Northeast States for Coordinated Air Use Management
NMHC	non-methane hydrocarbons
NO_x	oxides of nitrogen
NREL	National Renewable Energy Laboratory
OR DEQ	Oregon's Department of Environmental Quality
PM	particulate matter
psi	pounds per square inch
RFTA	Roaring Fork Transit Authority
RTD	Regional Transportation District
STRONGER	State Review of Oil and Natural Gas Environmental Regulations

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1 Introduction

The Roaring Fork Transit Authority (RFTA) and its VelociRFTA Bus Rapid Transit (BRT) program are unique in many ways. For example, VelociRFTA was the first rural BRT system in the United States and the operational environment of the VelociRFTA BRT is one of the most severe in the country, with extreme winter temperatures and altitudes close to 8,000 feet. RFTA viewed high altitude operation as the most challenging characteristic when it began considering the use of natural gas.

RFTA is the second-largest public transit system in Colorado behind Denver's Regional Transportation District (RTD), and it is one of the largest rural public transit systems in the country. In 2013, RFTA accepted delivery of 22 new compressed natural gas (CNG) buses that went into service after completion of maintenance and refueling facilities earlier that year. This paper examines the lessons learned from RFTA's experience of investigating—and ultimately choosing—CNG for their new BRT program and focuses on the unique environment of RFTA's BRT application; the decision process to include CNG fueling in the project; unforeseen difficulties encountered in the operation of CNG buses; public perception; cost comparison to competing fuels; and considerations for indoor fueling facilities and project funding.

2 RFTA History

RFTA's predecessor, the Roaring Fork Transit Agency, began operation in 1983 following the merger of transit services previously provided separately by the City of Aspen and Pitkin County. In November 2000, voters in seven jurisdictions in the Roaring Fork Valley created RFTA. The Roaring Fork Transit Agency was merged into RFTA in 2002. Currently, RFTA operates along a 70-mile corridor in Colorado's Western Slope, including the communities of Aspen, Snowmass Village, Pitkin County, Basalt, a portion of Eagle County, Carbondale, Glenwood Springs, New Castle, Silt, Rifle, and Garfield County. RFTA provides commuter bus service from Aspen to Glenwood Springs (Roaring Fork Valley), Glenwood to Rifle (Hogback), intra-city service in Aspen and Glenwood Springs, ski shuttle service to the four Aspen Skiing Company ski areas, Maroon Bells Guided Bus Tours, and a variety of other seasonal services (see Figure 1 for a map of RFTA's service territory).

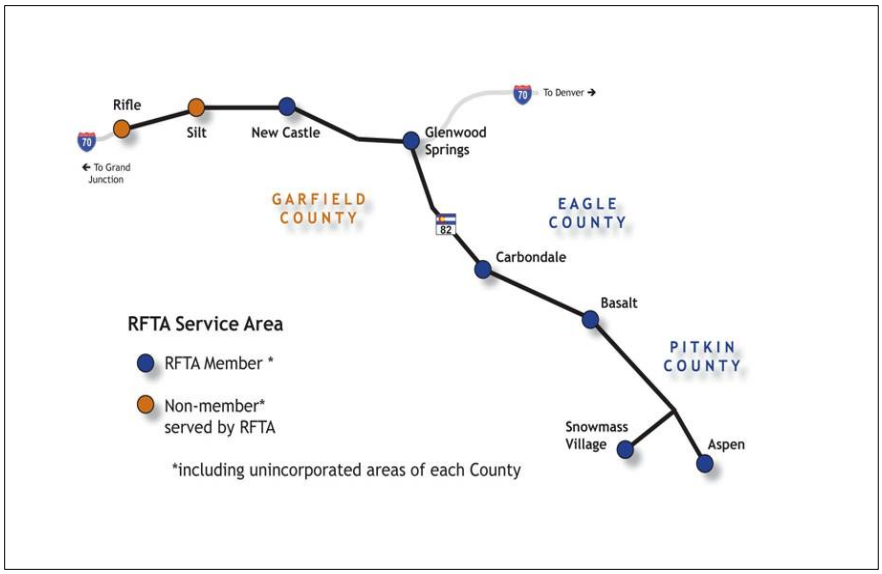

Figure 1. Map of RFTA service territory. ***Illustration from RFTA***

In 2014, RFTA served approximately 4.9 million passengers, similar in size to Newark, NJ,[1] making it the second-largest public transit system in the State of Colorado. Only Denver's RTD serves more customers, with 104M boardings in 2014.[2]

With a history of innovation and service, RFTA has been a leader in testing and deploying alternative fuel and advanced vehicle technologies in its buses. In recognition of these efforts and others, RFTA was named *Mass Transit Magazine*'s "Best Mass Transit System of North America" in 1996. In 2003, and again in 2006, 2009, and 2012, the Colorado Association of Transit Authorities (CASTA) named RFTA "Large Transit Agency of the Year". In 2012, RFTA was named a White House Transportation Innovator Champion of Change for developing

[1] "American Public Transportation Association: Ridership Report," accessed October 11 2015, http://www.apta.com/resources/statistics/Pages/ridershipreport.aspx.
[2] "Facts and Figures: RTD by the numbers," last modified January 2015, http://www.rtd-denver.com/factsAndFigures.shtml.

innovative ways to help advance the transportation industry. In 2014, RFTA received the Federal Transit Administrator's Outstanding Public Service Award. With a proven track record for innovation, RFTA was well positioned to take on the integration of CNG with their planned BRT.

3 Uniqueness of Application

Communities on Colorado's western slope have swelling populations, with an influx of visitors during the peak winter and summer seasons, and they are plagued by auto congestion and the lack of parking. The majority of the resort employees live in bedroom communities, where housing is more affordable, but this requires long commutes each day. As a result of this economic and employment activity, highway congestion has risen to unacceptable levels. To tackle this, in 1998 the Roaring Fork Railroad Holding Authority (subsequently merged into RFTA in 2001) commissioned a feasibility study of developing light rail on the 34-mile Rio Grande rail corridor, which extends from Aspen to Glenwood Springs. However, the estimated $370 million capital cost was unaffordable and infeasible given the resident population density of the region. In 2003, RFTA determined BRT was the preferred alternative because it would be considerably less expensive than the light rail option to address the region's current and forecasted mobility and highway congestion challenges. In 2009, project development began on the nation's first rural BRT system. Christened VelociRFTA and branded as fast, fun, and frequent, buses would run between Glenwood Springs and Aspen every 10 minutes during peak commute times in peak seasons, and every 12 minutes during the spring and fall (see Figure 2 for an illustration of RFTA's branding and messaging).

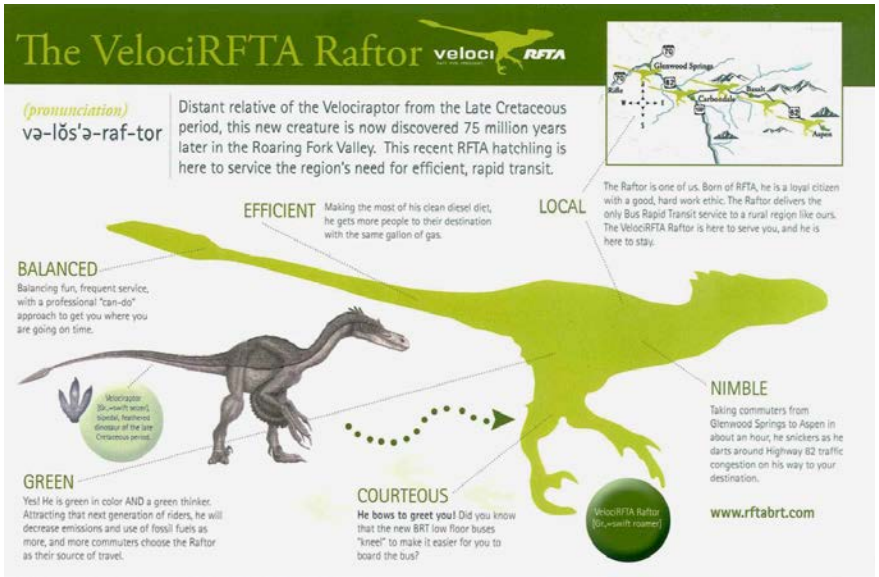

Figure 2. VelociRFTA advertising flyer. ***Illustration from RFTA***

RFTA and its VelociRFTA BRT program are unique beyond being the first rural BRT system in the country. The operational environment of the VelociRFTA BRT inflicts some of the most severe weather in the country, with winter time temperatures well below zero and altitudes close to 8,000 feet. High altitude operation was viewed as the one of the most challenging characteristics when RFTA began consideration of natural gas buses for use with the VelociRFTA BRT, which was an issue during previous experiences with the technology. Today, RFTA operates and maintains more than 100 heavy transit vehicles, including 22 CNG buses.

4 CNG Decision Process

The first priority for RFTA is moving people up and down the valley, and all other considerations were secondary. RFTA chose BRT as the low-cost option for mitigating the growing vehicle congestion issues in the Roaring Fork Valley. RFTA had been planning the BRT service for nearly 11 years prior to the decision to use CNG for the buses. The addition of CNG to the BRT program was made approximately 18 months (see timeline in Table 1) prior to the commencement of the VelociRFTA BRT service, creating a number of logistical and technical challenges with which RFTA expressed some significant concerns.

Table 1. RFTA's CNG Implementation Timeline

Aug 2011	• Initial Discussion on CNG as Potential Fuel for RFTAs BRT
Sept 2011	• CNG Solutions Summit Held
Dec 2011	• Facilities Upgrade and Fueling Infrastructure RFPs developed
Dec 2011	• Conditional notice intent given to Gillig
Mar 2012	• RFTA Board votes to move forward with CNG
Aug 2012	• Construction on facility and fueling facilities commence
Nov 2012	• Construction on facility and fueling facilities completed
Jan 2013	• Initial CNG buses received by RFTA
Jan 2013	• 4 CNG buses enter service for Winter X Games
July 2013	• Delivery of 18 CNG Buses
Sept 2013	• VelociRFTA BRT service commences with additional CNG buses

Many factors supported the decision to use CNG, including its availability as a domestic fuel source, increasing natural gas supply, lower price volatility, and fuel diversity, but economics played a significant role in the choice. Preliminary estimates suggested an annual fleet savings of $128,000 per year and a lifetime fleet savings of $1.54M based on a fleet of 22 buses, construction of a new fueling station, and modifications to the maintenance facility. At the time this was considered, traditional diesel prices were at historically high values and had presented real challenges to RFTA's operational costs. RFTA viewed the use of CNG favorably for a number of additional reasons, such as being an abundant and domestic fuel, having a track record of price stability, diversity of overall fleet fuel usage (i.e., hedging diesel use in other buses with CNG use in BRT), and lower overall fleet operating costs.

5 Project Due Diligence – Concerns and Hurdles

Due diligence in identifying and responding to stakeholder concerns was a high priority. This was especially important given the late decision to deploy CNG fueling in the nearly complete BRT service. Numerous stakeholders identified program trepidations and possible roadblocks at a charrette held by the Aspen Strategy Center. This resulted in more than 20 possible no-go scenarios, including:

Federal Transit Administration Concerns

- Project delays resulting from additional work to fuel on CNG
- Environmental permitting issues and impacts
- Additional long-term operating costs from CNG
- Demonstration that all issues related to fueling with CNG have been identified with a plan to address them

RFTA Concerns

- Bus performance
- Staffing for additional work
- Design, engineering, procurement, and construction of additional facilities
- Ability to modify bus purchase
- Training

Community Concerns

- Environmental impact
- Dialogue around natural gas extraction in the region
- Cost and schedule
- Technology familiarity.

RFTA was particularly concerned about bus performance due to its previous experience with CNG buses. In 1991, motivated by cost and environmental concerns, RFTA ordered one natural gas-fueled mini-bus for use as a shuttle. The bus was equipped with a gasoline engine that was converted to run on natural gas. While the technology used in the vehicle at the time does not compare to modern CNG vehicle technology, RFTA experienced significant performance problems and was unable to place the bus into revenue service without removing the CNG conversion. This failed investment contributed to initial hesitation in moving forward with CNG buses for the BRT services.

Given the amount of time spent planning the BRT service itself, the Federal Transit Administration (FTA) had serious concerns that the decision to order natural gas buses and install new fueling infrastructure would cause project delays, which could jeopardize project funding. FTA, RFTA, and the Roaring Fork community discussed concerns and worked together to develop solutions to provide a reasonable level of confidence in proceeding. In light of the

concerns identified and due diligence performed, RFTA made the determination to seek approval from RFTA's Board of Directors to proceed with purchasing CNG buses for the BRT service in March 2012.

6 Vehicle Performance

RFTA faced a unique operational variable in the use of CNG buses for their VelociRFTA BRT service: the altitude and road grade at which the buses would operate. Initially, RFTA voiced significant concerns regarding engine power loss at high altitude, which was an issue during its prior experience with CNG bus performance and technology. During the due diligence investigation, RFTA contacted a number of municipalities operating CNG buses at altitudes above 6,000 feet, including transit providers in Salt Lake City, Santa Fe, and Denver International Airport (discussed in more detail later). The Utah Transit Authority provided a favorable assessment of the use of CNG and reported on issues observed, such as lack of power at altitude in the earlier models. The Santa Fe Transit reported a similarly positive experience utilizing CNG bus engines from John Deere and Cummins Westport. RFTA also contacted multiple transit agencies using CNG buses to identify any operational differences between diesel and CNG. Their research indicated that, aside from a "softer start" due to slightly different low end torque curves, operation and driver perception were similar.

As part of the Aspen Strategy Center charrette and in subsequent conversations, RFTA discussed their concerns with Cummins Westport regarding high altitude performance of the Cummins Westport ISL-G engine. Cummins Westport provided reassurance by noting that more than 10,000 Cummins Westport ISL-G engines were now in service with 5,000,000 miles accumulated on CNG buses at 7,000 ft. The proven high altitude application of the Cummins Westport ISL-G engine represented a significant improvement compared to RFTA's previous experience with CNG when no true heavy-duty on-highway engines were available. To further alleviate any concerns, Cummins Westport emphasized the complete warranty coverage for its ISL-G engine.

Cummins Westport provided documentation stating that the ISL-G operates comparably to the diesel equivalent up to elevations of 6,500 feet. Above this altitude, peak power decreases at a rate of 3% for every 1,000 feet in altitude gain, while peak torque is unaffected up to 8,200 feet and then de-rates by the same 3% for every 1000 feet in altitude gain. CNG suffers a greater elevation impact than diesel because of the known efficiency loss between spark ignition CNG and compression ignition diesel. In effect, this means that at an altitude of 8,200 feet peak power would be approximately 6% less while peak torque would remain unaffected.

The quality of natural gas available in RFTA's service area was also an issue of concern identified during the evaluation process. Low-quality natural gas could affect engine performance, impacting the economics of the project and service dependability. Cummins Westport was instrumental in verifying the natural gas quality available to RFTA by the local utility and found no issues for concern.

7 Fueling Facility Field Trip

RFTA, in performing due diligence, visited the two largest fleet users of CNG in the state of Colorado. In September 2011, staff from the National Renewable Energy Laboratory (NREL) facilitated and guided tours of the natural gas fueling facilities for Denver International Airport and the City of Fort Collins. These tours allowed RFTA to witness firsthand how the operations worked and also to meet with the fleet and facility managers of each respective organization to discuss performance and concerns. In reflective discussions regarding these tours and their usefulness, it was RFTA's opinion that they were very persuasive in alleviating these concerns.

8 Design, Engineering, Procurement, and Construction of Additional Facilities

RFTA contracted with SGM Incorporated to manage the implementation of CNG with the BRT program. SGM is a multidisciplinary civil engineering, surveying, and consulting firm headquartered in Western Colorado near RFTA's Glenwood Maintenance Facility (GMF). For the design of the CNG fueling station, RFTA chose Trillium CNG™, which won a competitive solicitation to design, build, and monitor the fueling station. Specifically, solicitation laid out the following requirements:

- Fueling capacity up to 280 diesel gallon equivalent (DGE) per hour
- Single bus fueling up to 70 DGE in 15 minutes
- Redundant compression for backup fueling operations
- Dual dispensers, with single heavy-duty fueling indoors and light-duty fueling outdoors
- Ability to defuel into on-site storage (see Figure 3 for a picture of the de-fueling facility).

Figure 3. RFTA's CNG compressor station and de-fueling facility. ***Photo by George Mitchell, NREL 34978***

Trillium was also responsible for all fueling controls and integration as well as remote monitoring of all fueling operations. Final specifications for the GMF fueling facility were as follows:

- Up to 40 psi gas pressure service from the utility
- 4 stage compression
- 275 DGEs of on-site CNG storage
- 1200 amp electrical service
- 400 kW backup diesel generator
- Backup compression for redundancy and future expansion.

This level of service also correlated to an estimated operational cost for the CNG fueling station, leaving both electricity and natural gas costs as the only variable portion of the overall fuel price. With traditional fuels, price can depend on a variety of commodity, capital, and operating expenses.

Figure 4. VelociRFTA bus at indoor CNG fueling facility. ***Photo by George Mitchell, NREL 34949***

RFTA chose indoor fueling for their VelociRFTA BRT CNG buses (see Figures 4 and 5 for pictures of the indoor facility). The decision to include this feature was driven by their desire for a similar fueling process in the same facility for both diesel and CNG buses. This requirement is significant because it kept the experience very similar to the diesel vehicles. RFTA only identified one other indoor fueling facility supporting transit in the country—in Syracuse, New York—and RFTA connected with the facility managers to discuss insights and lessons learned. Through this discussion, RFTA recognized that it would likely have to make modifications to their GMF. RFTA consulted with Marathon Technical Services to determine the specific modifications necessary to accommodate indoor fueling of both diesel and CNG in the GMF.

Figure 5. Glenwood Maintenance Facility indoor CNG fueling pump. ***Photo by George Mitchell, NREL 34977***

During this phase, involvement of the local fire marshal was extremely critical. It was especially critical in this case as the City of Glenwood Springs, and the fire marshal, had a past negative experience involving propane fueled vehicles stored indoors. Working together, the consultant, fire marshal, and the contractors were able to come to quick agreement on the necessary GMF modifications, allowing work to progress. As mentioned earlier, indoor fueling of diesel buses already existed at the GMF, so a number of safety features unique to this application were already in existence. The indoor fueling requirement resulted in additional consideration of regulating codes and standards from a multitude of organizations responsible for buildings, fire code, and fueling standards, as well as plumbing and pressure vessels (see table 2 for a list of codes and standards consulted).

Table 2. Codes and Standards Consulted

2009 IBC – International Building Code
2009 IFC – International Fire Code
2009 IMC – International Mechanical Code
2009 IFGC – International Fuel and Gas Code
2009 IEC – International Energy Conservation Code
2009 IPC – International Plumbing Code
NFPA 30A - Code for Motor Fuel Dispensing Facilities and Repair Garages
NFPA 52 – Standard for CNG
NFPA 55 – Compressed Gases and Cryogenic Fluids Code
NFPA 70 – National Electric Code
NFPA 88B – Standard for Repair Garages
ANSI B31.3 Chemical Plant and Petroleum Refinery Piping
ASME Section VIII – Boiler and Pressure Vessel Code
NEMA – National Electrical Manufacturers Association
OSHA – Occupational Safety and Health Administration

To make the fueling and maintenance facility acceptable to local building and fire officials, modifications to the GMF included:

- Deflagration venting in the fueling area
- Overhead doors at each end of the fueling bay
- HVAC modifications consistent with relocation of ignition sources near the ceiling
- Electrical upgrades - Class 1, Div 2
- Improved ventilation
- Methane detection and controls.

The FTA had initially stated that there could be no delay in commencement of BRT service due to the late requirement of CNG fueling. Fueling infrastructure and facility modifications that began in August 2012 were completed in November of 2012. The entire maintenance and fueling facility became operational in January 2013, which was an exceptionally aggressive timeline for implementation.

9 Vehicle Selection

When RFTA first envisioned the VelociRFTA BRT service, the plan required a total of 18 dedicated BRT buses. At that time, RFTA was also scheduled to replace four transit buses used primarily in regional commuter service. RFTA ordered four 40-foot Gillig Low-Floor, Cummins Westport ISL-G replacement buses for its regional commuter service with the expectation that the buses would enable a shallower learning curve and serve as a test pilot for drivers and technicians, as well as the GMF. These buses were delivered in January 2013 and entered service coincidental with the commissioning of the GMF and first used to provide service during X Games Aspen. RFTA learned a great deal about cold weather operation and maintenance of CNG vehicles with these first four buses, including that a plug-in engine block heater would be necessary to enable CNG buses to start in freezing temperatures.

For BRT service, RFTA ordered 18 40-foot Gillig Low-Floor, Cummins Westport ISL-G buses (see Figure 6 for an illustration of the BRT buses) in December 2011; however, the order was placed prior to RFTA's decision to pursue CNG fueling and the buses were ordered with diesel engines. When RFTA decided to move forward with CNG in March 2012, the FTA stated that under no circumstances should the change interfere with the scheduled 2013 commencement of BRT service. RFTA consulted with Gillig regarding the delivery timing based on the late change to the CNG buses. Gillig indicated that it would take approximately 7 months to respond to the late change in vehicle fueling specifications. With this information, RFTA made the change, and 18 buses were delivered in July 2013 and entered service in September of 2013.

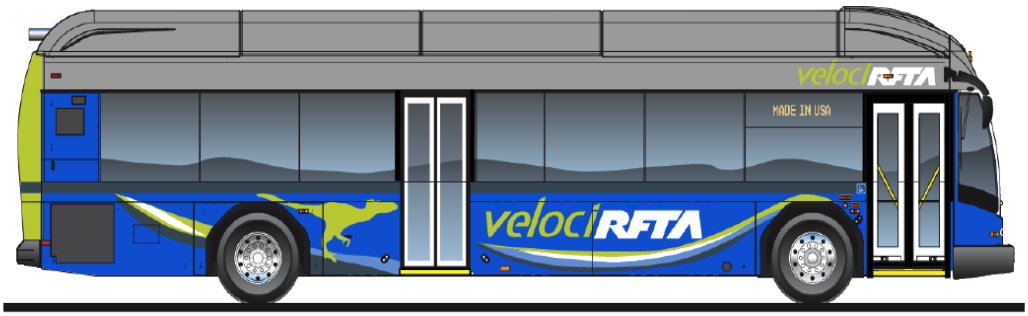

Figure 6. Illustration of the VelociRFTA BRT bus. ***Illustration from RFTA***

10 Public Concerns and Perceptions

As a portion of its due diligence effort, RFTA initiated dialog with the general public and RFTA's Board of Directors to solicit comment on the proposed use of CNG fuel in the BRT system. Without exception, that dialog centered around three specific issues: cost, technology familiarity, and environmental impact. For each issue, RFTA presented the intelligence it had gathered since 2011, solidifying its business decision and outlining the benefits, challenges, and uncertainties of CNG.

Cost Considerations

RFTA's CNG feasibility analysis was based upon the estimated "all-in" cost of CNG on a DGE, which compares CNG with the current cost for a gallon of diesel fuel. With the exception of a $365,000 Community Investment grant that RFTA received from Encana, RFTA's CNG cost/savings estimates did not include any other assumptions about subsidies from CNG infrastructure suppliers or engine/vehicle manufactures. RFTA developed a range of potential capital costs for the CNG fueling station, facility safety modifications, the incremental cost of CNG engine technology for 18 BRT buses, and the total cost of four CNG replacement buses. RFTA used its low and high range of CNG costs as a means of evaluating the financial feasibility of making the transition to CNG. Based upon this range of estimated costs, RFTA stated its confidence that the savings derived from using CNG—instead of diesel—to fuel 22 buses in its fleet should cover all of the associated capital costs and also generate a significant annual operating savings.

Additionally, RFTA performed a life cycle fuel and capital cost comparison of CNG, diesel-electric hybrid, and diesel buses. Based upon the commuter phase fuel consumption costs (i.e., the number of riders divided by number of gallons per mile), CNG vehicles were shown to have the lowest estimated overall fuel and capital life cycle costs per bus (even when the amortized fueling infrastructure costs were included).

Technology Familiarity

In response to the high price and volatility of diesel fuel and the potential instability of oil supplies, many transit systems across the United States have already transitioned to CNG. Today, approximately 25% of all new transit vehicles purchased in the United States are being equipped with CNG engine technology.[3] Natural gas is domestically produced, abundant, and the price has been relatively stable for the past 10 years.

While RFTA was initially hesitant to pursue CNG for BRT service due to its previous experience with the fuel in the early 1990s, RFTA admitted to a rapid change in its perception about the reliability of CNG engine technology. However, significant due diligence was completed to determine whether CNG engine technology was capable of working reliably and durably in RFTA's planned application.

Any transition to a different vehicle engine technology poses challenges. However, RFTA was confident any challenges resulting from the use of CNG could be overcome, just as they had been

[3] "2014 Public Transportation Vehicle Database," *American Public Transportation Association*, September 2014

when it began using a blend of biofuels or when it incorporated diesel-electric hybrid technology into its fleet. In order to ensure a smooth transition, RFTA had made plans to send one of its shop foremen to an ISL-G engine maintenance class provided by the Southern California Regional Transit Training Consortium. RFTA was planning to send this foreman to CNG Safety and Fuel Inspection courses in late 2015 and, subsequently, to provide similar training on-site for all of its Maintenance Department personnel. RFTA then developed a series of training programs for maintenance employees, drivers, and first responders to ensure a safe and smooth transition to CNG.

In the future, when other buses in RFTA's fleet are due for replacement, it is likely that some will be equipped with CNG technology. The potential for savings on fuel costs is significant, especially if diesel prices rise to traditional levels. Based upon performance to date, the savings will come from the lower all-in cost of CNG, as well as the better fuel economy experienced with CNG buses. Because the Aspen Maintenance Facility has not been upgraded to accommodate CNG vehicles, a portion of RFTA's fleet will continue to operate on diesel.

Environmental Impact

With regards to local air quality, RFTA presents emissions data provided by the Altoona Bus Testing and Research Center at Pennsylvania State University comparing the Cummins ISL diesel to the ISL-G CNG (see Table 3).

Table 3. Altoona Bus Testing and Research Center Emissions Data

	NMHC	NO_x	CO	PM
ISL-G	0.06	0.13	9.8	0.002
ISL Diesel	0.04	0.12	1.1	0.004
Heavy-Duty Emissions Standards	0.14	0.2	15.5	0.01

The results show nearly identical performance for non-methane hydrocarbons (NMHC), oxides of nitrogen (NO_x), and particulate matter (PM). Carbon monoxide emissions, while significantly higher for the ISL-G in comparison to the ISL diesel, are still less than 50% of the federal certification limit for heavy-duty engines.

In response to public concern regarding well-to-wheels emissions, RFTA presented expert testimony from Joel Swisher, PhD, PE on several sources of data comparing diesel to natural gas used in heavy-duty vehicles. These sources included California's Air Resources Board (CARB), Oregon's Department of Environmental Quality (OR DEQ), and the Northeast States for Coordinated Air Use Management (NESCAUM); they are reproduced below.

Table 4. Well-to-Wheels Emissions Data

	Direct Fuel CO_2 (gCO_2/MJ)	Upstream & Non CO_2 (%)	Efficiency Ratio (%)	Well-to-wheels GHG (gCO_2e/MJ)
		Diesel Fuel		
CA ARB	74.9	26%	100%	94.7
OR DEQ	74.9	22%	100%	91.5
NESCAUM	74.9	26%	100%	94
		Natural Gas (Heavy-Duty Vehicles)		
CA ARB	55.2	23%	90%	75.5
OR DEQ	56.3	25%	94%	74.7
NESCAUM	56.3	21%	90%	75.5

For the range of values given by the respective sources in Table 4, the well-to wheels GHGs were shown to be between 18% and 20% less for a heavy-duty vehicle when operated on CNG versus conventional diesel.

RFTA discussion served as a proxy for local as well as statewide discussions on hydraulic fracturing and extraction. Because of the significant amount of energy exploration and extraction in the State of Colorado, concerns were raised in relation to protecting the environment from possible impacts associated with the exploration for and extraction of natural gas. The following points were brought forward:

- At the time, Colorado had adopted the most stringent and comprehensive rules in the country to disclose chemicals used in hydraulic fracturing.
- The Colorado Oil and Gas Association, working with the Colorado Department of Natural Resources, developed a voluntary water quality testing program that will sample and make public water quality data before and after hydraulic fracturing.
- Due to the disparity in the economics of oil and natural gas, a fair amount of natural gas that is being produced was a co-product of crude oil. These products don't necessarily require separate wells, and in either case, will require some type of extraction.
- An independent study conducted by the non-profit organization State Review of Oil and Natural Gas Environmental Regulations (STRONGER) indicated that, although there is room for improvement, Colorado generally received high marks for its rules governing oil and gas operations and hydraulic fracturing.[4]

[4] "Colorado oil and gas rules score high in outside review," *Denver Business Journal*, October 31, 2011, http://www.bizjournals.com/denver/news/2011/10/31/colorado-oil-and-gas-rules-score- high.html.

11 Cost Sharing

RFTA's VelociRFTA BRT service was partially funded through the FTA's Very Small Starts Program for projects up to $50 million. Qualifying for the Very Small Starts Program resulted in a cost share for the BRT portion of the program of 54% to FTA and 46% to RFTA to cover the expected $46 million investment.

The decision to use CNG was estimated to add an additional $16.4 million to the cost of the original BRT program. Project expenditures fell into five categories highlighted in Table 5.

Table 5. BRT Program Project Expenditures

Project Category	Cost
22 CNG Buses	$10,715,000
Fuel Station Construction	$2,500,000
GMF Facility Modifications	$2,700,000
Project Management and Design Services	$390,000
Bond Insurance	$110,000

Funding to cover these expenditures came from three primary revenue sources: FTA grants ($9.4M), Qualified Energy Conservation Bonds issued by the State of Colorado ($6.65M), and a $365k grant for the fueling station from the Encana Corporation.

12 Field Experience

RFTA commissioned the VelociRFTA BRT service in September 2013. After nearly 12 months of service with the CNG BRT, RFTA began to understand its full potential. Initial performance results indicated a substantial savings per mile when compared to diesel. The following RFTA CNG facts were collected in August 2014:

CNG Buses

- 3.3 million miles fleet miles traveled
- 245,000 DGEs dispensed
- 5.7 miles per DGE
- CNG price - $2.68/DGE
- Fuel cost/mile – $0.47

Diesel Buses

- 4.7 MPG
- Diesel price - $3.42
- Fuel cost/mile - $0.72

Diesel Fuel Savings

- 52,872 gallons
- $362,123.

Today, with over 3.3 million miles of service, several unforeseen issues have arisen and some operational time has been lost. Compressor oil carryover was discovered as the result of multipoint failures on a couple of buses. Working with Cummins and Gillig, RFTA identified fuel filter service as the primary issue. Once identified, facilities personnel were trained to drain the filter with every fill.

RFTA identified integration issues between the Gillig chassis and the Cummins ISL-G engine when improper service of the vehicle's air cleaner resulted in complete engine failure due to ingestion of foreign material. Specifically, when Gillig integrated the Cummins ISL-G and associated fueling hardware, they had to relocate the vehicle's air cleaner from its original, desired location on a diesel bus. Because of the relocation, the removal and installation of the air cleaner cover became a blind operation on the CNG buses, sometimes resulting in improper installation. When installed incorrectly, this allowed road debris to bypass the air filter, causing permanent engine damage. Due to packaging constraints, the blind installation operation continues to exist. However, RFTA has adjusted its maintenance procedures to mitigate this issue.

Engine failure due to piston cracking began occurring within the first year of service. This issue could not be attributed to the unique operation of the RFTA BRT. When these issues appeared, the engine manufacturer, Cummins, stepped forward to repair the problem. At present, Cummins

has investigated the root cause of this failure and has addressed the problem by replacing the original pistons with a newly designed piston. As a result, there haven't been any failures for at least a year.

13 Current Perception

Two years after the launch of CNG BRT program, the internal perception is one of complete success. RFTA management, when asked, reply enthusiastically that they would attempt the program again. It is unclear as to whether the savings initially projected have occurred. With a long history of diesel bus operation and limited experience with CNG and BRT, it will take additional time to make an accurate assessment. In addition, the price of diesel has dropped precipitously over the past year and some experts predict the price will continue to decrease for a prolonged period.

While there have been issues, none have been insurmountable, and with the cooperation among Cummins, Gillig, and RFTA, each has been successfully overcome. It has been this cooperation that has kept the program on track and made it successful.

Community perception has been extremely popular, both from an acceptance of BRT and the use of CNG as a fuel. Usage of the VelociRFTA BRT has been overwhelming, requiring the use of diesel buses during peak periods to provide adequate capacity for passengers.

Drive acceptance has been high, with comments like, “It performs just like a diesel” and “It’s much quieter than a diesel.” Low overall vehicle noise level was also one of the reasons that CNG vehicles were acquired by RFTA.

In 2015, RFTA ordered a MCI motorcoach equipped with CNG engine technology. The bus is scheduled for delivery in December 2015. The approximate $700,000 cost of this vehicle is defrayed with a $300,000 Garfield County Federal Mineral Lease District grant, a $132,000 Department of Local Affairs Energy and Mineral Impact Assistance grant, and with RFTA local match funds.

14 Lessons Learned

RFTA sees the project as a success, but there were plenty of lessons learned in its execution. Each lesson helped to incrementally pave the way.

1. Seek the wisdom of others before reinventing the wheel. Let other entities guide your project in what works and what doesn't. Canvas other fleets to determine whether specific vehicle issues exist. Visit similar facilities to see how they have been implemented and what issues they've had to overcome.
2. Communicate with code and fire officials early and often. Bring local officials responsible for building and fire code enforcement into the discussion up front and be honest. The more comfortable they are, the smoother your program will be.
3. Think thoroughly through the procurement process. How will the specifications for the project be determined? How will it be sourced?
4. Involve all the stakeholders early to discuss the options for publically available fueling and maintenance options. These stakeholders can include counties, municipalities, auto dealerships, and private large fleets.
5. Make internal and external outreach a priority. Involve municipality building officials, fire officials, and fleet managers. Engage internal staff and Board of Directors directly. RFTA had political cohesion delivering a single vision involving a group with disparate needs.
6. Develop a strong working relationship with vendors. The relationship RFTA forged with Cummins and Gillig has helped in the continued success of the program.
7. Don't link projects. This is especially true when one is high risk and short timing. This single piece of advice will minimize the sleepless nights for all participants.
8. Train and educate stakeholders. From the initial investigation and design through implementation, it is critically important to train and educate all stakeholders, including building departments, fire marshals, first responders, maintenance and operations personnel, and even the riding public in all communities where the vehicles travel.
9. Consider information gaps. There is a continued need for more standardized building codes, training materials, and information sharing as it relates to CNG fueling and maintenance facilities.