Experiences with Compressed Natural Gas in Colorado Vehicle Fleets

Case Study Analysis

August 2012

Colorado Energy Office

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Abbreviations and Acronyms:

AFDC – Alternative Fuels Data Center

AFV – Alternative Fuel Vehicle

CEO – Colorado Energy Office (formerly Governor's Energy Office or GEO)

CNG – Compressed natural gas

CNGVC – Colorado Natural Gas Vehicle Coalition

DIA – Denver International Airport

DGE – Diesel gallon equivalent

DOE – U.S. Department of Energy

DOLA – Colorado Department of Local Affairs

GGE – Gasoline gallon equivalent

NREL – National Renewable Energy Laboratory

OEM – Original Equipment Manufacturer

psi – Pounds per square inch of pressure

RFP – Request for proposals

scfm – standard cubic feet per minute

Unit conversions:

Diesel Gallon Equivalent (DGE): One DGE contains 137,380 British thermal units (Btu)

Gasoline Gallon Equivalent (GGE): One GGE contain 124,340 Btu

Source: DOE Alternative Fuels Data Center (AFDC) http://www.afdc.energy.gov/afdc/progs/fuel_compare.php

Table of Contents

Executive Summary and Key Findings

Summary of Activities

This series of case studies is the product of in-person and telephone interviews with three Colorado fleet managers who use compressed natural gas (CNG) as a vehicle fuel and interviews with other CNG stakeholders. The fleets were selected using criteria that are intended to increase the usefulness of the overall product, including geographic diversity, length of CNG experience, diversity of vehicles, and ownership model. The case studies are based on a framework constructed with broad stakeholder input, designed to provide detailed information on fleet manager experiences with CNG vehicles and fueling infrastructure.

Other sources consulted to develop the information presented in the case studies include engineering economic analyses of CNG refueling systems and vehicles, knowledge and experience of Colorado Energy Office (CEO) staff, published reviews of CNG fleet experiences, national labs, CNG equipment manufacturers and engineering firms, and nonprofit organizations that promote CNG use. The draft case studies were reviewed by several CNG stakeholders prior to publication. The planning, procurement, maintenance, and other practices described in this study reflect those of individual fleets, and should not necessarily be construed as best practices for the industry as a whole. The results provided do not provide a substitute for site-specific analysis of CNG fueling infrastructure or fleet conversion projects. Numerous resources are provided to aid readers in their efforts to evaluate whether CNG is right for them. CEO can help further direct stakeholders to additional resources that address particular questions or challenges in greater detail.

Featured fleets include the following:

- Republic Services (Republic), a private sector waste and environmental management firm with a CNG fleet based in the Denver metro area;
- Denver International Airport (DIA), an airport with more than 15 years of experience with CNG and proven success as a CNG hub; and
- City of Grand Junction, a Western Slope municipality with a public/private partnership to provide public CNG fueling

	Grand Junction	DIA	Republic
Sector:	**Public**	**Public**	**Private**
Funding:	**Grants Internal Other***	**Internal**	**Internal**
CNG vehicles:	**7**	**221**	**34**
Near- to mid-term expansion plans:	**3 trucks on order**	**Add 25 to 50 vehicles**	**144 truck fleet replacement**
CNG use began:	**2011**	**1995**	**2011**
Vehicle types:	**Refuse trucks, other**	**Variety (most light duty)**	**Refuse trucks**
Fueling station:	**Time-fill and Fast-fill**	**Fast-fill**	**Time-fill**
Public refueling:	**Yes**	**Yes**	**No**
Payback period (years):	**10**	**7**	**2 to 3**
Fueling station cost:	**$1.3 million**	**$1 million****	**$2 million**
Current annual fuel savings:	**$40,000**	**$136,000**	**$420,000**
Maintenance cost changes due to CNG:	**Increase (not quantified)**	**25% increase**	**No increase**

*Vehicle registration fees
**Cost for 2006 upgrades; original station costs unknown

access.

Key Findings

In examining the experiences of the three fleets, several themes emerged that are instructive to the deployment of CNG vehicles and fueling infrastructure:

Decision to use CNG: A project champion is a key to any fleet's CNG deployment, but broad-based long-term support is also needed.

Management considerations: An organizational commitment to sustainable procurement can help tip the scale toward deployment of alternative fuel vehicles, including those that use CNG. For both public and private sector fleets, establishing the business case for CNG is crucial, as are vehicle performance and suitability for the applications in question.

Project accomplishments and metrics: Both DIA and Grand Junction have become catalysts for local expansion of CNG vehicle fleets and novel public/private partnerships because of their CNG fueling stations. Republic has achieved a 50 percent vehicle fuel cost reduction compared to diesel vehicles and has reduced compressor electricity costs by approximately 30 percent through compressor programming and use timing. Republic believes CNG has improved its brand recognition. Quantification of accomplishments and benefits is crucial to measuring success, maintaining organizational support, and building on existing deployment efforts.

Vehicle selection: Fleets are increasingly opting for OEM vehicles. Fleet managers are awaiting the release of more OEM pickups and a larger variety of heavy-duty engines. Availability of light-duty vehicles is still limited, which is a barrier to fleet expansion.

Fueling station design and economics: The design and costs of fueling infrastructure varied widely across the different fleets; fuel storage spheres and other equipment associated with fast-fill stations increase the upfront cost for fast-fill stations for public refueling access at Grand Junction and DIA. The total timeframe for station development ranges from four months to two years. Natural gas distribution system interconnection timeframes are a key variable in that equation.

Field experiences: Drivers and maintenance staff at Grand Junction and Republic are very satisfied with the performance of their newer refuse trucks. Grand Junction and Republic cite labor savings associated with reduced time spent fueling. DIA has a mix of old and new CNG vehicles and has some reported difficulties with fueling tanks in cold temperatures using fast-fill pumps. DIA also cites limits on payload capabilities for CNG pickups as an issue, though they are seeking to address these by buying new trucks with utility bodies. All fleets report some changes in maintenance procedures; maintenance increases appear to be greater for fleets with a wider variety of vehicle types and smaller fleets with more limited staff time to dedicate to new projects

Introduction

The Colorado Energy Office (CEO) [1] has prioritized the diversification of the state's transportation fuels portfolio as a means of increasing energy security, promoting environmental sustainability, supporting low energy costs for consumers and businesses, and driving job creation and economic development. To that end, Colorado's significant proven natural gas reserves create an opportunity to increase the use of clean, locally produced transportation fuels. The CEO has specifically identified natural gas as a viable, low-cost alternative to gasoline and diesel in vehicle fleet operations. A number of organizations in Colorado have transitioned their entire fleet or portions thereof to run on compressed natural gas (CNG), including the replacement or conversion of vehicles, the construction of fueling infrastructure, and modifications to maintenance facilities and/or practices.

The CEO commissioned this series of case studies to provide a blueprint for future CNG deployment in the state. The case studies document effective pathways toward realizing the financial, environmental, and other benefits of natural gas as a transportation fuel. The case studies provide information on numerous topics of interest to fleet managers who may be interested in CNG vehicles but have questions about whether it is the right fuel for them:

- Why fleet managers decide to use CNG vehicles,
- How fleet managers address concerns at both the managerial and maintenance staff levels,
- How fleet managers identify and select CNG vehicles that meet the demands of a given application,
- How to design, build and operate fueling stations in a cost-effective manner,
- What are field experiences from the perspective of maintenance staff and drivers,
- How much petroleum use can be displaced through the use of CNG, and
- What are the financial implications of CNG use?

Case Study Format

The case studies address the topics listed above and are organized as follows:

Background: This section provides an overview of the CNG fleet, including a project timeline, types of vehicles, the setting in which they are used, and the project's evolution from conception to implementation.

Decision to use CNG: This section addresses the motivation behind the switch to CNG and overall project goals.

Management considerations: This section describes any management considerations or concerns that required resolution prior to project implementation.

Project accomplishments and metrics: This section provides an overview of project accomplishments and metrics for the project. Greater detail is provided in subsequent sections.

Project funding: This section describes funding sources and requirements for the project, any barriers to obtaining funding, and how barriers were overcome.

Vehicle selection: This section describes how the fleet manager and other project participants identified and evaluated vehicles to meet the fleet's mission requirements.

Fueling station design and economics: This section describes how the organization designed, built, and operated its CNG fueling infrastructure.

Field experiences: This section describes the vehicle field experiences from the perspective of maintenance staff and drivers.

Lessons learned: This section summarizes key lessons learned for the different stages of CNG fleet deployment, including initial feasibility analysis, project approval, concept development and design, vehicle procurement, and operations and maintenance.

Selection of Fleets for Case Study

Criteria used in selecting fleets for study include fleet ownership, geographic location, vehicle type, and longevity of CNG fleet operation. Historically, CNG fleet vehicle implementation has been dominated by public sector fleets and select private sector fleets. Volatility in energy costs and improvements in the availability of CNG vehicles have spurred new interest in CNG by the private sector. Care is taken in these case studies to represent the business case for CNG in a manner informative to both private and public sector fleet managers.

[1] The Governor's Energy Office (GEO) was renamed the Colorado Energy Office (CEO) in July 2012.

Overview of Fleets Selected

Three fleets were selected to be the subject of these case studies. Republic Services (Republic) was selected because it is a private company and because its rapid adoption of CNG serves as a good illustration of the business case for CNG. Denver International Airport (DIA) proved an interesting subject due to its long history with CNG: the airport started using CNG vehicles when it opened in 1995 and has become a hub for CNG vehicles. Grand Junction, Colorado showcases the perspective of municipalities seeking to control fuel costs and support CNG adoption. Grand Junction also serves as an example of a public/private partnership to provide fueling access to vehicles outside the organization.

Republic Services (Republic). Republic is a national, privately owned waste and environmental management company with 350 locations in the United States. Republic uses CNG at 17 locations and began converting its Denver metro area fleet to CNG in 2011. It currently operates 20 CNG refuse trucks out of 144 total, and anticipates converting at least half of the fleet to CNG in the next two years.

Denver International Airport (DIA). DIA began using CNG vehicles when it opened in 1995. CNG vehicles meet emissions requirements to operate in the airport's two miles of underground tunnels. DIA owns 221 CNG vehicles; 35 percent of its light-duty fleet vehicles are alternative fuel vehicles (AFVs). Most of these use CNG.

City of Grand Junction. Grand Junction began using CNG vehicles in 2011 and currently operates five refuse trucks, a street sweeper, and dump truck. It has three more CNG refuse trucks on order, which will bring the total to eight out of 12 by the end of 2012. Grand Junction partnered with Monument Clean Fuels to provide access to fueling by other fleets and individual drivers.

Case Study: City of Grand Junction

Officials at the City of Grand Junction first began exploring alternatives to diesel fuel in 2007, when they commissioned a study on the potential to recover biogas (or renewable natural gas) from the city's wastewater treatment operations, refine the gas, and use it in vehicles or inject pipeline-quality gas into the natural gas distribution system. The study findings indicated that the potential biogas resource could support the entire fuel demand of the city's refuse hauling fleet. However, the cost to recover and upgrade the biogas at that time did not warrant moving forward with a project.

In 2009, the City of Grand Junction faced vehicle fuel budget shortfalls. City managers officials began seeking ways to reduce fleet costs, environmental impacts, and reliance on imported fuels. CNG represented a technically and economically viable substitute for diesel fuel. Refuse trucks once again were the focus of investigation, this time using pipeline quality natural gas, due to the availability of OEM equipment suitable for that application.

Fleet Facts

Ownership	Municipal
Funding sources	Grants Vehicle registration fees Internal funding
Total fleet vehicles	989
CNG vehicles	7
CNG use began	2011
Vehicle types	Refuse trucks (5) Street sweepers (1) Dump truck (1)
Refueling station	Time-fill for city vehicles and transit fleet partners Fast-fill public access

The city's financial and engineering staff researched available vehicle options and obtained bids from four vendors that offered side-by-side comparisons of CNG and diesel fueled trucks. Initial economic feasibility analysis suggested that CNG savings over diesel fuel would justify the incremental costs of the CNG vehicle purchases. The City Manager presented the case to the City Council, which approved the purchase of two CNG refuse trucks in 2010.

The number of CNG refuse trucks grew to five by early 2012, and the city soon ordered three more, bringing the number of CNG refuse trucks to eight (out of 12 total refuse trucks) by the end of 2012. The city has also added a CNG street sweeper and dump truck to its fleet.

Vehicles Used in CNG Fleets

Vehicle manufacturer	Refuse trucks: Mack TerraPro Street sweeper: Elgin Pelican Dump truck: International
OEM or retrofit	OEM
Engine manufacturer	Cummins Westport

The City of Grand Junction also built a time-fill CNG fueling station to serve its CNG vehicles and a publicly accessible fast-fill fueling station. The fast-fill station is operated by a private firm, Monument Clean Fuels.

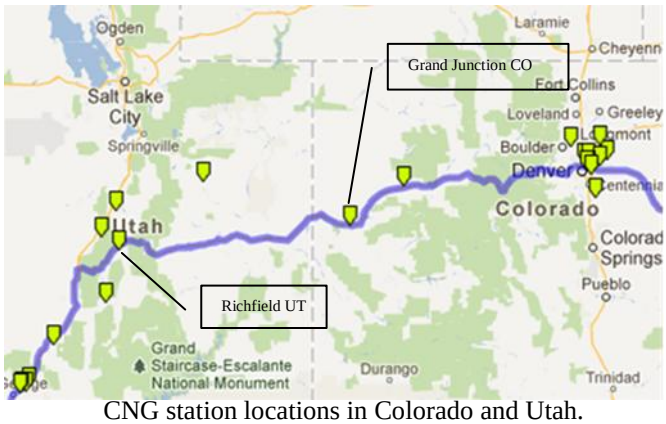
Decision to Use CNG

Fleet managers seeking to transition to CNG must contend with many questions about cost, performance, and other issues. City of Grand Junction Financial Operations Manager Jay Valentine cited cost savings as the dominant factor in considering the switch to CNG. Mr. Valentine noted that as the emissions performance of diesel technology improved, the cost of diesel trucks increased, thus narrowing the purchase price differential between conventional diesel and CNG-fueled trucks. Reducing vehicle emissions was the second highest factor, with energy security and energy self-sufficiency a close third.

Through the project, the city hoped to serve as a catalyst for increased CNG use in the region. Establishing refueling capacity in the region solves the "chicken or egg" dilemma that can and has impeded growth in CNG use. Without fueling infrastructure, consumers will not purchase CNG vehicles; and investment in refueling infrastructure can be risky without any guarantee of a market for the fuel. By including a publicly accessible fast-fill fueling station in its station design, the City of Grand Junction has made CNG vehicle ownership more feasible for consumers and other fleets.

The location of a fueling station in Grand Junction also moves Interstate 70 closer to being a viable corridor for

natural gas vehicles from Colorado to California, helping to fill a CNG fueling gap between Denver and western Utah.



CNG station locations in Colorado and Utah.
Richfield is 224 miles from Grand Junction.
Source: DOE AFDC

Yellow markers indicate CNG stations

The City of Grand Junction also developed a partnership with Grand Valley Transit, a county transit agency serving Mesa County, which now fuels two CNG buses at the City of Grand Junction's time-fill station.

Management Considerations

Project champions are a key element of any major organizational change. The City of Grand Junction's decision to implement CNG involved efforts from the City Manager's office, City Council, and project champions from multiple departments.

Mr. Valentine said that there was a lack of information at the time about vehicle availability and performance, operations and maintenance, and refueling system options that they could rely upon to guide their efforts.

The initial task was to establish that there was a vehicle option that met their application needs. Mr. Valentine coordinated this effort by soliciting bids for CNG and diesel refuse trucks. The resulting bids established that suitable vehicles were in fact available and quantified the incremental cost for CNG vehicle procurement. Mr. Valentine worked with the City Manager's office to get City Council approval to purchase the vehicles, with the understanding that investment in fueling infrastructure would be part of the overall project.

When the Council approved the purchase of the CNG refuse trucks, site-specific configuration and cost of the fueling station had not yet been developed. Terry Franklin, now Deputy Manager of the city's Utilities, Street Systems and Facilities Department, championed the technical effort to develop initial fueling station sizing and cost estimates. He relied upon a suite of CNG fueling analysis tools developed by the National Renewable Energy Laboratory (NREL), originally published in 2004, to develop alternative compressor station configurations and costs.[2] While the capital cost information was relatively dated, it provided a tool to compare the relative capital and operating costs for a variety of system scenarios. Mr. Franklin's efforts aided in the development of grant applications and station design procurement efforts.

One factor that helped convince the City Council to approve the CNG vehicle purchase was inclusion of a reference to a prior City Council resolution known as CORE (Conserving Our Resources Efficiently). This previously approved resolution committed to supporting resource conservation efforts by local government, including energy efficiency and pollution reduction measures that can reduce costs and enhance community sustainability and livability. The fact that CNG fit into a bigger commitment to sustainability that the City of Grand Junction had already established, even if it did not have specific procurement goals or metrics, helped push this project toward implementation.

Project Accomplishments and Metrics

Key accomplishments of the City of Grand Junction's CNG project include ongoing cost savings for the fleet and access to CNG fueling infrastructure for other fleets and the public.

Financial benefits: The City of Grand Junction did not apply a hard financial go/no go decision criterion to this project because it had a significant research, development, and deployment component. There are numerous public and ancillary, yet worthwhile, benefits to the organization and the greater community. Nonetheless, the financial performance of the project has exceeded expectations, with annual fuel cost savings of approximately $10,000 per year per CNG refuse truck, relative to diesel refuse trucks. This savings estimate compares diesel fuel costs at $3.33 per gallon in 2011 to the combined costs of operating and maintaining the CNG fueling station. Station operating costs include electricity purchase, natural gas commodity

[2] NREL, Compressed Natural Gas: A Suite of Tutorials, NREL/CD-540-37146, December 2004, on-line: http://www.nrel.gov/docs/gen/fy05/37146.pdf

Grand Junction Project Accomplishments and Metrics

Metric	Description
Annual petroleum offset (DGE)	34,150 DGE (12 month period from May 2011 – April 2012)
Refueling system cost	$1,358,458 ($240,457, or 18% paid for by City of Grand Junction)
Total cost of CNG vehicles	$1,072,620 for four refuse trucks
Incremental capital cost of CNG vehicles	$167,187 for four CNG refuse trucks
Annual fuel purchase savings	$40,000 for four CNG refuse trucks
Simple payback period	10 years, based on incremental vehicle cost plus City of Grand Junction investment in refueling system
Vehicle performance	Reduced vehicle emissions, noise, and odor Perceived minor power loss on steep hills
Maintenance impacts	Marginal increase in truck maintenance costs Fueling system limits ability to measure vehicle fuel efficiency
Economic development	Public fast-fill refueling station boosts interest in CNG vehicles Partnership with Grand Valley Transit to use time-fill station to fuel two new CNG buses increases utilization of time-fill station

purchase, and equipment maintenance, resulting in an estimated CNG cost of $1.14 to $1.34 per diesel gallon equivalent (DGE) between January and April 2012.

The city obtained grant funding and other financial support to pay for about 80 percent of the costs to develop the fueling station, and the city used its own funds for the remaining costs. The simple payback period to recover the incremental costs of the CNG refuse trucks and the City of Grand Junction's investment in the fueling station is 10 years, based on fuel cost savings from four refuse trucks. The project payback period will decrease as additional CNG vehicles are added to the fleet.

The positive financial outcome of the Grand Junction CNG fleet is not typical of smaller fleets that develop their own infrastructure. Recent analysis using the CNG Vehicle and Infrastructure Cash-Flow Evaluation (VICE) model developed by NREL suggests that the break-even point for investment in CNG infrastructure is highly sensitive to fleet size.[3] The investment required for a time-fill station is smaller than for a fast-fill station. As a result, for smaller fleets the payback period is shorter if the fleet opts for a time-fill system. Grand Junction installed a time-fill system to serve its own needs and a fast-fill station for public fueling.

Catalyzing deployment: This project resulted in establishment of a public/private partnership with Monument Clean Fuels, which provides public access to a fast-fill fueling station. Availability of publicly accessible fueling infrastructure has spurred increased interest in CNG vehicles in the region. The local Honda dealer, Fuoco Honda, now offers the CNG Honda Civic model for sale to the general public. Honda places stipulations on which dealers can sell CNG models, one of which is having sufficient fueling infrastructure available.[4] Another partnership is the investment by Grand Valley Transit in two CNG buses that fuel at the city's time-fill pumps, increasing the utilization of the fueling infrastructure. The project can rightly say that it has met its goal of serving as a catalyst for CNG vehicle and fuel demand in the Grand Valley.

Project Funding

Grand Junction purchased its CNG vehicles with its own funds. The CNG fueling station was funded with a combination of city funds, grants, and state vehicle registration fees. Grand Junction was confident in its ability

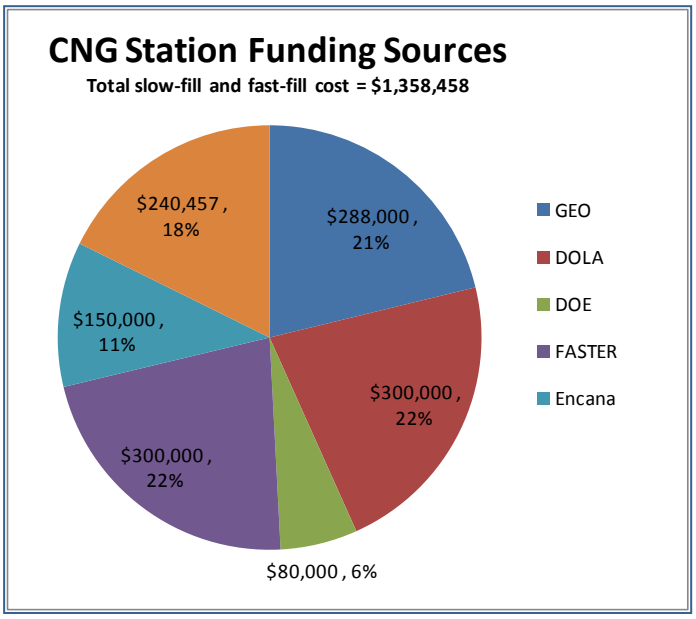
[3] NREL, Business Case for Compressed Natural Gas in Municipal Fleets, June 2010.

[4] Personal interview with Miles Proffitt, Sales Consultant, Fuoco Honda, Grand Junction, Colorado. June 7, 2012.

to secure grants for the fueling station because of the lack of CNG infrastructure in the area.

Overall, the City of Grand Junction paid for 18 percent of the capital cost of the fueling station, which totaled about $1.4 million. In comparison, fueling infrastructure for a retail gasoline station, including pumps, tanks and other dispensing equipment, totals about $500,000.[5]

The CEO, the Colorado Department of Local Affairs (DOLA), U.S. Department of Energy (DOE), and Encana all provided grant support to the project. The DOLA grant came from the New Energy Communities Initiative, offered jointly through CEO. The DOE funding came through its Energy Efficiency and Conservation Block Grant Program. Encana is a natural gas producer in Colorado. Additional funding was provided by the Colorado Department of Revenue via the FASTER program. The FASTER program was implemented in Colorado in 2009 and utilizes vehicle registration fees to pay for state road infrastructure.



Vehicle Selection

Schedule: Grand Junction makes vehicle purchase decisions on a staggered schedule based on vehicle age and application. Refuse trucks have a useful life that varies depending on loading technology.

Refuse Truck Useful Life by Configuration

Side-load: 6 years
Rear-load: 8 years
Front-load: 10 years

Grand Junction's first two CNG trucks replaced existing diesel refuse trucks that were due for replacement. Moving forward, when existing refuse trucks are retired, Grand Junction is replacing them with CNG trucks. Each purchase must be approved by the City Council. There are multiple benefits to a gradual replacement plan for the City of Grand Junction:

1. Gradual fleet replacement places less stress on the budget.
2. Grand Junction can maximize the value of its original vehicle investment.
3. A phased-in approach allows time to scale the fueling infrastructure to meet the demands of the fleet, reducing upfront infrastructure costs.

If a fleet wants to minimize the payback period for investment in fueling infrastructure, the fleet manager needs to take into account both fuel costs and vehicle acquisition costs. Grand Junction did not need to do this because grant funding enabled limited upfront investment in refueling infrastructure.

Equipment specification: Grand Junction chose an OEM equipment package (tractor, engine, and refueling system) rather than opting for a vehicle conversion. Grand Junction also selected dedicated CNG vehicles as opposed to bi-fuel vehicles, which use both natural gas and diesel fuel. This decision was based on availability of dedicated CNG vehicles that met its application needs.

Using OEM equipment means employees only needed to learn one diagnostics system and maintenance equipment purchases are more limited when compared to conversion or bi-fuel systems, which may have engines and diagnostic systems from multiple manufacturers.

Procurement process: The City of Grand Junction issued a request for proposals (RFP) for CNG refuse trucks at the end of 2009. All of the respondents, which included Faris Machinery, Autocar, Peterbilt, Heil, and Labrie, were from Colorado. The city selected Faris Machinery, a local dealer.

Personal interview with Jason Farrington, Monument Oil, June 16, 2012.

Chassis, body, and features were all important considerations in the selection process. Each CNG truck costs about $42,000 (18%) more than its diesel counterpart. The city initially ordered two trucks in early 2010. They were delivered in February 2011, roughly one year from the order date.

Vehicle choice: 2011 Mack truck with 2011 Wittke body

Incremental cost of CNG vehicle purchase:
The city paid for the first two CNG vehicles from its 2010 budget without any external funding. The city anticipated that fuel savings would offset the incremental cost of the CNG vehicles over time. Since the initial purchase, Grand Junction has purchased and received three additional CNG refuse trucks and purchased three more that are on order. The city also purchased a CNG street sweeper and dump truck. The city will not directly recover the $6,000 incremental cost of the CNG dump truck within the vehicle's lifetime because of its modest use profile. The city decided that the energy and environmental benefits of CNG justified the additional purchase costs of the vehicle.

Price for one diesel vehicle	Price for one CNG vehicle	Incremental cost for CNG vehicle
$226,359	$268,155	$41,796

Fueling Station Design and Economics

Grand Junction operates two CNG stations at its fleet maintenance site: a time-fill station and a fast-fill station. Three 40-horsepower compressors provide compression for both stations.

The time-fill station has 10 dispensers, or time-fill posts, that are used for the refuse trucks, sweeper, and dump truck. The time-fill station consists of a pole, hose, nozzle and associated plumbing and safety equipment. Average monthly fuel throughput for the time-fill station was 2,185 DGE for the most recent 12-month period.

During that period, the maximum throughput in a single month was 3,999 DGE, occurring in April 2012. When a CNG truck comes in for fueling, the driver connects the pump nozzle to the fuel tank. The truck then fuels unattended, reducing labor time needed for fueling. This process takes 2.5 to 3 hours if the truck's fuel tank is empty.

Grand Junction installed a fast-fill station that is accessible to the public as a condition of grant funding, but also as part of an overall desire to drive CNG vehicle deployment. The fast-fill station is operated by Monument Clean Fuels, a private company selected via an RFP process to be the retail arm of the project. Monument leases the land where the fast-fill station is located. As such, the public refueling station is available at a reduced total capital cost to the private partner, who pays for natural gas, compressor electricity use, and land rental costs while selling CNG to the public.

The fast-fill station looks more like a traditional gas station with a digital display, card reader, and pump nozzle.

Fast fill pump

The fast-fill station user interface is a military-style card reader system, which means that the card reader is separate from the pump a few feet away. Consumers who are new to the station or unfamiliar with typical fleet fuel tracking systems often have difficulty locating the card reader. Although there is no attendant, fleet employees are nearby and able to help those having difficulty.

Anecdotal experience suggests that the fast-fill station can sequentially fuel up to five cars fully, and most of a sixth, an unusual occurrence for the fast-fill pump. After such an

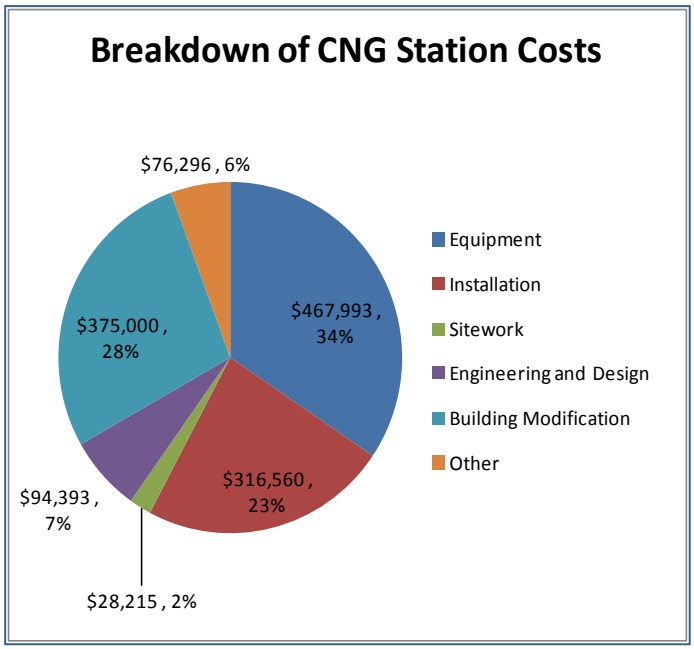
occurrence, the compressor will need to run for 2 to 2.5 hours to refill the storages spheres. Average monthly throughput for the fast-fill station is 661 DGE in the most recent 12 month period, with a maximum of 1,830 DGE for a single month.

The City of Grand Junction's CNG fueling station connects with Xcel Energy's natural gas distribution line. Natural gas is delivered at approximately 17 pounds per square inch (psi) of pressure. The City of Grand Junction had to take natural gas from a line located several hundred feet from the fueling location, even though a lower-pressure gas line was closer. According to Xcel, the closer line could not deliver natural gas with sufficient pressure to meet the needs of the compressor station. The line supplying the fueling station is an intermediate-pressure line with a maximum pressure rating of 150 psi, which could under special situations deliver pressures up to 20 psi. This better fit Grand Junction's needs for CNG compression.

City engineering staff was unclear on the reason for the need to use the line that further away, believed that it may have been associated with the utility's desire to ensure long-term service to nearby residential customers using the closer natural gas line. This illustrates a need for fleet managers and natural gas providers to communicate clearly and openly about their respective needs in order to ensure an efficient and cost-effective utility interconnection process.

Raymundo Engineering based in Walnut Creek, California, provided design services for the fueling station. The fueling station design/build process, from consultation to installation and construction of the refueling system, took approximately 12 months. GESI, now Mansfield Gas Equipment Systems, provided the fueling equipment, including three Ingersoll-Rand 40 horsepower compressors capable of delivering 174 standard cubic feet per minute (scfm) of gas.[6] The fast-fill station stores gas in three on-site spherical storage tanks with a combined total volume of 290 GGE. The fueling station commissioning coincided with the arrival of the first CNG refuse trucks in early 2011.

One drawback of the current fueling station configuration is that it does not permit tracking fuel use by vehicle, because the time-fill system has only one fuel flow meter. Additional flow meters have not been installed for each pump, due to the additional cost. This could result in missed opportunities for early identification of vehicle maintenance problems.



Costs. The total capital costs of the fueling station were $1,358,458 and are broken down by component in the chart below.

Equipment, building modifications, and installation costs were the largest cost components of Grand Junction's CNG station. Engineering and design were budgeted at 7 percent of the total cost, but this process ended up taking longer and being more expensive due to evolving design features that occurred throughout project implementation.

Field Experiences

Vehicle maintenance: There are a variety of changes in preventative maintenance procedures required when switching to CNG vehicles, including oil and other filter changes, specialized spark plug replacement, and changes in equipment diagnostics systems. One specific item cited by Grand Junction fleet supervisor Tim Barker is the need for specialized spark plugs for the refuse trucks. The plugs need changing every 1,500 to 2,000 hours of vehicle use. Each engine requires six spark plugs, costing $75 each. Another issue is related to the presence of "heavy ends" or "heavy oils" that can separate out from the CNG in the compressors.

[6] Mansfield Gas Equipment Systems, Recent Projects, online: http://www.mansfieldgasequipment.com/

There is a specific coalescing filter for the heavy ends on the vehicles that requires daily draining. If it is not drained regularly, in Grand Junction's experience the oil can get into the CNG fuel system and cause maintenance issues. Maintenance technicians at Grand Valley Transit were only draining this oil once per week, which resulted in performance issues. They have since adopted the once-per-day recommendation, and this has addressed the performance issues. In addition, compressor station maintenance procedures include draining oil from the compressor station itself on a daily basis. It is not typical to have to drain the coalescing filters this often. This issue may be caused by one or a combination of factors including:

- Water in the gas that the dryer is not removing,
- Oil carryover from the compressor, and
- Gas quality issues.

As of May 2012, the CNG, diesel, and gasoline vehicles all share the same maintenance shop. Grand Junction is building a new shop and retrofitting the existing one to accommodate new CNG vehicles joining the fleet. New maintenance facilities were not required for Grand Junction's recent addition of CNG vehicles; it is purely coincidence that maintenance facilities are being upgraded at this time to accommodate overall growth in fleet maintenance needs.

Intelligent procurement practices can often save money when a fleet purchases lubricants and specialized parts for CNG vehicles, particularly if the fleet can find non-OEM parts that do not compromise vehicle warranties.

Training requirements: When the project began, the vehicle maintenance technicians and drivers had no previous experience with natural gas fuel or technologies, so there was a learning curve for maintenance and fueling operations. Initially, the fleet manager and maintenance technicians worked together to learn new maintenance procedures from equipment manuals provided by engine manufacturer Cummins Westport. Beyond that, most of the training of new employees is on demand. When an issue arises, an experienced worker will show an untrained worker how to fix the problem. The workers are cross-trained on many systems, thereby engaging all maintenance staff in problem-solving. The fueling equipment manufacturer trained drivers on fueling practices and safety procedures. Such training is part of standard training and system orientation that any equipment vendor will pursue to ensure the success of a project.

Cummins Westport, a CNG engine and fuel system manufacturer, operates a virtual college for engine maintenance, which was a very helpful training tool for the vehicle technicians. Cummins Westport offers training CDs that the maintenance technicians watch during downtime or in dedicated training sessions. Three employees were also sent to an in-person CNG training hosted by Cummins Westport in Las Vegas.

One reported challenge is the inconsistency in maintenance recommendations among different sources, including engine manufacturers, truck manufacturers, and third-party training courses. For example, Cummins Westport suggests different routines than the truck manufacturers and third-party training courses.

Safety: City staff met with the fire marshal to inspect maintenance and fueling facilities and to educate the fire marshal about the fuel dispensing equipment and safety systems. The city's vehicle maintenance department does not have a dedicated CNG safety plan, but the city fire department is in the process of writing one.

Lessons Learned

The City of Grand Junction's CNG vehicle experience provides valuable lessons for other fleet managers who are considering converting to CNG, those who have already committed to CNG and are in the process of concept development and design, and those who are seeking ways to improve operations and maintenance in existing fleets.

Project implementation: Initially, the City of Grand Junction had difficulty finding information about vehicle performance and compressor station sizing and configuration. Grand Junction staff overcame this barrier by working closely with vendors and seeking technical assistance via CNG station sizing/configuration tools available through the National Renewable Energy Laboratory (NREL).

Grand Junction now requires inclusion of hybrid or CNG vehicles as part of its procurement process, which facilitates consideration of CNG options.

Natural gas interconnection costs were higher than anticipated because of a need for increased trenching to a natural gas line that the natural gas provider believed would meet the fueling station's long-term needs. Clear communication between natural gas providers and potential CNG fleets on the needs of both parties could facilitate a shorter, less costly interconnection process. By consulting

with the local utility, a fleet should be able to identify a site location that integrates with the utility's distribution system in the most cost-effective way possible.

A clear understanding of the project's fueling infrastructure requirements (including CNG demand, end users, local market, and team structure) will help in developing system specifications. This can reduce costly engineering design changes and project delays. Grand Junction learned that working with a firm without a local presence can stretch out design timeframes and potentially increase costs. For this project, the engineering costs were approximately 7 percent of the total, which is not unreasonable. However, because of multiple design changes associated with an evolving project purpose, the process was perceived to be more costly than it could have been.

Grand Junction was successful in obtaining grant funding for the project, but in the future, such funding may be less readily available. The city completed the project with the anticipation of growing its CNG fleet size to improve its return on investment. Without grants to defray the fueling infrastructure costs, it is unlikely that the city would have pursued the project using the same approach. One observation was that future projects will need to be more careful to ensure that they can justify their project when refueling infrastructure costs are not funded by grants.

Vehicle maintenance: As with all purchasing processes, fleet managers should shop around when seeking replacement lubricants, filters, and other specialized parts for CNG vehicles. By comparing specifications of OEM parts with those available on-line or other means, crews can reduce vehicle maintenance costs by using non-OEM components to the extent that doing so does not violate the terms of engine warranties.

Engine manufacturer Cummins Westport has numerous training resources and opportunities for vehicle maintenance staff that are a valuable fleet resource.

Fueling station: The Grand Junction fleet staff recommended installing fuel metering equipment for each pump, if it can be done cost-effectively. This would allow for predictive maintenance based on individual vehicles' mileage.

The public/private partnership between Monument Oil and Grand Junction serves as a model to limit financial risks for a private partner seeking to provide public access to a CNG fueling station. This partnership provides a bridge to a future time when the number of CNG vehicles on the road justifies investment in a purely private sector station. This interim measure ensures that the private sector is leading the effort to market CNG to consumers.

At the publicly accessible fast fill station, a dispenser with an integrated card reader would likely be more user friendly than a dispenser with a detached card reader.

For most fleets, there is a lack of information on how to manage energy use and cost of compressors. There is a significant learning curve required to develop an understanding of how to spread electricity demand from compressors over time to avoid demand charges.

Case Study: Republic Services

Republic Services (Republic) is the second-largest waste management services company in the country and operates in 2,800 communities. Republic has the benefit of having 17 fleets in the process of conversion to CNG operation.

Republic offers the perspective of a private sector company with national reach, where cost-competitiveness and customer satisfaction are paramount, and fleet capital investment decisions are carefully weighed against alternatives by a board of directors.

CNG vehicles currently represent a small portion of Republic's total Denver metro area vehicle fleet. Because of the relatively early stage of implementation of CNG in the Denver area, this case study looks at Republic's experiences through several lenses:

1. Nationwide financial and technical experiences
2. Recent prior experiences with natural gas deployment in the company's Boise, Idaho fleet, which has many operational similarities to the Denver fleet
3. Local implementation in the Denver area.

The company's goal for its Denver fleet is to run 50 percent of its vehicles on CNG in the next 1.5 to two years.

Fleet Facts

Fleet	Republic Services
Sector	Private
Funding sources	Private (Denver metro fleet)
Total fleet vehicles	144 revenue-producing
Total CNG vehicles	20; 14 more coming in 2012
Start of CNG use	February 2011
Vehicle types	Heavy-duty refuse trucks
Vehicle manufacturer	Autocar ACX
OEM or retrofit	OEM 100% CNG
Engine manufacturer	Cummins (ISL-G engines)

Decision to Use CNG

Republic believes that the switch to alternative fuels, including CNG, is the right thing to do for investors, customers, and the environment. The biggest drivers for CNG were fuel cost reduction, emissions reduction, and fuel cost stability over time. CNG offers lower fuel costs and better price stability than diesel fuel does. As EPA diesel vehicle NO_x emissions standards began requiring selective catalytic reduction (SCR) technology in 2010, Republic began evaluating less costly emissions compliance options. CNG already complied with NO_x requirements and offered a ready solution. Coincidentally, Cummins Westport began selling CNG engines that offered reliability and performance characteristics that older natural gas engines did not.

Republic's CNG decision-making criteria

- Fleet size: 50 trucks or larger
- Property ownership: Own the property, not lease
- Natural gas infrastructure: Access to natural gas distribution lines within a trenching distance that meets the financial needs of the project
- Zoning/permitting: Processes are not burdensome
- Truck replacement plan: Sufficient number of trucks must need near-term replacement.
- Availability of grants/incentives: Influences investment but is secondary to other factors.

Management Considerations

Republic operates 350 hauling divisions nationally. The company makes large investments at the corporate level and has several levels of approval. Each investment decision is ultimately site-specific and is made within the context of the entire fleet operation. Site-specific cost constraints are applied to items such as gas pipe trenching and zoning/permitting. Once these initial hurdles are overcome, Republic evaluates technical considerations, such as refueling site layout, station design, and parking lot layout, as well as maintenance shop improvements necessary for compliance with local fire and safety codes. A go/no go decision is made taking into account all of these factors.

If a project is approved, Republic negotiates contract terms with Clean Energy Fuels for fueling station development. The development timeline can range from three months to two years until commercial CNG operations commence.

Republic's Denver Area Project Accomplishments and Metrics

Metric	Description
Annual petroleum displacement (DGE)	260,000 (2012) 1.12 million for entire fleet at full implementation
Fueling station cost	$2 million
Incremental CNG truck costs	$25,000 per truck
Annual fuel savings	2012: $420,000 Full project: $1,811,040
Simple payback period	2 to 3 years
Vehicle performance	Better branding Quieter 22% lower GHG emissions
Maintenance impacts	Minimal

CNG vehicle purchase decisions are made via Republic's 10-year fleet replacement planning process. A prerequisite for the Boise fleet was obtaining a contract extension with the city. This was needed to ensure an adequate long-term revenue stream to support Republic's investment in infrastructure. In Colorado's Front Range, waste management companies compete for government, commercial, and industrial clients. As a result, Republic is not dependent on any single client for its revenue stream there. This lessens the risk that loss of a single large customer would negatively impact the returns after the company made the needed investment in CNG infrastructure and facility improvements.

Project Accomplishments and Metrics

Republic's transition to CNG began in Boise in 2009, while the Denver project started in 2011. As such, the Boise fleet is further along. At the end of 2012, Republic expects to have about 34 CNG trucks operating in its Denver metro area location. Republic expects to displace about 260,000 gallons of diesel annually. When the fleet transition is complete, about 1.12 million gallons of diesel will be displaced annually.

Financial impacts: Republic's payback periods for the investment in fleet vehicles and refueling infrastructure usually range from two to three years, and the return on investment capital (ROIC) must exceed 18 percent. The payback period for introduction of CNG vehicles at Republic's Boise location was less than one year, which leaves little room for disagreement in terms of project cost-effectiveness. These payback periods are particularly compelling when considering that in many markets, contracts with municipalities do not allow capital cost recovery within the first year; instead they require Republic to stagger cost recovery over multi-year periods.

Republic has not yet delivered a large enough number of CNG trucks to its Denver metro fleet to justify a detailed site-specific analysis of commodity costs, taxes, amortization, and electricity costs. Republic usually develops this information after CNG represents 25 percent of the fleet; in Denver that would be 36 CNG vehicles. However, Republic anticipates savings to be similar to those in other locations.

Republic is realizing savings of about $8 per engine hour in other CNG deployment locations when amortization of all investment is included. Fuel savings alone per engine hour, compared with diesel, are approximately 60 percent, even when considering a 12 percent reduction in fuel efficiency with CNG. Depreciation/amortization of the compressors, connection to the natural gas network, time-fill fueling infrastructure, and shop improvements add additional cost per engine-hour, but the savings per engine-hour usually remains in the 50 percent range compared to diesel fuel costs. Republic noted that no other alternative currently exists to generate savings of that magnitude. These financial returns are well in excess of Republic's internal targets and the cost of capital.

Other benefits: Republic's customers have been very supportive at every step of the way. Driver acceptance due to decreased odors and cleaner operations has been substantial. For Denver and the surrounding metropolitan area, obtaining new CNG trucks has increased visibility of

Republic's brand. There has been consolidation in the industry in the Denver metro area, and replacing older trucks with new, fully branded and clean CNG vehicles is important to making Republic stand out among its competition.

Emissions benefits from Republic's CNG use are substantial with Republic citing a greenhouse gas emissions reduction of 22% over their diesel trucks.[7]

Project Funding

Republic reviews CNG fueling plans as part of its capital allocation process. Through that process, Republic evaluates cash flow and returns to make funding decisions on competitive needs while considering the business needs of the local divisions.

Republic funded the entire Denver metro area project internally; the total capital cost of the fueling infrastructure and shop improvements was approximately $2 million. No incentives were used. This is typical, but Republic has received grant support for other projects. For example, Republic received U.S. Department of Energy (DOE) support for the Boise fleet conversion to help pay for fueling infrastructure and public access fueling.

Vehicle Selection

Schedule: At a regional level, Republic annually updates its 10-year truck plan and determines which units should be CNG or diesel as vehicles come due for replacement. Republic selects three to five locations in each region for CNG deployment each year, and then tries to accelerate the truck replacement process in those locations to move two or three years' replacements into a single year. In the

Denver metro area, Republic was unable to accelerate truck replacement due to the unique configurations required by Colorado weight laws. Instead, Republic's normal 10-year replacement schedule is being followed.

Equipment specification: Republic purchases trucks with AutoCar chassis, but varies body manufacturers based on the application and sector.

In some residential neighborhoods with alleys and commercial locations in congested areas, Republic needs to purchase some rear-loading trucks that are loaded by hand. Republic also purchases front-load and side-load vehicles that allow both manual and automatic loading.

Fueling Station Design and Economics

Each Republic location is unique. The design of the compressor station, parking and fueling options, and facility upgrades needed to comply with building, fire, and safety codes are completed and approved based upon current and anticipated fleet and business needs.

Truck configurations vary. Shown: automatic loading AutoCar chassis with McNeilus body

All utility connections are sized to handle the complete transition of the fleet to CNG, which often requires interconnection to higher-pressure gas pipelines instead of the local gas distribution network.

The Denver metro fleet fueling station was initially designed to serve 88 trucks, with a concrete pad, electrical, and plumbing for a second compressor skid, which would enable the station to eventually serve 144 trucks after a second phase of development. The station has 88 time-fill pumps. CNG use by Republic refuse trucks ranges from 3.5 to 4.5 DGE per engine hour. Each CNG trucks use 30 to 33 DGE of CNG per day, 12 percent more fuel on a heat input basis than conventional diesel. As of June 2012, total monthly CNG use is averaging about 13,700 DGE per

[7] Republic's greenhouse gas emissions reduction is based on a study published by the California Energy Commission:

TIAX LLC. Full Fuel Cycle Assessment, Well to Wheels Energy Inputs, Emissions and Water Impacts. Rep. no. CEC-600-2007-003. Sacramento, CA: California Energy Commission, June 2007.

This is an area of ongoing study as there is currently a significant variation in GHG emissions estimates for natural gas.

month at the Denver metro location. By the end of 2012, 260,000 DGE per year, or approximately 25 percent of total vehicle fuel use of 1.12 million gallons per year, is projected to be offset by CNG.

Republic's trucks fueling at CNG station.

Clean Energy designs and constructs Republic's fueling stations, including the one at the location in the Denver area. Republic owns the station, and it has an operations and maintenance (O&M) contract with Clean Energy to monitor and maintain the stations. Clean Energy monitors its CNG fueling stations remotely from its Seal Beach, California, location and provides maintenance on an ongoing basis using local technicians.

With the benefit of previous experience in working with CNG, Republic was able to make the decision move ahead with the Denver station in May 2011 and open the facility for time-fill operation by late September 2011

Republic indicated that it has run into significant differences among utilities in terms of timeframes for interconnection at its various sites around the country. Station interconnection timeframes can range from four months to two years, depending on the regulatory climate, complexity of the development, distance to interconnection to the local distribution network, and other project details.

The utility connection with Xcel Energy in the Denver area was simple, because the gas distribution line in front of the property was large enough with high enough pressure and volume to handle up to about 250 trucks. Just over one year elapsed between the time Republic made the decision to convert to CNG to first fueling of trucks including utility connections, equipment purchase, and construction.

The equipment for Republic's CNG stations is fairly standard and consists of two or three compressors, a dryer, meter set, 60 to 100 DGE of storage, and between 40 and 130 time-fill fueling spots where the trucks park. The Denver metro station has two 250 horsepower (hp) compressors, each with a CNG flow rating of 450 standard cubic feet per minute (scfm), for a total of 900 scfm. Each compressor can deliver 3.25 DGE per minute or about 200 gallons per hour. The trucks fuel simultaneously, usually during late evening or after midnight, when electricity costs are lowest. Each compressor can fuel six to seven trucks simultaneously. The system is designed to be redundant, so that if one compressor is not available, another compressor can handle the fueling needs of the entire fleet. Usually, Republic alternates the compressors, using one on even days and the other on odd days, to minimize the electrical draw and the demand on the electrical grid.

There is no public fueling component to the Denver area CNG station. The site is immediately adjacent to Adams County vehicle maintenance facility, but Republic did not pursue a partnership from the outset because the configuration of the site did not provide easy, safe, and cost-effective access to Republic's property. This is different from the Boise location, where a U.S. Department of Energy (DOE) Clean Cities grant was used in part to fund the station. A requirement of that grant was to include a public fueling component, which is run by Clean Energy.

Costs: All in, CNG costs Republic between $2 and $2.25 per DGE at its Denver area location. This is slightly higher than at other Republic locations, primarily due to the slower truck replacement schedule and relatively small number of CNG vehicles at the present time. Republic expects this cost to drop by about $0.40 per DGE as more trucks are delivered and it can spread the cost of the infrastructure over more fuel each day. Even so, current costs compare favorably with retail diesel costs in EIA's Rocky Mountain Region, which averaged $3.87 per gallon in 2011. Fuel cost savings per DGE range from $1.62 to $1.87, based on 2011 diesel prices.

Republic has invested time in understanding how utilities buy and sell electricity so that it can optimize costs. Nationally, Republic has reduced electricity costs by an estimated 30 percent by timing compressor use. At the Denver area location, as elsewhere, compressor electricity use is metered separately from the facility, so it is not difficult to quantify compressor costs or savings that can be gained through better energy management.

Natural gas hedging provides a means for natural gas customers to protect themselves against a financial loss due to volatility in future natural gas costs. Hedging reduces risk by ensuring predictability of costs, but in the process, it can result in additional transaction fees, price premiums, and other costs. There are many types of hedges, but they are typically divided into two categories:

- Physical: Examples include controlling volume of use and establishing fixed price contracts.
- Financial: Examples include investment in natural gas futures, swaps, options, or weather derivatives.

The benefits and costs of hedging need to be carefully weighed. Republic does not use natural gas hedging to control fuel costs on the commodity side, but rather to recover any fuel cost increases using a fee that is applied across customer invoices.

Field Experiences

Republic has had to make some changes for training, vehicle maintenance, and safety procedures and protocols. The change has not been dramatic, and Republic reports that in the Denver area operations, there is as of yet little measureable change in vehicle maintenance costs.

Vehicle maintenance: From a vehicle performance standpoint, there have been no changes. Maintenance procedure changes were minor and have not posed significant challenges.

Trucks are parked between nine and 12 hours per day at the fueling station. The driver pulls up to the CNG parking spot and connects to the CNG dispenser. The CNG fueling station reduces driver overtime for Republic, because it eliminates 10 to 15 minutes per driver per day spent waiting for the truck to fuel with diesel. According to Republic, when the drivers return in the morning, the trucks are fueled and ready to go.

The CNG trucks do have a slightly reduced driving range compared to the diesel trucks they replace. Nationally, a few of Republic's higher mileage routes have to take on some fuel during the day. However, this is a rare exception rather than the rule. Republic's refuse trucks can operate for a 10- or 11-hour shift on a 60-DGE-capacity tank without needing to refuel.

Training requirements: Drivers receive annual training of approximately one hour per year, including a 15 minute video on fueling procedures and safety, produced by Clean Energy/Avatar. Technicians receive training from Autocar and Cummins Westport with periodic recertification.

Safety: In accordance with Occupational Safety and Health Administration (OSHA) rules, Republic follows a lock-out tag-out (LO/TO) program for vehicle maintenance to ensure that vehicle engines are not started accidentally when maintenance technicians are working on them. This program has been maintained and has not changed much as a result of CNG vehicle implementation. Welding on units requires extra safety lock out procedures. Tanks are emptied (using a separate natural gas caddy) and removed before torches are used. Arc welding poses particular risks for CNG vehicles. Electric arcs from the vehicle to the fuel system can cause damage to the high-pressure system if not properly grounded.

The Denver area maintenance shop required significant facility safety improvements to meet building code requirements, including an air makeup system with a gas-monitoring system, a demising wall to physically separate the area monitored for gas from the remainder of the maintenance shop, conversion to infrared heating (open flame heating is not permitted), and auto-opening doors, among other ventilation system improvements. The air makeup system ensures that exhaust air from the CNG maintenance area is kept separate from intake air to prevent accumulation of methane gas. The use of a demising wall to physically separate the area where CNG fueling systems are maintained eliminates the need for methane monitoring in the entire maintenance building. In total, these improvements cost about $250,000. The system has operated well, and there has not been an alarm yet for air quality in the shop area. By comparison, the Boise maintenance shop upgrades cost approximately $30,000, because the facility was smaller and newer.

Because fire codes vary regionally in their interpretation, Republic consults with a professional engineer (P.E.) to coordinate with fire chiefs and county officials on which facility improvements are required, how to operate CNG equipment, manage any emergency circumstances, and provide general education on safety for tanks (e.g., tanks vent when they exceed certain temperatures) in the event of truck fires. Republic notes that communication with first responders is a critical part of its community partnership practices.

Lessons Learned

It is notable that the financial performance of CNG is such that Republic at a corporate level has consistently opted for

CNG vehicle fleet implementation time and time again. Republic notes that total investment across the company for CNG infrastructure and vehicles has exceeded $250 million since 2009.

The transition to CNG vehicles was not as significant a maintenance and training transition as many expected, although this depends on the specific fleet circumstances.

CNG vehicle performance for Republic's fleets has been comparable to that of diesel trucks. With few exceptions, the time-fill fueling stations are able to support vehicles working a full shift without the need to fuel during the day. Reduced vehicle noise, emissions, and odor have been positives for drivers and customers, and new trucks have been helpful for improving Republic's brand recognition.

Republic has had significant success in reducing compressor electricity use and costs by programming and timing compressor use.

Station interconnection with the natural gas distribution system is critical to implementing CNG, and fueling station providers should have an understanding of the utility interconnection process before beginning work. Connecting stations with the natural gas distribution system, along with phasing truck replacement, have been the biggest challenges for Republic in implementing CNG. Based on its experiences around the country, Republic recommends doubling the timeframe expected for interconnection in planning for a CNG station, as a general rule of thumb.

Local fire team education is important, as code interpretation varies significantly by locality, and truck fires in the waste industry happen more frequently than one might expect. A number of states have adopted the International Fire Code (IFC), which references the National Fire Protection Association Code 52 Vehicular Gaseous Fuel Systems Code as the standard, although any individual Authority Having Jurisdiction (AHJ) may apply this code differently. Colorado is a home-rule state, in which municipalities can adopt their own codes. Therefore, local CNG fleets need to refer to the codes included or referenced in their local government charters.

Given the significant investment surrounding CNG, Republic's board has ongoing discussions regarding its CNG fleet build-out plans. It is important to include all parts of the organization in the information-gathering and decision-making processes.

CNG fuel use for waste-collection operations in the western U.S. are currently in excess of 25 percent of all gallons consumed. Republic operates in 13 western states (including Texas and Oklahoma). Expectations are to move CNG to a 60 percent share for collection trucks over the next four to five years through the addition of more CNG stations and trucks. As Cummins and other engine manufacturers bring additional options for 12- and 15-liter engines to market, the fleet transition process will accelerate across Republic's operations. Limitations to the conversion process include the ability to manage the conversion process, small displacement size of the ISL-G Westport 9-liter engine, and access to the natural gas distribution network.

Case Study: Denver International Airport

CNG use at Denver International Airport (DIA) began as a way to safely and cost-effectively operate vehicles in DIA's two miles of underground tunnels. Today, buses, tugs, loaders, baggage carts, light-duty pickups, street sweepers, and a variety of other vehicles all operate on CNG. In all, 221 dedicated CNG vehicles are in use at DIA. In addition, CNG use at DIA has expanded to include many other vehicles operated on the airport's 53-square-mile territory[8], such as private rental car and parking shuttles fleets (USAirport Parking, Canopy Airport Parking, WallyPark, and Parking Spot) that operate adjacent to the airport.

Fleet Facts

Fleet owner	City and County of Denver
Funding sources	Airlines and concessionaires
Total fleet vehicles	1,080 drivable vehicles
Total CNG vehicles	221
Year CNG use began	1991 Stapleton/ 1995 DIA
CNG vehicle types	Light-duty Buses Street sweeper
Vehicle manufacturer	Multiple
Engine manufacturer	Cummins Westport, GM, Ford, and John Deere
OEM or retrofit	Both; new are mostly OEM

DIA opened in 1995, however, the Stapleton Airport (DIA's predecessor) began using CNG in 1988. The use of CNG at the airport continued with the opening of DIA and is part of an overall commitment to alternative fuels; 35 percent of all light-duty vehicles at the airport are AFVs, with most of these running on CNG. DIA's "Green Fleet" also operates electric and hybrid electric vehicles. Currently, all of the CNG vehicles at DIA operate exclusively on CNG as dedicated vehicles. At one time, as many as 68 vehicles were bi-fuel vehicles. These vehicles could not operate on conventional fuels in the tunnel due to the emissions restrictions in the tunnel system. As a result, staff would choose CNG vehicles rather than risk using a vehicle that was not permitted to operate in the tunnel system. This limited the use of bi-fuel vehicles, so conventional fuel tanks on these vehicles were drained and capped.

The goal for CNG expansion is to increase the number of CNG vehicles by 25 to 50 units in the next several years, provided that DIA can increase the capacity of its fueling infrastructure.

DIA's CNG Buses

Decision to Use CNG

Victor Lovato, the Assistant Director of Fleet Maintenance at DIA, has overseen most aspects of fleet management first hand. According to Mr. Lovato, the primary driver for CNG use at DIA in the beginning was technical; CNG vehicles can meet emissions requirements for operation in two miles of underground tunnels that link DIA's three concourses and train maintenance facilities. CNG vehicles were available, clean-burning, and provided fuel cost savings over conventional vehicles. Another key motivation for choosing natural gas was to mitigate the risk of fuel spills in the tunnels. Because natural gas is lighter than air, it would dissipate into the ventilation system instead of pooling in the tunnel. Energy security was also an important factor. For private fleets that serve DIA customers and travelers, CNG has a variety of economic and environmental benefits. Many of the private fleets that operate in the DIA vicinity take advantage of the fueling infrastructure and maintenance support available at the airport. As illustrated in the Grand Junction case study, existing infrastructure can tip the scale in favor of CNG vehicle purchases.

Management Considerations

The decision tree for approving capital expenses for projects at DIA is complex because of the way that DIA

[8] Denver International Airport, Do You Know DIA?, on-line: http://flydenver.com/doyouknowdia

generates revenue. DIA obtains its revenue through landing fees, concession revenues, parking fees, aviation fuel taxes, facility rentals, car rentals, and other fees. As a result, DIA has an obligation to ensure that costs and the quality of services provided to the airlines are competitive. Airport management, the City and County of Denver, airlines, service fleets, and fuel suppliers all work as a team to meet the complex needs of the airlines. This has implications for budget development, vehicle choice, and vehicle replacement intervals.

DIA fleet management provides airport management recommendations on Green Fleet procurements each year. Airlines and the Denver Mayor's office provide input on budgets. Given DIA's revenue model, the business case to buy alternative fuel vehicles (AFVs) must also be demonstrable to airline customers. The Mayor's office also has made a commitment to sustainable development goals, outlined in Greenprint Denver and other city policies. In recent years there have been limited funds available for AFV purchases. However, DIA anticipates spending $3.5 million over the next four years to replace older CNG vehicles.

Project Accomplishments and Metrics

CNG vehicle technology meets DIA's specific application needs in a clean and cost-efficient manner. Furthermore, CNG vehicles and conversion systems are available for the wide variety of fleet applications that DIA requires. Other options for operating safely in underground tunnels are not viable because of DIA's wide variety of vehicles and economic factors associated with other solutions. Examples of technologies used in other analogous situations are not viable for technical and economic reasons. Seattle, Washington uses diesel/electric hybrid buses in transit tunnels. Hybrid vehicles are not available to meet DIA's wide range of applications. Costly and complex ventilation schemes such as those used in Chunnel service tunnels in Europe, are not feasible for DIA for financial reasons.

A key accomplishment of DIA's CNG efforts is its role as a successful catalyst for CNG vehicle deployment by other fleets that serve DIA travelers. DIA provides public access to CNG fueling infrastructure at its rental car fueling station. These accomplishments bolster DIA's credentials as an environmental leader to the public and to the airlines.

CNG use aids in recertification of DIA's Environmental Management System (EMS) to the stringent ISO 14001 standard. This EMS standard is one part of DIA's commitment to aggressively and proactively manage environmental impacts through reduction of emissions of criteria air pollutants and implementation of other energy conservation and pollution minimization measures.

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Denver International Airport Project Accomplishments and Metrics

Metric	Description
Annual petroleum displacement	114,000 GGE/year
Annual fuel cost savings (Assumes $1.75/GGE CNG and $2.95/GGE costs)	$136,458
Fueling system capital cost (2006 upgrade)	$1 million
Incremental capital cost of CNG vehicles (based on 4x4 pickup)	30% higher for CNG
Maintenance impacts	25% higher than gas or diesel
Simple payback period[1]	7 years
Vehicle performance	Reduction in payload for pickups
Economic development	Private partnerships with USAirport Parking, Canopy Parking, Parking Spot and WallyPark for refueling access

[1]The numbers above represent only those by operations of the airport's fleet itself and does not include other vendors that operate a CNG fleet at DIA. There are limitations to any direct economic comparison between conventional and CNG vehicles because of the limited alternatives available at the time of the initial investment. Incremental CNG vehicle purchase and maintenance costs are excluded from the payback analysis because of the lack of a viable alternative. This estimated payback period includes projected fuel cost savings vs. refueling system capital costs

Project Funding

As previously mentioned, DIA does not operate using funding from the City and County of Denver. Operations are funded through airline terminal fees, gate fees, landing fees, and other vendor fees. DIA has used its own funds for the vast majority of CNG vehicle purchases and infrastructure costs. In 2007, it received about $1 million in grant funding from the Sustainable Technology Environments Program (STEP) Foundation, which it put toward AFV purchases.

Vehicle Selection

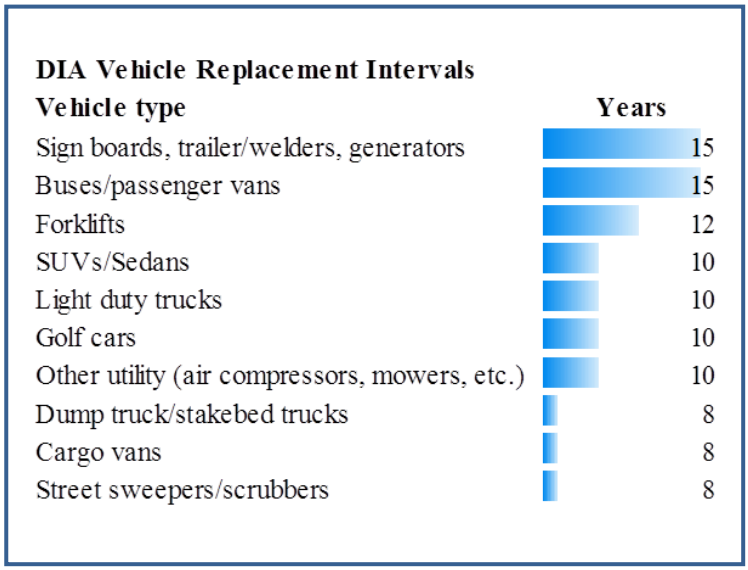
Schedule: DIA has established vehicle replacement intervals for CNG vehicles in its fleet; these are used as general guidelines. DIA's fleet management extends the life of some vehicles if they have demonstrated light use or maintenance needs. In other cases, DIA accelerates vehicle replacement schedules due to rapid acceleration in vehicle technologies.

Because of the stringent application needs and increasing performance requirements for many mission-critical pieces of runway maintenance equipment, and because of high daily vehicle mileage (in excess of 300 miles in many cases), DIA's CNG vehicle implementation has been limited mostly to light-duty vehicles and vehicles that operate in the airport tunnel system. One exception is the purchase of two Crosswind CNG street sweeper vehicles.

Annual vehicle mileage varies extensively by vehicle application. Many of the vehicles with highest mileages are security, electrician, or other operational vehicles that log 150 miles or more per day. DIA does not opt for CNG vehicles in these applications due to their specialized mission-critical needs. Many of the vehicles in the CNG fleet are not high mileage vehicles; of the light-duty CNG pickups, average daily vehicle miles traveled is 21 miles per day. This has implications for the payback period for CNG fleet investments, discussed below.

Equipment specification: Many of DIA's existing CNG vehicles are 10 to 12 years old and were converted from gasoline operation to use CNG. DIA outsources vehicle conversions to local companies such as FuelTek, Go Freedom Fuel, and Kois Brothers. DIA is seeking to replace older CNG vehicles with packaged OEM vehicles. In DIA's experience, OEM vehicles are easier and less costly to purchase for a variety of reasons. Operationally, the onboard software and information technology (IT) systems are integrated as packages from major manufacturers. DIA operates many different makes and models of CNG vehicles. DIA has trained staff and tools and equipment for diagnostics and maintenance of GM vehicles.

Procurement process: DIA fleet managers must purchase vehicles within their annual procurement windows to avoid losing allocated funding in subsequent budget years. If the research and procurement process is complicated, they risk missing the window. Like many municipal governments, DIA uses the Colorado state vehicle contract to procure vehicles, reducing the lead time to purchase vehicles. The vehicle purchase specifications are well defined and purchase orders can be cut right away.[9] Orders take about three to four months to fulfill. Some vehicle conversions may increase the timeline by an additional month.



[9] Colorado fleet vehicle purchase contract information is on-line: http://oa.mo.gov/gs/fm/vehiclecontracts.htm

Fueling Station Design and Economics

Clean Energy designed and built the CNG fueling infrastructure at DIA and operates six fast-fill stations. Clean Energy owns the station equipment and charges DIA a service fee for maintaining the compressors and delivering CNG to DIA.

The stations that serve the DIA fleet are located on the air side (i.e., on runway service roads or other areas that are not accessible to the public). The public South Terminal station is currently disabled for ongoing hotel construction.

Location, Type, and Number of Fueling Islands

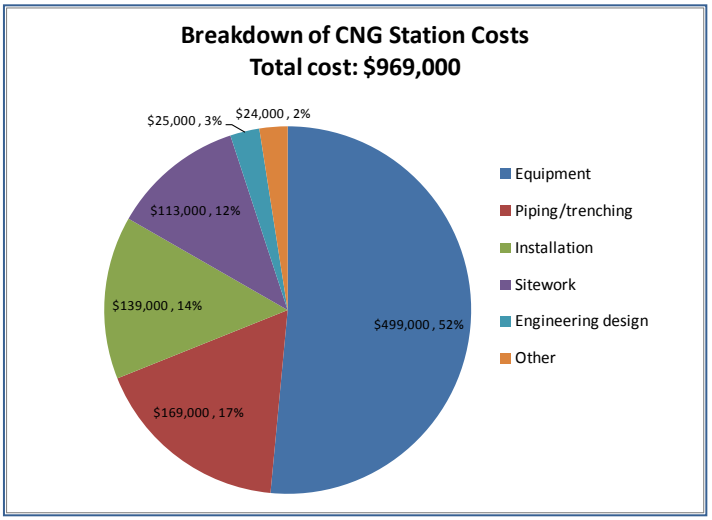
Station name	Public/ private	#of refueling islands
Fleet Maintenance	Private	2
Cargo	Private	2
Concourse A	Private	1
Concourse B	Private	2
Concourse C	Private	1
Rental Car Road	Public	4
South Terminal (disabled)	Public	1

Clean Energy is in the sixth year of a seven-year contract with DIA (with three option years) to maintain the CNG fueling stations and sell fuel to DIA and other airport CNG users. CNG costs, including Clean Energy's combined service fee and natural gas costs, to DIA are approximately $1.26 per GGE. The cost of natural gas fluctuates on a monthly basis. DIA also pays for the electricity; at the time of this study, DIA data on compressor electricity usage was not available. Estimated values for compressor station electricity use for a fast-fill fueling station, based on 150 gallons per day of use and a 100 hp compressor, are $0.49 per GGE; adding this to natural gas and Clean Energy service fee charges results in total delivered CNG cost of $1.75 per GGE for DIA.

Most of the fast-fill stations operate at 3,600 psi. The fleet maintenance station operates at 3,000 psi. Upgrading this station to 3,600 psi and adding another fueling island (piping to site is already complete) is anticipated to occur in the near- to mid-term.

The capital investment in CNG fueling infrastructure by DIA at the beginning of Clean Energy's contract in 2006 was nearly $1 million. This investment resulted in a major reconfiguration of the refueling infrastructure at DIA. It does not represent the total capital costs for the refueling infrastructure. The original development of DIA's fueling infrastructure occurred prior to 1995. Information on the original installation costs was not available.

Equipment was the largest line-item cost, as shown in the CNG station cost breakdown below.



Within equipment costs, compressors were the largest component; other major equipment included dryers, dispensers, card readers, and other fuel dispensing equipment. Piping and trenching represented another significant portion of the infrastructure costs. Approximately 1.5 miles of natural gas line was required, with a total trenching distance of about one mile.

Engineering and design costs were relatively minimal, and were incurred only for the installation of the large rental car fueling station. No building modifications were required, as the fueling stations are located outdoors. Site work consisted of limited excavation, compressor pad installation, and system fencing and wall construction.

DIA Refueling System Configuration

Name	Fleet Maintenance	Rental Car Road	South Cargo	Concourse A	Concourse B	Concourse C
Dispenser type	Retail 2-hose	Greenfield Retail 2-hose	Natural Fuels Fleet	Natural Fuels Fleet	Natural Fuels Fleet	Natural Fuels Fleet
Refueling hoses	2	8	2	2	4	2
Number of compressors	2	3	1	Shared System 2 Ariel + 1 IMW		
Type of compressor	Ingersoll Rand 0525NG	Ariel	Ingersoll Rand 0520NG	IMW	IMW	IMW
Compressor capacity (hp)	20HP	500HP	20HP	350HP		
Type of storage spheres	Cherco	ASME	CPI	Cherco	Cherco	Cherco
Number of storage vessels	3	4	3	3	2	1

Fueling experience: Fuel use (2011) by DIA vehicles totaled 742,000 GGE, about 15 percent of which was CNG. Buses are the largest fuel users. Use of CNG jumped from 7,000 gallons per month to 9,500 gallons per month in the summer of 2011 due to the conversion of 70 vehicles to CNG operation. DIA purchases natural gas directly from Xcel Energy using a separate agreement from other utility purchases. Natural gas prices fluctuate monthly.

Annual DIA Fleet Vehicle Fuel Use

Fuel type	Quantity (GGE)
Diesel	388,000
Gasoline	240,000
CNG	114,000
Total	742,000

At the DIA Maintenance site and other private fueling sites, the user enters his or her vehicle and badge number into a keypad located on a pedestal in an enclosed area. The system sends this information to the work order maintenance system. The user interface works well for drivers, and integration with DIA's fleet management IT infrastructure facilitates the collection and analysis of cost and maintenance data.

At public fueling pumps, the look and feel for the dispenser system is similar to that of a retail gasoline fuel pump.

According to Victor Lovato, DIA experiences fleet fueling performance issues in winter when drivers are not able to achieve a complete fill due to the inability to maintain sufficient gas pressure in storage spheres. Vehicle fuel gauges sometimes are not accurate, and they will dip after vehicles leave the fueling station. In freezing temperatures, tanks may only be half full when trucks leave the pump. Nozzles may freeze and break in the winter. This is a contributing factor to the limited use of CNG in mission critical equipment. Equipment productivity can be limited if snow removal vehicles have to leave the runways for refueling. The fueling station at the maintenance site can serve four or five trucks back to back, but at the end of a shift, one or two trucks might not be filled completely.

DIA Fast-Fill Dispenser

In support of approving fuel contract option years, DIA would like to see several fueling upgrades from Clean Energy, including upgrading the gas pressure at the maintenance facility to 3,600 psi and installation of more storage spheres and refueling pumps.

For all fuel types (not just CNG) DIA has some concerns about the availability of backup power to operate fueling equipment in the event of a power outage.

Field Experiences

Vehicle performance: Because of the long history of CNG use at DIA, it is important to distinguish between issues associated with older vehicles and those of newer ones. Older vehicles (for example, 2002 and older), many of which were conversions, can be more difficult to start in cold weather and have less power, but these are less common issues for newer models**.**

For CNG pickups, both old and new, available cargo space is a concern. For light-duty pickup trucks, payload is constrained by the 9-gallon tanks that can occupy up to half of the pickup bed. DIA is considering purchasing pickups with utility bodies so they can fit ladders and other larger equipment in the back of CNG trucks.

Vehicle maintenance: DIA technicians perform nearly all maintenance in house except for transmission replacement, which is easier and faster for specialized transmission shops. DIA's CNG New Flyer buses are an exception. DIA has a contract with AMPCO to operate most of these buses. Penske maintains the buses under contract to AMPCO. DIA provides the fueling infrastructure for the buses.

DIA vehicle fleets run 24 hours per day, seven days per week. Maintenance crews are run in two shifts: a Sunday-to-Wednesday crew and a Wednesday-to-Saturday crew. Ten to 12 technicians may work on each shift. Wednesday is an overlap day, where there may be as many as 30 technicians on site. During emergencies, all crews are available. The majority of all technicians are able to work on CNG vehicles, although there are two CNG specialists who conduct detailed diagnostics (especially for non-OEM systems), emissions testing, and troubleshooting. The DIA facility has its own dynamometer to conduct emissions testing for DIA and other airport service vehicles to approve them for use in DIA's underground tunnel system.

Most maintenance for CNG vehicles has gone from preventative maintenance to predictive in nature. For example, technicians are trained to identify the presence of carbon fouling on air intakes. This could be an indication of fuel quality issues that, if left unaddressed, could result in the need for costly injector replacement.

On average, DIA spends an estimated 25 percent more on maintenance for CNG vehicles, mainly for preventative and predictive maintenance. CNG vehicles receive an annual inspection and emissions testing in support of permitting for tunnel use. For older vehicles, tank replacement and disposal adds to maintenance costs. Metal recyclers will not take tanks unless they are emptied and cut in half. DIA purchased a band saw to cut tanks.

Performance of several vehicle types is notable. DIA's CNG Dixie Choppers are reliable and work well on CNG. These drivable lawnmowers are tasked with keeping grass to less than 6 inches in height to prevent wildlife conflicts on runways. Grounds crews use these highly maneuverable mowers to cut around light "delineators" next to runways. One the other hand, DIA has had difficulties with its two sweeper/scrubber units, which have non-OEM CNG engines used to drive the sweeper units.

Training requirements: DIA operates many different types of CNG vehicles, including OEM and non-OEM equipment. As a result, DIA runs at least six different diagnostics and maintenance systems. DIA trains staff on each of these systems both when the systems are first implemented and on an ongoing basis. Existing staff train new technicians as needed. Total training time is approximately 30 to 40 hours per year per maintenance crew of approximately 10 technicians. High-pressure systems are labeled if they require technicians to have specialized to work on them (e.g., fuel system filter checks and replacement).

Clean Cities has been a key partner for information, training, and equipment demonstrations for DIA, as have the Colorado Natural Gas Vehicle Coalition (CNGVC) and Encana.

Safety: DIA uses vendor-provided and in-house procedures for technicians and drivers that address fueling and maintenance of high-pressure gas systems. DIA has its own fire department training systems and procedures but has had a limited need for new systems or protocols for use with CNG.

Lessons Learned

DIA has a long track record with CNG vehicles, and its fleet is very diverse in terms of vehicle applications. DIA's decision to build out its CNG fleet was based on a technical need for lower-emission vehicles in airport tunnels. Recommendations for fleet managers considering CNG center on the need to build broad-based support for CNG and ensuring that CNG is a match for the organization.

DIA has been very successful in establishing fueling station partnerships with other public entities and private-sector businesses. DIA fueling infrastructure supports several mid-size transit fleets that serve the airport. An assessment performed in 2006 indicated that 52 different entities were using the CNG fueling infrastructure at DIA. These companies included airlines, major shuttle companies, 20 concessionaires and 16 contractors.

Number of Companies Using DIA's CNG Fueling Stations in 2006

Company type	Number	Description
Airline	13	Multiple airline customers
Concession	20	Food and beverage, publications, other
Contractor	16	Janitorial, baggage handling, logistics
Federal	2	US Customs, US Postal Service
Security	1	Medical services

DIA has demonstrated that CNG fueling infrastructure at a transportation hub can drive CNG vehicle purchases and use. It is reasonable to expect that other clusters of fleets can have similar results if they implement CNG, albeit at smaller scales. Co-locating public CNG stations with private fueling stations can occur in a variety of different applications— not just airports. Any location with a convergence of fleets could represent a good opportunity for CNG deployment (county government, airports, waste management, cement delivery, etc.).

The next step for AFV implementation at DIA, budget permitting, is to introduce between 25 and 50 new CNG or bi-fuel vehicles. These next steps are exciting because of the increasing availability of mid-size and larger CNG pickup trucks. A gap that DIA's fleet managers still see moving forward is the availability of light-duty supervisor vehicles and pickups. DIA also hopes to encourage more growth in CNG fuel use through the creative application of incentives for other end users.

Conclusions and Recommendations

CNG Opportunities

Financial: Fuel cost savings from CNG deployment can be significant. Republic has achieved 50 percent fuel cost reductions through CNG deployment across multiple fleets. While this magnitude of savings may not be attainable for all fleets, this is a significant selling point.

Labor cost savings for CNG refueling are not often quantified but can be significant. Both Republic and the City of Grand Junction cited a reduction in employee time spent fueling vehicles at the end of a shift due to use of time-fill stations. Some of this labor cost savings comes in the form of reduced overtime.

Energy management: Some fleets might be able to reduce costs through compressor energy management. Some fleet managers did not have all the necessary knowledge to manage compressor electricity use. Republic cited success nationally in reducing electricity use and cost in this area.

Environmental and other benefits: Ancillary benefits of CNG (e.g., noise and odor reduction, "buy local," and U.S. energy security) help organizations improve their customer relationships, increase employee satisfaction, and build brand loyalty.

Partnerships: Partnerships with public-sector and private-sector entities using a "hub" model can promote CNG use at major commerce and transportation centers. DIA is a good example, with potential for expansion to other users. Grand Junction's public/private partnership to provide public CNG fueling demonstrates that these partnerships can operate effectively at smaller scales as well. Partnerships can help create sufficient CNG infrastructure to support private investment in CNG vehicles.

Commercial fleets may be open to co-location of public and private fueling stations depending on the ability to configure appropriate site access and ensure safety.

Fleet managers have also benefited from training, funding, and technical support from a variety of organizations, including but not limited to the Colorado Natural Gas Vehicle Coalition, CEO, Clean Cities, Cummins Westport, and natural gas producers such as Encana, Noble, Chesapeake and Anadarko.

Recommendations for Fleet Managers

All levels of the organization must be dedicated to CNG implementation for the long-term.

CNG has to fit the organization's business needs and financial goals.

CNG has to fit the applications and vehicle use patterns.

- **Develop vehicle specifications for each application.**
- **High-mileage applications (greater than 300 miles per day) may require refueling during shifts and could reduce productivity if vehicles need to leave the job site.**
- **Frequent idling poses maintenance problems for CNG vehicles.**

Fleet managers must decide whether to phase in CNG or transition all at once.

Conduct as much training as possible for drivers and maintenance staff.

Emphasize predictive maintenance in addition to preventative maintenance.

Municipalities: CNG can help municipalities shore up transportation fuel budgets if fleet sizes are large enough to justify investment in fueling infrastructure.

There is also potential for municipalities to team with private-sector partners for fueling station access. Municipalities can fuel CNG vehicles at private-sector stations, improving the economics for private-sector partners, reducing the need for public capital investment in CNG infrastructure, and reducing municipal fuel costs (relative to those of gasoline and diesel fuel).

Policy: Organizational policies, ranging from a very general statement of support for increasing sustainability to more specific goals for energy efficiency and alternative

fuels, can help tip the balance toward investment in clean energy technologies.

State vehicle purchasing agreements can simplify and accelerate CNG vehicle procurement by providing clear, well-defined vehicle specifications. State purchasing agreements may also offer better pricing. The multi-state Memorandum of Understanding (MOU) signed by Colorado Governor John Hickenlooper and other state governors committing to encourage CNG vehicle procurement may help create markets that increase CNG vehicle availability.

Barriers to CNG Vehicle Deployment

Utility interconnection: Fleets see the difficulty and length of time required to complete natural gas interconnection for refueling as an obstacle to CNG refueling station development.

Fleet managers also have difficulty assessing the impacts of compressor electricity use and demand charges associated with fueling stations, especially when stations do not have dedicated meters.

Fueling: Improvement of performance for fast-fill pumps may be needed for vehicles with higher daily mileage.

Issues include incomplete refueling in winter, accuracy of fuel gauges, ability to acclimate drivers to "think in psi" and concerns about ability to fuel a larger number of vehicles with existing storage capacity. To some extent, these issues may be solved by installation of new fueling technology.

Building modifications: Uncertainty in requirements for building modifications required for CNG use in maintenance facilities could be reduced. This is a difficulty in Colorado because it is a home-rule state, where fire codes can vary by municipality. Early and frequent coordination with the fire marshal should help expedite this process.

Vehicle performance: The perception of performance from past conversion systems still creates skepticism when an organization is considering a transition to CNG. DIA is experiencing some of these performance issues now, because it still has older CNG vehicles in its fleet. However, vehicle performance experiences for both Republic and Grand Junction have been very positive for drivers and customers. Reported vehicle fuel efficiency estimates vary; Republic's estimate of a 12 percent reduction in fuel efficiency on a fuel-heat-content basis, compared to diesel vehicles, is based on its significant experience working with newer heavy-duty truck models. There still remains hesitance on Republic's part to implement CNG trucks at higher elevations due to concerns about operation under full loads at altitude.

Vehicle maintenance: Inconsistencies in recommended maintenance intervals for CNG engines among manufacturers and across vendors and third-party training providers can be frustrating for fleet maintenance managers. CNG vehicle maintenance costs are reported to be equal to or higher than comparable gasoline or diesel vehicles for the fleets in these three case studies.

Estimated impacts on maintenance costs range from none (i.e., CNG use has no significant impact on overall maintenance costs) for Republic to a 25 percent increase for DIA.

Clarity on tank certification and assistance for tank disposal for older vehicles can be improved.

Vehicle availability: Availability of a wider variety of OEM sedans, SUVs, and light-duty pickups that use CNG could increase CNG vehicle purchases.

Expansion of options for CNG vehicles that preserve payload capacity for crew pickups would likely be helpful to fleets seeking to transition to CNG.

The timeframe to fulfill an order for a CNG vehicle can vary significantly depending on the level of customization and desired features for a vehicle.

Training: Perceptions of disruptions in operations and/or significant training requirements for CNG vehicle operators and maintenance staff still are a concern for fleet managers. This is the case despite improved availability of training resources from engine manufacturers and fueling station equipment providers.

Recommendations for Future Outreach and Technical Assistance

Compressor energy management training resources for fleet managers and staff would address a common knowledge gap. Training resources could cover topics such as an overview on electricity markets and how they operate, understanding of demand charges, and how to operate compressors to minimize additional charges.

The electricity usage of compressors can be significant for many stations and often incurs demand charges by electric utilities. These demand charges are typically similar for commercial and industrial customers and are reflective of the cost of service to that customer. With low vehicle usage, the financial impacts of the demand charges can cause the economics of a station to quickly deteriorate. Efficient station design can ameliorate this effect, especially if done in consultation with utility providers. Once stations reach high levels of usage, demand charges typically have much less of an impact on station profitability.

Design assistance and analysis of the costs and feasibility of co-locating public and private fueling stations could result in new partnerships that improve the business case for fueling infrastructure investments.

CEO could play a role in development and dissemination of information on natural gas distribution systems, CNG station interconnection, and other considerations involved in station siting from the natural-gas-provider and end-user perspectives.

CEO can support fleet manager efforts to evaluate the feasibility and cost of transitions to CNG. Efforts can include providing fleet prescreening spreadsheet tools and working with partners such as NREL to develop and disseminate up-to-date economic analysis tools. Other local partners (e.g., CNGVC, Colorado Municipal League, and Clean Cities) can continue to increase efforts with CEO support.

Analysis of successful grant-writing efforts by the City of Grand Junction and re-examination of how grant funding availability may have changed can help in developing realistic recommendations for smaller fleets regarding CNG cost-effectiveness.

Continuing and expanding community forums for fleet managers and other CNG users to share information will result in shared benefits.

There is additional room to disseminate information on safety procedures and issues surrounding CNG. This can be used to reduce burdens of developing internal environmental, health, and safety procedures. This information also can be adapted for use by local first responders.

Wider availability of publically accessible fueling infrastructure will encourage CNG use by fleets. The fueling infrastructure can be co-located with an existing vehicle fleet to reduce the capital investment required to provide this service. This is particularly true outside of major metropolitan areas and for on-road trucking and logistics fleets that need reliable refueling access. The infrastructure does not need to be associated with an existing fleet, but until there is a sufficient concentration of CNG vehicles, the economics for stand-alone fueling station development will remain challenging.

Contact

Alex Schroeder
Senior Manager Transportation Fuels

Tom Hunt
Transportation Fuels Associate

Colorado Energy Office
Phone: (303) 866-2100
Web: http://www.colorado.gov/energy/

Additional Resources

- Business Case for Compressed Natural Gas in Municipal Fleets. NREL: http://www.afdc.energy.gov/afdc/progs/view_citation.php?10676/CNG
- Refuse Hauler Fleet Experiences. NREL: http://www.afdc.energy.gov/afdc/fleets/refuse_haulers_experiences.html
- Greening Garbage Trucks: Trends in Alternative Fuel use, 2002-2005. INFORM: http://www.informinc.org/ggt.php
- Guide to Available Natural Gas Vehicles and Engines, NGVAMERICA http://www.ngvamerica.org/pdfs/marketplace/MP.Analyses.NGVs-a.pdf
- U.S. DOE AFDC: http://www.afdc.energy.gov/afdc/

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