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# ALTERNATIVE FUEL STUDY FOR REFUSE COLLECTION VEHICLES – FINAL REPORT



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CITY OF TUCSON, ARIZONA  
ENVIRONMENTAL SERVICES DEPARTMENT

FEBRUARY 2010

**WIH RESOURCE GROUP**  
*Environmental & Logistical Solutions™*



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Detailed information has been included in the Appendix of this report. The intention is to summarize the pertinent information to keep the report succinct.

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## Natural Gas Fueled Refuse Collection Vehicles

Natural gas occupies more volume than traditional liquid fuels; therefore, it must be compressed or liquefied to make it practical for transport applications. Most vehicles use Compressed Natural Gas (CNG) in the gaseous form compressed to pressures above 3,100 pounds per square inch. To store more fuel onboard a vehicle in a smaller volume, natural gas can be liquefied. To produce Liquid Natural Gas (LNG), natural gas is purified and condensed into liquid by cooling to -260°F (-162°C). Because it must be kept at such cold temperatures, LNG is stored in double-wall, vacuum-insulated pressure vessels.

Since the late 1990s, a new trend has emerged in the refuse and recycling collection industry – one that until the last few years was almost unnoticed. Fleet operators have begun to explore new technologies and alternative fuels for their trucks driven by a variety of health, environmental, economic and national security factors.

A few fleets have been experimenting with bio-fuels and hybrid electric drive-trains, but the strongest shift by far has involved replacing diesel trucks with those fueled by natural gas. A look at this trend, the performance of natural gas trucks and the factors driving this change suggests that a shift of significant proportions may be getting underway.

In 1998, only 240 natural gas refuse trucks were operating in the U.S. By 2002, when the first analysis ever done of this industry appeared the numbers had almost tripled to 692. By the end of 2005, the number of natural gas refuse trucks appeared to be close to 1,500. From 2002 to 2004, the total number of vehicles of all types powered by natural gas nationwide grew by just 20 percent, according to U.S. Energy Information Administration (Washington) data.

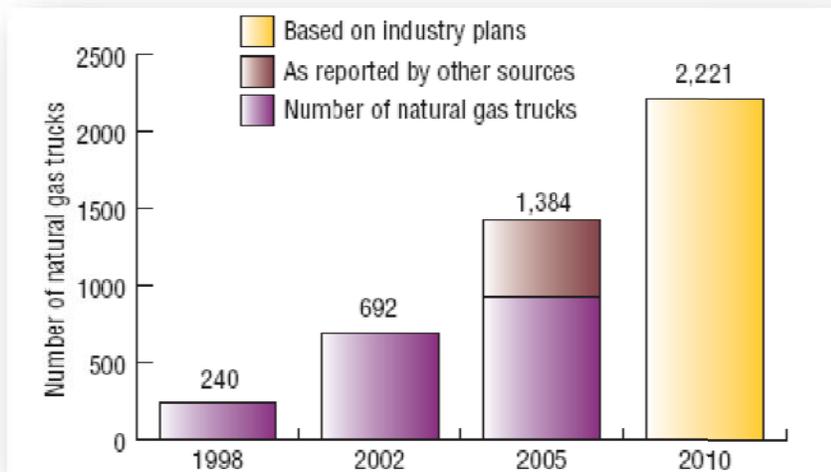
By contrast, *industry sources* reported a growth rate of 89 percent in the refuse and recycling collection truck sector (see Figure 2.1). Even though natural gas trucks constitute only about one percent of the overall collection truck fleet in the U.S., which totals more than 179,000 trucks, this sector emerged as the second leading market after transit buses for heavy-duty natural gas vehicles. Waste management industry leaders were projecting that 2,221 natural gas refuse trucks would be in service by 2010. Actual current present-day estimates show the vehicle count already exceeding 2,500 AFVs in operation throughout the U.S., exceeding previous estimates for 2010.

In 2005, 27 of the 31 fleets operating natural gas trucks in the U.S. were located in California, which includes a total of 1,268 trucks. Two factors explain the concentrated use of natural gas refuse trucks in California to date. First, the State's South Coast Air Quality Management District (Diamond Bar, California), concerned about air quality in the Los Angeles Region and reducing dependence on foreign oil, mandated that operators of municipal fleets containing more than 15 heavy-duty vehicles had to buy natural gas-powered vehicles. Second, California was providing the heavy-duty sector with public funds to support the purchase of the more expensive alternative-fuel vehicles





**Figure 2.1 National Natural Gas Refuse Vehicle Trends**



Source: Resource Recycling

The growth in the use of natural gas refuse trucks has definitely been spurred by the many advantages cited by fleet operators that natural gas enjoys over diesel. From an economic standpoint, natural gas costs less per gallon equivalent than diesel, even though the price for both fuels has escalated in recent years. At the end of September 2005, the national average price for natural gas was \$2.36 per diesel gallon equivalent (DGE), compared to \$2.81 for diesel. Since then, diesel fuel prices have fluctuated significantly with some areas of the country paying over \$5.00 per gallon for diesel, while the prices for a DGE of natural gas has remained relatively the same, and in even dropped in net price with federal government incentives to utilize natural gas that began in 2006.

From a regulatory perspective, natural gas engines have shown that they can already meet the U.S. Environmental Protection Agency’s (Washington) 2007 and 2010 emission standards. Under these rules, particulate matter and nitrogen oxide emissions from heavy-duty engines must be reduced by more than 90 percent. For nitrogen oxide emissions, the natural gas engines that will be available in 2007

Because of their operation / duty cycles (i.e., continual stopping and starting on and off route), refuse trucks burn approximately a gallon of fuel every 2.8 miles, making them one of the most inefficient vehicles on US roads. Traveling approximately 25,000 miles annually, refuse trucks consume on average 8,900 gallons of diesel fuel per year per vehicle. Thus, the 175,000 refuse trucks on US roadways may burn nearly 1.7 billion gallons of diesel fuel per year—an amount equivalent to almost 30 million barrels of oil.

Summary of Alternative Fuels Benefits over Diesel Fuels:

- Equal maintenance costs
- Lower fuel costs
- Cleaner – significant reduction in emissions
- Less noise pollution



While every refuse fleet operator has individual needs and goals, exploring the natural gas refuse truck option involves mainly being sure to ask the right questions:

- What vehicles must I replace?
- Where does natural gas fueling station exist or who can build it?
- How much oil-derived fuel can I displace?
- Will the manufacturer assure the performance of its vehicles and that its emissions will meet or exceed government standards?
- What will the total costs be?

Since 2007, the weight of natural gas powered engines as well has decreased. CNG and LNG fuel tank location alternatives have been dramatically expanded to accommodate most truck chassis. The new 2010 U.S. EPA emission standards mandates have impacted diesel engine performance and have increased the fleet vehicles' tare weights.

## Analysis of Key Issues

The City of Tucson's interest in this information is to assess the potential for utilizing CNG or LNG fueled refuse collection vehicles in their own refuse (solid waste) and recycling collection operations. The surveys and interviews conducted by WIH's Staff with various cities and other private sector companies that currently utilize and operate CNG fleets, centered on securing industry experience, data and knowledge on the following key items of interest to the City of Tucson's ESD Staff is the comparison of biodiesel, CNG, and LNG in the following areas:

- |                   |                              |
|-------------------|------------------------------|
| 1. Fuel Cost      | 5. Performance & Maintenance |
| 2. Vehicle Cost   | 6. Infrastructure Cost       |
| 3. Vehicle Weight | 7. Emissions                 |
| 4. Fuel Capacity  |                              |

## Fuel Costs

Natural gas is measured by volume or weight (standard cubic feet or pounds), but is sold by energy content (therms). To begin making an economic comparison of fuels, it is easiest to compare the prices based on energy content - after all, energy is what you are purchasing, not volume or weight. This method of comparing fuels yields a diesel gallon equivalent price for natural gas, abbreviated as DGE. A therm of natural gas has an energy value of 100,000 BTUs. For comparison, how much does natural gas cost for the equivalent amount of biodiesel? Take the price of natural gas (\$1.31 per therm), multiply it by the energy value of bio diesel (127,500 BTUs per gallon) then divide by the energy value of natural gas (100,000 per therm). The mathematical conversion is:  $\$1.31 \times 127,500 / 100,000 = \$1.67$  per DGE. LNG has an energy value of 82,000 therms per gallon. The conversion of LNG to DGE is  $\$1.51 \times 127,500 / 82,000 = \$2.35$ . The following table summarizes the costs for each alternative.

	<b>Diesel</b>	<b>CNG</b>	<b>LNG</b>
2009 Price per Unit	\$2.50	\$1.31	\$1.51
BTUs per Unit of Measurement	Gallon	Therm	Gallon
BTUs per Unit of Measurement	127,500	100,000	82,000
DGE Ratio	1.00	1.28	1.55
Fuel Cost per DGE	\$2.50	\$1.67	\$2.35



Reported MGP for CNG / LNG trucks varies from 2.5 DGE to 3.5 DGE. Cummins is reporting that the fuel consumption for the ISL-G is comparable to a diesel ISL engine. Assuming the 2008 Autocars currently used by the City of Tucson have the Cummins diesel ISL engine, the average mileage is 2.7 per gallon of fuel. Converting from a diesel gallon to therms, the diesel ISL engine will consume 1.27 therms or 127,500 BTUs of energy and travel from 2.7 miles.

The ISL-G engine will also require 127,500 BTUs of energy to travel the 2.7 miles. So the performance of the engine can be expressed as either 2.7 MPG or 2.7 per 1.27 BTUs.

## Diesel vs. CNG Collection Truck

In order to gauge exact incremental costs, the City would require sales quotes on identically specified refuse trucks. Here are a three documented purchases in Colorado in the past six months. These were identical spec units – CNG to diesel that includes taxes and other applicable charges. These recent purchases put CNG equipped vehicles at a \$40,000 premium over diesel equipped collection trucks.

Autocar chassis with a McNeilus collection body

Diesel Cab and Chassis \$160,655 + McNeilus Body \$114,500 = \$275,155

CNG Cab and Chassis \$166,513 + McNeilus CNG Body \$154,189 = \$320,702

Incremental Cost for Autocar / McNeilus CNG Refuse Truck: **\$45,547**

Peterbilt chassis with a Heil Rapid Rail body

Diesel 320 Cab and Chassis – \$128,200 + Heil Rapid Rail Body - \$128,988 = \$257,188

CNG 320 Cab and Chassis - \$131,468 + Heil CNG Rapid Rail Body - \$160,988 = \$292,456

Incremental cost for Peterbilt / Heil Rapid Rail Refuse Truck **\$35,268**

Peterbilt chassis with Heil Durapack 7000 body

Diesel 320 Cab and Chassis – \$128,200 + Heil Durapack 7000 Body - \$135,891 = \$264,091

CNG 320 Cab and Chassis - \$131,468 + Heil Durapack CNG 7000 Body - \$167,891 = \$299,359

Incremental cost for Peterbilt / Heil Durapack Refuse Truck **\$35,268**

## Gross Vehicle Weight and Payload

CNG fueled vehicles typically have heavier tare weights due to the need for larger fuel tanks to store the compressed gas than that of their diesel-powered counterparts.

Actual payload per CNG refuse collection vehicle varies not only due to the CNG engine and fuel tank requirements, but by truck and body manufacturer. As equipment tare weights vary between the manufacturers, industry subject matter experts (SMEs) that the WIH Resource Group Project Team interviewed stated that one of the more recommended and lighter weight vehicle combinations is the Autocar truck with an Amrep body. This equipment manufacturer combination, coupled with four axles yields a legal payload capacity of approximately 11 tons. Conversely, a Mack truck with a McNeilus body yielded only an 8.75 ton payload with the same four axle configuration. In this example, the basic difference is the weight variance between the truck and body manufacturer combination.

Most of the refuse collection firms interviewed operate with identical DGE capacity as they would have operated or did operate there diesel equipment. Meaning, if they carried the standard 60 diesel gallons on board, they would have a 60 DGE package installed on the CNG trucks. It is



important to keep in mind that refuse collection organizations typically tend to use only ½ or 2/3rds of their capacity typically. With 60 DGE on board there is an approximate weight displacement of 1,000 to 1,200 pounds.

## Fuel Capacity

Aside from the vehicle tare weights, dependent on the truck and body manufacturer combinations, there is a sizeable variance among the placement and size and quantity of the fueling tanks. Industry interviews with the SMEs revealed that natural gas fuel tanks vary in size (capacity), physical location on the vehicle and the quantity, or number of CNG tanks. The reason for the variance is that operational refuse and recycling collection service areas and distances from the start and end of routes to either transfer stations or disposal sites vary dramatically. In urban areas, vehicle fuel capacity is geared towards 50 - 60 miles per day of travel per vehicle. In the rural areas, where route density is less, trucks require greater fuel and associated fuel tank capacity to travel greater distances between refueling.

On board vehicle fuel tanks for compressed natural gas are referred to as CNG Cylinders. Compressed Natural Gas (CNG) cylinders are available in a number of different types, weights and sizes to suit different applications. As a general rule, as cylinder weight decreases, cylinder costs increase. In some cases, cylinders are available for lease from vehicle converters or gas suppliers. Available tank sizes vary from 50 to 90 Diesel Gallon Equivalent Capacity (DGE) configurations. LNG fuel tanks are very standard in size and mounting and are typically side mounted to the frame rail of the truck. Available tanks sizes vary from 50 to 90 Diesel Gallon Equivalent Capacity (DGE) configurations.

## Natural Gas Fueled Vehicle Performance and Maintenance

The following items of concern were mentioned by COT staff – ESD and / or COT Fleet Maintenance staff at a meeting held on July 22, 2009 with members of the WIH Resource Group Project Team. Here are the corresponding responses from the WIH Resource Group Project Team based on industry research and prior professional experience on this subject:

1. **Lack of Engine Horsepower** - The performance enhancement that the Cummins ISL G 320 horsepower engines achieve over previous engines and early stage engines is in many ways significant. The ISL G is the first of the NG engines to have a matching torque curve and HP output (see Appendix I of this report - the ISL G Cummins Westport information).
2. **Engine breakdown and towing as a result** – No significant data to respond to this concern as it has passed with the newer engine technology.
3. **Tank inspection requirements – time out of service** - Federal Law requires issuance of guidance for CNG tank inspection. The National Highway Traffic Safety Administration (NHTSA) has mandated that natural gas fuel tanks for vehicles produced after December 2, 1996 be inspected for damage or deterioration every 36 months, or 36,000 miles, whichever comes first, or after a fire or accident. Also – in order to be certified to do inspections one has to take a course which only costs \$200 according to one source
4. **Slow-fill verses Fast-fill** – CNG fuel tank compression and documented experience in fueling times to one another and to that of Diesel. **Slow-fill** is designed to fuel during scheduled down time. **Fast-fill** can be designed to fuel at any speed the client requires.



It's all about compression and size of equipment. There are some states that limit how fast fuel can be dispensed, whether it's gasoline, diesel or other.

5. **Driver / Operator dissatisfaction with CNG trucks – acceptance of CNG fueled trucks and engines - any satisfaction surveys, driver comments, etc?** All current information and reports available on drivers' input is that there is zero noticeable difference between an ISL diesel and an ISL-G CNG engine.
6. **Listing of CNG engine manufacturers outside of Cummins Westport?** Currently Cummins is the only US manufacturer of heavy duty NG engines.
7. **Samples of available CNG fleet maintenance and engine training** - Cummins and / or Cummins Westport will be able to provide this to the City of Tucson Fleet Maintenance Staff. Training involved is essentially high pressure gases 101 and then unique components to the ISL-G engines, primarily spark plug changes and coalescing filters (see Appendix I of this report).
8. **3000 PSI versus 3600 PSI line and pump fueling issues – the City has both and is concerned over issues** – All new vehicles and fueling stations use 3600 psi fueling standard – 3000 psi is only found in older vehicles. 3600 psi vehicles are backward compatible and can fuel on 3000 psi lines if that is the only thing available.

The following table provides a summary of CNG-fueled vehicles to that of its biodiesel counterpart vehicles.

**Table 5.1 – CNG Vehicle Performance Compared to Biodiesel**

<b>Horsepower</b>	- ISL G is 320 horsepower
<b>Acceleration</b>	- Comparable to biodiesel
<b>Cruising Speed</b>	- Comparable to biodiesel
<b>Service Life</b>	<ul style="list-style-type: none"> <li>- Similar or better</li> <li>- Some natural gas fleets report service lives 2 to 3 years longer than conventional fleets and periods between required maintenance.</li> <li>- Some natural gas fleets report lower maintenance costs, including the ability to drive longer between oil changes.</li> <li>- High-pressure CNG tanks require periodic inspection and certification by a licensed inspector.</li> </ul>
<b>Vehicle Range</b>	<ul style="list-style-type: none"> <li>- Similar or lower</li> <li>- Extra storage tanks can increase range, but the additional weight may displace some payload capacity.</li> </ul>



## Infrastructure Fueling Station Costs

The approximate cost of constructing a natural gas fueling station is \$900,000 for a single compressor and \$1,400,000 for a dual compressor system. Since the City of Tucson already has two fueling stations that are operational and would not require the costs associated with a complete development of new fueling stations.

## Emissions

Compared with vehicles fueled by conventional diesel and gasoline, natural gas vehicles can produce significantly lower amounts of harmful emissions such as nitrogen oxides, particulate matter, and toxic and carcinogenic pollutants.

Vehicles fueled with natural gas result in lower emissions of sulfur dioxide, particulate matter, and 20% less carbon dioxide than gasoline or diesel. It is one of the cleanest burning fuels. Natural gas is non-toxic, non-corrosive, less combustible than most other fuels, and has few associated health risks. CNG is stored under high pressures. The range of flammability and combustion is much narrower with CNG, making it safer than biodiesel. The flashpoint for natural gas is 1100 ° Fahrenheit, much higher than biodiesel.

Natural gas is lighter than air and will dissipate if leaked whereas gasoline will sink and puddle. Dedicated NGVs produce little or no evaporative emissions during fueling and use. In gasoline vehicles, evaporative and fueling emissions account for at least 50% of a vehicle's total hydrocarbon emissions.

Exposure to the levels of suspended fine particulate matter found in many U.S. cities has been shown to increase the risk of respiratory illness and other health problems. Much of the particulate matter in urban areas is due to transportation. Natural gas produces only tiny amounts of particulate matter. Natural gas is abundant, low-cost, and domestically produced.

## City of Tucson ESD's Fleet

The City of Tucson (COT) Arizona Environmental Services Department (ESD) has an extensive fleet of solid waste and recycling collection vehicles which it utilizes to collect all residential solid waste and recyclables, as well as all commercial waste and provides some industrial (roll off) services. The Table below summarizes the City of Tucson's solid waste and recycling collection fleet. The vehicles vary in age range, body type, chassis and vehicle type. All refuse collected by City vehicles is disposed of at the City's only active landfill – the Los Reales Landfill.

Residential ASLs	Front Load	Roll – Off Trucks	Rear Loaders
66	22	12	5
<b>45 Active Daily</b>	-	-	3 - Man Routes

The City of Tucson began using B20 biodiesel in a pilot test program in July of 2006. This program included 40 vehicles of various types. The majority of which were refuse vehicles. In October of 2006 most of the City's diesel powered vehicles (with the exception of several emergency response vehicles) began using B20 exclusively. Today the blend used is still B20.



## Fleet Cost Comparison: Diesel to CNG to LNG

An analysis of the current and projected costs was completed to determine the average cost of operating a fleet of diesel, CNG, and LNG equipped trucks. The following table details the cost for each fuel alternative. CNG (3<sup>rd</sup> Pty) assumes an independent company constructs and operates a CNG fueling station and recoups the cost over a ten year period.

	B-20 Diesel	CNG	CNG (3 <sup>rd</sup> Pty)	LNG	Notes
<b>2009 Price per Unit</b>	\$2.50	\$1.31	\$2.31	\$1.51	<b>A</b>
<b>BTUs per Unit of Measurement</b>	Gallon	Therm	Therm	Gallon	<b>B</b>
<b>BTUs per Unit of Measurement</b>	127,500	100,000	100,000	82,000	<b>C</b>
<b>DGE Ratio</b>	1.00	1.28	1.28	1.55	<b>D</b>
<b>Fuel Consumption (gal per hr.)</b>	4.0	3.6	3.6	3.6	<b>E</b>
<b>Fuel Cost per Hour</b>	\$10.01	\$6.03	\$10.62	\$8.47	<b>F</b>
<b>MPG in DGE</b>	2.7	2.7	2.7	2.7	<b>G</b>
<b>Average Daily Miles</b>	90	90	90	90	<b>H</b>
<b>Fuel Cost per Mile</b>	\$0.92	\$0.62	\$1.09	\$0.87	<b>I</b>
<b>Annual Truck Hours</b>	1,820	1,820	1,820	1,820	<b>J</b>
<b>Annual Fuel Consumption in DGE</b>	7,280	8,354	8,354	10,188	<b>K</b>
<b>Annual Fuel Cost</b>	\$18,222	\$10,970	\$19,324	\$15,415	<b>L</b>
<b>Infrastructure Costs</b>					
<b>Pumping Station at TOP Center</b>	0	800,000	-	750,000	<b>M</b>
<b>Annual Station Cost (10 yr @ 6%)</b>	0	106,580		99,918	<b>N</b>
<b>Total Costs (10 yr @ 6%)</b>	\$-	\$1,065,797		\$999,185	<b>O</b>
<b>Infrastructure Cost per Gallon</b>	\$-	\$0.29		\$0.27	<b>P</b>
<b>Total Cost per DGE</b>	\$2.50	\$1.96	\$2.95	\$2.62	<b>Q</b>
<b>Less Tax Credit (VETC) per DGE</b>	0	0.43	0.43	0.35	<b>R</b>
<b>Rebate Admin Cost (1% of fuel cost)</b>		0.02	0.03	0.02	<b>S</b>
<b>Net cost with VETC</b>	\$2.50	\$1.55	\$2.55	\$2.29	<b>T</b>

### Table Notes

- A. Current fuel cost per unit
- B. Unit of measurement
- C. BTUs per Unit of Measurement
- D. BTU measurement (Item C) / 127,500 biodiesel BTUs
- E. Assumed burn rates
- F. (Fuel consumption x DGE Ratio) x Unit Price or (Items (D\*E)\*A)
- G. MPG for diesel from Tucson fleet data, CNG/LNG from report
- H. Average daily miles from Tucson fleet data
- I. Fuel price x DGE ratio / MPG or (Items A \* D) / G
- J. Annual truck hours (7 hours a day x 5 days a week x 52 weeks)
- K. Burn Rate x DGE Ratio x Annual Truck hours or (Items (E \* D)\*J)
- L. Annual fuel consumption x Per Unit Price (K \* A)
- M. Build cost of the CNG/LNG fuel station



- N. Annual station cost on a 10 year 6% note  
 O. Total principal and interest for the fueling station  
 P. Total Infrastructure cost divided by estimated DGEs over 10 years  
 Q. Cost per Unit x DGE + Infrastructure Cost (Items (A \* D) + P)  
 R. VETC Tax credit per DGE (\$0.55 / DGE ratio)  
 S. Unit Cost x DGE ratio x 1% (Items A \* D x 1%)  
 T. DGE Cost - VETC Credit + 1% Admin Cost (Q - R + S)

The following table summarizes information collected from the study as well as base assumptions to project the fleet costs from 2010 to 2019. Annual inflation was assumed at 3% for truck purchases and 5% for fuel.

Assumption / Description	CNG	LNG	Biodiesel
<b>Truck Purchase Cost (3% annual increase)</b>	327,501	327,501	238,000
<b>Federal Tax Credit (ends 2010)</b>	(32,000)	(32,000)	-
<b>Net Cost per Truck</b>	295,501	295,501	238,000
<b>Total Truck Costs (11 trucks per year to 2014)</b>	3,250,511	3,250,511	2,618,000
<b>Annual Cost per Truck (5 year depreciation)</b>	59,100	59,100	47,600
<b>Cost per New Truck Hour (1,820 hrs per year)</b>	\$32.47	\$32.47	\$26.15
<b>Fuel Consumption per Truck / year (in DGE)</b>	6,552	6,552	7,280
<b>CNG/LNG Annual Tank Inspection Costs</b>	\$0.50	\$0.50	
<b>DGE price per gallon</b>	\$1.76	\$2.47	\$2.63
<b>Fueling Station Cost per Gallon</b>	\$0.29	\$0.34	
<b>Total Fuel Cost per Gallon</b>	\$2.05	\$2.81	\$2.63

Utilizing the information and assumptions above, the annual costs as well as the following scenarios were modeled to determine the overall costs of each collection fleet. The results are summarized in the table on the following page. The lowest cost alternative is noted with bold type font.

**Scenario 1:** What if diesel increases to \$4 per gallon in 2010 and increases each year at 5%

**Scenario 2:** What if the VETC fuel tax credit of \$0.43 per DGE remains unchanged

**Scenario 3:** Diesel fuel consumption increases to 4.5 gallons per hour under the new 2010 diesel emission standards

**Scenario 4:** Combine Scenario 2 (VETC fuel tax credit) and Scenario 3 (4.5 GHP)

**Scenario 5:** Combine Scenario 1 (Diesel at \$4), Scenario 2 (VETC fuel tax credit), and Scenario 3 (4.5 GHP)

Assumption / Description	2010 to 2015 Year Cost			2016 to 2019 Year Cost		
	CNG	LNG	B-20	CNG	LNG	B-20
Cum. Cost per Truck Hour (1,820 hrs per year)	\$37.51	\$37.51	\$27.77	\$37.35	\$37.35	\$27.77
Total Fuel Cost per DGE	\$2.28	\$3.14	\$2.98	\$2.83	\$3.91	\$3.80
Cost per Truck Hour	\$44.49	\$47.59	\$39.01	\$50.28	\$54.17	\$43.98
Cost per Mile @ 90 Miles per Route	\$3.46	\$3.70	\$3.03	\$3.91	\$4.21	\$3.42
Annual Cost per Truck	\$80,975	\$86,607	\$70,995	\$91,517	\$98,597	\$80,047
Annual Fleet Size (in 2015 / 2019)	55	55	55	55	55	55
Cumulative Annual Fleet Cost	\$18,222,412	\$19,503,566	<b>\$15,900,396</b>	\$38,356,249	\$41,194,923	<b>\$33,510,699</b>
<b>SCENARIO 1 WHAT IF</b>						
Diesel at \$4 and increases 5% each yr.						
Cost per Truck Hour	\$44.49	\$47.59	\$45.23	\$50.28	\$54.17	\$48.74
Cost per Mile	\$3.46	\$3.70	\$3.52	\$3.91	\$4.21	\$3.79
Annual Cost per Truck	\$80,975	\$86,607	\$82,317	\$91,517	\$98,597	\$88,699
Cumulative Annual Fleet Cost	<b>\$18,222,412</b>	\$19,503,566	\$18,481,717	\$38,356,249	\$41,194,923	<b>\$37,995,586</b>
<b>SCENARIO 2 WHAT IF</b>						
VETC Fuel Tax Credit stays in effect?						
Cost per Truck Hour	\$44.18	\$47.55	\$39.01	\$48.26	\$52.43	\$43.98
Cost per Mile	\$3.44	\$3.70	\$3.03	\$3.75	\$4.08	\$3.42
Annual Cost per Truck	\$80,402	\$86,541	\$70,995	\$87,838	\$95,426	\$80,047
Cumulative Annual Fleet Cost	\$17,425,873	\$18,818,951	<b>\$15,900,396</b>	\$36,750,177	\$39,812,698	<b>\$33,510,699</b>
<b>SCENARIO 3 WHAT IF</b>						
Diesel fuel consumption increases to 4.5 GPH?						
Cost per Truck Hour	\$44.49	\$47.59	\$40.50	\$50.28	\$54.17	\$45.88
Cost per Mile	\$3.46	\$3.70	\$3.15	\$3.91	\$4.21	\$3.57
Annual Cost per Truck	\$80,975	\$86,607	\$73,706	\$91,517	\$98,597	\$83,500
Cumulative Annual Fleet Cost	\$18,222,412	\$19,503,566	<b>\$16,518,548</b>	\$38,356,249	\$41,194,923	<b>\$34,888,618</b>
<b>SCENARIO 4: COMBINE 2 &amp; 3</b>						
Cost per Truck Hour	\$44.18	\$47.55	\$40.50	\$48.26	\$52.43	\$45.88
Cost per Mile	\$3.44	\$3.70	\$3.15	\$3.75	\$4.08	\$3.57
Annual Cost per Truck	\$80,402	\$86,541	\$73,706	\$87,838	\$95,426	\$83,500
Cumulative Annual Fleet Cost	\$17,425,873	\$18,818,951	<b>\$16,518,548</b>	\$36,750,177	\$39,812,698	<b>\$34,888,618</b>
<b>SCENARIO 5: COMBINE 1, 2, &amp; 3</b>						
Cost per Truck Hour	\$44.18	\$47.55	\$47.50	\$48.26	\$52.43	\$51.23
Cost per Mile	\$3.44	\$3.70	\$3.69	\$3.75	\$4.08	\$3.98
Annual Cost per Truck	\$80,402	\$86,541	\$86,443	\$87,838	\$95,426	\$93,234
Cumulative Annual Fleet Cost	<b>\$17,425,873</b>	\$18,818,951	\$19,422,534	<b>\$36,750,177</b>	\$39,812,698	\$39,934,116

- APPENDIX A – REFUSE COLLECTION VEHICLES
- APPENDIX B - PUBLIC AND PRIVATE SECTOR SURVEY
- APPENDIX C - GREATER TUCSON ALTERNATIVE FUELING LOCATIONS
- APPENDIX D - CUMMINS WESTPORT, INC. CNG & LNG SERVICE SUPPORT LETTER
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- APPENDIX F - FAB INDUSTRIES / AFV FLEET SERVICE - FUEL TANK MOUNTING OPTIONS
- APPENDIX G - CLEAN ENERGY FUELS – NATURAL GAS ALTERNATIVE FUELS OVERVIEW
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- APPENDIX I - CUMMINS WESTPORT, INC. CLEAN CITIES PRESENTATION AND ISL-G ENGINE SPECIFICATIONS



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## Related Resources and Reports

Alternative Fuel Refueling Station Locator: [www.afdcmmap.nrel.gov/nrel](http://www.afdcmmap.nrel.gov/nrel)

Alternative Fuels Data Center: [www.afdc.nrel.gov](http://www.afdc.nrel.gov)

British Petroleum, Statistical Review of World Energy. 2007, (BP p.l.c.)

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Cummins Westport Inc. 101 - 1750 West 75th Avenue, Vancouver, B.C. Canada V6P 6G2.  
<http://www.cumminswestport.com>

Idaho Office of Energy Resources, P.O. Box 83720, Boise, Idaho 83720-0098.

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NGVAmerica - Natural Gas Vehicles for America. 400 N. Capitol St. NW, Washington, DC 20001.  
Phone: 202/824-7366. [http://www.ngvc.org/about\\_us/index.html](http://www.ngvc.org/about_us/index.html)

Natural Gas Vehicle Coalition, 1100 Wilson Boulevard, Suite 850 Arlington, VA 22209.  
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## **Public Sector Agencies**

Arizona Department of Environmental Quality (ADEQ) – Phoenix, AZ  
City of Culver City, CA – Culver City, CA  
City of Boise, ID – Boise, ID  
City of Fresno, CA – Fresno, CA  
City of Glendale, California – Glendale, CA  
City of Phoenix, AZ - Phoenix, AZ  
City of Sacramento, CA – Sacramento, CA  
City of Santa Monica, CA – Santa Monica, CA  
Town of Smithtown, NY – Smithtown, New York  
U.S. Department of Energy (DOE) – Washington, D.C.  
U.S. Energy Information Administration (EIA) – Washington, D.C.

## **Private Sector Solid Waste Service Providers**

Allied Waste (Republic Services) – Boise, ID  
Burrtec Waste Industry, Los Angeles, CA  
CleanScapes – Seattle, WA  
Napa Recycling – Napa, CA  
Tri-CED Recycling – Union City, CA

## **Alternative Fuels, Equipment and Infrastructure Service Providers**

Applied LNG Fuels Technology – Dallas, TX  
Chart / NexGen Fueling – Georgetown, TX  
Clean Energy Fuels - Seal Beach, CA  
Cummins Westport – Vancouver, B.C.  
FAB Industries / AFV Fleet Service – Fontana, CA  
Fuel Solutions – Los Angeles, CA  
Greenfield NGV Refueling Systems – Pratteln, Switzerland  
McNeilus Truck and Manufacturing – Dodge Center, MN



### **Other Organizations and Associations**

Alternative Fuels and Vehicle Institute (AFVi) – Las Vegas, NV

American Gas Association (AGA) – Washington, DC

Clean Cities Tucson Regional Coalition – Tucson, AZ

Compressed Gas Association (CGA) – Chantilly, VA

International Association of Natural Gas Vehicles (IANGV) - Remuera, Auckland New Zealand

NGVAmerica – Washington D.C.

Valley of the Sun Clean Cities Coalition, Inc. – Phoenix, AZ



# Acronyms and Abbreviations

ADEQ	Arizona Department of Environmental Quality
AFV	Alternative Fuel Vehicle
AGA	American Gas Association
ALT	Alternative
ANSI	American National Standards Institute
ASTM	American Society for Testing and Material
ARB	Air Resources Board
B20	A blend of 20% biodiesel and 80% petroleum diesel
BACT	Best Available Control Technology
BMP	Best Management Practice
CARB	California Air Resources Board
CEQA	California Environmental Quality Act
CGA	Compressed Gas Association
CIP	Capital Improvement Planning
CNG	Compressed Natural Gas
CO	Carbon Monoxide
COT	City of Tucson
DOC	Diesel Oxidation Catalyst
DOT	Department of Transportation
DGE	Diesel Gallon Equivalent
DPF	Diesel Particulate Filter
DPM	Diesel Particulate Matter
EIR	Environmental Impact Report
EPA	Environmental Protection Agency
ESD	Environmental Services Department
FMVSS	Federal Motor Vehicle Safety Standards
GHG	Greenhouse Gas
HC	Hydrocarbon
LNG	Liquefied Natural Gas
LPG	Liquefied Petroleum Gas (Propane)
MDS	Methane Detection System
NOx	Oxides of Nitrogen
NG	Natural Gas
NGV	Natural Gas Vehicle
PM	Particulate Matter
PM10	Particulate matter less than 10 micrometers in diameter
PM2.5	Particulate matter less than 2.5 micrometers in diameter
PPM	Parts per million
PSI	Pounds per Square Inch
PSIG	Pounds per Square Inch, Gauge Pressure
ROG	Reactive Organic Gas (also known as volatile organic compound, VOC)
SAE	Society of Automotive Engineers
SCF	Standard Cubic Feet
SOx	Sulfur Oxide
ULSD	Ultra-low Sulfur Diesel
VFV	Variable Fuel Vehicle
VOC	Volatile organic compound



# Glossary of Terms

<b>Alternative Fuel</b>	As defined by the Energy Policy Act of 1992, these include ethanol, natural gas, propane, hydrogen, biodiesel, electricity, methanol, and p-series fuels. These fuels are being used worldwide in a variety of vehicle and equipment applications. (Note: pure biodiesel – B100 – is considered an alternative fuel under EPA Act. Lower-level biodiesel blends are not considered alternative fuels by the US Department of Energy.). Non-petroleum based fuels are commonly referred to as ‘alternative fuels’ and can have emission reduction benefits for certain pollutants; nonetheless, it is important to note the official definition of ‘alternative fuel’ provided by the U.S. Department of Energy.
<b>Cancer Risk</b>	A quantification of the probability that cancer will develop in a human being due to exposure to a toxic air contaminant (for example, diesel particulate matter). The risk is usually expressed as the number of individuals who may develop cancer out of a population (for example “1 in 10 million”) due to exposure to the toxic air contaminant. Sometimes, the risk is also expressed as “chances in a million”.
<b>Cost Effectiveness</b>	The relationship between cost and emission reductions, stated in terms of dollars per weight of emissions, and used to compare relative costs of projects, technologies, and fuels.
<b>Criteria Pollutant</b>	Under the Clean Air Act Amendments of 1990 the EPA set National Ambient Air Quality Standards (NAAQS) for six important pollutant types which are harmful to human health and the environment. Collectively, these pollutants are referred to as the “criteria” pollutants. These are: CO, Lead, NOx, PM10, PM2.5, Ozone and SOx.
<b>Dispersion Modeling</b>	Dispersion modeling is a modeling tool capable of predicting concentrations of pollutants in air in the vicinity of the pollutant sources. It is typically used to predict PM concentrations at receptor locations around a source of PM. AERMOD and CALPUFF are two of several dispersion modeling tools.
<b>Dose/Dosage</b>	The amount of a contaminant or pollutant that is absorbed or deposited in the body of an exposed organism (for example, a human being) for an increment of time. It is measured in units of [mass].
<b>Emissions Inventory</b>	An emissions inventory is the quantification of emissions rates and/or total emissions over a specified period of time from all sources (or a subset of sources) associated with a defined facility, operation, or geographic location.
<b>Exposure</b>	Contact between a person (for example, skin, nose, or mouth) and a chemical (for example, a toxic air contaminant). Exposure is measured in units of [concentration x time].



<b>Human Health Risk</b>	A health risk assessment (HRA) is the quantitative Assessment (and sometimes non-cancer health effects) that may result from human exposure to pollutants such as toxic air pollutants. HRAs are complex and typically involve emissions quantification, air dispersion modeling, and risk modeling. HRAs estimate the overall potential for cancer and other health impacts in a specific population due to exposure under idealized and simplified conditions, (e.g., living outdoors at one location over a 70 year lifetime). HRAs do not predict an individual's actual likelihood of developing these impacts.
<b>Infrastructure</b>	Refer to the resources required to support alternative fueling (e.g. personnel, fueling equipment (storage tanks, compressors), gas lines (for CNG) or tanker trucking services (for LNG), fuel storage and logistical support.
<b>Nitrogen Oxide (NOx)</b>	Nitrogen oxides are typically created during the engine combustion process, and are major contributors to regional smog formation. NOx is defined as a "criteria pollutant".
<b>Particulate Matter (PM)</b>	Any material, except pure water, that exists in the solid or liquid state in the atmosphere. The size of the particulate matter can vary from coarse (e.g. wind-blown dust) to fine (combustion by-products). This Plan focuses on PM with a particle size of 2.5 to 10 microns (PM2.5-PM10).
<b>Toxic Air Contaminant</b>	Toxic Air Contaminants (TACs) are pollutants that may cause serious, long-term health effects in humans, such as cancer, even at low levels. The ARB has a currently identified list of approximately 200 TACs which includes some VOCs and PM emissions from diesel combustion, among others.
<b>VDECS</b>	Verified Diesel Emission Control System. This refers to a variety of control technologies for reducing emissions of PM, NOx or HCs from diesel engines, that have been verified by the CARB to reduce emissions by a specified percentage.
<b>(VOCs)</b>	VOCs are Volatile Organic Compounds - Carbon-containing compounds that evaporate into the air (with a few exceptions). VOCs contribute to the formation of smog and/or may be toxic. VOCs often have an odor. Examples include gasoline and paint solvents. VOCs are also known as reactive organic gases (ROG).



# Appendix A – Refuse Collection Vehicles

## City of Tucson Refuse Collection Fleet

The City of Tucson (COT) Arizona Environmental Services Department (ESD) has an extensive fleet of solid waste and recycling collection vehicles which it utilizes to collect all residential solid waste and recyclables, as well as all commercial waste and provides some industrial (roll off) services. Environmental Services provides Tucson citizens and businesses with solid waste collection and disposal. Other services include:

- Recycling and waste reduction services.
- Operating the City's Los Reales Landfill in compliance with State and Federal regulations.
- Cleaning up groundwater at old landfills.
- Ensuring that the City's air quality and industrial waste discharge permits are up-to-date and in compliance.

Environmental Services (ES) provides single-family households and multi-family housing (up to 24 units) with automated garbage and recycling service once each week, both collected on the same day. ES residential customers are charged a monthly fee for garbage and recycling collection which is included in their Utility Services bill.

The following services are provided to residential customers:

- Weekly Trash Collection
- Recycling
- Brush and Bulky Materials Collection
- Household Hazardous Waste Disposal Options

## Curbside Residential Collection and Recycling

The City of Tucson (COT) utilizes a mixed fleet (by brand of chassis and body types) of approximately 45 refuse collection vehicles (truck(s)) to collect residential refuse (municipal solid waste – MSW), each with a one person crew to automatically empty containers of garbage into the truck. The standard collection vehicle is a 25 cubic yard capacity automated side loading (ASL) collection truck (see picture at left).



The COT currently provides weekly collection of refuse (garbage) on the same day as recycling collection. The total cost of this service per residential household is \$14.50 (effective July 1, 2009) and is included in ratepayer's Utility Services bill, which also includes Tucson Water and Pima County Sewer charges.

Most residents have a 90-gallon green garbage container collected at the curb. In some areas, up to three households share 300-gallon containers in



alleys. Each resident is allotted 1/3 of the volumetric space of the alley containers.

Residential recyclables are collected primarily in blue 90-gallon roll carts and some smaller 65 gallon and 48 gallon carts provided to the customer at no additional charge. The City's ESD provides weekly curbside collection of an unlimited amount of recyclables on the same day as garbage collection. A variety of source-separated recyclable materials are collected curbside. The collection of recyclable materials is accomplished by a one person crew utilizing a side loader through body truck, where the driver can segregate materials at the curb.

Weekly curbside and alley residential solid waste and recycling collection service is offered to approximately 133,000 households in the City of Tucson ESD. Recyclables are collected in separate trucks on the same day as garbage pickup.

### Commercial Refuse Collection

The City of Tucson Environmental Services (ESD) provides garbage collection from one to six days a week at commercial locations. ESD provides a variety of sizes and types of refuse and recycling containers— frontload metal (dumpsters) and compactors to provide customers with the type of equipment to best meet their business' needs.



Waste in commercial containers is collected using front-load or rear-load type collection vehicles. The containers range in volumetric size from two to eight cubic yards in capacity, with collection frequency from once a week to five times a week, depending on the needs of the individual customer.

Most of the City's commercial waste is collected using the front-load style commercial collection trucks (as pictured at left) and front-load style containers however rear-load service is provided in areas such as the downtown area due to tight access or overhead electrical wires. The COT serves approximately 3,900 commercial accounts.



### Brush and Bulky Collection



Three – person crews visit each of Tucson's 26 residential trash service areas twice each year to provide curbside Brush and Bulky collection.



# Appendix B – Natural Gas & Biodiesel Fuels

## Natural Gas Overview

Natural gas is a very simple fuel. Around 90% of natural gas is methane (CH<sub>4</sub>) which is just one carbon atom with four hydrogen atoms attached, with the remainder comprising of propane, butane and other components. Composition varies according to the source of the natural gas.

The only simpler fuel available is hydrogen, which is technically an energy 'carrier' rather than an energy source itself. As yet there is no economic method of creating and distributing large quantities of hydrogen, so, until this occurs, natural gas will remain the clean fuel of choice for some time. Being rich in Hydrogen, natural gas is often used as a feedstock, which is one of the reasons why natural gas vehicles are often referred to as the 'pathway to the hydrogen economy'. Ultimately, an investment in natural gas infrastructure is an investment in hydrogen infrastructure.

The population in general is most familiar with Natural Gas as a fuel to be used for cooking on natural gas fueled stoves (as pictured at right). This is the exact same natural gas (NG), only liquefied (LNG) or compressed (CNG) that is piped underground and stored that can be used as an alternative vehicle fuel.



Natural gas is made up primarily of methane with trace amounts of other gases. It occurs naturally underground and is extracted through gas wells or in conjunction with crude oil production. For storage purposes it can be stored as compressed natural gas (CNG) or liquid natural gas (LNG).

## Vehicles Utilizing Natural Gas (NG)

Natural gas vehicles (NGV) are the most advanced alternative fuel technology available commercially. Applications include transit and school buses, refuse trucks, light-duty vehicles, vans, passenger cars and taxis. LNG is not suitable for light-duty vehicles but is an ideal fuel for large (class 8) trucks, transit buses, and medium-duty fleet trucks. There are over 110,000 NGVs on the road in the U.S. fueling at 1,300 locations. Over half of these sites are commercially accessible.

According to the Environmental Protection Agency, there are more than 90,000 CNG vehicles on the road, including one (1) out of every five (5) transit buses. Some vehicles come already equipped to run either entirely on CNG (dedicated) or on both CNG and gasoline or diesel (bi-fuel). Additionally, some vehicles can be converted to run on CNG. Both light and heavy-duty vehicles can utilize CNG. All U.S.-based, full-sized transit bus manufacturers offer CNG buses.

## How Does Natural Gas Perform?

Vehicles running on NG may have reduced range as compared to similar diesel model vehicles. This is a limitation of the fuel storage tanks rather than a limitation of the fuel. For example a dedicated CNG Honda Civic GX has an eight-gallon tank and a gasoline powered Civic has an eleven-gallon tank. However, NGVs experience the same fuel economy with CNG as they do with gasoline. Bi-fuel vehicles have a longer range because they have two fuel tanks and can run on gasoline or diesel in addition to CNG. Because methane does not have to vaporize before being burned with oxygen, natural gas can burn cleaner, especially at colder temperatures than gasoline or diesel. LNG is kept at very low temperatures to increase storage capability and therefore



provides longer ranges than CNG. Vehicles operating on CNG and LNG have a longer engine life and require less frequent oil change intervals.

## What Are the Benefits of Using Natural Gas?

The burning of natural gas for fuel results in lower emissions of sulfur dioxide, particulate matter, and 20% less carbon dioxide when compared to gasoline or diesel. It is one of the cleanest burning fuels. Natural gas is non-toxic, non-corrosive, less combustible than most other fuels, and has few associated health risks. CNG is stored under high pressures. The range of flammability and combustion is much narrower with CNG, making it safer than gasoline. The flashpoint for gasoline is 250 degrees Fahrenheit whereas the flashpoint for natural gas is 1100 ° F. Natural gas is lighter than air and will dissipate if leaked whereas gasoline will sink and puddle. Dedicated NGVs produce little or no evaporative emissions during fueling and use. In gasoline vehicles, evaporative and fueling emissions account for at least 50% of a vehicle's total hydrocarbon emissions.

Exposure to the levels of suspended fine particulate matter found in many U.S. cities has been shown to increase the risk of respiratory illness and other health problems. Much of the particulate matter in urban areas is due to transportation. Natural gas produces only tiny amounts of particulate matter. Natural gas is abundant, low-cost, and domestically produced.

## How is Natural Gas Produced?

Most natural gas comes from three types of wells: natural gas-and-condensate wells, oil wells, and coal bed methane wells. In 2003, California had over 1,200 natural gas-and-condensate wells operating. Well-extracted natural gas requires a cleanup process before it can be used in vehicles or residences.

## Where Does Natural Gas Come From?

More than 99 percent of the natural gas used in the United States comes from domestic or other North American sources. However, increasing demand for natural gas in power plants will require new supplies from non-North American countries, increasing our dependence on foreign sources of energy. The Energy Information Administration (EIA) predicts that, by 2025, more than 15 percent of our natural gas supplies will be imported from countries other than Canada and Mexico.

## How is Natural Gas Delivered to Transportation Customers in Arizona?

Primarily it is imported by pipeline from Canada and the Rocky Mountain and Southwestern states. Arizona natural gas utilities distribute the fuel to customers. Most CNG and LNG vehicle fueling stations are owned and operated by private companies and local governments.

## How is Natural Gas Stored?

In smaller fueling locations and on vehicles, NG is stored in thick-walled steel, aluminum, or composite tanks built to last more than 20 years.

## Is Natural Gas Flammable?

When released, compressed natural gas will mix with air and become flammable only when the mixture is within 5 to 15 percent natural gas. When the mixture is less than 5 percent natural gas, it doesn't burn. When the mixture is more than 15 percent natural gas, there is not enough oxygen to allow it to burn. Because natural gas is lighter than air, it quickly dissipates when released from tanks.



## What are the Benefits of Using Natural Gas in Transportation?

Natural gas is produced both worldwide and domestically at relatively low cost and is cleaner burning than gasoline or diesel fuel. Natural gas vehicles show an average reduction in ozone-forming emissions of 80 percent compared to gasoline and diesel powered vehicles.

### Natural Gas Benefits

Natural gas is a domestically available, inherently clean-burning fuel. Using compressed natural gas (CNG) and liquefied natural gas (LNG) as vehicle fuels increases energy security, paves the way for fuel cell vehicles, and improves public health and the environment. Using renewable natural gas provides even more benefits.

### Increasing Energy Security

The United States imports more than 60% of its petroleum, two thirds of which is used to fuel vehicles in the form of gasoline and diesel. The demand for petroleum imports is increasing. With much of the worldwide petroleum reserves located in politically volatile countries, the United States is vulnerable to supply disruptions.

Natural gas vehicles are an immediate solution to the nation's energy security needs. Most of the natural gas consumed in the United States is produced domestically or by politically stable countries, and an extensive natural gas infrastructure exists. Using natural gas vehicles instead of conventionally fueled vehicles reduces U.S. dependence on foreign oil and increases energy security.

### Paving the Way for Fuel Cell Vehicles

Fuel cell vehicles powered by hydrogen might be the future of transportation. Natural gas vehicle and infrastructure development can facilitate the transition to this technology. With the highest hydrogen-to-carbon ratio of any energy source, natural gas is an efficient source of hydrogen—in fact, it is the number one source of commercial hydrogen used in the United States. The vast U.S. network of natural gas transmission lines offers the potential for convenient transportation of natural gas to future refueling stations that reform hydrogen from the gas.

Because natural gas and hydrogen are both gaseous fuels, lessons learned from developing natural gas technologies might aid the transition away from conventional liquid fuels to gaseous hydrogen fuel. Issues shared by natural gas and hydrogen include:

- Fuel storage
- Fueling
- Station siting
- Training
- Facilities
- Public acceptability

Vehicles fueled with hydrogen-natural gas blends (HCNG) are a first step toward a hydrogen-based transportation network. Fueling vehicles with HCNG can help build demand for a hydrogen infrastructure while providing enhanced emission reductions.



## Protecting Public Health and the Environment

Compared with vehicles fueled by conventional diesel and gasoline, natural gas vehicles can produce significantly lower amounts of harmful emissions such as nitrogen oxides, particulate matter, and toxic and carcinogenic pollutants as well as the greenhouse gas carbon dioxide.

### Natural Gas reduces:

- Benzene emissions by 97% compared to diesel and 99% compared to gasoline
- Nitrogen oxides by 87% compared to diesel and 35-60% compared to gasoline
- Carbon dioxide by 10% compared to diesel and 25% compared to gasoline
- Carbon monoxide by 90-97% compared to gasoline
- Non-methane hydrocarbons by 50-75% compared to gasoline
- Lead and sulfur emissions by 100% compared to both diesel and gasoline
- Smoke and particulate matter (PM10) significantly

Natural gas occupies more volume than traditional liquid fuels thus it must be compressed or liquefied to make it practical for transport applications. Compressed Natural Gas (CNG) is the most common application for NGVs though Liquefied Natural Gas (LNG) use is becoming increasingly common.

### CNG and LNG as Natural Gas Vehicle Fuels (NGVs)

When comparing fuel prices it is important to consider energy content of fuels. CNG is sold either by the kilogram or the cubic meter (m<sup>3</sup>) and LNG is measured in liters. A cubic meter of natural gas contains approximately 38.3\* mega joules per cubic meter (MJ/m<sup>3</sup>), which is approximately the same amount of energy as a liter of diesel (38.8\* Mj/l). In some countries, CNG or LNG is sold by the Gasoline per Gallon Equivalent (GGE) or Diesel per Gallon Equivalent (DGE). In these cases the energy content has already been taken into account so the fuel price comparison can be made directly. NGVs, or Natural Gas Vehicles, look like any other vehicle. The difference is that NGVs operate on natural gas as opposed to the fuel typically pumped into fleet vehicles' tanks.

Found in reservoirs deep below the earth's surface and ocean floors, natural gas is formed by the decay of organic matter. Natural gas reserves come from large quantities of plant and animal remains that have accumulated between layers of sediment on the bottoms of lakes and oceans over millions of years. The pressure from the layers of sediment and the heat from the earth's core convert the organic materials into natural gas, petroleum and coal. All oil deposits contain natural gas, although natural gas is often found without oil.

NGVs typically use one of two varieties of natural gas: Compressed Natural Gas (CNG) or Liquefied Natural Gas (LNG). The preferred fueling method for light to medium NGVs, CNG stations dispense between five and ten gallons per minute. Heavy-duty NGVs with weight and range requirements typically fuel up on LNG, which allows them to store more fuel on board with less tank weight. L/CNG stations can service both types of NGVs by converting LNG into CNG.

The natural gas (NG) used for fueling Natural Gas Vehicles (NGVs) is the same natural gas that is piped to millions of homes for cooking and heating throughout North America. The interest in natural gas as an alternative transportation fuel stems mainly from its clean-burning qualities, its domestic resource base, and its commercial availability. Because of the gaseous nature of this fuel, it must be stored onboard a vehicle in either a compressed gaseous (compressed natural gas, CNG) or liquefied (liquefied natural gas, LNG) state. CNG and LNG are considered alternative fuels under the Energy Policy Act of 1992.



## Liquefied Natural Gas

To store more energy onboard a vehicle in a smaller volume, natural gas can be liquefied. To produce LNG, natural gas is purified and condensed into liquid by cooling to  $-260^{\circ}\text{F}$  ( $-162^{\circ}\text{C}$ ). At atmospheric pressure, LNG occupies only 1/600 the volume of natural gas in vapor form. A GGE equals about 1.5 gallons of LNG. Because it must be kept at such cold temperatures, LNG is stored in double-wall, vacuum-insulated pressure vessels. LNG fuel systems typically are only used with heavy-duty vehicles.



## What Is LNG Fuel and How Is It Processed?

Liquefied natural gas is a naturally occurring mixture of hydrocarbons (mainly methane, or  $\text{CH}_4$ ), that has been purified and condensed to liquid form by cooling (refrigerating) cryogenically to  $-260^{\circ}\text{F}$  ( $-162^{\circ}\text{C}$ ). At atmospheric pressure, it occupies only 1/600 the volume of natural gas in vapor form.

Because it must be kept at such cold temperatures, LNG is stored in double-wall, vacuum-insulated pressure vessels. Compared to the fuel tanks required for using compressed natural gas (CNG) in vehicles operating over similar ranges, LNG fuel tanks are smaller and lighter. However, they are larger, heavier, and more expensive than diesel fuel tanks.

Methane is the simplest molecule of the fossil fuels and can be burned very cleanly. It has an octane rating of 130 and excellent properties for spark-ignited internal combustion engines.

Compared to conventional fuels, LNG's flammability is limited. It is nontoxic, odorless, noncorrosive, and noncarcinogenic. It presents no threat to soil, surface water, or groundwater. LNG is used primarily for international trade in natural gas and for meeting seasonal demands for natural gas. It is produced mainly at LNG storage locations operated by natural gas suppliers, and at cryogenic extraction plants in gas-producing states. Only a handful of large-scale liquefaction facilities in the United States provide LNG fuel for transportation.

## Where does LNG come from?

Most LNG is imported to the United States from Trinidad and Tobago, Qatar, Algeria, Nigeria, Australia and Indonesia. It is transported in large, modern LNG ocean carriers to one of eight U.S import terminals in:

- Cove Point, Maryland Began operation in 1978
- Elba Island, Georgia Began operation in 1978
- Everett, Massachusetts Began operation in 1971
- Lake Charles, Louisiana Began operation in 1982
- Gulf Gateway Energy Bridge Began operation in 2005
- Freeport, Texas Began operation in 2008
- Sabine, Louisiana Began operation in 2008
- Northeast Gateway, Offshore Boston Began operation in 2008
- Additionally, there is an import terminal in Puerto Rico

Upon reaching its destination, LNG is stored as a liquid before being warmed back into a gas and sent out via pipelines as natural gas. Even though there are only eight import terminals in the



United States, there are more than 100 LNG production, transport and storage facilities across the country.

The United States also exports LNG to Japan from Kenai, Alaska. Without a pipeline or an LNG import terminal on the West Coast, it is impossible to bring the Alaskan natural gas to the lower 48 states for domestic consumption.

### What are the advantages of LNG?

LNG takes up a much smaller fraction of space than natural gas. Six hundred cubic feet of natural gas turns into just one cubic foot of liquefied natural gas. In areas where geologic conditions are not suitable for developing underground gas storage facilities, LNG has provided the opportunity to economically store natural gas. The gas is stored at what are called peak-shaving facilities, for use during high-demand periods. It is stored as a liquid at these facilities until it is needed, at which point it is returned to its gaseous state and sent through pipelines to consumers.

Since the volume of LNG is 600 times smaller than natural gas, it is more efficiently transported over long distances by sea. This takes place in specially designed ships. The real advantage is that LNG allows us to import natural gas from other countries around the world. This expands and diversifies U.S. natural gas supplies, which in turn increases supply reliability and security.

### Calculating Energy Equivalent Fuel Economy for LNG and Diesel

LNG is measured in mass units (pounds) when it is delivered to the truck's storage system. However, the dispenser at the LNG station electronically converts the measurement from pounds to gallons and displays gallons of LNG dispensed at a specific pressure. The next step in calculating fuel economy is to adjust the LNG gallons to atmospheric pressure rather than the pressure dispensed into the truck. This is called a standard LNG gallon.

Because LNG contains less energy per gallon than diesel, comparing simple miles per gallon of LNG and diesel trucks would not accurately compare their true fuel efficiencies. Diesel gallon equivalents (DGEs) are commonly used to solve this problem. A DGE is the quantity of LNG (or any other fuel) that contains the same energy as a gallon of diesel. Because 1.67 gallons of LNG contain the same energy as 1 gallon of diesel, 1.67 gallons of LNG equal 1 DGE.

The fuel economy of LNG vehicles is calculated based on energy content of the LNG fuel plus energy content of the diesel used, giving the following final fuel economy calculation with units of miles per DGE: Fuel Economy = Miles traveled/(LNG std gal/1.67 + diesel gal).



### Compressed Natural Gas

Compressed Natural Gas, or CNG, is natural gas under pressure which remains clear, odorless, and non-corrosive. Although vehicles can use natural gas as either a liquid or a gas, most vehicles use the gaseous form compressed to pressures above 3,100 pounds per square inch. Heavy Duty vehicles utilize CNG compressed at 3,600 PSI.

CNG is natural gas that has been compressed into a high-pressure container for transportation (such as the tanks shown at right). Since the 1960s, CNG has become a vehicle fuel alternative to oil-based gasoline and diesel fuel. The International



Association for Natural Gas Vehicles (IANGV) estimates that more than one million vehicles worldwide operate on CNG.

In the United States more than 1,300 CNG refueling stations are available. The total includes public service stations and private depot-based refueling stations intended to serve fleets. Several companies provide CNG/LNG refueling infrastructure to fleets on a component or turnkey basis.

To provide adequate driving range, CNG must be stored onboard a vehicle in tanks at high pressure—up to 3,600 pounds per square inch. A CNG-powered vehicle gets about the same fuel economy as a conventional gasoline vehicle on a gasoline gallon equivalent (GGE) basis. A GGE is the amount of alternative fuel that contains the same amount of energy as a gallon of gasoline. A GGE equals about 5.7 lb (2.6 kg) of CNG.



### Biodiesel Fuel

Biodiesel is a naturally oxygenated fuel produced from organic feed sources such as soybeans, cooking oil, and animal fats.

Biodiesel can be used in its pure form (B100 or "neat") or blended at a 20% ratio with petroleum diesel (B20, i.e. 20% biodiesel in diesel is called B20) to achieve cost efficiency and improve cold weather performance. As mentioned earlier, the City of Tucson's current refuse collection fleet operates on a B20 blend of Biodiesel.



Biodiesel can be used in any diesel vehicle without modification. It is used extensively in parts of Europe and is gaining support in the United States. Applications include buses, delivery trucks, waste disposal and recycling trucks, construction and farm equipment, heavy-duty freight hauling, and boats.

### How Does Biodiesel Perform?

Biodiesel performs just like traditional diesel, though B100 may result in a minimal power loss at the high end and a slight reduction in fuel economy. B20 users generally experience no marked difference in fuel economy from petroleum diesel. Pictured at lower left is the City of Tucson's Thomas Price Service Center Biodiesel Storage tank.



ASTM International has reviewed biodiesel performance and issued a final specification (users should be sure that any fuel they purchase meets ASTM D6751). Because biodiesel acts as a lubricant, it reduces wear and tear on the engine, reducing maintenance costs and extending engine life.

Biodiesel remains blended with petroleum diesel so it can be easily stored and dispensed in existing facilities. Biodiesel thickens more than diesel fuel in



cold weather and special systems or minor modifications are required for use of B100. Vehicles produced prior to 1993 should have rubber seals in fuel pumps and fuel systems replaced with non-rubber (Viton) seals.

### **What are the Benefits of Using Biodiesel?**

Biodiesel results in significantly lower emissions of particulate matter, carbon monoxide, hydrocarbons, visible smoke and noxious odors than petroleum diesel.

Depending on the feed source, biodiesel can result in lower life-cycle carbon dioxide emissions, however not lower than when compared to natural gases.



# Appendix C – Industry Research and Interviews

This Section provides a summary of the independent research that WIH Resource Group’s Project Team conducted on behalf of the City of Tucson. The independent research consisted of developing an interview survey, identifying known alternative fuel fleet users (both CNG and LNG) and Original Equipment Manufacturers (OEMs) for engines, fueling stations, fuel tanks and truck chassis and refuse collection bodies as well as alternative fuel suppliers.

## Industry Research

The WIH Resource Group project team conducted a series of interviews and meetings with individuals that are considered subject matter experts (SMEs) from public agencies, private sector solid waste collection companies and industry suppliers of both alternative fuels and engines.

The private and public sectors interviewed are currently operating CNG and/or LNG fuel refuse collection fleets in the United States. The purpose of these interviews was to obtain information about the companies, understand their experience and knowledge in the use of CNG- and LNG - powered refuse collection vehicles.

The companies interviewed for this study are identified in the following table.

### Private Sector Companies, Suppliers and Public Agencies Interviewed

Private Sector Companies	Public Agencies	CNG Suppliers (Fuel and OEMs)	LNG Suppliers (Fuel and OEMs)
Allied Waste (Republic Services)	City of Burbank, CA	AFV Fleet Service	AFV Fleet Service
Burrtec Waste	City of Boise, ID	Clean Energy Fuels	ALT Fuels
CleanScapes	City of Culver City, CA	Cummins Westport	Chart / NexGen Fueling
Napa Recycling	City of Fresno, CA	Fuel Solutions	Clean Energy Fuels
Tri-CED Recycling	City of Glendale, CA	Greenfield NGV Refueling Systems	Cummins Westport
Waste Connections	City of Phoenix, AZ	McNeilus Truck and Manufacturing	
Waste Management	City of Sacramento, CA City of Santa Monica, CA Town of Smithtown, NY		

Prior to the interviews, each company or agency was provided a survey and a list of the issues that it would be asked about during its interview. A list of the issues that were discussed during these interviews is provided in the table on the following page.



## Private Sector Companies and Public Agencies Survey Questions

### Issue

1. Comparison of Liquefied Natural Gas (LNG), Compressed Natural Gas (CNG), and biodiesel with regards to gross vehicle weight and payload.
2. Comparison of LNG, CNG, and biodiesel with respect to fuel tank capacity, fuel loss and fueling frequency.
3. Analysis of vehicle performance in terms of productivity number of stops, start and stop, unit life, etc.
4. Vehicle maintenance experience with LNG and CNG vehicles.
5. Vehicle capital cost and funding approached with respect to grants and dealer pricing for tax rebates and state tax credits.
6. Evaluation of natural gas fueling options slow fill verses fast fill.
7. Emissions from Alternative Fuel Vehicles (AFVs) compared to diesel fuel vehicles.
8. Analysis on issues stemming from the mounting of the fuel tanks to the body, specifically the following:
  - Height restrictions in COT alleys or underpasses;
  - Tank serviceability by mechanics and required fall protection

## Surveys and Interviews

The WIH Resource Group Project Team informed each organization that some of the issues discussed in the interview could involve proprietary information. In response, each organization was assured that only the company's contact information would be included in the report. As such, this report contains a summary of the information collected from the interview responses.

An aggregated summary of industry responses to the technical and operating issues discussed in the interviews is included on the following pages.



## **1. Comparison of Liquefied Natural Gas (LNG), Compressed Natural Gas (CNG), and biodiesel with regards to gross vehicle weight and payload.**

Most parties interviewed reported a 200 pound to 600 pound range of tare weight increase (payload reduction impact) of natural gas powered refuse trucks to that of diesel powered vehicles. These statements were made based on 50-75 diesel gallon equivalent natural gas fuel tanks being utilized.

Several parties noted that they anticipate that entire weight variance to shift to the benefit of natural gas powered trucks as a result of the U.S. EPA 2010 emissions reductions requirements that will cause diesel powered engine manufacturers to add particulate traps and other pollution emission reduction filters that will not only increase the tare weight of the vehicle, but decrease its fuel economy too, offering an advantage to natural gas powered fleets. Most parties surveyed stated that The cost savings in fuel alone can pay for any incremental increase associated with moving to CNG powered vehicles.

## **2. Comparison of LNG, CNG, and biodiesel with respect to fuel tank capacity, fuel loss and fueling frequency.**

While all parties reported a fuel tank capacity reduction impact – CNG's Diesel Gallon Equivalent (DGE) is approximately 1.4 and LNG was reported to have a Diesel Gallon Equivalent (DGE) range of 1.5 - 1.7 DGE, depending on who was being interviewed (an industry average of 1.67 DGE for LNG) – newer onboard fuel tank technology and improved tank designs are noticeable decreasing in weight and allowing natural gas powered refuse vehicles to gain in the weight difference of their diesel powered counterparts. As a result, a few parties commented that the new DGE for CNG will be more like 1.2.

The only fuel loss reported was with respect to LNG powered trucks, when LNG powered trucks go “down” unexpectedly, the LNG fuel tends to vaporize, leaving the fuel tank at or near empty creating a need to have the vehicle towed if left for an extended period of time before repairing the vehicle and being able to refuel.

Fueling frequency for natural gas trucks was reported to be no different than diesel powered vehicles – requiring daily refueling based on “average” daily routes. These comments were based on a range of feedback from fleets that had onboard fuel tank capacity range of between 50 and 75 diesel gallon equivalent (DGE). The other critical element in developing fuel tank specifications for new CNG fleets is to contrast necessary daily truck fuel range with that of the collection routes and the DGE ratios for determining what capacity and how many of the CNG fuel tanks must be mounted to the refuse truck to insure critical travel ranges are met.

Also, actual time to fuel for a “fast-fill” CNG truck was comparable to fueling a standard diesel or biodiesel powered vehicle (estimated range of between 10 and 15 minutes per vehicle fueling). Drivers positively comment about the fact that CNG and LNG are odorless compared to diesel when fueling and there is no concern over spilling fuel.

Several commented preferring CNG over LNG fuel as it is a more readily available as fuel source via existing underground pipelines and does not involve the need for having a semi-tractor deliver it or large storage tanks for storing it on site.



### **3. Analysis of vehicle performance in terms of productivity number of stops, start and stop, unit life, etc.**

All parties interviewed reported no impact to productivity with new and later model Cummins Westport ISL-G engines that were either powered by CNG or LNG, especially in the newer 320 horsepower engines. Several parties interviewed even commented that they had fairly steep grades enroute to their landfills and that the natural gas powered fleet was comparable to that of its diesel and biodiesel counterpart vehicles.

### **4. Vehicle maintenance experience with LNG and CNG vehicles.**

The Responses were a bit mixed here in that some reported that they experience no cost difference between natural gas and diesel powered refuse trucks for maintenance and others reported the 1,500 hour interval requirement for replacing the spark plugs cost about for the Natural Gas fleet created a higher annual cost per refuse collection vehicle of between \$500.00 and \$1,500.00 per vehicle, again depending on the source.

In all cases, parties interviewed citing receiving adequate training for their mechanics for providing servicing to the CNG and LNG powered vehicles and that their local OEM's dealer support services were adequate and responsive in meeting their needs.

There was a mixed response on the number of fleets that outsource engine repair work versus performing it in-house. In terms of maintenance, the cost for traditional preventative maintenance services was equal between the three fuel types.

Several natural-gas-tenured fleet maintenance managers commented that the reliability of the natural gas powered trucks is as good as diesel powered trucks and their engines.

### **5. Vehicle capital cost and funding approached with respect to grants and dealer pricing for tax rebates and state tax credits.**

On average parties interviewed stated a cost differential of \$48,000 to \$50,000 per natural gas refuse truck over its biodiesel counterpart, however all went on to say that they were able to secure grant funding and government incentives to offset the cost differential. Each party interviewed cited a range of sources for grant funding and pricing incentives and most of them have been captured later in this report in Sections 4.5 and 4.6.

### **6. Evaluation of natural gas fueling options slow fill verses fast fill.**

Parties interviewed first commented that the time to fill either a CNG or LNG powered refuse vehicle is similar to that of a diesel powered vehicle. The only difference being for CNG, the compression – pounds per square inch (PSI). If in a fast-fill application, 3,600 PSI cannot be achieved, the CNG fuel tanks will only reach approximately 75 – 80 % capacity, reducing the vehicle's travel range. Conversely, they also reported that a "time-fill" (fast - fill) reduces the driver's time for fueling and increases the density and fuel tank capacity as it has a better fill percentage verses a fast fill.

Most parties reporting using the fast-fill method, however several stated they would prefer a slow-



fill method as they know it would reduce their driver time at the fueling station pump, improve their refuse vehicle's fuel range and offers simultaneous fueling of multiple vehicles.

## 7. Emissions from Alternative Fuel Vehicles (AFVs) compared to diesel fuel vehicles.

All parties reported knowing there is a significant advantage offered by Alternative fueled refuse collection vehicles, although most only cited parts of what they could recall in terms of the incremental benefits.

In summary though, Biodiesel is a diesel replacement fuel made from a blend of new and/or used vegetable oils and/or animal fats. Just like petroleum diesel, Biodiesel operates in compression-ignition engines. Blends of up to 20% Biodiesel (mixed with petroleum diesel fuels) can be used in nearly all diesel equipment and are compatible with most storage and distribution equipment.

## 8. Analysis on issues stemming from the mounting of the fuel tanks to the body, specifically the following:

- Height restrictions in COT alleys or underpasses;
- Tank serviceability by mechanics and required fall protection

Most all parties interviewed provided favorable feedback with respect to concerns over overhead passes that could interfere with the CNG fuel tanks mounted on top of the body or behind the cab of the refuse truck.

There are a wide range of mounting locations on the truck, chassis, body and shelf behind a trucks' cab to insure the fuel tanks are kept safe from harm's way. Most fuel tank OEMs now have developed enclosures for protecting the actual CNG fuel tanks (cylinders) from being exposed to potentially dangerous situations and obstructions that could puncture or any way damage the fuel tanks.

Knowing this was a serious concern for the City of Tucson, the WIH Resource Group Project Team conducted significant research and interviews of industry subject matter experts and the findings of the research are summarized in Section 7 of this report.

In terms of fuel tank serviceability, all reported utilizing third party certified contractors (fuel tank inspectors) so their own fleet maintenance and mechanics were not directly involved in inspecting the tanks at the required intervals making the fall protection and non-issue.

## Current Private and Public Sector NG Fleets

Refuse trucks powered by economical, clean-burning, environmentally friendly natural gas — a proven alternative to diesel-powered refuse trucks — are being deployed in increasing numbers by municipalities and refuse operators nationwide.

Over 2,500 natural gas refuse collection vehicles are in operation nationwide in about 57 communities. Those numbers are projected to nearly double in the next year as the new 2010 U.S. EPA emissions requirements kick in and new tax incentives take effect. Municipal public works and sanitation departments and their contract haulers have many natural gas vehicles



(NGVs) to choose from, including collection trucks from most of the major refuse truck chassis providers.

### Current Private & Public CNG Refuse Fleet Operators

Private Sector	Public Sector
Waste Management	Smithtown, NY
Republic Services (Allied Waste)	City of Los Angeles, CA
Waste Connections	County & City of Sacramento, CA
Alpine Waste	City of Fresno, CA
CR&R	City of San Diego, CA
Burrtec Waste	City of Long Beach, CA
CalMet	Santa Monica, CA
Athens	Tulare, CA
South City San Francisco	Palo Alto, CA
CleanScapes	Bakersfield, CA
Brookhaven	San Antonio, TX
Harrison Disposal	Austin, TX
Specialty Solid Waste	Philadelphia, PA
Alameda County Industries	Atlantic City
Amador Valley Industries	City of Denver, CO
Norcal Waste Systems	City of Seattle / Seattle Public Utilities
Smithtown, NY Private Sector Contractors: Garofalo, Jody Enterprises, Brothers Waste & Dejana	

Source: Clean Energy Fuels, Inc, Cummins Westport and NGV Industry Associations.

In the Western U.S., California is home to a large number of natural gas refuse trucks serving municipalities statewide. Waste Management pioneered the move to natural gas in California in 1998. Clean Energy partnered with Waste Management to supply the fuel, and to build and operate its fueling station.

In the Eastern U.S., the Town of Smithtown, New York in 2006 required that all refuse haulers serving their community switch from diesel-powered to natural gas-powered refuse trucks by January 2007. This requirement was the first of its kind for a New York State municipality. Clean Energy partnered with Smithtown to provide a fixed fuel price for its contractors, as well as helpful financing for their purchase of new vehicles. In early 2008, the Town of Brookhaven, NY also made this mandate. Other municipalities are planning to mandate natural gas.

The average price of natural gas is up to \$1.00 less per diesel gallon equivalent (DGE) and refuse truck operators can get fixed-price, multi-year natural gas fueling contracts from CNG and NG fuel suppliers like Clean Energy.

The use of natural gas as a vehicle fuel helps reduce U.S. dependence on foreign crude oil. In 2005, 64% of the crude oil used in the United States was imported from foreign sources other than Canada. By comparison, in 2005, an estimated 97% of the natural gas used in the United States was supplied from the United States and Canada, making it less vulnerable to foreign supply disruption and price volatility.



## Industry Trends

An ever-increasing number of public and private refuse operators are using natural gas-powered refuse trucks because they're cleaner and quieter than diesel-powered units, yet deliver the same power and performance that drivers want, and because they're less expensive to operate.

Natural gas fleets also have the added advantage that they displace petroleum fuel. As world oil demand outpaces supply and causes prices at the pump to rise, fleet operators should factor this into their strategic planning, especially given our reliance on politically unstable oil producing regions of the world.

Fortunately, about 97% of all natural gas used in the U.S. comes from the lower 48 states and Canada and supplies are abundant. As tough new heavy-duty engine emissions requirements take effect, natural gas engine suppliers are meeting – and exceeding – the challenge, providing 2007-compliant engines ahead of schedule and offering 2010-compliant engines as early as mid-2007.



Meanwhile, “clean diesel” proponents continue to grapple with complex new engine control and emissions after-treatment strategies as well as rising diesel fuel prices, all of which push diesel truck ownership costs even higher.

Depending on location, natural gas fuel costs as much as \$.75 - \$1.00 less than diesel on an equivalent gallon basis. In refuse applications, where strenuous duty-cycles and high yearly operating hours cause very high fuel use, savings like these are hard to ignore. In addition, natural gas's clean burning attributes translate into less maintenance, longer engine life and better resale value too.

An added bonus is new federal tax incentives that went into effect in 2006, which lower the purchase cost of natural gas vehicles, fuel station equipment and fuel. These incentives further improve NGVs' life-cycle cost advantage over petroleum-powered cars and trucks.

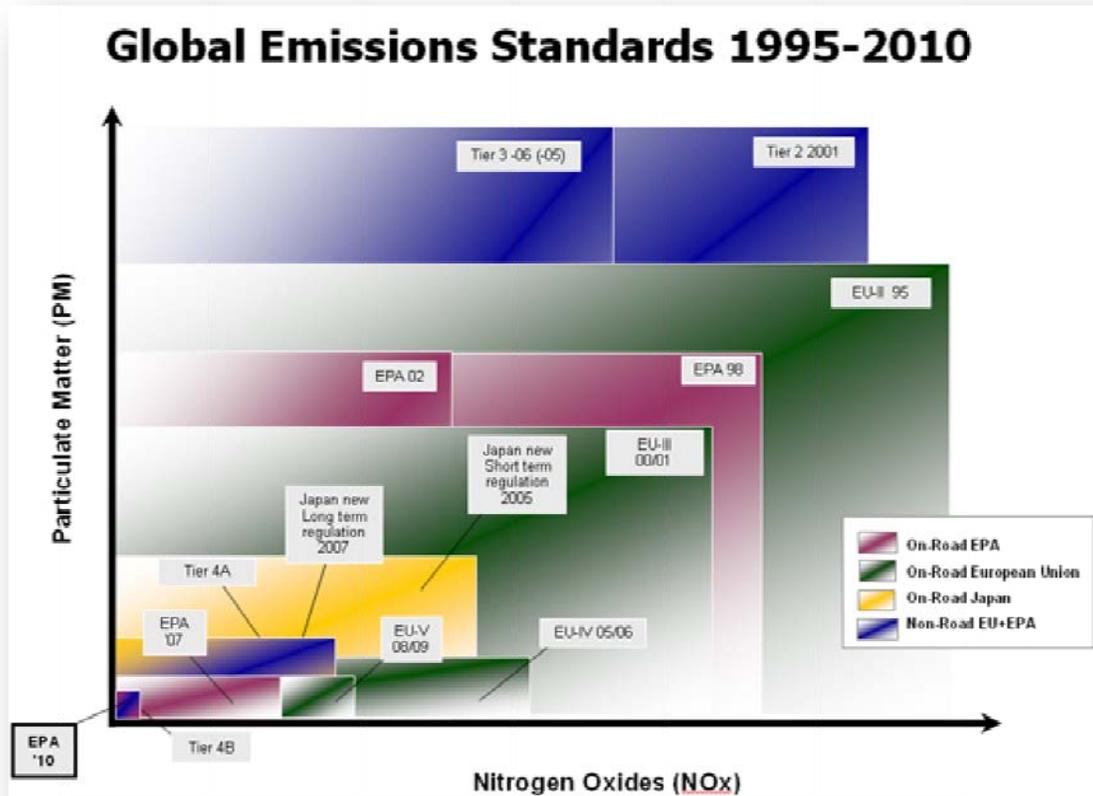
Pike Research, a market research and consulting firm that provides in-depth analysis of global clean technology markets, recently presented a study where anticipates a new period of growth for natural gas vehicles (NGV) sector in many parts of the world. The CleanTech market intelligence firm forecasts that the number of NGVs on the road worldwide will grow to 17 million vehicles by 2015, up from 9.7 million in 2008. In 2015, NGV sales will surpass 3 million vehicles for the first time.

Pike Research adds that the top five markets for NGVs are currently Pakistan, Argentina, Brazil, Iran, and India. Over the next five years, Pike forecasts that Canada, India, and the United States will be the fastest growing markets. In the U.S., the growth will be driven by greater adoption of NGVs within government and corporate fleets.



## Contemplating U.S. EPA 2010 Emissions Reduction Requirements

“The real challenge for diesel will come in 2010,” site industry OEM leaders. The diesel engine industry has had to dig down deep into its technology ‘bag of tricks’ to meet the 2007 standard but the next phase of NOx requirements has them a bit perplexed, None of the choices are all that appealing. They may go with selective catalytic reduction (SCR) using urea like the Europeans, or they could play with sophisticated combustion geometry and exhaust after-treatment devices and controls, They keep assuring everyone that they can do it but they don’t want to talk about the additional hit in performance and fuel economy, let alone the complexity of the maintenance to keep these systems running right.



Natural gas engine manufacturers, on the other hand, have certified engines well below the 2007 requirement of 1.2 g/bhp-hr NOx and .1 g/bhp-hr PM. Cummins Westport Inc also has U.S. EPA certification for powerful new engines to the 2010 .2g/bhp-hr NOx and .01g/bhp-hr PM standard already well in advance of the 2010 timeline. These units will emit one-sixth the NOx of the latest available diesel engines.

Natural gas technology has advanced rapidly over the last decade. Today’s natural gas heavy-duty engines are several generations better than the first units deployed in the late 1990s and early 2000s. While there were definitely early adopters of the technology in other sectors including refuse, many improvements resulted from deployment of heavy-duty natural gas engines in the transit sector, where natural gas is now well established, accounting for about one out of every four transit buses on order.



## Federal Alternative Fuel Tax Incentives

### **DISCLAIMER**

The information in this section should not be viewed as an official or legally binding document. Other requirements or exceptions may apply. For more detailed information, please consult an IRS tax representative and / or official IRS publications.

### **Alternative Fuel Infrastructure Tax Credit**

Section 1342 of the Energy Policy Act of 2005 provides a tax credit equal to 30% of the cost alternative refueling property, up to \$30,000 for business property. Qualifying alternative fuels are natural gas, propane, hydrogen, E85, or biodiesel mixtures of B20 or more. Buyers of residential refueling equipment can receive a tax credit for \$1,000. For non-tax-paying entities, the credit can be passed back to the equipment seller. The credit is effective on equipment put into service after December 31, 2005. It expires December 31, 2009 (hydrogen property credit expires in 2014)



This legislation also extends the Tax Deduction Timeline that was established by EPL 1992, Section 179, and extended by the Working Families Tax Relief Act of 2004.

In May 2006, the Internal Revenue Service (IRS) published Form 8911, which provides a mechanism to claim the infrastructure tax credit. Owners who install qualified refueling property on multiple sites can utilize the credit for each property. The instructions define what is considered qualified property and the value of the credit. See [IRS Form 8911](#).

### **Alternative Motor Vehicle Credit**

Section 1341 of the Energy Policy Act of 2005 provides a tax credit to buyers of new alternative fuel vehicles placed in service as an alternative fuel vehicle after January 1, 2006. The legislation provides for a tax credit equal to 50% of the incremental cost of the vehicle, plus an additional 30% of the incremental cost for vehicles with near-zero emissions (SULEV or Bin 2 for vehicles <14,001 lb GVWR). The IRS has issued two notices to establish rules for manufacturers and qualified vehicle buyers to claim the credit. The [Current Tax Credits](#) table has information on certified vehicles and available credits.

The credit is available on the purchase of light-, medium, and heavy-duty vehicles and fuel-cell, hybrid, and dedicated natural gas, propane, and hydrogen vehicles. Light-duty lean burn diesel vehicles are also eligible.

The tax credit is capped based on vehicle weight as follows:

- \$5,000: 8,500 GVWR or lighter
- \$10,000: 8,501 - 14,000 GVWR
- \$25,000: 14,001 - 26,000 GVWR
- \$40,000: 26,001 GVWR and heavier



For non-tax-paying entities, the credit can be passed back to the vehicle seller. The tax credit can be applied to vehicle purchases made after December 31, 2005. The credit expires December 31, 2010.

IRS Notice 2006-9, issued in January 2006, establishes procedures for manufacturers to certify to the IRS that a vehicle meets requirements to claim the credit and the amount of the credit for which the vehicle is eligible.

IRS Notice 2006-54, issued in June 2006, extends the Qualified Alternative Fuel Motor Vehicle (QAFMV) tax credit to vehicle conversions. This IRS guidance states that new or used vehicles, placed in service as alternative fuel vehicles after January 1, 2006, qualify for the tax credit when the conversion system manufacturer has received a certificate of conformity from the EPA or California Air Resources Board. This guidance also establishes that manufacturers (conversion system installers) must provide certification to the IRS that a vehicle is eligible for a tax credit. The IRS must then provide the manufacturer with acknowledgement that a vehicle qualifies for the credit. The credit is taken by the buyer of a vehicle, and IRS Form 8910 should be used to claim the credit. The credit cannot be sold or transferred but can be carried forward by the seller for use in later years. This legislation replaces the Clean Fuel Vehicle Property Tax Deduction previously available to purchasers.

The Alternative Motor Vehicle Credit for Hybrid Vehicles is based on the number of qualifying vehicles sold by each manufacturer and the date of purchase. IRS Fact Sheet-2007-9 "Credit Available for Taxpayers Who Purchase or Lease Hybrid Vehicles in 2006" offers help for drivers of hybrid vehicles in determining their eligibility for the credit. Some of the rules are fairly straightforward, while others are more convoluted. Specific credits for each hybrid vehicle are available online and more information can be found at [www.irs.gov/newsroom/article/0,,id=165649,00.html](http://www.irs.gov/newsroom/article/0,,id=165649,00.html). To claim the Alternative Motor Vehicle Credit, drivers of hybrid vehicles need to complete IRS Form 8910.

Additional information about hybrid vehicles and the new tax credits for hybrid vehicles as well as Alternative Fuel Vehicles can be found at <http://www.fueleconomy.gov/feg/taxcenter.shtml>.

### **Biodiesel and Ethanol (VEETC) Tax Credit**

The American Jobs Creation Act of 2004 (Public Law 108-357) created tax incentives for biodiesel fuels and extended the tax credit for fuel ethanol. The biodiesel credit is available to blenders/retailers beginning January 2005. It also established the Volumetric Ethanol Excise Tax Credit (VEETC), which provides ethanol blenders/retailers with \$.51 per pure gallon of ethanol blended or \$.0051 per percentage point of ethanol blended (i.e., E10 is eligible for \$.051/gal; E85 is eligible for \$.4335/gal). The incentive is available until 2010.

Section 1344 of the Energy Policy Act of 2005 extended the tax credit for biodiesel producers through 2008. The credits are \$.51 per gallon of ethanol at 190 proof or greater, \$1.00 per gallon of agri-biodiesel, and \$.50 per gallon of waste-grease biodiesel. If the fuel is used in a mixture, the credit amounts to \$.0051 per percentage point ethanol or \$.01 per percentage point of agri-biodiesel used or \$.0050 per percentage point of waste-grease biodiesel (i.e. E100 is eligible for \$.51 per gallon). For more information, see IRS Form 637 and IRS Publication 510.



## Federal Motor Fuels Excise Tax Credit

On October 1, 2006 the alternative fuel excise tax credit provision of the 2005 Federal Highway Act, also known as SAFETEA-LU (Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users) went into effect. With this provision, fleets using compressed natural gas (CNG), propane (LPG), or liquefied natural gas (LNG) to power vehicles may qualify for an excise tax credit, income tax credit, or a direct payment from the IRS. This credit extends to tax-exempt entities including state, local, and tribal governments, as well as non-profit and other tax exempt organizations.

The current excise taxes are \$0.183 per gallon of LPG or gasoline gallon equivalent (GGE) of CNG, and \$0.243 per gallon of LNG. The excise tax credit enacted in SAFTEA-LU is \$0.50 per GGE of CNG and \$0.50 per liquid gallon of LPG and LNG.

The excise tax credit can be claimed by the entity responsible for paying the tax, such as the fuel retailer. Also, tax exempt entities such as cities, school districts or transit agencies that fuel from an on-site fueling station, even if it is owned by a third party, can claim the excise tax credit in the form of a direct payment from the IRS. For more information, see IRS Form 8849.

## American Recovery and Reinvestment Act of 2009

The recently enacted American Recovery and Reinvestment Act of 2009 (P.L. 111-05) (or stimulus package) provides billions in new funding for programs that could potentially benefit NGVs. Of primary interest to NGV America members are the following: 1) Department of Energy Pilot Program for alternative fuel, infrastructure and advanced technology vehicles - \$300 million; 2) U.S. EPA Diesel Emission Reduction Program - \$300 million; 3) Federal Transit Administration capital expenditures- \$8.4 billion; 4) Department of Energy Block Grants for Energy Efficiency and Conservation - \$3.2 billion; and 5) General Services Administration Federal Fleet acquisition of fuel efficient vehicles - \$300 million.

The stimulus package also included two important changes to the tax credits for natural gas vehicles and fueling infrastructure. Those changes are highlighted here but not summarized in detail. The NGV tax credit is now able to be taken against the alternative minimum tax for individuals (not businesses) and the value of the fueling infrastructure credit was increased (\$50,000 maximum credit for businesses and \$2,000 maximum credit for home refueling units). For more information on NGV tax incentives, click here: <http://www.ngvc.org/incentives/federalTax.html>.

The information provided below is intended to provide a brief overview of each funding opportunity and provide information on how to apply for funding or work with organizations that qualify for funding as most of this money is directed to governmental authorities. Some of the agencies responsible for disbursing this funding have not yet released solicitations or guidance providing more specific information on how the funding will be allocated.

## Department of Energy Clean Cities Program – Pilot Programs

ARRA provides the U.S. Department of Energy Clean Cities with \$300 million to support pilot projects that advance the use of alternative fuels and advanced technology vehicles. In February, DOE amended an earlier solicitation for alternative fuel projects to include details on how stakeholders can apply for the additional \$300 million. The amended solicitation originally was issued in December 2008 and includes funding for infrastructure development, acquisition of alternative fuel vehicles, and education outreach efforts. The deadline for project funding under the initial solicitation is still March 31, 2009. The deadline for filing for the new money is May 29,



2009. A second deadline of September 30, 2009 has been established to process additional requests should funds remain.



According to the DOE, the \$300 million in new funding will be allocated toward pilot projects that advance the use of alternative fuels and advanced technologies. DOE intends to allocate the funding in accordance with section 721 of the Energy Policy Act of 2005. This program authorizes funding for not more than 30 geographically dispersed pilot projects. DOE plans to provide a minimum of \$5 million and a maximum of \$15 million for projects. The non-federal cost share for projects is 50 percent.

Applications for this funding must be submitted by a state or local government, or metropolitan transportation authority (or a combination of these) and be joined by a designated Clean Cities Coalition.

The new funding will support the incremental cost of acquiring of alternative fuel vehicles (including certain off-road applications like port vehicles) as well as development of alternative fuel refueling infrastructure. Dedicated and bi-fuel vehicles qualify for funding under this new solicitation. As the purpose of the stimulus package is to quickly inject needed investment into the U.S. economy, DOE's notice emphasizes that "shovel ready" projects will be accorded priority consideration.

Funding Notice:

<https://ecenter.doe.gov/iips/faopor.nsf/UNID/9FEFD7404BACF12F8525757400701AFE?OpenDocument>

Clean Cities Website: <http://www1.eere.energy.gov/cleancities/>

Clean Cities' Solicitations: <http://www.afdc.energy.gov/cleancities/progs/solicitations.php>

## EPA Diesel Emission Reduction Program

ARRA provides the U.S. Environmental Protection Agency with \$300 million in new funding for diesel emission reduction grants. The U.S. EPA has posted information on its website on the availability of stimulus funding. According to EPA, the funding for the National Clean Diesel Campaign will be allocated as follows: (1) \$156 million for the National Clean Diesel Program; (2) \$30 million for the SmartWay Finance Program; (3) \$20 million for "emerging technologies"; (4) \$88 million to states to administer programs; and, (5) \$6 million to EPA to administer programs. As is the case with other stimulus funding, there is a priority on getting this money out the door quickly.

EPA's website indicates that funding solicitations are expected to be available by March 17. Once the solicitations are formally announced, EPA plans to provide as little as 40 days to submit applications. Funding awards under the National Clean Diesel Campaign (\$156 million) are slated for May 2009. For the state funding initiative, state authorities were required to provide "notice of intent to apply" by March 6. EPA plans to award this funding to state authorities by April 17.

Under the above programs, cleaner fuels like natural gas qualify. Repowering of existing engines also qualify. The emerging technology category is reserved for technologies that show promise to significantly reduce diesel emissions and which have not yet been certified by U.S. EPA or California authorities. Eligible applicants include state and local government authorities, air quality or transportation agencies and certain non-profit organizations. Persons interested in requesting



funding under these initiatives should work with state environmental agencies, and the regional diesel collaboratives.

EPA's website for Recovery Funds: <http://www.epa.gov/otaq/eparecovery/>

## Federal Transit Administration Capital Expenditures

In March 2009, the Federal Transit Administration (FTA) issued a notice detailing plans for distributing \$8.4 billion in ARRA funding for transit capital improvements. Most of the funding for capital improvements, about \$6.0 billion, will be apportioned by formula grants. The largest portion of this new funding, or \$4.3 billion, goes to large urban areas with populations of one million or more. Funding not apportioned by formula, i.e., competitive and discretionary grants, will be addressed in future notices.

The formula grant apportionments require the submission of applications for the funding. The FTA notice provides extensive details on the requirements for these submissions. It is absolutely essential that areas qualifying for the funding move quickly to apply for the funds. Grant applications for these funds must be submitted by July 1, 2009. ARRA requires that at least 50 percent of the funds apportioned must be obligated by September 1, 2009. After that date, FTA will withdraw and reallocate to other areas any portion of the 50 percent not obligated. Funds will be considered obligated when an application for funding is approved. By March 5, 2010, all funds apportioned to an area must be obligated or FTA will withdraw them and reallocate them to other areas that have not had any funds withdrawn. These areas will then have until September 30, 2010 to obligate the funds.

Given the very tight time constraints included in the law, applications for funding most likely will include projects that have already been selected by local and state authorities. This does not mean that new projects can't be proposed but it does mean that the window for such projects is extremely tight. FTA's notice also indicates that projects must be listed in an approved Metropolitan Transportation Plan, Transportation Improvement Plan or Statewide Transportation Improvement Plan. The notice indicates that funds can be used for projects for which contracts have been signed or bids awarded. Funds, however, cannot be used to replace funds already obligated under an existing FTA grant. The federal share for projects funded with this new money can be as high as 100 percent.

For purposes of the industry, funding can be used for acquiring buses, rehabilitating buses, remanufacturing buses, leasing equipment or facilities, preventative maintenance of facilities, acquiring or constructing facilities. A portion also can be used for administering program, but funds cannot be used for operational expenses. Grant recipients can include metropolitan planning organizations, transit authorities, or state governors.

Persons interested in advancing natural gas projects should immediately reach out to local transit agencies and metropolitan planning organizations. Some things to consider when approaching these organizations are whether existing projects include language that is flexible enough to accommodate additional bus acquisitions or a larger planned facility. There also may be ways to modify or expand projects that are already in the pipeline in order to accommodate natural gas buses, vehicles, or infrastructure. The FTA announcement also indicates that grantees can save time in some cases by piggybacking on existing contracts or partnering with other grantees on joint purchases.

FTA & Guidance: <http://edocket.access.gpo.gov/2009/pdf/E9-4745.pdf>.



FTA website for Recovery Funds - [http://www.fta.dot.gov/index\\_9118.html](http://www.fta.dot.gov/index_9118.html)

## Energy Efficiency and Conservation Block Grants (EECBG)

ARRA provides \$3.2 billion for the U.S. Department of Energy to allocate for projects under the Energy Efficiency and Conservation Block Grant Program. This program was authorized as part of the Energy Independence and Security Act of 2007 (Pub. L. No. 110-140, §§ 541 - 543) but previously was unfunded. The grant program allocates funding according to a formula with 68 percent going to city and county programs, 28 percent going to state programs, 2 percent for DOE to provide for competitive grants, and 2 percent for tribal programs. This program provides funding for a number of different types of energy efficiency and conservation programs including those involving transportation, buildings and other appropriate sectors. DOE has not issued formal guidance for this program. However, it has updated information on its website to provide an overview of the types of projects it expects will qualify for funding. This information indicates that funding will be provided to projects involving the development and implementation of transportation programs that conserve energy and also for projects that reduce or capture methane and other greenhouse gases. DOE also has additional authority to approve other activities which fulfill the intent of this program.

DOE website for EECBG Funding: [http://apps1.eere.energy.gov/wip/block\\_grants.cfm?print](http://apps1.eere.energy.gov/wip/block_grants.cfm?print)

## U.S. General Services Administration Federal Fleet Acquisitions

ARRA provides \$300 million in new funding to help federal agencies acquire motor vehicles with higher fuel efficiency including hybrid and plug-in electric vehicles. GSA has until September 30, 2011 to spend this funding. The new law and the committee report accompanying it provide some guidance on how this money must be spent. No funds, however, may be obligated until GSA submits to Congress a plan on how it plans to spend the funds and how it plans to comply with the requirement to substantially increase fuel efficiency of federal fleet vehicles and reduce emissions. The law indicates that the report should be submitted to Congress within 90 days of passage. Each vehicle purchased must have a higher fuel economy, as measured by EPA, than the vehicle being replaced and the overall government-purchased vehicles must have an improved fuel economy at least 10 percent greater than the vehicles being replaced. Natural gas vehicles are not specifically mentioned as qualifying for the new funding but we are hopeful that the fuel efficiency provision will take into account the benefits of displacing petroleum with alternative fuels. The current fuel economy calculations in fact reward AFVs for their petroleum reduction benefits.

At the time this summary was prepared, there was no further guidance on this program from GSA. However, future GSA announcement likely will appear here:

[http://www.gsa.gov/Portal/gsa/ep/contentView.do?contentType=GSA\\_OVERVIEW&contentId=25888](http://www.gsa.gov/Portal/gsa/ep/contentView.do?contentType=GSA_OVERVIEW&contentId=25888) – Recovery information site

[http://www.gsa.gov/Portal/gsa/ep/contentView.do?contentType=GSA\\_OVERVIEW&contentId=25429](http://www.gsa.gov/Portal/gsa/ep/contentView.do?contentType=GSA_OVERVIEW&contentId=25429) – Fleet & Automotive site

## Vehicle Capital Cost, Grant Funding & Tax Rebates

The CNG market is more stable than the gasoline market. CNG generally costs 15 to 40 percent less than gasoline or diesel. CNG requires more frequent refueling, however, because it contains only about a quarter of the energy by volume of gasoline. In addition, CNG vehicles cost between \$1,500 and \$3,500 annually more than their diesel-powered counterparts. This is primarily due to



the higher cost of the fuel cylinders. As the popularity and production of CNG fuel refuse collection vehicles continues to increase, CNG vehicle costs are decreasing.

Once new natural gas trucks are in service, their operators stand to save money. Not only has the price of natural gas been significantly lower than that of diesel fuel for many years (approximately \$.50 per diesel gallon equivalent (DGE) cheaper), but an excise tax credit available under the Energy Policy Act (2005) has made this fuel an even better bargain. Estimated savings for new 45 compressed natural gas trucks the City of Tucson is contemplating, may produce fuel savings of more than \$225,000 per year over biodiesel.

In interviews with industry CNG Fueling Station Operator/Maintenance and fuel suppliers, WIH Staff collected the following data relative to the typical capital costs and standard contractual arrangements for the development of a fueling station infrastructure:

### **O&M Service Contract**

The client issues a P.O. or issues a check to design, engineer & build a station and then they will own it outright while a fueling station operator / supplier provides the Operations & Maintenance piece (which is valued on a per diesel gallon equivalent cost basis).

### **CNG Supplier Provides Capital for the Project**

The client brings nothing to the table other than a commitment to meet a certain truck procurement number or gallon consumption number by an agreed upon date typically for trucks that the CNG supplier have to be at “x” number of trucks by year three for the return on capital - where “x” is determined by the cost of the fueling station due to several factors such as:

- A. Cost of high pressure gas line extension where applicable
- B. Cost of electrical extension
- C. Valuation of needed compression
  1. This is factored based on time-fill v. fast-fill, fill window, cubic feet per minute of gas needed at peak fueling times, etc.
  2. Stations can cost us anywhere from \$700,000 to well over \$2,000,000.
  3. This cost can be recaptured by the CNG supplier through the volume of larger haulers such as Allied Waste and their relatively high gallon consumption.

### **Grant Funding & Tax Rebates**

This majority of these Key Issues were covered in Section 4.3 in significant detail. Please refer to that Section of this report for in-depth coverage of this topic. One topic not covered there is the Volumetric Excise Tax Credit (VETC).



### Volumetric Ethanol Excise Tax Credit (VEETC)

The VEETC is a per gallon federal tax credit that is extended to any party that procures natural gas for use in a Natural Gas Vehicle. The tax credit is \$0.50 per gasoline gallon energy equivalency (GGE) (125,000 BTUs). In the case of CNG sold in a diesel gallon equivalent (DGE) (139,000 BTUs), this number would be \$.556 per gallon (GGE (0.50) converted to DGE x (1.112) = 0.556). VEETC for LNG is calculated at .50 per LNG gallon x 1.7 for DGE = .85 per DGE.

### Comparison of VEETC Net Impact on Alternative Fuels

Fuel Type	Consumption Price (per DGE)	VEETC Impact	Total Consumption Price (per DGE) including VEETC
LNG	\$2.48	(\$ .85)	\$1.64
CNG	\$.82	(\$ .556)	\$.27
Biodiesel	\$2.10	\$.00	\$2.10

#### Annual CNG fuel savings over Biodiesel with VEETC

$\$2.10 - \$0.27 = \$1.83 \times 35 \text{ gallons} \times 260 \text{ days} / 12 \text{ months} = \mathbf{\$1,387.75 \text{ monthly per truck}}$   
 $\$1,387.75 \times 12 \text{ months} = \mathbf{\$16,653 \text{ annually per truck}}$

#### Annual LNG fuel savings over Biodiesel with VEETC

$\$2.10 - \$1.64 = \$0.46 \times 35 \text{ gallons} \times 260 \text{ days} / 12 \text{ months} = \mathbf{\$348.83 \text{ monthly per truck}}$   
 $\$348.83 \times 12 \text{ months} = \mathbf{\$4,186 \text{ annually per truck}}$

### Natural Gas Fueling Options – CNG & LNG

This key Issues is covered in-depth in Section Six. Of critical importance is selecting the right configuration is key to any fueling station’s success. The main considerations in choosing a station type are the number and type of vehicles fueled and their fueling pattern. Secondary considerations include location, potential future growth, and permitting restrictions. There are three major CNG station types for consideration in fueling heavy duty vehicles discussed in Section Six.

### Alternative Fuels and Diesel Emissions Impact

Diesel engines are one of this country’s dirtiest transportation modes and most visible sources of air pollution. In fact, it is estimated that 60% of all toxic emissions come from on-road, heavy-duty diesel engines. The majority of residents in urbanized areas are exposed to diesel exhaust and toxic diesel particulate matter, often at levels that exceed those that have been shown to be damaging to human health. Children, the elderly and highly exposed occupational groups are particularly at risk. Not only do people deserve cleaner, healthier air but the continued economic growth of our major cities could very well depend on it.

As important as choosing the right heavy-duty fuel is, the immense rhetoric and misinformation surrounding this issue has made it nearly impossible for many well-meaning city staff, officials and civic leaders to make an informed and accurate decision.

### Infrastructure Fueling Station Costs

This key issue topic is covered in depth in Section Six of this report. Section Six provides a high-level review of key items required for siting, developing, engineering and construction of natural



gas fueling stations. It provides an overview of the key items that need attention and is intended to provide a general idea of what is “included” as equipment. It is not exactly a detailed checklist, but does provide a solid list of considerations, assumptions and related costs under two Scenarios (A and B).

## Engine Maintenance Service Support & Parts Availability

As part of the research conducted by the WIH Resource Group Project Team, Cummins Westport was contacted in response to concerns expressed by the Maintenance Administration of the City of Tucson.

The Maintenance Administration expressed concern over local parts availability for natural gas powered refuse collection vehicles, local OEM engine dealer service support and warranty service. In response to these concerns, the Arizona regional management for Cummins responded by writing a letter (see Appendix D of this Report) that stated the following:

*“Thank you, Mr. Wallace, for bringing to my attention the opinion that you were made aware of at a meeting that took place in Tucson last week. I would like to address these concerns at this time.*

*We have been taking care of CNG and LNG buses in Arizona since they were first released in the late 1980’s. We have kept trained and experienced technicians in both Tucson and Phoenix for many years, and currently service the Sun Tran fleet, City of Tucson Fire Dept., and various school garages. We make sure our field service technicians are trained and familiar with all of our available platforms and try to communicate with our customers before they buy equipment, to insure that remains the case.*

*We are excited to learn that alternative fuel engines are being considered for Tucson equipment, since we believe we have the finest natural gas engines available in today’s marketplace.*

*We also feel that our support staff can keep your equipment functional and productive whether they are diesel or natural gas.*

*Let me assure you that Cummins Rocky Mountain, as well as Cummins Engine Co., is going to be supporting the customers that trust us with their purchases. We currently have employees that live and work out of Tucson in service trucks. However, we will take whatever measures are necessary to supply technical service and support. The long term satisfaction of our customers is our goal for continued growth.*

*Please feel free to share this information with anyone at the City of Tucson that you deem appropriate. I would also extend the offer of a personal visit with any skeptics, to answer any technical or support questions that may not have been answered in this letter.”*

*Thank You for your interest,  
Guy H Remenap  
General Sales Manager  
Cummins Rocky Mountain LLC*



Mr. Remenap went on to say that while Cummins Westport does not have a local service center in the greater Tucson area (the nearest one is located in Phoenix), they do have several field service technicians that are CNG and LNG engine repair certified Technicians and routinely perform service for a wide range of both public and private sector clients in the greater Tucson area including Sun Tran. Mr. Remenap was very passionate about Cummins interest in providing service support, warranty work etc. and offered to meet with City staff and elected officials as needed to alleviate any concerns. He went on to say that the Cummins Field Service Technicians that they would provide to the City of Tucson are local Tucson area residents and have service vehicles domiciled at their homes and are on call virtually 24 hours per day 365 days per year.

## Arizona's Regs. & Laws Pertaining to Alternative Fuels

The guidelines that the Arizona Department of Environmental Quality (ADEQ) requires be followed are from the EPA, Code of Federal Register (CFR) Title 40. The rules/laws pertain to all classes (light and heavy duty) of vehicles operated throughout the State of Arizona. Staff from ADEQ's Tucson Inspection and Compliance Unit offices provided the following CFR References as outlined.

### CFR 49-542.05 - Alternative Fuel Vehicles

A. Except for a vehicle fueled by hydrogen, the following apply:

1. Each original equipment manufactured alternative fuel vehicle that is registered in or used to commute into area A or area B pursuant to section 49-542, subsection A is subject to the emissions inspection requirements prescribed in this article including subsection C of this section.
2. Each alternative fuel vehicle that is not original equipment manufactured alternative fuel vehicle and that is registered in or used to commute into area A or area B pursuant to section 49-542, subsection A is subject to the emissions inspection requirements prescribed in this article.

B. Except for a vehicle fueled by hydrogen, for each vehicle that is registered in or used to commute into area A or area B as prescribed by section 49-542, subsection A and that is either an original equipment manufactured alternative fuel vehicle or an alternative fuel vehicle that is not an original equipment manufactured alternative fuel vehicle, the vehicle shall be tested before the vehicle is registered in this state as an alternative fuel vehicle both while operating on gasoline and while operating on alternative fuel, if applicable. In the fourth registration year and in subsequent years, the vehicle shall be tested both while operating on gasoline and while operating on alternative fuel, if applicable, pursuant to the requirements of section 49-542.

C. For all emissions inspections before the fourth registration year after purchase or lease of new original equipment manufactured alternative fuel vehicle, the owner of the vehicle shall do one of the following:

1. Have the vehicle inspected pursuant to this information.
2. Pay a twenty-five dollar fee in area A and a nine dollar fee in area B. The owner shall pay this fee together with the registration fee for the vehicle to the registering officer. The registering officer shall deposit, pursuant to sections 35-146 and 35-147, these fees in the air quality fund established by section 49-551. The registering officer may enter into an intergovernmental agreement with another department of this state to collect and



deposit the fee. An owner who chooses to have an emissions inspection pursuant to this article is not required to pay the fee prescribed in this paragraph for that emissions test cycle.

D. The registration renewal notice required for the second and third registration year of a new original equipment manufactured alternative fuel vehicle shall include a notice to the vehicle owner that even though an emissions inspection test is not required pursuant to subsection B of this section the owner may choose to have an emissions inspection because of vehicle emissions performance warranty limitations on emissions components of the vehicle.

E. The department of environmental quality shall compile and maintain data regarding the results of emissions inspections of all alternative fuel vehicles pursuant to this article.

### **R18-2-1017. Inspection of Government Vehicles**

A. Inspection of government vehicles operated in areas A and B shall be conducted as follows:

1. At a licensed fleet station operated by the government entity;
2. At a state station upon payment of the fee;
3. At a state station upon payment of the contracted fee, either singly or in combination with other government fleet operators.

B. A government vehicle except a federally owned vehicle that is excluded from the definition of motor vehicle under 40 CFR 85.1703, shall be inspected according to this Article and shall have a Government Vehicle Certificate of Inspection affixed to the vehicle if in compliance with state inspection requirements.

1. The vehicle emissions inspector performing the inspection shall punch out the appropriate year and month on the Government Vehicle Certificate of Inspection to designate date of the vehicle's next annual or biennial inspection. The vehicle emissions inspector, at the time of inspection, shall record the serial number of the Government Vehicle Certificate of Inspection on the vehicle inspection report. If the vehicle emissions inspection is performed at a fleet station, the emissions inspector, at the time of inspection, shall record the serial number in the block labeled "Certificate of Inspection No." on the "Fleet Vehicle Inspection Report/Monthly Summary." Each Government Vehicle Certificate of Inspection shall be used in serial number order. Presence of a current Government Vehicle Certificate of Inspection indicates a government vehicle has met the state of Arizona emissions inspection requirements.
2. A government vehicle, with the exception of a motorcycle or an undercover law enforcement vehicle, shall have the Government Vehicle Certificate of Inspection affixed to the lower left side of the rear window as determined from a position facing the window, from outside the vehicle. If a vehicle does not have a rear window, the Government Vehicle Certificate of Inspection shall be affixed to the lower left corner of the windshield as determined from the driver's position.
3. A government motorcycle shall have the Government Vehicle Certificate of Inspection affixed to the lower left-hand corner of the windscreen as determined from the driver's position. If the Government Vehicle Certificate of Inspection cannot be affixed to the lower left-hand corner of the windscreen, the Government Vehicle Certificate of



Inspection may be affixed to a visible position on the front or left side of the left front fork of the motorcycle. The fork shall be determined from the driver's position.

- C. The Government Vehicle Certificate of Inspection shall be purchased from the Department in lots of 25.
1. The fee for a certificate of inspection shall be fixed by the Director according to A.R.S. § 49-543, and shall be based upon the Director's estimated costs to the state of administering and enforcing the provisions of this Article as they apply to issuance of certificates of inspections. Payment for certificates shall be included with an application for certificates. Checks shall be made payable to the Department of Environmental Quality.
  2. Only the Department may sell or otherwise transfer certificates of inspection.
- D. All Government Vehicle Certificates of Inspection shall be designed, issued, and administered to ensure compliance with this Article. The Department shall be the only source of supply for Government Vehicle Certificates of Inspection.
- E. Government entity fleet stations shall inspect the fleet vehicles according to R18-2-1019 except that a government vehicle certificate of inspection shall only be used for government vehicles.
- F. A government entity fleet station shall send a quarterly statement identifying vehicles and test results to the Department within 10 business days following the end of the quarter.

## Historical Note

Effective September 30, 2009 Senate Bill 1320 changes some of the MVD registration process for Alt/Fuel vehicles. To qualify as an Alternative Fuel vehicle it must run on one of the following types of fuel:

- (a) Electricity; (b) Solar energy; (c) Liquefied petroleum gas, natural gas, hydrogen or a blend of hydrogen with liquefied petroleum or natural gas that complies with either of the following:
- (i) Is used in an engine that is certified to meet at a minimum the United States environmental protection agency low emission vehicle standard pursuant to 40 Code of Federal Regulations section 88.104-94 or 88.105-94.
  - (ii) Is used in an engine that is certified by the engine modifier to meet the addendum to memorandum 1-A of the United States environmental protection agency.
- (d) Only for vehicles that use alcohol fuels before August 21, 1998, alcohol fuels that contain not less than eighty-five per cent alcohol by volume.
- (e) A combination of at least seventy per cent alternative fuel and no more than thirty per cent petroleum based fuel and that operates in an engine that meets the United States environmental protection agency low emission vehicle standard pursuant to 40 Code of Federal Regulations section 88.104-94 or 88.105-94 and is certified by the engine manufacturer to consume at least seventy per cent alternative fuel during normal vehicle operations.



# Appendix D – Tucson Fueling Station Infrastructure and Alternatives

## Natural Gas Fueling Station Requirements

This section provides a high-level review of key items required for siting, developing, engineering and construction of natural gas fueling stations. It provides an overview of the key items that need attention and is intended to provide a general idea of what is “included” as equipment. It is not exactly a checklist, but does provide a solid list of considerations, assumptions and related costs under two Scenarios (A and B).

Scenario A assumptions and cost estimates are based on a typical single compressor and Scenario B is based on typical dual compressor skid. To a degree these scenarios are irrelevant to the City of Tucson since it already has two fueling stations that are operational and would not require the costs associated with a complete development of new fueling stations, such as design, engineering, site preparation, layout, construction, etc. Here is a summary of typical considerations when contemplating a new natural gas fueling facility.

- Gas line pressures and capacity
- Proximity of Gas line to location
- Appropriate electrical nearby
- Soil
- Fueling window
- Redundancy needs
- Maximum growth potential of site

## Fueling Station Cost Estimates

There is much to consider when building a compressed natural gas (CNG) or liquefied natural gas (LNG) fueling station. This section provides a summary of key items for consideration and as illustrative packages for the City of Tucson and provides some costs estimates for development of both CNG and LNG fueling stations from industry resources.

## CNG Fueling Station

This section provides a “snapshot” with some assumptions based on municipal averages that have been developed based on two run Scenarios (A and B) for a CNG fuel station below with a cost “window.”

### Assumptions:

- 28 Diesel Gallon Equivalent (DGE)/day;
- 45 active refuse collection vehicles (trucks) – fleet size;
- 14 hour per day fueling window;
- Time-fill (aka “slow fill” - limited fast-fill capabilities);
- 30 PSIG inlet @  $\leq 50'$  from compressor compound;
- Single/non-redundant compressor skid (cost A);
- Dual compressor skid with 100% redundancy (cost B although this is probably not necessary, so instead recommend two 75% capacity compressors before dual 100%, but it's a reference point));



- Electrical drop within 50' of compressor compound, electrical at three-phase/480V:

### **Illustrative Package Includes:**

- Compressor skid
- Single compressor skid (A)
- Dual fully redundant compressor skid (B)
- Fuel Storage
- Single ASME high pressure buffer storage bottle
- Dryer
- Time-fill posts, hoses & fueling assemblies (assumes dual hose posts, one post for two trucks)
- Engineering
- Permitting
- Construction/Installation
- Start-up services

**Scenario A: Typical single compressor: \$900,000**

**Scenario B: Typical dual compressor skid: \$1,350,000**

It is important to keep in mind that these prices are “typical” and estimates only. They should not be viewed as an appraisal of the City of Tucson needs/requirements, nor should they be used as bookmarks for potential quotes from any vendor in the future.

### **What Size Station is Needed?**

One must first determine the amount of CNG fuel required daily for your CNG Fleet. For example a typical CNG school bus covers 80 miles per day, gets 4 miles per gallon and is parked at night for up to 12 hours or more. Assuming you have 6 CNG school buses in your fleet you will require 120 GGE per night. (80 miles, divided by 4 mpg = 20 GGE per bus, times 6 buses = 120 GGE total.) Since you have 12 hours to accomplish fueling your system can be a time-fill type system and the compressor can be sized based upon your need of 120 gallons over a 12 hour period.

### **What size station do I need?**

One must first Determine the amount of CNG fuel required daily for your CNG Fleet. For example a typical CNG school bus covers 80 miles per day, gets 4 miles per gallon and is parked at night for up to 12 hours or more. Assuming you have 6 CNG school buses in your fleet you will require 120 GGE per night. (80 miles, divided by 4 mpg = 20 GGE per bus, times 6 buses = 120 GGE total.) Since you have 12 hours to accomplish fueling your system can be a time-fill type system and the compressor can be sized based upon your need of 120 gallons over a 12 hour period.

### **How much does a typical CNG fuel station cost?**

There is no "typical" CNG fuel station and the costs depend essentially upon 3 things:

1. The amount of CNG fuel required determines the type and size compressor needed.
2. The amount of fuel required over what period of time?
3. The site of conditions where the station is to be constructed.



## How does CNG fueling work?

The primary components of a CNG station are, one or more gas or more gas compressors, a Gas dryer, time-fill fueling post assemblies, and might include a series of CNG fuel storage tanks and or a fast-fill island type dispenser with a credit card reader to activate fueling. The compressors take low line pressure gas from the main, compress it up to high pressure and dispense it into CNG vehicles via time-fill or fast-fill fueling methods.

## What is the difference between Fast-Fill and Time-Fill and why would I choose one over the other?

If all or most of the City's CNG vehicles return to one location overnight or during the day, for a period of hours, Time-Fill is the most efficient and economical means of fueling. In Time-Fill configuration the vehicles can be parked in their fueling stall, the hose connected and the vehicles will slowly fuel overnight. Fueling typically begins automatically when the first vehicles is connected and will shut off automatically when the last vehicle is full. No attendant needed.

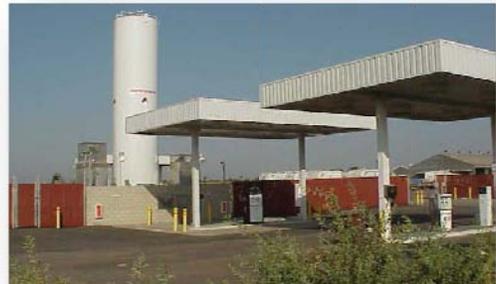
In a Fast-Fill configuration the CNG compressor takes the low line pressure gas and compresses it up to 5000 PSI into appropriately rated CNG storage vessels. CNG vehicles then pull up to CNG Fast-Fill dispenser which resembles an ordinary liquid fuel dispenser like you see at a gasoline station. Fast-Fill CNG fueling requires about the same amount of time as fueling with any conventional fuel. Most Fast-Fill CNG systems incorporate a credit card reader for authorizing, dispensing and billing the transaction.

## What is the cost of a gallon CNG?

This depends upon where it is purchased. There are many CNG public access fueling stations throughout greater Tucson. Some are owned by private fueling companies others by various governmental agencies. Prices currently may range from \$1.75 to \$2.50 per GGE gasoline gallon equivalent. A CNG fueling station location map for the greater City of Tucson area is located in the Appendices of this report.

## LNG Fueling Station

In contrast to CNG, LNG offers another type of alternative fueling solution, the IMC 6000 from Chart industries. The cost estimate is approximately \$525,000. An additional \$125,000 is required for installation, for a total of \$650,000. This cost estimate was provide by ALT Fuels and is based on one fueling station. Given the geography of the City of Tucson, refuse collection vehicle routing and need for reduced time from and to the beginning of routes, a minimum of two LNG fueling stations would be needed increasing the price to \$1,300,000 total for the two LNG fueling stations.

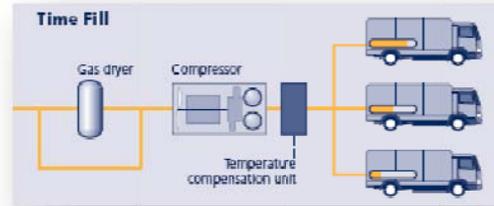


## Fueling Station Filling Methods

Selecting the right configuration is key to any fueling station's success. The main considerations in choosing a station type are the number and type of vehicles fueled and their fueling pattern. Secondary considerations include location, potential future growth, and permitting restrictions. There are three major CNG station types for consideration in furling heavy duty vehicles:

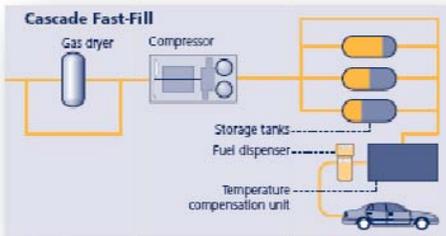


**1. Time-fill Stations** (also known as “Slow-fill”) fill vehicles over a six- to eight-hour period. Compressors compress natural gas from pipeline pressure (5–200 psi) to the required vehicle pressure (3000–3600 psi) and dispense it into multiple vehicles simultaneously. These stations are best for vehicles such as school buses and refuse collection and utility trucks that return to a central location and can fuel while parked for an extended period. Among all options, they are least expensive to build and staff, requiring no full-time attendant. But extended fueling time is needed because time-fill stations have relatively small compressors and no CNG storage.

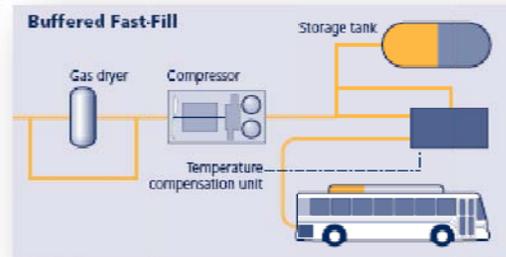


**2. Cascade Fast-fill Stations** provide fast and convenient fueling similar to that provided by conventional liquid fuel stations. CNG storage vessels arranged in cascades, or banks, are used to quickly fill vehicles during peak fueling times, when the compressors alone cannot meet demand. During off-peak times, the compressors refill the CNG storage cascades. These stations

are suitable for fueling light-duty vehicles at public access stations where use patterns are random. They are also suitable for fueling fleets of light-duty vehicles, such as taxis and police cars, that require a fast fill and have peak fueling periods. Cascade fast-fill stations are not appropriate for continuous, high-volume fueling because the compressors are not large enough to provide a fast fill once the CNG storage has been depleted. Most of the several hundred public access CNG stations in North America use a cascade fast-fill system.



**3. Buffered Fast-fill Stations** provide fast, continuous, high volume fueling. Relatively large compressors run continuously during fueling, filling vehicles and, in the interval between vehicles, a CNG storage buffer. The storage buffer provides CNG to vehicles at the beginning of the fueling cycle and allows the compressor to run for long periods. Unlike CNG storage in cascade fast-fill systems, buffer storage is not separated into separate banks. Buffered fast-fill stations are suitable for quickly fueling large numbers of heavy-duty, high-fuel-capacity vehicles, such as transit buses and refuse trucks.



**Existing Tucson Area Fueling Facilities**

The City of Tucson currently operates two compressed natural gas (CNG) fueling stations for City-owned vehicles at its Thomas Price Service Center (located at Park & Ajo) and the City’s Eastside Service Center. The Price Service Center station provides CNG fuel to the City’s bus fleet, and both stations provide fuel to 109 other City fleet units.

In addition to the Cities two locations, there are a wide range of both public and private sector alternative fueling stations near, and in, the greater Tucson area. Table 6.1 provides a summary of the local Biodiesel, CNG and LNG fueling stations.



**Alternative Fuel Fueling Stations Near Greater Tucson**

Name	Address	City	Fuel Type	Accessibility	One Way Miles from Tucson
Arizona Petroleum Products	1015 S Cherry St	Tucson	Biodiesel	Public	1.5
Amphitheater School District	241 E Pastime Rd	Amphitheater	Biodiesel / CNG	Private Access Only	4.5
Davis Monthan Air Force Base	4655 S Flightline Rd	Tucson	Biodiesel / CNG	Government Only	4.9
Chevron	12030 N Dove Mountain	Marana	Biodiesel	Public	16.7
Arizona Biodiesel	721 N Monterey St	Gilbert	Biodiesel	Public	93.6
City of Tucson Fleet Services	4004 S Park Ave	Tucson	CNG	Government Only	3.6
City of Tucson Fleet Service	7575 E Speedway	Tucson	Biodiesel / CNG	Government Only	8.6
Southwest Gas Corporation	3401 E Gas Rd	Tucson	CNG	Private Access Only	3.8
Whitton Plumbing	1110 W Glenn St	Tucson	Biodiesel	Private Access Only	4.5
Arizona Department of Transportation	1444 W Grant Rd	Tucson	CNG	Government Only	4.5
Clean Energy - Tucson International Airport	3034 E Corona	Tucson	CNG	Public	4
Pima Community College District Support Services	6680 S Country Club Rd	Tucson	CNG	Government Only	3.5
Pima Community College District Support Services - West Campus	2202 W Anklam Rd	Tucson	CNG	Government Only	4.9
East Valley Bus Maintenance and Operation Facility	2050 W Rio Salado Pkwy	Tempe	LCNG	Government Only	103
Phoenix Public Transit Department - South Facility	2225 W Lower Buckeye Rd	Phoenix	LCNG	Government Only	107.4
Phoenix Public Transit Department - West Facility	405 N 79th Ave	Phoenix	LCNG	Government Only	113.8
Phoenix Public Transit Department -	2010 W Desert Cove Ave	Phoenix	LCNG	Government	116.3



Source: U.S. Department of Energy - Energy Efficiency and Renewable Energy - Alternative Fuels and Advanced Vehicles Data Center

### Los Reales Landfill Site

While this site was originally listed for consideration as an alternative fueling station for this project it was ruled out early on by the City of Tucson’s ESD. As such, a brief site description is included; however specific feasibility analysis was not conducted on this location.

The City of Tucson's Los Reales Landfill located at 5300 E. Los Reales Road opened in 1967 and is the only active landfill owned and managed by the City of Tucson. Los Reales is a regional landfill and serves the residents and businesses of Tucson and Pima County. The landfill consists of approximately 380 acres. Each day approximately 1,500 tons of solid waste is brought to the landfill for disposal. Los Reales is open to private, commercial haulers and residential, self-haulers.



### Eastside Service Center

The Eastside Service Center is located at 7575 Speedway Drive in Tucson and is considered a satellite shop located at the City's Eastside Center provides maintenance and repair services to fleet units (primarily Police, Solid Waste, and Streets Maintenance) stationed on Tucson's east side. Field mechanics provide maintenance and repair services to units broken down in the field. Pictured at left are the Eastside’s compressors and CNG storage tanks.

Currently, this facility has a CNG fueling station with compressor and storage tanks (pictured at left) with two CNG fueling pumps alongside the biodiesel fuel pumps at the fuel island. One of the CNG pumps is a 3,000 PSI rated CNG fueling pump and the other is a 3,600 PSI rated CNG pump, both of which could be used to fuel CNG refuse collection vehicles, however the 3,000 PSI pump would be restrictive, only allowing for filling approximately 75-80% of a CNG’s fuel tanks’ rated capacity, whereas the 3,600 PSI CNG pump could achieve 100% tank fill capacity. Both existing fuel pumps at the Eastside Service Center are “fast fill” (see pump pictured at right).

The City of Tucson would ***not*** need a new station to be built for its existing refuse collection fleet as they have adequate existing CNG fueling stations that could be retro-fitted to dispense 3,600 psi for around \$350,000 at the Eastside Service Center. This cost estimate was provided by Clean Energy Fuel’s engineering department.





## Thomas Price Service Center

The Thomas O. Price Service Center (Price) is the primary fueling facility for the City of Tucson fleet services, central maintenance facility, home to Sun Tran's bus fleet and the ESD's refuse collection truck fleet. The facility has been in operation since 1972.

The facility is located at the southwest corner of Ajo Way and Park Avenue and is called the Thomas O. Price Service Center. Historically, the facility has maintained 23 twelve-thousand gallon underground storage tanks (USTs) for gasoline and diesel (see picture at right of fuel island).



Along with traditional fuels, the Price Service Center also currently provides B20 Biodiesel fuels to the City's refuse collection fleet along with CNG alternative fuel. The Price Service Center currently has four fuel pumps with PSI ranges as high as 3,600 PSI, the pressure needed to maximize fuel tank capacity in refuse collection vehicles.



The current CNG fueling facility serves four fast-fill fueling pumps and over 75 Time-fill (also known as slow-fill) fueling pumps for the City's Sun Tran bus fleet co-located on adjacent property to the Price Service Center.

Pictured at left is the backbone to the Price Service Center's CNG fueling stations, the four compressors that offer a series of redundancy for backup in the event of failure of any of the primary online compressors utilized for compressing the natural gas to 3,600 PSI from traditional natural gas line pressure. According to industry sources with Clean Energy, Fuel Solutions, Inc.

and Southwest Gas, the existing CNG fueling station infrastructure at Price Service Center could be retrofitted at a minor cost to the City of Tucson to accommodate the fueling of all of the existing refuse collection in addition to continuing to provide time-fill fueling to the Sun Tran fleet.

## Sun Tran Prince Road / Romero Drive Site

The City of Tucson has a Sun Tran transit facility near Prince Road and Romero Drive located on 26 acres. As of this writing, Southwest Gas and / or Sun Tran has retained the services of Fuel Solutions, Inc. Fuel Solutions, Inc. is a consulting and engineering firm based in California that provides its services to public- and private-sector vehicle fleet operators. WIH Resource Group interviewed Reb Guthrie, Principal and Project Manager, for Fuel Solutions, Inc.

The new Northwest Bus Storage and Maintenance facility is located near Interstate 10 and Prince Road and will accommodate up to 150 new buses in Phase II. Estimated completion of this project phase is November 2009. Phase III will expand the facility to accommodate up to 250 buses. Federal Stimulus funds were just authorized for this project, which will go out to bid in early 2010.



## Prince Road / Romero CNG Fueling Station Cost Estimates

Southwest Gas has estimated the natural gas line extension at a cost of \$1.4 million. This cost would come down if the City keeps the volumes steady at the City's current Park Avenue location.

One strong consideration / case scenario is for the City of Tucson ESD to upgrade the Park Avenue station and utilize it for the City's refuse fleet and have a new station built for Sun Tran at their new facility near Prince and Romero. This avoids potential conflicts associated with public perceptions of (sometimes unsightly) solid waste (garbage trucks) being parked at or near public transit buses. This also allows both departments exclusive dedicated CNG fueling stations with the potential to utilize the others' as a backup fueling facility, however they aren't sharing a fueling station every day.



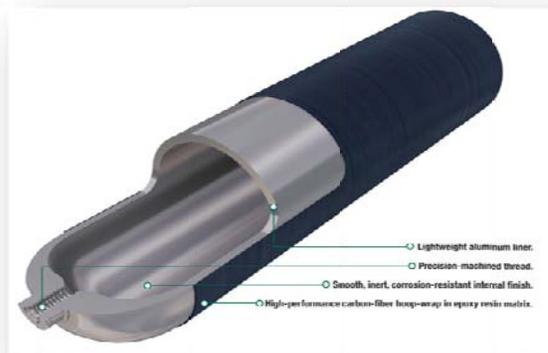
# Appendix E – CNG Fuel Tank Issues Assessment

## CNG Fuel Tank Types

On board vehicle fuel tanks for compressed natural gas are referred to as CNG Cylinders. Compressed Natural Gas (CNG) cylinders are available in a number of different types, weights and sizes to suit different applications. As a general rule, as cylinder weight decreases, cylinder costs increase. In some cases, cylinders are available for lease from vehicle converters or gas suppliers.

### Cylinder Types Include:

- **Type 1: This is an all metal - cylinder made of steel.** There is no covering, other than paint, on the outside of the cylinder. This is the most common type of cylinder.
- **Type 2: Hoop-wrapped steel or aluminum.** This is a metal cylinder (steel or aluminum) with a partial wrapping that goes around the cylinder. The wrapping is usually made of glass, aramid or carbon, contained in an epoxy or polyester resin (pictured at right).
- **Type 3: Fully-wrapped steel or aluminum.** This type of cylinder is fully wrapped with the same kind of material used for the partial wrapping of a Type 2 cylinder. This type of cylinder has a metal liner usually aluminum (pictured lower left below).



- **Type 4: All Composite (non-metallic).** This type of cylinder is fully wrapped with the same kind of material used for the partial wrapping of a Type 2 cylinder. This type of cylinder has a plastic liner.

## CNG Vehicle Fuel Container Standards

All CNG vehicle fuel containers MUST meet the federal government's Federal Motor Vehicle Safety Standard (FMVSS) 304 (49 CFR 571.304), Compressed Natural Gas Fuel Container Integrity. All CNG vehicle fuel containers should meet American National

Standards Institute (ANSI)/Canadian Standards Association (CSA) NGV2, Basic Requirements for Compressed Natural Gas Vehicle Fuel Containers. This industry standard is more comprehensive and up-to-date than FMVSS 304.



## Label Requirements (S7.4, FMVSS 304)

“Each CNG fuel container shall be permanently labeled with the information specified in paragraphs (a) through (h) of this section.” (g) The statement: ‘This container should be visually inspected after a motor vehicle accident or fire and at least every 36 months or 36,000 miles, whichever comes first, for damage and deterioration.’”

## Periodic In-Service Inspection Requirements (Sec. 4.1.4, NGV2)

“Each container shall be visually inspected at least every 36 months, or at the time of any re-installation, for external damage and deterioration....The inspection shall be performed by a qualified container inspector in accordance with (1) the manufacturer’s recommendations and (2) the inspection procedures provided in Compressed Gas Association (CGA) pamphlet C-6.4”

## Fuel Tank Mounting

LNG fuel tanks are very standard in size and mounting and are typically side mounted to the frame rail of the truck (as pictured at right) this is primarily out of necessity for convenience and accessibility to the fuel tanks.

In the case of CNG fuel tanks, a wide variety of options are now available from a widening range of fuel tank manufacturers and suppliers. This section will describe the various locations available for mounting CNG fuel tanks on refuse collection vehicles. The variety of options of mounting locations arose from the need to relocate the tanks to less convenient location on the truck's body or chassis for a variety of reasons.



Since then and in recent years, Industry leading CNG fuel tank manufacturers have developed Roof Mount, Behind the Cab, Deck Mount and Side Mount systems which are compact and have the highest strength-to-weight ratio in the field today. The advantages and disadvantages of each mounting location vary depending on the refuse vehicle, service application, specific line of business (LOB), local overhead height restrictions, routing topography and a host of other factors.



Many manufacturers offer fully enclosed outer cases to protect the CNG fuel tank cylinders (such as pictured at left).

## Tank Mounting Options Include:

- Roof Mount
- Shelf Mount / Behind the Cab Mounting
- Frame Rail / Side Mount



## Roof Mount

### Features Include:

- Reduces truck chassis overall length needs
- Available in 50 to 90 Diesel Gallon Equivalent Capacity (DGE) configuration
- Can be coupled with Frame Rail / Side Mount for greater on board fuel capacity
- Great for use with ASLs and Front Loaders
- Height can be modified to avoid overpass interference



## Shelf Mount / Behind the Cab Mounting

### Features Include:

- Available in 50 to 90 Diesel Gallon Equivalent Capacity (DGE) configuration
- Can be coupled with Frame Rail / Side Mount for greater on board fuel capacity
- Great for use with ASLs and Rear Loaders

## Enclosed Frame Rail / Side Mount

### Features Include:

- Available in 50-70 Diesel Gallon Equivalent Capacity (DGE) configuration
- Can be mounted on either side of vehicle
- Great for use with Front loaders, Roll off trucks and Rear Loaders



## CNG Tank Inspection Requirements

Federal Law requires issuance of guidance for CNG tank inspection. The National Highway Traffic Safety Administration (NHTSA) has mandated that natural gas fuel tanks for vehicles produced after December 2, 1996 be inspected for damage or deterioration every 36 months, or 36,000 miles, whichever comes first, or after a fire or accident. It is the customer's responsibility to get their CNG fuel containers inspected by 3 years or 36,000 miles and to be in compliance with FMVSS requirements and industry standards.

This is a relatively new requirement that applies only to fuel tanks that are classified as pressure vessels. Although it is new to the automotive industry, the requirement for periodic inspections of pressure vessels is a long established practice in the compressed gas industry.



The purpose of this TSB is to provide an overview of the CNG tank inspection procedures, to clarify the criteria for rating damage to natural gas tanks, and to identify the level of damage requiring tank replacement.

### What is Involved with the Inspection?

The natural gas vehicle industry standard is Basic Requirements for Compressed Natural Gas Fuel Containers - ANSI/IAS NGV2. Paragraph 4.1.4 of this standard refers to the Compressed Gas Association (CGA) pamphlet C-6.4 (Methods for External Visual Inspection of Natural Gas Fuel Containers and Their Installations). C-6.4 lists the visual inspection requirements in detail including the examination of the:

- Installation
- Containers
- Valves and relief devices
- Labeling

C-6.4 requires that an accurate and reliable written report be provided for each container inspected and that an inspection label be placed on each container stating:

- Date the container was inspected;
- Inspection agency

### What is required to conduct a cylinder inspection?

- A copy of CGA pamphlet C-6.4 (Methods for External Visual Inspection of Natural Gas Fuel Containers and Their Installations). This publication provides information and procedures for conducting visual inspections of natural gas fuel containers. It also contains industry general container inspection pass/fail criteria limits.
- A copy of CGA pamphlet C-6.2 (Guidelines for Visual Inspection & Requalification Fiber Reinforced High Pressure Cylinders) (Figure 2). This publication is not absolutely required, but it is highly recommended if type 2, 3 or 4 cylinders are being inspected. C-6.2 provides more descriptive detail regarding what is acceptable/non-acceptable damage to fiberglass reinforcement of type 2, 3 or 4 cylinders.

C-6.2 and C-6.4 can be purchased through the CGA located at:

#### Compressed Gas Association

Compressed Gas Association  
4221 Walney Road, 5th Floor  
Chantilly, VA 20151-2923  
703-788-2700  
Website - [www.cganet.com](http://www.cganet.com)

- A copy of Gas Research Institute (GRI) publication GRI-97/0250 (Natural Gas Vehicle Cylinder Care and Maintenance Handbook) (Figure 3). This publication, also,



is not absolutely required, but is highly recommended. GRI publication 97/0250 provides a more detailed overview of cylinder inspection procedures than do the other publications, and is especially useful for training of cylinder inspectors.

- GRI-97/0250 can be purchased through the Gas Technology Institute (GTI) located at:

<b>Gas Technology Institute</b>
Gas Technology Institute 1700 South Mount Prospect Road Des Plaines, IL 60018 847-768-0500 Website - <a href="http://www.gastechnology.org">www.gastechnology.org</a>

### Cylinder Supplier's Re-Inspection Criteria

Basic Requirements for Compressed Natural Gas Fuel Containers - ANSI/IAS NGV2, paragraph 4.1.4, states that, "requirements for re-qualification by inspection or testing during the service life shall be specified by the container designer." Accordingly, most cylinder manufacturers publish unique and specific re-inspection criteria that are closely tailored to their own cylinder designs. In the event of a conflict between the manufacturer's re-inspection criteria and C-6.4 criteria, the manufacturer's criteria shall take precedence. The C-6.4 criterion is industry general, and is typically more conservative than the manufacturer's criteria. These re-inspection criteria can be obtained from the manufacturer at the address printed on the cylinder label or at addresses listed at the end of this document. A High Intensity Light that is capable of illuminating all surfaces of the cylinder(s) to be inspected is required.

- Angled inspection mirrors will be required to view cylinder surfaces that are partially concealed in installation.
- Various hand tools will be required to remove covers, shields, etc. so that the external cylinder surfaces, brackets, valves, etc. can be viewed.
- A torque wrench is required to verify that mounting bracket bolts are properly tightened, and to re-install covers, shields, etc. that are removed to aid in the inspection.
- Depth Gages are required to determine the depth of any cuts, pits, and abrasions that may be encountered.

### Who Can Perform the Inspections?

C-6.4 states that a qualified inspector should perform the visual inspection of a natural gas vehicle fuel container. C-6.4 states that a qualified inspector must have one of the following:

- Have a minimum of two years experience conducting container inspections
- Be supervised by someone with two years experience
- Be approved by the container manufacturer, or
- Be certified as an inspector by an appropriate organization (i.e., CGA)
- C-6.4 also specifies that a qualified inspector must also have:
- Knowledge of the types of containers used in CNG vehicle systems, and damage allowances for each type
- Understanding of inspection requirements, tests, procedures, etc



Therefore, a qualified inspector does not have to go through any particular training or certification process as long as they can meet the criteria listed above and possess the level of knowledge or resources specified in the Compressed Natural Gas Association requirements C-6.4 (summarized above). An inspector could be a dealership technician, a utility technician, or anyone else that qualifies according to C-6.4. However, it is highly recommended that inspectors become certified, as Ford requires that final inspection reports must be signed-off by a certified inspector for warranty or other work paid for by Ford. To locate a certified inspector in your area, visit the CSA International website at: [www.csa-international.org/](http://www.csa-international.org/)

### What is the CSA certification process?

The CSA certification process is a certification process for CNG container inspectors. This is the preferred way to become qualified to inspect CNG containers but is not the only way. To become certified as a CNG cylinder inspector by CSA, an applicant must complete a 2-day training course and successfully pass the final examination given at the end of the course. Certification classes are taught periodically at several locations. At the present time, the normal tuition costs vary between \$250 and \$300 per student. This normally includes the cost of individual training manuals. With prior notice, it is also possible to arrange for on-site certification classes at a location of your choice. Those desiring such on-site classes must pay instructor's travel expenses in addition to individual tuition costs.