A Review and Evaluation of “Examination Of Replacing Diesel Fueled Vehicles With Natural Gas Fueled Vehicles” -- A Study Performed by the Southwest Research Institute for the City of San Antonio, TX

Prepared by the Clean Vehicle Education Foundation

February 2006

INTRODUCTION

The Clean Vehicle Education Foundation (CVEF) is a non-profit [501(c)(3)] technology research and education organization. CVEF's mission is to advance the research, development, demonstration and deployment of clean fuel-powered vehicles and to increase public awareness of the benefits of these vehicles.

In January 2006, the CVEF was contracted by NGVAmerica, a national trade association headquartered in Washington, DC, to review and evaluate a study titled "Examination of Replacing Diesel Fueled Vehicles with Natural Gas Fueled Vehicles," performed for the City of San Antonio by the Southwest Research Institute® (SwRI®), an independent, non-profit applied research and development organization. The purpose of that study was to examine the environmental and economic impact of utilizing natural gas-fueled vehicles in future purchases beginning with model-year 2007. SwRI selected refuse haulers and recycling trucks as the subject vehicles of its study. CVEF was asked to perform a comprehensive review and evaluation of the data and assumptions used by SwRI in order to assess the validity of the report's findings and recommendations. This report is the result of that evaluation.

SUMMARY OF FINDINGS

The CVEF concludes that, while its methodology is sound, SwRI's "Examination of Replacing Diesel Fueled Vehicles with Natural Gas Fueled Vehicles" includes a number of outdated or erroneous assumptions and omits a number of key factors that undermine the validity of many of its findings, calling into question many of its recommendations. The most serious flaws in the analysis include the following:

1) As SwRI points out, financial incentives were not considered in its analysis. However, there are significant financial incentives for the purchase and use of natural gas vehicles and installation of natural gas fueling infrastructure provided by the federal Energy and Highway Bills – both signed into law in August of 2005. These incentives are directly applicable to the City of San Antonio's refuse and recycling fleet, and have a large impact on the relative economics of using natural gas versus diesel.
2) SwRI's fuel cost analysis is based on the U.S. Energy Information Administration's (EIA) 2005 forecast (completed in 2004). That analysis has been widely criticized as being unrealistic with respect to future oil prices. EIA's most recent forecast, issued after SwRI completed its study, reflects the significant changes that occurred to the energy markets in 2005 and anticipates much higher petroleum prices. In preparing this report, CVEF has properly used the EIA's 2006 forecast. .
3) SwRI significantly underestimates the economic impact of upcoming changes in national heavy-duty engine emission and fuel standards to the costs of purchasing, operating and maintaining diesel trucks.
4) SwRI assumes that both heavy-duty diesel and natural gas engines will just meet the 2010 EPA heavy-duty emission standards. That may not, in fact, be true.

SwRI concludes that "[c]onverting the fleet of refuse haulers and recycle trucks [to natural gas] is not cost effective under the current assumptions used in this study." When the erroneous assumptions are corrected and the omissions are properly factored into the analysis, however, CVEF reaches the opposite conclusion: namely, that natural gas trucks will continue to be less costly and provide better emission performance than diesel trucks. **Specifically, CVEF concludes that the City of San Antonio could save over $10,000,000 between 2007 and 2020 by purchasing and using only natural gas refuse trucks.**

The CVEF therefore recommends that the City of San Antonio adopt the natural gas option for its refuse trucks, and further, that the City not wait until 2007 to begin the natural gas phase-in, but begin as soon as possible.

ANALYSIS AND EVALUATION

In evaluating SwRI's report, the CVEF found problems with a number of the assumptions used. There also were three major omissions. These collectively had serious impacts on SwRI's analysis of future (1) fuel cost, (2) vehicle purchase, maintenance and operating costs and (3) vehicle emissions. The following is a detailed discussion of all these factors.

Fuel Cost: Highway Act Natural Gas Fuel Incentive

The SwRI analysis fails to take into account a new federal natural gas fuel-use incentive. In August of 2005, Congress passed and the President signed into law the "Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users" – also known as the Highway Bill. Because of concern over America's dependence on foreign oil, Congress included in that bill an excise tax credit (referred to as the Volumetric Energy Excise Tax Credit for Alternative Fuels or VEETC) to sellers of CNG or LNG.[i] The credit is 50-cent per gasoline-gallon-equivalent for CNG and 50-cents per *liquid* gallon for LNG when these fuels are used as a motor vehicle fuel. On a diesel-gallon-equivalent basis, this excise tax credit is 55.6 cents for CNG and 84.6 cents for LNG. In situations where there is no seller (e.g., where the CNG fueling facility is owned and operated by the customer), the customer or user of the fuel is eligible for the credit.[ii] While this is not a rebate per se, in effect, it acts like one. In other words, the seller (or user of the fuel if the user owns and operates the CNG station) files a form with the U.S. Internal Revenue Service (IRS) once a quarter, and the U.S. Treasury sends a check. Using the average fuel use figures employed by SwRI (i.e., 17,500 miles driven each year per truck and fuel economy of 2.5 miles per diesel gallon), each refuse truck operated by the City of San Antonio would receive an annual payment from the IRS of $3,892 if the vehicle operates on CNG and $5,922 if the vehicle operates on LNG. The credit goes into effect on October 1, 2006 and is scheduled to expire on September 30, 2009. However, it is widely expected that Congress will extend the credit beyond 2009.[iii] The SwRI report does not mention this credit, nor is it included in the SwRI analysis.

Fuel Cost: EIA Diesel and Natural Gas Price Forecast

For its analysis of the relative future economics of diesel versus natural gas trucks, SwRI relied on the U.S. EIA's 2005 Annual Energy forecast of diesel and natural gas prices. As SwRI itself points out, EIA's 2005 petroleum forecast was unrealistically low. As SwRI states: "The problem with this data is that it based on a 2010 average annual crude cost of $25/barrel whereas the price of crude in 2005 has been as high as $61/barrel". In January 2006, petroleum prices reached $68 per barrel. However, SwRI appears to say that this does not affect the validity of its analysis when it states:

> "It is recognized that these values may not reflect that City's actual price of fuel, but the relative difference between the fuels is reflected. Furthermore, the trends are accounted for in these predictions. That is, the City's actual price for diesel may be slightly higher than predicted, but that same difference will be found in the price of natural gas."

That assertion is incorrect. For its *2006 Annual Energy Forecast*, issued in December of 2005, EIA used more realistic assumptions about the future prices of petroleum and natural gas that show diesel and natural gas prices diverging. When data from this updated forecast is used, the annual cost advantage per truck for natural gas versus diesel fuel increases by $1,792 to $3,288, depending on the year. The derivation of these figures is shown below.

Table 1 shows the comparison of the projected diesel prices from EIA's 2005 and 2006 forecasts, and the differences in dollars per millions of BTUs ($/MMBTU).

Table 1
Price of Diesel Fuel
($/MMBTU)

Year	**2005 Forecast**	**2006 Forecast**	**Difference**
2010	$10.760	$14.290	$3.530
2015	$10.710	$14.560	$3.850
2020	$10.660	$14.780	$4.120
2025	$10.850	$15.150	$4.300

Table 2 shows the same data in dollars per diesel gallon. The difference is significant – ranging from 45 to 55 cents per gallon.

Table 2
Price of Diesel Fuel
($/Diesel Gallon)

Year	2005 Forecast	2006 Forecast	Difference
2010	$1.377	$1.829	$0.452
2015	$1.371	$1.864	$0.493
2020	$1.364	$1.892	$0.527
2025	$1.389	$1.939	$0.550

Using the same average annual truck fuel consumption (7,000 gallons per year) and average truck fuel economy (2.5 miles per diesel gallon) employed by SwRI, Table 3 shows the implications of using the more realistic 2006 EIA price forecasts on the cost of using diesel fuel to power the City of San Antonio's refuse trucks. The increased cost ranges from $3,163 to $3,853 per year per truck.

Table 3
Increased Annual Cost of Using Diesel Fuel
$/Truck
2005 vs 2006 EIA Data

Year	Net Price Difference	Gallons/ Truck	Additional Cost/Truck
2010	$0.452	7,000	$3,163
2015	$0.493	7,000	$3,450
2020	$0.527	7,000	$3,692
2025	$0.550	7,000	$3,853

Table 4 shows the comparison of natural gas prices in $/MMBTU and Table 5 shows the same data in $/diesel gallon equivalent (DGE).

Table 4
Price of Natural Gas
($/MMMBTU)

Year	2005 Forecast	2006 Forecast	Difference
2010	$8.560	$10.090	$1.530
2015	$9.110	$9.610	$0.500
2020	$9.450	$9.900	$0.450
2025	$9.690	$10.320	$0.630

Table 5
Price of Natural Gas
($/Diesel Gallon Equivalent)

Year	2005 Forecast	2006 Forecast	Difference
2010	$1.096	$1.292	$0.196
2015	$1.166	$1.230	$0.064
2020	$1.210	$1.267	$0.058
2025	$1.240	$1.321	$0.081

Table 6 shows the implications of using the more realistic 2006 EIA price forecasts on the cost of using natural gas to power the City of San Antonio's refuse trucks -- again, using the same average annual truck fuel consumption (7,000 gallons per year) and average truck fuel economy (2.5 miles per diesel gallon) employed by SwRI. The increased cost ranges from $403 to $1,371 per year per truck.

Table 6
Increased Annual Cost of Using Natural Gas
$/Truck
2005 vs 2006 EIA Data

Year	Net Price Difference	Gallons/ Truck	Additional Cost/Truck
2010	$0.196	7,000	$1,371
2015	$0.064	7,000	$448
2020	$0.058	7,000	$403
2025	$0.081	7,000	$564

Table 7 shows the net differences between the 2005 and 2006 forecasts for both diesel fuel and natural gas, and the net differences.

Table 7
Change in Forecasted Prices
($/Diesel Gallon Equivalent)

Year	Diesel Price Change	Nat. Gas Price Change	Net Difference
2010	$0.452	$0.196	$0.256
2015	$0.493	$0.064	$0.429
2020	$0.527	$0.058	$0.470
2025	$0.550	$0.081	$0.470

Table 8 shows increased fuel cost advantage for natural gas over diesel fuel (per year per truck) for the City of San Antonio using the 2006 EIA forecast compared to the 2005 forecast used by SwRI. The increased cost advantage ranges from $1,792 to $3,288.

Table 8
Savings Per Truck
with Natural Gas

Year	Net Price Difference	Gallons/ Truck	Addition Savings w/ Natural Gas
2010	$0.256	7,000	$1,792
2015	$0.429	7,000	$3,002
2020	$0.470	7,000	$3,288
2025	$0.470	7,000	$3,288

Fuel Cost: Ultra Low Sulfur Diesel
SwRI appears to have failed to take into account that, beginning in 2006, the cost of diesel fuel (over and above the impact of the world price of petroleum) is expected to increase because of the phase-in of EPA's ultra low sulfur diesel (ULSD) regulation.[iv] Under this rule, major petroleum refiners must ensure that the sulfur content of on-road diesel fuel *reaching users* is not more than 15 parts per million (ppm). Currently, the average sulfur content of diesel fuel is 350 ppm. Because of probable sulfur contamination during transport (e.g., from pipelines and trucks), the refiners will actually be producing diesel fuel closer to zero ppm sulfur. It is unclear how much more it will cost to produce ULSD than regular diesel. In testimony, the petroleum refining industry forecast up to 50 cents per gallon, while EPA forecast only a few cents per

gallon.[v] However, more recently, EIA stated: "While considerable uncertainty exists in both the supply and demand estimates [for ULSD], this analysis indicates that even though the market could see supply meet demand at a cost increase for production between 5.4 and 7.6 cents per gallon, there are a number of scenarios in which inadequate supply of ULSD could result."[vi] In other words, EIA believes the increase in cost for ULSD could be greater than 7.6 cents per gallon (or over $500 per refuse truck for the City of San Antonio). Note that these numbers refer to the cost *at the refinery.* The actual fully loaded cost at the rack (distributor) is likely to be significantly greater.

Vehicle Purchase Cost: Energy Bill Incentives

The SwRI analysis does not take into account a new federal natural gas vehicle purchase credit. In August of 2005, Congress passed and the President signed into law the Energy Policy Act of 2005. Because of concern over America's dependence on foreign oil, Congress included in that legislation a financial incentive for the purchase of natural gas vehicles.[vii] That incentive is now in effect.[viii] Specifically, the provision provides an income tax credit to the buyer of a new, dedicated natural gas vehicle of 50 percent of the incremental cost of the vehicle, plus an additional 30 percent if the vehicle meets certain tighter emission standards. For heavy-duty vehicles such as refuse trucks (i.e., vehicles over 26,000 lbs.), the credits can only be applied to the first $40,000 of the incremental price. In other words, the maximum tax credit for these vehicles is $32,000 (80 percent of $40,000). For non-tax-paying entities (such as the City of San Antonio), the *seller* of the vehicle can take the credit, with some or all of the incentive passed to the buyer in the form of a lower vehicle purchase price. According to SwRI, the incremental price for a natural gas refuse truck is $40,000 (SwRI states: "The City of San Antonio has recently received quotes from a vehicle OEM indicating the current price of a refuse hauler at $130,000 for diesel and $170,000 for natural gas."). As discussed below, Cummins Westport and Deere, two of the major suppliers of heavy-duty natural gas engines, both meet the tighter emission standards and will continue to meet the tighter standards through 2010. Therefore, natural gas refuse trucks powered by their engines will be eligible for a $32,000 purchase incentive, bringing the incremental price down to $8,000. In its analysis, SwRI uses an 8-year amortization for the vehicles. Therefore, the savings from this vehicle purchase incentive could be $4,000 per year per truck.

Vehicle Purchase Cost: TERP Grants

The SwRI analysis does not take into account Texas Emission Reduction Program (TERP) grant opportunities available for refuse trucks in 2006. Depending on the diesel refuse truck that is replaced (NOx reduction drives the grant amount), an additional $5,000 to $8,000 could be realized as a grant from the state for natural gas refuse trucks.

Vehicle Purchase Cost: Increase in 2007 Vehicles

SwRI significantly underestimates the increased cost of heavy-duty diesel vehicles that will meet the 2007 EPA emission standards.[ix] SwRI states: "… an estimate has been made to account for the increase in technology for the diesel vehicle in 2007 and again in 2010. The cost increase for 2007 is estimated at $1,500 over 2005's purchase price and $3,000 for 2010. These estimates are based on advanced aftertreatment (traps and catalysts) requirements." A figure as low as $1,500 for the increase in diesel vehicle cost in 2007 is not supported by any public statements by vehicle manufacturers. All public estimates are much greater. For example, in a recent presentation, Dee Kapur, President of International Truck and Engine's truck group said that stricter diesel emissions standards starting with 2007 models could add $5,000 to $6,000 to the price of a new medium duty vehicle and up to $10,000 to a new heavy-duty vehicle. "We recognize that this is a pretty significant increase in pricing …" he said.[x] A significant portion of that price increase is due to the incorporation of traps needed to reduce particulate matter and related sensors, controls and peripheral supplemental fuel hardware. With respect to the 2010 EPA emission standard, no diesel engine manufacturer has yet announced how they plan to meet the 0.20 NOx requirement. Current research is focused on NOx adsorption technologies and Selective Catalytic Reduction (SCR) using urea injection, both of which are considered problematic as they require more sophisticated engine and after-treatment controls and/or on-board storage of a another substance. Until a technology path is selected, it is impossible to forecast a cost impact for 2010 diesel engines at this time. Clearly, the $3,000 assumed by SwRI is much too low. Meanwhile, as discussed below, the technology used by natural gas engine manufacturers will permit natural gas engines to meet the 2010 standards in 2007 with an increase cost of only a few percent – in the hundreds, not, thousands, of dollars.[xi] Since the 2007 engines will already meet the 2010 standards, there will be no increase in cost for natural gas trucks in 2010.

Vehicle Fuel Economy

It is very probable that SwRI overstates the fuel economy advantage of new (2007 and beyond) diesel engines over natural gas engines. The SwRI states:

> "Natural gas engines are spark-ignited, throttled engines, and thus have a slightly lower fuel economy… A diesel engine has no throttle and therefore has very little pumping losses … SwRI has applied a 10 percent diesel equivalent gallon fuel economy penalty to the natural gas vehicles in this study. This is consistent with other refuse hauler fleet experience."

This may have been the experience in the past, but it not true today and will certainly not be true in the future. The relative efficiencies of natural gas versus diesel engines have been drawing closer as emission standards have tightened (in 2004, 2007, 2010), and natural gas engine technologies have improved. Changes in combustion controls and timing and/or engine gas recirculation (EGR) and related increases in heat rejection and back-pressure have diminished diesel's historical edge in power/performance and fuel economy. A recent study (December of 2005) compared natural gas and diesel transit buses operated by the Washington Metropolitan Area Transit Authority (WMATA). The WMATA study concluded that, not only were the natural gas buses less polluting (i.e., the 2004 CNG buses produce 49 percent lower NO_x emissions and 84 percent lower PM emissions than the 2004 diesel buses), but the natural gas and diesel buses had basically the same fuel economy -- 2.4 mpg.[xii] As to the future, Cummins-Westport International forecasts: "Relatively stable cost-per-mile over the three time frames [pre-2007, 2007-2009 and post 2009] for natural gas, resulting from the combination of lower incremental engine/vehicle costs for natural gas engines to meet the emission standards and increased efficiency expected with the advanced natural gas technology."[xiii] Meanwhile, diesel engines that meet the 2007 standard are expected to suffer some additional efficiency loses. This especially will be true in duty-cycles (like with refuse trucks) where the engine does not produce sufficient heat to regenerate the particulate trap. In these cases, diesel fuel will be used to regenerate the trap. This parasitic load will reduce operating efficiency. It is instructive to look back at the last time there was an EPA-imposed change in emission standards (2002/2004). In discussing the impacts of those changes at a conference in 2004, the director of technology and training for U.S. Xpress said that, for his company, "fuel mpg is off as much as 9% …"[xiv] The vice president of purchasing for Schneider National (which operates 9,000 tractors) said: "the 3% to 5% drop in mpg with '02 engines 'has wiped out 10 years of fuel economy improvements …'"[xv] It is expected that there will be another loss in diesel engine efficiency in 2007 and again in 2010. At some point in the 2007-2010 time frame, the engine efficiency of natural gas and diesel engines will cross, after which natural gas engines will have an engine efficiency advantage.

Vehicle Maintenance Costs

Since some maintenance costs are greater for natural gas trucks (e.g., spark plugs) and some are less (e.g., fewer oil changes), SwRI "assumed comparable maintenance costs for both NGVs and diesel powered vehicles." When the 2007 engines are introduced, natural gas vehicles are expected to have a maintenance cost advantage over diesel engines, however. With the introduction of active particulate traps and other sophisticated (and more fragile) after-treatment technologies, it is expected that diesel vehicle maintenance cost will increase. Again, it is instructive to look back at the last time there was an EPA-imposed change in emission standards (2002/2004). Federal Express' fleet manager said "his fleet had been experiencing failures with sensors, EGR valves, EGR coolers and injectors. 'No huge horror stories, but lots of pain and **extraordinary costs.**'"[Emphasis added][xvi] Diesel particulate traps will need to be cleaned yearly, a several hour process requiring use of a special cleaning device that currently costs between $7,000-$8,000. In addition, traps currently on the market are designed with a life-expectancy of approximately 100,000 miles, which – based on an 8-year vehicle life schedule at 17,500 miles per year -- will require replacement after 5-6 years. The cost of purchasing and installing a new filter in 2012 is projected to be $2,500-$4,000, based on expected price reductions due to economies of scale. Furthermore, disposal of the ash removed from these particulate filters is becoming more costly as states rule this precious-metal-laden waste to be a hazardous material. The SwRI report also cites the added cost for training maintenance (and driver and collections) personnel on the use, fueling and maintenance of natural gas vehicles. Nowhere does the SwRI report mention the added cost for training for diesel maintenance technicians to learn about the new, more sophisticated engine and exhaust after-treatment technologies.

Fueling Station Cost/Energy Bill Incentive

As SwRI points out, among the one-time costs of pursuing the natural gas option is the cost of the on-site natural gas fueling equipment. SwRI states that it "has estimated that a medium sized facility to be $250,000. This facility would incorporate a 225 scfm compressor, with one dispenser and two hoses. The monthly costs to operate and maintain the facility are estimated to be $1,000." There are two factors that should be considered here. First, in the federal energy legislation discussed above, Congress approved an income tax credit for natural gas fueling equipment.[xvii] As with the NGV purchase credit discussed above, for non-tax-paying entities, the *seller* of the fueling equipment can take the credit. This tax credit is equal to 30 percent of the cost of natural gas refueling equipment, up to $30,000 or over 10 percent of the cost of the station described by SwRI. However, since, as SwRI points out, fueling equipment is amortized over 20 years, the annual impact of this credit to the City of San Antonio is small. Second, and more important, whether the City opts for CNG fueling or LNG fueling (see discussion below), there are companies in the NGV business that specialize in building, owning and operating private NGV fueling stations. If the City guarantees that it will use a minimum amount of fuel per month (approximately, 30,000 GGE), these companies would guarantee a price for CNG or LNG below the price of diesel fuel. This option would relieve the City from concerns about station first-cost, operating costs and maintenance.

2010 Engine Emission Comparisons

SwRI repeatedly states that by 2010 natural gas engines will have no emission advantage over diesel engines. For at least three reasons, that assertion is probably incorrect: (1) the implementation of the 2010 standards may be delayed; (2) EPA's vehicle certification process does not provide accurate information to make comparisons; and (3) heavy-duty natural gas vehicles may well be less polluting than diesel vehicles post-2009.

First, the diesel engine industry may be successful in delaying the 2010 standard. There is recent precedent for this. In 1998, the California Air Resource Board (CARB) concluded that diesel emissions pose a threat to human health.[xviii] The resolution adopted by CARB called for "immediate and continuing efforts to replace diesel-fueled school and public transit buses with cleaner alternative-fuel buses," and set a goal of replacing the state's remaining diesel transit fleet by 2010. The diesel industry opposed the rules, stating at the time that, if given the opportunity to participate, it would deliver products that achieved the aggressive standards that CARB determined are needed to protect human health and the environment.[xix] Therefore, in February 2000, CARB approved the Fleet Rule for Transit Agencies, which allowed transit agencies to choose between two paths: an alternative fuel path and a diesel path.[xx] Unfortunately, by 2004 when the new, tighter transit bus standards were to go into effect, no engine manufacturers were producing diesel engines that met CARB's standards. As a result, CARB was forced to relax the standards to levels that diesel engines could meet.[xxi] The 2010 emission standards are tight – requiring NOx to be reduced by another 80 percent from the 2007 levels (which themselves reduce NOx by 50 percent from the 2004 levels). Diesel engine manufacturers repeatedly have stated how difficult and expensive the 2010 standards will be to meet. If the 2010 deadline for the new emission standards approaches and no diesel engine manufacturer has agreed to produce a diesel engine that achieves those standards (as happened in California), Congress and the Administration will be under severe pressure to relax and delay the 2010 standards. These engines, therefore, will not be more expensive than the 2007 engines, but they will produce six times the NOx compared to the 2010 standard.

A second reason that diesel engines might not have the same emissions as natural gas engines in 2010 relates to the manner in which engines are certified. The primary concern for the City of

San Antonio is the actual pollution that vehicles generate – not some less meaningful on-paper comparisons. Unfortunately, EPA certification is not necessarily a reliable measure of emissions performance. It has long been recognized that EPA's certification system significantly underestimates emissions from light-, medium- and heavy-duty vehicles because the certification procedures does not reflect real-life driving styles and conditions.[xxii]

A third reason that natural gas engines may continue to produce fewer emissions than diesel engines in 2010 and beyond concerns differences in their basic technology. Diesel engines are lean-burn "compression ignition" engines. While historically there have been performance advantages to compression ignition engines, it is increasingly difficult (and expensive) to reduce the next unit of emissions from this type of engine without reducing efficiency. Natural gas engine manufacturers have other options. In order to meet the very tight 2010 emission standards, heavy-duty natural gas engine manufacturers are moving to "stoichiometric" engines, which is the technology used in spark-ignited gasoline engines.[xxiii] One of the primary advantages of stoichiometric engines is that, with the use of three-way catalysts, emissions can be reduced quite low without loss of efficiency. Cummins-Westport and Deere have already demonstrated and announced that they will be offering engines that meet the strict 2010 emission standards in model year 2007.[xxiv] When this technology is coupled with the inherently cleaner burning characteristics of natural gas and other advancements in natural gas engines, by 2010, it may be possible to surpass the 2010 standards. Diesel fuel cannot be used in stoichiometric engines, which closes off this fertile avenue for emissions improvement.

Greenhouse Gases

One emission not discussed by SwRI in its report is greenhouse gases. The full cycle emissions of greenhouse gases (including methane) from diesel vehicles at one time were less than for natural gas vehicles, but this is no longer the case.[xxv] In 2004, when the NOx limit on diesel engines was reduced from 4.0 gm/bhp-hr to 2.5 gm/bhp-hr, some efficiency was lost in complying diesel engines. Meanwhile, the efficiency of heavy-duty natural gas engines has continued to improve.[xxvi] Importantly, the greenhouse gas advantage of heavy-duty natural gas vehicles is expected to increase further. All things equal, greenhouse gas production is directly proportional to energy used, and future diesel engines will require more energy to operate for two key reasons. First, as indicated, beginning in 2006, refiners must begin selling only ULSD. ULSD is a more refined product that will take more energy to produce. Second, and more importantly, the 2007 diesel engines will be less efficient than current engines, using more energy per mile traveled.[xxvii] Climate change has been a international and national concern. Increasingly, it is becoming a local concern. For example, currently, over 200 U.S. mayors have signed on to the Conference of Mayors' Climate Protection Agreement. If San Antonio were to become a signatory, an NGV program (including natural gas refuse trucks) could play a major role.

Other Studies

There have been other studies performed recently on the future economics of natural gas versus diesel vehicles that reflect many of the factors discussed above. For example, Cummins-Westport states that the cost per mile advantage for diesel vehicles over natural gas vehicles will disappear during the 2007-2009 timeframe. After 2009, Cummins-Westport expects that natural gas engines will have a cost per mile advantage.[xxviii] A second study (conducted by TIAX LLC) reaches a similar conclusion.[xxix] TIAX concludes that 2010-technology heavy-duty NGVs will be "highly competitive with their diesel counterparts," and, *if oil prices rise above $31 per barrel*, heavy-duty natural gas vehicles will be less expensive over the lifetime of the vehicles.[xxx] EIA forecasts that petroleum will continue well above $31 per barrel through 2030.[xxxi]

CNG Versus LNG

SwRI states: "Compressed natural gas (CNG) versus liquefied natural gas (LNG) is recommended for the City's fleet primarily for economic reasons. SwRI believes that fast-fill CNG refueling (versus slow-fill) is the most appropriate refueling strategy for the refuse hauler and recycling truck fleet. Fast-fill refueling will have the least impact on current fleet operations and protocol. Fast-fill enables vehicles to refill mid-day, which is often required during heavy operating days. Furthermore, this option would enable the City to consider future options with other CNG vehicles, such as light-duty support vehicles. A slow-fill refueling facility would be sized and laid out to meet the City's refuse hauler fleet and would preclude the ability to refuel other future vehicles."

CNG and LNG vehicles both have environmental and economics advantages compared with heavy-duty diesel vehicles. But each has attributes that make them either more or less attractive in specific applications. In applications where weight, on-board space and range are issues, LNG often is the preferable alternative. LNG refuse trucks are providing very cost-effective service in a number of communities around the country. The CVEF is *not* advocating LNG over CNG. However, the CVEF believes it would be a mistake for the City of San Antonio to discount the LNG option without performing a more in-depth technical and economic evaluation. The following are some issues that the City should consider:

On-Board Storage

CNG is stored on board vehicles as a compressed gas in specially reinforced cylinders at 3000-3600 psig. LNG is stored on board vehicles in special cryogenic cylinders resembling a vacuum flask to retain the cold temperature. When gas is liquefied, its volume contracts significantly. Therefore, for 70 DGEs of fuel, CNG (fuel and tanks) would require 80 percent more on-board space than LNG.

Weight

A DGE of natural gas weighs about one-third less than a gallon of diesel fuel. However, CNG and LNG tanks weigh more than a comparable diesel fuel tank. A full 70 DGE LNG tank weighs about 300 pounds more than a comparable, full diesel tank. A full 70 DGE CNG tank weighs about 720 pounds more than a comparable, full diesel tank.

Range

SwRI states: "Vehicle range may be reduced [with natural gas trucks] which can impact routing and refueling." As discussed above, since LNG requires less on-board storage space than CNG, if range is an issue, more storage capacity can be installed with LNG in the same space as a lesser-fuel -capacity CNG system.

Venting

SwRI states: "While [LNG] tank technology continues to improve, a 100 percent insulated tank does not exist. Thus, there is always a small amount of heat entering the tank and adding energy to the fuel. As the fuel heats up, the liquid begins to boil and the pressure within the tank increases. In order to prevent overpressure rupture, LNG tanks are allowed to vent to atmosphere when the pressure rises above a preset point." While this is accurate, the issue of venting has been shown to be a minor (or non-existent) one for fleet vehicles. Venting is only an issue when vehicles are left unused for extended periods.[xxxii] Fleet vehicles tend to be in daily use. If LNG vehicles are left unused for extended periods (e.g., for repairs or other extended service), simple precautions must be taken to either de-fuel the tanks or account for the venting.

"LNG Aging"

SwRI states: "Another problem associated with venting is called LNG aging. LNG is usually not pure methane, but rather a mixture of methane, ethane, propane, butane, and other hydrocarbons. When LNG heats up, the first constituent to boil off is methane. If a tank sits long enough it could boil off a large portion of the methane, leaving a mixture of mostly heavy hydrocarbon in liquid form. If this fuel is delivered to the engine, there is a potential for significant and very costly engine damage." This also is true, but aging is only an issue when heat induced venting occurs (see above). In fleet applications, this has been shown to be a minor or non-existent issue.

LCNG Stations

SwRI states: "LNG is almost exclusively used in heavy-duty fleet vehicles and most commercially available light-duty vehicles only use CNG. It would be considerably advantageous for the City to consider future applications of light-duty NGVs to take advantage of the reduced fuel costs. However, if the City locks in with LNG, it is considerably more complicated to fuel CNG vehicles and effectively eliminates future purchases unless another CNG facility is installed." This is not correct. Once LNG fueling exists at a location, it is quite cost-effective to install LCNG fueling, i.e., fueling CNG vehicles with CNG produced from the LNG. A LCNG station is built to deliver 4500 psig through a dispenser providing either 3000 or 3600 psig to CNG vehicle tanks. An LCNG station does this through a LCNG pump and a high-pressure vaporizer. The pump pulls LNG from the bulk storage tank and pressurizes the liquid to 4500 psig, and then send it through a high pressure vaporizers which turns the liquid into 4500 psig compressed natural gas. The natural gas is then odorized and sent to storage. One of the major differences between an LCNG station and a CNG station is that the LCNG pump compresses liquid, while a CNG station compresses vapor. Liquid is much easier to compress than gas, and a CNG compressor can require five to fifteen times the horsepower of a LCNG pump. Hence, the operating costs are lower. A number of LCNG stations are operating well and cost-effectively around the country.

Fuel Cost

SwRI states: "The most significant advantage of CNG over LNG is the cost per equivalent gallon. CNG costs less than LNG even when fully burden [sic] with equipment and O&M. LNG delivered cost is 1.5 to 2 times that of CNG. Also, LNG is subject to local sales tax, CNG from pipeline is not. Both are subjected to road tax." This passage is curious. First, neither CNG nor LNG is subject to federal excise (i.e., road use) tax for municipalities such as the City of San

Antonio. Second, the cost of CNG and LNG vary from jurisdiction to jurisdiction. It does not appear that SwRI secured price quotes for local San Antonio LNG suppliers. Third, as mentioned above, the federal excise tax credit for LNG is 84.6 cents per DGE while for CNG it is 55.6 cents per DGE. This difference could significantly affect the economics of LNG versus CNG.

CONCLUSIONS

The focus of SwRI's analysis is two-fold: emissions reduction and cost. SwRI shows that natural gas refuse trucks will provide more emissions benefits than diesel trucks through 2009. There are some compelling arguments that natural gas trucks will continue to provide significant emissions benefits (see above) after that period. However, because so many factors are unknowable at this time, the exact benefit will not be known until 2010.

As to cost, the picture is clearer. SwRI states: "This study showed that CNG fuel costs are likely to be less than diesel fuel costs over the next 15 years … However, the differential is not significant enough to offset the increased vehicle costs, initial infrastructure capital costs, and increased training costs." When just *some* of the cost factors discussed above are considered, this conclusion by SwRI is shown to be incorrect.

Figure 1 shows the total cost (calculated by SwRI) of SwRI's three scenarios:

- Scenario 1 - Purchase all diesel vehicles
- Scenario 2 - Purchase all natural gas vehicles after 2007, but with no economy of scale considerations
- Scenario 3 - Purchase all natural gas vehicles after 2007, but *with* economy of scale considerations.

Using SwRI's model, Figure 2 shows the same three scenario using EIA's 2006 Annual Energy Forecast prices for diesel and natural gas instead of the 2005 numbers. Figure 3 adds the 55.6 cents per DGE federal excise tax credit. Figure 4 adds the federal vehicle purchase credit. Table 9 shows the annual costs for Scenario 1 (Diesel Option) and Scenario 2 (Natural Gas Option with no Economies of Scale) depicted in Figure 4.

Figure 1: SwRI Scenarios

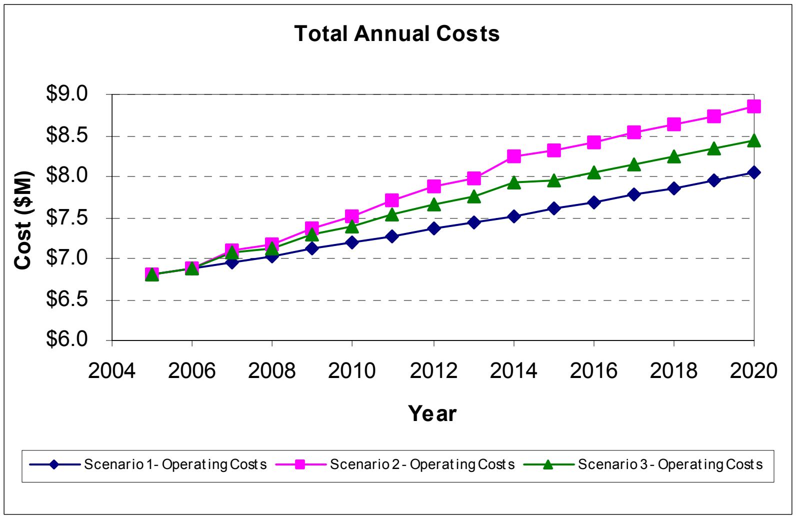

Figure 2: 2006 EIA Data

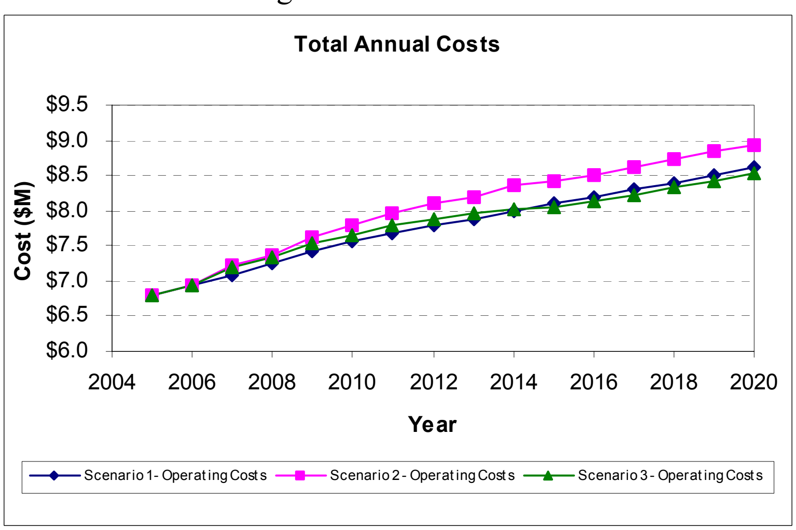

Figure 3: 2006 EIA Data and Excise Tax Credit

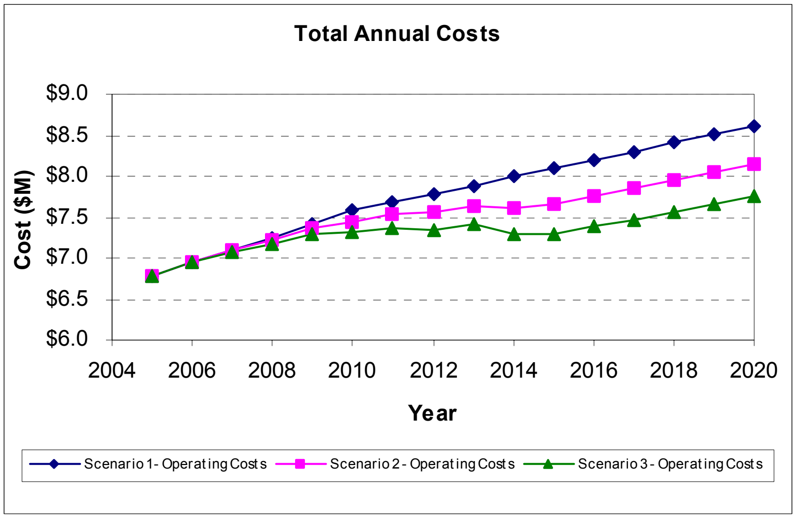

Figure 4: 2006 EIA Data and Excise and Vehicle Purchase Tax Credits

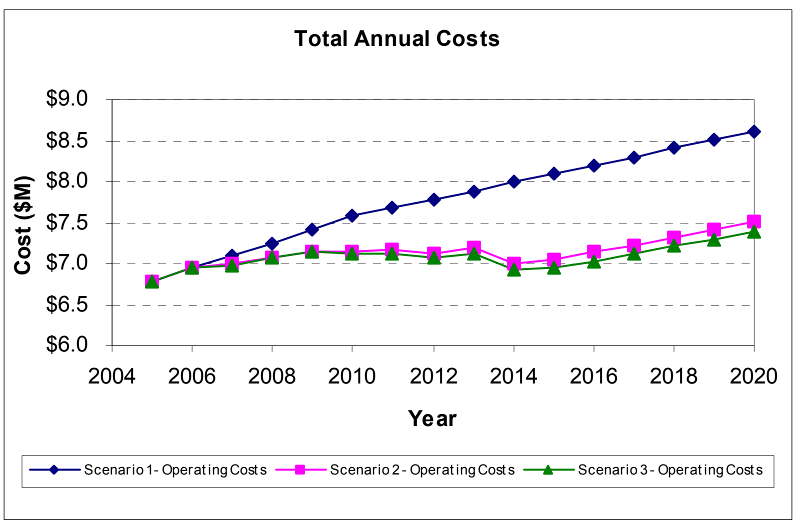

Table 9: Annual Cost: Diesel vs. Natural Gas Option

Year	Diesel	Natural Gas	
2005	$6,783,469	$6,783,469	Assumes only diesel trucks purchased in these two years
2006	$6,939,571	$6,939,571	
2007	$7,095,169	$6,988,278	
2008	$7,248,351	$7,083,738	
2009	$7,411,848	$7,153,365	
2010	$7,574,506	$7,148,910	
2011	$7,681,517	$7,160,669	
2012	$7,788,544	$7,123,017	
2013	$7,890,029	$7,188,002	
2014	$7,991,392	$7,003,254	
2015	$8,097,342	$7,046,665	
2016	$8,199,051	$7,136,502	
2017	$8,302,321	$7,230,135	
2018	$8,403,165	$7,319,974	
2019	$8,502,904	$7,411,429	
2020	$8,603,864	$7,501,997	
TOTAL	$110,790,003	$100,495,935	
SAVINGS		**$10,294,068**	

Just using the more current (and more realistic) EIA forecast of diesel and natural gas price and factoring in the impacts of the federal excise tax and vehicle purchase incentives signed into law in the Energy and Highway Bills, it is clear that the natural gas option is far more cost effective than the diesel option. In fact, the City of San Antonio could save over $10,000,000 from 2007 through 2020 under the natural gas option. The City could save even more if natural gas refuse trucks began to be purchased in 2006 instead on 2007.

Note that Figure 4 and Table 9 do not even take into account other factors discussed above that would skew the economics in favor of the natural gas option even further – such as the greater purchase, maintenance and operating cost expected for diesel trucks beginning in 2007, the greater per gallon cost of ultra-low sulfur diesel (which will be required beginning in the fall of 2006) and the fact that there will be economies of scale benefits for natural gas trucks.

RECOMMENDATIONS

Based on this analysis, the CVEF has the following three recommendations for the City of San Antonio:

1) Request that SwRI verify the accuracy and validity of the CVEF analysis.

2) Adopt the natural gas option for its refuse trucks and begin the natural gas phase-in as soon as possible (i.e., do not wait for 2007).

3) Evaluate both the CNG and LNG option.

Endnotes

[i] Sec. 11113 of P.L. 109-59. The incentive also applies to propane, hydrogen and some minor fuels.

[ii] For tax paying entities, partially offsetting the value of the excise tax credit is an increase in the motor fuels excise tax rate for both CNG and LNG. The CNG rate would increase from 4.3 cents per gasoline gallon equivalent to 18.3 cents. The LNG rate would increase from 11.9 cents to 24.3 cents on a LNG gallon basis. However, this excise tax does not apply to municipalities such as the City of San Antonio.

[iii] A VEETC credit already has been extended for ethanol and bio-diesel and is it expected that those credits will be extended again. Telephone conversations with Richard Kolodziej, president of NGVAmerica (January 20, 2006) and Brian Feehan, Managing Director, Propane Vehicles, the Propane Education and Research Council (January 21, 2006).

[iv] See "Control of Air Pollution from New Motor Vehicles: Heavy-Duty Engine and Vehicle Standards and Highway Diesel Fuel Sulfur Control Requirements," EPA, 40 CFR Parts 69, 80, and 86, published January 18, 2001.

[v] See comments submitted to EPA on ULSD rule by: ExxonMobil (IV-D-228) p. 2-3; Independent Fuel Terminal Operators Association (IV-D-217) p. 3-5; Marathon Ashland Petroleum (IV-D-261) p. 2, (IV-F-74);
NY Assoc. of Service Stations & Repair Shops (IV-F-45); Petroleum Marketers Association of America (IV-F-67); Phillips Petroleum Company (IV-D-250) p. 5; Ports Petroleum Co, Inc. (IV-F- 117) p. 190; U.S. Chamber of Commerce (IV-D-329) p. 5; and Western Independent Refiners Association (IV-D-273) p. 3, "Heavy-Duty Engine and Vehicle Standards and Highway Diesel Fuel Sulfur Control Requirements: Response to Comments," EPA, EPA420-R-00-027, December 2000.

[vi] "The Transition to Ultra-Low-Sulfur Diesel Fuel: Effects on Prices and Supply", The US Energy Information Administration, June 8, 2001

[vii] Sec. 1341 of P.L. 109-58. The incentive also applies to dedicated vehicles powered by propane, hydrogen and M85.

[viii] The credit is effective on purchases made after December 31, 2005 and expires December 31, 2010. As with the fuel credit, the alternative fuel industries are working with Congress to extend that credit beyond 2010.

[ix] Currently, EPA emission standards for heavy-duty engines are 2.5 grams per brake horsepower hour (gm/bhp-hr) for nitrogen oxides (NOx) and volatile organics compounds (VOCs) and 0.1 gm/bhp-hr for particulate matter (PM). Beginning with model year 2007 engines, those standards will be 0.2 gm/bhp-hr of NOx and 0.01 gm/bhp-hr of PM. However, EPA will permit a phase-in of the new NOx standard during model year 2007, 2008 and 2009. The manufacturers have indicated that the will implement that phase in by ensuring that all engines manufactured during the 2007-2009 period produce no more than 1.2 g/bhp-hr of NOx.

[x] "Emissions Compliance Could Cost $5,000-$10,000 Per Engine," Truckinginfo.com, November 9, 2005.

[xi] See John Deere news release "John Deere Power Systems Showcases 9.0l Natural Gas Engines At Gathering Of Transit Industry Leaders," September 2005, and Cummins-Westport news release "Cummins Westport, DOE, And NREL Partner To Deliver Next Generation Natural Gas Engine Three Years Ahead Of U.S. Regulations," February 9, 2005. In these releases, these natural gas engine manufacturers announced that they would have 2010 compliant heavy-duty engines available for the market in 2007 using stoichiometric engines.

[xii] This was an "apples-to-apples" study where a total of twelve 40-foot, low-floor WMATA buses were tested using West Virginia University's Transportable Heavy-Duty Vehicle Emission Testing Laboratory. These buses were of two types: CNG and low-sulfur diesel (approximately 17 ppm sulfur). All CNG buses had lean burn natural gas engines and oxidation catalysts. All diesel buses had catalyzed particulate filters, and one group of diesel buses had exhaust gas recirculation (EGR). "Emission Testing of Washington Metropolitan Area Transit Authority (WMATA) Natural Gas and Diesel Transit Buses," National Renewable Energy Laboratory, December 2005. Also see proceedings of October 26-28, 2005 Transit Users Group meeting.

[xiii] "Advantages And Opportunities With Cummins Westport Natural Gas Engines," CWI presentation, 2005 (from CWI website)

[xiv] See "Fleets already concerned about '07 engine costs," Diesel Progress North America, April 2004.

[xv] Ibid.

[xvi] Ibid.

[xvii] Sec. 1342 of P.L. 109-58. This provision also provides tax credits for fueling stations dispensing propane, hydrogen and E85. The tax credit currently is scheduled to expire after December 31, 2009.

[xviii] "Proposed Identification of Diesel Exhaust as a Toxic Air Contaminant Report," unanimously adopted by CARB on April 22, 1998.

[xix] For example, according to a February, 2000 Engine Manufacturers news release, "Not only does EMA [the Engine Manufacturers Association] support CARB's proposal, we have committed to pull ahead its deadline to meet more stringent particulate matter (PM) standards," said Glenn Keller, EMA Executive Director. "We remain committed to improving diesel emissions reduction technologies and have vowed to meet CARB's 0.01 PM standard by October 2002 - that's a full 15 months ahead of the January 2004 deadline."

[xx] "Final Statement of Reasons for Rulemaking, Including Summary of Comments and Agency Responses;
Public Hearing To Consider The Adoption Of A Public Transit Bus Fleet Rule And Emission Standards For New Urban Buses," February 24, 2000.

[xxi] See "Staff Report: Initial Statement of Reasons; Proposed Modifications To The Fleet Rule For Transit Agencies And New Requirements For Transit Fleet Vehicles," January 7, 2005. The final regulations are not yet available.

[xxii] "The Environmental Protection Agency says that, by the end of the year, it will propose significant changes to the way it estimates automobile fuel economy ratings. The agency has long been faulted for test methods, based on decades old driving habits, that in most cases overestimate the miles per gallon drivers can expect. A survey of 303 vehicles among those Consumers Union tested for model years 2000-2006 -- each driven 8,000 to 10,000 miles -- found that, in 90 percent of the cases, EPA mileage estimates were inflated, in some cases grossly so. Some Consumer Union tests showed vehicles falling 40 and 50 percent below EPA estimates in city fuel economy. The EPA is acting as consumer groups such as the American Automobile Association and Consumers Union are calling for such changes, and consumers, spurred by the latest surge in gasoline prices, are paying more attention to their fuel consumption. Since heavy-duty engines are not even tested in vehicles on chassis dynamometers – but rather outside a vehicle on engine dynamometers, the disconnect between emission certification levels and actual on-road emissions is even worse.

EPA said three changes will be at the core of its proposal:

- Altering testing to reflect today's more aggressive and high-speed driving habits, as well as addressing congestion in cities and expanding suburbs.
- Accounting for vehicles driven in cold climates, where fuel economy suffers.
- Calculating the impact of accessories, such as air conditioners, that cut fuel economy.

Vehicles tested for EPA ratings are tested not by the EPA, but by auto manufacturers using EPA standards. The firms submit their results to the agency, which duplicates the tests in 10 percent of cases to check for accuracy. The wheels of the test vehicles, which are usually optimized models, never turn on real pavement. The testing is done on dynamometers, calibrated to simulate real-life conditions. The EPA test is based on 30-year-old standards. The city test requires that a vehicle be run for 11 simulated miles with 23 stops, about 5 minutes of idle time, at an average speed of 21 miles per hour on the highway, a 10-mile drive, and the average speed is 48 miles per hour on a smooth road.

The tests do not account for extreme temperatures, the use of air conditioners, bad road conditions, or increased urban and suburban traffic jams -- all of which can reduce fuel efficiency. Further, today's drivers reduce their mileage by being far more aggressive in moving from intersections and passing each other on state roads, suburban roads, and at urban intersections." Quoted from NGVCommunications newsletter, November 25, 2005. Also see "EPA plans to overhaul tests to set more accurate mileage," USA Today, November 20, 2005.

[xxiii] Deere and Cummins Westport, op. cit.

[xxiv] Ibid.

[xxv] CARB, op. cit.; NREL, op. cit. Also, note the following: "With 2010 technology, natural gas vehicles are projected to have 16% lower CO2 emissions compared with gasoline vehicles and 13% lower CO2 emissions compared with diesel vehicles. The inherently lower greenhouse gas intensity of natural gas vehicles could be further exploited by optimized engine technology and new concepts for heavy-duty engines," Market Development Of Alternative Fuels: Report Of The Alternative Fuels Contact Group, European Union, December 2003.

[xxvi] "In addition to showing the emissions advantage of CNG buses, this project showed promising fuel economy results for the CNG buses compared with the diesel buses. The following fuel economy comparisons are made on a diesel gallon equivalent basis. The John Deere CNG buses exhibited a 9.0% fuel economy improvement compared with the MY 2004 DDC diesel buses and a 2.9% improvement compared with the MY 2000 DDC diesel buses." NREL, op. cit.

[xxvii] See for example "Fleets already concerned about '07 engine costs," Diesel Progress North America, April 2004.

[xxviii] Ibid.

[xxix] "Comparative Costs of 2010 Heavy-Duty Diesel and Natural Gas Technologies: Final Report," TIAX LLC, July 15, 2005.

[xxx] Ibid.

[xxxi] According to the latest U.S. EIA forecast (Annual Energy Outlook 2006 with Projections to 2030, December 12, 2005), the price of oil is expected to be in the $47 - $59 range for the period from 2005-2030. "In the reference case … the average world crude oil price continues to rise through 2006 and then declines to $46.90 per barrel in 2014 (2004 dollars) as new supplies enter the market. It then rises slowly to $54.08 per barrel in 2025 … about $21 per barrel higher than the price in *AEO2005* ($32.95 per barrel) … The prices in the *AEO2006* reference case reflect a shift in EIA's thinking about long-term trends in oil markets." Others are less sanguine about oil prices than EIA. According to a Reuters story reported in MSNBC On-line ("Goldman Sachs: Oil Prices to Stay High For Years'" December 18, 2005), Goldman Sachs Global Investment Research recently stated: "We disagree … that crude oil prices reached their peak levels earlier in 2005," said the firm's Global Investment Research. The story goes on to say that analysts said oil demand remained resilient and supply growth lackluster, prompting them to keep their average U.S. crude price forecast for next year unchanged at $68 a barrel. They predicted oil prices could see 1970s-style price surges to as high as $105 a barrel during this period. Other analysts are not as pessimistic.

[xxxii] J2343, the SAE recommended practice to ensure the safe design and operation of LNG-powered heavy-duty trucks now has the following requirement: "Vehicle LNG Tanks shall have a design hold time (build/pressure without relieving) of 5 days after being filled net full and at the highest point in the design filling temperature/pressure range."