NGVAMERICA
Natural Gas Vehicles for America

The Great Discontinuity: Why Historical Studies Are Not a Useful Guide in Making Current and Future Heavy-Duty Vehicle Purchase Decisions

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INTRODUCTION

Over the last decade, there have been many studies conducted that compare the emissions and cost of natural gas versus diesel vehicles. Some show diesel vehicles to be more cost effective, with emissions approaching the low levels of natural gas vehicles. Others show natural gas vehicles as continuing to have superior emissions *and* a cost advantage on a life cycle basis. Unfortunately, for one reason or another, the majority of these studies have been flawed. Some are "apples-to-oranges" studies, i.e., they compare current technology with one fuel with older technology with the other. Some others omit factors that are critical to a fair comparison. Still others use questionable methodology.

But even recent, credible studies are not very useful as a guide to heavy-duty fleet decision-makers when making current and future purchase decisions because federal government actions – both in terms of financial incentives and emission regulations – are changing both the technology, cost and emissions profile of heavy-duty engines. This paper provides an outline of the factors that have changed (and are changing) and their impact on emissions and cost.

NGVAmerica is the national trade association of the natural gas vehicle industry, and, consequently, is an advocate the use of natural gas vehicles. Because of that, some may question the objectivity of this paper. Therefore, fleet decision makers are urged to independently verify the facts and conclusions detailed in this paper.

DIESEL VS. NATURAL GAS EMISSIONS

Beginning in 2007, heavy-duty engine manufacturers are required by the U.S. Environmental Protection Agency (EPA) to significantly reduce emissions of their new engines. Nitrogen oxides (NOx) and volatile organic compounds (VOCs) must be cut by 50 percent (from 2.5 grams per brake horsepower hour [g/bhp-hr] to 1.2 g/bhp-hr) and particulate matter or soot (PM) by 90 percent (from 0.1 g/bhp-hr to 0.1 g/bhp-hr). In addition, beginning in 2010, heavy-duty engines must reduce their NOx emissions by another 80 percent to 0.2 g/bhp-hr.[i] To put this into perspective, before 1998, the allowable NOx+VOC emission level was 5.0 g/bhp-hr.

The Diesel Approach

Through the use of sophisticated technology (i.e., active particulate traps), all diesel engine manufacturers are expected to meet the 1.2/0.01 2007 standards. To permit these technologies to function, the formulation of diesel fuel has had to change, too. Beginning, in June of this year, EPA regulations require refiners to begin producing diesel fuel with a much lower sulfur content. Currently, the average sulfur content of on-road diesel fuel is 350 parts per million (ppm). Beginning in June, the producers must ensure that the diesel fuel delivered into vehicles has a sulfur content that doesn't exceed 15 ppm – referred to ultra-lower sulfur diesel (ULSD). Using higher sulfur-content diesel fuel could poison the catalysts, and void 2007 vehicles' warrantees.

Given the nature of diesel fuel, achieving the 2007 emission standards is a major technological achievement. Achieving the 2010 NOx standard will much more difficult still. No diesel engine manufacturer has announced how or if they will meet the 0.2 2010 standard

The Natural Gas Approach

Natural gas engine manufacturers have taken a different approach that will allow them to meet the 2010 emission standards in 2007. Diesel engines are lean-burn “compression ignition” engines. While, historically, there have been performance advantages to compression ignition engines, it is increasingly difficult 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.[ii] 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, two of the leading heavy-duty natural gas engine manufacturers, have already demonstrated and announced that they will be offering engines that meet the strict 2010 emission standards in model year 2007 using stoichiometric engines.[iii] 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.

NOx Emissions

Given the discussion above, the significant current NOx emission advantage of natural gas engines over diesel engines will grow substantially been 2007 and 2010. Diesel engines will be producing 1.2 g/bhp-hr while natural gas engines will be producing 0.2 g/bhp-hr – a six-to-one advantage.

What Happens After 2010?

Diesel advocates state that, after 2010, diesel engines and natural gas engines will have the same emissions. While 2010 is a number of years in the future, that assertion is probably incorrect. First, as discussed above, the very natural of natural gas permits the use of technology that is unavailable to diesel fuel. Improvements in natural gas engines are expected to continue, and, by 2010, natural gas engines may be cleaner than the 2010 standards.

Second, all the emissions numbers discussed above are “certification” numbers. In other words, these are the emissions that are produced during the engine certification process. Light-duty vehicles are certified on a “vehicle dynamometer” -- i.e., the vehicle/engine is tested as a unit using normal driving patterns. For a number of reasons, heavy-duty engines are certified on an “engine dynamometer” -- i.e., the engines are tested separate from the vehicles into which they will be placed. Recent studies have shown that, in-use, newer diesel engines produce far more emissions than the standards to which they are certified.[iv] Natural gas engines appear to produce emissions much closer to their certification numbers.

And, third, 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.[v] 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.[vi] 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.[vii] 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.[viii] As discussed above, the 2010 emission standards are quite stringent. 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 would be under severe pressure to relax and delay the 2010 standards. These engines, therefore, will not have the added technology cost of a 2010-compliant engine, but they will produce six times the NOx compared to the 2010 standard.

Greenhouse Gases

The full cycle emissions (well-to-wheels) 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.[ix] 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.[x] 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.[xi] For all these reasons, greenhouse gas emissions for heavy-duty natural gas vehicles will be approaching 80 percent of that for heavy-duty diesel vehicles.

DIESEL VS NATURAL GAS COSTS

In 2005, Congress passed two major pieces of legislation that include substantial incentives for the purchase and use of natural gas vehicles. Meanwhile, diesel engines that will meet the 2007 EPA emissions standards will cost more to buy, more to operate and more to maintain. The following is a detailed discussion of all these factors.

Fuel Cost: Highway Act Natural Gas Fuel 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.[xii] 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.[xiii] 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. 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.[xiv]

Fuel Cost: EIA Diesel and Natural Gas Price Forecast
According to the U.S. Energy Information Administration (EIA), natural gas has had, currently has, and will continue to have a significant price advantage over both gasoline and diesel fuel.[xv] According to EIA, in 2010, diesel fuel is forecast to cost 40 percent more than compressed natural gas.[xvi]

Fuel Cost: Ultra Low Sulfur Diesel
ULSD will cost more than higher sulfur diesel.[xvii] As discussed above, major petroleum refiners must ensure that the sulfur content of on-road diesel fuel *reaching users* is not more than 15 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.[xviii] 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."[xix] In other words, EIA believes the increase in cost for ULSD could be greater than 7.6 cents per gallon. 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. Depending on location and distance between refinery and end-user, fleet operators that have already started using ULSD are paying as much as 14 cents-16 cents more per gallon. In addition, while reduction of sulfur content is necessary to avoid fouling of the expensive exhaust after-treatment devices, it also reduces the fuel's lubricity. Additives are necessary to provide that lubricity. These fuel additives further increase the cost per gallon of diesel fuel at the rack.

Vehicle Purchase Cost: Energy Bill Incentives
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.[xx] That incentive is now in effect.[xxi] 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 transit buses or refuse trucks (i.e., vehicles over 26,000 lbs.), the credits can 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 municipalities), 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. As discussed above, Cummins

Westport and Deere both meet the tighter emission standards and will continue to meet the tighter standards through 2010. Therefore, heavy-duty natural gas vehicles will be eligible for a $32,000 purchase incentive.

Vehicle Purchase Cost: Increase in 2007 Vehicles

Diesel engines meeting the 2007 EPA emission standards will cost substantially more. 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.[xxii] At the 2006 American Public Transportation Association's Bus & Paratransit Conference, several transit agencies commented that they had already been quoted increases as much as $15,000 for 2007 buses. 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 0.2 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 another substance (urea). Until a technology path is selected, it is impossible to forecast a cost impact for 2010 diesel engines at this time. Meanwhile, as discussed above, 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.[xxiii] Since the 2007 engines will already meet the 2010 standards, there will be no increase in cost for natural gas vehicles in 2010.

Comparative Vehicle Fuel Economy

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 backpressure 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.[xxiv] As to the future, Cummins Westport 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."[xxv] Meanwhile, diesel engines that meet the 2007 standard are expected to suffer some additional efficiency loses. This especially will be true in duty-cycles 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% …"[xxvi] 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 …'"[xxvii] 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

When the 2007 engines are introduced, natural gas vehicles are expected to have a maintenance cost advantage over diesel engines. 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][xxviii] 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 30,000 miles per year -- will require replacement after 3-4 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.

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.[xxix] A second study (conducted by TIAX LLC) reaches a similar conclusion.[xxx] 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.[xxxi] EIA forecasts that petroleum will continue well above $31 per barrel through 2030.[xxxii]

CONCLUSIONS

With respect to cost and emissions performance of diesel and natural gas vehicles, during the 2006/2010 period, there will be a historic discontinuity with the past. During this period, the emission advantages of heavy-duty natural gas engines will continue, while the life-cycle costs of diesel vehicles will begin to exceed the costs of natural gas vehicles. Studies that compare emissions and cost performance of even relatively new (i.e., 2005) heavy-duty vehicles are not useful to fleet managers in making current and future vehicle purchase decisions. This paper is an attempted to detail the factors that fleet purchasers should take into account when weighing the relative benefits of natural gas versus diesel heavy-duty vehicles.

Endnotes

[i] Technically, beginning with model year 2007 engines, the EPA emission standards will be 0.2 gm/bhp-hr of NOx. However, EPA will permit a phase-in of the new NOx standard during model year 2007, 2008 and 2009. Diesel engine 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.

[ii] 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.

[iii] Ibid.

[iv] "Heavy-Duty Vehicle Chassis Dynamometer Testing for Emissions Inventory, Air Quality Modeling, Source Apportionment and Air Toxics Emissions Inventory," Project E-55/59; Phase 2 Final Report; Coordinating Research Council, et al., July 12, 2005

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

[vi] 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."

[vii] "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.

[viii] 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.

[ix] 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.

[x] "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.

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

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

[xiii] 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.

[xiv] 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 Joe Jobe, Executive Director, the National Biodiesel Board (January 21, 2006).

[xv] According to the latest U.S. EIA forecast (Annual Energy Outlook 2006 with Projections to 2030, December 12, 2005), "the average U.S. wellhead price for natural gas in the *AEO2006* reference case declines gradually from the current level as increased drilling brings on new supplies and new import sources become available. The average price falls to $4.46 per thousand cubic feet in 2016 (2004 dollars), then rises gradually to more than $5.40 per thousand cubic feet in 2025 (equivalent to about $10 per thousand cubic feet in nominal dollars) and more than $5.90 per thousand cubic feet in 2030." As to petroleum, EIA forecasts that 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.

[xvi] Ibid. Table A3. Energy Prices by Sector and Source.

[xvii] 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.

[xviii] 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.

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

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

[xxi] 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.

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

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

[xxiv] 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.

[xxv] “Advantages And Opportunities With Cummins Westport Natural Gas Engines,” CWI presentation, 2005 (from CWI website)

[xxvi] See “Fleets already concerned about '07 engine costs,” Diesel Progress North America, April 2004.

[xxvii] Ibid.

[xxviii] Ibid.

[xxix] Ibid.

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

[xxxi] Ibid.

[xxxii] EIA op. cit.