Compressed Natural Gas as a Fuel for Concrete Mixer Trucks: The Business Case

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Contractors have yet to define their role in the movement towards sustainability in the built environment. As they search, one thing is certain: proposed solutions must be based upon a sound business case. Transportation during the construction process has been identified as one area where the environmental impacts of construction may be reduced. Compressed natural gas is an alternative fuel that can be used in construction vehicles of all types, including concrete mixer trucks. The question is: will switching from diesel fuel to compressed natural gas save money while providing increased value during the construction process? This research examines the various costs and savings associated with such a transition. Results of the study indicate the costs are a function of numerous operational parameters, government policies, as well as the cost and availability of compressed natural gas. A general multi-variable financial model was developed to aid in the analysis. The model may be used by companies that wish to examine the financial impacts of including compressed natural gas fueled concrete mixer trucks in their fleet.

Key Words: sustainable construction, concrete mixer trucks, alternate fuels, financial analysis

Introduction

The mandate to implement sustainable practices in the built environment is clear. Significant activity is underway to improve the environmental performance of constructed facilities, particularly buildings. The effort to date has primarily focused on three strategies: 1) Improving the energy efficiency of the operational phase of buildings; 2) Recycling and reusing building materials; and 3) Minimizing material waste (Kibert 2007; Jensen and Kouba 2007). The research to date covering the environmental characteristics of the construction phase is sparse. The authors believe there are several reasons for this: first, there is an incorrect assumption in the environmental community that construction phase impacts are minor when compared to the operational phase of buildings; and second, there are substantial challenges associated with finding accurate data for analysis. The authors also believe that construction companies are anxious to incorporate sustainable practices into their operations, but the construction industry is fiercely competitive, and any process modification that increases environmental performance must also meet the financial test of increasing financial performance.

Transportation and related fuel consumption account for significant resource consumption and environmental impact in the US. For example, 71% of all petroleum (oil) used in the US is used in the transportation sector (US Department of Energy, 2011). National and local policy is quickly moving to either increase efficiency or promote alternative fuel, largely driven by two concerns:

1. A desire to reduce dependence in the US upon imported petroleum;

2. A focus upon global carbon emissions.

Transportation related to construction activity is a significant portion of total US transportation (Bilec, et. al. 2010; Palapanappian, et al. 2010). US transportation consumes over 13 million barrels of petroleum each day. Heavy trucks used in construction account for approximately 380,000 barrels each day, about 3% of total consumption (Davis, Diegel, & Boundy, 2010). Transportation is a significant component of the environmental impact of some construction operations (Palapanappian, et. al. 2010). For instance, in 2002, 77,000 concrete mixer trucks traveled 1.2 billion miles, averaging 15,600 miles per truck annually (US Census Bureau 2004). The National Ready Mix Concrete Association (NRMCA) in a benchmark study of its members reported that concrete mixer trucks average 3.4 miles per gallon of diesel fuel. Taken together, these data mean the average mixer truck traveling 15,600 miles annually consumes about 4600 gallons of diesel fuel producing a variety of emissions, most notably about 51 tons of carbon dioxide CO_2 (NRMCA, 2008).

Compressed natural gas is an alternative fuel that can be used in construction vehicles of all types, including concrete mixer trucks, to increase the environmental performance of the construction process. This paper examines the financial implications of switching the fuel for concrete mixer trucks from diesel to compressed natural gas, and examines the various costs and savings associated with such a transition.

Literature Review

Compressed natural gas (CNG) has recently garnered particular attention as an alternative fuel for the transportation sector. The National Renewable Energy Laboratory (NREL) has been conducting experiments and evaluation studies for over a decade on the potential for using CNG in heavy haul highway transport vehicles, and has developed a data-rich website concerning CNG as a vehicular fuel (US DOE, 2010a). There are substantial motivations to substitute CNG for diesel fuel and gasoline in the US:

1. Natural gas is plentiful and burns more cleanly than gasoline or diesel fuel;

2. Natural gas is generally less expensive;

3. Government incentives promote its use.

Proven US reserves of natural gas are estimated to be adequate for 90 years at current consumption rates. Even if natural gas were used to totally replace coal in generating electricity, domestic supplies would last for 50 years. (Rotman, 2009). The United States has a well-developed natural gas distribution system with about 300,000 miles of transmission pipelines and an additional 1.9 million miles of distribution pipelines capable of quick and economical distribution anywhere in the lower 48 states (US DOE, 2009).

Natural gas is a mixture of hydrocarbons, predominantly methane, extracted from gas and oil wells. It is non-toxic, non-corrosive, and non-carcinogenic. Natural gas accounts for approximately one quarter of the energy used in the US, with about one third going to buildings, one third to industrial uses, and one third to electricity production. Only three percent is used for transportation fuel (US DOE, 2011).

To be used as a vehicle fuel, it must first be either compressed or liquefied to allow adequate storage capacity on vehicles to obtain a reasonable driving range. Compressed natural gas (CNG) is stored at pressures up to 3,600 pounds per square inch (psi). CNG quantities are measured in terms of either gasoline gallon equivalents (GGE) or diesel gallon equivalents (DGE) with a GGE or DGE being the amount of CNG that contains the same amount of energy as a gallon of gasoline or diesel, respectively. A GGE equals about 5.7 pounds of CNG. Producing liquefied natural gas (LNG) involves purifying and condensing the natural gas into a liquid by cooling to -260° F. LNG is stored in double-wall, vacuum-insulated pressure vessels, and is typically used only with heavy-duty trucks. A GGE equals about 1.5 gallons of LNG (NIST 2011).

Natural gas has a high octane rating and works well in spark-ignited internal combustion engines, burning cleanly and producing few emissions. It substantially meets the new US Environmental Protection Agency (EPA) emission standards for on-road heavy truck engines that became effective January 1 of 2010 without significant engine modification, unlike diesel engines that required substantial new technology to meet requirements. CNG engines met the new standards with only minor exhaust treatment by adding passive three-way catalyst (TWC) exhaust after-treatment devices packaged as part of the muffler that are maintenance free. Cummins-Westport is the only US CNG engine manufacturer.

Several industries have already taken the step of using CNG to power their vehicle fleets. In the service delivery industry, UPS and Fed Ex have incorporated CNG trucks into their fleets. In the communication service industry

AT&T has switched a number of their service vehicles to CNG power. The public utilities sector of Waste Management has introduced CNG powered vehicles into their refuse truck fleets in cities such as New York; Seattle; El Paso, Texas; Norwich, Connecticut; Milwaukee, Wisconsin; Columbus, Ohio and many more. Universities and public school districts using CNG across America are also adopting CNG for their campus service vehicles and buses. Some campuses and school districts include the University of Oklahoma, the University of Illinois-Chicago, Tulsa Public Schools in Oklahoma, and Lower Marian School District in Pennsylvania. Even Disneyland has turned to CNG for its trams and service vehicles (U.S. Department of Energy, 2011). Several companies in the concrete industry have incorporated CNG concrete mixers into their fleets including Ferrara Bros. Building Materials Corporation in New York, Sandman Inc. in California, and Boral Limited in Australia (Ritossa, 2011).

Ideal operating characteristics for CNG are relatively short trips with significant amounts of stopping and starting, and daily periods of inactivity. Short trips allow for frequent refueling and frequent stopping and starting dramatically increases emissions from diesel engines but does not affect emissions from CNG engines. Concrete mixer trucks are ideal candidates, with average round-trip distance of about 25 miles and average daily driving distance of less than 80 miles (NRMCA 2008). Mixer trucks are normally parked at night.

Baseline Economic Considerations

The initial cost of a CNG fueled mixer truck is about $45,000 more than an equivalent diesel fueled truck. The additional cost is due to the cost of pressure fuel tanks, the higher cost of the natural gas engine, and a methane detection system. A typical system would include five - 15 gallon fuel tanks at a cost of about $20,000. The natural gas engine adds about $20,000, and a methane detection system adds an additional $5,000. This configuration allows an operating range of about 200 miles between refueling. The CNG truck weight will be about 800 pounds more than an equivalent diesel fueled truck, so there is some weight disadvantage.

Natural gas is readily available throughout the US, but CNG and LNG are not. Refueling station location and CNG flow rate at the station are critical concerns. Many CNG truck operators choose to construct a CNG compression and refueling station on their property near their maintenance yard, which requires a connection to a natural gas supply line, a CNG compressor, a CNG storage tank, and refueling connection equipment.

A typical CNG fuel station is made up of five components: compression, metering, drying, storage cylinders, and dispensing. The natural gas is compressed through three stages to 3600 psi. Gas is held in storage cylinders at each stage of compression for dispensing at a variety of pressures: Typically 2300 psi, 2900 psi, and 3600 psi. Drying is necessary to control the moisture level of the CNG to avoid operational problems in the CNG engines (Ritossa, 2011).

If operational characteristics allow, trucks can be refueled overnight by connecting to the refueling station at the end of the work-day, and disconnecting at the beginning of the next work-day. For instance, if an operator had 10 CNG trucks operating 80 miles per day each, at 3.4 miles per DGE, each truck would consume approximately 25 DGE of fuel per day. If five of the ten trucks were to be refueled every day and could be fueled overnight, allowing 6 hours for refueling would require a fuel flow rate of 45 DGE per hour. If the five trucks were to be refueled in only 1 hour, the required flow rate would be 250 DGE per hour. The 45 DGE per hour CNG station would cost approximately $500,000 to install. The 250 DGE station would be closer to $700,000.

The cost of alternative fuels varies widely across the US. In July 2011 the nationwide average price as reported in the Clean Cities Alternative Fuel Report for diesel fuel was $3.95 per gallon, with CNG being $2.07 per DGE (USDOE, 2010). These prices are for retail fuel, and only tell part of the story. A truck operator may construct their own CNG compression station and purchase natural gas from a public utility natural gas company. The price for natural gas for vehicle fuel from Southwest Gas in Arizona is $0.698 per therm (Southwest Gas, 2011). One therm is equal to 100 cubic feet under set pressure and temperature conditions and is also equal to 100,000 British Thermal Units (BTU) of heat energy. One DGE is equal to 1.35 therms, resulting in a natural gas purchase price of $0.95 per DGE prior to compression.

The federal government provides an incentive of $0.59 per DGE to promote the use of CNG as a motor fuel, paid directly to the fueling station operator. The fueling station operator is required to pay federal excise tax on motor fuel of $0.244 per DGE pumped. In this case, the net cost of fuel for an operator refueling their own trucks in

Arizona would be $0.95 for the natural gas from Southwest Gas, less $0.59 alternate fuel incentive, plus $0.244 federal excise tax on road fuel, for a total cost of $0.61 per DGE.

There is one more important federal incentive for purchase of natural gas fueled vehicles. In the waning hours of the 2010 Congress, a provision was enacted allowing companies to expense 100% of the cost of new natural gas fueled capital equipment placed in service in 2011, which reduces to 50% for 2012, on their tax returns for those years.

There are also state incentives for CNG fueled vehicles that vary by state. In Arizona, a state motor fuel tax of $0.26 per DGE is waived for CNG. Another incentive is a reduced vehicle license tax rate for trucks fueled by CNG. The first year license fee for a new $150,000 mixer truck in Arizona would be $4200. The first year license fee for a new CNG fueled $195,000 mixer truck would be $78 (Arizona Revised Statutes, 2005).

Economic Analysis

The number of variables involved in conducting an economic analysis forecloses the possibility of a closed form solution, but does lend itself to modeling and implementing a what-if scenario analysis technique. To facilitate the model, an excel spreadsheet was built using the variables shown in Table 1. These variables were included in the creation of four discounted cash flow (DCF) models that run for the expected service life of the vehicles. DCF modeling was chosen because it provides a method to compare uneven or varying incomes and expenses over time, and it is a widely accepted financial analysis tool. For this study, the outcome of the model is the net present value (NPV) of the cost of ownership of the vehicles, meaning that an investment with a lower NPV is less costly than one with a higher NPV. The models created include the leveraged and unleveraged cases and compare the results of purchasing and operating the same number of either diesel fueled or CNG fueled trucks, with the end result being the NPV of the expense and income streams for each of the cases. Table 2 presents the NPV values determined using the variable values shown in Table 1 except for the number of trucks purchased, which ranges from 1 to 20. As shown in Table 2, the advantage for the use of CNG fueled vehicles increases as the number of vehicles operated on CNG increases, and decreases with a smaller number of CNG operating trucks, a result of capitalizing the cost of an on-site refueling station.

Table 1

Variables included in DCF model

Number of Vehicles Purchased	10	Vehicles
Price of Diesel Vehicle	$150,000	$/Diesel Vehicle
Price of CNG Vehicle	$195,000	$/CNG Vehicle
Will you finance your vehicles?	Yes	Yes or No
Down Payment Amount	10%	Percentage
Annual Interest Rate	5%	Percentage
Term of Loan	5	Years
Expected Vehicle Life, years	12	Years
Expected Diesel Vehicle Salvage Value	$25,000	$/Diesel Vehicle
Expected CNG Vehicle Salvage Value	$10,000	$/Natural Gas Vehicle
Annual Miles per Vehicle	15,000	VMA
Price per Gallon: Diesel Fuel	$3.95	$/Gallon
Price per DGE for CNG Fuel	$0.61	$/DGE
CNG Federal Excise Tax Credit per DGE	$0.59	$ Credit/DGE
CNG State Road Tax Credit per DGE	$0.26	$ Credit/DGE
Additional Incentives Available	$4,000	$ Credit/Vehicle
Will you construct a refueling station?	Yes	Yes or No
Will you finance your refueling station?	Yes	Yes or No
Down Payment Amount	20%	Percentage of Total Cost
Annual Interest Rate	8%	Annual Interest Rate
Loan Term	10	Years
Hours Available for Refueling	6	Refueling Hours/Day
What rate of return do you expect on invested capital?	12%	Percentage ROI
Cost per kilowatt hour of electricity	$0.12	$/kwh
Annual Diesel Fuel Price Escalation	5%	Percentage
Annual CNG Fuel Price Escalation	2%	Percentage

Table 2

Net Present Value According to Fleet Size

Number of Vehicles	1	5	10	20
NPV Diesel, Unleveraged	$277,779	$1,388,895	$2,777,790	$5,555,580
NPV CNG, Unleveraged	$498,249	$1,291,244	$2,282,488	$4,264,976
NPV Diesel, Leveraged	$252,982	$1,264,910	$2,529,820	$5,059,641
NPV CNG, Leveraged	$422,010	$1,080,323	$1,903,214	$3,548,996

Notable in the variables list of Table 1 is the lack of vehicle maintenance expenses for either the diesel or the CNG fueled vehicles. Vehicle manufacturers indicate they anticipate maintenance costs to be similar. It is also important to note that these DCF models do not include state or federal income taxes.

Other scenarios presented herein relate to purchasing fuel from commercial refueling stations, and discontinuing government incentives. The results of these scenarios are presented in Table 3.

Table 3

Net Present Value Considering Fuel Sources, With and Without Government Incentives for 10 Vehicles

	With Incentives		Without Incentives	
CNG Fuel Source	Commercial	On-Site	Commercial	On-Site
NPV Diesel, Unleveraged	$2,777,790	$2,777,790	$2,777,790	$2,777,790
NPV CNG, Unleveraged	$2,348,141	$2,282,488	$3,122,128	$2,601,881
NPV Diesel, Leveraged	$2,529,820	$2,529,820	$2,529,820	$2,529,820
NPV CNG, Leveraged	$2,025,780	$1,903,214	$2,724,854	$2,279,521
Cost Assumptions: Diesel Fuel Price per Gallon = $3.95, CNG Price per DGE, Commercial Refueling = $2.07, CNG Price per DGE, On-Site Refueling = $0.61 Commercial Incentives Eliminated: State Road Tax Waiver, Other State Tax Waivers On-site Incentives Eliminated: Federal Excise Tax Rebate, State Road Tax Waiver, Other State Tax Waivers				

Many scenarios could be considered. The number of variables is large, and anyone considering a transition to CNG fuel must exercise careful due diligence to fully understand all of the financial implications.

Conclusions

This study has resulted in the development of a tool which can be used to consider the feasibility of operating concrete mixer trucks using CNG as a fuel rather than diesel fuel. The tool developed uses a discounted cash flow model to calculate the lifetime cost of ownership of equivalent diesel fueled and CNG fueled concrete mixer trucks. Twenty-six operating variables are included in the model. This study found that, in addition to the benefits associated with conforming to national policy, operators of concrete mixer trucks can save money on the cost of ownership and operation of concrete mixer trucks if the switch to CNG fuel.

There are also several roadblocks to the widespread adoption of CNG as a vehicle fuel. These include the paucity of CNG fueling stations in many areas of the country, and the limited availability of original equipment manufacturers (OEM) installing CNG engines in vehicles.

In spite of these roadblocks, there are solutions to all of these problems for concrete mixer trucks. Freightliner and Kenworth are both supplying OEM concrete mixer trucks with CNG engines manufactured by Cummins-Westport. The owners of CNG mixer trucks can band together and install CNG production facilities at a location convenient to their concrete batching locations, thereby virtually eliminating there fuel cost for their vehicles.

The DCF model shows that CNG fuel can reduce the cost of ownership of concrete mixer trucks. Variables having a large impact on financial feasibility include the cost of onsite fueling facilities, the number of CNG trucks in the fleet, the persistence of government incentives, and the escalation of fuel costs over time. The DCF model is available for download on the authors' website at http://construction.asu.edu/NSFPFI.

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