By Jim Castelaz, CEO & Founder and Shyam Nagrani, VP Marketing

Every 1000 EVs (15,000lb on a daily 100 mile route) on the road will save 5M gallons of diesel per year and reduce GHG emissions by over 52,000 tons of CO2e per year.

Alternate Fuels: Electric and Natural Gas will coexist

As natural gas prices come down to new, low levels, many investors question the competitiveness of any other alternative fuel, including electricity. In this paper we first analyze the economics of natural gas when compared to traditional gasoline/diesel and all-electric. Then, we discuss other important factors to fleets making purchase decisions – including price volatility, range, refueling infrastructure, technical risk factors, regulations and environmental issues.

Industry experts believe that natural gas and electric vehicles will coexist because they offer solutions for different vehicle applications. Natural gas is a good solution for long haul trucks, while electric is an excellent solution for local delivery vehicles and shuttle buses. Every natural gas vehicle on the road demonstrates one more fleet that is not satisfied with the diesel status quo, which builds the alternative fuels market to the benefit of all alternative fuels, including electricity. This paper outlines all of the above factors leading up to this conclusion.

Economics

According to the April 2012 report, compressed Natural Gas (CNG) had a U.S. national average price of $2.32 per DGE[1]. One DGE (Diesel Gallon Equivalent) is the amount of CNG required to equal the mileage from one gallon of diesel fuel. Electricity is $0.60 per DGE[2].

A CNG conversion is around a $30,000 upcharge[3]. An electric powertrain with the Motiv ePCS costs about $50,000 for batteries (at today's prices)[4] and $25,000 for the balance of the electric drive system, including Motiv's components. However, for an electric powertrain, the engine and transmission are not needed, netting a $15,000 gain from not buying these components. So, the total upcharge for an electric vehicle is $60,000. In the short term, federal and state government rebates reduce this upcharge. As battery prices drop, as they are projected to, this upcharge will be reduced.

A CNG vehicle still uses an engine and transmission consequently it does not demonstrate any maintenance savings versus a traditional diesel vehicle. Electric vehicles (EVs) have regenerative braking, reducing brake wear and increasing drive range. EVs have no transmissions and far fewer moving parts; only a motor and differential. Anecdotal reports show **EV maintenance costs to be 40 – 50% diesel vehicle costs.**

Figure 1 below shows the payback for diesel, a Motiv-equipped EV, and CNG.

---

[1] According to fueleconomy.gov and Clean Cities Alternative Fuel Price Report: http://www.afdc.energy.gov/afdc/pdfs/afpr_apr_12.pdf

[2] Calculated based on 6 MPG gasoline and 1 kWh/mi electricity – suitable for class 4-5 vehicle. $0.10/kWh electricity price. This may be lower for off-peak industrial charging.

[3] Wall Street Journal: http://online.wsj.com/article/SB10001424052702304707604577422192910235090.html

[4] DOE projections for today seem to be inline with price quotes Motiv has received at $500/kWh. They project $350/kWh by 2015: http://www.whitehouse.gov/files/documents/Battery-and-Electric-Vehicle-Report-FINAL.pdf

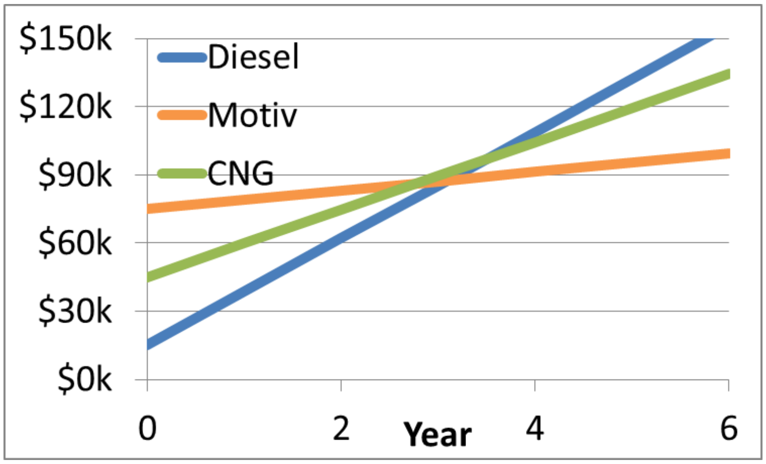

Figure 1 - Powertrain Lifetime Cost

The same results are presented in the following table, Table 1. Note this data assumes $3,500 in maintenance per year[5], which is reduced to $1,700 per year for electrics. It is cut in half because powertrain maintenance is significantly reduced due to fewer moving parts and less brake wear from regenerative braking[6]. Maintenance costs for CNG vehicles tend to be higher than for traditional vehicles, since none of the mechanical complexity of the engine or transmission is removed, and additional mechanical complexity is added in the fuel system. These projections assume that CNG maintenance can eventually come down to $4,500 per year for CNG vehicles. In both the Figure and Table, the cost is the total powertrain cost (not the total vehicle cost), which includes the initial powertrain purchase price and all fuel and maintenance expenses over the lifetime of the powertrain.

Table 1 - Powertrain Lifetime Cost by Year

Year	Diesel	Motiv	CNG
0	$15	$75	$45
1	$39	$79	$61
2	$62	$83	$77
3	$86	$87	$93
4	$109	$91	$109
5	$133	$96	$126
6	$156	$100	$142
7	$180	$104	$158
8	**$203**	**$108**	**$174**
9	$227	$112	$190
10	$250	$116	$206

$ in thousands

Over an 8 year lifetime, a diesel powertrain has a total lifetime cost of $203,000, a Motiv EV lifetime costs are $108,000, while CNG is $174,000. **A Motiv EV saves the operator $95,000 while CNG saves only $29,000. So a Motiv EV saves $66,000 versus a CNG vehicle over this same 8 year lifetime**. As most trucks have a 10 – 15 year life cycle, the savings can be even more dramatic. Engines in diesel and CNG vehicles will need to be re-built after 6 to 8 years. In an electric vehicle re-build, the only

[5] Based on data from Bauer's Transportation and their shuttle buses.

[6] Based on reports from all-electric transit buses by NREL running in Long Beach, available from Motiv.

component requiring replacement is the battery. However, most batteries project a lifetime of 3000 to 5000 cycles, which is well in excess of 8 years. In all-electric vehicle the batteries are only cycled once per day, or roughly 2400-2900 cycles in 8 years.

Other Factors

Price Volatility

Price volatility of CNG is twice that of gasoline or diesel[7]. This may be due to the under-developed CNG infrastructure in the U.S. There are 180,000 diesel fueling stations in the U.S. compared to about a 1,000 for CNG. While natural gas may be prevalent, a CNG vehicle requires an expensive fueling station to compress that natural gas. The capital expense of installing a CNG fueling station ($1M to $1.3M) limits the usable infrastructure. Electricity costs on the other hand are very stable, and infrastructure is available everywhere without expensive fueling stations being required.

Range

Natural gas can be put into vehicles as Compressed Natural Gas (CNG), or Liquefied Natural Gas (LNG). LNG is used in applications where a CNG-fueled vehicle (or an electric vehicle) does not have enough range, such as long-haul trucks driving 400 – 500 miles/day. LNG is significantly more expensive and less prevalent than CNG for the vehicle upfit and fuel. The same fuel report estimates LNG pricing at $3.05/DGE, based on a data set of 12 fueling stations.

The medium-duty trucks that Motiv is targeting will have enough daily driving range from either CNG or electricity, both of which are below the range of a diesel vehicle. These vehicles typically have no range anxiety since they go on planned routes and are charged or fueled overnight at the depots where they are parked. Thus, from a range perspective, CNG and electricity are both acceptable. However, CNG range may be problematic if the vehicle must drive some distance to the refueling station, as most fleets cannot afford to install their own. For electricity, charging can always be done at the vehicle depot.

Refueling Infrastructure

The medium-duty trucks that Motiv targets will not need significant refueling infrastructure for electricity. These vehicles already are stored in commercial or industrial buildings that typically have 480VAC 3 phase power. With the Motiv ePCS, the fleet will only have to install a minimal plug set, which any electrician can do in under an hour.

A CNG refueling station at the vehicle's depot is can cost $1M to $1.3M[8]. The cost driver is the large machinery, such as compressors, required to get the pressures necessary for refueling (typically 3600 psi).

Technical Risk Factors

Once a fleet decides to look at alternative fuel, they face the introduction of a new technology. CNG and electric drive vehicles both include technical risks. CNG provides marginal lifetime cost savings in relation to the new level of technical risk. Electricity, through the Motiv electric Powertrain Control System (ePCS), provides much more significant lifetime savings. Taking the example of Table 1, CNG

---

[7] According to fueleconomy.gov and Clean Cities Alternative Fuel Price Report: http://www.afdc.energy.gov/afdc/pdfs/afpr_apr_12.pdf. See standard deviation in prices, pg 5-6.

[8] Estimate given by George Survant, Fleet Manager of Time Warner Cable, at HTUF 2012 presentation, Charlotte, NC

savings over diesel over an 8 year period for a class 5 truck are about $29,000 while the similar savings for an electric truck are $95,000.

Regulations and Certifications

CNG vehicles modify an engine which must be recertified with the California Air Resources Board (CARB). This is a long and expensive process. EVs require registration, but since they have zero emissions, the certification process is quite minimal as there is no engine to certify.

Emissions

EVs have zero tailpipe air pollution emissions, including NO_x and particulate matter (PM). CNG has carbon monoxide (CO) emissions lower than gasoline, and about equivalent with diesel[9]. Its NO_x and non-methane hydrocarbon emissions vary greatly depending on conversion[10], but it has higher methane emissions, since methane is the major constituent of natural gas. Methane is a major contributor to greenhouse gas (GHG)-related global warming. Because methane emissions offset much of the GHG combustion savings, **CNG emits only 6-11% lower lifecycle GHG emissions than gasoline**[11].

EVs GHG emissions vary depending on the electricity grid. In California, their **GHG wells-to-wheel emissions are 80% less than diesel equivalent**, down from 2.2 kg CO_2e/mi for diesel to 0.45 kg CO_2e/mi for electricity[12].

Conclusion – CNG and Electricity as Complementary technologies

As advanced medium and heavy vehicle technologies continue to develop, there will be a role for both electricity and natural gas. LNG may become a compelling fuel for long-haul trucks. However, for local, medium-duty trucks that drive planned routes about 100 miles/day, the compelling economics and intangibles around electricity make it a better fit for this segment. The Motiv ePCS eases this transition into electricity by providing forward compatibility with emerging battery technology and allowing them to use off-the-shelf, easily-available, warranted battery packs.

Experienced fleet managers expect to use both EVs and natural gas powered vehicles, EVs for local routes and LNG for long haul. These 2 technologies will co-exist in the foreseeable future as they provide different advantages and complement each other.

As fleets move into alternative fuels and away from traditional diesel, they will become more educated about the different options available to them. Fleets who first try CNG or LNG may be more open to adopting electric vehicles once they prove that their fleet can indeed show positive economics with alternative fuels. The momentous shift that is underway is moving vehicles away from dependence on foreign, high-carbon fuels and towards alternative fuels like natural gas and electricity.

These complementary fuels – electric and natural gas will co-exist and are together growing the alternative fuels market segment, to the benefit of both.

---

[9] http://www.air-quality.org.uk/26.php

[10] Bhandari et. al. "Performance and Emissions of Natural Gas Fueled Engine" J. Sci. Ind. Res 64 May 2005, http://nopr.niscair.res.in/bitstream/123456789/5150/1/JSIR%2064(5)%20333-338.pdf

[11] Argonne National Lab's GREET model, cited by U.S. DOE http://www.afdc.energy.gov/vehicles/natural_gas_emissions.html

[12] Based on CA GREET model