MPG, Cost, and GHG Results for Alternative Fuel Vehicles in 2011

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ABSTRACT

Converting commercial vehicles to alternative energy is important to achieving sustainable transportation. School buses, delivery trucks, utility vans, street sweepers, snow plows, street pavers, bucket trucks, paratransit vans, and shared cars all contribute to greenhouse gas emissions but may be owned and operated by a mix of public and private entities. Converting these vehicles to alternative energy sources and making alternative fueling infrastructure available requires community engagement with a variety of stakeholders among which public and private fleet managers are particularly important. However, with the choice of different technology options, such as CNG, hybrid, LPG, electric, plus the range of vehicle types and uses, it can be hard for community stakeholders and decision makers to identify the most appropriate solution. This paper brings clarity to these issues by presenting data collected from over 300 alternative fuel vehicles and over 80 alternative fueling stations deployed over the last two years by over 30 organizations in New York State using a wide variety of commercial vehicle types and technologies. Actual fuel economy, incremental vehicle purchase cost, fueling station purchase cost, greenhouse gas reductions, and fuel cost savings data clarifies the real word performance of alternative fuel vehicles and alternative fuel stations so as to inform decisions and drive the adoption of sustainable transportation.

Introduction

Alternative fuel vehicles provide fleet operators novel opportunities to conserve fuel costs and reduce greenhouse gas emissions. The range of available technology includes compressed natural gas, hybrid electric, plug in hybrid electric, electric, and propane. However, fleet operators may be unfamiliar with the performance and costs associated with these vehicles. Moreover, vehicle and fuel dealers may exaggerate claims about the cost of ownership or payback periods of these vehicles. This information gap forms a barrier to adoption and makes it more difficult for fleet operators to select the most suitable technology. To bridge this gap, this paper presents data collected from 332 alternative fuel vehicles and 84 alternative fuel stations that were purchased in 2010 and 2011 in New York State. Fleet operators will be able to use this data to understand the expected fuel economy, expected incremental vehicle purchase cost, expected fueling station purchase cost, expected fuel cost savings, and expected greenhouse gas reductions of alternative fuel vehicles over a conventional fuel vehicle.

Background

The alternative fuel vehicles and alternative fuel stations analyzed were purchased with grant funding under New York State Energy Research and Development Authority's (NYSERDA) administration of the Department of Energy's (DOE) Clean Cities FY09 Petroleum Reduction Technologies Projects for the Transportation Sector funded by the American

Recovery and Reinvestment Act (ARRA). Clean Cities is the DOE's flagship alternative-transportation deployment initiative, sponsored by the Vehicle Technologies Program. Clean Cities advances the nation's economic, environmental, and energy security by supporting local actions to reduce petroleum consumption in transportation through the efforts of more than 8,400 stakeholders participating in nearly 100 Clean Cities coalitions across the United States. This grant funded up to 100% of the incremental costs of vehicles (the cost above a comparable vehicle that uses conventional fuel) and up to 50% of the cost to purchase and install fueling stations. Grant recipients included local governments, schools, utilities, and private companies in New York State. Grant recipients were free to propose the alternative energy technology and vehicle type that best satisfied their fleet's needs. DOE selected NYSERDA's proposal as one of 25 projects nationwide.

Methodology

Project partners chose vehicles that use five different alternative fuels or advanced technologies: 215 compressed natural gas (CNG) vehicles, 61 hybrid electric vehicles (HEV), 3 plug in hybrid electric vehicles (PHEV), 8 electric vehicles (EV), and 45 propane (LPG) vehicles.[1] For the fueling stations, electric fueling stations comprised 79 of the stations, CNG comprised three, and LPG two. This uneven distribution means that the sample size for some of the results presented here can be quite small.

The grant recipients agreed to provide quarterly mileage and fuel use data for each vehicle purchased or converted under the grant. For this analysis, the same quarter's worth of data for each vehicle was used in order to avoid seasonal fluctuations in performance. Comparing one vehicle's summer performance when operating its air conditioner with another vehicle's fall performance when little or no air conditioning was needed could have been misleading. The quarter selected was the period of October to December 2011.[2] This was the most recent quarter for which data was available at the time of this analysis and, because the deployment of vehicles was staggered over 2010 and 2011, was the quarter for which the greatest number of grant recipients reported data on vehicle usage. Vehicle performance in the fall quarter would have been less influenced by heating and cooling demands than the summer or winter quarter. However, it is beyond the scope of this paper to draw conclusions about the performance of alternative fuel vehicles in different climate zones. Grant recipients were also asked to respond to a survey about their vehicles and provide miles per gallon data on a comparison vehicle and a summary of their actual fuel prices.

Fuel Economy

The business case for purchasing an alternative fuel vehicle rests heavily on the incremental cost of the alternative fuel vehicle, the price of fuel, and the vehicle's fuel economy. Of these three factors, the incremental cost and price of fuel can be reliably determined from local fuel suppliers and vehicle dealers. But the real world fuel economy of the alternative fuel vehicles can be difficult to determine. While the U.S. Environmental Protection Agency

[1] An explanation of these technologies can be found at the DOE website: http://www.afdc.energy.gov/afdc/vehicles

[2] The exception to this is the data for the neighborhood electric vehicles, where cumulative data since vehicle deployment was used because of the high variability between the miles per kWh data for these vehicles over these three months.

publishes fuel economy data for light duty vehicles, it currently does not publish similar data for medium- or heavy-duty vehicles or fuel conversion kits. Fuel economy is also a key factor in the greenhouse gas reduction potential of alternative fuel vehicles.

Table 1 shows the fuel economy of the alternative fuel vehicles funded by this grant calculated using the October through December 2011 mileage and fuel use data self-reported by the grant recipients. The sample size for each type of vehicle is listed so as to acknowledge that some averages may represent data from only a few or even one vehicle. However, the fuel economy numbers presented in this table cannot be directly compared across fuels. For example, the result that LPG van averaged 16 miles/gallon of LPG and the CNG vans averaged 8.5 miles/GGE[3] of CNG does not mean that the LPG vehicle has better fuel economy than the CNG vehicles. The LPG van may use 6 gallons of LPG to travel 100 miles and the CNG vans may use 12 GGE of CNG to travel 100 miles, but this does not indicate whether using 6 gallons of LPG emits more or less greenhouse gas or cost more or less than using 12 GGE of CNG. Without further calculation, Table 1 does not allow fleet operators to judge the different alternative fuel options against each other or against a fleet operator's current fleet of conventional diesel or gasoline vehicles. The exception to this is HEV vehicles, because HEV use the same fuel as conventional vehicles, diesel or gasoline, so fleet operators need only know their current fleet's fuel economy to judge the results for the HEV vehicles.

In order to compare fuels, the fuel economy averages must be converted into the same unit of measure, such as fuel cost per mile driven. The price per gallon of LPG divided by the miles per gallon of LPG yields the cost/mile using LPG. Doing a similar calculation for CNG yields the fuel cost per mile using CNG, allowing these data points for the LPG van and CNG vans to be compared. Fleet operators can determine the fuel cost per mile of their current conventional fuel fleet to compare the fuel cost per mile calculated for the alternate fuel vehicles presented in Table 1. The cost of the alternative fuel can be found by researching local suppliers or by consulting price reports from governmental sources such as the DOE's Alternative Fuels & Advanced Vehicles Data Center Alternative Fuel Price Report. Table 1 presents the results from the vehicles funded under this grant in terms of fuel economy instead of fuel cost per mile because of the variability of fuel prices. Fuel prices vary by state, between cities, and over time. Presenting this data in terms of fuel economy allows fleet operators to apply the fuel prices that are relevant for their fleet and calculate a relevant price per mile for these alternate fuel vehicles.

Table 1. Fuel Economy of Vehicles by Technology

Type	Technology	Units	Average Fuel Economy	Sample Size
bucket truck	HEV	Miles/Gal of Diesel	4.9	9
	CNG	Miles/GGE of CNG	3.9	10
heavy duty truck	HEV	Miles/Gal of Diesel	4.6	25
log loader	HEV	Miles/Gal of Diesel	0.2	1
neighborhood electric vehicles	EV	Miles/kWh	6.1	6
	CNG	Miles/GGE of CNG	6.4	1
passenger bus	HEV	Miles/Gal of Diesel	8.1	8
	HEV	Miles/Gal of Gasoline	15.6	1
pickup truck	LPG	Miles/Gal of LPG	8.5	4
	CNG	Miles/GGE of CNG	0.4	1
sanitation packer truck	HEV	Miles/Gal of Diesel	2.3	1
	HEV	Miles/Gal of Diesel	8.4	2
	HEV	Miles/Gal of Gasoline	7.4	2
school bus	LPG	Miles/Gal of LPG	4.1	40

[3]GGE is the abbreviation for gasoline gallon equivalents.

Type	Technology	Units	Average Fuel Economy	Sample Size
	PHEV[4]	Miles/Gal of Diesel	8.8	3
	CNG	Miles/GGE of CNG	24.0	2
sedan	HEV	Miles/Gal of Gasoline	37.7	5
street sweeper	CNG	Miles/GGE of CNG	0.2	2
SUV	HEV	Miles/Gal of Gasoline	33.0	6
	CNG	Miles/GGE of CNG	8.5	195
	EV	Miles/kWh	2.8	2
van	LPG	Miles/Gal of LPG	16.0	1
	CNG	Miles/GGE of CNG	7.0	4
medium duty truck	HEV	Miles/Gal of Diesel	8.5	1

Approximate Fuel Cost per Mile

Nationwide average fuel prices can be used to calculate an approximate fuel cost per mile, providing a more assessable, but less accurate, set of performance results for the alternative fuel vehicles funded under this grant. These prices do not reflect the actual prices faced by the fleets featured in this study, which may have led to different decisions about which alternative fuel to choose than might be indicated by national prices. Included in Table 2 are the nationwide average fuel prices for gasoline, diesel, CNG, LPG, and electricity.[5] However, it is important to emphasize that fuel prices vary geographically. For example, in January 2012 the price per GGE of CNG ranged from $1.69 in the lower Atlantic region to $2.42 in New England (DOE, 2012c).[6] Furthermore, over time the prices of gasoline, diesel, CNG, propane, and electricity change and the price advantage one fuel may offer today may not last over the service life of the vehicle. In addition, these average prices do not reflect the Federal and State incentives and laws that may confer favorable tax treatment for fuel. The DOE's Alternative Fuels & Advanced Vehicles Data Center, Federal & State Incentives & Laws, provides an online searchable database on incentives and laws pertaining to alternate fuels.

The approximate fuel cost per mile of the 332 alternative fuel vehicles can be calculated using the nationwide average fuel prices and the fuel economy figures presented in Table 1. Table 2 shows the approximate fuel cost per mile broken out by vehicle type and technology. Electric vehicles achieved the least expensive fuel cost per mile, as can be seen by comparing the neighborhood electric vehicles and electric vans with vans and sedans that use a fossil fuel. School buses serve as a useful point of comparison because four types of alternative fuel school buses were purchased under this grant, PHEV, diesel HEV, gasoline HEV, and LPG. The PHEV and both types of HEV school buses achieved between 44 and 46 cents per mile, whereas the LPG school buses averaged 75 cents per mile. Although this would appear to reflect poorly on LPG technology, this result depends on the price of LPG used to convert miles per gallon of LPG to fuel cost per mile. For example, a school district which deployed 6 of the LPG school buses reported that its actual price per gallon of LPG was $1.97, considerably less than the nationwide average fuel price of $3.08. Part of the reason it was able to realize this low price was that it

[4] Grant recipients only reported the gallons of diesel used by the PHEV and did not report kWh.
[5] Prices of gasoline, diesel, CNG, and LPG are based on data collected between January 13, 2012, and January 27, 2012, as reported by the DOE Clean Cities Alternative Fuel Price Report January 2012. Price of Electricity is based on the 2011 nationwide average retail price for the commercial sector as reported by the EIA, Electric Power Monthly February 2012.
[6] The lower Atlantic region includes West Virginia, Virginia, North Carolina, South Carolina, Georgia, and Florida. The average fuel price per GGE of CNG for the Central Atlantic region which includes NY was $2.28 (DOE, 2012c).

could take advantage of the Alternative Fuel Excise Tax Credit of $0.50 per gallon of LPG.[7] The school district achieved a fuel cost per mile for their propane school buses of 50 cents per mile, which is only several cents higher than the fuel cost per mile calculated using the nationwide average fuel price for the PHEV and HEV school buses. An even more dramatic example of how organizations are able to achieve lower fuel prices is a utility company whose cost per GGE of CNG was $0.66, a signification amount below the nationwide average of $2.13 per GGE of CNG. Because of the variation in fuel prices between organizations as well as across geography and time, Table 2 should be used as a rough guide only to the estimated fuel cost per mile of alternative fuel vehicles. Fleets considering alternative fuel vehicles should conduct similar calculations based on local prices.

Table 2. Approximate Fuel Cost per Mile using Nationwide Average Fuel Prices

Type	Technology	Fuel	Nationwide Average Fuel Prices[8]	Cost/mile	Sample size
neighborhood electric vehicle	EV	kWh	$0.1032	$0.02	6
van	EV	kWh	$0.1032	$0.04	2
sedan	CNG	GGE of CNG	$2.13	$0.09	2
sedan	HEV	Gal of Gasoline	$3.37	$0.09	5
SUV	HEV	Gal of Gasoline	$3.37	$0.10	6
van	LPG	Gal of LPG	$3.08	$0.19	1
pickup truck	HEV	Gal of Gasoline	$3.37	$0.22	1
van	CNG	GGE of CNG	$2.13	$0.25	195
medium duty truck	CNG	GGE of CNG	$2.13	$0.30	4
passenger bus	CNG	GGE of CNG	$2.13	$0.33	1
pickup truck	LPG	Gal of LPG	$3.08	$0.36	4
school bus	PHEV[9]	Gal of Diesel	$3.86	$0.44	3
medium duty truck	HEV	Gal of Diesel	$3.86	$0.45	1
school bus	HEV	Gal of Gasoline	$3.37	$0.45	2
school bus	HEV	Gal of Diesel	$3.86	$0.46	2
passenger bus	HEV	Gal of Diesel	$3.86	$0.47	8
heavy duty truck	CNG	GGE of CNG	$2.13	$0.55	10
school bus	LPG	Gal of LPG	$3.08	$0.75	40
bucket truck	HEV	Gal of Diesel	$3.86	$0.78	9
heavy duty truck	HEV	Gal of Diesel	$3.86	$0.84	25
sanitation packer truck	HEV	Gal of Diesel	$3.86	$1.66	1
sanitation packer truck	CNG	GGE of CNG	$2.13	$5.67	1
street sweeper	CNG	GGE of CNG	$2.13	$8.55	2
log loader	HEV	Gal of Diesel	$3.86	$18.22	1

Estimated Annual Fuel Savings

In addition to the caveat that fleet operators should recalculate the above data using local fuel prices before making decisions about their own fleets, the average fuel economy realized by grant recipients may not be relevant to a fleet operator with a different set of operating parameters. A utility van driving in the New York City area will experience a different mix of

[7] The Alternative Fuel Excise Tax Credit expired on 12/31/2011 (DOE, 2012d)

[8] Prices of gasoline, diesel, CNG, and LPG are based on data collected between January 13, 2012, and January 27, 2012, as reported by the DOE Clean Cities Alternative Fuel Price Report January 2012. Price of electricity is based on the 2011 nationwide average retail price for the commercial sector as reported by the EIA, Electric Power Monthly February 2012.

[9] Grant recipients only reported the gallons of diesel used by the PHEV and did not report kWh.

city and highway driving than would a fleet operator located in a less densely populated area of the state. While it was impractical to ask grant recipients to track the vehicles' driving mix between city and highway driving, grant recipients were asked to provide data on a conventionally fueled vehicle that was operated in a similar manner to their alternative fuel vehicles. For example, a school that deployed a LPG school bus was asked to provide mileage and fuel use data on a comparable diesel school bus. The grant recipient was allowed to decide which conventional fuel vehicle to supply data on because the grant recipient is in the best position to determine which has the most comparable routing, loading, upfits or other use parameters that could affect fuel economy.

Providing data from a conventionally fueled comparison vehicle was optional, and responses were received from 18 of the 33 grant recipients. However, because the larger fleets did respond, comparison data is available for 74% of the vehicles. Table 3 lists the fuel economy of the alternative fuel vehicles and the fuel economy of the comparison vehicle provided by the grant recipients. The fuel economy of the HEV vehicles can be directly compared with the fuel economy of the conventionally fueled vehicles because both vehicles use the same fuel. Three of the HEV fleets achieved a fuel economy improvement of more than 50%. Two of the HEV fleets achieved fuel economy improvements of less than 15%. The other two HEV fleets show decreases in fuel economy. This should not necessarily be taken to mean that hybrid technology caused a decrease in fuel economy. There may have been other factors that affect fuel economy, such as driving style and routes driven, that could have influenced fuel economy enough to overshadow the benefit of hybrid technology. Although it is beyond the scope of this analysis to identify the particular factors that allowed some fleets to make effective use of HEV technology where others failed to do so, it does point to the conclusion that other factors besides technology influence fuel economy. These factors include driver behavior, maintenance, geography, and climate. Table 3 also uses the nationwide average fuel prices presented in Table 2 to estimate the cost per mile and the annual cost savings between the alternative fuel vehicle and the conventional fuel comparison vehicle. This is done to facilitate comparison of the result of switching fuel.

Table 3 uses nationwide average fuel prices to calculate annual fuel cost savings instead of using actual fuel prices from the grant recipients because the purpose of this analysis is to evaluate the performance of alternative fuel vehicles, not to evaluate the effect of local fuel prices or particular Federal or State level financial incentives for fuel. Table 3 shows that none of the LPG school bus fleets studied showed fuel cost savings when using nationwide average fuel prices. However, when fuel costs are recalculated using the grant recipients' actual fuel prices, two of the LPG school bus fleets show cost savings compared to diesel buses and the other two show much smaller losses. This highlights the impact that local fuel prices can have on the success of alternate fuel vehicles. Table 4 shows the cost per mile and annual fuel cost savings for the fleets that reported actual prices. While the actual fuel prices shown in Table 4 may have less relevance for fleet managers trying to make a purchase decision with their own local prices, the cost per mile data in Table 4 can be used as proof of concept, showing that alternative fuel vehicles can reduce fuel cost not just in theory but also in practice.

Table 3. Fuel Cost Savings by Fleet – Average Fuel Prices

Fleet	Savings (Loss) per vehicle	Sample Size	Fuel	Av. Fuel price	MPG	Cost/ Mile	Miles/ Year
CNG sedans	$947	2	CNG (GGE)	$2.13	24.0	$0.09	8,108
			comp - gasoline	$3.37	16.4	$0.21	8,108
CNG heavy duty trucks	$1,072	10	CNG (GGE)	$2.13	3.9	$0.55	5,468
			comp - diesel	$3.86	5.2	$0.74	5,468
CNG Vans	$459	16	CNG (GGE)	$2.13	11.1	$0.19	5,217
			comp - gasoline	$3.37	12.1	$0.28	5,217
CNG Vans	$522	161	CNG (GGE)	$2.13	7.6	$0.28	4,643
			comp - gasoline	$3.37	8.6	$0.39	4,643
neighborhood elec vehicles	$664	6	EV (kWh)	$0.10	6.1	$0.02	1,943
			comp - gasoline	$3.37	9.4	$0.36	1,943
HEV diesel bucket trucks	($191)	8	HEV Diesel	$3.86	4.8	$0.81	7,713
			comp - diesel	$3.86	4.9	$0.79	7,713
HEV diesel heavy duty truck	$615	1	HEV Diesel	$3.86	3.9	$0.98	5,064
			comp - diesel	$3.86	3.5	$1.11	5,064
HEV diesel school bus	($145)	1	HEV Diesel	$3.86	7.3	$0.53	10,760
			comp - diesel	$3.86	7.5	$0.52	10,760
HEV diesel heavy duty truck	$1,619	1	HEV Diesel	$3.86	10.0	$0.38	10,744
			comp - diesel	$3.86	7.2	$0.54	10,744
HEV diesel passenger buses	$5,375	5	HEV Diesel	$3.86	8.1	$0.48	18,323
			comp - diesel	$3.86	5.0	$0.77	18,323
HEV diesel school bus	$2,751	1	HEV Diesel	$3.86	9.6	$0.40	12,880
			comp - diesel	$3.86	6.3	$0.62	12,880
HEV gas school buses	$326	2	HEV Gasoline	$3.37	7.4	$0.45	21,240
			comp - gasoline	$3.37	7.2	$0.47	21,240
HEV gas sedans	$297	3	HEV Gasoline	$3.37	41.7	$0.08	4,871
			comp - gasoline	$3.37	23.8	$0.14	4,871
LPG school buses	($3,414)	6	LPG	$3.08	4.0	$0.76	16,863
			comp - diesel	$3.86	6.9	$0.56	16,863
LPG school buses	($2,017)	6	LPG	$3.08	3.9	$0.79	14,947
			comp - diesel	$3.86	5.9	$0.65	14,947
LPG school buses	($1,118)	8	LPG	$3.08	4.1	$0.74	12,665
			comp - diesel	$3.86	5.9	$0.65	12,665
LPG school buses	($3,922)	4	LPG	$3.08	3.7	$0.82	14,051
			comp - diesel	$3.86	7.1	$0.54	14,051
LPG pickup trucks	($890)	3	LPG	$3.08	7.4	$0.42	10,828
			comp - gasoline	$3.37	10.1	$0.34	10,828
PHEV diesel school bus[10]	$5,156	1	PHEV Diesel	$3.86	10.0	$0.39	14,692
			comp - diesel	$3.86	5.2	$0.74	14,692
PHEV diesel school buses[11]	$304	2	PHEV Diesel	$3.86	8.1	$0.47	12,870
			comp - diesel	$3.86	7.8	$0.50	12,870

[10] Table 3 underestimates the fuel cost per mile of PHEV vehicles because grant recipients did not report the amount of electricity consumed by PHEV vehicles only the amount of diesel consumed.
[11] *ibid*

Table 4. Fuel Cost Savings by Fleet – Actual Fuel Prices

Fleet	Savings (Loss) per vehicle	Sample Size	Fuel	Fuel Price	MPG	Cost/Mile	Miles/Year
CNG heavy duty trucks	$3,733	10	CNG (GGE)	$0.66	3.9	$0.17	5,468
			comp - diesel	$4.43	5.2	$0.85	5,468
CNG vans	$1,264	16	CNG (GGE)	$0.66	11.1	$0.06	5,217
			comp - gasoline	$3.64	12.1	$0.30	5,217
CNG vans	$433	161	CNG (GGE)	$2.56	7.6	$0.34	4,643
			comp - gasoline	$3.69	8.6	$0.43	4,643
HEV diesel bucket trucks	($198)	8	HEV Diesel	$4.00	4.8	$0.84	7,713
			comp - diesel	$4.00	4.9	$0.82	7,713
HEV diesel school bus	($121)	1	HEV Diesel	$3.21	7.3	$0.44	10,760
			comp - diesel	$3.21	7.5	$0.43	10,760
HEV diesel heavy duty truck	$1,350	1	HEV Diesel	$3.22	10.0	$0.32	10,744
			comp - diesel	$3.22	7.2	$0.45	10,744
HEV diesel passenger buses	$5,152	5	HEV Diesel	$3.70	8.1	$0.46	18,323
			comp - diesel	$3.70	5	$0.74	18,323
HEV diesel school bus	$2,224	1	HEV Diesel	$3.12	9.6	$0.33	12,880
			comp - diesel	$3.12	6.3	$0.50	12,880
HEV gas school buses	$272	2	HEV Gasoline	$2.81	7.4	$0.38	21,240
			comp - gasoline	$2.81	7.2	$0.39	21,240
HEV gas sedans	$259	3	HEV Gasoline	$2.94	41.7	$0.07	4,871
			comp - gasoline	$2.94	23.8	$0.12	4,871
LPG school buses	($207)	6	LPG	$1.92	4.0	$0.47	16,863
			comp - diesel	$3.18	6.9	$0.46	16,863
LPG school buses	$1,170	6	LPG	$1.97	3.9	$0.50	14,947
			comp - diesel	$3.44	5.9	$0.58	14,947
LPG school buses	$1,817	8	LPG	$1.50	4.1	$0.36	12,665
			comp - diesel	$2.98	5.9	$0.51	12,665
LPG school buses	($587)	4	LPG	$1.86	3.7	$0.50	14,051
			comp - diesel	$3.23	7.1	$0.46	14,051
LPG pickup trucks	$234	3	LPG	$1.87	7.4	$0.25	10,828
			comp - gasoline	$2.76	10.1	$0.27	10,828
PHEV diesel school bus[12]	$4,486	1	PHEV Diesel	$3.36	10.0	$0.34	14,692
			comp - diesel	$3.36	5.2	$0.64	14,692
PHEV diesel school buses[13]	$247	2	PHEV Diesel	$3.15	8.1	$0.39	12,870
			comp - diesel	$3.15	7.8	$0.41	12,870

Estimated Greenhouse Gas Emissions

Reducing greenhouse gas emissions is an important reason why many fleets adopt alternative fuel vehicles. Using the fuel economy results for each fleet and the greenhouse gas intensity of each fuel type provided by the DOE Argonne National Laboratory GREET Fleet Footprint Calculator, Table 5 shows the well-to-wheels greenhouse gas emissions of each fleet. Table 5 also shows the GHG emissions for the fleets' comparison vehicles running on conventional fuel for a benchmark. For all but three fleets, GHG emissions were reduced by adopting alternative fuel vehicles. The largest reductions were achieved by electric, HEV, and PHEV fleets. Fleet managers can use the results presented in Table 5 to make the environmental case for adopting alternative fuels vehicles. Note that GHG emissions are calculated from well to

[12] Table 4 underestimates the fuel cost per mile of PHEV vehicles because grant recipients did not report the amount of electricity consumed by PHEV vehicles only the amount of diesel consumed.
[13] *ibid*

wheels, meaning that the emissions from fuel extraction, processing, distribution, etc. are added to the amount of emissions released from burning the fuel itself.

Table 5. Well to Wheels GHG Emissions by Fleet

Fleet	Sample Size	MPG[14]	GHG short tons per 10,000 miles	Comp Fuel	Comp MPG	Comp GHG short tons per 10,000 miles	GHG (reduction) increase per 10,000 miles
CNG sedans	2	24.0	4.1	gasoline	16.4	7.6	(3.5)
CNG heavy duty trucks	10	3.9	25.4	diesel	5.2	27.2	(1.8)
CNG vans	16	11.1	8.9	gasoline	12.1	10.4	(1.5)
CNG vans	161	7.6	13.0	gasoline	8.6	14.5	(1.5)
neighborhood electric vehicles	6	6.1	1.4	gasoline	9.4	13.3	(11.9)
HEV diesel bucket trucks	8	4.8	29.8	diesel	4.9	28.8	1.0
HEV diesel heavy duty truck	1	3.9	36.1	diesel	3.5	40.5	(4.4)
HEV diesel school bus	1	7.3	19.4	diesel	7.5	18.9	0.5
HEV diesel heavy duty truck	1	10.0	14.1	diesel	7.2	19.6	(5.5)
HEV diesel passenger buses	5	8.1	17.5	diesel	5.0	28.3	(10.8)
HEV diesel school bus	1	9.6	14.8	diesel	6.3	22.6	(7.8)
HEV gasoline school buses	2	7.4	16.8	gasoline	7.2	17.4	(0.6)
HEV gasoline sedans	3	41.7	3.0	gasoline	23.8	5.3	(2.3)
LPG school buses	6	4.0	19.3	diesel	6.9	20.5	(1.2)
LPG school buses	6	3.9	20.0	diesel	5.9	24.0	(4.0)
LPG school buses	8	4.1	18.8	diesel	5.9	24.0	(5.2)
LPG pickup trucks	3	7.4	10.6	gasoline	10.1	12.4	(1.8)
LPG school buses	4	3.7	20.9	diesel	7.1	19.9	1.0
PHEV diesel school bus[15]	1	10.0	14.1	diesel	5.2	27.0	(12.9)
PHEV diesel school buses[16]	2	8.1	17.3	diesel	7.8	18.2	(0.9)

Incremental Vehicle Cost

The estimated fuel cost savings and greenhouse gas reductions must be put in context of the investment needed to adopt alternative fuel vehicles. Ignoring for now the caveats with the nationwide average fuel prices, Table 3 above would seem to suggest that school bus fleets should forgo LPG in favor of hybrid technology. However, this ignores the upfront cost that must be incurred to purchase an alternative fuel vehicle instead of a conventional fuel vehicle, and the variation in cost between technologies. Consider that HEV school buses have an incremental cost of approximately $70,000 compared to an incremental cost of approximately $8,800 for LPG school buses.[17] Note that a full analysis of the life-cycle cost of alternative fuel vehicles would also take into account factors such as maintenance costs, repair costs, and training costs. Estimating the life-cycle cost of alternative fuel vehicles is beyond the scope of this analysis. However, the incremental or conversion costs presented in Table 6 do provide a rough estimate of the cost premium that is needed to achieve the fuel cost savings and GHG reductions of these vehicles.

[14]CNG vehicles listed as Miles per GGE. Electric vehicles listed as Miles per kWh.
[15] Table 5 underestimates the GHG emissions of PHEV vehicles because grant recipients did not report the amount of electricity consumed by PHEV vehicles only the amount of diesel consumed.
[16]*ibid*
[17]The recent changes in EPA emissions standards has decreased the incremental costs of alternate fuel vehicles. For example, the incremental cost reported for the 2011 and 2012 model year LPG school buses was $6,900.

Table 6. Incremental Vehicle Cost

Type	Technology	Average of Incremental or Conversion Cost Per Vehicle	Sample Size
bucket truck	HEV	$55,300	9
heavy duty truck	CNG	$70,300	10
	HEV	$42,900	25
log loader	HEV	$41,200	1
neighborhood electric vehicles[18]	EV	(-$12,300)	6
passenger bus	CNG	$27,500	1
	HEV	$81,400	8
pickup truck	HEV	$2,000	1
	LPG	$9,800	4
sanitation packer truck	CNG	$55,700	1
	HEV	$41,000	1
school bus	HEV	$70,900	4
	LPG	$8,800	40
	PHEV	$111,800	3
sedan	CNG	$7,100	2
	HEV	$5,400	5
street sweeper	CNG	$72,500	2
SUV	HEV	$8,300	6
van	CNG	$15,100	195
	EV	$10,500	2
	LPG	$9,000	1
medium duty truck	CNG	$34,000	4
	HEV	$39,900	1

Fuel Station Cost

An added cost for alternative fuel vehicle fleet operators may be lack of fueling station availability. DOE's Alternative Fuels & Advanced Vehicles Data Center, Alternative Fueling Station Locator provides a convenient way for fleet operators to search for alternative fuel stations in their area. However, having the ability to fuel the vehicle at the fleet's garage can be a significant convenience. Both of the grant recipients with PHEV vehicles who responded to the phone survey answered that they have on-site charging stations. Eight of the nine grant recipients with LPG vehicles who responded to the phone survey answered that they have an on-site fueling station. Three of the seven grant recipients with CNG vehicles who responded to the phone survey answered that they have on-site fueling stations. Table 7 provides the average cost of fueling stations funded under this grant. As a point of caution, because wage rates vary between states, the cost of installing fueling stations in New York State will different from the cost in other states.

[18]Note that the neighborhood electric vehicles cost less than their comparison vehicle, a gasoline pickup truck, but are top speed restricted.

Table 7. Fuel Station Cost

Type Of Station	Average Cost of Fueling Station	Sample Size
CNG[19]	$1,514,493	3
EV[20]	$10,018	79
LPG[21]	$65,096	2

Grantee Experience with Adoption of Alternative Fuel Vehicles

The 33 grant recipients who purchased vehicles were also asked to participate in a NYSERDA phone survey, 32 of which responded. The purpose of the phone survey was to identify issues that the grant recipients faced in deploying alternative fuel vehicles. The phone survey asked four questions:

- Would you recommend this vehicle technology to others?
- What has been your experience with vehicle maintenance?
- What has been your experience with vehicle performance?
- Do you have your own fueling station? If not, what is the distance to the station you use?

All of the grant recipients deploying CNG responded that they would recommend CNG. However, one of the seven proceeded to describe some very serious setbacks they experienced with the CNG vehicle. This respondent complained of leaking CNG tanks, transmission problems caused by the added weight, and a design flaw that placed the fuel gauge underneath the vehicle. This made it difficult for the driver to check the fuel remaining as they would need to exit the vehicle to do so. This, together with the fact that the closest fueling station was 13 miles from their garage, meant that the vehicles ran out of fuel multiple times. Unlike with gasoline or diesel, they found that they could not bring fuel to the vehicles, and instead had to tow the vehicles to the CNG station. Although some of these issues may be unique to this fleet, it does highlight the need for oversight and the need to carefully manage the range of vehicles that do not run on gasoline or diesel. On the other hand, respondents highlighted several benefits of CNG. One city found that CNG is quieter than diesel, which was a very useful attribute for their CNG street sweeper because it was assigned for night operations. In the respondent's opinion this makes up for the increased maintenance issues they experienced with the CNG street sweeper. The use of CNG also alleviated the hassle of scheduling diesel deliveries as the gas is piped rather than trucked to the City's garage.

The survey results for the hybrid vehicles, HEV and PHEV, were mixed. Of the 17 responses, 9 would recommend, four would not, and four were uncertain. The primary problem that respondents raised, mentioned by four respondents, was disappointment with fuel economy compared to what they expected based on manufacturers' claims. Other respondents were pleased with the fuel economy. Another issue raised by respondents was that the complexity of the hybrid system meant that they could not conduct repairs themselves and when the vehicles were in for repairs they experienced delays with parts. Fleet operators should therefore account for the different maintenance needs that alternate fuel vehicles have.

[19] Of the 3 CNG stations installed, 1 consisted of 40 time fill and 1 quick fill dispensers, and 2 consisted of 2 quick fill dispensers each. The costs of these stations were similar.
[20] Each EV station consisted of 1 dispenser
[21] Of the LPG stations installed, 1 consisted of 1 tank and 1 dispenser, and 1 consisted of 2 tanks and 1 dispenser

All nine of the respondents with LPG vehicles recommended the vehicles, although one did complain that fuel economy was less than expected. Interestingly, a different respondent found that the style of driving can have a large impact on the fuel economy, and pointed out that proper driver training is a necessity. Note that all of the grant recipients funded under this grant were required to conduct training for their drivers and mechanics. Two of the recipients spoke to the range limit of a vehicle that cannot be conveniently refueled en route. One school district is in the process of asking other school districts in the area to select propane as their alternate fuel of choice so that the schools will be able to use each other's fueling stations. Fleet operators considering alternative fuel vehicles of any type should create a training plan and review the fueling stations available in their area.

Conclusion

Deploying alternative fuel vehicles gives fleet operators the potential to realize financial and environmental benefits. However, uncertainties surrounding the fuel use of alternative fuel vehicles can present a decision-making barrier. The fuel economy, incremental vehicle purchase cost, fueling station purchase cost, greenhouse gas reductions, and fuel cost savings data for the 332 alternative fuel vehicles funded under NYSERDA's administration of the DOE's Clean Cities FY09 Petroleum Reduction Technologies Project for the Transportation Sector funded by ARRA can be used by fleet operators to better understand these uncertainties. Combining the data presented in this analysis with local pricing data and knowledge of local conditions can help inform fleet operators as to what alternative fuel vehicle technologies are best suited to local needs and conditions.

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