Alternative Fueled Taxicab Fleets

Summary:
Transition 25% of Pennsylvania's existing taxi cab fleet to compressed natural gas (CNG), hybrid electric vehicle (HEV) technology or a combination of the two by the year 2020.

Background Discussion:
Data compiled from PennDOT indicates that there were 3,150 taxi cabs in service in the Commonwealth of Pennsylvania in 2010[1]. The data is broken down by county, number of taxis and average annual miles traveled.

TABLE 1: 2010 Pennsylvania Taxicab Registrations by County[1]

COUNTY OF REGISTRATION	NUMBER OF TAXIS	AVERAGE ANNUAL MILES*	COUNTY OF REGISTRATION	NUMBER OF TAXIS	AVERAGE ANNUAL MILES*
Allegheny	340	15,300,000	Lancaster	24	1,080,000
Armstrong	1	45,000	Lawrence	1	45,000
Beaver	10	450,000	Lebanon	7	315,000
Berks	51	2,295,000	Lehigh	22	990,000
Blair	14	630,000	Luzerne	38	1,710,000
Bradford	6	270,000	Lycoming	13	585,000
Bucks	167	7,515,000	Mercer	1	45,000
Butler	19	855,000	Mifflin	3	135,000
Cambria	4	180,000	Monroe	31	1,395,000
Carbon	1	45,000	Montgomery	322	14,490,000
Centre	49	2,205,000	Northampton	16	720,000
Chester	35	1,575,000	Northumberland	16	720,000
Clarion	6	270,000	Philadelphia	960	43,200,000
Clinton	6	270,000	Pike	6	270,000
Columbia	5	225,000	Somerset	2	90,000
Cumberland	5	225,000	Union	1	45,000
Dauphin	292	13,140,000	Venango	2	90,000
Delaware	414	18,630,000	Warren	2	90,000
Erie	36	1,620,000	Washington	6	270,000
Fayette	4	180,000	Wayne	5	225,000
Franklin	2	90,000	Westmoreland	16	720,000
Huntingdon	1	45,000	Wyoming	4	180,000
Indiana	3	135,000	York	16	720,000
Lackawanna	21	945,000	Out of State	144	6,480,000

*Average mileage based on the IRS mileage estimate of 45,000 miles annually

The current analysis of the 2010 registration data indicates that the statewide fleet consists of 3,150 taxis distributed across 47 counties with 144 being registered outside of the Commonwealth. The largest numbers of taxi registrations are seen in the urban counties of Philadelphia, Delaware, Allegheny, Montgomery and Dauphin. These five counties account for 74% of the taxis in the Commonwealth.

Using the IRS taxicab audit estimate of 45,000 miles per year per taxi we assume the annual miles traveled by the Pennsylvania fleet to be 141,750,000 miles. The greenhouse gas (GHG) emissions numbers presented in this analysis were calculated using the emissions factors for pounds of CO2/gallon, found in Table 2, as provided by the US Department of Energy (DOE) and the National Renewable Energy Laboratory's (NREL) Barwood Cab Fleet Study.

By using the factors in Tables 1, 2 and 3 the annual CO2e emissions were able to be calculated. First the number of taxis in the PA fleets was multiplied by the average annual travel miles. This number was then divided by the fuel economy MPG for fuel mode and then multiplied by the specific emissions factor for a particular fuel. Lastly by dividing by 2000 we were able to calculate the tons of CO2e emissions for each fuel mode, which in turn was converted to million metric tons of carbon dioxide equivalents (MMtCO2e). The results of these calculations can be found in Table 5.

The analysis shows the potential GHG emissions that would result if the 2010 fleet was comprised of 25% CNG vehicles (Scenario #1), or 25% HEV (Scenario #2).

CNG and Methane Losses:

Natural resources from within the U.S., particularly from deep shale formations such as the Marcellus, offer opportunity for economic prosperity and renewed optimism for greater energy independence and security. With adherence to environmental safeguards, natural gas can easily be the cleanest of the fossil fuel options for generating electricity, providing building heat and for use in transportation however, the climate change implications of utilizing these resource can be profound.

The climate effect that results from replacing other fossil fuels with natural gas depends largely on the sector and the type of fuel being replaced. These distinctions have been, for the most part, absent in the policy debate. When estimating the net climate implications of fuel-switching strategies, outcomes should be based on the complete fuel cycle, a Life Cycle Analysis (LCA), and account for changes in emissions of relevant radiative forcing agents. This is consistent with the approach used in the development of other plans developed for consideration in this action plan report.

The EPA's latest national GHG inventory, 2009, of the amount of methane (CH^4) released from leaks and venting in the U.S. natural gas network, from production through distribution to the ultimate consumer, is 570 billion cubic feet (Bcf). This corresponds to an emissions rate equal to 2.4% of gross U.S. natural production (1.9 – 3.1% at a 95% confidence level)[1]. There may be some disagreement as to the specific level of methane leakage but EPA's value of 2.4% is based on industry-reported data. This leakage rate is applicable in the analysis of any and all utilization of natural gas and is applied to the volume of natural gas estimated to be used for transportation under this initiative.

Methane, when considered on a 100-year time horizon, is 25 times more potent of a GHG than CO_2 but over a shorter, 20-year time horizon it is 72 times more potent than CO_2 [3]. The shorter time frame is particular relevant since many policy decisions are analyzed within such a window. With the addition of more wells and increased Marcellus Shale play activity, left unchecked, the amount of fugitive and vented CH_4 emissions will only increase, compounding any efforts to decrease emissions of GHGs.

[1] National Academy of Science: 2012, February 2012, *Greater Focus Needed on Methane Leakage from Natural Gas Infrastructure*

Given the 2.4% leakage and loss rate throughout the natural gas system, along with the associated CH_4 emissions from the transportation sector itself, CNG vehicles do not represent a viable mitigation strategy for climate change.[4] Converting a fleet of gasoline cars to CNG would actually increase radiative forcing for 80 years before any net climate benefit would be achieved. After about 150 years and assuming all things remain static, this would result in about a 10% reduction in cumulative radiative forcing (warming potential), as compared to the use of gasoline. Stated differently, converting a fleet from gasoline or diesel to CNG would result in many more decades of net increased GHG emissions, because of the greater radiative forcing early on. However, if the gas system leakage and loss emissions rate was reduced from the current estimate of 2.4% down to a rate of only 1.6%, a fleet conversion to CNG cars would result in immediate climate benefits.

Beginning in 2015, US EPA regulations will require natural gas operators to employ green completion technology to prevent gas from escaping into the atmosphere after the well has been hydraulically fractured, typically when the most methane is released. This technology captures gas and condensate that is released during the flowback period after hydraulic fracturing. By implementing green completions, emissions are expected to be reduced by up to 95%. The new Federal regulation also includes requirements for other sources of emissions in the oil and gas industry, including storage vessels. The US EPA has also encouraged operators to join the Natural Gas STAR Program. This program was first developed in 1993 and provides operators with information on cost-effective methane emission reduction technologies and practices and requires participating operators to submit annual reports describing the actions they've taken to reduce their emissions. As more and more shale wells are drilled and hydraulically fractured each year, programs like this will become more important at controlling methane leakage from natural gas production and distribution

Emissions Reductions:

In Scenario #1, a 25% increase in the number of CNG taxis in the PA fleet is represented and a 25% decrease in gasoline powered taxis is also seen. Under this scenario, 748 CNG cabs are added. Subsequently the 2,993 gasoline taxis is reduced to 2,245 taxis. In this scenario the 25% increase of CNG taxis, along with an upstream CNG leak reduction rate below 1.6%, could result in a net calculated decrease of 5,158 tons of CO2e in the annual fleet emissions.

In Scenario #2, a 25% increase in the number of HEV taxis is shown, commensurate with a corresponding decrease in gasoline powered taxis. Under this scenario, 748 HEV cabs are added. As in Scenario #1 the 2,993 gasoline taxis is reduced to 2,245 taxis however, in this scenario the 25% increase of HEV taxis results in a net decrease of 11,976 tons of CO2e in annual fleet emissions

.

The disparity between emissions from the CNG powered vehicles and the HEV technology vehicles is due to the amount of fuel used by each fuel mode fleet vehicle. Based on BTU value and the fuel economy (MPG) data, a CNG powered taxi requires more fuel to travel an equal distance as the HEV taxi.

TABLE 2: Pounds of Life Cycle CO2 Emitted for Each Fleet Mode (Greet Model)

Fuel Type	Pounds CO2e/Gallon
CNG	19.74
HEV	24.95
Gasoline	24.95

TABLE 3: Fuel Economy, MPG for Taxi Fleet

Data Source	MPG		
	Gasoline	CNG	Hybrid
U.S. Dept of Energy, NREL	16	n/a	33-48

NREL, Barwood Cab Fleet Study	17	17	n/a

TABLE 4: Baseline Scenario Fleet Characteristics and Emissions

Base Year	Total Fleet Miles	Fleet Size	Average Annual Taxi Miles	Taxis by Fuel Mode			Annual CO2e Emissions (Short Tons)			Total Emissions (MMtCO2e)
				Gasoline	CNG	HEV	Gasoline	CNG	HEV	
2010	141,750,000	3,150	45,000	2,993	79	79	98,819	2,058	1,105	0.09

***Assumes 5% of current fleet is AFV**

TABLE 5a: Scenario #1 (CNG) 2013-2020 Emissions

Year	Annual Total Miles	Fleet Size	Ave. Vehicle Miles	Taxi Type			Emissions Reductions (MMtCO2e)			
				Gasoline	CNG	HEV	Gasoline	CNG*	HEV	Total
2013	141,750,000	3,150	45,000	2,899	94	79	0.09	0.00	0.00	0.09
2014	141,750,000	3,150	45,000	2,805	187	79	0.08	0.00	0.00	0.09
2015	141,750,000	3,150	45,000	2,711	281	79	0.08	0.01	0.00	0.09
2016	141,750,000	3,150	45,000	2,617	374	79	0.08	0.01	0.00	0.09
2017	141,750,000	3,150	45,000	2,523	468	79	0.08	0.01	0.00	0.09
2018	141,750,000	3,150	45,000	2,429	561	79	0.07	0.01	0.00	0.09
2019	141,750,000	3,150	45,000	2,335	655	79	0.07	0.02	0.00	0.09
2020	141,750,000	3,150	45,000	2,241	748	79	0.07	0.02	0.00	0.09
TOTAL				**2,241**	**748**	**79**	**0.62**	**0.08**	**0.01**	**0.70**

TABLE 5b: Scenario #2 (HEV) 2013-2020 Emissions

Year	Annual Total Miles	Fleet Size	Ave. Annual Miles	Taxi Type			Emissions (MMtCO2e)			
				Gasoline	CNG	HEV	Gasoline	CNG	HEV	Total
2013	141,750,000	3,150	45,000	2,899	79	94	0.09	0.00	0.00	0.09
2014	141,750,000	3,150	45,000	2,805	79	187	0.08	0.00	0.00	0.09
2015	141,750,000	3,150	45,000	2,711	79	281	0.08	0.00	0.00	0.09
2016	141,750,000	3,150	45,000	2,617	79	374	0.08	0.00	0.00	0.09
2017	141,750,000	3,150	45,000	2,523	79	468	0.08	0.00	0.01	0.08
2018	141,750,000	3,150	45,000	2,429	79	561	0.07	0.00	0.01	0.08
2019	141,750,000	3,150	45,000	2,335	79	655	0.07	0.00	0.01	0.08
2020	141,750,000	3,150	45,000	2,241	79	748	0.07	0.00	0.01	0.08
TOTAL				**2,241**	**79**	**748**	**0.62**	**0.01**	**0.04**	**0.67**

Tables 5a and 5b provide estimated greenhouse gas emissions, for each fuel type in the CNG scenario and HEV scenario. Hybrid automobiles and CNG automobiles are capable of reducing CO_2 emissions by as much as 25% when compared to conventional gasoline powered automobiles. A DOE, NREL Taxicab study comparison of 10 conventional gasoline powered Ford Crown Victoria taxis and 10 CNG powered Ford Crown Victoria taxis demonstrated that CNG exhaust emissions were significantly lower than their gasoline counterparts.[5] In addition, the testing demonstrated that although both the gasoline and CNG vehicle emissions fell within the EPA's applicable standards the CNG vehicles had significantly lower levels of non-methane hydrocarbons (NMHC), carbon monoxide (CO) and oxides of nitrogen (NOx).

In general HEVs produce lower emissions than conventional gasoline powered vehicles do. These lower emissions are the result of the combination of a conventional internal combustion engine (ICE) propulsion system with an electric propulsion system. The presence of the electric powertrain is intended to achieve either better fuel economy than a conventional vehicle, or better performance. A hybrid-electric produce less emissions from its ICE than a comparably-sized gasoline car, since an HEV's gasoline engine is usually smaller than a comparably-sized pure gasoline-burning vehicle.

The results of this analysis are presented in Table 6. Annual emissions are presented in MMtCO2e for each of the three fuel types along with an annual CO2e emissions total and a final total GHG reduction by the year 2020 for each fuel scenario. As indicated in the table the cumulative GHG reductions are 0.07 MMtCO2e for the HEV scenario and 0.04 MMtCO2e for the CNG scenario.

Table 6: Summary of Annual (2020) and Cumulative (2013 - 2020) GHG Emissions and Emissions Reductions by Scenario*

	Taxis by Fuel Mode			Annual Emissions CO2e/tons			2020 Annual Emissions (MMtCO2e)	Cumulative Emissions (MMtCO2e)	2020 Emissions Reductions (MMtCO2e)	Cumulative Emissions Reductions (MMtCO2e)
Scenario	Gasoline	CNG	HEV	Gasoline	CNG	HEV				
BAU	2,993	79	79	98,819	2,057	1,105	0.09	0.74	0.00	0.00
CNG	2,241	748	79	73,986	19,546	1,105	0.09	0.70	0.01	0.04
HEV	2,241	79	748	73,986	2,064	10,499	0.08	0.67	0.01	0.07

**** Possible emissions reduction with CNG upstream leakage rate below 1.6%***

Economic Cost:

When doing an analysis of the cost-effectiveness of the transition represented in Scenario #1, additional factors, besides the incremental cost of the CNG automobiles, must be taken into consideration. A significant drawback to the transition of fleet taxis to CNG is the cost of a new CNG vehicle or the cost of a retro-fit kit to convert an existing gasoline powered vehicle to a CNG powered unit.

Currently retro-fit/ repowering is the only available option because only one OEM CNG small passenger automobile is available in the US. In today's market the cost of a retro-fit kit, depending on vehicle size, can range from $10,000 to $14,000. With this kind of re-fit cost per unit, in addition to the cost of the platform vehicle, the cost per unit can easily approach $35,000 to $40,000 per unit. CNG retro-fit kits present a sizable investment and are not always the best economical route to take especially when considering the CNG conversion of a used vehicle. The age and condition of the automobile/cab must be taken into consideration in order to determine if this type of investment is warranted. A retrofit to an existing vehicle that is near its useful life period may experience a catastrophic failure before the investment pay-back period has been reached. For this reason, total replacement of the unit with an OEM model, when available, or new vehicle conversion may be the best option.

One of the most popular hybrid taxis found on the streets of the U.S. today is the Toyota Camry Hybrid. The 2012 MSRP for the Camry Hybrid LE (base model) is $25,900. With the unavailability of a Toyota Camry in a CNG fuel mode for a direct comparison, based on vehicle size and retro-fit kit availability a Chevrolet Malibu was chosen as the comparison vehicle. The 2012 MSRP for the Chevrolet Malibu (base model) is $22,110. Add to this the incremental cost of $10,000 -$14,000 for a CNG retro-fit conversion kit and the investment for a new CNG taxicab can approach $35,000 per unit. The cost to compare for a used Ford Crown Victoria was estimated at $8,000 for the business as usual scenario.

Tables 7a and 7b illustrate the net costs and cost effectiveness of each scenario. The net costs are negative indicating that the costs to implement the initiatives provides a significant savings, as compared to maintaining the current fleet of conventional (gasoline) taxis with poor fuel economy. It is estimated that the gross costs associated with implementing this initiative in 2020 are $45 million and $41 million, respectively, for the CNG and HEV scenarios. These gross-level costs are offset by savings from the estimated cost of maintaining the current taxi fleet at $74 million.

Along with a switch from conventional gasoline to the alternative fuel CNG, comes a change to the fueling infrastructure of the fleet depot or the local fueling stations. Currently the majority of the Pennsylvania taxicab fleets consists of gasoline powered vehicles either utilizing public gasoline stations or fleet fueling infrastructure. With the transition of a taxi fleet to CNG powered vehicles the logistics and cost of a CNG fueling station must also be taken into consideration. An engineering analysis should be conducted to determine if a fleet depot has access to CNG and also has the physical capability to house CNG-related infrastructure. Major facility reconfiguration and/or the purchase of additional real estate could be required to house and maintain a CNG fleet which would result in additional capital costs over and beyond the incremental cost of the vehicles. In comparison, HEV taxis can utilize existing fueling and maintenance infrastructure.

Another aspect to consider with the transition of a fleet to AFVs is vehicle maintenance costs. In this respect maintenance costs are reported to be slightly lower, about 25% on a per-mile basis, for CNG taxis when compared to the maintenance costs of a gasoline unit.[6]

Table 7a: Estimated GHG Reductions* and Cost-effectiveness CNG

Annual Results (2020)			Cumulative Results (2013 - 2020)		
GHG Reductions ($MMtCO_2e$)	Net Costs (Million $)	Cost-Effectiveness ($\$/tCO_2e$)	GHG Reductions ($MMtCO_2e$)	Net Costs (NPV, Million $)	Cost-Effectiveness ($\$/tCO_2e$)
0.007	$-29	$-4,392	0.037	$-23	$-619

**** Possible emissions reduction with GNG upstream leakage rate below 1.6%***

Table 7b: Estimated GHG Reductions and Cost-effectiveness HEV

Annual Results (2020)			Cumulative Results (2013 - 2020)		
GHG Reductions ($MMtCO_2e$)	Net Costs (Million $)	Cost-Effectiveness ($\$/tCO_2e$)	GHG Reductions ($MMtCO_2e$)	Net Costs (NPV, Million $)	Cost-Effectiveness ($\$/tCO_2e$)
0.014	$-33	$-2,373	0.067	$-42	$-634

Conclusion:

The use of HEV taxicabs does present certain advantages over CNG units in that the technology does not require any reconfiguration of an existing depot as with the addition of CNG infrastructure. HEV technology can be introduced into a taxi fleet and use the existing conventional refueling infrastructure. HEV vehicles are also expected to have lower maintenance costs due to reduced stress and maintenance on mechanical components such as brake linings. In addition the electric drive has fewer moving parts than conventional drive units, thus requiring less maintenance than a traditional transmission. More efficient operation and higher average fuel economy of the HEV technology significantly reduce annual fuel costs over both conventional fuel and CNG vehicles. However, typical fuel economy is expected to decrease when a HEV vehicle is operated in the summer months due to increased energy demand by vehicle accessories.

The data in this analysis supports that there could be significant reductions in GHG emissions realized with the adoption of either CNG taxis or HEV taxis to replace existing gasoline powered units. Cost effectiveness of the fuel mode selected along with availability of the technologies at the present will dictate the early choice for pioneer taxi fleets. Looking toward the future when CNG and HEV/EV OEM vehicle and public and private fueling infrastructure are more readily available taxi fleets will be able to select from multiple alternative fuel modes to fit their individual needs and goals.

Implementation Steps:

- Encourage taxi fleet owners to utilize AF vehicles and AF technology when replacing taxicabs that are scheduled for normal replacement.
- Keep taxi fleet owners updated on available state and federal alternative fuel vehicle incentives.
- Special state grants solicitations for taxi companies to install AF infrastructure.
- Special state grants solicitations to assist taxi companies with the incremental cost associated with the purchase of dedicated AF vehicles.

Key Assumptions:

- HEV and CNG taxicabs are superior to conventional gasoline powered taxis in reducing GHG emission.
- GHG emissions could be further reduced with the transition of gas powered taxis to AFV and AF technology taxis.
- The electric drive components and systems market will continue to progress and provide more products at lower prices to the taxicab market.
- CNG infrastructure and OEM vehicles will become readily available within the next few years.
- Methane leakage rate for CNG.

Key Uncertainties:

- Availability of State and Federal Grant dollars for AF vehicles and infrastructure
- Cost or alternative fuels and AF technology
- Availability of CNG infrastructure in all areas throughout the Commonwealth.
- Availability of OEM vehicles in near future.

Additional Benefits and Costs:

- Direct reduction of gasoline fuel usage through the utilization of CNG and Hybrid (gasoline) technology without the added cost of new infrastructure.
- Criteria Pollutants reduction

Potential Overlap:

None Identified

References:

NREL, 1999: Barwood Cab Fleet Study Summary, May, 1999.
PennDot, 2011: Report of Registrations for Calendar Year 2010,
USEPA, 2010: Clean Alternative Fuels: Compressed Natural Gas, EPA4240-F-00-033, March 2002

US Department of Energy's Energy Information Administration (EIA) database
Argonne National Laboratory's Greenhouse Gases, Regulated Emissions and Energy Use in Transportation (GREET) model and the Fuel Economy factors
IRS Taxi Library: Taxicab Overview
HybridCARS. 2006: Hybrid Taxicabs, March, 2006
Taxicab, Limousine & Paratransit Association 2009: Analysis of Alternative Fuels & Vehicles for Taxicab Fleets, July 31, 2009
Idaho National Laboratory, 2006: hybrid Electric Vehicle Fleet and Baseline Performance Testing, April, 2006

End Notes:

[1] *PennDot, 2011: Report of Registrations for Calendar Year 2010*
[2] National Academy of Science: 2012, February 2012, *Greater Focus Needed on Methane Leakage from Natural Gas Infrastructure*
[3] Argonne National Laboratory, 2011, November 2011, *Life-Cycle Analysis of Shale Gas and Natural Gas*
[4] National Academy of Science: 2012, February 2012, *Greater Focus Needed on Methane Leakage from Natural Gas Infrastructure*
[5] *NREL, 1999: Barwood Cab Fleet Study Summary, May, 1999.*
[6] Taxicab, Limousine & Paratransit Association: 2009, July 2009, *Analysis of Alternative Fuels & Vehicles for Taxicab Fleets.*