



# *Alternative Fuel Vehicles*

**The Road Ahead**

## **Introduction**

Alternative fuel vehicles offer an unprecedented opportunity to transform and transition our nation's transportation fuel source from petroleum to alternative fuels. The vehicle sector is currently virtually 100% dependent on liquid fuels. Expanding the diversity of fuel sources used in the transportation sector will increase flexibility in responding to any disruptions in the supply of petroleum-based fuels, which will in turn protect the economy from the adverse impact of sudden changes in the availability and/or price of petroleum products. This added flexibility alone makes the development of alternative fuel vehicles attractive.

The U.S. government, as part of its initiative to address the issue of climate change, has pledged investments of billions of dollar to ensure the viability of cleaner and more efficient alternative fueled vehicles. The potential exists to drastically reduce our nation's CO2 emissions by making prudent transportation fuel diversity investments.

The U.S. Department of Energy has appropriated \$25 billion to retool the vehicles that Americans drive. As a result of climate change concerns and last summer's historic high costs for oil, there is currently substantial momentum to reduce our nation's dependency on petroleum to fuel our vehicles as well as to clean the environment and reduce fuel costs at the same time. This is the vision, but we must collectively work to implement the path toward independence. It will require a collaborative effort on behalf of energy suppliers, electric and gas utilities, research institutions, universities, the automobile industry, battery manufacturers, national laboratories, government, and all consumers to achieve this monumental change. By working together, we can collectively accomplish the task. The key will be to maintain momentum in the face of near term petroleum prices, which have fallen from the summer 2008 high.

This white paper will focus on ideas to advance the adoption of Natural Gas Vehicles (NGVs), Plug-In Hybrid Electric vehicles (PHEVs) and ultimately Electric Vehicles (EV). We will explore the technology, the benefits and the barriers to implementation that would need resolution, as well as recommending policy changes and other actions required to turn this vision into a reality.

## **Natural Gas Vehicles (NGV)**

According to NGVAmerica, there are approximately 150,000 NGV vehicles in the United States, with approximately 7 million NGV vehicles in service worldwide. Natural gas can be used in all types of vehicles including cars, motorcycles, vans, trucks, buses, and even trains. For example, more than one of every 10 transit buses on the road in the United States is fueled with natural gas. NGVs have the potential to improve the fuel economy and also reduce emissions. In 2007, about 31 BCF of natural gas was used to displace 250 million gallons of petroleum in the transportation industry. The EPA estimates that vehicles on the road account for 60% of carbon monoxide pollution and about one-third of hydrocarbons and nitrogen oxides emissions in the United States.

Because the carbon-to-hydrogen ratio in methane, the primary constituent of natural gas, is lower than for petroleum products, NGVs reduce greenhouse gases emitted by a vehicle by 25% or more compared to a petroleum-fueled vehicle. NGVs also provide an excellent opportunity to improve the fuel diversity of the transportation sector while improving and stabilizing the security of energy supply.

### **Technology**

NGV engines operate on the same principles as gasoline fueled vehicles, and in most instances are just modified gasoline engines. During engine ignition, natural gas which is stored in a highly compressed state flows into the fuel line from on-board storage cylinders. As the fuel approaches the engine, a regulator reduces the pressure of the gas from approximately 3600 psi to the required fuel injection pressure, then the gas feeds through a multipoint gaseous fuel injection system into the engine cylinder. Unlike gasoline, natural gas is already in a vapor state before reaching the cylinder. And since it has a higher octane rating than gasoline, the engine can operate at higher compression ratios. Natural gas is mixed with air in the cylinder of the engine and then is ignited by a spark plug to move the piston up and down. Sensors and computers make the required fuel to air mixture adjustments, optimizing the fuel/air ratio to provide the best combination of power and emissions. A solenoid valve allows the flow of natural gas to the combustion engine. When the car is not running the solenoid valve shuts off the flow of natural gas.

The fuel tanks of early models of NGVs were heavy and large. However, new integrated storage systems take less cargo space, while being made of lighter and stronger carbon/fiberglass composite material. Advanced electronic engine control systems have improved the power output and reduced the emissions of NGVs as compared to earlier models.

### **Benefits**

According to the United States Environmental Protection Agency, NGVs offer the following advantages in comparison to conventional gasoline vehicles:

- Reduce carbon monoxide emissions by 90% - 97%
- Reduce carbon dioxide emissions by 25%
- Reduce nitrogen oxides emissions by 35% - 60%
- Reduce non-methane hydrocarbon emissions by 50% - 75%
- Emit little or no particulate matter

NGVs are already available and combine top performance with low emissions. The Honda Civic GX is rated as the cleanest production vehicle in the world – cleaner than any hybrid-electric car -- and has been in production for over a decade.

NGVs can help the United States reduce its dependence on foreign oil, enhancing our energy security. Natural gas is our country's second largest energy resource and a vital component of our energy supply. Approximately 98% of the natural gas used in the

United States comes from North America; by comparison, 66% of the oil we use is imported from foreign nations.

Natural gas is one of the cleanest, safest and most useful forms of energy. The natural gas industry has existed in the United State for over 100 years and continues to grow. Domestic natural gas reserves are twice that of petroleum. And new discoveries of natural gas are ongoing. For example, recent advances in drilling and extraction technology have made gas trapped in shale deposits – which are abundant in the United States – economic to develop. Some of these shale gas deposits are located in the northeast United States, including in New York State, so developing these resources will both increase the supply of natural gas (and likely lower its price) as well as provide economic stimulus to the areas where those shale deposits exist.

Despite these advantages, less than 1% of natural gas is currently used for transportation. In order to increase the use of this fuel in the transportation sector, significant barriers must be overcome and significant capital investments must be made.

### **Market and Regulatory Barriers**

One of the biggest obstacles facing the NGV market is the lack of a mature, widely-available compressed natural gas (CNG) fueling infrastructure system to support a large fleet of NGVs. There are approximately 1100 refueling stations across the nation. NGVs have been an important part of New York City and New York State vehicle fleets (both private and governmental) for over a decade. During this decade, we have seen that infrastructure developers are hesitant to build until they receive assurance that vehicle sales will be sufficient to support the high capital costs required to build CNG fueling stations; consumers are unwilling to commit to purchasing NGVs in large numbers until infrastructure is widely available. This “chicken and egg” stalemate will be impossible to resolve without either significant economic incentives to encourage investment by both individuals (to buy vehicles) or investors (to build infrastructure), or public policy initiatives that will resolve the stalemate.

Local building codes and fire codes also make it difficult in some instances to install CNG fueling station infrastructure. Because of differences among local codes, fueling equipment manufacturers and fueling equipment installers must customize their products and services to meet the specific needs of local officials. While local codes can and should be customized to account for significant differences that exist due to local needs, highly specialized codes cause costs of CNG equipment to increase and make installation difficult and time consuming, further frustrating efforts by private investors to build the infrastructure needed before NGVs become attractive to private individuals. These local codes can also slow or halt consumer adoption of innovative CNG technology, for example home CNG fueling “appliances” that allow consumers to fuel their NGV using the gas service at their residence.

Utility rates to serve CNG fueling stations are designed to be competitive with other forms of firm gas transportation on LDC systems. Since NGVs are true year-round base load, they are typically more economical for an LDC to serve because the upstream

pipeline capacity and local distribution infrastructure needed to serve the NGV load can be utilized all year long (and not just during the winter heating season as is true of heating load), suggesting possible rate incentives allowing for lower gas transportation rates to CNG fueling stations can be justified on an economic basis.

Utilities in New York State have been the primary operators of consumer-level CNG fueling stations, but each utility has its own payment and billing system. In order for an NGV to travel from one area to another and fuel up in other utility zones, customers need to be registered as a customer in each utility's billing system. State-wide – and, preferably, national – standards for fueling station billing systems at utilities would encourage adoption of NGVs by customers.

## **Plug-in Hybrid Electrical Vehicle (PHEVs) and Electric Vehicles (EVs)**

The development of PHEVs and EVs has gained momentum over the last few years, coinciding with the concerns over recent high prices of gasoline, climate change, and national energy security. Automakers recognize a consumer market not only anxious to reduce transportation costs but also to respond aggressively to the concerns of climate change and energy security. Indeed, some automakers have already had commercial success with Hybrid Electric Vehicles (HEVs), thus proving that the technology is safe, attractive to consumers and profitable to manufacture.

The development of the PHEV technology results from extensive collaboration between electric power companies, the Electric Power Research Institute (EPRI), universities, automobile and battery manufacturers, national laboratories, and research institutes.

EVs are vehicles that run on battery stored electricity alone. This technology will become more attractive as battery technology advances and economies of scale (resulting from PHEVs' expanded use of batteries) lower costs. The advantage EVs present is greater simplicity, and potentially cheaper vehicles, since an internal combustion engine, generator, controls, etc. are not needed for an EV. Several business models related to battery charging infrastructure that may make EVs more attractive are currently being explored.

### **Technology**

The PHEV, like HEVs available on the market today, operates on battery power for a clean, quiet ride and increased fuel efficiency in local driving, and a liquid fuel for unlimited driving range. In both types of vehicle, the battery is charged when the internal combustion engine is running and when the driver uses the brakes. When the battery depletes its charge to a preset minimum energy level, the vehicle automatically switches to Internal Combustion Engine mode. A PHEV is an HEV with significantly more electrical storage capacity and the ability to recharge its energy storage system with electricity drawn from the electric grid. This results in an improvement of fuel economy by allowing use of a smaller engine and a control system that keeps the engine running at an efficient operating point. The battery pack can also be recharged by an electric

generator that is connected to the engine. When the brakes are applied, the motor is temporarily made to operate as generator and charges the battery pack.

The electric-only target driving range of a PHEV is 20 to 40 miles, depending primarily on battery storage capability and the drive cycle. Batteries can be recharged from a conventional 120 volt AC source, although some PHEV battery designs can also accommodate a 240-volt source for quick charging. EPRI reports that 50% of American vehicles travel less than 26 miles/day, and this is within the potential all-electric range of a PHEV.

### **Benefits**

A joint study by EPRI and NRDC showed that the widespread adoption of PHEVs can reduce GHG emissions from vehicles by more than 450 million metric tons by 2050. This is equivalent to removing the emissions output of 82.5 million passenger cars. This was a landmark study because it utilized detailed models of the electric system and the transportation sector with sophisticated atmospheric air quality models.

Several benefits result from the use of grid electricity as a transportation fuel. PHEVs can reduce direct emissions at the vehicle tailpipe and indirect emissions at fuel source when they recharge using a portfolio of efficient combustion, low emitting or renewable generation.

Equipped with vehicle-to-grid (V2G) capability, a PHEV could possibly provide power back to the grid. This technology is still under evaluation and must be researched further. Off-Peak charging for PHEVs coincides with the peak for wind generation in New York (since the wind tends to blow more at night) and could help to drive a zero emission transportation sector where PHEVs would be charged primarily by renewable resources. Offsetting these benefits could be the system impact should transmission and distribution system wires no longer benefit from an overnight cool-down period. This impact could reduce line ratings, and needs to be studied further to determine the extent of the system impact as well as the penetration of PHEVs and EVs that could cause such an impact.

Studies have also shown that, because of the lower cost of fuels used to power electric generation (as compared to the cost of petroleum), consumers and businesses that use PHEVs primarily fueled by electricity from the grid can reduce the cost of fuel for their vehicles. While the amount of savings depends on a number of factors, including the rate structure of the electric utility serving the consumer, this cost savings may provide a strong economic incentive for consumers to purchase PHEVs. In addition to lower costs for consumers, since much of the electricity generated in the United States is generated using domestic natural gas, nuclear, coal, hydro or wind technologies, it can be expected that fueling PHEVs via the grid will reduce fuel price volatility for consumers, since all of the generating technologies mentioned either have no fuel cost (for wind and hydro) or rely on fuels which exhibit significantly less price volatility than petroleum. And since our electricity is primarily fueled with domestically-sourced fuels, PHEV use also enhances our nation's energy security. Ideally, EVs would be charged off-peak and consistent with optimum grid conditions.

## **Market and Regulatory Barriers**

A roadblock to widespread utilization for electric vehicles has been their limited driving range, which is entirely predicated on the design of the batteries. The batteries for electric vehicles need to supply the required energy for the driving range, they have to be light and have the required power density.

Battery development is constrained by inherent tradeoffs between five main battery attributes: power, energy, longevity, safety, and cost. Two leading battery designs rely on nickel-metal hydride and lithium ion. Other battery technologies are in various stages of development and many different types of chemical combinations are currently being tested to achieve the energy storage density needed to encourage widespread adoption PHEVs.

Battery development and research is so critical that fourteen U.S. technology companies are joining forces to form a consortium that would build the first advanced PHEV battery manufacturing plant in the United States. New York State companies and universities have unique capabilities in creating the new battery technologies, representing an excellent economic development opportunity for the State. Governor Patterson has called for the creation of an upstate research consortium on hybrid electric batteries and energy storage technologies.

Other barriers to adoption include the design of local utility tariffs to accommodate not just local PHEVs and EVs to use the electric system, but also allow PHEVs and EVs from other areas the ability to recharge in other electric systems. This universality of fueling capability throughout the nation must be resolved; no one will buy a car that can't be "tanked up" outside one's own region. Billing becomes a technical issue that must be addressed through innovative Smart Grid technology. This will require an integrated communications infrastructure and corresponding price signals. Smart chargers enabled by the smart grid will help manage the distribution infrastructure and allow for accurate billing.

## **Proposal**

Alternative fuel vehicles have the potential to benefit the environment, our nation's economy, and our energy security. The natural gas used in New York is virtually 100% produced in North America, and the vast majority of our electricity is produced using domestic fuels (or has no fuel component at all, in the case of wind power and hydro power). New York State is recognized as leader in NGV deployment along with California, and has an opportunity to repeat this with aggressive support of PHEV infrastructure. We should continue our leadership by adopting the following measures:

### **General Measures:**

1. Place a surcharge of one dime (\$0.10) on every gallon of petroleum-based gasoline sold in New York State, and use the proceeds of this ten penny tax to fund increased alternative fuel vehicle fueling infrastructure. This tax would raise approximately \$120 million per year in New York, and could be used to provide a production tax credit aimed at compressed natural gas fuel sales that would allow the cost of the fuel to be reduced. The funds could also be used to provide subsidies to customers who wish to install home fueling appliances or to pay for special hookups to allow for rapid charging of PHEVs and EVs in public areas like commuter rail stations.
2. Discounted electric and gas rates should be approved for owners of alternative fuel vehicles that subscribe to time-of-use guidelines. Time-of-day electric rates should be sanctioned that sell electric power at low cost for night-time fueling. Special low electric and gas rates could be made available to natural gas vehicle fueling stations, which typically fuel at night when power and gas costs are less. Special discounted natural gas rates for residential customers should be provided for small home-based CNG fueling stations that operate during off-peak hours for the gas system. Care must be taken, however, to study the impact of incremental energy infrastructure use that will result from the electrification of the transportation system, including impact of greater electric usage on gas transmission capacity (since a high amount of electric generation is gas fired).

#### **NGVs:**

1. Make fleet CNG fueling stations that receive public funding available for use by the general public. Large transit CNG stations often are busy at night, leaving additional capacity available during the day for use by others.
2. LDCs and other providers of public CNG fueling infrastructure need to harmonize their billing and payment systems so that only a single fueling card is needed to use any CNG fueling station anywhere in New York State; if possible, this effort should be extended to the largest geographic region possible. Making fueling infrastructure usable by as wide a population as possible will enhance its use.
3. Streamline local building codes, fire codes, and operational regulations relevant to CNG fueling stations and installations, with an emphasis on harmonizing codes. Preferable would be adoption of a national set of codes, which would allow CNG equipment manufacturers and installers the scale needed to reduce costs of new CNG fueling infrastructure. In order to encourage sales of NGVs we should promote home vehicle fueling. We should consider writing state rules and modifying building and fire codes that will allow for greater penetration of these appliances.

#### **PHEVs and EVs:**

1. A New York State Electric Fueling Collaborative should be created to centralize the analysis of the impact of electric fuel vehicles on the power grid. This collaborative will work with all stakeholders to analyze, through implementation of pilot programs, the impacts of PHEVs and EVs on the bulk system and local distribution grid, and should also assess the impact of emissions on air quality and the economic impact of New York State. The collaborative can also promote

- efforts to harmonize payment and billing systems throughout New York State so that electric vehicles from anywhere in New York (and preferably from a larger geographic area, or even nationwide) can seamlessly plug-in and recharge in any part of the state. Such pilot programs should be implemented quickly in order to study system impacts, benefits, billing and tariff systems and consumer behavior.
2. Promote the benefits of PHEVs and EVs among the educational system and partner with them to fulfill the promise of widespread deployment and enhancements of PHEVs and EVs.
  3. Smart Grid technologies and advanced metering will impact the way PHEVs and EVs interact with the electric system including vehicle-to-grid capabilities. Implementation of Smart Grid technologies that can identify electric vehicles using the electric system can be the solution to universal access to the electric grid for electric vehicles, and remove the barrier of requiring each electric vehicle to have its own account with every electric utility before recharging. The industry needs to develop proper analytical and billing systems to capture these new dynamics.

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