DELAWARE VALLEY dvrpc REGIONAL PLANNING COMMISSION

Executive Summary

October 2011

Ready to Roll?

Overview of Challenges and Opportunities for Alternative Fuel Vehicles in the Delaware Valley

DVRPC's "Ready to Roll?" report provides an overview for policy-makers and citizens in the Greater Philadelphia region about the challenges and opportunities for expanded use of alternative fuel vehicles. The full report can be found in the publications section of www.dvrpc.org.

What are Alternative Fuel Vehicles?

Alternative Fuel Vehicles (AFVs) use combinations of vehicle fuels and technologies to reduce the use of petroleum in on-road vehicles. These include low-carbon fuels (sometimes blended with petroleum), electricity, and hybrid technologies combining internal combustion engines with electric motors. The AFVs covered in this report include those most widely available today or likely to become available in the next ten to twenty years. These fall into three broad types:

1: Vehicles powered by an internal combustion engine (ICE):

Low carbon fuels, such as biofuels or biofuel blends, compressed natural gas, and propane can be used to power traditional ICE vehicles, and in the case of biofuels require little or no engine modifications.

2: Vehicles powered by a battery-driven electric motor:

Electric motor-powered vehicles use batteries charged by plugging into the electric grid, or by electricity produced on-board using an ICE-powered generator or hydrogen fuel cell.

3: Hybrid electric vehicles: Hybrid electric vehicles are driven by both an electric motor and an ICE, with a transmission that draws on one or the other as required. The figures on pages 4 and 5 illustrate a number of configurations.

Benefits of Alternative Fuel Vehicles:

On-road transportation—which accounts for close to one-third of Greater Philadelphia's total energy use—is almost completely dependent on petroleum. Expanded use of AFVs is a key strategy for reducing petroleum use in our region. The benefits to doing so include:

- **Reduced air pollution from the combustion of fossil fuels:** The Greater Philadelphia region is a designated air quality "non-attainment" area, meaning that it does not meet the National Ambient Air Quality Standards (NAAQS) outlined by the U.S. EPA in the Clean Air Act for pollutants considered harmful to public health and the environment. These emissions and other air toxins can be reduced by improved vehicle technology and cleaner burning fuels.

- **Improved national security and a stronger domestic economy from reduced dependence on foreign oil supplies:** In 2005, the Greater Philadelphia region used more than 2 billion gallons of gasoline and 392 million gallons of diesel fuel. At today's prices, this costs regional consumers over $8 billion annually. Most of this fuel is from oil imported into the United States, and all of it is from outside the region. The use of AFVs presents an opportunity to produce and distribute fuels and vehicle technologies domestically, thereby strengthening the opportunity to retain locally the billions of dollars spent on imported vehicle fuel.

- **Reduced greenhouse gas (GHG) emissions:** On-road transportation accounts for a quarter of our region's annual greenhouse gas emissions. In addition, for every five pounds of tailpipe emissions, an additional pound of GHG emissions associated with the extraction, production, and distribution of the fuel is created. AFVs have the potential to significantly decrease these emissions.

- **Reduced long-term driving costs:** The use of AFVs has the potential to reduce operating costs of driving. Vehicle maintenance costs are expected to be lower with some AFVs. Additionally, although many of the fuels used to power AFVs are currently more expensive than petroleum-based fuels, a diversified fuel mix may lower price volatility associated with the use of foreign oil supplies.

Barriers for Alternative Fuel Vehicles:

Despite the benefits of AFVs outlined above, there are significant barriers to their expanded use. The issues and challenges associated with the use of AFVs are shared to some degree by most, if not all, AFVs.

Generally, these issues include:

- **The relative cost, convenience, and availability of alternative fuel vehicles compared to traditional petroleum-based internal combustion technology:** In order for AFVs to be selected by consumers over traditional gasoline or diesel powered internal combustion engines, the cost, convenience, and availability of both the fuel and vehicle must be competitive with traditional vehicles. Consumers are used to the long driving range, lower cost, convenience, and availability of refueling that gasoline and diesel fueled vehicles provide. Currently, none of the AFVs studied in the report—with the possible exception of some hybrid electric vehicles—can readily compete on these parameters with traditional gasoline and diesel fuels.

- **The development of distribution, storage, and refueling/charging infrastructure:** Fuels for AFVs can be inexpensively transported from point of production to distribution through pipeline infrastructure (or wires, in the case of electricity). However, there are two challenges: first, the existing petroleum and natural gas pipeline networks and refueling stations are not compatible with many fuels used to power AFVs, including ethanol, hydrogen, and biodiesel. Parallel pipeline and refueling station infrastructure will need to be developed.

  The second challenge is for electric vehicles: Battery charging currently takes significantly longer than refueling (hours as opposed to minutes), which poses significant challenges for siting charging stations in locations conducive to longer refueling times (e.g., home and work).

- **Energy storage:** Some fuels used to power AFVs present challenging storage hurdles. Energy density—the amount of energy stored in a given volume or weight of fuel—is lower for most alternative fuels than it is for gasoline or diesel. This limits the amount of energy that can be carried on the vehicle. Energy capacity is particularly challenging for heavy trucks; there are currently no viable technologies to replace ICEs for long distance trucking.

- **The environmental and national security impact of fuel production:** The production of fuels for AFVs (including electricity) can be achieved with lower environmental impact than gasoline, and be sourced domestically. However, some current methods of production have an environmental impact comparable to that of traditional petroleum fuels. In addition, some technologies—particularly for batteries—require materials that may not be widely available domestically.

Figure 1:

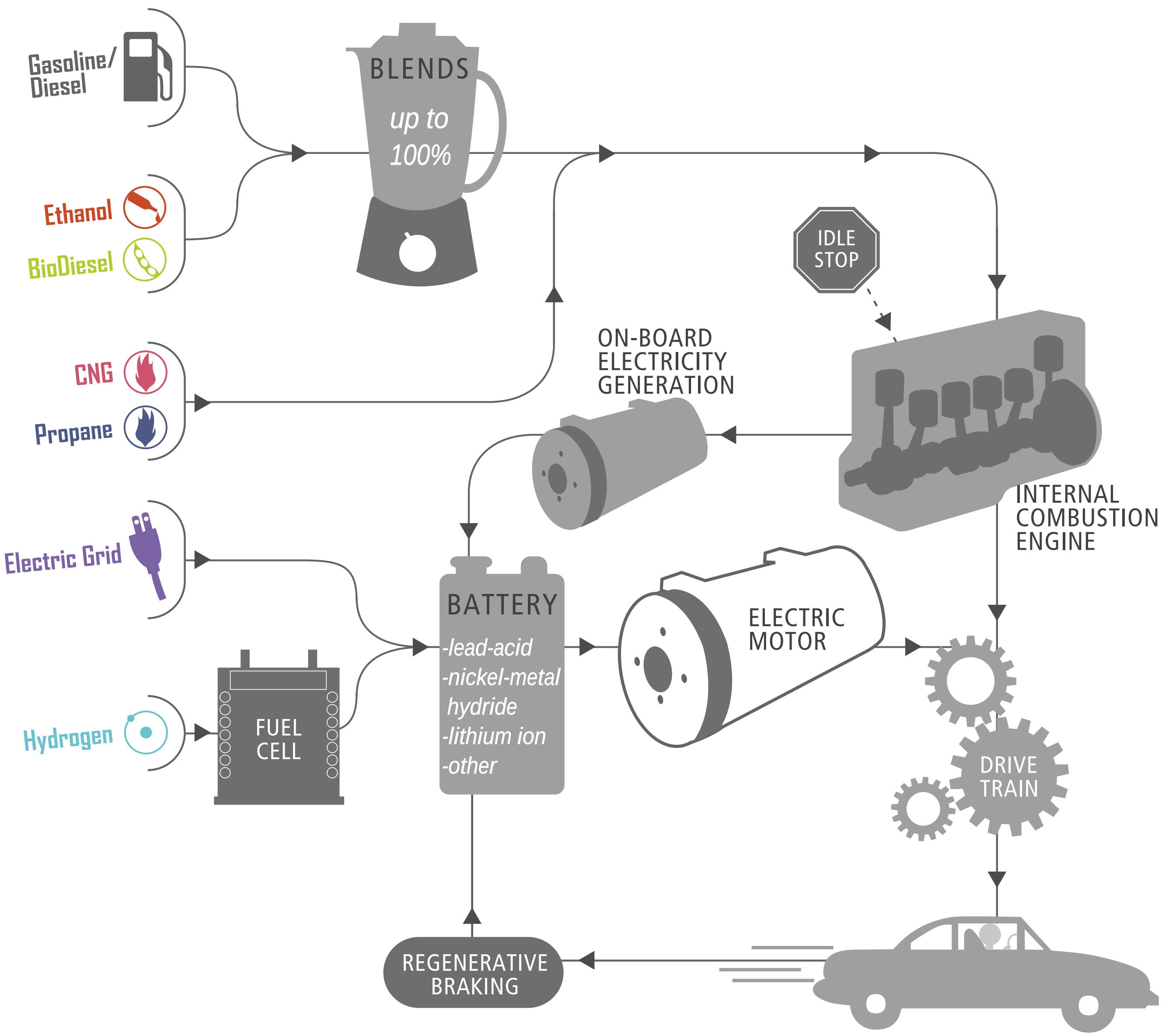
Summary of Alternative Fuel Vehicle Issues

	Vehicle Range	Refueling Type	Cost
INTERNAL COMBUSTION ENGINE — Biofuels: Ethanol, BioDiesel	Comparable to conventional vehicle	Refueling time for biodiesel and ethanol blends is comparable to diesel and gasoline. However, the distribution and refueling infrastructure required for ethanol and biodiesel is not fully compatible with the existing system. This will require investments in new fueling infrastructure. As a result, there is limited access to refueling stations for biodiesel and ethanol.	Slightly more expensive than counterpart fossil fuel on a gallon equivalency basis.
INTERNAL COMBUSTION ENGINE — Fossil Fuels: CNG, Propane	Vehicle Range is low compared to conventional vehicle	Similar to biodiesel and ethanol, the refueling time for natural gas and propane is comparable to gasoline and diesel. While pipeline infrastructure has been developed for natural gas, refueling stations are rare. Natural gas and propane may be best suited for fleets of limited range.	Natural gas costs less than gasoline and diesel on a gasoline gallon equivalent (GGE) basis. Propane costs more than gasoline and less than diesel on a GGE basis.
ELECTRIC MOTOR — Electric Grid, Hydrogen	Vehicle Range is very low compared to conventional vehicle*	Refueling times for grid charged electric vehicles is typically 4 to 12 hours depending on voltage. A 30 minute "quick charge" to 80% is possible at high voltages. The location of refueling stations is problematic. On-board charging systems have short refueling times, although hydrogen fueling is challenging due to volume required for gas tanks.	Grid electricity is lower in cost than gasoline. On-board ICE costs are low, on-board hydrogen fuel cells have high cost.
HYBRID MOTOR — Electric Grid + Gasoline/Diesel	Vehicle Range is comparable with conventional vehicle	Same as for conventional vehicle.	Lower fuel cost due to higher fuel economy. Higher vehicle cost.

*Nissan Leaf: 73 miles; Chevy Volt: 35 miles (without ICE assist)

Source: DVRPC

Schematic of Alternative Vehicle Components



The diagram in Figure 2 above provides a simplified overview of the relationship between the most common alternative fuel vehicle (AFV) technologies. Fuel/energy sources are shown on the left. Listed first are liquid fuels (gasoline, ethanol, and biodiesel) and gases (natural gas and propane) that are burned in internal combustion engines. These are followed by electricity used to charge the batteries for powering an electric motor. The electricity grid is shown first, followed by a hydrogen fuel cell, which allows on-board non-combustion conversion of hydrogen to electricity.

As the illustration shows, batteries may also be charged by on-board generation of electricity powered by an internal combustion engine. As indicated, there are several different battery technologies which provide power to an electric motor. Either an electric motor or an internal combustion engine can drive the vehicle via the drive train, or they can work together in a hybrid electric vehicle. Two other technologies are shown as well. The first is regenerative braking, which uses the energy of stopping the car to charge the battery. The second is "idle stop," which stops the engine when the vehicle is not moving, and then instantly restarts it when it is needed. Although idle stop technology is widely used in hybrid vehicles, it can also be deployed in traditional vehicles.

As the diagram shows, an almost limitless number of AFVs can be configured using various combinations of fuels and technologies—no one AFV will use all the fuels and technologies, of course, but will be made up of some combination. On the following page are schematic illustrations of how four types of AFVs currently on the market are configured.

Hybrid Electric Vehicle

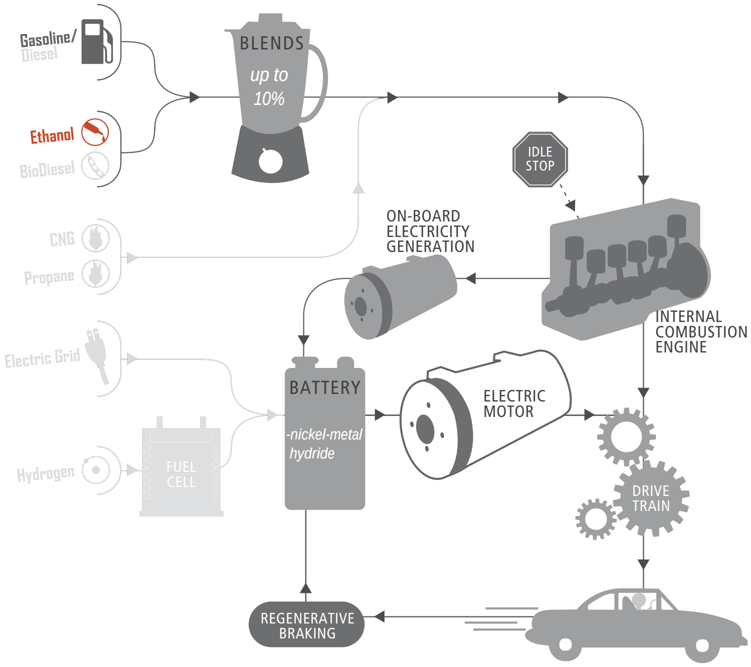


Figure 3 above shows the configuration of a hybrid electric vehicle (HEV), such as the Toyota Prius. It is a gasoline-fueled vehicle using both an internal combustion engine and an electric motor to drive the vehicle's wheels depending on power needs and battery charge. The electric motor is powered by batteries that are charged using an on-board generator. It also has controls to turn the internal combustion engine off when the vehicle is stopped ("idle stop").

Plug-in Hybrid Electric Vehicle

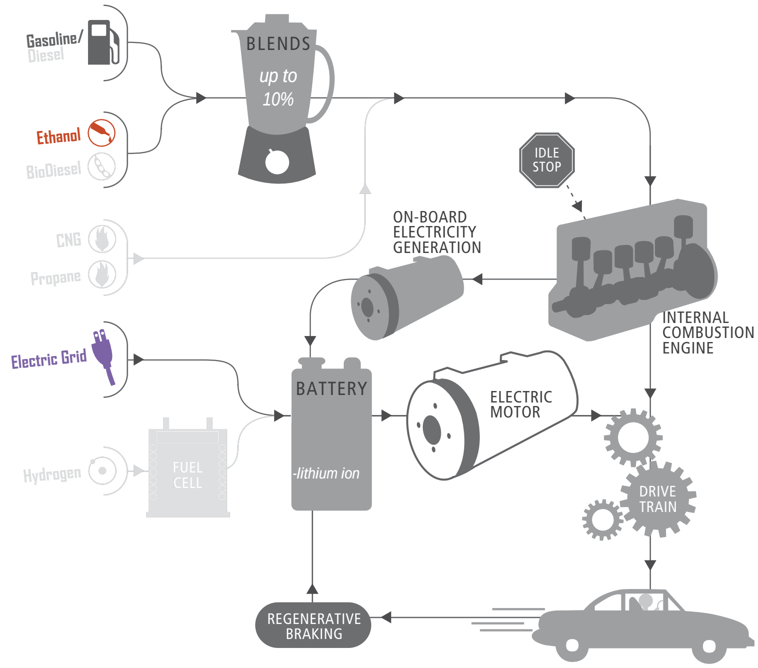


Figure 4 above shows the schematic of a plug-in hybrid electric vehicle (PHEV), such as GM's Chevrolet Volt. It is powered by an electric motor using a battery charged by plugging in the car to the grid. If the battery becomes discharged in use, an on-board gasoline-fueled internal combustion engine (ICE) recharges the battery via a generator. When the vehicle commands more power than the electric motor can provide, the on-board gasoline-fueled ICE directly assists in driving the wheels.

All-Electric Vehicle

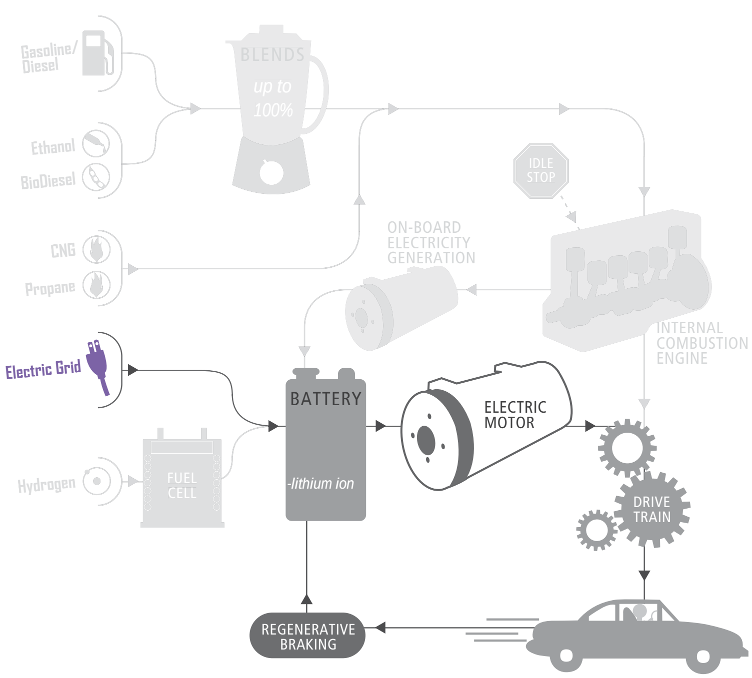


Figure 5 above shows an all-electric vehicle, such as the Nissan Leaf. It is powered by an electric motor using a lithium ion battery charged by plugging in the car to the electricity grid.

Natural Gas Vehicle

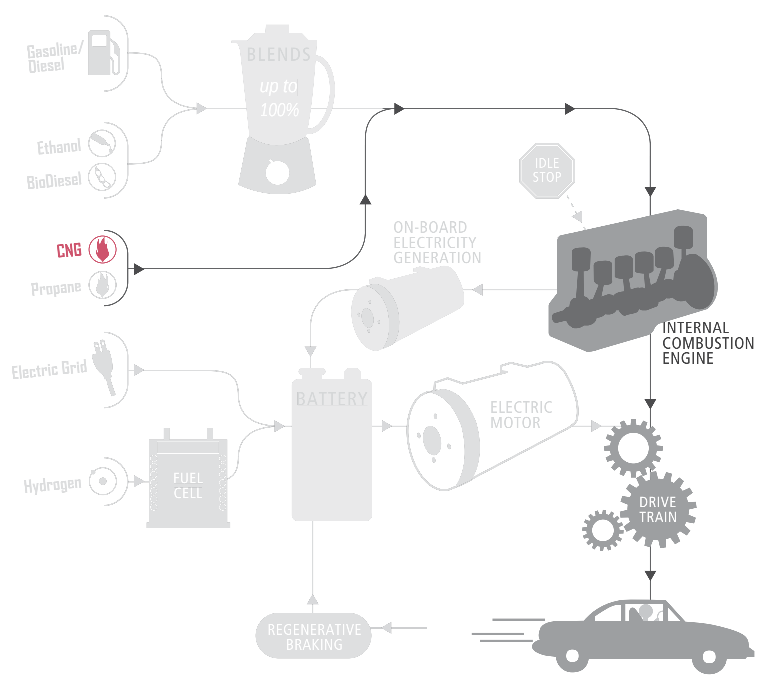


Figure 6 above shows a vehicle powered by compressed natural gas, such as the Honda Civic GX. It is powered by an internal combustion engine that burns natural gas instead of gasoline.

Conclusion

A successful transition away from our petroleum-based road transportation system will require a combination of technological advances, such as improvements in production of biofuels, improvements in battery storage, and faster battery recharge times, as well as expansion of distribution facilities and infrastructure for the new fuels.

The key findings of DVRPC's Ready to Roll? report include:

1: Some liquid biofuels have an energy density approaching that of gasoline and can be replenished very quickly in the vehicle, making them strong candidates as replacement fuels. Ethanol and biodiesel can be produced using feedstocks and technology that results in significantly lower GHG emissions compared to gasoline and diesel. However, some methods of ethanol production pose environmental and economic impacts comparable to those of gasoline. In addition, the current pipeline and distribution network is much less extensive than for gasoline.

To address these barriers:

- Continue research into low cost biofuel production using production processes that have lower GHG emissions and environmental impacts than current processes.
- Develop policies regarding installing pipeline and distribution infrastructure for biofuels, including fueling pumps at gasoline stations and fleet fueling operations.
- Encourage fleets to purchase biofueled vehicles in order to build demand.

2: Natural gas and propane are widely available, affordable fuels, and refueling is relatively quick. GHG emissions are significantly lower than for gasoline. However, the energy density of these fuels is low, and there is not a wide network of refueling stations. Natural gas and propane are well-suited for vehicle fleets that start and end the day in a central location where refueling can take place. Similar to gasoline, the production of these fuels has significant negative impact on the environment.

To address these barriers:

- Develop policies to encourage purchase of natural gas vehicles and installing natural gas fueling infrastructure for fleets.
- Develop policies to ensure transparency, cleaner extraction techniques, and proper safeguards to lessen the impacts of natural gas extraction and refinement.

3: Electric vehicles do not yet have an energy capacity that allows a vehicle range approaching that of the gasoline powered vehicle, and refueling time (charging time) is significantly longer than it is for gasoline. While in theory electric vehicles could be refueled anywhere the electricity grid extends, the siting and expense of refueling infrastructure remains a barrier (e.g., for those in dense urban areas without off-street parking). Emissions from these vehicles depend on the source of the electricity used to charge them. Battery production has significant negative impact on the environment.

To address these barriers:

- Continue research into increasing battery capacity and reducing charge time.
- Prepare the electric grid and pricing system for vehicle charging.
- Continue efforts to reduce GHG content of electricity.
- Encourage appropriate fleet purchases of electric vehicles.
- Hydrogen, which provides energy for fuel cell electric vehicles, can achieve a fast refueling time, but the energy density is very low, requiring large on-board hydrogen storage capacities or short ranges. Production of hydrogen is currently relatively expensive and is sourced from fossil fuels.

For more information on the alternative fuel vehicles discussed in this report, the following resources are provided:

The U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy:

Alternative Fuels and Advanced Vehicles Data Center: The Alternative Fuels and Advanced Vehicles Data Center (AFDC) is a comprehensive clearinghouse of data, publications, tools, and information related to advanced transportation technologies. **www.afdc.energy.gov/afdc/**

Alternative Fueling Station Locator: The U.S. Department of Energy, Energy Efficiency and Renewable Energy Web site has an online search tool where you may find the nearest alternative fueling stations by fuel type and region. **www.afdc.energy.gov/afdc/locator/stations/**

U.S. Department of Energy (USDOE) Clean Cities Program: The USDOE Clean Cities program's mission is to "advance the national, economic and energy security of the United States by supporting local decisions to reduce use of petroleum fuels in vehicles." Clean Cities carries out this mission through a network of over ninety volunteer coalitions throughout the county, who develop public/private partnerships to promote alternative fuels and vehicles, fuel blends, fuel economy, hybrid vehicles, and idle reduction. **www1.eere.energy.gov/cleancities/**

Clean Cities Coalitions in the DVRPC region:

The NJ Clean Cities Coalition (NJCCC): The goals of the NJCCC include the facilitation of the reduction of our dependence on imported oil, reduction of regional air pollution from vehicle emissions, assistance to stakeholders and other local businesses and public entities with regulatory environmental compliance, encouragement of economic development through job creation, and to create a positive community image. **www.njcleancities.org**

The Greater Philadelphia Clean Cities Program (GPCC): is a public—private partnership designed to promote the use and infrastructure for alternative fuel vehicles, or AFVs, in Eastern Pennsylvania. **www.phillycleancities.org/Pages/Default.aspx**

Fueleconomy.gov: This Web site is a partnership between the U.S. Department of Energy and the U.S. Environmental Protection Agency that compares gas mileage, emissions, air pollution ratings, and safety data for new and used vehicles, including alternative fuel vehicles.

Reports:

Transportation Research Board: Modal Primer on Greenhouse Gas and Energy Issues for the Transportation Industry (2010) TRB Transportation Research Circular E-C143: Modal Primer on Greenhouse Gas and Energy Issues for the Transportation Industry is designed to provide transportation decision makers with an inclusive, educated, and objective overview of the current state of the transportation industry from a greenhouse gas and energy standpoint.

Transportation's Role in Reducing U.S. Greenhouse Gas Emissions: Volume 1 USDOT, 2010 This study examines the impact of a number of proposed strategies for reducing transportation GHG emissions, including the introduction of alternative fuels. The assessments are based on published scientific literature, current policy studies, and best professional estimates. Each strategy is assessed relative to projections of future transportation GHG emissions based on U.S. Energy Information Administration Annual Energy Outlook (AEO) estimates.

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DELAWARE VALLEY dvrpc REGIONAL PLANNING COMMISSION

The Delaware Valley Regional Planning Commission is dedicated to uniting the region's elected officials, planning professionals, and the public with a common vision of making a great region even greater. Shaping the way we live, work, and play, DVRPC builds consensus on improving transportation, promoting smart growth, protecting the environment, and enhancing the economy. We serve a diverse region of nine counties: Bucks, Chester, Delaware, Montgomery, and Philadelphia in Pennsylvania; and Burlington, Camden, Gloucester, and Mercer in New Jersey. DVRPC is the federally designated Metropolitan Planning Organization for the Greater Philadelphia Region — leading the way to a better future.

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