Summary of Current Status of Alternative Fuels and Vehicles

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1. INTRODUCTION

Motor vehicles are the underlying source for two major global issues the United States (U.S.) faces: 1) the dependence on foreign oil from unstable political regions, and 2) the increase in carbon dioxide (CO₂) emissions, a leading contributor of greenhouse gases (GHGs) that affect Earth’s climate. There are 200 million drivers traveling 10 trillion vehicle miles each year in the U.S. In the Denver region alone, vehicles are driven more than 70 million miles each day.

Dependence on foreign oil: A matter of U.S. Security
The U.S. uses about 14.5 million barrels of oil per day for transportation (which equates to 609 million gallons) and imports more than 60% of its petroleum, two-thirds of which is used to fuel vehicles in the form of gasoline and diesel. The demand for petroleum imports is increasing and with much of the worldwide petroleum resources located in politically volatile countries, the U.S. is vulnerable to supply disruptions.

Climate Change
While the U.S. contains only 5% of the world’s population, it is responsible for 25% of global GHG emissions. Transportation accounts for 28% of GHG emissions in the U.S., second to electric power (Figure 1). It is the fastest growing source of GHGs, accounting for 47% of the net increase in total U.S. GHG emissions since 1990. Trends in Colorado are similar, with electric power being the lead source of CO₂ emissions at 42%, followed by transportation at 31% (Figure 2). Many scientists say that cutting GHG emissions by 20% from 2005 levels by 2020 and 83% by 2050 is necessary to avert the worst consequences of global warming. The State of Colorado has set a target of reducing GHG emissions 80% below 2005 levels by 2050. Employing GHG reduction strategies in the transportation sector can have a significant impact on CO₂ levels. Transportation CO₂ reduction can be viewed as a four-legged stool, with one leg related to the carbon content in fuels, another related to vehicle fuel efficiency, a third to the amount to driving or vehicle miles traveled (VMT ), and a fourth leg related to improved operational efficiency of existing roadways (Figure 3). While all four of these reduction strategies are crucial, this report focuses on components of the first two strategies; specifically, alternative and emerging fuels, and alternative and advanced vehicle technologies.
The benefits associated with the use of alternative fuels and alternative vehicle technology in lieu of gasoline and petroleum include security, environmental and health benefits. These benefits apply to most of the fuels and vehicles discussed in this report. Additional benefits, as well as challenges and controversy, will be discussed under each fuel and vehicle type.

Alternative and emerging fuels (Section 2) are discussed in the first part of this report, followed by alternative and advanced vehicles types (Sections 3 and 4, respectively).

Section 5 of this paper includes a brief discussion on the various incentive types and programs that are available for alternative fuel vehicles, identifying many resources available at the federal and state levels, where further information can be obtained.

**Figure 2**

2005 Colorado CO2 Emissions from Fossil Fuel Combustion

- Residential: 9%
- Commercial: 4%
- Industry: 14%
- Transportation: 31%
- Electric Power: 42%


**Figure 3**

GHG Reductions from Transportation

2. **ALTERNATIVE AND EMERGING FUELS**

According to the Energy Policy Act of 1992 (EPAct), alternative fuels are defined as non-petroleum based fuels that could help reduce the dependence on foreign oil. Alternative fuels come in the form of both renewable and non-renewable fuels. This section identifies various alternative fuels, vehicle types they are compatible with, additional benefits, challenges and/or related controversy, and other pertinent information. The Alternative Fuels and Advanced Vehicles Center, which is part of the Department of Energy (DOE), is an online resource that has a section dedicated to identifying alternative fueling stations by type and by state. Alternative fueling stations are located throughout the United States and their availability continues to grow. The following link from the DOE’s Alternative Fuels and Advanced Vehicle Data Center allows users to find alternative fuels stations throughout the U.S. and by state. Additional resources on alternative fuels can be found in the Incentives and Resources section of this paper.

A. **Biodiesel (B100)**

Biodiesel is a renewable, domestic fuel produced from a wide range of vegetable oils, animal fats, or recycled restaurant greases. Pure or neat biodiesel, also known as B100, differs from raw vegetable oils since it does not contain glycerin, which gets removed through a refinery process called transesterification. Biodiesel and petroleum can be blended together at any ratio. The most common blend is B20 (20% biodiesel and 80% diesel), since any vehicle that currently uses petroleum diesel can use up to a B20 blend with limited or no modification to the engine. Not all diesel manufacturers cover biodiesel use in the warranties, therefore the U.S. Department of Energy (DOE) suggests contacting the vehicle manufacturer before choosing to use biodiesel.

Biodiesel is non-toxic, which makes it safe to transport and store. There are environmental and health benefits as well, since its use results in the reduction of commonly known emissions including, but not limited to, hydrocarbons (HC), carbon monoxide (CO) and particulate matter.

Because biodiesel use lowers emissions of particulate matter, many cities and counties have incorporated biodiesel into their fleet fuel supplies in a variety of mixtures. Fleet managers can adjust the blend of biodiesel they use from 100% (B100) to a mix of 5% biodiesel and 95% regular diesel (B5), depending on their goals and budgets.

It is the goal of the National Biodiesel Board (NBB) to replace the equivalent of 5% of the nation’s on-road diesel fuel with biodiesel by 2015. In 2008, approximately 700 million gallons of biodiesel was produced domestically in the United States, with 691 fuel stations available. According to the DOE, there are 24 biodiesel stations in Colorado, with 9 located in the Denver region.

B. **Electricity**

Electricity is considered an alternative fuel when used to power electric vehicles (EVs) and plug-in hybrid electric vehicles (PHEVs) directly from the power grid. Vehicles that run on electricity emit zero tailpipe emissions. Any emissions come from the electricity production process at power plants where the electricity is generated. The electric grid can be powered by both conventional, non-renewable sources such as coal and nuclear, or from renewable energy.
sources such as wind, solar, or geothermal. The net emissions are zero if the vehicle is exclusively running on electricity derived from a renewable resource. More discussion on the types of vehicles fueled by electricity (PHEVs, BEVs, HEVs), as well as the Vehicle to Grid (V2G) program, can be found in the next section of this paper on alternative fuel vehicles (AFVs).

C. Ethanol

Ethanol is an alcohol-based fuel made from various plant materials derived from corn (what most ethanol in U.S. is currently comprised of), barley, wheat, sugar cane, and fruit. Almost half of U.S. gasoline contains ethanol in a low-level blend, which oxygenates the fuel, thereby reducing air pollution. A high-level blend, E85, is a blend of ethanol (85%) and gasoline (15%). Only E85 or higher is considered an alternative fuel by the EPAct. All vehicles have the capability to run on low-level blends (E10) or lower. E10 or greater cannot legally be used in non-flexible fuel vehicles. Flex fuel vehicles (FFVs) have the ability to run on E85, conventional gasoline, or a combination of both. As of 2008, there were approximately 7.3 million FFVs on the road in the U.S. and approximately 1,781 E85 fueling stations. Seventy-five of these stations are located in Colorado.

There are some challenges to ethanol. Vehicles using ethanol get approximately 20–30% fewer miles per gallon (mpg) than using pure gasoline, since ethanol contains less energy than gasoline. Engines are now being designed to increase fuel efficiency of ethanol. Another challenge is that ethanol cannot be transported through pipelines with gasoline because it picks up excess water and impurities. Many argue that the U.S. currently lacks the infrastructure to support wide ethanol use, and because it can only be transported through trucks, trains and barges, it's more expensive to transport.

Ethanol use is not without controversy. Many argue that the energy required in growing the grain and then transforming it into ethanol requires more energy from fossil fuels than the ethanol generates. The process has become more efficient over time but there’s no absolute consensus in the scientific community. A study published in Environmental Science and Technology found that cars fueled by ethanol could be as or more damaging to human health as those running on conventional gasoline power. The study used a model that compared the effects of a fleet of vehicles running on E85 to a fleet running on 100% gasoline. The model showed that using E85 in fleets resulted in an increase in ozone which, when inhaled, can inflame lung tissue, worsen asthma, and impair the body’s immune system. Additionally, while E85 decreases two cancer-causing compounds – benzene and butadiene – in the atmosphere, it increases the levels of two others – formaldehyde and acetaldehyde. A study conducted by the EPA showed that over a 30-year time period, corn-ethanol plants powered by coal or natural gas produced more emissions than gasoline, except when powered by the cleanest possible power.

Because the majority of ethanol is derived from corn crops, it is also argued that a high demand for this fuel could result in diverting environmentally vital land, like forests and grasslands, to grow the crops. There are also many critics who argue against using a food crop like corn as a fuel, when there are food shortages around the world and its production pushes food prices higher.

On May 6, 2009, the Obama administration proposed rules to limit emissions of climate-changing gases from the manufacture of ethanol, a major step towards defining a policy on
ethanol, which would likely curtail the expansion of corn ethanol production. The Environmental Protection Agency (EPA) issued a draft rule (also May 6, 2009) on a “renewable fuel standard including provisions on how much carbon dioxide can be released in the production of ethanol and other biofuels.” (New York Times – [http://www.nytimes.com/2009-05-06/business/energy-environment/06ethanol.html](http://www.nytimes.com/2009-05-06/business/energy-environment/06ethanol.html)) Clearly, the argument for and against corn ethanol is ongoing and viewpoints and policies are rapidly changing.

D. Cellulosic ethanol – an emerging fuel

Ethanol has been referred to as an “important bridge” to better biofuels by Environmental Protection Agency (EPA) administrator Lisa Jackson. Cellulosic ethanol is considered one of the better biofuels. Many biofuel experts believe that corn ethanol is a transitional technology and will be replaced by cellulosic. Cellulose, derived from plant matter, cannot be used for food, and is deemed a waste product by the agriculture industry. Such materials, also referred to as biomass, that can be converted into cellulosic ethanol include; timber harvesting residues, corn stover (remaining stalks after corn is harvested), sawdust, paper pulp, hog manure, municipal garbage, grasses and wood (including switch grass), eucalyptus and hybrid poplar. The production of cellulosic ethanol emits minimal greenhouse gases and requires less water than is used in the production of conventional ethanol. Additionally, far less land is required to grow the energy crops to produce cellulosic ethanol. With the abundant agricultural and forest resources in the U.S. that can be converted to biofuels, the DOE Billion Ton Study found that these resources can be used to displace approximately 30% of current gasoline consumption by 2030, on a sustainable basis. The waste products of all American farms, converted into cellulosic ethanol, would provide as much fuel as the U.S. currently imports from Venezuela and the Persian Gulf combined.

The production of cellulosic ethanol is complicated and expensive, though it is expected to become cost competitive by 2012. Range Fuels, based in Broomfield, CO, has developed new technologies that generate no toxic waste and very few greenhouse gases in the production of cellulosic ethanol. According to Chris Colquitt, a driver relationship manager for General Motors, the company is on track towards meeting its goal to reduce oil use by 30% with cellulosic ethanol by 2030. Finally, the proposed renewable fuel standard, issued by the EPA on May 6, 2009, maintains a quota for the production of 100 million gallons of cellulosic ethanol by 2010.

E. Hydrogen (Fuel Cells)

Hydrogen gas, the simplest and most abundant element in the universe, has the potential to revolutionize transportation. Hydrogen is mainly being researched as an energy source for fuel cell vehicles.

Water is the only emission as a result of using hydrogen in cell fuels, a unique benefit to this fuel type. Additionally, when used with fuel cells, hydrogen has tremendous potential in other energy applications such as generators and grid electricity production. If hydrogen is produced with renewable energy for use in fuel cell vehicles, future transportation could virtually be pollution-free and no longer dependent on imported petroleum. While the benefits are apparent, there are technological challenges. Hydrogen exists minimally in the Earth’s atmosphere and is mainly found in the form of water, hydrocarbons (such as methane), and other organic matter. The main challenge is “unlocking” it from these compounds.
Research and development is currently being conducted on creating hydrogen fuel cells to power vehicles. Recently, the U.S. Energy Secretary announced that funding for fuel cell vehicles research and development will be cut from the federal budget beginning in 2010. No hydrogen vehicles are currently commercially available at this time.

F. Methanol

Methanol, commonly known as wood alcohol can be used as an alternative fuel. It occurs naturally in the environment and is created synthetically by a process using natural gas as a feedstock.

The use of methanol has dramatically declined since the 1990s and vehicles that run on this fuel are no longer being manufactured by automakers. It is still used as fuel for competition types of vehicles such as monster trucks, dirt bikes, and drag and mud racing vehicles.

G. Natural Gas

Natural gas, a domestically produced alternative fuel, is comprised of 90% methane and a mixture of hydrocarbons produced from gas wells from crude petroleum production. This fuel is clean-burning and is readily available to customers.

Natural gas can be used in vehicles that run on “dedicated” natural gas or bi-fuel vehicles that can use natural gas as well as conventional fuels like gasoline or diesel. Only compressed natural gas (CNG) and liquefied natural gas (LNG) can be stored in a vehicle. The Honda Civic GX, which uses CNG, is the only light-duty original engine manufacturer (OEM) vehicle that is commercially available. Other types of natural gas vehicles are available through conversions or system retrofits, including light-, medium-, and heavy-duty vehicles ranging from taxi fleets, to transit and school buses, to refuse haulers. According to NGV America, there are over 120,000 natural gas vehicles (NGVs) on the road and over 1,100 fueling stations in the U.S. Approximately 16 stations exist in the Denver region.

H. Propane

Propane, also known as liquefied petroleum gas (LPG), is a readily available by-product of natural gas processing and petroleum refining. It’s the third most commonly used fuel in vehicles behind gasoline and diesel. Because the fuel has a high energy density, propane vehicles have a good driving range.

Propane has several benefits over traditional fuels and is readily available. Additionally, it is a safer fuel to use due to propane tanks being 20 times more resistant to punctures than gasoline tanks. It is also the least flammable of all alternative fuels.

Currently, there is only one light-duty vehicle, the propane-dedicated Ford F-150, commercially available. Conversions by a certified installer are available for most light-duty vehicles and other vehicles such as school buses and street sweepers. It is estimated there are over 270,000 propane-powered vehicles in the U.S. and 2,127 propane fueling stations, of which 45 are located in Colorado.
I. P-Series

P-Series is a blend of natural gas liquids known as pentanes plus, ethanol, and the biomass-derived co-solvent methylethrahydrofuran (MeTHF). The ingredients of this blend are all domestically produced, renewable and non-petroleum. P-Series can’t be used in regular gasoline-powered vehicles; however, it can be used in lieu of gasoline, or blended with any portion of gasoline, in FFVs. P-Series was officially designated an alternative fuel by the U.S. DOE in 1999, though currently it is not produced in large quantities nor widely used.

J. Emerging fuels

In addition to the aforementioned alternative fuels, there are emerging fuels that are currently under research and development, but have not yet been fully commercialized. Emerging fuels are either designated alternative fuels or under consideration to be so by the EPAct. Like alternative fuels, emerging fuels share many of the same benefits. Emerging fuels include:

- Biobutanol (blends of 85% or more with gasoline)
- Biogas
- Biomass to Liquids (BTL)
- Coal to Liquids (CTL)
- The Fisher-Tropsch Process
- Gas to Liquids (GTL)
- Hydrogenation-Derived Renewable Diesel (HDRD)
- Ultra-Low Sulfur Diesel (ULSD) (EPAct only considers ULSD produced from non-petroleum and renewable sources an alternative fuel)

More information on emerging and advanced fuels can be found on the webpage of the U.S. Department of Energy's Alternative Fuels and Advanced Vehicles Data Center.
3. **ALTERNATIVE FUEL VEHICLES**

This section and the next give an overview of alternative fuel vehicle (AFV) and advanced vehicle technologies; identifying the array of technologies that are currently in use, as well as future technologies and prototypes still being researched. These sections also cover some of the various types of vehicles that manufacturers are producing.

Today, there are more than a dozen alternative and advanced vehicles in production or use. The primary users of these vehicles and fuels are government-regulated and voluntary private fleets; however, consumers are showing a growing interest in them. Many vehicles either powered exclusively by alternative fuels or by a combination of gasoline and alternative fuel are converted from vehicles originally designed to run on conventional gasoline. These vehicles are referred to as converted, conversion, or retrofitted vehicles. The most common type of conversion is altering vehicles to run on compressed natural gas (CNG) and liquefied petroleum gas (LPG).

Alternative fuel vehicles, as defined by the Energy Policy Act (EPAct) of 1992, include any dedicated, flexible-fuel or dual-fuel vehicles designed to operate on at least one alternative fuel. Qualifying vehicles include electric, flexible-fuel, natural gas, and propane vehicles. They are available in a variety of models ranging from light-duty sedans, SUVs, pickup trucks and vans to heavy-duty buses and trucks.

**A. Diesel Vehicles**

Most diesel vehicles can run on biodiesel blends without engine modification. In January 2001, a ruling made it possible for fleets to earn EPAct credits for use of biodiesel blends of at least 20%. While the ruling does not make B20 an alternative fuel, it gives one credit for every 450 gallons of pure biodiesel used in biodiesel blends.

**Benefits/challenges**

B20 (and lower-level blends) can be used in nearly all diesel equipment and generally do not require engine modification, making it the most common biodiesel blend in the U.S. According to the U.S. DOE, advanced diesel vehicles using EPA-mandated ultra-low sulfur diesel (ULSD) fuel are among the most fuel-efficient vehicles available today, resulting in substantially lower emissions and improved engine efficiency. Biodiesel contains less energy than petroleum diesel; however, B20 users report no noticeable difference in performance or fuel.

**Technology curve**

Diesel vehicles are available in light- and heavy-duty vehicles and are used by both individuals and fleets alike. Diesels seem to be making a comeback and the demand for light-duty diesel vehicles could double in the next 10 years. More auto manufacturers will be producing light-duty diesels, and these vehicles will be more fuel efficient and environmentally friendly than ever.

**B. Electric vehicles (EVs)**

Electric vehicles are powered exclusively by electricity, which is stored in a rechargeable battery or other energy storage device. The device is replenished by plugging the vehicle into a power source, through an onboard charger or a charger located outside the vehicle. Because these
vehicles obtain electricity from the power grid, the charging process indirectly results in air pollution unless powered from a source that is 100% renewable. The vehicles themselves however, produce no exhaust or emissions. These vehicles are different from Plug-in Hybrid Electric Vehicles (PHEVs) which also contain internal combustion engines (ICEs). PHEVs are discussed later in this section.

**Benefits/challenges**
As previously mentioned, electric vehicles are considered zero emissions vehicles since they produce no tailpipe or evaporative emissions. They do get electricity from the power grid, so unless the power is derived from a renewable source, it is not pollution free. More than 95% of the electricity used to charge EVs is produced domestically, therefore reducing dependence on foreign oil. Additionally, because EVs have fewer moving parts than an internal combustion engine (ICE), they require less service than gasoline-powered vehicles. They also have quiet motors and stronger acceleration.

The challenges with electric vehicles are related to the battery. The batteries are heavy, expensive, and offer limited power and range. Most EVs can only go up to 150 miles before recharging versus gasoline vehicles that typically get up to 300 miles before refueling. Recharge time takes between 4-8 hours. Research is underway to improve battery technologies and resolve these issues.

**Technology curve**
Currently, there are no light-duty electric vehicles available by major manufacturers. Electric vehicles are available as neighborhood electric vehicles (NEVs) and as scooters and bicycles. Light-duty vehicles can be converted to electric vehicles with conversion kits but can be very costly. It is expected sometime in 2010 that light duty electric vehicles will be made available to the public by several niche manufacturers.

Tesla Motors, for example, is currently taking orders for its high-end models, which are expected to be delivered in 2012. Prices start at approximately $50,000, have a drive-range of 160 to 300 miles, and a 45-minute battery charge time.

**C. Flexible-fuel vehicles**
Flexible-fuel vehicles or flex-fuel vehicles (FFVs) are capable of operating on E85, gasoline, or a mixture of both. Unlike bi-fuel vehicles, these vehicles contain one fueling system. With a few exceptions, they are identical to gasoline-only models.

**Benefits/challenges**
The main benefit is these vehicles can run on E85, displacing petroleum demand. While there is no loss in performance when using E85, ethanol contains less energy than gasoline and provides about 20-30% fewer miles per gallon.

**Technology curve**
FFVs have been around since the 1980s and there are currently dozens of light-duty models available that can be found at most dealerships.
D. Natural Gas Vehicles

There are two types of vehicles that run on natural gas: dedicated and bi-fuel. The dedicated vehicles are powered exclusively by natural gas, whereas the bi-fuel vehicles have two separate fueling systems enabling them to run on either conventional fuel like gasoline or natural gas. Natural gas vehicles run on CNG or LNG, both considered alternative fuels. Dedicated natural gas vehicles produce fewer emissions and perform better than bi-fuel vehicles.

Benefits/challenges

NGVs produce significantly lower amounts of harmful emissions and decrease demand on foreign oil. It has been reported by some vehicle owners that natural gas vehicles have a longer service life of 2-3 years compared to gasoline and diesel vehicles, as well as extended time between required maintenance. Like vehicles that run on ethanol, the driving range is generally less than diesel and gasoline-fueled vehicles due to the lower energy content.

Technology curve

OEM natural gas vehicles have been on the decline in recent years. Many light-duty vehicles, however, can reliably and economically be retrofitted to operate on natural gas. The Honda Civic GX Sedan is the only light-duty, dedicated natural gas vehicle that is available. The 2009 model starts at just over $25,000. Several types of heavy-duty vehicles use natural gas including transit buses, school buses, and refuse trucks.

E. Propane Vehicles

Propane (LPG) is considered an alternative fuel under the EPAct and has been used in vehicles since the 1920s. Most propane vehicles are converted from gasoline vehicles. Like natural gas vehicles, there are dedicated propane vehicles that run exclusively on propane and bi-fuel propane vehicles with two separate fueling systems.

Benefits/challenges

One of many benefits in using propane as a fuel is lower maintenance costs. The engine life of a propane vehicle is up to two times that of gasoline engine due to its high octane rating and low carbon and oil contamination characteristics. The power, acceleration, and cruising speed of propane vehicles are similar to gasoline-powered vehicles, however because the energy content of propane is 25% less than gasoline, the driving range of dedicated vehicles is generally less.

Technology curve

Converting or retrofitting gasoline-powered vehicles to run on propane can be done economically and reliably by certified installers. It is estimated there are more than 270,000 propane vehicles in the U.S and more than 10 million worldwide, many of which are used in fleets, including light- and heavy-duty trucks, buses, taxicabs, police cars, street sweepers, school buses, and rental and delivery vehicles.
4. **ADVANCED VEHICLES**

The terms “advanced technology” or “advanced vehicle” include vehicle types that use electricity to power the motor including electric, hybrid-electric, plug-in hybrid electric and fuel cell vehicles. Under the EPAct, hybrids do not qualify as alternative fuel vehicles since they are powered primarily by conventional gasoline.

**A. Hybrid Electric Vehicles**

A hybrid electric vehicle (HEV) is made up of the combination of an internal combustion engine of a conventional vehicle and a battery electric motor of an electric vehicle. HEVs do not get plugged in, but rather the battery is recharged by regenerative braking. HEVs are not considered alternative fuel vehicles under the EPAct, however they do qualify for certain incentives.

**Benefits/challenges**

HEVs have the performance, driving range and convenient fueling of conventional (gasoline and diesel) vehicles, yet they have the potential to be two to three times more fuel-efficient. Because HEVs use conventional fuels as well as an electric engine, they can get up to 40 to 70 miles per gallon (mpg). The overall costs of HEVs are almost competitive with similar conventional vehicles, as purchase cost premiums may be offset by savings in fuel costs and tax incentives.

**Technology curve**

While the current HEVs use conventional fuels such as gasoline and diesel, future models have the potential to use alternative fuels such as biodiesel, natural gas, ethanol or some other type of biofuel in conjunction with the battery electric motor. HEVs are flexible, used for both personal transportation and in fleets, and are widely available in light-duty vehicles, and becoming more popular for medium- and heavy-duty trucks. Some of the more popular light-duty HEVs include, but are not limited to, the Toyota Prius, Honda Civic and the Ford Escape Hybrid.

**B. Plug-in Hybrid Electric Vehicles**

The plug-in hybrid electric vehicle (PHEV) shares the same characteristics as the HEV, having an electric motor and internal combustion engine, but the battery can also be recharged by plugging the vehicle into a standard 110-volt electrical outlet, found in most households. Because the battery packs in PHEVs are larger than those found in conventional HEVs, most of the power comes from the stored electricity during a typical day of driving. PHEVs are not considered alternative fuel vehicles under the EPAct; however, they do qualify for incentives.

**Benefits/challenges**

While the PHEVs are still in the pre-commercial stage of development, there are many foreseen benefits to this vehicle technology. The cost for electricity to power PHEVs is estimated to be less than a quarter of the cost of gasoline, resulting in substantial cost savings. If the power used to charge the battery is derived from nuclear or a renewable energy source, then no fossil fuels are used during the all-electric range. Other benefits include reduced trips to the gas station, convenience of home recharging, potential opportunities to provide emergency back-up power in the home, and vehicle-to-grid (V2G) applications.
Research and development efforts are bringing the PHEV closer to widespread commercialization and vehicles are already being tested. There are some barriers that need to be removed, the greatest being the battery technology. In order to be competitive, the batteries need to be cheaper, lighter, less bulky and longer lasting.

**Technology curve**

Vehicle to grid (V2G) technology is emerging in conjunction with the PHEV. V2G technology allows a two-way connect between the PHEV and the local utility grid. When the vehicle is not in use, it can be plugged into the grid and the utility provider could take advantage of the extra electricity storage capacity in the vehicle batteries to help meet peak electricity demand. Essentially, when the vehicle is plugged-in during the peak energy use of the day, it feeds stored energy back to the grid, and at night, the vehicle re-charges when energy demand is low. This technology will allow utility companies to buy back energy from PHEV owners. President Obama recently said he wants one million PHEVs on the road by 2015 and wants them to average 150 mpg. This indicates there is political support for continued progress of this vehicle technology.

Hybrids-Plus in Boulder, Colorado has converted two HEVs, the Ford Escape and the Toyota Prius, into PHEVs, which have been field-tested for over two years now. General Motors Corp.’s Chevrolet Volt is one of the first major plug-in models to test the market and is scheduled for production in limited number in late 2010. An estimated cost of $40,000 may prove to be too expensive to be commercially successful in the short term. According to GM, Toyota is planning a limited introduction of 150 Prius PHEVs to commercial fleet owners in the U.S. in 2010.

**C. Fuel Cell Vehicles**

Fuel cells are similar to the battery in an electric car in that they power the electric motor with electricity. They differ from a battery, however, in that they generate their own electricity, rather than just store it. A fuel cell is a device that uses hydrogen (or hydrogen-rich fuel) and oxygen (air) to create electricity (by an electrochemical process), which is then stored in a battery and powers the electric motor of the vehicle. The only by-product that fuel cells produce is water, which is typically released as vapor. Fuel cells can also be fueled with hydrogen-rich fuels, such as methanol, natural gas, petroleum distillates, or gasoline, which are passed through “reformers” to extract the hydrogen from the fuel. This process, called reforming, does emit CO₂, though much less than conventional gasoline-powered vehicles.

There are many benefits associated with fuel cells. Fuel cell technology is very attractive as a fuel for transportation because of its ability to cleanly produce electricity from hydrogen and oxygen. Fuel cells are safe, reliable, convenient, and have a high power density. The refueling process can be completed within a few minutes, whereas battery recharging can take hours. The materials used to produce fuel cells, which includes platinum, are expensive. The greatest technical challenge is the storage of hydrogen onboard the vehicle. Since the amount of hydrogen that can be stored onboard is limited, FCVs don’t travel as far as a conventional vehicle on a full tank of fuel. Currently, they get about 200 miles before having to refuel. A vehicle needs to have a driving range of 300-400 miles between refueling to be competitive with vehicles that run on gasoline. Cold weather poses another issue since fuel cell systems contain water, which freezes at low temperatures.
Fuel cell vehicles are still in the research and development stage but are closer to production as technology and infrastructure improves. NREL has been working on developing durable, less expensive materials for fuel-cell components. A recent decision by the Energy Secretary, however, will likely slow down or halt government-funded research. On May 7, 2009, Energy Secretary, Dr. Steven Chu said in releasing energy-related details of the administration’s budget, that cars powered by hydrogen fuel cells would not be practical over the next 10 to 20 years and the government will cut off funds for the vehicles’ development beginning in 2010; effectively a $100 million cut from 2009.

Dr. Arnold Miller, at Vehicle Projects LLC in Golden, CO, has made great strides in fuel cell research and development, though his work specifically focuses on fuel cells in locomotives. He has been involved in projects with the Burlington Northern Santa Fe (BNSF) Railroad and the U.S. Army. BNSF, which serves ports in Southern California, is implementing fuel cell locomotive technology to reduce traffic and improve air quality. The U.S. Army is funding a project with the intent of locating fuel cell locomotives on army bases for security-related reasons. Fuel cells can also serve as generators to power a hospital and other essential facilities in the case of losing electricity from the grid in an attack or otherwise.
5. INCENTIVES

Incentives available for alternative fuel vehicles are ever-changing as new technologies and policies evolve. DRCOG staff is in the process of creating a section within the Regional Sustainability section of the DRCOG website, dedicated to incentives available, along with other valuable resources on alternative fuels and vehicles, such as alternative transit and fueling options for fleets. This section of the website will be updated on a regular basis to reflect the most current information available. Refer to the Alternative Fuels and Vehicles section at; http://www.drcog.org/index.cfm?page=RegionalSustainability

Incentives for alternative fuel vehicles are available in the form of tax deductions and tax credits. These two incentive types differ from one another and are defined as follows:

- A tax deduction reduces the amount of income for which a person is taxed. For example, if one’s taxable income were $50,000, a $2,000 deduction would reduce it to $48,000. Therefore, one would pay taxes on an income of $48,000 instead of $50,000, which means one’s actual savings would be a fraction of the $2,000 deduction.

- A tax credit reduces the total amount of income tax that a person owes. So, if one owes $10,000 in federal income tax, a $2,000 credit would reduce the amount owed to $8,000. With a credit, one’s actual savings would be $2,000. Tax credits go to the purchaser of the vehicle, whether that’s a business or individual, so long as the vehicle is owned.

A. Federal

DOE and EPA

The United States Department of Energy (DOE) and the United States Environmental Protection Agency (EPA) have created a website identifying tax credits available for AFVs. Qualifying AFVs purchased or placed into service between January 1, 2005 and December 31, 2010 may be eligible for a federal income tax credit of up to $4,000. Vehicles placed into service before January 1, 2005 may be eligible for a $2,000 clean-fuel vehicle tax deduction. For more information refer to the following link; http://fueleconomy.gov/feg/tax_afv.shtml

IRS’s Alternative Motor Vehicle Credit Information

For an up-to-date status of IRS tax credits for hybrids and AFVs, refer to the link below provided by the IRS. The Alternative Fuel Motor Vehicle Credit was enacted by the Energy Policy Act of 2005 and includes separate credits for four distinct categories of vehicles: Qualified Hybrid Vehicles, Qualified Fuel Cell Vehicles, Qualified Alternative Fuel Motor Vehicles (QAFMV) and Heavy Hybrids, and Advanced Lean-Burn Technology Vehicles. http://www.irs.gov/businesses/corporations/article/0,,id=202341,00.html

B. State (Colorado)

Alternative Fuels and Advanced Vehicles Data Center- Colorado Incentives and Laws

The Colorado legislature meets annually from early January to early May. During the session, the governor must sign or veto legislation within 10 days of transmittal (except Sundays) or it becomes law without signature. The information provided on website was last updated in July 2008.
http://www.afdc.energy.gov/afdc/progs/state_summary.php/CO

**Governor’s Energy Office (GEO)**
This link to the GEO includes summaries of current energy related federal tax incentives, including transportation and alternative fuel incentives.
http://www.colorado.gov/energy/index.php/?/resources/energy-related-federal-tax-incentives/

C. **Alternative Fuel and Vehicles**

*Alternative Fuel Vehicle Institute*
AFVI provides fleet operators with high-quality education, training and technical assistance on the broad range of alternative fuels and vehicles available on today’s marketplace. Their website, an excellent source for information on AFs and AFVs, especially for fleets, also contains links to resources on incentives.
http://www.afvi.org/index.html
6. CONCLUSION

The future seems most promising for vehicles that use batteries including the EV, HEV, and PHEV. The biggest challenge with these vehicles lies with the battery. One of the world's foremost experts on advanced battery technology, Donald R. Sadoway, Ph.D., a professor of materials chemistry at the Massachusetts Institute of Technology, recently told an audience, “at the end of the day it all comes down to batteries. There is plenty of room at the top—we're nowhere near the upper limits of the technology. Lithium-ion batteries could be made two to three times more energy dense than they are now.” However, in Sadoway’s view, “there needs to be additional money to bridge the gap from theoretical to final product.” In order to significantly reduce emissions, battery technology needs to be implemented in tandem with increasing the use of renewable sources for electric power generation.

Alternative fuel and vehicle technology is increasing in popularity and gaining public and political support due to the associated benefits. Some of the technologies in this paper are already being used while others are on the brink of commercialization. Alternative fuel and vehicle technology are two necessary strategies in the effort to reduce the effects of climate change and dependence on foreign oil, and in increasing energy sustainability for the DRCOG region and our nation.