

Securing a Clean Energy Future

Greener Fuels, Greener Vehicles: A State Resource Guide





Founded in 1908, the National Governors Association (NGA) is the collective voice of the nation's governors and one of Washington, D.C.'s most respected public policy organizations. Its members are the governors of the 50 states, three territories, and two commonwealths. NGA provides governors and their senior staff members with services that range from representing states on Capitol Hill and before the Administration on key federal issues to developing and implementing innovative solutions to public policy challenges through the NGA Center for Best Practices. For more information, visit www.nga.org

Foreword



—*Minnesota
Governor
Tim Pawlenty*
NGA Chair,
2007-2008

For the better part of the past century, America has enjoyed the spoils of an energy system that has been relatively inexpensive and easy to use. But our continued reliance on this finite system has made us increasingly vulnerable to unstable countries that house vast amounts of the world's energy resources and has jeopardized our relationship with the environment.

Our country is too dependent on foreign sources of energy. By 2030, we will be providing only 65 percent of our own energy needs—35 percent will come from foreign sources, mostly oil. Our total energy-related carbon dioxide (CO₂) emissions are projected to increase more than 25 percent by 2030.

Continuing down this dangerous pathway risks our economic well-being, energy security, environmental future, and quality of life.

America is at a tipping point. As has happened at other key moments in our nation's history, the public is ahead of policymakers, with citizens seeking strong leadership for a new direction. As some of this country's leading policymakers, my colleagues and I have a unique opportunity to move the United States toward a cleaner, more independent, more secure energy future. That's why as chair of the National Governors Association, I'm launching a yearlong initiative—*Securing a Clean Energy Future*—to enlist the efforts of all governors to make our nation a global leader in energy efficiency, clean technology, energy research, and the deployment of alternative fuels.

I believe we can and must craft a new, more comprehensive and multifaceted energy future that does not require sacrificing prosperity.

Our new energy future can increase our national security, improve our environment and bring economic benefits to our communities.

In their 2007 State of the State Addresses, 45 governors discussed initiatives to develop alternative sources of energy or promote conservation. *Securing a Clean Energy Future* will draw on these and other efforts to benefit every state and the nation as a whole. This initiative will focus both on what we can do immediately and on what we must do in the future to reduce overall energy demand while keeping our economy strong. A bipartisan task force, comprised of forward-looking governors who share a common desire to advance clean energy ideas and who represent a cross-section of the country, will guide the initiative's efforts.

Over the course of the next year, *Securing a Clean Energy Future's* gubernatorial task force will identify and implement approaches that:

- Use our energy resources better through efficiency and conservation;
- Promote non-petroleum-based fuels such as ethanol and biodiesel;
- Take reasonable steps to reduce greenhouse gas emissions; and
- Accelerate research and development of advanced clean energy technologies.

Achieving these goals will require a new devotion to conservation, research, piloting of new energy technologies, and development of a clean fuels infrastructure. Changing our current practices, reducing our current dependencies, and using new technologies will take a long-term commitment. States have shown they are willing to lead the way. Together, we can find and follow a pathway to a better, cleaner, more independent energy future.

The *Securing a Clean Energy Future* Task Force

Minnesota Governor Tim Pawlenty—Co-Chair
Kansas Governor Kathleen Sebelius—Co-Chair
Connecticut Governor M. Jodi Rell
Florida Governor Charlie Crist

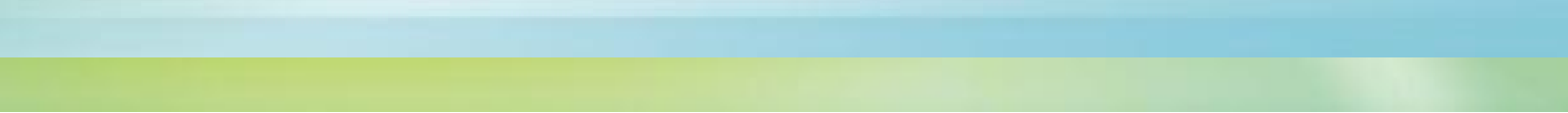
Hawaii Governor Linda Lingle
Montana Governor Brian Schweitzer
Pennsylvania Governor Edward G. Rendell
Washington Governor Chris Gregoire



The nation faces significant and serious energy challenges that call for action today.

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Executive Summary

The United States' transportation sector is 97 percent reliant on oil, with 60 percent of this oil imported. By 2030, with demand continuing to grow, we will import 4 million barrels more of petroleum per day than we did in 2005. This heavy reliance on mostly imported oil leaves our nation vulnerable to supply interruptions that lead to price fluctuations, economic instability, and real hardship for consumers. In addition, mobile sector greenhouse gas emissions currently account for more than one-third of the U.S. total, adding to concerns about climate change, and are projected to increase 37 percent over the next 25 years. It is in this context that policymakers, private companies, researchers, and citizens alike are exploring and developing domestically based, cleaner alternatives to our current oil-dependent transportation system.

Despite recent surges in ethanol use and hybrid vehicle technology, alternative fuel and vehicle technologies are still in their infancy. Experts have long recognized that there is a chicken-and-egg dilemma hampering the development of alternative fuel markets: (1) consumers will not purchase vehicles that run on alternative fuel unless they know they can buy this fuel easily at both their corner station and at highway rest stops; and (2) fuel suppliers will not fund and build enough ethanol, natural gas, or other alternative fueling stations unless they know they will have a steady supply of consumers.

These are daunting concerns, but if they are addressed simultaneously, the alternative fuels market may eventually reach a critical mass for both consumers and suppliers. Three core challenges must be addressed to pave the way for future progress:

- Lack of alternative fuels in the marketplace;
- Limited fuel distribution systems to get the fuels from refiners to vehicles; and
- Inadequate supply of alternative vehicles produced and used by consumers.

States already are taking important steps to further expand the nascent alternative fuel supply, distribution network, and vehicle market, and they are positioned to drive even more change. Governors generally can take the following four types of policy actions to meet the three core challenges:

1. Provide **financial incentives** through tax credits, deductions, grants, and other means to spur market response;
2. Pass **rules and mandates** requiring, for example, that state fuel distributors sell a certain quantity of alternative fuels;
3. Use their considerable **purchasing power** to boost the adoption of alternative fuels or vehicles (for example, by purchasing new indigenous fuel-production supplies or buying hybrid vehicles for use in state fleets); and
4. Invest in **research and demonstration** (R&D) efforts to speed new technologies to the marketplace.

Curbing America's oil dependence will require overcoming a 100-plus-year reliance on petroleum-fueled transportation. While the federal government is taking steps in this direction, states have the power to lead America by enacting policy changes, cooperating with other states and the private sector, and educating the public about the role of greener fuels and greener vehicles.

Introduction

This best practices *State Resource Guide* discusses the many alternative transportation fuels and vehicle technologies available in the marketplace today—ethanol, biodiesel, natural gas, electricity, hybrid electric vehicles, and others—as well as the fuels and technologies of tomorrow, such as hydrogen, hydrogen fuel cells, coal-to-liquids, diesel vehicles, and plug-in electric hybrids.

This guide provides a brief overview of the economic and environmental implications of an oil-dependent transportation sector. In addition, it reviews alternative fuels and vehicle technologies in use today, describes innovations coming in the future, and explains their associated benefits and limitations. It also touches on approaches to addressing vehicle fuel use, an important aspect of the overall discussion, and looks at state policy tools to encourage greener

transportation, such as financial incentives, rules and mandates, purchasing power, and research and demonstration. Finally, the guide provides an overview of the core barriers to wider consumption of alternative fuels and vehicles, along with examples of state policies designed to overcome the following roadblocks to their adoption: lack of alternative fuels in the marketplace, limited fuel distribution system, and inadequate supply of alternative vehicles.

By better understanding alternative fuels, vehicles, infrastructure, and technologies, governors can take collective action—tailored to their states' unique industrial resources, geography, and economic and demographic composition—to help the United States reduce its reliance on petroleum, lower greenhouse gas emissions, and secure a clean energy future.

The Cost of Our Reliance on Oil for Transportation

America is the world's leading consumer of petroleum, using more than 7.6 billion barrels of oil a year, over 60 percent of which is imported. Our transportation sector is 97 percent reliant on oil and accounts for more than two-thirds of the total annual U.S. oil use, or an annual 140 billion gallons of gasoline and 45 billion gallons of diesel fuel. As transportation demand is projected to grow, so too is our demand for imported oil. Under a business-as-usual scenario, by 2030, we will import 4 million barrels more of petroleum per day than we did in 2005.¹

This dependence on oil to meet our growing demand for travel leaves our economy vulnerable to price increases. In October 2003, oil was \$25 a barrel. Recently, the cost has been as high as \$100 a barrel, a fourfold increase. We are likely to see continued price fluctuations and increases due to rising costs associated with growing world oil demand, historic low capacities in oil-producing countries, refinery outages, and political instability in oil-rich nations and regions.

In addition to economic costs, the American transportation sector's oil dependency has serious and growing environmental repercussions. The mobile sector of the U.S. economy emits more than one-third of our total greenhouse gas emissions, adding to the climate impacts associated with the buildup of greenhouse gas emissions in the atmosphere.² Between 1990 and 2005, transportation greenhouse gas emissions grew by more than 24 percent, faster than any other sector of the economy over this time period.³ Future emissions are expected to be even greater. Under a business-as-usual scenario, by 2030, transportation greenhouse gas emissions are projected to increase 37 percent.⁴

To address these concerns, states are leading the push to develop greener fuels and vehicles by supporting greater use of alternative fuels and encouraging state-of-the-art fuel-production technologies, fostering distribution of infrastructure, and deploying advanced technology vehicles. Below we review the benefits of current and future alternative fuel and vehicle technology and barriers to their wider application.

Alternative Vehicles and Fuels

The American consumer wants a cleaner fuel vehicle. In 2006, U.S. auto dealers sold a record 1.5 million alternative fuel vehicles, beating automakers' own sales projections by 50 percent. These robust sales bumped up the total number of hybrid gas-electric, ethanol, biodiesel, and other alternative fuel vehicles on the road today to nearly 7 million.⁵ But despite the larger-than-expected sales growth, alternative fuel vehicles are still just 2 percent of the total U.S. vehicle market.

Moreover, the U.S. Energy Information Administration (EIA) expects the use of alternative transportation fuels, including

compressed natural gas (CNG), liquefied petroleum gas (LPG or propane), ethanol, and biodiesel to more than triple from 4 billion gallons in 2005 to 14.6 billion gallons in 2030. However, even if this rate is achieved, this would offset only 8 percent of U.S. gasoline consumption in 2030.

Despite their small market share today, there are many alternative fuels and vehicles now available and others expected to roll out in the future.

This guide covers the following alternative fuels in use:

- Ethanol • Biodiesel and Renewable Diesel • Natural Gas
- Electricity • Hybrid Electric Vehicles • Propane • Methanol
- P-series

Next it provides an overview of these fuels and vehicles likely to be available in state markets in the near future:

- Hydrogen • Plug-In Hybrids • Advanced Diesel Vehicles
- Coal-to-Liquids • Biobutanol • E-diesel

Below is a review of the types of alternative vehicles (**Table 1**) and fuels that are in the marketplace today or that have the potential to gain widespread use in the future, as well as a discussion of production, supplies, policies to expand development, and other factors that might contribute to the adoption of alternatives to imported oil for the transportation sector.

According to an August 2007 report by the Alliance of Automobile Manufacturers,⁶ the nation's auto manufacturers are currently offering consumers more than 60 models of alternative fuel vehicles, up from 12 models in 2000.

Table 1 Alternative Fuel Vehicles (Model Year 2007)⁷

Fuel/Technology	Vehicle Make and Model	
Hybrid Electric	Chevrolet Silverado Dodge Ram Ford Escape GMC Sierra Honda Accord Honda Civic Honda Insight Lexus GS450h Lexus LS 600hL	Lexus RX 400h Mercury Mariner Nissan Altima Saturn Aura Green Line Saturn Vue Green Line Toyota Camry Toyota Highlander Toyota Prius
Diesels/Biodiesels	Chevrolet Express Dodge Ram Ford E-Series Ford F-Series Super Duty GMC Savana GMC Sierra 2500 HD GMC Silverado 2500 HD	Jeep Grand Cherokee Mercedes-Benz E320 BLUETEC Mercedes-Benz R320 CDI Mercedes-Benz ML320 CDI Mercedes-Benz GL320 CDI Volkswagen Touareg TDI
E85 Flex-Fuel	Chrysler Sebring Chrysler Aspen Dodge Durango Dodge Caravan Dodge Grand Caravan Chrysler Town & Country Dodge Dakota Dodge Ram Jeep Grand Cherokee Jeep Commander Ford Crown Victoria Lincoln Town Car Mercury Grand Marquis Ford F-150 Chevrolet Impala Chevrolet Monte Carlo	Chevrolet Tahoe Chevrolet Police Tahoe GMC Yukon Chevrolet Suburban GMC Yukon XL Chevrolet Silverado GMC Sierra Chevrolet Avalanche Chevrolet Express GMC Savana Chevrolet Uplander Buick Terraza Mercedes-Benz C230 Sport Sedan Nissan Armada Nissan Titan
Compressed Natural Gas(CNG) Dedicated	Honda Civic GX	
Hydrogen Fuel Cell	Honda FCX*	

*Honda plans limited retail marketing of this vehicle in summer 2008. Source: U.S. Department of Energy

Ethanol

Ethanol fuel is an alcohol made from sugars—corn, sugar cane, beets, grain sorghum, and potatoes—and, more recently, cellulose, such as woody crops, wood waste, switch grasses, agricultural residues, and municipal solid wastes that have been converted into simple sugars.

Production Processes

Ethanol is produced in two primary ways: dry mill and wet mill.

Dry-mill ethanol plants are optimized to produce ethanol with carbon dioxide (CO₂) and animal feed as byproducts. In these facilities, corn is ground into coarse flour. Next, water and enzymes are added, the mixture is heated, yeast is put in, and the entire mixture is fermented. This fermented “mash” is sent to a distillation system where molecular sieves remove the water to produce 200-proof ethanol. The ethanol is denatured (usually with gasoline or another toxic agent) to make it unfit for human consumption. The final fuel-ethanol blend is stored in specially designed tanks, either on site or near the production facility. The solids and liquids remaining after distillation are generally recombined for sale as animal feed, although some facilities remove the moisture from this grain to extend its shelf life. This dried byproduct is referred to as distillers’ grain.

Wet-mill ethanol plants primarily produce corn sweeteners, ethanol, and other products (e.g., oil, animal feed, and starch). These mills extract the starch from the corn, process it into sugars, and ferment the sugars into ethanol. The first step is to soak the corn in hot water, which separates the protein from the starch. The product is then ground, and the germ is separated. The remaining slurry, which contains gluten, starch, and fiber, is finely ground and separated so that the fiber can be blended into animal feed. The remaining mixture is then dried to make cornstarch or processed into sugars, corn syrup, and other sweeteners. These sugars are also fermented to produce ethanol.

Supply

Corn-based ethanol is the most prevalent biofuel used in the United States today. However, other feedstocks including, straw, grasses, and wood—are widely viewed as the successors to today’s corn-based ethanol plants.

Corn-Based Ethanol

Today there are 120 ethanol refineries nationwide with the capacity to produce more than 7 billion gallons of corn-based ethanol annually, according to the Renewable Fuels Association, the national trade association for the ethanol industry. In 2007, the National Corn Growers Association reported that more than 17 percent of the 13-billion-bushel U.S. corn crop was used for ethanol production.

Section 1501 of the Energy Policy Act of 2005 required the U.S. Environmental Protection Agency (EPA) to establish a Renewable Fuel Standard (RFS) to increase the volume of renewable fuel that can be blended with gasoline. In 2008, the U.S. EPA updated the RFS, requiring that 4.66 percent of gasoline be renewable. Refiners, importers, and blenders use this standard to calculate their renewable volume obligation. Both renewable fuels blended into gasoline or diesel and those used in their neat form as motor vehicle fuel qualify. Ethanol alone has almost tripled the federal RFS and the supply is growing (Table 2).

Table 2 U.S. Supply of Corn-Based Ethanol, Current and Projected*

2004	3.9 billion gallons
2006	6.5 billion gallons
2007	8.5 billion gallons
2010*	10 billion gallons
2012*	13 billion gallons
2015*	15 billion gallons
2022*	36 billion gallons

Source: U.S. Department of Energy

In December 2007, President Bush signed the Energy Independence and Security Act (EISA) of 2007, expanding the national RFS to at least 36 billion gallons of biofuels by 2022, of which no more than 15 billion gallons can be from conventional sources (i.e., corn-based). The new RFS schedule increases consumption to a minimum of 9 billion gallons nationwide by 2008 and to 15 billion gallons by 2015, reaching the 36-billion-gallons-requirement by 2022. The U.S. EPA will conduct a rulemaking in 2008 to revise the current RFS regulations to reflect the law’s new energy provisions.

Cellulosic Ethanol

By 2022, 21 billion gallons of cellulosic ethanol will be needed to meet the EISA requirements. Starting in 2009, the national RFS establishes a new fuel production subset for advanced biofuels. This includes subcategories of cellulosic biofuels and biomass-based diesel. As noted earlier, these so-called second-generation biofuels made from woody biomass, plant-based cellulose, and other natural materials are widely viewed as the successors to today’s corn-based ethanol fuel. Although there is only one U.S. cellulosic ethanol plant in operation today in **Georgia**, the conversion of any such starch into fuel opens up a new avenue to reducing petroleum use and greenhouse gas emissions over the long term.

While cellulosic ethanol production capacities are currently low, its potential to reduce petroleum consumption may be more significant than corn-based ethanol. A recent joint government study determined that the United States has the potential to supply an estimated 1.3 billion tons of feedstock materials needed annually—enough to meet one-third of the current demand for transportation fuels.⁸ Another national biomass assessment found that the United States has the potential to produce 50 billion gallons of ethanol from wood residue, switchgrass, and agricultural residue without relying on land used now used for food crops.⁹ Further production innovations, as well as improvements in plant-to-fuel conversion efficiencies, could produce some 165 billion gallons of ethanol solely from perennial grasses, such as switchgrass, by 2050.^{10,11}

Benefits and Costs of Ethanol

Regardless of its feedstock, ethanol is either mixed with gasoline in low-percentage blends as a fuel additive or in higher percentages to create an alternative fuel. As a low-level blend, ethanol mixes well with gasoline; almost all fuel ethanol in the United States is combined with gasoline in percentages ranging from 2 percent to 10 percent (known as E2 or E10).

The most common higher blend of ethanol is known as E85—85 percent ethanol and 15 percent gasoline. E85 is classified as an alternative fuel under the Energy Policy Act of 1992. E85 is preferred to mid-level blends (e.g., E50) because 85 percent ethanol is the most that can be blended safely with gasoline and still be used by today's flexible fuel vehicles (FFVs), which have specially designed tanks and engines that allow cars and light trucks to operate on either E85 or gasoline, depending on their availability. (FFVs are discussed in greater detail later in this guide.)

While E10 and lower-level blends of ethanol improve engine performance, using E85 in FFVs provides emissions-reduction benefits by diminishing particulate matter (PM), carbon monoxide (CO), and oxides of nitrogen (NO_x) on a volumetric basis. Ethanol can also reduce greenhouse gas emissions when compared gallon to gallon with gasoline. A study from the Argonne National Laboratory indicates that corn ethanol reduces lifecycleⁱ greenhouse gas emissions (i.e., total fuel CO₂, nitrous oxides [N₂O], and methane [CH₄] emissions from production, manufacturing, transportation, and distribution) by 12 to 19 percent compared with gasoline. However, both air quality and greenhouse gas emissions benefits depend on how the ethanol is produced.

While most ethanol is used as E10 blends, with the remainder consumed as E85, a few states, including **Kansas**, **Minnesota**, and **Oklahoma**, are looking to develop programs to expand the availability of a variety of mid-range ethanol-gasoline blends, such as E20, E30, and E50.

A related issue is the ethanol industry's concern about an E10 "wall"—that is, that the supply of E10 will soon exceed demand. Given the lack of E85 vehicles that are able to accept this overabundance of ethanol, some stakeholders have called for the use of ethanol blends greater than E10. However, these blends are currently illegal to use in non-FFVs and uncertainty exists about how underground storage tanks and the lines from the tanks to the dispensers would handle blends greater than E10. Because of these concerns, states wishing to use blends greater than E10 must obtain U.S. EPA waivers. These waivers can be expensive and time-consuming to obtain.ⁱⁱ

Regardless of the blend, the rapid increase in demand for corn ethanol has raised concerns. Using corn-based ethanol for fuel leads to higher crop prices, driving the conversion of more corn to ethanol, which in turn may further increase food prices.

Economic and ecological concerns also arise in the corn-ethanol discussion. Ethanol is highly subsidized; from 1995 to 2005, it received \$51 billion in federal tax breaks through gasoline refiners' credits and production credits that primarily benefit large companies and agribusiness firms. In addition, extensive corn planting for ethanol reduces the sowing of other crops and uses greater amounts of fertilizer—corn crops require more fertilizer than any other U.S. crop besides cotton—which can impair water quality. Corn-based ethanol farming also uses significant amounts of water. Producing a one-gallon-of-oil-equivalent in ethanol requires about 2,700 gallons of water.

In addition to food, water, and economic issues, environmental concerns exist. The recent surge in ethanol production is likely to increase local nitrogen oxides and volatile organic compounds because the plants are mostly coal-fired facilities. Moreover, CO₂ emissions from such facilities potentially reduce much of the product's contribution to an overall reduction in greenhouse gas emissions. Additionally, if ethanol demand continues to lead to greater corn production, other challenges could emerge including loss of habitat, loss of species diversity, release of carbon sequestered in the soil, and concerns over the nation's use of genetically modified corn crops, which have stirred health-related controversies.

In contrast, the latest research by the Argonne National Laboratory shows that biofuels from switchgrass and other biomass crops could cut greenhouse gas emissions by up to 85 percent per equivalent gallon of gasoline.¹² However, much work remains to achieve the full promise of cellulosic ethanol. In particular, the true potential for cellulosic fuel is unknown because of these, among other, technological and cost uncertainties:

ⁱ A primary reason that ethanol and other biofuels offer significant greenhouse gas savings is due to carbon sequestration from growing biofuel feedstocks, which partially offsets production and combustion emissions. Lifecycle emissions calculations take into account emissions from crop production, fuel refinement, transport, and combustion.

ⁱⁱ Section 211 of the Clean Air Act gives the U.S. EPA the authority to approve any new fuel or fuel additive that does not impair the emissions-control systems of vehicles and that can be shown, quantitatively, to produce tailpipe and evaporative emissions that balance out and are "substantially similar" to those of gasoline (i.e., fuel systems materials compatibility, vehicle drive ability, exhaust emissions, and evaporative emissions).

- **Technology**—Establishing a new generation of biofuels will require scientific breakthroughs to optimize the processes for breaking down cellulosic material, including pretreatment, enzyme hydrolysis, and sugar fermentation. In addition, progress must be made on the integration of these processes into a single cellulosic ethanol plant, often called a biorefinery.
- **Cost**—Producing fuel from cellulosic material has much higher capital costs than conventional grain ethanol processes. Researchers at the Department of Mechanical Engineering at Iowa State University compared the capital and operating costs for an ethanol plant with that of a similarly sized biorefinery. They found that to construct a plant capable of delivering a 150-million-gallon-gasoline-equivalent, the cost was around \$111 million for a conventional grain ethanol plant and as much as \$854 million for an advanced biorefinery.

Distribution

Whatever their feedstock, ethanol producers face unique distribution challenges. The few plants located near waterways can ship their ethanol by barge—an economical, although not a CO₂-emissions-free-option. But most ethanol plants are concentrated in the Midwest while demand is concentrated on the coasts. Today, almost all ethanol is shipped by truck—fueled with oil—to a facility where it is blended with gasoline.

The least expensive and most environmentally friendly distribution option for ethanol is by pipeline—the way most gasoline is shipped—but here again the solution is not cut and dry. Water has an affinity for ethanol, so any pipeline would have to keep water out. Next, ethanol is a better solvent than gasoline, so shipments in existing pipelines could pick up impurities; moreover, its corrosiveness could shorten the pipeline's lifetime. Finally, most gasoline pipelines originate in the South—the base of the U.S. oil exploration and refinery industry—rendering them impractical conduits for transporting Midwest-produced ethanol.

Vehicles Using Ethanol

Ethanol has less energy content per gallon than gasoline, but at blends of E10 and below, there is not a discernible difference in driving range. In fact, as noted earlier, because of its high-octane level and its ability to operate in any gasoline vehicle, ethanol in small amounts is valued as a gasoline blend. For these reasons, all automobile and vehicle engine manufacturers approve the use of ethanol blends at E10 and below.

However, blends above E10 require use of flexible fuel vehicles (FFVs), which are specially designed cars and trucks first developed by Ford Motor Company in the mid-1980s. Crafted to run on either regular unleaded gasoline or a gasoline/ethanol blend of up to 85 percent ethanol, these vehicles contain a special fuel tank, fuel system, and engine. The engine and fuel systems are modified to

account for the corrosive nature of ethanol, and contain special sensors that analyze the fuel mixture and control the fuel injection timing to adjust for different fuel blends.¹³ Because a gallon of ethanol has about two-thirds the energy of a gallon of gasoline, FFVs running on E85 need to refuel more frequently.

Since 1992, automobile manufacturers have sold 5 million FFVs and these vehicles are the most prevalent type of alternative fuel vehicle on the road in the United States today. Recent production increases mean that automakers will be producing more than 2 million FFVs per year. Yet this is still a fraction of the 15.6 million light-duty cars and trucks sold in the United States in 2006. Moreover, there is no guarantee that these FFVs use ethanol, and many consumers are often unaware that they own vehicles capable of operating on E85.

Infrastructure

All gasoline pumps in the United States can use up to 15 percent ethanol. Ethanol fuel blends up to 10 percent are sold in every state; one-third of U.S. gasoline now contains up to 10 percent ethanol to boost octane or to meet air-quality requirements.

Next to E10, E85 is the most common ethanol blend and is now offered in 40 states. Stations are more common in the “Corn Belt”—**Minnesota, Iowa, and Illinois**. As of early 2007, nearly 1,400 U.S. fueling stations offered E85 to the more than 5 million FFV drivers on the roadways. However, studies have found that the high cost of constructing these refueling stations is a key barrier preventing widespread purchase of E85-fueled FFVs.

As noted earlier, **Kansas, Minnesota, and Oklahoma** are planning to expand the availability of a variety of specially labeled and certified pumps selling mid-range ethanol blends such as E20, E30, and E50. However, because of engine manufacturer warranties and air-quality concerns, only FFVs are legally allowed to use these higher blends (beyond E15).

While ethanol use is expanding rapidly, E85 in particular is still not widely available or accepted by consumers. Price, availability, and familiarity are key attributes by which many consumers consider when buying FFVs or filling up with E85. According to a 2007 study by the Massachusetts Institute of Technology,¹⁴ states will need decades of marketing programs and subsidies to ensure market penetration of alternative fuels. The study authors note that there is a tipping point in the diffusion of alternative fuels and AFVs: Subsidies for an alternative fueling infrastructure that persist long enough can push the marketplace over a critical threshold of viability. The U.S. Department of Energy (DOE) recently concluded that federal and state government policy and regulation will affect the development of the ethanol industry for the foreseeable future.

Biodiesel and Renewable Diesel

Biodiesel is a diesel-like liquid fuel derived from soybean vegetable oil or from fats found in restaurant grease. Biodiesel is produced through a refinery process called transesterification, which involves reacting oil with an alcohol to remove glycerin, creating mono-alkyl esters of long-chain fatty acids. The most common sources of oil for biodiesel production in the United States are soybeans, but yellow grease (e.g., recycled restaurant cooking oil) does provide a small percentage of the feedstock.

According to U.S. regulations, fuel-grade biodiesel must be produced to strict industry specifications for proper performance.¹⁵ Biodiesel is the only alternative fuel to have fully completed the health effects testing requirements of the 1990 Clean Air Act Amendments, and it is registered with the U.S. EPA as a motor fuel legal for sale and distribution.

Renewable dieselⁱⁱⁱ is another type of alternative diesel fuel, derived from plant oils; animal fats; and wastes, sludge, and oils from wastewater facilities. It is technically a non-ester renewable diesel and is a hydrocarbon chain (unlike biodiesel, which is a mono-alkyl ester). Although it is not yet certified for use in many states, renewable diesel fuel is registered with the U.S. EPA as a fossil fuel alternative. More testing is required to ensure its viability as a fuel or fuel additive.

Supply

In the United States, 90 percent of biodiesel is made from soybeans although it is produced from other crops, including sunflowers, canola, cotton, and peanuts and also from waste vegetable oils. Other crops that produce oil seeds are being considered as biofuel sources, including mustard seeds, tallow trees, safflower, and leafy, weed-like plants known as crambe and camelina. Microalgae have also been attracting interest because of tests that show these algae—through cellular photosynthesis—produce 30 to 100 times more types of biomass per acre than traditional biofuel feedstocks.

In 2005, about 75 million gallons of biodiesel were produced. The U.S. Department of Agriculture (USDA) predicts biodiesel production to increase significantly by 2012. Projected supplies are 1.4 billion gallons by 2007, 2 billion gallons by 2010, and 3.4 billion gallons by 2015. Biodiesel is supported by the federal government, which provides subsidies of \$1.00/gallon for biodiesel produced from soybeans and \$0.50/gallon for biodiesel made from yellow grease.

Biodiesel is blended with diesel fuel in varying percentages (e.g., B20 is 20 percent biodiesel, 80 percent petroleum diesel). Low to mid-level blends ranging from B1 to B20 are most prevalent and can be safely used in unmodified diesel engines. Additionally, low biodiesel blends of 5 percent or less provide engines with beneficial lubrication. On the other hand, blends above B20 can cause fuel system

component (hoses, etc.) degradation on some older vehicles. These vehicles may require engine modifications to avoid maintenance and performance problems. In addition, some fleet operators also report a loss of power when operating on B20 or higher blends.

Because biodiesel has low concentrations of sulfur and aromatics, using it to replace diesel fuel can reduce criteria air pollutants. B20 blends reduce PM and carbon monoxide by up to 20 percent. Some studies, however, have found that these biodiesel blends may lead to small increases in NO_x emissions, although these can be mitigated through the use of catalytic converters.¹⁶ (Testing results vary.)

On a volumetric basis, biodiesel has 6 to 8 percent less energy per gallon than petroleum diesel, meaning more biodiesel by volume than diesel fuel is necessary to power a vehicle the same distance. Despite its lower energy content, biodiesel still reduces carbon dioxide emissions compared to diesel fuel. A 1998 study sponsored by the U.S. DOE and USDA found that pure biodiesel (B100) used in urban transit buses reduced net CO₂ emissions by 78 percent compared with petroleum diesel.¹⁷

Distribution

Biodiesel is distributed from the point of production via truck, train, or barge to retail fueling stations and then to end users, such as large vehicle fleets. Most biodiesel distributors will deliver pure or pre-blended (with petroleum diesel) biodiesel depending on the customer's preference. Pipeline distribution of biodiesel, which would be the most economical option, is still in the experimental phase.

Biodiesel production is simple and production facilities can be started with relatively little capital. U.S. biodiesel production occurs at 148 plants, which produce varying amounts of biodiesel, ranging from 1 million to 25 million gallons.

Because of the low cost and flexibility of production, some states are requiring that agencies purchase designated biodiesel that is developed in-state, assuming it is cost-competitive with fossil fuel oil. Such provisions are designed to spur new demand in rural agricultural commodities, build value-added agricultural processing, and support capital investment in new biodiesel production facilities.

Vehicles

Most diesel engines can accept low-level blends of biodiesel, up to B20, with little or no engine modification. However, for blends above B20, U.S. engine and equipment manufacturers require additional precautions, handling procedures, and maintenance rules, as well as some fuel system and engine modifications. As a result, there is limited use of higher blends of biodiesel.

ⁱⁱⁱ Renewable diesel is defined as diesel fuel derived from nonpetroleum products. Biodiesel is a type of renewable diesel fuel having a specific chemical formula.

Infrastructure

There are currently more than 800 biodiesel refueling stations in the United States. Barriers to developing a larger biodiesel infrastructure include the costs associated with distributing the fuel and blending it with petroleum diesel. However, biodiesel is more easily integrated into existing fueling stations than other alternative fuels because only limited modifications to existing diesel fuel storage tanks and fuel pumps are needed.

Natural Gas

Natural gas is a mixture of hydrocarbons—mainly methane (CH₄)—that is produced either from gas wells or in conjunction with crude oil production. As delivered through the pipeline system, it also contains hydrocarbons such as ethane, propane, and other gases, including nitrogen, helium, carbon dioxide, hydrogen sulfide, and water vapor.

Most natural gas is extracted from gas and oil wells. Much smaller amounts of natural gas are derived from supplemental sources such as synthetic gas, landfill gas, other biogas resources, and coal-derived gas. Natural gas has a high octane rating and excellent properties for spark-ignited internal combustion engines. It is nontoxic, noncorrosive, and noncarcinogenic. It presents no threat to soil, surface water, or groundwater.

Supply

America has a 150-year supply of natural gas, a fuel that currently accounts for approximately one-quarter of the energy used in the United States. Of this, about one-third is for residential and commercial use, one-third is for industrial use, and one-third is for electric power production. Less than one-tenth of 1 percent is currently used for transportation fuel. Natural gas is one possible source of hydrogen (a detailed discussion of hydrogen is presented later in this guide). Natural gas functions^{iv} in the following ways:

- **Compressed Natural Gas (CNG)**—To provide an adequate driving range, CNG must be stored on board a vehicle in high-pressure tanks of up to 3,600 pounds per square inch. A CNG-powered vehicle gets about the same fuel economy as a conventional gasoline vehicle.
- **Liquefied Natural Gas (LNG)**—To store more energy on board a vehicle in a smaller volume, natural gas can be liquefied. To produce LNG, natural gas is purified and condensed into liquid by cooling it to -260°F (-162°C). At atmospheric pressure, LNG occupies only 1/600th the volume of vaporized natural gas. A gasoline gallon equivalent (GGE) equals about 1.5 gallons of LNG. Because it must be kept at such cold temperatures, LNG is stored in double-walled, vacuum-insulated pressure vessels. LNG fuel systems typically are only used with heavy-duty vehicles.¹⁸

Distribution

Natural gas is shipped by pipeline, trucks, rail, and ship. CNG is primarily delivered through a series of pipelines located around the country. LNG is transported in specially designed sea vessels or cryogenic trucks. LNG has less volume than natural gas, making it much more cost-efficient to ship over long distances where pipelines do not exist. After LNG is transported by truck, rail, and ship, it is stored in specially designed tanks and can also be regasified and distributed by pipeline, as necessary. Some states have expressed safety and other concerns about siting of LNG terminals.

Vehicles

There are currently more than 130,000 natural gas vehicles (NGVs) on U.S. roads. While these include passenger cars and trucks, most are heavy-duty transit buses, school buses, and refuse haulers. According to the U.S. DOE, more than 10 percent of the nation's transit bus fleet and 20 percent of new buses on order operate on natural gas. The number of new light-duty original equipment manufacturers of NGVs has declined in recent years; as of November 2007, only one production light-duty natural gas vehicle was available: the Honda Civic GX sedan. Because of low-volume production, passenger NGVs tend to cost about \$3,000 to \$6,000 more than similarly styled gasoline vehicles. However, certified installers can reliably retrofit many light-duty vehicles for natural gas operation.

Despite limited NGV deployment, some experts say this market has growth potential for both private users and fleet operators. One reason, according to the International Association for Natural Gas Vehicles, is due to international market growth: Worldwide, there are 5 million NGVs in service.¹⁹

Heavy-duty vehicles that run on natural gas are more expensive; natural gas buses cost about \$30,000 to \$40,000 more than equivalent diesel buses. However, heavy-duty vehicle fleet operators report that the higher purchase cost for such vehicles is offset by lower operating costs in terms of maintenance, fuel, and fuel economy. The natural gas infrastructure is also well-suited for heavy-duty vehicle fleets because these vehicles typically refuel at a central location.

Infrastructure

There are now roughly 800 compressed natural gas fueling stations, mostly serving fleets. Data from the **California** Energy Commission, the U.S. DOE, and other sources estimate that most compressed natural gas “fast-fuel” stations cost between \$300,000 and \$1 million to build, depending on whether CNG stations are single-hose time-fill or are more complex “fast-fill” stations with several refueling hoses. Additionally, some manufacturers plan to offer equipment to allow home vehicle refueling for homes running on natural gas, which may help increase the passenger natural gas vehicle market.

^{iv} Both compressed and liquefied natural gas work the same way when used in vehicles.

Electricity and Electric Vehicles

In electric vehicles (EVs), electricity is stored in a device, most often a battery, which is used to operate the vehicle. EVs are highly efficient: 75 percent of their energy is converted into powering the vehicle, compared with 20 percent for internal combustion engines. EVs are considered zero-emission vehicles. However, depending on the source of electricity used to charge their batteries, these cars and trucks may contribute to emissions at the point of electricity generation.

Supply, Distribution, Vehicles, and Infrastructure

For current EVs, most electricity used for recharging their batteries comes from the existing power grid and would thus be widely available. However, in addition to current power generations, local electric sources such as solar or wind energy also could be used if they were compatible with the vehicles' electric charging devices and energy storage units.

Currently, the major automakers do not manufacture any light-duty electric vehicles. Neighborhood electric vehicles (NEVs), however, are made by a variety of companies. These small vehicles are commonly used for neighborhood commuting, light hauling, and delivery but are limited to areas with speed limits of less than 35 miles per hour or to off-road service at college campuses, airports, and resorts. NEVs are not eligible for fleet credit under the Energy Policy Act of 1992, but their ability to move people around in limited commute areas could make them useful in certain applications.²⁰

EVs tend to be much costlier than regular vehicles, mainly attributable to the battery. EVs also have a limited range—150 miles per charge compared with 300 miles for the average gasoline vehicle. Moreover, some electric vehicles have chargers on board while others plug in to a charger located outside the vehicle and both types require different charging stations in order to access the grid. Batteries for EVs also take four to eight hours to fully recharge. Thus, EVs' advancement is dependent on the development of next-generation batteries, which must overcome size, cost, and technological challenges such as energy storage, performance, life, and abuse-tolerance limitations.

As noted earlier, depending on the power supply used, EVs could offer substantial environmental benefits. According to the Union of Concerned Scientists (UCS), even if EVs are recharged with electricity derived from today's fossil fuels, they can still reduce net greenhouse gas emissions by up to 70 percent compared with the U.S. gasoline-powered vehicle fleet.²¹

Hybrid Electric Vehicles

Hybrid electric vehicles (HEVs) combine the internal combustion engine of a conventional vehicle with the battery and electric motor of an electric vehicle. HEVs are powered by any two discrete energy sources—an energy conversion unit (e.g., internal combustion engine or fuel cell) and an energy storage device (e.g., battery). This

combination offers lower emissions than conventional vehicles, with the power, range, and convenient fueling of today's gasoline and diesel vehicles. (See **Table 3** for HEV benefits and costs.)

In addition HEVs have smaller engines but incorporate other fuel-conserving technologies, such as roll-resistant tires, lightweight materials, and aerodynamic features that improve their fuel economy. Since 1999, hybrid electric vehicles have saved close to 230 million gallons—or 5.5 million barrels—of fuel in the United States, according to a recent analysis conducted by the U.S. DOE's National Renewable Energy Laboratory (NREL).²²

Table 3 Benefits and Costs of Hybrid Vehicles²³

Benefits	Costs
Increased fuel economy	Higher purchase price
Fewer greenhouse gas emissions	Limited vehicle supply
Cost savings compared to gasoline vehicles	Expensive batteries

A study by UCS found that HEVs could achieve from 15 to 18 percent fuel-efficiency improvement with a maximum fuel-efficiency potential of as much as 50 percent.²⁴ The CO₂ emissions avoided by HEVs under this scenario were 14 percent by 2012 and as much as 35 percent by 2020.²⁵ The UCS study concluded that a typical mid-sized car with a fuel economy of about 27 miles per gallon (mpg) could improve its fuel economy to:

- 55 mpg for a mild hybrid (e.g., motor/battery systems, regenerative braking, and engine downsizing);
- 65 mpg for a full hybrid (e.g., battery to start the vehicle and operate it until it reaches the speed at which the combustion engine can be operated more efficiently); or
- 80 mpg for a plug-in hybrid (e.g., allows vehicle's battery to be recharged from a clean electricity grid).

The Institute of Transportation Studies agreed with UCS's findings and went even further in a 2004 study that looked at full penetration of hybrids. The authors concluded that if all vehicles in the U.S. fleet were replaced by HEVs, fuel economy would increase from the current level of approximately 25 mpg to 38 mpg employing mild hybrid technology (with vehicle costs increasing 7 percent to 9 percent) and to 42 mpg employing full hybrid technology (with vehicle costs increasing 16 percent to 18 percent).

Plug-In Hybrids

Plug-in hybrid electric vehicles (PHEVs) combine the benefits of pure electric vehicles with the advantages of HEVs. Like electric vehicles, they plug in to the electric grid and can be powered solely by

the energy stored in their batteries, albeit for a short period. Alternatively, like HEVs, PHEVs have gasoline- and diesel-powered combustion engines that pick up where the battery leaves off, enabling greater driving ranges. The PHEVs of the future may use alternative fuels such as biodiesel, natural gas, or ethanol in conjunction with an advanced battery. As with EVs, advancement of hybrids and PHEVs is dependent on breakthroughs in advanced battery life. Automakers are currently operating demonstration PHEVs and the California Air Resources Board's Zero Emission Vehicle Technology Review forecasts PHEVs to reach mass commercialization volumes of 100,000 per year by 2015.

If their market penetration is expanded, PHEVs have significant potential to reduce CO₂ emissions compared with the current light-duty vehicle mix in the nation's fleet. A study by the Electric Power Research Institute and the Natural Resources Defense Council found that full penetration of PHEVs into the market could significantly reduce annual greenhouse gas emissions; in one scenario, cumulative greenhouse gas emissions reductions from 2010 to 2050 could range from 3.4 billion to 10.3 billion metric tons.²⁶

Supply, Distribution, and Infrastructure

While there are no commercially available PHEVs, there are a number of light-duty HEVs for sale, and more HEVs enter the marketplace each year. Since 1999, when the two-seat Honda Insight was first introduced, annual HEV sales have risen exponentially—by an average of

72 percent for the past five years. In 2006, their average fuel economy, based on new U.S. EPA estimates, was 35 miles per gallon for new hybrid models, a 45 percent fuel-economy improvement over the replaced conventional vehicle. In 2007, sales are projected to reach upwards of 374,000 vehicles—a 48 percent increase from 2006 sales (Table 4).

Other Fuels and Vehicles Used Today

Most alternative fuels and vehicles in use today are those discussed above—biofuels, natural gas, and electric-gas hybrids. However, these other fuels and vehicles available to states and consumers also could replace petroleum in an environmentally friendly way:

- **Propane**—Propane is a byproduct of two sources: natural gas processing and crude oil refining. Propane or liquefied petroleum gas (LPG) was recently a popular alternative fuel choice for vehicles because there exists an infrastructure of pipelines, processing facilities, and storage places for LPG's efficient distribution. However, the availability of new light-duty original equipment manufacturers of propane vehicles has declined in recent years. Certified installers can economically and reliably retrofit many light-duty vehicles for propane operation. Propane engines and fueling systems are also available for heavy-duty vehicles such as school buses and street sweepers. However, retrofitting of light-duty vehicles requires heavy tanks, which leads to a loss of power and truck space and a need for frequent refills.
- **Methanol**—Methanol, also known as wood alcohol, can be used as an alternative fuel in flexible fuel vehicles that run on M85 (a blend of 85 percent methanol and 15 percent gasoline). However, it is not commonly used because automakers are no longer supplying methanol-powered vehicles. In the future, methanol could possibly be the fuel of choice for providing the hydrogen necessary to power fuel cell vehicles (see the "Alternative Fuels and Vehicles" section).
- **P-Series**—This is a blend of natural gas liquids, ethanol, and the biomass-derived cosolvent methyltetrahydrofuran (MeTHF). P-Series fuels are clear, colorless, 89-93 octane-liquid blends that are formulated to be used alone or mixed with gasoline in any proportion in dedicated vehicles. However, these fuels are not currently being produced in large quantities and are not widely used.

Table 4 U.S. HEV Sales

Year	Vehicle Sales
2000	9,000
2001	20,000
2002	36,000
2003	48,000
2004	84,000
2005	210,000
2006	253,000
2007*	374,000

**Projections for 2007 assume monthly sales for July-December 2007 will be the same as average monthly sales in January-June 2007 (as reported in hybridcars.com).*

The Fuels and Vehicles of the Future

While there are a variety of alternative fuel vehicles available today, many more clean fuel and advanced vehicle technologies exist but are not yet available outside of limited tests and laboratory demonstrations. Additional research, development, and demonstration will be necessary to overcome key cost and other barriers before these fuels, vehicles, and engine technologies are ready for widespread consumer use. However, they hold the potential of substantially lowering carbon emissions as well as reducing fuel imports and operating costs.

Hydrogen

Hydrogen is extracted either directly from an energy source or from the heat released from the burning of an energy source that is used, in a closed chemical cycle, to produce hydrogen from a feedstock (e.g., water). Hydrogen can be produced from multiple sources—nuclear, natural gas, coal, biomass, wind, solar, geothermal, and hydroelectric. This is done in one of three ways: catalytic, electrolytic, and photolytic.

- **Catalytic Reforming**—Most of the hydrogen produced in the United States today is done through a form of thermal production called steam methane reforming, in which high-temperature steam (700°-1,000°C) and a hydrocarbon, such as methane, are catalytically reacted to form hydrogen and oxides of carbon. Other types of production heat coal or gasify biomasses to release hydrogen, which is part of their molecular structure.
- **Electrolytic Production**—In this process, electrolysis is used to split water into hydrogen and oxygen. Electrolyzers are small, appliance-sized devices that are well-suited for small-scale distributed hydrogen production. Research is also under way to examine larger scale electrolysis that could be tied directly to renewable electricity production.
- **Photolytic Production**—Photolytic processes use light energy to split water into hydrogen and oxygen. Currently in the very early stages of research, these processes offer long-term potential for sustainable hydrogen production with low environmental impact.

Hydrogen has been used effectively in a number of internal combustion engine vehicles as pure hydrogen mixed with natural gas. More of the research, however, has focused on the development of hydrogen fuel cells.

Supply

As mentioned, hydrogen can be derived from any number of energy sources. About 95 percent of the approximately 9 million tons of hydrogen being produced annually in the United States currently comes from natural gas reforming, which is the equivalent to fueling more than 34 million cars. Should hydrogen become a more widely used fuel, however, other sources will need to be found, given the limited supply of natural gas in the United States. Most other methods for producing hydrogen are still in the experimental phase.

Distribution

Hydrogen is most often distributed in the following ways:

- **Pipelines**—This is the least expensive way to deliver large volumes of hydrogen. However, the network is limited, with only about 700 miles of pipelines located near large petroleum refineries and chemical plants in **Illinois**, **California**, and along the Gulf Coast.
- **Trucking**—Transporting hydrogen gas by truck, railcar, ship, or barge in high-pressure trailers is expensive (due to high compression needs) and is used primarily for short distances (under 200 miles).
- **Liquefied Hydrogen Tankers**—Although expensive, cryogenic liquefaction enables hydrogen to be transported more efficiently over longer distances by truck, railcar, ship, or barge compared with using high-pressure trailers.

Barriers to hydrogen market availability relate to the production of hydrogen and include the high cost of hydrogen production, low availability of these production systems, and the challenge of ensuring safe delivery systems.

Vehicles

Due in part to limited availability of hydrogen, no hydrogen-fueled vehicles are commercially available to consumers today, although a small number are being used as demonstration vehicles, many of them modifications of existing vehicles. To date, only Honda has said it would start mass-producing an experimental vehicle, the FCX, in the near future—by 2008, according to the company.

The other type of hydrogen vehicle is a hydrogen fuel cell vehicle (HFCV). These cars and trucks operate using an electrochemical cell that converts the energy of a reaction between liquid hydrogen and oxygen into electrical energy. Hydrogen fuel cells are stored on board cars or trucks, and emit no pollutants—just water and heat. Thus, unlike EVs, which use electricity from the grid and store it in a battery, HFCVs create their own electricity.

There are no current HFCVs in operation today. The major factor preventing HFCVs from being widely deployed is the high cost of the fuel cell. The National Academy of Sciences (NAS) said in a 2004 report that the cost of a fuel cell system, including the on-board storage of hydrogen, needs to drop by more than 50 percent to make such vehicles viable.²⁷

In addition to their high incremental cost, the extent to which HFCVs work as a viable solution to reducing oil dependence hinges on the source of the hydrogen used in the fuel cell. Using a natural gas reformer to produce hydrogen would have a lifecycle emission rate of about 150-190 grams of CO₂ per mile, similar to today's hybrid electric vehicles. However, if the hydrogen were instead

produced through electrolysis using electricity derived from nuclear power or renewable resources, the lifecycle emissions would drop to 16 grams of CO₂ per mile. The difference is important to understanding the potential—and the limitations—of these vehicles for reducing greenhouse gas emissions from the U.S. vehicle fleet.

Infrastructure

A network of hydrogen fueling stations has not yet emerged for several technical and financial reasons. First, most hydrogen is produced near where it is used, typically at large industrial sites which related to the distribution challenges noted above. Second, there is a need for more research into the cost of building a hydrogen station. This includes capital costs for equipment such as compressors and storage tanks; noncapital costs for construction including design and permitting; and total costs such as cost per station and cost per kilogram of hydrogen produced. Finally, in addition to shipping and cost barriers, federal regulations require the reporting of any hydrogen fuel dispensed, produced, and delivered, which can create administrative burdens for states wishing to build new hydrogen stations.

Advanced Diesel Vehicles

While not an alternative fuel, today's diesel engines nonetheless offer a 15 to 25 percent improvement in fuel economy compared with similarly sized gasoline engines. This greater fuel economy is due to the higher energy of diesel fuel—diesel contains 13 percent more energy than gasoline—and to the efficiency of diesel engines.

Supply

While diesels currently account for less than 4 percent of vehicle sales, increased success in developing cleaner diesel engines that are able to meet new, stricter air pollution standards have renewed automaker interest in selling such vehicles domestically. These seven automakers offer diesel vehicles for sale in the United States: Chevrolet, Dodge, Ford, GMC, Jeep, Mercedes-Benz, and Volkswagen.

Vehicles

Diesel vehicles are popular in Europe and are growing in acceptance in the U.S. market. While diesel vehicles are available for sale in all 50 states, in the United States they account for less than 4 percent of current vehicle sales.

One reason for low diesel vehicle penetration is concern over the ability of diesels to meet stringent new U.S. air quality standards. Yet thanks to advances in engine technologies, the expanded use of ultralow sulfur diesel fuel, and improved exhaust after-treatment, new diesel cars and trucks will likely be able to meet the same air pollutant standards as gasoline vehicles in the near future.²⁸

Further, because of diesel fuel's higher energy content, vehicles operating on it have higher fuel economy and lower CO₂ emissions. The U.S. EPA's *2006 Fuel Economy Guide* shows that four of the top 10 most fuel-efficient vehicles are diesel powered. Today's diesel vehicles emit 24 to 33 percent fewer CO₂ emissions per mile than their gasoline counterparts.²⁹

Still, the advances in engine and emissions control technology noted above have helped spur market optimism. A January 2005 report issued by the University of Michigan Transportation Research Institute's Office for the Study of Automotive Transportation and the Michigan Manufacturing Technology Center projected that in 2009 advanced diesel vehicles may account for as many as 1.8 million of the almost 17 million automobiles sold in the United States.³¹ According to a study by J.D. Power and Associates, sales are expected to nearly double in the next decade, accounting for 10 percent of total U.S. vehicle sales by 2015.³²

Distribution and Infrastructure

Another reason for interest is diesel fuel is its widespread availability. Diesel fuel is currently sold at more than 100,000 U.S. gas stations and is distributed through an extensive network of pipelines, trucks, and barges.

Coal-to-Liquids

Because coal is abundant and relatively cheap compared with natural gas and oil it is being considered as an energy source for transportation. As the name implies, coal-to-liquid (CTL) is the conversion of coal into liquid transportation fuels. However, coal is thermodynamically very stable and any conversion process is energy intensive. Getting fuels from coal is commonly referred to as coal liquefaction and can be done in one of two distinct approaches:

- **Indirect Coal Liquefaction (ICL)**—In this process, coal is put under high heat and pressure to create a synthesis gas comprised of hydrogen and carbon monoxide. The resulting "syngas" is treated to remove mercury and sulfur. This gas enters a second stage, called the Fischer-Tropsch process, which converts it into liquid fuels and other chemical products.
- **Direct Coal Liquefaction (DCL)**—Using this technology, coal is pulverized and mixed with oil and hydrogen in a pressurized environment. This process converts the pulverized coal into a synthetic crude oil that can be refined into a variety of fuel products, including gasoline, diesel, and LPG.

The ICL-based Fischer-Tropsch diesel provides similar or better vehicle performance than conventional diesel. Tested by the U.S. Department of Defense in 6.5-liter diesel engines, it has been shown to reduce regulated criteria air pollutant emissions from a variety of diesel engines and vehicles, and the near-zero sulfur content of these fuels can enable the use of advanced emission control devices.

Moreover, most of the CO₂ is already concentrated and ready for capture and possible sequestration or for use in enhanced oil or gas recovery. South Africa-based Sasol, the most established coal-to-liquids producer, is supporting a demonstration project in **Pennsylvania** that will use the Fischer-Tropsch process to make liquid fuels from coal waste.

The DCL process converts coal into a synthetic crude oil that can then be refined into a variety of fuel products. Under laboratory demonstrations, DCL processes can convert one ton of coal to yield about a half-ton of liquid fuels. While DCL technology has not yet proven to be cost effective outside of the laboratory, Sasol continues to develop its processes and a number of smaller companies are working to establish commercial-scale coal-to-liquids production.

While both CTL processes differ in their state of deployment, each is well understood. The principal drawback to either type of CTL technology is that current production methods release more CO₂ in the conversion process than is released in the extraction and refinement of petroleum. This is largely due to the lifecycle emissions, which include emissions released during the conversion process and the associated environmental degradation from coal and tar sands³³ extraction.

In both cases, streams of relatively pure CO₂ are produced, which would have to be captured, dried, compressed, and stored underground to reduce greenhouse gas emissions. This carbon capture and sequestration could alleviate some of the CO₂-related problems linked to CTL, but this is still a relatively untested and costly technology. Recent reports indicate that in the absence of carbon capture and sequestration coal-derived fuel (CTL) doubles CO₂ emissions compared to gasoline.³⁴

Supply

One-quarter of the world's proven coal reserves are in the United States, making it an attractive option for developing a domestic source of energy free of the security risks currently associated with imported petroleum. Other significant methods or sources for producing CTL in the United States include oil shale and tar sands extraction, heavy oil, enhanced oil recovery, and coal-derived liquids.

Domestic production of fuels from these resources could reduce dependence on imported oil. Although very little CTL conversion goes on today in the United States, nearly every major oil company has announced plans to build pilot or commercial plants to produce synthetically derived diesel fuel through improved CTL processes.

Making CTL viable requires that federal, state, and local officials consider a range of policy options to stimulate needed capital investment. CTL also faces significant technological and practical challenges that constrain its development, including lack of techno-

logical readiness, low market demand, concerns about economic and environmental impact, and a lack of a water route and overall shipping infrastructure.

Vehicles

In addition to supply and distribution constraints, CTL is a diesel substitute whereas the U.S. fleet is primarily comprised of gasoline-powered vehicles. And, as noted earlier, it is likely that CTL-fueled vehicles would increase CO₂ emissions over conventional automobiles.

Distribution and Infrastructure

CTL delivery would not require new or modified pipelines, storage tanks, or retail station pumps. The Task Force on Strategic Unconventional Fuels, established by the Energy Policy Act of 2005, has just completed an integrated strategy and program plan to coordinate and accelerate the commercial development of strategic unconventional fuels within the United States, including oil shale and tar sands, heavy oil, enhanced oil recovery, and coal-derived liquids.

The task force concluded that declining domestic oil production and rising U.S. demand for oil will increase the nation's dependence on foreign sources of oil. This growing import dependence challenges the strategic interests of the United States, particularly as global conventional oil production may soon fall short of demand, the task force said, concluding that CTL could be one way to meet the demand for domestic fuels. However, significant technological, environmental, and cost concerns must be overcome to make these fuels viable.

Advanced Biomass (Biobutanol and E-Diesel)

Biobutanol is produced from biomass feedstocks. Currently, butanol's primary use is as an industrial solvent in lacquers and enamels. Like ethanol, biobutanol is a liquid alcohol fuel that can be used in today's gasoline-powered internal combustion engines. The properties of biobutanol make it highly amenable to blending with gasoline. It also is compatible with ethanol and can improve the blending of ethanol with gasoline. However, the energy content of biobutanol is 10 to 20 percent lower than that of gasoline and there are no practical applications of this fuel in use today.

E-Diesel is a fuel that uses additives to blend ethanol with diesel. It includes ethanol blends of 7.7 to 15 percent and up to 5 percent special additives that prevent the ethanol and diesel from separating at very low temperatures or if there is water contamination. However, E-Diesel is currently an experimental fuel and demonstrations are being conducted to determine the economic and environmental viability of its use in heavy-duty trucks, buses, and farm machinery.

Increasing Fuel Economy

In addition to alternative fuels, improvements in vehicle fuel economy—the average mileage traveled by an automobile per gallon of fuel—can significantly offset the amount of petroleum used in cars and trucks. While states do not have a direct role in setting vehicle fuel economy standards, they can take a number of steps to encourage technology and behaviors that can reduce fuel use. In addition, several states are looking to adopt measures being pursued by **California** to reduce vehicle greenhouse gas emissions beyond the levels required by federal law.

Federal Fuel Economy Standards

National vehicle fuel economy standards are established and implemented by the federal government under the Corporate Average Fuel Economy (CAFE)³⁵ Act, which requires every automaker who sells at least 50,000 vehicles in the United States to meet a specific fuel economy average for its entire fleet in any given model year. In December 2007, President Bush signed the Energy Independence and Security Act of 2007,³⁶ which requires automakers to meet an average CAFE standard of 35 mpg by 2020. The provision also sets the nation's first fuel economy standard for heavy-duty trucks. The act also leaves open the possibility of additional increases in the CAFE standard at a “maximum feasible rate” between the years 2021 and 2030.

California's Vehicle Standards and the U.S. EPA Waiver Process

Separate from the federal CAFE standards, several states are taking action to reduce vehicle greenhouse gas emissions that will impact fuel use. Under unique authority granted by the U.S. Clean Air Act, **California** has adopted a rule to reduce tailpipe greenhouse gas emissions from its share of the nation's new passenger vehicles, starting with model year 2009. Sixteen states have adopted or are in the process of adopting California's standards, as permitted by federal law.^v However, implementing this rule calls for a waiver from the U.S. EPA.

In 2005, California applied for a waiver. In late December 2007, the U.S. EPA rejected California's waiver, stating that the new national CAFE standards, described above, would deliver greater reductions in vehicle greenhouse gas emissions compared with a state-by-state approach. The agency also asserted that greenhouse gases are global in nature, unlike the local air pollutants covered by California's previous U.S. EPA-approved waivers. In California and 15 other states have asked a federal court to reverse the U.S. EPA's decision. In a response to the U.S. EPA, California cites technical analysis by the California Air Resources Board showing that the California standards, if adopted nationally, would produce greater emissions savings compared to the federal program by 2020. Legal proceedings and congressional hearings are set to examine both positions.³⁷

Those states that have adopted the California standards will cumulatively reduce GHG emissions by 145 million metric tons by 2016.

Mileage Improvement Technologies

Beyond the federal CAFE standards, and the actions being pursued by California and other states to directly address vehicle greenhouse gas emissions, states can advance a number of mileage improvement technologies for use in new cars and trucks. These are near-term technologies states can implement to reduce petroleum use and mitigate greenhouse gas emissions, without waiting for federal mileage standards to take effect. In addition, vehicle accessories and efforts to adjust driver behavior can save fuel used by cars and trucks already on the road.

The American Council for an Energy-Efficient Economy recently documented three leading technological improvements that could collectively improve fuel efficiency:³⁸

Engine Modifications—In a typical car or truck, all engine cylinders are in use under all driving conditions, with timing and valve lift fixed to maximize engine performance. However, there are technologies that can vary these operational parameters to emphasize fuel efficiency while maintaining performance. Some examples of these engine technologies include:

- **Variable Valve Timing (or Variable Valve Timing and Lift)**—These systems automatically alter valve timing and lift to provide a better fuel/air mix and improve combustion. These technologies can improve fuel economy by an average of 5 percent.
- **Cylinder Deactivation**—This technology shuts down one or more cylinders when the extra power is not needed. This is particularly applicable to vehicles with V-6 and V-8 engines. This technology can improve fuel economy by 7.5 percent.

Improved Transmission—Conventional transmission systems control the ratio between engine speed and wheel speed using a set number of gears. New variable transmission technologies enable engines to operate at near optimal speed more frequently. Some examples of these transmission technologies include:

- **Continuously Variable Transmissions (CVT)**—By allowing an infinite number of speeds within an automatic transmission, CVTs reduce the mechanical losses associated with transmission operation. CVTs replace gears with a pair of pulleys connected by a belt or chain that can produce an infinite number of engine/wheel speed ratios. This can improve fuel economy by 6 percent.

^vTo date, the states that have adopted or seek to adopt California's requirements are **Arizona, Colorado, Connecticut, Florida, Maine, Maryland, Massachusetts, Minnesota, New Jersey, New Mexico, New York, Oregon, Pennsylvania, Rhode Island, Vermont,** and **Washington**, according to California officials.

- **Automated Manual Transmissions**—These are lighter than conventional automatic transmissions and do not require the driver to do actual gear shifting. Instead, shifting is controlled by a hydraulic system or electric motor. Five- or six-speed automatic transmissions instead of the four-speed automatic transmission standard can improve fuel economy by 7 percent or more.

Direct-Fuel Injection—In conventional cars, fuel is mixed with air to create an air-fuel combination that is then pumped into the cylinder. In direct-injection fuel systems, petroleum is injected directly into the cylinder, which allows for a more efficient fuel intake, creating improved performance that can boost fuel economy by 12 percent.

Many of these new engine and transmission technologies are already in mass production and there are a number of other emergent technologies scheduled for introduction in the near future. While they may be more expensive in terms of upfront vehicle cost, the resulting fuel savings over the vehicle's life greatly exceed the upfront cost.³⁹

Advanced Vehicle Accessories That Can Save Fuel

Although new engine technologies offer significant fuel savings, they can take a long time to be fully adapted by the industry and integrated into the U.S. fleet. State fleets, consumers, or businesses may also look to vehicle accessories that provide immediate fuel savings and reduce CO₂ emissions. Today, the two prevalent technologies are advanced tires and engine lubricants, which are cost-effective, accessible ways to improve car and truck fuel efficiency.

Low-rolling-resistance tires minimize the energy lost to heat between the tire and the road, within the tire sidewall, and between the tire and the rim. The U.S. DOE estimates that 5 to 15 percent of fuel is consumed to overcome passenger-car tire-rolling resistance.

Car manufacturers commonly install low-rolling-resistance tires on new vehicles to help meet CAFE standards, but only a limited number of such tires are used as replacements. If all replacement tires in the United States were as efficient as the originals, it is estimated that the U.S. passenger fleet would save up to 8 billion gallons of gasoline annually by 2015.

Starting in July 2008, a **California** law will require the California Energy Commission, in consultation with the California Integrated Waste Management Board, to adopt and implement a statewide energy-efficient replacement tire program that mandates labeling and fuel efficiency standards for all substitute tires sold in the state.

Like low-rolling resistance tires, low viscosity motor oils and lubricants can provide additional fuel savings for passenger vehicles and heavy-duty trucks by reducing energy losses from internal friction. Testing has revealed fuel economy benefits ranging from 1 percent to more than 5 percent in passenger vehicles that use these types of substances.

Although tires and lubricants are two of the most effective fuel-savings accessories, vehicle maintenance provides significant benefits as well. Regularly changing fuel filters and spark plugs, and following other manufacturer-recommended replacement schedules for parts can also contribute to vehicle fuel savings. These are explored in more detail in the next section.

Other manufacturer-installed vehicle accessories can save gasoline. These include integrated starter-generators that allow vehicles to turn off at idle then quickly restart, as well as electric power steering and air conditioners. Manufacturers also are developing more fuel-efficient cars and trucks that reduce aerodynamic drag through sleeker body design and the use of lightweight materials.

Driver Behavior and Idling Reduction

Beyond vehicle accessories, driver behavior modifications can provide even more immediate fuel savings.

Actions that states and individuals can take to improve gas mileage through improved operation of light-duty vehicles include driver safety, eliminating extra weight, proper tire inflation, and routine engine maintenance.

Maximum fuel efficiencies can be achieved by influencing driving patterns in ways that reduce the energy required to operate a vehicle, thus allowing the engine to reach optimal efficiency. Habits that reduce fuel use include better trip planning; avoiding aggressive driving behaviors (speeding, rapid acceleration, and deceleration); reducing excess weight and aerodynamic drag; maintaining steady speeds; anticipating traffic conditions; practicing smooth acceleration and deceleration; and upshifting as soon as possible.

The following types of federal and state programs can encourage driver behavior modifications:

- Public education campaigns focusing on fuel savings from better driver behavior;
- Driver training courses, such as mandatory programs for poor drivers, voluntary classes for interested drivers, and drivers' education courses that integrate fuel efficiency topics; and
- Specialized licensing for heavy-duty fleet vehicle operators, such as public transit bus drivers.

In addition to driver behavior improvements, better vehicle maintenance practices improve vehicle efficiency. Underinflated tires decrease fuel economy by as much as 0.4 percent for every pound per square inch (psi) of pressure below proper inflation levels. Similarly, poor maintenance of mechanical systems and filters and the failure to change worn-out oils can diminish fuel economy. Below are results from a U.S. EPA study that quantified benefits that could accrue from using these programs for regional or state fleet programs.

Another short-term action states are taking to avoid wasted fuel is to implement and fully enforce idling reduction laws. More than 25 states and jurisdictions also have implemented laws and regulations addressing vehicle idling times and speed limits. Examples include:

- In **Connecticut** there are two anti-idling laws, one for school buses and the other for all motor vehicles (the latter makes an exception and allows idling in certain circumstances, such as when cars are being serviced, are having mechanical difficulties, or are subject to cold temperatures).
- In **Massachusetts**, the state's idling laws make it illegal to idle any motor vehicle for more than five minutes. The Massachusetts law exempts vehicles in repair or service. The state also posts highly visible signs to remind motorists about the state vehicle idling law.⁴⁰
- In 2005, the **Tennessee** Department of Transportation (TDOT) agreed to lower the speed limit to 55 mph from 70 mph on highways in an effort to reduce heavy-duty truck emissions. TDOT cited a study conducted by the U.S. Federal Highway Administration showing that reducing truck speeds by 10 mph can reduce emissions by 18 percent or more per truck.

Truck Stop Electrification

Trucks are a crucial part of the U.S. economy, shipping 90 percent of all goods nationwide, according to the U.S. Bureau of Transportation Statistics. However, they are also the second largest user of oil in the transportation sector. States have been working to address this sector as well, in particular through incentives to encourage truck stop electrification.

Heavy-duty trucks use 18 billion gallons of diesel fuel annually, or 12 percent of U.S. fuel consumption, and contribute a corresponding share of greenhouse gas emissions. Moreover, the U.S. DOE projects freight emissions will triple by 2025, accounting for almost one-third of transportation CO₂ output.⁴¹

Truck engine idling is a significant source of these vehicles' emissions, consuming 1 billion gallons of diesel fuel per year and emitting 11 million tons of CO₂ annually. In particular, overnight idling associated with long-haul trucking is estimated to consume 838 million to 2 billion gallons of fuel annually—nearly 5 percent of heavy-truck fuel. This situation costs \$6 billion in lost fuel, increases engine maintenance needs, and exposes drivers to toxic air pollutants.

Recent developments in truck stop electrification (TSE) technology have provided new options for drivers. Installed at truck stops or rest areas, TSE technology provides a stationary power source that allows the parked driver to operate all on-board systems, including heating, ventilation, and air conditioning, and devices running on AC electrical power.

Examples of state programs include:

- **New York** is a national leader in the installation of TSE infrastructure, pioneering the nation's first TSE demonstration project. IdleAire off-board systems were installed at two existing sites on the New York State thruway that can accommodate 45 long-haul trucks. The service is provided to trucks for \$1.40 an hour.
- In **Oregon** and **Washington** the Climate Trust is partnering with the U.S. EPA and the Oregon Department of Energy to develop the Interstate 5 truck idle reduction project. The program will make use of idle reduction technology provided by Shurepower LLC at 275 spaces in seven truck stops. It is estimated that the project will displace 100,000 tons of CO₂, 1,400 tons of NO_x, and 40 tons of particulate matter, while saving 10 million gallons of diesel fuel. The Climate Trust will purchase carbon offsets from the project to overcome some of the financial barriers to TSE implementation.

Automakers, original equipment manufacturers, and engine developers have made strides in developing and selling advanced technologies that can boost vehicle fuel efficiency and reduce greenhouse gas emissions from today's cars and trucks. While states do not have a direct role in setting federal fuel economy standards, many are taking action to deploy the advanced vehicle, engine, and idling technologies described above; others are developing driver education training programs and materials. Collectively, these actions can have a positive, near-term impact on U.S. passenger vehicle emissions.

Table 5 Fuel Savings from Driver Behavior Programs

Program	Fuel Economy (benefit percentage)	Fuel Savings (per gallon)
Driver Safety	5-33	\$0.14-\$0.92
Observe the Speed Limit	7-23	\$0.20-\$0.64
Eliminate Extra Weight	1-2/per 100 lbs	\$0.03-\$0.06
Keep Your Engine Tuned	4	\$0.11
Replace Air Filters Regularly	Up to 10	Up to \$0.28
Keep Tires Properly Inflated	Up to 3	Up to \$0.08
Use Recommended Motor Oil	1-2	\$0.03-\$0.06

Source: U.S. Environmental Protection Agency

State Actions to Promote Green Fuels and Vehicles

While modifying existing petroleum-based technology offers some savings, achieving significant reductions in oil imports and greenhouse gas emissions and will require even greener fuels and vehicles.

Experts have long recognized that there is a chicken-and-egg dilemma hampering the development of alternative fuel markets: (1) consumers will not purchase vehicles that run on alternative fuel unless they know they can buy this fuel easily at both their corner station and at highway rest stops; and (2) fuel suppliers will not fund and build enough ethanol, natural gas, or other alternative fueling stations unless they know they will have a steady supply of consumers.

These are daunting concerns, but if they are addressed simultaneously, the alternative fuels market may eventually reach a critical mass for both consumers and suppliers. However, three core barriers must be addressed:

- Lack of alternative **fuels** in the marketplace;
- Limited fuel **distribution** systems to get the fuels from refiners to vehicles; and
- Inadequate supply of alternative **vehicles** produced and used by consumers.

Challenges to Building Alternative Fuel and Vehicle Markets

Each of these three core barriers to alternative fuel use contains its own set of cost, market, and policy challenges. For **fuels**, challenges coalesce around the limited supply and production capacity for non-petroleum fuels. The lack of economies of scale means consumers face higher fuel costs compared with gasoline and diesel users. The resulting limited supply also means consumers are less likely to find and use such fuels.

These technological and capacity supply challenges overlap with the second barrier—limited fuel **distribution** networks. Here, the challenge rests with a severe shortage of fuel infrastructure and delivery systems. There are few alternative fuel pumps available, mainly due to high installation costs. Yet even if pumps were more prevalent, getting fuel from production sites to consumer markets is constrained by the limited fuel distribution capacity.

For ethanol, which is the most prevalent alternative fuel in the United States, a dedicated fuel pipeline is prohibitively expensive because of the lack of concentrated market demand. Surface transportation shipping options are also squeezed due to shortages of truckers and because railroads are running at or near capacity in much of the country. These distribution challenges make it harder to introduce fuels to consumers and to expand alternative fuels into new markets.

As with fuels, the primary challenge for **vehicles** is cost, lack of supply, and limited consumer awareness. Automobile dealers are often weary of stocking alternative fuel vehicles that are more expensive than regular cars and trucks. Beyond the stocking issue, many consumers are simply unaware of the availability of existing alternative fuel vehicles. In the case of ethanol flexible fuel vehicles, which are being produced in growing numbers, many owners report that they are not even aware they are driving a car or truck capable of running on a fuel other than gasoline.

In 1992, recognizing these intertwined challenges, Congress passed the Energy Policy Act, which was designed to reduce U.S. oil dependence by requiring that an increasing annual share of gasoline and diesel fuel be replaced with nonpetroleum transportation fuels. The act also mandated alternative fuel vehicle purchase targets for select public and private fleets. Yet today, alternative fuel vehicles are still only 2 percent of the total U.S. vehicle market and alternative fuel sales account for just 3 percent of total transportation fuel use.⁴² Clearly, more work remains.

Policy Tools for States to Address These Challenges

States are well-situated to surmount these obstacles and nurture along the alternative fuel supply and distribution network and vehicle market. Governors generally have the following four policy options to meet the three core barriers to a fully developed green fuels/green vehicles marketplace:

1. Provide financial incentives through tax credits, deductions, grants, loans, and other means to spur market response;
2. Pass rules and mandates requiring, for example, that state fuel distributors sell a certain quantity of alternative fuels;
3. Use their considerable purchasing power to boost the adoption of alternative fuels or vehicles (for example, by purchasing new indigenous fuel-production supplies or buying hybrid vehicles for use in state fleets); and
4. Invest in research and demonstration (R&D) efforts to speed new technologies to the marketplace.

Overcoming Barriers: State Examples

Governors across the country are applying one or more types of policy tools to build sustainable alternative fuel sources, infrastructure, and advanced vehicle markets. Some of these state policy actions are described below.

Challenge: Alternative Fuels

Governors are combining some or all of their policy options to expand alternative fuel supplies.

Tax credits, deductions, grants, and loans, in particular, can spark in-state alternative fuel production. These **funding incentives** play a critical role in moving alternative fuels to market; 23 states now provide incentives promoting ethanol production and use, and a similar number have tax credits supporting production facilities and alternative fuel production.

Hawaii has enacted a refundable ethanol fuel facility tax credit of up to 30 cents per gallon of capacity per year for up to 8 years, or until 100 percent of the amount invested in the facility has been returned to investors in the form of tax credits, to encourage the displacement of ground transportation fuel demand with locally produced biofuels.

In **Kentucky**, former Governor Ernie Fletcher signed energy legislation in 2007 that created a variety of incentives designed to spur production of biofuels. The law expanded an existing biodiesel tax credit of \$1 per gallon to include renewable diesel, and increased a cap on the total tax credit from \$1.5 million to \$5 million in 2008 and to \$10 million in 2009. The bill also created new tax credits of \$1 per gallon for ethanol produced from corn, soybeans, or wheat, and for ethanol produced from cellulosic biomass, each of which includes a cap of \$5 million.

State funding mechanisms to promote alternative fuel production are also designed in part to leverage indigenous state feedstocks to build new markets and create jobs. Furthermore, these funding programs help states meet their alternative fuel use goals by creating a new stream of nonpetroleum fuels.

To encourage clean fuels production in his state, **Massachusetts** Governor Deval Patrick proposed legislation to exempt from state taxes cellulosic ethanol produced from forest products, switch grass, and agricultural wastes. The gas-tax incentive for cellulosic ethanol is projected to create 3,000 new jobs and \$320 million in economic investments for the state. Three Massachusetts refineries are also in the planning stages, with local and national distributors preparing to compete in biofuels distribution.

To gauge fuel production capacity, some states have procured studies to assess their own fuel supply and market potential. For example, a report published in June surveying the **Oregon** bioenergy industry identified 80 potential biodiesel, ethanol, and biomass facilities that could produce a combined 400 million gallons per year of ethanol

and another 315 million gallons of biodiesel.⁴³ In **Washington**, the Washington State University Energy Extension has done similar work, identifying both oilseed crushers and state potential biofuels production facilities.

New York has supported a set of financial incentives to encourage the production and use of alternative fuels that includes the following components:

- Eliminating state taxes on renewable transportation fuels (e.g., ethanol and biodiesel);
- Expanding renewable fuel stations through the use of a \$25 million gas station grant program;
- Providing \$20 million for the development of a public-private-funded cellulosic ethanol plant;
- Allowing a 15-cent tax credit per gallon of renewable fuel produced.

In **Wisconsin**, Governor Jim Doyle has created the Wisconsin Energy Independence Fund, which will make \$150 million in grants and low interest loans available to Wisconsin businesses looking to expand production and use of renewable energy, including alternative transportation fuels. In addition, beginning in 2009, the state will offer a tax credit equal to 10 cents per gallon for biodiesel fuel producers in the state that produce at least 2.5 million gallons of biodiesel per year.

In **Georgia**, a company called Range Fuels broke ground on a cellulosic ethanol plant in November 2007 that will be capable of making 20 million gallons of ethanol from wood and wood waste a year, with production expansion plans of 100 million gallons annually. This public-private partnership includes \$76 million as part of a Technology Investment Agreement between Range Fuels and the U.S. Department of Energy.

In **Florida**, one 2007 Renewable Energy Technologies state grant program recipient was Citrus Energy LLC, which received \$2.5 million for a project called “Fuel Ethanol Production from Citrus Waste Biomass.” The Clewiston, Florida, company will construct a 20-million-gallon-per-year ethanol biorefinery to turn citrus waste into ethanol. The project promises to turn this abundant agricultural waste product into a clean, affordable, and locally produced biofuel.

In **Washington**, the Energy Freedom Loan program was established in 2006, in part, to stimulate the construction of facilities in Washington to generate energy from farm and organic feedstocks into biofuels. The program offers low-interest loans to local governments, ports, and other public entities and is intended to leverage additional private financing. To date, the Washington State Department of Agriculture has completed agreements worth \$13 million to support biofuels projects.

As a result of **Montana** Governor Brian Schweitzer’s “Clean and Green” energy development initiative in 2007, Montana offers a variety of tax incentives for facilities that produce cellulosic and non-foodstuff ethanol, biodiesel, and coal-to-liquid fuels that incorporate carbon sequestration.

An increasing number of states are passing **rules and mandates** requiring alternative fuel production quotas. Currently, nine states have comprehensive plans in place requiring that refiners blend a minimum percentage content of renewable fuel into state gasoline and diesel supplies by a certain date (**Table 6**).

These renewable fuel standards aim to stimulate economies through new or expanded indigenous fuel production and through the creation of jobs necessary to support such processing facilities. For example, an economic analysis by the University of Missouri estimated that the state’s renewable fuel standard will provide a \$348 million boost to **Missouri’s** economy through in-state ethanol production.

Table 6 State Renewable Fuel Standards

Requirement	Target Date/Details	State
E20 B2	2013 2005	Minnesota
E10	2006	Hawaii
E10	2008	Missouri
E10	2006	Montana
E10 B5	2012	New Mexico
E10 B2	Upon production of 40 million gallons/year (ethanol) and 5 million gallons/year (biodiesel) in MT, OR, WA, ID	Oregon
E2 B2	Six months after 50 million gallons/year production (ethanol) and 10 million gallons/year (biodiesel)	Louisiana
25% of fuel sales	2015	Iowa
2% of fuel sales (ethanol and biodiesel)	2008 (E10 and B5 if sufficient in-state production)	Washington

Since the late 1990s, **Minnesota** has had an E10 statewide standard. In 2005, Governor Tim Pawlenty proposed and signed legislation doubling that to E20 statewide by 2013, which is the nation's most aggressive ethanol standard. The state is currently working to conduct the analysis necessary to support EPA approval of that fuel. In 2005, Minnesota also was the first state to implement a 2 percent biodiesel blending requirement. Governor Pawlenty announced in August 2007 that Minnesota would be seeking to increase this B2 requirement to B20 by 2015.

Also in 2005, Governor Pawlenty issued the "SmartFleet" executive order requiring a 25 percent reduction in gasoline use by 2010, a 50 percent reduction in gasoline use by 2015 as well as a 10 percent reduction in petroleum-based diesel fuel use by 2010, and a 25 percent reduction in petroleum-based diesel fuel use by 2015.

In 2007, California Governor Arnold Schwarzenegger issued an executive order establishing a Low-Carbon Fuel Standard (LCFS), which sets a greenhouse gas standard for transportation fuels to advance research on alternatives to oil and to reduce the "lifecycle carbon intensity"^{vi} of state transportation fuels. The goal is to reduce the carbon intensity of transportation fuels sold in California by 10 percent by 2020.⁴⁴

The California LCFS program will establish a credit trading program to allow fuel providers to meet the standard in the most cost-effective manner. This would provide fuel providers with flexibility on how they can meet the standard.

In March 2006, **Wisconsin** Governor Jim Doyle signed Executive Order 141, which directs the state's Department of Administration to require, through its fleet management policy, that all state agencies reduce the use of petroleum-based gasoline in state-owned vehicles by 20 percent by 2010 and by 50 percent by 2015. In addition, state agencies will reduce the use of petroleum-based diesel fuel in state-owned vehicles by 10 percent by 2010 and 25 percent by 2015. Finally, the state has developed a plan to facilitate increased usage of renewable fuels in the state's flex fuel vehicle fleet.

Other state renewable fuel mandates are being complemented by some of the financial tools discussed above, including credits for private-sector blenders and producers. **Hawaii** Governor Linda Lingle's renewable fuels mandate has led to a \$100 million private sector investment in support of three new biofuel conversion facilities, which will collectively produce 160 million gallons of biodiesel per year. In addition, the state will work with the private sector to create a network of refueling stations located near these production facilities.

When adopting fuel mandates, states need assurances that some of the necessary fuel supply to meet their targets can be produced from indigenous sources. One way this is achieved at the state level is

through the adoption of **rules and requirements** backed up by state **purchasing power**.

In **Pennsylvania** Governor Edward Rendell aims to use state spending to help the state replace 1 billion gallons of transportation fuels with domestically produced alternative and renewable fuels by 2017. Through the "PennSecurity Fuels Initiative," the state energy strategy, Pennsylvania will set aside funding to support the production of clean and renewable fuels. By using the power of the purse Governor Rendell is building a state market and the production capacity for nonpetroleum fuels that will help meet state goals.

In **Washington** by 2015, all state agencies and local government subdivisions of the state must satisfy 100 percent of their fuel needs using either electricity or biofuels produced from recycled materials or indigenous feedstocks.

While state-targeted funds are important to expanding fuel supplies, significant long-term reductions in petroleum use require more **research and demonstration (R&D)** in areas such as second-generation biofuels. State R&D programs can form the building blocks for future research and demonstration of cost-effective, low-carbon alternative fuels.

Similar state biofuels R&D initiatives exist in **Michigan**, where Governor Jennifer Granholm is supporting an investment that includes research into energy conversion of biodiesel byproducts, such as cellulosic ethanol. This effort involves a plan to design a National Biofuels Energy Laboratory with private partners, along with construction of a biodiesel plant capable of producing 10 million gallons of alternative fuels per year.

One example of this is in **Tennessee** where Governor Phil Bredesen has launched a \$72 million biofuels program to support the research, agricultural application and technology transfer impacts of the Tennessee Biofuels Initiative. The University of Tennessee and Oak Ridge National Laboratory are leading this initiative, which also includes a pilot 5 million gallon per year cellulosic ethanol biorefinery. It also further bolsters the recent creation of a Bioenergy Science Center at Oak Ridge National Laboratory (ORNL) that is supported by a \$135 million, 5-year U.S. DOE grant to produce biofuels from biomass feedstocks.

In **Texas**, Governor Rick Perry announced a \$5 million grant from the state's Emerging Technology Fund (ETF)⁴⁵ for the Texas A&M Agriculture and Engineering Bioenergy Alliance. The alliance, a partnership between the Texas Agricultural Experiment Station and the Texas Engineering Experiment Station, will use the funds to hire new commercially focused faculty who can accelerate the market viability of next-generation biofuels. The Texas A&M system is positioned to integrate the development and design of oil-based feedstocks with emerging technologies.

^{vi} Under the California LCFS fuel providers would be required to track the global warming intensity (GWI) of their products, measured on a per-unit energy-delivered-by-the-motor-vehicle basis, and reduce this value over time. This measurement of total lifecycle GWI per unit of delivered energy is called carbon intensity.

In 2007, **Washington** committed \$2 million dollars over two years to support Washington State University research on biofuels crops that are more economically and environmentally sustainable and provide further potential for developing value added bioproducts such as animal feed, fiber products, and biopesticides.

Challenge: Fuel Distribution and Infrastructure

To reduce petroleum, the United States likely will need a new fueling infrastructure, which comes with a daunting series of financial and technical challenges. Currently, alternative fuel distribution and delivery networks are severely constrained—for example, there are less than 3,000 alternative fuel equipped filling stations nationwide compared with more than 130,000 gasoline filling stations. These challenges make it harder to introduce fuels to consumers or to grow new alternative fuels markets.

However, states are using several different policy tools and mechanisms to address the dearth of alternative fuel filling stations. **Financial incentives**, including tax credits, but also loans and other incentives, are common mechanisms used by states to encourage the construction of new pumps and, in some cases, build fuel distribution networks.

Many states provide income or business tax credits to offset the siting, construction, and land acquisition costs required for new alternative fuel stations. **Connecticut** has a Corporation Business Tax credit that covers up to 50 percent of expenditures related to the construction of, improvements to, or equipment related to compressed natural gas, liquefied natural gas, or liquefied petroleum gas refueling stations or electric vehicle recharging stations.

Colorado's Department of Revenue offers an income tax credit of 35 percent for tax years 2006-2009 and 20 percent for tax years 2009-2011 to offset the cost of construction or acquisition of public alternative fuel facilities. This can be up to \$400,000 and funding is increased for refueling facilities that dispense renewable fuels.

A related example is the **Illinois** E85 Clean Energy Infrastructure Development Program, which provides up to 50 percent of the total cost for converting an existing fueling facility to one that dispenses E85. This fund provides as much as \$3,000 per pump, or a maximum of 30 percent toward the cost of constructing a new E85 fueling station.

Either in addition to or in lieu of tax credits, some states are providing grants to deploy an alternative fuel infrastructure. For example, grants of up to \$5,000 are available through the **Indiana** E85 Fueling Station Grant Program for the purchase of new E85 refueling equipment or the conversion of existing equipment. A similar grant program exists in **Minnesota**. Created by Governor Tim Pawlenty, the state operates a Smart Fleet Committee, a group of technical ex-

perts who help existing service stations install E85 storage tanks or dispensers. The committee is also available to service private sector entities that wish to build new public E85 refueling facilities.

Over the next three years, **Iowa** will be awarding \$13 million from the state's Renewable Fuel Infrastructure Program for the installation or conversion of E85 and biodiesel refueling stations. This program provides direct assistance grants to retailers and biodiesel wholesale distributors and will expand consumer access to renewable fuels.

A similar effort is proposed in **Michigan**, where Governor Jennifer Granholm plans to invest \$7 million as part of the state's comprehensive energy plan to increase the number of biofuel pumps across the state.

In addition to financial incentives, states are using their broad **purchasing power** to support new refueling infrastructure sites. **Pennsylvania** has two renewable energy-financing mechanisms: the Alternative Fuels Incentive Grant⁴⁶ (AFIG) and the Pennsylvania Energy Harvest Grant (PEHG) programs.⁴⁷ Select portions of these funds are used to pay down the cost of fuels infrastructure. In addition, fuel that is produced in Pennsylvania and used for transportation purposes receives a state reimbursement of up to 5 cents per gallon annually for as much as 12.5 million gallons of biodiesel or ethanol produced in a calendar year.

In June 2007 **Tennessee** Governor Phil Bredesen announced the first round Green Island grants. Nearly \$2 million has been allocated to this program to establish "Green Island" interstate biofuel corridors. Retail station owners can apply for 80 percent cost-sharing grants up to \$45,000 per pump to install E85 or B20 refueling sites.

To help meet the state's renewable energy goals, **Wisconsin** offers tax credits to increase both the production and use of biofuels. These tax credits will encourage fueling stations to install new renewable fuel pumps, or to retrofit existing pumps to accommodate renewable fuels. Under the credit, each service station that installs or retrofits pumps that dispense fuel containing at least 85 percent ethanol or 20 percent biodiesel will be eligible for up to \$5,000 in tax credits, per station, per year.

To further build fuel diversity in their transportation sectors, a number of states are embarking on individual or collective **R&D** to support clean fuel infrastructure programs. These state R&D efforts often consist of preliminary research efforts, such as studies or reports, designed to deploy a hydrogen refueling infrastructure to support an anticipated future state fleet of hydrogen and fuel cells vehicles.

In **California** Governor Arnold Schwarzenegger declared that the state's 21 interstate freeways are the "California Hydrogen Highway Network."⁴⁸ This statement represents a commitment to work with

legislators, energy providers, automakers, and others to build a network of hydrogen refueling stations, safety standards for hydrogen refueling stations, and incentives for building new stations by 2010.

In **Connecticut**, the Department of Economic and Community Development is required by state statute to establish a research and deployment plan for fuel cell economic development that includes the installation of infrastructure for hydrogen production, storage, transportation, and fueling capability.

The **Idaho** Commissioner of Commerce is authorized by Governor C.L. “Butch” Otter to participate in projects to design, develop, and construct hydrogen refueling stations that eventually link urban centers along key trade corridors across the jurisdictions of Manitoba, **North Dakota**, **South Dakota**, **Minnesota**, **Iowa**, and **Wisconsin**. These energy stations will accommodate a wide variety of advanced fueling platforms.

As discussed above, **Montana**’s “Clean and Green” energy development initiative includes financial support for research and development equipment and for manufacturing facilities related to fuel cells, electric vehicles, and hybrid electric vehicles.

In **New York**, the New York State Energy Research and Development Authority, the New York State Thruway Authority, and the New York Department of Environmental Conservation have collectively undertaken a feasibility study on the construction of alternative fuel refilling facilities along the New York State Thruway. The report will include the current and projected price of the advanced alternative fuel refilling equipment for the next decade and will also evaluate the cost, regulatory needs, and other aspects of adding such fuel pumps to every public gasoline station on the thruway.

Challenge: Alternative Fuel and Advanced Vehicles

Related to the need for greater fuel supplies is the need to increase the number of alternative fuel and advanced vehicles, which are essential to state and national efforts to reduce petroleum consumption. Despite growing sales of hybrid gas-electric, ethanol, biodiesel, and other alternative fuel vehicles and greater attention by automakers on their development for consumers, much wider deployment of these vehicles is needed. States are using the full set of policy tools at their disposal, including developing new partnerships to help address this challenge.

As is the case with fuel supplies and distribution, one such tool used by states is direct **financial incentives**, which include tax credits as well as reduced sales and excise taxes. These incentives can aid consumers wishing to purchase alternative fuel vehicles by offsetting the higher incremental costs of alternative fuel vehicles. Numerous states also offer tax incentives to companies and individual consumers to encourage the purchase of advanced technology vehicles, such as hybrid electric vehicles (HEVs). States with tax incentives in place to promote HEV purchases include **Colorado**, **Connecticut**, **Louisiana**, **Maine**, **New Mexico**, **New York**, **Oregon**, and **Utah**.

Specifically, in **Oregon**, the Residential Tax Credit and the Business Energy Tax Credit programs provide residents and business owners with tax credits toward the purchase of qualifying HEVs. Eligible hybrids are defined as having a hybrid drive train (gas/electric), regenerative braking, an energy storage device (battery), and the capability for significant fuel savings. Residents may apply for a total tax credit of \$1,500 toward their personal income tax. Business owners may receive 35 percent of the cost difference between a conventional fuel vehicle and a HEV of the same class and size.⁴⁹

Looking beyond vehicle tax credits, the **California** Air Resources Board and California Energy Commission have been asked by Governor Arnold Schwarzenegger to develop new incentives for projects that promote high-efficiency, alternative fuel light, medium, and heavy-duty vehicles, for both individual and public fleets.⁵⁰ One such model might be found in **Oklahoma**, where the state Department of Commerce Office of Community Development was authorized by Governor Brad Henry to design and implement a low-interest revolving loan for both private and nonprofit organizations that are offering financial assistance for the acquisition of alternative fuel vehicles or alternative fuel vehicle conversions.

Washington will be exempting new passenger cars, light duty trucks, and medium duty passenger vehicles powered by a clean alternative fuel from retail sales tax for the period January 1, 2009, until January 1, 2011.

While incentives are needed to offset advanced and alternative fuel vehicle incremental costs, state government is also expanding the purchase and use of low-carbon, fuel efficient vehicles for use in state light-duty vehicle fleets. Currently more than half of all states have so-called “green fleet” programs that set goals or targets for fuel efficiency. Each adds differing requirements that support early markets for alternative fuel vehicles and other advanced technology cars and trucks.

These fleet programs are examples of **rules or mandates** and are often part of gubernatorial executive orders requiring the use of specific fuels and advanced technology vehicles in state fleets. For example, in **Florida**, Governor Charlie Crist signed an executive order in July 2007 requiring that new state vehicles be fuel efficient and use ethanol and biodiesel fuels, when available. In **Kansas**, an executive order by Governor Kathleen Sebelius requires 2 percent biodiesel blends to be used in state diesel-powered vehicles and 10 percent ethanol for bulk vehicles. In **Minnesota**, Governor Tim Pawlenty issued Executive Order 06-03⁵¹ directing Minnesota departments and employees to increase the use of E85 fuel and biodiesel in all state-owned flexible fuel vehicles. In **Hawaii**, state government fleets are required to purchase only alternative fuel vehicles, HEVs, or vehicles in the one-fifth most energy efficient in their class.

Green fleet rules also show how states can apply their **purchasing power** to support the uptake of new vehicle technologies. This is seen in **Connecticut**, where cars and light-duty trucks purchased by the state must have an estimated average fuel economy of at least 40 mpg and obtain the best achievable fuel economy per pound of CO₂ emitted in its vehicle class. In **Kentucky**, the state Office of Energy Policy is implementing a new law to shift half of the state-owned passenger vehicles to hybrids, advanced lean-burn vehicles, and fuel cell vehicles. In **Washington** starting in 2009, at least 30 percent of all new vehicles purchased by state contract must be clean-fuel vehicles and this percent increases by 5 percent each year. In **Wisconsin**, Governor Jim Doyle issued Executive Order 141 directing state agencies to facilitate usage of renewable fuels in the state's flex fuel vehicle fleet by making all state employees driving flex fuel vehicles aware of the renewable refueling stations in the location of their destination. In addition, the governor's order encouraged all state employees to strive to use E85 and biodiesel fuels when operating state-owned vehicles whenever practical and cost effective.

States are also engaging in partnerships that support advanced vehicle research, development, and demonstration. These policy mechanisms often include advanced vehicle demonstrations, pilot programs, and public-private partnerships—agreements that use public resources to attract private capital—to finance the deployment of clean vehicles.

For example, in **New Jersey**, to the state's Department of the Environment is working with Mack Truck, Inc. to design and implement a demonstration project in which two Mack garbage trucks, operated by Waste Management Inc., will be converted to run on LNG derived from the Burlington County Resource Recovery Complex and other state landfills. Rutgers University's EcoComplex is hosting the project's feasibility testing.

In **Michigan**, the state is supporting a National Biofuels Energy Laboratory, and Governor Jennifer Granholm just announced a public-private partnership between Michigan, the private sector, and the U.S. DOE on a new research laboratory that aims to align automobile suppliers with state and federal R&D programs on advanced vehicle energy, environment, and competitiveness. This partnership will also create 200 new jobs in Michigan.

In addition to specific investments in advanced vehicle R&D programs, many states are coupling direct research and deployment funds with other measures to encourage advanced alternative fuel vehicle use in their states. **New York, Connecticut, Florida, Michigan,** and **Ohio** have in place longer term program incentives to launch hydrogen vehicles capable of significantly reducing vehicle greenhouse gas emissions.

Conclusion

The idea of alternative fuels powering automobiles is not new—Henry Ford's Model T from 1908 was a flexible fuel vehicle, designed to run on either gas or ethanol. The discovery of cheap oil put a stop to Ford's vision for operating his vehicles on homegrown feedstocks—until now.

Today, states have the opportunity to change policies, cooperate with other states and the private sector, and educate the public on a new way forward in transportation, using some of the groundbreaking ideas from the past and implementing pioneering solutions of their own.

Governors can institute clean fuel programs, such as renewable standards and fleet efficiencies. They can build communication bridges between government, industry, and research institutions to encourage the use and production of alternative fuels and vehicle technologies. With strong leadership and informed policy decisions, governors and states can steer the United States toward a secure, clean energy future.

Appendix: Recommendations from Governors' Summit on Alternative Transportation Fuels and Advanced Vehicles

On December 13 and 14, 2007, the National Governors Association Center for Best Practices (the NGA Center) held the Governors' Summit on Alternative Transportation Fuels and Advanced Vehicles in Tampa, Florida. The Governors' Summit was the first meeting of state policy makers and experts under Minnesota Governor Tim Pawlenty's *Securing a Clean Energy Future* initiative.

The Governors' Summit was designed to provide participants with information necessary to help states develop a comprehensive transportation program to reduce demand for imported oil and mitigate greenhouse gas emissions.

During the two-day summit, national experts and state leaders engaged in a dialogue on the challenges of oil dependence, energy security, and greenhouse gas emissions. Participants also learned more about tools, policies, and gubernatorial strategies for advancing clean fuels and vehicle technologies and for developing the necessary infrastructure to accommodate them. Breakout sessions identified key actions states can take to meet their growing need for clean transportation solutions. The following discussion summarizes the results from daily, facilitated breakout sessions.

Breakout Sessions: An Overview

Each day, summit participants were divided into regions—Northeast/Mid-Atlantic, Southeast, Southwest/West, and Midwest—and asked to identify near- and longer-term actions each state can take to meet its respective transportation energy needs. To help streamline discussions, participant suggestions were categorized according to the following topics:

- Vehicles
- Fuels
- Infrastructure
- Land use and vehicle miles traveled (VMT)
- Research and deployment (R&D)

Recommendations that did not fit within these categories were classified as miscellaneous.

Facilitators first asked state participants to identify barriers to deploying clean, advanced transportation fuels and technologies. Participants were then asked to present their recommendations to governors for advancing the use of alternative fuels and advanced vehicle technologies. At the end of these breakout sessions participants voted for their two top recommendations.

Participant recommendations included programs and policies to increase alternative fuel use, deploy advanced vehicle technologies, and reduce growth in vehicle miles traveled. The top recommendations by topic from each region, as well as cross-cutting proposals that appeared in multiple regions, are presented below (Table 7).

Table 7 Top Participant Recommendations from Regional Breakout Session

Topic	Description	Region
Fuels	Create low carbon fuel standard	Northeast/Mid-Atlantic
Fuels	Use less petroleum and more alternative fuels in state fleets	Southeast
Fuels	Increase support for cellulosic ethanol research	Southeast
Fuels	Grants to clean fuel marketers	Southwest/West
Fuels/Infrastructure	Implement Midwest Governors Agreement	Midwest
Fuels/Infrastructure	Implement existing infrastructure/biofuels research	Midwest (multiple regions)
Infrastructure	Develop a resource guide to alternative fuel station development (i.e., toolkit with model permits, technology syntheses, case studies, etc.)	Southwest/West (multiple regions)
Land use	Develop zoning and land use regulations that are tied to grants to reduce vehicle miles traveled	Northeast/Mid-Atlantic (multiple regions)
Miscellaneous	Provide resource center for alternative fuels	Southeast (multiple regions)
R&D	Improve efficiency of alternative fuel production facilities	Midwest
R&D	Analyze feedstocks for alternative fuel production facilities	Northeast/Mid-Atlantic
R&D	Streamline permits for alternative fuel production	Southwest/West
Vehicles	Provide waivers for higher blends of ethanol (E20)	Midwest
Vehicles	Provide education and outreach on availability of alternative fuels	Northeast/Mid-Atlantic
Vehicles	Use alternative fuel vehicles in state fleets	Southeast
Vehicles	Develop a low-greenhouse-gas vehicle program and/or a “feebate” [*] program to encourage the purchase of more efficient vehicles	Southwest/West

*A vehicle “feebate” program provides a rebate for vehicles emitting fewer greenhouse gas emissions and places a surcharge on vehicles with higher greenhouse gas emission rates. The surcharges on high-emitting vehicles fund the rebates for the lowest emitting vehicles. The goal of such a program is to internalize the cost to society of high-emitting vehicles and provide an incentive for manufacturers to produce and deliver vehicles with lower greenhouse gas emissions. A number of states are considering adopting feebate programs.

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