Regulations and Incentives for Alternative Fuels and Vehicles

Elisheba Spiller

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Regulations and Incentives for Alternative Fuels and Vehicles

Elisheba Spiller*

1. Introduction

Transportation accounts for approximately one third of all US CO₂ emissions and raises serious energy security issues. Increased demand for transportation fuels and low penetration of alternative fuel vehicles has exacerbated these policy concerns and their costs.

In addition, transportation and gasoline consumption have externalities -- spillover effects that are not incorporated in fuel and vehicles costs and prices. These include, for example, lost productivity associated with traffic congestion, accidents, and increased smog and pollution levels. The externalities associated with private transportation, while appreciated for decades, have never been successfully incorporated into the costs of petroleum based transportation fuels and vehicles.

The most efficient way to address the externalities associated with driving and gasoline consumption is through economic instruments. Unfortunately, no single policy, tax or incentive offers an individually optimal solution that would simultaneously diminish driving, decrease gasoline consumption, and enhance energy security -- generally agreed upon policy goals. For example, a gasoline tax may change driving patterns or it may cause individuals to simply shift to more fuel-efficient vehicles without the alleviation of congestion. On the other hand, a congestion fee could decrease peak-time usage of highways, though it would not necessarily affect overall gasoline consumption or the choice of fuel efficiency. Therefore, grouping taxes or incentives (such as a gasoline tax combined with congestion taxes) could help to alleviate multiple externalities associated with driving and gasoline consumption. Furthermore, to maximize intended outcomes, a tax would need to vary over time and space depending on congestion levels.

Security, equity and administrative concerns tend to impose political constraints on policy makers, limiting their willingness to price externalities through taxes. Congestion taxes would, for example, negatively impact low income drivers, while emissions or driving taxes are infeasible absent dashboard technologies to measure emissions or driving patterns. Economists estimate an optimal gasoline tax (one that addresses the multiple externalities associated with driving) to be approximately $1/gallon, more than double the current average federal and state gasoline tax on gasoline (see Parry and Small [2005]¹ Williams [2006]², and West and Williams [2007]³). Yet, discussions of any tax sufficient to alter driving behavior are purely academic given the current anti-tax rhetoric and reticence of many policy makers in Washington.

Policymakers have looked to alternative fueled vehicles that run on electricity, biofuels or natural gas as a means of meeting these policy objectives, and as an alternative to taxes. Yet because the costs of these alternatives -- including financial, infrastructure, adjustments and performance tradeoffs -- remain high, local and federal government agencies have taken a series of steps to reach key policy goals through the

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implementation of a range of regulations and incentives for alternative transportation fuels (ATFs), alternative fueled vehicles (AFVs), and electric vehicles (EVs).

Many of these incentives and regulations focus on research and development (R&D), demonstration and deployment, and infrastructure development, and most (though not all) are designed to reduce the costs of the alternatives. However, recent presidential administrations have implemented policies that target certain technologies over others. For example, the Bush Administration’s policies focused on promoting fuel cell and ethanol (E85) vehicles, while the Obama Administration has placed a strong emphasis on electric vehicles. This pattern of promoting specific technologies has been problematic as it does not allow the more commercially and technologically viable alternative vehicles to emerge as a market choice. Critics of “picking winners” argue that policies like a carbon or gasoline tax would be more “technology neutral” and allow for the most efficient technologies to emerge.\textsuperscript{4,5}

In spite of the investment of billions of federal dollars over the past 30 years, market penetration of alternative fuel vehicles remains quite low; even with the enormous federal expenditures in the promotion of these vehicles, they accounted for less than 6\% of the overall vehicle stock in 2011.\textsuperscript{6} As such, it seems appropriate to take a step back and analyze our decision to incentivize the adoption of alternative vehicles and fuels.

- **First**, have the mandates, incentives and regulations focused on alternative fuels and vehicles been successful in diminishing GHGs and other pollutants, decreasing gasoline consumption, or increasing energy security? While it is important to analyze the effectiveness of these policies in mainstreaming AFVs, their ability to do so matters only in so much as the underlying objectives (such as improving environmental outcomes) are achieved. Can we, for example, be energy independent by mandating alternative fuels and vehicles without also encouraging conservation and decreased vehicle miles travelled?
- **Second**, are these regulations cost-effective, and what is the cost to the government of implementing these incentives and regulations? Given that the current government deficit exceeds $15 trillion, implementing costly incentives and regulations may crowd out other policies and cause significant welfare impacts.
- **Third**, do these mandates and incentives for the adoption and utilization of expensive AFVs impose less of a social and economic cost on society than externality taxes?
- **Fourth**, have these policies resulted in substantial technological development?
- **Finally**, are these policies able to be implemented given the current technological constraints we face? Although these policies may have the goal of improving technology, in the short run the objectives detailed in legislation might not be met, thus it may be necessary to adjust our expectations of what government intervention can quickly achieve.

This paper discusses the incentives and regulations for alternative fuels and vehicles in more detail.
2. Alternative Fuels

2.1 Ethanol and Cellulosic Biomass

Ethanol is the most widely adopted alternative fuel in the US. Since 2005, most gasoline is mixed with up to 10% ethanol, as a result of the federal Renewable Fuel Standard (RFS) and gasoline content regulations. Given its relatively low cost of production (compared to other renewable fuels), the most commonly utilized biofuel in the US is corn-based ethanol. This and other incentives have boosted national biofuel production. Cellulosic biomass (CB) and sugar-based ethanol, due to technology and other limitations, have not been utilized to the same extent as corn ethanol in spite of concerns over its GHG balance, associated land use and “fuel for food” issues associated with its production. Furthermore, the US government has established strong barriers to the importation of sugar ethanol in spite of its superior environmental performance. CB also has better environmental performance than corn ethanol, yet it is technologically immature and needs additional research to improve its affordability.

2.1.a US Regulatory History of Ethanol

Ethanol has been used as a fuel in the US since before the Civil War. In 1862, however, the US government placed a $2.08/gallon alcohol tax to help fund the war (equivalent to $35/gallon in 2007 dollars) and no exception was made for ethanol. The result of this tax was the replacement of ethanol by kerosene as the fuel of choice. Fifty years later, the tax was lifted, improving market opportunities for ethanol. In fact, the first flexible fuel vehicle (FFV) to run on ethanol, gasoline and kerosene was produced by Ford in 1908.

Over the years, production and utilization of ethanol increased substantially, until the end of WWII, when the increased energy demand for war materials was no longer needed. Ethanol was not viably produced again until the late 1970s, when concerns for energy security and oil dependence after the Arab oil embargos spurred the interest in alternative transportation fuels and the passage of the Energy Tax Act of 1978. This statute helped boost production of ethanol by providing a tax credit for the portion of gasoline that was blended with at least 10% ethanol. At the time, the excise tax for gasoline was 4 cents/gallon, which amounted to a 40 cents/gallon tax credit for every gallon of ethanol blended into gasoline. This subsidy was increased over time: in 1983, the Surface Transportation Assistance Act increased the subsidy to 50 cents/gallon; and in 1984, the Tax Reform Act increased the subsidy to 60 cents/gallon. However, in 1990, the Omnibus Budget Reconciliation Act decreased the subsidy to 54 cents/gallon, and in 1998 the Transportation Equity Act for the 21st Century phased the subsidy down to 51 cents/gallon by 2005. The subsidy was further decreased to 45 cents/gallon in 2004, with the American Jobs Creation Act, which also changed the recipient of the credit from the producer to the blender and was due to phase out by December 2011.

By 1980, it was apparent that this incentive was largely going to ethanol importers. In fact, the government surveyed ethanol production in the US and found only 10 producing ethanol facilities. The response was the Energy Security Act of 1980, which imposed an import tariff on ethanol of 40 cents/gallon, effectively offsetting the excise tax credit for those importing ethanol. The Omnibus Reconciliation Act of 1980 also applied a 2.5% ad valorem tariff to ethanol imports from most countries. These import tariffs helped to price Brazilian sugarcane imports out of the US market and helped boost domestic production of ethanol.
Other incentives for the production of ethanol included 10 cents/gallon to small producers (those with production capacities below 60 million gallons per year), established in 1990 and reissued in 2004 through the Volumetric Ethanol Excise Tax Credit (VEETC – part of the American Jobs Creation Act), which also provided a $1.01/gallon credit to producers of cellulosic ethanol. The cost of producing cellulosic ethanol has decreased over the years, but current costs are around $2-$3/gallon, as seen in Figure 1. Though these costs are hard to estimate (and may vary significantly across producers), the trend has been of decreasing costs over the last decade. The VEETC expired at the end of 2011 and cost the government billions of dollars in subsidies over the past 30 years.

![Figure 1. Cellulosic Ethanol Production Costs over Time](image)

http://www.greencarcongress.com/2010/02/celllicetec2-20100216.html

### Table 1. Ethanol Tax Policies

<table>
<thead>
<tr>
<th>Legislation</th>
<th>Tax/Credit</th>
</tr>
</thead>
<tbody>
<tr>
<td>1862 Internal Revenue Act</td>
<td>$2.08/gallon tax</td>
</tr>
<tr>
<td>1906 Free Alcohol bill</td>
<td>Repealed 1862 tax</td>
</tr>
<tr>
<td>1978 Energy Tax Act</td>
<td>40cents/gallon ethanol excise tax credit</td>
</tr>
<tr>
<td>1980 Energy Security Act</td>
<td>Import tariff on ethanol of 40c/g</td>
</tr>
<tr>
<td>1980 Omnibus Budget Reconciliation Act</td>
<td>2.5% ad valorem tariff to ethanol imports</td>
</tr>
<tr>
<td>1983 Surface Transportation Assistance Act</td>
<td>Increased ethanol excise tax credit to 50c/g</td>
</tr>
<tr>
<td>1984 Tax Reform Act</td>
<td>Increased credit to 60cents/gallon</td>
</tr>
<tr>
<td>1990 Omnibus Budget Reconciliation Act</td>
<td>Decreased credit to 54c/g, phased down to 51 in 2005; 10c/g credit to small producers</td>
</tr>
<tr>
<td>2004 American Jobs Creation Act/ Volumetric Ethanol Excise Tax Credit</td>
<td>Decreased credit to blenders to 45c/g; Added $1.01/gallon credit to producers of cellulosic ethanol -Expired in Dec., 2011.</td>
</tr>
</tbody>
</table>
2.1. b Renewable Fuel Standard (2005 RFS1 and 2007 RFS2)

The Energy Policy Act of 2005 included a Renewable Fuel Standard (RFS1), which mandated a minimum amount of alternate fuels to be blended into gasoline beginning in 2006. The mandate required that refiners purchase a certain amount of renewable fuels (RFs) to be blended into gasoline prior to distribution. The amount of RFs mandated by RFS1 increased yearly from 4 billion gallons in 2006 to 7.5 billion gallons by 2012. However, in 2007 the Energy Independence and Security Act of 2007 (EISA) revised RFS1 and greatly expanded the mandate to 36 billion gallons of RFs by 2022 (now known as RFS2). As seen in Figure 2, total gasoline consumed in the US is approximately 9 million barrels per day, thus the mandate in RFS1 was equivalent to about 5% of total gasoline consumed in 2012, while RFS2 effectively increased that percentage to 11%.

RFS1 also created an incentive for refiners to utilize cellulosic biomass, providing them with 2.5 renewable fuel credits for CB fuel, meaning one gallon of CB fuel would count as 2.5 gallons of renewable fuel. RFS1 also set a floor on the quantity of CB fuel that needed to be included in the overall renewable fuel goal, though the actual minimum volume would depend on the amount of CB that is projected to be available in the coming year and the projected sales of gasoline. The implementation of the law required EPA to estimate the amount of gasoline projected to be sold and CB available, yet the standard could not drop below the floor (as detailed in Table 2). While RFS1 set the floor at 250 million gallons in 2013, RFS2 drastically increased that amount, mandating that by 2022, half of all eligible renewable fuels must be CB.

As Figure 3 demonstrates, RFS1 and RFS2 had significant impacts on total ethanol produced. The USDA indicates that the number of ethanol plants went from 50 in 1998 to 204 in 2010.

### Table 2. RFS Standards

<table>
<thead>
<tr>
<th>Year</th>
<th>RFS1 Standard (Billions of Gallons)</th>
<th>RFS2 Standard (Billions of Gallons)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Renewable Fuels Minimum</td>
<td>Cellulosic Biomass Min.</td>
</tr>
<tr>
<td>2006</td>
<td>4.0</td>
<td>-</td>
</tr>
<tr>
<td>2007</td>
<td>4.7</td>
<td>-</td>
</tr>
<tr>
<td>2008</td>
<td>5.4</td>
<td>-</td>
</tr>
<tr>
<td>2009</td>
<td>6.1</td>
<td>-</td>
</tr>
<tr>
<td>2010</td>
<td>6.8</td>
<td>-</td>
</tr>
<tr>
<td>2011</td>
<td>7.4</td>
<td>-</td>
</tr>
<tr>
<td>2012</td>
<td>7.5</td>
<td>-</td>
</tr>
<tr>
<td>2013</td>
<td>-</td>
<td>0.25</td>
</tr>
<tr>
<td>2015</td>
<td>-</td>
<td>0.25</td>
</tr>
<tr>
<td>2020</td>
<td>-</td>
<td>0.25</td>
</tr>
<tr>
<td>2022</td>
<td>-</td>
<td>0.25</td>
</tr>
</tbody>
</table>
Figure 2. U.S. motor gasoline and diesel fuel consumption, 2000-2035 (million barrels per day)


Figure 3. Historic US Ethanol Production


2.1.c Brazil

Brazil is the world’s primary exporter of ethanol, and the second largest producer behind the US. Unlike the US, however, it uses sugar and soy as feedstocks. Sugar ethanol is desirable from a GHG perspective, decreasing GHG emissions by 78% compared to gasoline, though production techniques such as open-field burning of sugarcane leaves can dramatically diminish this benefit.22 Furthermore, land use associated with sugarcane production in Brazil can be problematic, as it can reduce carbon capture from
trees and biodiversity when forest areas are converted to sugarcane. Walter et.al. (2011) take into account sugar ethanol’s lifecycle and demonstrate that while the GHG benefits relative to gasoline are on average positive, they can be (slightly) negative depending on where the deforestation takes place.

In contrast to the United States, the economy of Brazil is bio-fuels centric. In 1975, Brazil passed the National Alcohol Program (Pro-Alcool) with the goal of phasing out all gasoline based transportation fuels. This Program mandated that all Brazilian vehicles run on a blend of gasoline and ethanol, with a minimum of 10% in 1976 and increasing to 22% by 1993. In 2007, the mandate increased the minimum percentage of ethanol to 25%, though it was dropped to 18% in 2011 given ethanol supply shortages. Some vehicles had to make minor adjustments to their engines to comply with the mandate at first, though FFVs soon penetrated the market and by 2003 they comprised 90% of all vehicles purchased in Brazil.

Given the high level of ethanol adoption in Brazil, the question arises of whether the carbon savings from gasoline displacement offsets the emissions due to deforestation or land use change for sugar cane production. Lapola et.al. (2010) find that the deforestation due to sugarcane and soybeans from Brazil’s increased biofuels mandate would actually create by 2020 a “carbon debt” that would take 250 years to pay off with gasoline. In short, the CO₂ benefits from Brazil’s biofuel mandate are recovered only after 250 years. In sum, Brazil’s goal of being gasoline-free will not necessarily result in a better overall climate outcome in the long run, given its high demand for ethanol and utilization of soy for ethanol production. It does however satisfy Brazil’s energy security objectives and enables the export of a large percentage of Brazil’s oil, creating higher value for its domestic energy resources.

2.1.d Analysis of Environmental and Economic Impacts of Biofuels

Concerns have been expressed about the myriad of unintended and environmental consequences associated with the production and distribution of corn ethanol. One of these concerns is the possible increase in food prices associated with competition for land use. However, this issue is generally overstated. In fact, the National Academy of Sciences (NAS) estimates that although this displacement causes food commodities, primarily corn and soy, to increase in price, a 20-40% price increase in commodities only increases the prices of food containing these products by 1-2%. On the other hand, biofuel production has unintended environmental consequences both in its production and its utilization. Depending on how the biofuels are produced, and what land-use and land cover changes occur due to their production, the GHG benefits from gasoline displacement may be completely offset.

Furthermore, biofuels can increase water and air pollution. Water quality can be affected by corn production, through eutrophication or hypoxia, due to fertilizer use, decreased soil quality, and other factors. The amount of water used to produce biofuels is also orders of magnitude greater than used in the production of petroleum products. Furthermore, biofuels emit higher quantities of other air pollutants (such as particulate matter, ozone, and sulfur oxides) than gasoline. For example, 10% ethanol-gasoline mix emits more of all air pollutants (except for carbon monoxide) than gasoline alone, while E85 emits more acetaldehyde and formaldehyde than gasoline alone (though emits lower levels of NOx and other air pollutants). Yang et.al. (2012) find that gasoline blended with 85% corn ethanol results in a 6-108%
greater environmental impact than gasoline alone (on average 23%), when taking into account full lifecycle impacts on GHG emissions, water quality, and 10 other environmental factors.

In addition to the environmental effects of biofuels production and use, the policies regarding biofuels, such as RFS, come with significant fiscal impacts and social costs. The Congressional Budget Office found in 2010 that the costs of the standard ranged from $1.78/gallon of corn ethanol to $3/gallon of CB, and that the implicit cost per ton of CO$_2$ reduced is $750/metric ton for ethanol and $275/ton for CB.\textsuperscript{33}

A major motivation for the renewable fuel standard was that it would create a technology “pull” sufficient to incentivize the development of the basic technologies for CB, as well as attract the venture capital needed for additional development and commercialization. Unfortunately, there has been little R&D in this area, and the technological advances have not been sufficient. The National Academy of Science conducted a report in 2011 to analyze the impact of RFS2 on the economy and environment. The outlook was dismal: the analysis suggests that the goals set by RFS2 of 16 billion gallons of cellulosic biomass cannot be met absent some major technological innovation and policy changes. NAS also concluded that there is insufficient commercially viable refinery capacity required to produce the mandated amount of CB biofuel.\textsuperscript{34}

This is unfortunate: Federal yearly support of $100-$400 million in grants from 2006 to 2008 to help CB producers build production facilities\textsuperscript{35} appear to have had minimal impact on the progress of technology development and construction of production facilities. A perverse effect of a mandate that cannot currently be achieved may be reliance on foreign sources for biofuels, thus diminishing the energy security benefits that could have been achieved under the RFS. Also, biofuels are not cost competitive with gasoline, even at today’s high gasoline prices. NAS’ analysis indicates that biofuels will only be a cost-effective alternative to gasoline under extreme technological innovation in refineries and oil prices of at least $191/barrel.\textsuperscript{36}

On the other hand, the RFS may help overcome the possible increase in gasoline prices due to the removal of the ethanol subsidies. While many have speculated that the elimination of ethanol subsidies would lead to higher pump prices, the EPA indicates that the RFS alone could result in a decrease in gasoline prices of approximately 2.5 cents/gallon.\textsuperscript{37} It is likely that a portion of the subsidy was passed on to the consumer. Absent any major changes in production, removal of the tax credit, while retaining the RFS mandate, would likely result in an increase of 2 cents/gallon at the pump. On the other hand, if producers were not passing along the subsidies, then there will be no negative impact on the consumer from removal of the tax credit. In any case, the amount of ethanol mixed into gasoline will not change due to the removal of the credit (given the RFS mandate), and a 2 cent/gallon increase would only result in a $10/year increase for the average consumer (under 10,000 yearly VMT and a 20mpg vehicle). Thus, the removal of the credit will most likely have more of an impact on the blender’s profits than total gasoline demanded, and may also make it more costly for the producers to meet the RFS standard. However, the RFS could help to alleviate the negative economic impacts from the removal of the ethanol subsidies.

\textbf{2.2 Alternative Refueling Stations}

One of the main barriers to adoption of alternate fueled vehicles is the current lack of refueling stations.\textsuperscript{38} Consumers will avoid vehicles if they are not able to refuel or recharge them easily. In the classic chicken
and egg conundrum faced by alternative fuels and vehicles, producers will also be less likely to install fueling stations if there is insufficient demand for these alternative fuels. Thus, the federal government has promoted policies to incentivize the construction of alternative refueling stations and associated infrastructure in order to break this unfortunate cycle.

2.2. a US Legislation

The Energy Policy Act of 2005, besides creating RFS1, also sought to promote the installation of alternative fuel refueling stations. This statute provided a tax credit which would cover 30% of the cost of installing an alternative refueling station (of which 85% of the volume has to consist of ethanol, CNG, LNG, liquefied petroleum gas or hydrogen; or 20% of biodiesel; electric charging stations were not included), up to $30,000. In 2009, the stimulus bill increased the amount of the credit up to 50% of the cost, with a maximum of $50,000. In 2010, the Tax Relief Act extended the alternative fuel vehicle refueling property credit through the end of 2011, but decreased the percentage and total amount of the credit back to EPAct 2005 levels.

EISA also took a (albeit small) step to help in the creation of refueling stations by requiring that the head of each federal agency install at least one alternative fuel pump for service to their vehicle fleet by January 1, 2010. This mandate, while not strictly enforced, required Federal agencies to report through an online reporting tool (Federal Automotive Statistical Tool-FAST) information about the fueling center including amounts of fuel dispensed by type. This information is then compiled by the DOE in order to determine how many alternate fuel pumps are available and how many refueling stations are non-compliant. In June 2011, DOE reported that the percentage of agencies complying with the mandate had increased to 66%, up from 34% in 2010. Enforcement of the mandate could have increased compliance, suggesting that the success of such policies could be improved by incorporating incentives that complement and help support or enforce the mandates—either positive or negative incentives such as tax credits or penalties. The federal fleet mandate for AFVs is discussed in more detail later in this document.

Alternative refueling stations are still limited as can be seen in Figures 4 and 5, and account for less than 8% of all stations in the country (given 2010 levels of US gasoline stations). This suggests that the incentives for building new stations were inadequate, and unfortunately, the lack of refueling stations continues to present a major barrier to adopting alternative fueled vehicles.
Figure 4. Total Refueling Stations by Fuel Type in 2012

Data from US DOE, Alternative Fuels and Advanced Vehicles Data Center: “Alternative Fueling Station Total Counts by State and Fuel Type”

**The large amount of electric fueling stations is due primarily to an abundance of these in CA**

Figure 5. US Refueling Stations 2009


**Each dot represents 10 refueling stations in the state (rounded up to the next 10), and the dots do not correspond to specific locations in the state.**
2.2.b Natural Gas and Blue Corridors

In Argentina, Brazil and Italy where natural gas is widely used in vehicles, refueling stations are very common. These countries do however, confront inter-country transportation issues; this is especially important for the transportation of goods in heavy duty trucks but presents issues for ease of passenger vehicle travel as well.

This concern has led to a push for “blue corridors” in South America and Europe -- inter-country pathways that connect countries with natural gas refueling stations. The development of these corridors is facilitated by economic and political arrangements between the countries in question. In South America, this arrangement is MERCOSUR (Mercado Comun del Sur, or The Common Southern Market), comprised of Argentina, Brazil, Paraguay, and Uruguay. In Europe, the European Commission serves this function. Both entities are pursuing blue corridors to promote reductions in gasoline consumption and to help stimulate adoption of natural gas heavy duty vehicles in member countries with lower adoption rates.

These corridors allow for a sharing of the investment cost by the two connected countries. Both the blue corridor projects in South America and Europe have begun recently (or are still in pilot programs), and as such it is difficult to measure the impact on natural gas adoption or GHG emissions. Nevertheless, these corridors may provide a template for an integrated approach to refueling issues in the US. Most of the refueling stations in the US are centered in large MSAs, which makes it prohibitive to travel very far with AFVs. This is especially problematic for long distance trucking in the US, where the lack of refueling stations has all but prevented alternative fuel adoption by smaller, independent carriers that lack access to or funding for private, company specific refueling infrastructures for alternative fuels. Heavy duty trucks account for 20% of mobile GHG emissions; boosting the adoption of AFVs in this sector could help to significantly mitigate emissions. Blue corridors in the US could similarly help enable interstate travel, especially since incentives and policies vary widely from state to state.

3. Alternative Vehicles

Government efforts to enhance energy security and mitigate mobile emissions have also focused on alternate fueled vehicles. During the Bush administration, policies tended to focus on incentives for AFVs (and later fuel celled vehicles), though policies during the Obama administration have focused more on less fuel-dependent (or independent) vehicles such as electrics, plug-in hybrids, and fuel celled vehicles. However, while these advanced technology vehicles have become more popular over the past few years, they still remain a relatively small portion of the vehicles on the road. Figure 6 shows sales of AFVs and hybrids from 2005-2009. In 2009, sales totaled at less than 1.2 million vehicles, accounting for approximately 11% of all vehicle sales, of which E85 vehicles comprised the largest portion of sales.
Over the past twenty years, numerous regulations and incentives designed to stimulate the market for alternative fuel and advanced technology vehicles have been implemented. These have included incentives for consumer purchases under the assumption that assistance in developing markets would lower vehicle costs and stimulate additional research. Cost reduction remains a serious issue for these relatively immature vehicles (such as EVs and FCs, although FFVs are very similar in price relative to their internal combustion engine vehicle counterparts).

Range limitations and battery costs are still serious concerns for electric vehicles. The current technological leader in batteries is the nickel-metal hydride (Ni-MH) battery, though the lithium-ion (Li-ion) battery (such as the one used in the Nissan Leaf) has recently emerged as a promising competitor: it is lighter, can be charged more rapidly and doesn’t need to be completely discharged prior to recharging. However, Ni-MH batteries are less expensive and are currently the battery of choice for electric vehicles. Table 3 shows the differences in terms of energy and price between Ni-MH and Li-ion batteries compared to conventional internal combustion engine lead acid batteries. Though these numbers may vary by producer, they represent the general trends of power and price across different types of batteries. Energy density is the amount of electricity that can be stored per weight; power density is the proportion of dischargeable energy to chargeable energy; and cycle life is the number of times the battery can be discharged and recharged.

The remainder of this section looks at some of the major regulations and incentives that have been proposed throughout the US with regard to alternative vehicles, both electric and non-electric.
Table 3. Comparison of Battery Types

<table>
<thead>
<tr>
<th>Battery Type</th>
<th>Lead Acid (conv. car battery)</th>
<th>Ni-MH</th>
<th>Lithium-ion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy density (Wh/Kg)</td>
<td>35</td>
<td>60</td>
<td>120</td>
</tr>
<tr>
<td>Power Density (W/kg)</td>
<td>180</td>
<td>250-1000</td>
<td>1,800</td>
</tr>
<tr>
<td>Cycle life</td>
<td>4,500</td>
<td>2,000</td>
<td>3,500</td>
</tr>
<tr>
<td>Cost ($/kWh)</td>
<td>269</td>
<td>500-1,000</td>
<td>1,000-2,000</td>
</tr>
</tbody>
</table>

Sources: Deutsche Bank, 2009; METI, 2009a; Nishino, 2010; The Institute of Applied Energy, 2008; Woodbank Communications Ltd, 2005. Table taken from Lowe et.al. (2010)

3.1 Corporate Average Fuel Economy and Greenhouse Gas Standards

The Corporate Average Fuel Economy Standards (CAFE) were established in the Energy Policy and Conservation Act (EPCA); in 2007, EISA amended EPCA and proposed standards for MY 2011-2020 vehicles. The new EISA standards were transformative: they included a 35 MPG mandate by 2020 for light duty vehicles. EISA also required, for the first time, the setting of efficiency standards for medium and heavy-duty trucks, though did not specify a MPG mandate.

Importantly, these new standards decreased the level of credit manufacturers would receive for selling flex-fuel vehicles (FFVs). Previous CAFE standards incentivized the production of FFVs by allowing manufacturers to increase the overall fleet MPG average through the sale of these vehicles regardless of the actual fuel used (as described in more detail in the next section). This was problematic, however: as GAO established in 2000 (confirmed later by DOE in 2008 and the EPA in 2010), FFVs were primarily being fueled with gasoline in spite of the alternative fuel option. The EISA amendments of EPCA directed NHTSA to phase out this incentive for FFV production completely by 2019. In short, EISA set the highest MPG CAFE standards to date, started the process for regulating the fuel efficiency of medium and heavy-duty trucks, and phased out the credits for AFVs.

However, there are many unintended consequences related to increased fuel efficiency standards, including, for example, the rebound effect and new source bias. The rebound effect is the tendency for individuals to drive more due to cheaper operating costs, as increased fuel efficiency reduces the effective price per mile. This effect has been estimated to be anywhere between 4.5% and 31%, and can offset efficiency gains. New source bias refers to reduced purchases of new vehicles due to the higher vehicle prices associated with more stringent efficiency regulations; the net result is that older, less efficient vehicles tend to stay on the roads longer. NHTSA/EPA estimate that its new National Program – designed to harmonize vehicle regulations, and described in more detail in Section 3.1.c -- will result in $142-182 billion in fuel savings, assuming a 10% rebound effect and a -1 price elasticity of demand for vehicles. This does not, however, take into account the impact on the used vehicle market or scrappage, thus partially ignoring new source bias (though the negative price elasticity picks up some of the reduced demand for these vehicles given higher prices). Even with penalties for manufacturers, concerns remain that the overall costs of improving efficiency could be high enough to encourage non-compliance, reducing the overall benefits of the program.
The story of how current efficiency and emissions standards for mobile sources were set is quite intricate, encompassing actions at both the State and federal level, up to and including Supreme Court decisions. The policy process that led to these standards is described next.

3.1.a Massachusetts vs. EPA

Until 2007, the Clean Air Act (CAA) required the US EPA to regulate air pollutants from mobile sources to protect the public health and welfare. Greenhouses gases had not been determined to be an air pollutant under the CAA, limiting EPA’s authority to regulate tailpipe GHGs. In 2003, several organizations petitioned the EPA to regulate GHG emissions from mobile sources, yet EPA denied the petition, saying it lacked authority under the CAA to do so. In response, 12 states, 2 cities, and a number of organizations sued the EPA, to force the agency to regulate GHG emissions from mobile sources, asserting that it did indeed have such authorities under the CAA. In 2007 the US Supreme Court in Massachusetts vs. EPA, sided with the petitioners. While the Supreme Court decision was clear, the EPA remained concerned that the costs associated with implementing national standards and regulations for GHG management would be high and ineffective, given the global nature of the problem.

3.1.b CA’s Attempt to Regulate GHG Emissions from Mobile Sources

In California, the CA Air Resources Board (CARB) had been regulating non-GHG mobile emissions within the state for decades. The mobile source provisions in the CAA (Title II) intended for emissions standards to be set at a national level to maintain uniformity of regulation across all states, an approach that was beneficial to vehicle manufacturers. Title II however allowed for an exception in Section 209 (b): any state that by March, 30, 1996 had adopted standards that were at least as stringent as the federal standards could receive a waiver to these provisions in the CAA. CA was the only state that adopted regulations prior to 1996, and thereby was the only state eligible for the waiver. However, the waiver could be denied if it was found that: “(A) the protectiveness determination of the State is arbitrary and capricious; (B) the State does not need such State standards to meet compelling and extraordinary conditions; or (C) such State standards and accompanying enforcement procedures are not consistent with section 202(a) of the Act” (Federal Register, 3/6/08, p. 12158).

While CA was successful in obtaining a waiver for other state-based regulations, it took the state several years to acquire a waiver for GHG emissions regulations. In 2002, CA enacted AB 1493, placing CARB in charge of regulating GHG emissions from mobile sources. Under this authority, CARB enacted GHG emissions standards in 2004 requiring a gradual decline in emissions over time for each manufacturer. This spurred California’s initial waiver request to the EPA, seeking authority to regulate GHG as air pollutants. Given the lawsuit the EPA was facing at the time, it chose to defer action on CA’s waiver petition until EPA’s authority to regulate GHG had been either confirmed or denied by the courts. Vehicle manufacturers opposed CA’s waiver petition, claiming its standards were excessively stringent relative to the rest of the country. EPA initially denied CA’s waiver in 2008, noting that “California does not need its greenhouse gas standards for new motor vehicles to meet compelling and extraordinary conditions” (Federal Register, 3/6/08, p.12156). The EPA claimed that since CA faced the same threat of climate change as the rest of the country, the “compelling or extraordinary conditions” test in article (B) (as detailed above) did not apply. The failure to meet one test was sufficient for the denial of the waiver.
However, since this initial denial, 13 additional states have adopted CARB’s proposed GHG standards, and under CA’s receipt of the waiver, these states would also be allowed to implement the standards.\footnote{61}

3.1.c The National Program

In light of the finding on \textit{Massachusetts vs. EPA}, President Obama announced in May 2009 a plan for the EPA to impose GHG emissions standards for light duty vehicles.\footnote{62} The President directed NHTSA, in charge of setting CAFE standards, to work with the EPA to establish the National Program, setting limits of efficiency and GHG standards for motor vehicles and ensuring that regulatory approaches were harmonized. The result of this coordinated approach was a national standard set at the same levels of the CA standard; thus addressing the concerns of automakers about having to satisfy different standards at the national and state levels. Furthermore, having two different sets of regulations could actually result in higher overall emissions. Goulder et.al. (2012)\footnote{63} find that the effort by the 14 states to adopt CA’s GHG standards had negative environmental impacts: adopting states tended to have lower emissions while emissions in non-adopting states actually increased. Given the high standards in the adopting states, manufacturers were able to reach the federal standard faster, allowing them to sell more vehicles with high emissions in the non-adopting states. Thus, overall emissions worsened due to the difference between federal and state regulations. Fortunately, CA accepted the standards for the National Program as consistent with its own.\footnote{64} This agreement, along with increasing external pressure from both the President and environmental groups, led to a revision of the waiver request, and subsequently, the EPA granted CA the waiver in June 2009.

The National Program has enabled a uniform national standard for GHG emissions from mobile sources across the country. It also decreased allowances and credits the manufacturer could receive for AFVs and other vehicle technologies (such as air conditioning), though it maintains credits for electric and fuel celled vehicles. I discuss the details of these allowances in more detail below.

3.1.d Light-Duty Vehicles

Although CA was not allowed to regulate GHG emissions from mobile sources until 2009, the CA mobile emissions regulations were used as the basis for current standards issued by the National Program for MY 2012-2016 light duty vehicles. The National Program mandates a fleet average of 34.1 MPG and GHG emissions of 250 grams/mile for MY 2016. It was necessary to lower the MPG requirement from 35MPG in order to solve the problem that the GHG standards provided more allowances to manufacturers than did the CAFE standards. On the one hand, EPCA did not allow CAFE standards to be affected by air conditioner (A/C) credits, while the GHG standards utilized the A/C credits as an allowance to help manufacturers reach the standard. These A/C credits were allowances given to manufacturers who made improvements in the air conditioning system in the vehicle: since A/C is one of the most energy intensive parts of a vehicle, improving the efficiency of these systems was considered by EPA as GHG emission improvements. Furthermore, the 250 g/mile GHG standard would correspond to a 35MPG standard if the manufacturers met the GHG standard through efficiency improvements alone. Thus, in order to coordinate across these two standards and to allow for the fact that the A/C allowances differed across these, the MPG requirement was set slightly lower than proposed in EISA.\footnote{65}
As mentioned earlier, FFVs are commonly run on gasoline alone, and these new standards dealt with this issue directly. In previous CAFE standards, FFVs were assumed by EPCA to run 50% of the time on gasoline, and 50% of the time on the ATF. Furthermore, the manner in which emissions for the ATF were calculated was based on a multiplier: each gallon of ATF was counted as 0.15 gallons of gasoline. These two assumptions jointly implied that, for example, an FFV that emits 330 g/mile of CO\textsubscript{2} while utilizing ethanol and 350 g/mile of CO\textsubscript{2} while utilizing gasoline would be estimated as having the following total average emissions:

\[
CO_2 = \frac{(330 \times 0.15 + 350)}{2} = 199.8 g/mi
\]

This provided a major incentive for manufacturers to sell these vehicles, as this allowance facilitated compliance with both the emissions standards and the efficiency requirement. Given the 0.15 conversion factor, this increased the MPG of a FFV by a factor of 6.67: for example, a 15 MPG AFV would be rated at 100 MPG.\textsuperscript{66} This diminished greatly the environmental effectiveness of these standards, as it did not take into account the actual fuel utilized by these vehicles. In fact, the National Program’s Final Rule cites the Regulatory Impact Analysis of RFS2 as claiming that “Data show that, on average, FFVs operate on gasoline over 99 percent of the time, and on E85 fuel less than 1 percent of the time” (Federal Register 5/7/2010, p.25437).

The new standards pursuant to EISA changed this allowance structure for FFVs, providing the two allowances (the 50/50 assumption and the conversion factor) only for MY 2012-2015 vehicles. For MY 2016 and later, these two allowances were phased out. Also, starting with MY 2016, EPA will assume that the utilization of ATFs is negligible; the manufacturer must provide evidence demonstrating the use of ATFs for vehicles sold or request an alternate weighting value to be determined by the EPA. This leaves the burden of proof on the manufacturer and diminishes the incentive to produce FFVs. Furthermore, the conversion factor no longer holds after 2016 and a vehicle’s actual emissions are tested while using an ATF. Finally, the National Program limits the amount of allowances in the average fleet MPG calculation: a manufacturer can only accrue up to 1.2MPG in allowances due to sales of FFVs.\textsuperscript{67}

These standards, though they decreased the incentive to produce FFVs, created some flexibility for electric and fuel celled vehicles. EVs, PHEVs, and FCVs are assumed to have emissions of zero g/mile, effectively ignoring upstream and life-cycle emissions. While this benefit is phased out after the manufacturer has sold a certain amount of these vehicles, the regulators did not consider it likely that the limit would be reached within the time frame of the regulation.\textsuperscript{68} This was intended to provide incentives to manufacture EVs, to be phased out when economies of scale were achieved.

\subsection*{3.1.e New CAFE Standards and Compliance}

In May 2010, President Obama set goals for the next round of CAFE standards, affecting MY 2017-2025 light duty vehicles. The proposed standard is much more stringent, calling on the manufacturers to increase average efficiency to 54.5 MPG by 2025.\textsuperscript{69} Because this standard is so difficult for manufacturers to achieve, the proposed standards would actually increase allowances for AFVs and EVs relative to the 2016 rule: one EV (or FCV) would count as 2 EVs/FCVs, and one PHEV would count as 1.6 (though this multiplier is proposed to phase down by MY 2021).\textsuperscript{70} This sort of multiplier had been previously ruled
out by EPA, as the agency claimed “that the multiplier, in combination with the zero grams/mile compliance value, would be excessive” (Federal Register, 5/7/2010, p. 25401).

This regulation has not yet been finalized and may change after the comment period and subsequent revisions. As it currently stands however, it creates strong incentives for automakers to manufacture EVs, PHEVs and FCVs. The proposed regulation also brings back the zero g/mile allowance for a certain amount of vehicles sold, further incentivizing the production of these vehicles in the beginning of the program. Unfortunately, creating allowances that target very high levels of fuel efficiencies allows manufacturers to sell more vehicles that do not meet the CAFE standards, thus increasing overall fuel consumption.

The regulation may need to implement these allowances for very high efficient vehicles not only because of the stringent standard, but also because of the way in which the CAFE standard is calculated. These standards set a limit on the efficiency that each manufacturer needs to reach, calculated through a sales-weighted harmonic average. What this implies is that the vehicles within a fleet are averaged given the fuel economy over a set of miles, instead of over a set of gallons, as the arithmetic mean would imply. For example, if a fleet has three regular cars and one electric vehicle, with relative efficiencies of 10, 15, 20, and 100MPG, the harmonic average is calculated as:

$$\frac{\frac{1}{10} + \frac{1}{15} + \frac{1}{20} + \frac{1}{100}}{4} = 17.6\text{MPG}$$

whereas the arithmetic average would be calculated as:

$$\frac{10 + 15 + 20 + 100}{4} = 36.25\text{MPG}.$$  

This in essence decreases the ability of a manufacturer to reach a specific goal through efficiency improvements, as the harmonic average mitigates the impact of outliers, and thus decreases the importance of very high fuel efficient vehicles. For example, improving the MPG of the electric vehicle in the above equation could never bring the harmonic average to surpass 18.5MPG: even if its MPG was infinite, the harmonic average would stay at 18.5. Therefore, utilizing harmonic rather than arithmetic averages means that CAFE standards diminish the incentive to produce very highly efficient vehicles (though it does incentivize increasing the MPG of low and middle efficiency vehicles, which can have larger impacts on fuel savings). As such, if the policy wants to incentivize the production of electric vehicles, then allowances in the standard for electric vehicles are essential.

However, increasing fuel efficiency has diminishing returns. For example, replacing a sedan in the fleet with a hybrid equivalent costs the manufacturer around $3,000 \textsuperscript{71} given current hybrid technology (though exact costs are unknown, the difference in price between a hybrid car and its non-hybrid counterpart is approximately this amount). \textsuperscript{72} On the other hand, replacing an efficient non-hybrid vehicle with an electric vehicle costs anywhere between $10,000 and $30,000, \textsuperscript{73} mostly due to the cost of the battery (which based on warranty information is projected to need to be replaced more frequently than the battery in a hybrid due to its usage and cycles). Yet, reductions in gasoline consumption are much larger from replacing the sedan with the hybrid than replacing the efficient vehicle with an electric. Consider two vehicles: a 12MPG vehicle and a 30MPG vehicle. Increasing the 12MPG vehicle by 2 miles per gallon would result in fuel savings of 1.19 gallons per 100 miles driven. On the other hand, increasing the
30MPG vehicle to 40MPG would result in 0.08 gallons of fuel saved per 100 miles (assuming no change in VMT- if the rebound effect occurs, then the 40MPG vehicle will be driven more than the 30MPG vehicle, thus reducing even further the amount of gasoline saved).

Figure 7 demonstrates graphically the downward slope of these returns. This figure shows gasoline savings by increases in fuel efficiency (under assumed VMT of 15,000 or 7,500). For example, replacing a 20MPG traditional gasoline vehicle with a 40MPG hybrid vehicle would save 375 gallons (at 15,000 VMT) at a cost of $3,000, while replacing it with a 100MPG electric vehicle would save 600 gallons at an average cost of $20,000. This implies marginal costs of $8/gallon reduced vs. $33/gallon reduced, demonstrating that although total gallons reduced are higher, it is less efficient (in an economic perspective) to replace a traditional vehicle with an EV compared to replacing it with a hybrid. An even larger number of gallons could be saved by replacing a 10MPG vehicle with a traditional gasoline 20MPG vehicle – and without spending thousands of dollars to do so.

![Figure 7. Fuel Savings by MPG, VMT](image)


### 3.1. Heavy-Duty Vehicles

For the first time, the EPA and NHTSA have created a comprehensive Heavy-Duty National Program of emissions and efficiency. This legislation establishes standards separately for three different types of vehicles; 1) Class 7 and 8 combination tractor-trailers; 2) Vocational vehicles; and 3) Medium-duty pickup trucks and vans. These regulations also incentivize the production of alternate fueled and electric vehicles, although less so than the proposed light duty regulations.

Emissions from AFVs are calculated through CO₂ tailpipe emissions testing, while EVs are assumed to have zero emissions. FFVs are treated similarly to current regulations for light duty vehicles – a 50/50 weighting assumption through MY 2015, after which the weighting factor depends on the demonstrated ATF usage by each manufacturer. However, no conversion factor is assumed. Thus, the heavy-duty...
legislation does less to promote production of AFVs than the light-duty legislation, which is unfortunate given the extremely low level of adoption of these new technologies by the heavy-duty vehicle market.

EPA and NHTSA claim that these improvements to fuel efficiency will save the industry $50 billion in fuel, yet this claim is troubling as the industry has not made these improvements on its own. This under-investment in energy saving technologies that pay back over time has been referred to as an “energy paradox” (see Harrington and Krupnick [2012]). The trucking industry and other analysts dispute the availability of fuel saving technologies, and attribute under-investment to hidden costs, such as engineering tradeoffs between fuel efficiencies and torque, or safety tradeoffs.

For the regulations in the heavy-duty sector to be effective in decreasing petroleum consumption, more incentives for alternate fuels and vehicles are necessary than what has been developed in these first efficiency and emissions standards. In fact, merely increasing the fuel efficiency of new vehicles will not necessarily result in a diminished use of gasoline, given rebound effects. Furthermore, hidden costs and technological limitations are present in this industry, causing an under-utilization of efficient technologies. Policy makers need to understand the basis behind the energy paradox and take into account the rebound effect in order to craft policies that are effective in diminishing gasoline consumption.

3.2 Market Stimulation

The government has taken a series of steps to stimulate the market in ways that would encourage wider use of alternative vehicles. These fall into two categories: incentivizing and mandating the adoption of these vehicles by government agencies and consumers; and creating voluntary initiatives and demonstrations to increase awareness and understanding. This section discusses these policies and their impacts on the market for alternative vehicles.

3.2.a Mandated Adoption of Alternative Vehicles

EPAAct 1992 presented an important set of incentives and supporting regulations for alternative fuels and vehicles (in addition to ethanol). For example, it established goals for federal agencies to adopt alternative fueled and electric vehicles, under the direction of the US Department of Energy (DOE). This legislation mandated (a soft mandate) that new government fleet purchases contain a minimum of 25% AFVs in 1996, increasing to 75% in 1999. The control of AFV ownership by federal fleets was conducted through voluntary provision of information. DOE claims that since 2003, almost 100% of the federal fleets have complied with or exceeded this mandate, and those that fell short reached agreements with the federal government. This mandate however had an unfortunate unintended consequence. For much of the period after the passage of EPAAct 1992, oil -- and therefore gasoline-- prices were very low. It was far less expensive for government AFVs to run on petroleum based fuels than alternative fuels. Consequently, the mandate was largely met but petroleum based fuel consumption did not markedly decrease. DOE recently reported that even if all agencies had complied fully with the mandate, the vehicles would only have replaced less than 1% of gasoline consumed in 2010, illustrating a large net economic cost -- the adoption of thousands of higher-priced AFVs with little benefit on the fuel side. Though the price difference between FFVs and traditional vehicles is negligible these days (between $50 and $100), in 1992 it was not. The federal fleet mandate in EPAAct 1992 resulted in an extra 200,000 AFV purchases, with little to no GHG
emissions benefits. Furthermore, 200,000 vehicles is less than 1% of all vehicle purchases, so it is unlikely that this mandate contributed to the decrease in FFV prices. CAFE standards, which included many credits for the manufacture and use of AFVs, was likely a much more important factor in closing this price gap than the federal fleet AFV mandate.

The fact that these vehicles were primarily used with gasoline led to the adoption of fuel usage mandates in future regulations. EPAct 2005 amended EPAct 1992 to mandate that agencies purchasing FFVs operate them exclusively on alternate fuels. Those agencies not able to use alternative fuels due to lack of fueling stations or other hardships were able to receive a waiver. These waivers were then utilized by the federal government to identify areas where ATFs were not readily accessible. Using the information gathered from these waivers, EISA 2007 mandated a 10% increase in usage of alternate fuels by federal fleets, simultaneously with the refueling station requirement discussed in Section 2.

In order to expand the number of first adopters outside the government, the mandates in EPAct 1992 also affected alternative fuel providers. Alternate fuel producers and refiners were required to purchase a minimum percentage of AFVs per year- increasing to 90% in 1999. In order to enforce these regulations, penalties of $5,000-$50,000 were implemented for non-compliance. These regulations were intended to create an example for the public of AFV usage, as well as to help spur the market. In 2001, the DOE reported a 91% compliance rate amongst for fleets covered by the statute. Regardless of these high compliance rates, the petroleum replacement goals set out by EPAct 1992 of 10% by 2000 and 30% by 2010 were not met. Historical experience suggests that mandating AFVs at the federal fleet level may have more value as a demonstration than as overall decline in petroleum-based fuel consumption.

### 3.2.b California ZEV Mandates

The state of California has implemented several mandates for the use of zero emission vehicles (ZEVs). Given CA’s major problems of transportation pollution in places like Los Angeles, there has been a push over the decades to implement more stringent efficiency and emissions standards. CA has been able to affect standards through the EPA waivers (as discussed in the CAFE standards section of this paper), and has become the earliest promoter of advanced vehicle technologies. In fact, in 1990 California utilized one of these waivers to pass a ZEV mandate, which directed that by 2003 10% of all sales by the large manufacturers must be ZEVs. Unfortunately, the ZEV mandate, while popular among constituents, became a contentious matter and was fought, amended, and changed over the decade-long policy process.

The first set of changes occurred in 1996. As the mandate ramped up ZEV sales from 2% of total vehicle sales in 1998 to 10% in 2003, concerns of manufacturers over meeting intermediate goals resulted in the removal of all mandates prior to 2003, while leaving intact the 10% mandate for 2003. Manufacturers’ concerns about meeting the 2003 deadline intensified in 2001, causing the mandate to be changed further- this time, it allowed the manufacturers to meet the ZEV mandate through the production of non-ZEV vehicles, such as Partial Zero Emissions Vehicle (PZEVs) and Advanced Technology PZEVs (AT PZEVs). Soon after, regulators faced a lawsuit preventing them from enforcing the mandate; leading to more regulatory changes and further expansion of the types of vehicles that met the requirements for the mandate. In 2008, the mandate was once again changed to allow the manufacturers to produce a greater number of PHEVs to meet the mandate, but only if they also produced a minimum number of pure ZEVs.
Even though the regulators faced massive opposition to these mandates, in 2009, they increased the requirement for pure ZEVs from 11% in 2009 to 16% in 2018, although the manufacturers were allowed to use a portion of PZEVs and AT PZEVs sold to meet the mandate. The new Advanced Clean Car Rules of 2012 (which set the newest CA ZEV mandates) were even more stringent: credits for non-zero emission vehicles were phased out after 2018.

Lessons Learned from CA’s ZEV Mandate History

Both the benefit and drawback of a ZEV mandate is that it places the burden on the manufacturers, tasking them with advance technology and pricing to promote the purchase of ZEVs. While this reduces the burden on the government and consumers, manufacturers feel pressured and will fight to avoid compliance. Indeed, this was the case with the CA ZEV mandates: it was met at every point with lawsuits and opposition from the manufacturers.

Would this have been different had the CA regulators produced significant financial incentives on the consumer demand side? Though the ZEV mandate was never coupled with tax credits or rebates for vehicle purchases, there were a number of federal and state incentives in place after 2007, including tax credits, rebates, and HOV stickers for the purchase of ZEVs. These rebates and tax credits (which are discussed in the next section in more detail) may have simultaneously enabled a more stringent approach and engendered less opposition to the ZEV mandate.

Electric vehicle sales remained relatively flat between 2005 and 2009, averaging approximately 2,000 new vehicles per year with a total of 57,000 by 2009. CA has the majority of these vehicles: in 2009, there were approximately 31,500 electric vehicles in use in the state, which amounted to 55% of the national electric vehicle stock. This demonstrates that though CA is still the leader in ZEV ownership, it was unable to successfully reach any of its goals in terms of percentage of ZEVs purchased.

The history of ZEV regulation in California suggests that mandates, while appealing to governments for both budgetary and policy reasons, are not optimized without complementary incentives. “Sticks without carrots” can reduce compliance and increase opposition to both mandates and ZEVs in general. Also, mandates that are phased in over time tend to encourage lawsuits and the weakening of the original targets or requirements.

3.2.c Consumer Incentives

In addition to incentives and mandates on vehicle manufacturers, the federal and state governments have provided incentives to consumers for purchasing AFVs.

A major goal of EPAct 2005 was to stimulate the production and utilization of alternative vehicles: hybrids, fuel cell vehicles, AFVs, and FFVs. To help market these vehicles, the statute established consumer based incentives in the form of tax credits for their purchase. These tax credits ranged from $2,500-$8,000 for light duty fuel celled vehicles, and up to $40,000 for heavy duty FCVs. The size of the tax credit increased with the vehicle’s efficiency, creating an even larger incentive to purchase high fuel efficiency vehicles. For hybrids, the credit ranged from $1,500-$3,000 for light duty vehicles and between $3,000 and $12,000 for heavy duty vehicles, depending on the efficiency increase relative to a non-hybrid equivalent.
These credits were phased down for each manufacturer during a 15 month period, or until its first 60,000 vehicles were purchased. This helped boost purchases of these vehicles, though the economic benefits depended on the popularity of each vehicle. For example, the Toyota Prius tax credit ended within a few months of the regulation, while it was still possible to receive a credit for other vehicles several years later, such as the Chevrolet Malibu Hybrid.

Consumers were already purchasing the Prius in greater quantities than other hybrids, thus the added tax credit may have been more of a windfall than an incentive to these consumers. In fact, in 2004, Toyota had sold over a million Prius. Providing consumers a credit for purchasing one of the first 600,000 Prius sold in 2005 therefore did not necessarily increase sales.

Incentivizing early adoption of alternative vehicles can help manufacturers achieve economies of scale and help level the playing field for late adopters. On the other hand, certain manufacturers (such as Toyota) who have already commercialized AFVs or ZEVs do not need these types of incentives.

### Table 4. Initial Tax Credits for Different 2005 Hybrid Models

<table>
<thead>
<tr>
<th>Vehicle (Example)</th>
<th>Credit</th>
<th>2005 MSRP</th>
<th>MPG (city/highway)</th>
<th>2005 MSRP (non-hybrid version*)</th>
<th>MPG (non-hybrid version*)</th>
<th>Yearly Fuel Cost Savings**</th>
</tr>
</thead>
<tbody>
<tr>
<td>Honda Accord Hybrid</td>
<td>$650</td>
<td>$30,655</td>
<td>25/33</td>
<td>$22,715</td>
<td>21/31</td>
<td>$266.19</td>
</tr>
<tr>
<td>Honda Insight CVT</td>
<td>$1,450</td>
<td>$19,845</td>
<td>45/49</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Honda Civic Hybrid</td>
<td>$1,700</td>
<td>$20,415</td>
<td>39/43</td>
<td>$13,775</td>
<td>25/34</td>
<td>$560.05</td>
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<tr>
<td>Ford Escape 4WD</td>
<td>$1,950</td>
<td>$27,445</td>
<td>30/28</td>
<td>$23,150</td>
<td>19/23</td>
<td>$740.66</td>
</tr>
<tr>
<td>Toyota Prius</td>
<td>$3,150</td>
<td>$21,815</td>
<td>48/45</td>
<td>$15,365</td>
<td>28/37</td>
<td>$543.20</td>
</tr>
</tbody>
</table>

MSRP data: cnet.com; MPG data: Edmunds.com

*non-hybrid versions: Honda Accord, Honda Civic, Ford Escape, and Toyota Corolla. Honda Insight has no gasoline equivalent vehicle.

**Cost savings based on 15,000 VMT, $3.5 gasoline price, and EPA 45/55 definition of average efficiency (relative to non-hybrid version)

The American Recovery and Reinvestment Act of 2009 (ARRA, the stimulus bill) provided further incentives to consumers for the purchase of ATVs. These included a consumer tax credit of $2,500 to $7,500 (depending on the size of the battery) for the purchase of electric vehicles. This credit ended after the manufacturer sold 200,000 vehicles. ARRA also provided a consumer tax credit for electric vehicle conversion for 10% of the cost of conversion up to $40,000.

The recession has caused an overall decrease in vehicle purchases, making these tax credits an important stimulus to the economy. During the recession, the government also provided a Cash for Clunkers program to incentivize the purchase of more efficient vehicles. Cash for Clunkers provided consumers with up to $4,500 rebates for turning in an older, low fuel efficient vehicle (a “clunker”) to used towards the purchase of a more fuel efficient vehicle. Hybrids or EVs (as long as they cost less than $45,000) were eligible for such purchases. 

Li et.al. (2011) and Mian and Sufi (2010) find that Cash for Clunkers had small impacts on emissions and fuel efficiency; the program did however stimulate sales in 2011 and 2012. 

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the (very) short term, largely by displacing future sales. This suggests that this program was more of an economic stimulus tool than a tool to stimulate advanced technology vehicle markets.

State governments have also provided non-monetary incentives for the purchase of ATVs. In many states, state and local governments provide stickers granting access to High Occupancy Vehicle (HOV) lanes for hybrid, electric and partial zero emission vehicles (regardless of vehicle occupancy). The 1990 Clean Air Act Amendments first implemented these allowances for “Inherently Low Emission Vehicles” (ILEVs), vehicles categorized by the EPA as having low emissions, and which generally ran on alternative fuels. The 1998 Transportation Equity Act for the 21st Century helped states to extend this allowance to individual owners of ILEVs. This allowance was provided in many states—indeed, 9 of 20 states with HOV lanes granted HOV stickers to ILEVs. Several of these states, including California, added hybrids to the list of HOV allowed vehicles. CA currently implements HOV allowances for all electric vehicles sold and for the first 40,000 AT PZEV until January 1, 2015. Between 2005 and 2008, California also issued 85,000 stickers to 3 hybrid vehicle models: the Toyota Prius, the Honda Civic Hybrid, and the Honda Insight.

The HOV allowances for hybrids in California were only available until July 2011. These stickers were valued highly by hybrid vehicle buyers; some research suggests that that individuals were willing to pay as much as $3,200 more for a vehicle that came with such a sticker. However, Diamond (2009) finds that the HOV sticker did not significantly affect hybrid purchases in CA, implying that the HOV allowance was more of a windfall benefit to hybrid owners than a hybrid vehicle market booster.

3.2.d Demonstrations and Voluntary Programs

The federal government has also established several demonstration and voluntary programs designed to encourage adoption of AFVs largely by increasing awareness of and research into their development. EPAct 1992 provided several financial incentives including loan guarantees and grants for trial programs designed to boost AFV demand through demonstration of their use. The Clean Cities Program was such a program, established to help reduce petroleum consumption, and focused on activities at the local level. Clean Cities has been implemented in 100 cities across the nation; it establishes partnerships of local public and private stakeholders, to help in the adoption of advanced vehicle technologies, reduction of gasoline consumption, and fuel economy improvements. The program also provides assistance to fleets for employing alternative vehicles and disseminating information to educate consumers about the benefits of AFVs. Clean Cities claims to have displaced approximately 3 billion gallons of gasoline with alternate fuels, with the largest contributions coming from natural gas and ethanol.

EPAct 2005 also included several voluntary programs to help generate widespread adoption of alternative vehicles, such as fuel cell school buses. In general, the success of these programs is fairly limited and some were never implemented; this was the case with the FC school bus project due to the extremely high costs of capital (a FC school bus costs around $2-3 million compared to $350,000 regular school bus) and hydrogen (2-4 times more expensive than diesel).

EISA 2007 also provided incentives for the creation of voluntary programs to encourage the use of electric vehicles, authorizing $90 million per year for this purpose. The “Plug-in Electric Drive Vehicle Program” provided grants to local and state government agencies and private/non-profit entities to create projects that would encourage the use of EVs and other advanced vehicle technologies. These grants were
intended to stimulate R&D of technology in the early stages of adoption. EISA also created the Near-Term Transportation Sector Electrification Program, which authorized $95 million a year for grants to large scale electric transportation projects, including an electric vehicle competition. It also created an electric vehicle education program to encourage the study of EVs in schools and Universities.\textsuperscript{113}

Though these sorts of demonstrations and voluntary programs can help to increase understanding and acceptance of alternative vehicles, their impact appears to be limited. Barriers to their adoption are still significant, and until these are overcome, there will likely be fewer alternative vehicles than is socially optimal.

3.3 Technological Advancements and R&D

The federal government has also invested in research to reduce the high cost of AFVs and batteries, so as to help eliminate the barriers to adoption.

In 2007, the National Academy of Sciences recommended that the Department of Energy establish a program to invest in the development of advanced technologies, called Advanced Research Projects Agency-Energy (ARPA-E). This program was intended to support cutting edge technological research by independent entities, such as Universities, firms and others, to address long-term energy issues.\textsuperscript{114}

ARPA-E was authorized in the America COMPETES Act, though it did not receive any funding until October 2009, when ARRA provided the program with $400 million. These funds are used to support 37 different energy projects focusing on renewable energy research, energy storage and fuel-independent vehicles.\textsuperscript{115} Together, two rounds of ARPA-E projects have provided funding to advance technology development for advanced vehicles, including EVs, AFVs, and fuel cell vehicles, as well as funding for battery development.

EISA 2007 also implemented a grant program to help develop plug-in hybrid electric vehicles (PHEVs) and EVs, and a $25 billion loan program to aid in the development of infrastructure that produces alternative vehicles and their components.\textsuperscript{116} Furthermore, EISA guaranteed loans for the production of EVs and for the production of advanced batteries.\textsuperscript{117}

Federal R&D support may be the most important and impactful way to advance the adoption of alternative vehicles. Though cost reduction and performance remain key focus areas for research, the price of Li-ion batteries has decreased over the years, while their energy density has increased, as can be seen in Figure 8. R&D investments can therefore help accelerate cost reductions and performance improvements.
4. Conclusion

Over the last three decades, there has been a worldwide push to adopt non-petroleum transportation fuels and to develop vehicles that can run on these alternative fuels. The US has taken a multi-faceted approach to encourage these developments, devising a range of incentives, mandates, tax credits, loan guarantees, demonstration programs and voluntary programs to condition markets, require or encourage manufacturers to produce and consumers to purchase AFVs and EVs. Some policy tools have been complementary but success in general has been relatively limited. Opposition from interest groups, lack of enforcement and monitoring, incoherent policies, low gasoline prices, technological stagnation, lack of refueling stations, and other complications still present substantial barriers to broad deployment and acceptance of AFVs and EVs. Also, these policies have arguably failed at achieving the underlying goals: improving GHG emissions and pollution, decreasing gasoline consumption, and increasing energy security. Questionable or limited progress towards these objectives suggests that federal dollars have not been well spent and that we have yet to find the appropriate mix of government incentives that will enable substantial progress towards these goals.

Providing costly incentives for highly efficient alternative vehicles, such as EVs, PHEVs, and FCVs, is arguably a very inefficient way of reducing GHG emissions, given the high costs to government and vehicle manufacturers and the diminishing returns to gasoline reduction from efficiency increases. Allowances in standards for these vehicles are more costly and less effective policy instruments than focusing on increasing the MPG of the least fuel efficient vehicles.

While it may be less economically efficient to promote electric and other high fuel efficient vehicles, government investments in research to accelerate the advancement of the underlying technologies may be one of the most successful ways to mainstream these vehicles. Focusing on bringing down battery costs, for example, will result in lower vehicle prices, and increased adoption, without having to subsidize or mandate the purchase of the vehicle. Once the costs of electric vehicles have become competitive with internal combustion engine vehicles, adoption will occur on a much greater scale.

Clearly, many of these policies have fallen short of achieving their primary goals and are difficult to implement, especially when the policies are structured in ways that exacerbate opposition from
manufacturers. The lack of penalties for non-compliance and the lack of enforcement of existing penalties have also diminished policy effectiveness. Likewise, policies that have long waiting periods prior to their implementation encourage lawsuits and increase uncertainty.

Given the increasing emphasis on promoting these alternative vehicles, it is time to take a step back and ask whether this set of policy tools provides the correct avenue for reaching the goals of environmental improvement and energy security. Stronger compliance mechanisms, coupled with regulatory certainty and a clearer understanding of the technology constraints and market conditions is desirable and could help achieve policy goals. However, the policies detailed in this paper do not address the other externalities associated with driving, such as congestion and accidents, so their scope is somewhat limited. Policies that target driving behaviors, such as a VMT or gasoline tax, for example, could arguably do more to address all the issues mentioned above, and also fit within a much simpler administrative framework. These types of policies have not been adopted due to the public’s negative opinion of them. Yet if we spent merely a fraction of the resources that we have placed in promoting alternative fuels and vehicles on instead attempting to change the public’s perception (such as an intensive campaign promoting coupling taxes with lump sum rebates), we might have been able to reach a more optimal solution.

6 DOE/EIA: Annual Energy Outlook 2011, Table 58- Light-Duty Vehicle Stock by Technology Type.
10 TEA-21 - Transportation Equity Act for the 21st Century, §9003(b)(h)(2)
14 Ibid.


EPAct 2005, §1512


EPAct 2005, §1342.

ARRA 2009, §1123.

Tax Relief Act 2010, §711.

EISA 2007, §246(a).

US DOE, Alternative Fuels Data Center, “Public Retail Gasoline Stations by State and Year”


Ibid, §102(k)(1)(B).


54 Ibid, page 25379.
55 Ibid, page 25517.
56 Ibid, page 25519.
59 Clean Air Act, Title II, § 209(b).
60 McCarthy (2007), pp. CRS3-3
65 Ibid, page 25330.
68 Ibid, pp. 25435-25436.
70 Ibid, page 48761.
72 Interview with William Chernicoff, Energy & Environmental Research Group Manager, Toyota Motor North America, Inc. 3/19/2012.
75 Ibid, page 57125.
78 Ibid, §310.
79 Department of Energy (2008), page 17.
83 DOE (2008), page 13.
84 Ibid, page 2.
85 EPAct 2005, §701.
86 EISA 2007, §400FF (a)(2)
88 Ibid, §512.
90 DOE (2008), page 33.
92 Ibid.


EPAct 2005, § 1341.


ARRA 2009, § 1141.

Ibid, § 1143.


The Transportation Equity Act for the 21st Century, § 1216 (a)(5).


EPAct 1992, Title VII.

US Department of Energy, Clean Cities Program: http://www1.eere.energy.gov/cleancities/about.html

EPAct 2005, § 743.


EISA 2007, § 131.

Ibid.
