ENERGY TECHNOLOGY INNOVATION POLICY

A joint project of the Science, Technology and Public Policy Program and the Environment and Natural Resources Program
Belfer Center for Science and International Affairs

HARVARD Kennedy School
JOHN F. KENNEDY SCHOOL OF GOVERNMENT

Biofuels and the Corporate Average Fuel Economy Program:

The Statute, Policy Issues, and Alternatives

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Discussion Paper 2008-05
May 2008

energytechnologypolicy.org

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May 16, 2008

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Abstract

This paper attempts a comprehensive discussion of the relationships between the Corporate Average Fuel Economy (CAFE) program and the supply of biofuels in the United States. Areas treated include pertinent statutory and regulatory background, stakeholder perspectives, potential environmental implications, the market viability of alternative-fuel vehicles, the supply of ethanol, and policy recommendations. The CAFE program contains a set of provisions included by the Alternative Motor Fuel Act of 1988 (AMFA), which provide automakers with incentives to market alternative-fuel vehicles. Several structural deficiencies that affect the law in its current form are found and discussed. The potential of the biofuels provisions in the CAFE program to further the goals of oil displacement and enhancing energy security are discussed. It is found that this potential may remain limited if the biofuel provisions in CAFE are not revised to better account for issues related to the consumer acceptance of biofuel-capable vehicles and to the geographical correlation between biofuel supply and vehicle deployment.

Citation

This paper may be cited as: Collantes, Gustavo, “Biofuels and the Corporate Average Fuel Economy Program: The Statute, Policy Issues, and Alternatives.” Discussion Paper 2008-05, Cambridge, Mass.: Belfer Center for Science and International Affairs, May 2008. Comments are welcome and may be directed to Gustavo Collantes at the Belfer Center, Kennedy School of Government, Harvard University, 79 JFK Street, Cambridge, MA 02138.

Energy Technology Innovation Policy

The overarching objective of the Energy Technology Innovation Policy (ETIP) research group is to determine and then seek to promote adoption of effective strategies for developing and deploying cleaner and more efficient energy technologies, primarily in three of the biggest energy-consuming nations in the world: the United States, China, and India. These three countries have enormous influence on local, regional, and global environmental conditions through their energy production and consumption.

ETIP researchers seek to identify and promote strategies that these countries can pursue, separately and collaboratively, for accelerating the development and deployment of advanced energy options that can reduce conventional air pollution, minimize future greenhouse-gas emissions, reduce dependence on oil, facilitate poverty alleviation, and promote economic development. ETIP's focus on three crucial countries rather than only one not only multiplies directly our leverage on the world scale and facilitates the pursuit of cooperative efforts, but also allows for the development of new insights from comparisons and contrasts among conditions and strategies in the three cases.

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1. Introduction

"The Congress [of the United States] finds and declares that—

1. *the achievement of long-term energy security for the United States is essential to the health of the national economy, the well-being of our citizens, and the maintenance of national security;*
2. *the displacement of energy derived from imported oil with alternative fuels will help to achieve energy security and improve air quality;*
3. *transportation uses account for more than 60 percent of the oil consumption of the Nation;*
4. *the Nation's security, economic, and environmental interests require that the Federal Government should assist clean-burning, nonpetroleum transportation fuels to reach a threshold level of commercial application and consumer acceptability at which they can successfully compete with petroleum-based fuels;*
5. *(…) ethanol, and natural gas are proven transportation fuels that burn more cleanly and efficiently than gasoline and diesel fuel;*
6. *the production and use as transportation fuels of ethanol, (…), and compressed natural gas have been estimated in some studies to release less carbon dioxide than comparable quantities of petroleum-based fuel;*
7. *(…)*
8. *there exists evidence that manmade pollution—the release of carbon dioxide, chlorofluorocarbons, methane, and other trace gases into the atmosphere—may be producing a long term and substantial increase in the average temperature on Earth, a phenomenon known as global warming through the greenhouse effect; and*
9. *ongoing pollution and deforestation may be contributing now to an irreversible process producing unacceptable global climate changes; necessary actions must be identified and implemented in time to protect the climate, (…)"*

The reader may be tempted—justifiably—to think that the preceding Congressional statement is very recent. After excluding a few references to methanol in the original text which would have given the experienced reader a revealing clue, the sentiment expressed in the above excerpt is highly reminiscent of what has been motivating much of the activity on energy policy for the last three or so years in the United States. The text in question is, however, anything but recent—it is Section 2 of Public Law 100-494, the Alternative Motor Fuel Act, passed by Congress in 1988.[2]

However fascinating to the student of policy, the similarity of the policy challenges facing the United States in the late 1980's and early 1990's with those of today is a blunt invitation to think about what caused this country to be now in a situation so similar to the one it was in 30 years ago. This is an invitation that policymakers, scholars, as well as anyone involved in informing energy policy should not pass on.

[2] Set out as a note under 42 U.S.C. §6374. Some publications have erroneously referred to this law as Pub. L. 100-94.

In the United States, the policy mechanism that has spearheaded the quest for reducing oil consumption in road transportation for the last 30 years is the Corporate Average Fuel Economy (CAFE) program. Strategies such as travel demand management, smart growth, transit-oriented development, road pricing, fuel taxing, fuel switching, and vehicle technology mandates have either had limited success or limited commitment. For reasons beyond the scope of this paper, the CAFE program, adopted in 1975, has remained a favorite in policymakers' bag of ideas every time the issue of excessive dependency on oil resurges in the policy debate—even if the fuel economy standards themselves have remained unaltered between 1975 and 2007. Observing the trends in several key variables –as presented in Figure 1—one may obtain a good general picture of the consequences of our policy inefficacy.

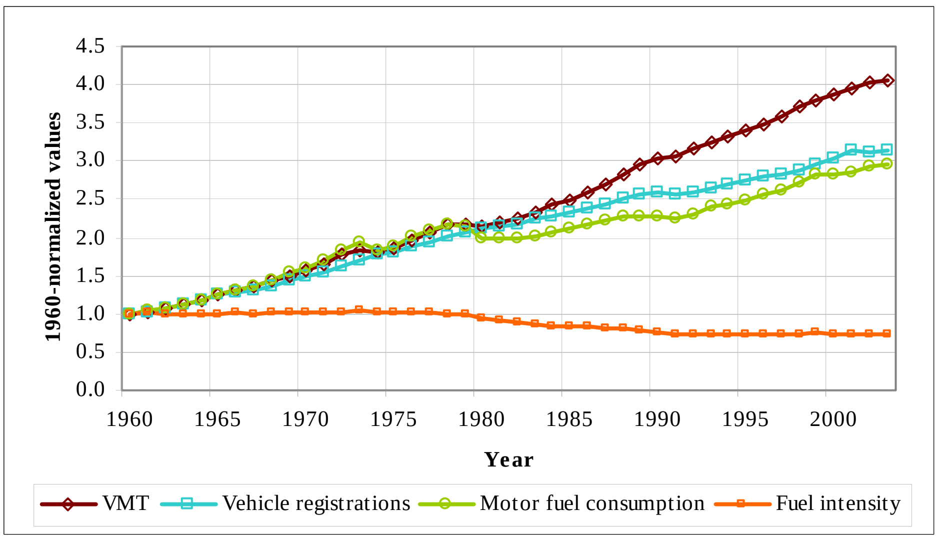

Figure 1. 43-year trends in various relevant variables, normalized to their values in 1960 (Data: Energy Information Administration)

In 1988, in the midst of a rise of national awareness about oil security and environmental degradation (Collantes, 2006a, Collantes and Sperling, 2007), the Alternative Motor Fuels Act (AMFA) amended the CAFE program to include incentives for the production of alternative-fuel vehicles. In the current energy and climate policy debates, CAFE reform and alternative fuels—most notably biomass-derived fuels—are again at center stage. Illustrating the importance of these issues in the political agenda, Congress passed the Energy Independence and Security Act of 2007 (EISA 2007), signed into law (Pub. Law 110-140) by President Bush on December 19, 2007.

This paper is concerned with analyzing the role that the interplay of CAFE and ethanol—the alternative fuel that presently captures the most attention among policymakers—can play in the context of a national interest to enhance energy security and reduce greenhouse gas emissions from the transportation sector. It will be shown in the paper that, even with the passage of the EISA 2007, several policy windows will likely open in this area in the near future. This paper was written with such policy windows in mind, hoping to provide useful insights and inform future policy activity in this area. Analyses of fuel-economy and alternative-fuel policy taken separately abound (e.g. Greene, 1998;

NRC, 2002; Jacobsen, 2006; Hill, et al., 2006; Fleming et al., 2006). The main contribution of this paper is on the important, and often neglected, question of the *interplay* of the two. One excellent exception is Rubin and Leiby (2000).

In Section 2, I provide background on the statutory link between CAFE and alternative fuels. In Section 3, I describe and discuss the policy debate over the statutory provisions that connect CAFE to biofuels. In Section 4, I discuss some of the potential societal consequences of the interplay between ethanol production and fuel economy regulations in their current form. In Section 5, I elaborate on the important question of consumer acceptance of new vehicle technologies and its relation to flex-fuel vehicles. In Section 6 I present an overview of the factors that affect the price of ethanol. I conclude in Section 7 with a general discussion and suggestions for future policy.

2. Statutory Background

The careful study of the statutory or regulatory history of a program is always a worthwhile contribution to policy history. But more importantly, it is an unavoidable stepping stone preceding an analysis or evaluation of the program in question, as it helps understand the Congressional intent or the policy goals that engendered the program in the first place. In this section I summarize the history of AMFA—the key statutory link between the CAFE program and biofuels.

On July 21, 1987, Senator Rockefeller (D-WV) introduced S. 1518, the Methanol and Alternative Fuels Promotion Act of 1987. This bill, similar to one introduced by Senator Danforth (R-MO) in the 99th Congress two years before (S. 1097), amended title V of 15 U.S.C. §2001 et seq., the Motor Vehicle Information and Cost Savings Act (MVICSA), to provide incentives for the manufacturing of automobiles powered by alternative fuels. A Conference Committee combined most of the Senate bill with an additional package of incentives originated in the House amendments. The Conference agreement amends title III of the Energy Policy and Conservation Act and title V of MVICSA. The amendments to MVICSA include a CAFE incentive program applicable to vehicles capable of operating on alternative fuels. On October 14, 1998, Senate Bill S. 1518 was passed (and then signed into Public Law 100-494) with the amended short title of Alternative Motor Fuel Act.

The intent of Congress when passing AMFA was "to encourage (1) the development and widespread use of methanol, ethanol, and natural gas as transportation fuels by consumers; and (2) the production of methanol, ethanol, and natural gas powered motor vehicles" (42 U.S.C. §6374). The underlying motivation, set forth clearly in Pub. L. 100-494 Sec. 2 (transcribed in the Introduction), was to enhance long-term national energy security through reductions in oil importation and, even if secondarily, to reduce emissions of heat-trapping gases from motor vehicles. The Energy Policy Act of 1992 (Pub. L. 102-486) amended MVICSA and changed its object from "alcohol or natural gas" to "alternative fuels," a concept including also liquefied petroleum gas, hydrogen, coal derived liquid fuels, fuels other than alcohols derived from biological materials, and electricity (106 Stat. 2878). The key element in the rationale behind AMFA was to solve the “chicken-and-egg dilemma” whereby auto manufacturers had no incentives to sell vehicles for which the necessary fuel infrastructure was not in place and fuel providers had no incentives to supply fuels for which no sufficient demand existed. Congress expected that, as alternative-fuel vehicles were adopted in the marketplace, fuel providers would deploy a fuel distribution and dispensing infrastructure to supply these vehicles (U.S. Code Congressional and Administrative News, 1989).

To better understand the policy context at the time when AMFA was adopted, most policymakers and environmental groups had their eyes and hopes on methanol—not ethanol—as the alternative fuel with competitive chances vis-à-vis gasoline. Several policy initiatives, both in Washington, DC, and in California, were geared toward incentivizing the market penetration of methanol (e.g. Collantes, 2006a; Gordon, 1991). Methanol is a fuel with a different constituency than ethanol. While it is not argued here that AMFA was structured to favor any particular energy constituency, the issues surrounding large-scale utilization of methanol are not the same as those of ethanol, and therefore understanding this background provides a better picture of the expectations at the time. On signing S. 1518 (AMFA) into Public Law 100-494, President Reagan said:

> *“This legislation also opens up new markets for natural gas and coal, our two most plentiful energy resources in this country. The success of these projects could improve employment and the economies in the hard-pressed oil- and gas-producing areas of the country. This bill takes advantage of existing government programs and mechanisms to assist alternative fuels. Most important, it's not intended to create massive new bureaucracies or new taxpayer subsidies”* (Ronald Reagan Presidential Library, 2007).

Specifically, Congress, through AMFA, endeavored to induce manufacturers to deploy vehicles capable of operating on alternative fuels by providing for special treatment of such vehicles under the CAFE program. Automobile fuel economy regulation is codified in Chapter 329, Title 49 of the United States Code. AMFA resulted in amendments to this chapter related to alternative fuels. As codified in 49 U.S.C. §32905, the fuel economy of a vehicle powered by alternative fuel is based on the notion of “fuel content of the alternative fuel”: a legislatively-established petroleum-fuel equivalence of alternative fuels. Reflecting Congress’s awareness of the lower per-gallon mileage that alternative fuels generally yield relative to gasoline, Section 32905 establishes that, for the purpose of measuring fuel economy, one gallon of alternative fuel is equivalent of 0.15 gallons of petroleum fuel. Thus, the Administrator of the Environmental Protection Agency (EPA) is to estimate the fuel economy of a vehicle running on alternative fuel by dividing the actual miles per gallon by 0.15.[3] This way, not only would CAFE not hinder the commercialization of alternative-fuel vehicles, but also deploying such vehicles would help manufacturers meet their CAFE requirements. Further, AMFA prohibits the Department of Transportation (DoT) to use the fuel economy obtained through the alternative-fuel capability of vehicles to estimate the maximum feasible fuel-economy standard. To determine the maximum feasible average fuel economy level, the DoT

[3] According with procedures set forth in Title 40 CFR, Ch. I, Subchapter Q, Part 600, the U.S. EPA is responsible for new-vehicle testing and the estimation of their fuel economy.

Secretary “(1) may not consider the fuel economy of dedicated automobiles [automobiles that operate only on alternative fuel]; and (2) shall consider dual fuel automobiles to be operated only on gasoline or diesel fuel” (49 U.S.C. §32902).

Section 32905 subsection (b) establishes that the fuel economy of dual fueled (or flex-fuel) vehicles manufactured while the program is active, is to be estimated as

$$FE = \left[\frac{0.5}{FE_{gas}} + \frac{0.5}{\left(FE_{alt} / 0.15 \right)} \right]^{-1} \quad \textbf{Equation 1}$$

Where, FE : Estimated fuel economy for CAFE purposes

FE_{gas} : Fuel economy of the vehicle when it uses only gasoline or diesel

FE_{alt} : Fuel economy of the vehicle when it uses only a liquid alternative fuel.

In Equation 1, FE_{alt} is divided by 0.15, reflecting the alternative-fuel energy equivalency prescribed in subsection (a).[4] Assigning the same weight (0.5) to the fuel economies when using petroleum fuel and alternative fuel, rests on the ad-hoc assumption that, on average, flex-fuel vehicles will run half of the time on each fuel type. It is estimated, however, that flex-fuel vehicles have historically run on gasoline over 99% of their mileage (e.g. RFA, 2002; Koplow, 2006).

A number of conditions apply. First, to foster consumer acceptance, alternative-fuel vehicles qualifying for special treatment must have a minimum driving range of 200 miles (this minimum range is prescribed by the Secretary and does not apply to electric vehicles). Second, the AMFA provisions in the CAFE program would be temporary. The provisions will become effective on 2003 and, originally, would remain in effect through 2004, with a possible 4-year extension.

Section 772 of the Energy Policy Act of 2005 revised Section 32905 of title 49 of the U.S. Code, providing for an extension of the program through the year 2010 and a possible additional extension for the years 2011-2014. The procedure related to the additional extension is established in subsection (f) of Section 32905 which, as amended, reads:

“(f) Extending Application of Subsections (b) and (d).--Not later than December 31, 2007, the Secretary of Transportation shall--

(1) extend by regulation the application of subsections (b) and (d) of this section for not more than 4 consecutive model years immediately after model year 2010 and explain the basis on which the extension is granted; or

(2) publish a notice explaining the reasons for not extending the application of subsections (b) and (d) of this section. “

[4] Section 32905(a) establishes that, for the purposes of estimating the fuel economy of a vehicle operating on alternative fuel, one gallon of alternative fuel is to be considered equivalent to 0.15 gallons of fuel.

Third, a given manufacturer can use alternative fuel-capable vehicles to increase its average fuel economy for a particular model year up to a maximum of 1.2 miles per gallon (mpg) during the core years of the program, and up to 0.9 mpg during the years of the extension, if granted.

A rulemaking process by the Department of Transportation was thus due by the end of 2007. However, 2007 found Congress immersed in a heated debate over the reform of the CAFE program. Several proposals were entertained, all of which failed to capture the necessary number of votes. Finally, a proposal emerged from intense negotiations led by the Speaker of the House, Rep. Nancy Pelosi (D-CA) and the Chairman of the Committee on Energy and Commerce, Rep. John Dingell (D-MI). This proposal was included as part of H.R 6—known as the Energy Independence and Security Act of 2007—which included revisions to, and effectively extended the applicability of, the AMFA provisions of the CAFE program. Most importantly, the Act terminated DoT's authority over the future of these provisions and set forth precise statutory directions as to the applicability of the fuel-economy credits for flex-fuel vehicles.

Section 109 of the EISA 2007 amended 49 U.S.C. §32906 to read "the maximum increase in average fuel economy for a manufacturer attributable to dual fuel automobiles is (…) 1.2 miles per gallon for each of model years 1993 through 2014". The fuel economy credits will be phased out gradually starting in 2015 and ending in 2019.

3. Stakeholder Analysis — Who Likes AMFA and Who Doesn't?

Before it was struck by the EISA 2007, 49 U.S.C. §32902(f) directed the Secretary of Transportation to issue, not later than December 31, 2007, a rulemaking either extending or terminating the fuel-economy credits for alternative fuel vehicles. Probably in light of an imminent Congressional agreement to revise the CAFE program, NHTSA never issued a Notice of Proposed Rulemaking (NPRM) on this matter. While discussions between NHTSA and stakeholders were naturally taking place, no official documents were submitted and made publicly available.

In this section, I include a discussion of the policy debate over the extension of the AMFA provisions that was due, under the original statute, on December 31, 2001. As part of the rulemaking process, the interested stakeholders submitted comments following NHTSA's NPRM. The central arguments made by the different sides in their comments are presented and discussed, on hopes of understanding the structural causes for conflict in this debate and, possibly, identify common ground.[5]

Required by statute, U.S. DoT, U.S. Department of Energy (DoE), and U.S. EPA submitted a joint report to Congress on 2002, assessing the AMFA CAFE credit incentive program. According to the report, the program had achieved, to that point, "mixed results" (DoT, et al., 2002, p. iii). Sieving the results from the three-agency report, the

[5] These comments are the latest available, since NHTSA never started a rulemaking process on the extension of the AMFA credits in 2007.

main conclusion was that the program had been key to the deployment of flex-fuel vehicles by manufacturers, but that unless it is revised and complemented it will not generate reductions in oil consumption or greenhouse gas emissions.

Recognizing the constrained environment under which NHTSA operates, the three-agency report did an excellent job at highlighting most of the key issues. The fuel economy concessions granted by the program to OEMs that deployed flex-fuel vehicles had unequivocally resulted in increases both in oil consumption and greenhouse gases emissions, and the report acknowledged these effects with no hesitation. In a conclusion that proved controversial, however, NHTSA submitted that it was uncertain whether manufacturers' CAFE would have been higher in the absence of the AMFA program. The report states:

> *"It is also possible that manufacturers might have responded to strong consumer demand for performance and utility and produced the same vehicles without the provision as they did with it. In this case, manufacturers would have chosen to pay civil penalties rather than meet the CAFE standard."* (DoT, et al., 2002, p. iv)

According to 1993-1999 data presented in the three-agency report, Ford Motor's passenger-car CAFE corrected for flex-fuel vehicles was only 0.01 to 0.03 mpg bigger than it would have been, had the company deployed no flex-fuel vehicles. However, Ford's light-duty truck CAFE for 1999 (the year when the company started producing light-duty flex-fuel trucks) increased from 19.84 mpg to 20.41 mpg—a 0.57 mpg increase—when accounting for the flex-fuel correction. DaimlerChrysler's CAFE increase from flex-fuel light-duty trucks in the same year was 0.94 mpg, from 19.80 to 20.74 mpg. In other words, the production of flex-fuel light-duty trucks significantly diminished Ford's penalties and allowed DaimlerChrysler to actually meet the 20.7 mpg CAFE requirements for that year.

In March 2002, NHTSA issued a NPRM proposing to extend the AMFA alternative-fuel provisions in CAFE after their expiration on 2004.[6] The proposal sharply divided stakeholders. During the public comment following the NPRM, one group of stakeholders expressed a blunt opposition to such extension. This group believed that the agency's intention to extend the program was not supported by the findings of the three-agency report, such as the very limited observed development of an alternative-fuel infrastructure, the relatively miniscule consumption of E85 to that day, and the increase in oil consumption. This group of stakeholders included the Alliance to Save Energy (ASE), the American Council for an Energy Efficient Economy (ACEEE), the Center for Auto Safety (CAS), Environmental Defense (ED), the Natural Resources Defense Council (NRDC), Public Citizen, Sierra Club, and the Union of Concerned Scientists (UCS).

A second group of stakeholders made explicit a strong support for the proposed rulemaking on the argument that the AMFA provisions have been instrumental in

[6] Docket No. NHTSA-2001-10774.

bringing vehicles capable of operating on alternative fuels to the market, and in creating a favorable environment for the deployment of alternative-fuels infrastructure. This group included the Alliance of Automobile Manufacturers (AAM), the Colorado Corn Administrative Committee, DaimlerChrysler, the Maryland Grain Producers Association, the Minnesota Corn Growers Association, the National Corn Growers Association (NCGA). Elected officials who voiced support for the extension of the AMFA provisions included Sen. Allard (R-CO), Sen. Ashcroft (R-MO), Sen. Bayh (D-IN), Sen. Bond (R-MO), Sen. Grassley (R-IA), Sen. Hagel (R-NE), Sen. Levin (D-MI), Sen. Daschle (D-SD) the members of the Congressional Auto Caucus, and the Governors of the states of Kansas, Missouri, New Mexico, and Wisconsin. Other stakeholders, such as the Renewable Fuels Association (RFA) and the National Ethanol Vehicle Coalition (NEVC), were supportive of the proposed rulemaking, while cautioning that it would be only one of the necessary measures to ensure broader adoption of alternative fuels.

The preferences of the second group eventually prevailed. Effective October 1, 2001, NHTSA issued a Final Rule extending the alternative-fuel incentive provisions through 2008. The key element in their argument was their interpretation of Congressional intent:

> *"Our review of the legislative history has led us to conclude that, when AMFA was enacted in 1988, Congress intended the incentive to be extended if the policy underlying it had begun to work, but the purposes had not yet been fully achieved. That is the situation in which we find the nation as we consider whether to extend the dual fuel vehicle incentive"* (NHTSA, 2001, p.32).

Each of the groups submitted perspectives and concerns that hold legitimacy. A stakeholder analysis is then of interest to clearly map policy preferences across stakeholders and identify opportunities for the two sides to find common ground and work together on win-win strategies.

Table 1 presents the results of a content analysis of the comments submitted to NHTSA by stakeholders, following the NPRM. I transformed the policy issues raised in the documents into a set of fifteen statements and, based on a reading of the comments, interpret the positions of each of the stakeholders as one of the following alternatives: "Yes", "No", "Yes with caveats", and "No position expressed".

The first question captures whether the stakeholder supported or opposed the extension of the AMFA provisions, thus providing a visual of the two sides of the debate. Statements 2 and 13 capture two questions that found much consent across both sides, namely that more FFV were deployed as a consequence of the AMFA provisions and that additional measures were needed to ensure that those vehicles would use E85 in significant volumes. Similarly, no explicit disagreement was found over the issue represented by statements 4, 7, and 15 although many stakeholders chose not to comment on them. The decision not to comment on a given issue may be motivated by strategic behavior or argumentation logic. While the former applies to statements 4 and 15, the latter is the case with statement 7—some stakeholders call for the termination of the AMFA incentives, with no option to develop a revised version. Statements 2, 5, 12, and 14 represent issues that were raised by the anti-AMFA camp, but were ignored in the comments of the pro-AMFA camp.

Statements 6, 8, 9, 10, and 11 represent the areas where explicit disagreement was found. The graphic representation of the content analysis enables a quick realization that disagreement was not too sharp. Some pro-AMFA stakeholders either opposed or *explicitly* conditioned their agreement with statements 8-11, thus bringing their positions somewhat closer to those of the anti-AMFA camp. NEVC, an organization that advocates the use of E85 and production of FFV, and RFA, the trade organization for the U.S. ethanol industry, voiced their concerns about AMFA's inability, in and of itself, to accomplish Congress's vision.

The stakeholder analysis suggests that there was an underlying agreement across the board on that AMFA had fallen short of fulfilling Congress's vision of triggering the supply of alternative fuels—E85 in particular—in significant volumes. Disagreements arose on the question of whether such supply could develop in the foreseeable future even if AMFA remained in place and whether the benefits from a potential increase in E85 consumption exceeded the costs in terms of oil consumption and greenhouse gases emissions. Most stakeholders recognized that new policies were needed to generate a meaningful supply of alternative fuels, though the anti-AMFA camp believed that fuel-economy credits should not be part of the package.

NHTSA could have played the role of policy broker to find common ground across parties. Unfortunately, the agency was not trusted by the environmental community, as evidenced by the public comments they submitted (captured by statement 6 in the content analysis). The stakeholders opposing AMFA believed that NHTSA's intention of extending the fuel-economy incentives was in absolute conflict with the evidence introduced by the report that NHTSA itself co-authored with EPA and DoT.

Further analysis of the perspectives presented by the stakeholders is included in the Policy Discussion section.

Policy issue \ Stakeholders	NRDC	UCS	ACEEE	ED	ASE	Public Citizen	Sierra Club	CAS	AAM	NEVC	RFA	Minnesota	Colorado	Maryland	Governors	NCGA
1-Should AMFA program be extended?	No	No	No	No	No	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2- AMFA resulted in deployment of FFV	Yes	Yes			Yes	Yes		Yes	Yes	Yes	Yes	Yes				
3- CAFE increase, better for energy security		Yes		Yes	Yes	Yes	Yes	Yes								
4- AMFA program resulted in more oil consumption	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes			Yes					
5- AMFA program resulted in more GHG emissions	Yes	Yes		Yes		Yes	Yes	Yes								
6- NHTSA candidly assesses the program results	No			No		No	No	No	Yes							
7- AMFA program needs restructuring		Yes			Yes						Yes					
8- AMFA increases energy security	No	No		No	No	No	No		Yes	Yes	Yes, with caveats					
9- AMFA results aligned with Congress's vision	No	No		No	No	No			Yes	No						
10- AMFA can help infrastructure development		No		No					Yes	Yes, with caveats	Yes, with caveats	Yes	Yes		Yes	
11- AMFA can help increase E85 consumption	No	No	No	No			No		Yes	Yes	Yes, with caveats	Yes	Yes	Yes	Yes	
12- Most ethanol will likely be used for E10	Yes	Yes					Yes	Yes								
13- Additional measures needed for E85 consumption	Yes	Yes	Yes						Yes	Yes	Yes	Yes		Yes		Yes
14- AMFA benefits bigger than its costs		No		No	No	No	No	No								
15- E85 is competitive with gasoline	No		No	No		No			No							

: Yes

: No

: Yes, with caveats

: No position expressed

Table 1. Stakeholders' positions on the key issues of the policy debate over the extension of the AMFA provisions.

4. Carbon Implications — Not All (Corn) Ethanol is Born Equal

Different ethanol production pathways have nontrivially-variant impacts in terms of natural resources consumption (e.g. land and water), ecosystems conservation, and carbon emissions. The magnitude of such impacts will certainly be correlated, though not necessary linearly, to production levels. Any biofuel policy that overlooks these concepts and generalizes every gallon of ethanol under one single nominal umbrella—for example, "corn ethanol"—is inherently flawed. It is well known that the well-to-tank (WTT) carbon intensity of a gallon of ethanol can vary significantly depending on the feedstock (e.g. Tilman et al., 2006). There has been less discussion, however, about the potential variance in WTT carbon intensity of ethanol produced from the *same* feedstock. Land-use change, farming practices, energy supply to the biorefinery, and ethanol distribution infrastructure and logistics are all variables affecting the carbon footprint of a given gallon of ethanol (or any biofuel, for that matter) available at the pump.

Important to the climate impacts of farming practices are the strategies adopted for land fertilization. Variables within such strategies include the amount of nitrogen fertilizer used (typically, 2 percent of the nitrogen in the fertilizer ends up as nitrogen in nitrous oxide, a greenhouse gas) and whether corn stover is left to decompose in the field after harvesting. Choices in terms of energy sources and technologies used in ethanol production may have even more significant implications for climate policy. Currently, most biorefineries in the United States use natural gas boilers, with a small minority of plants operating coal boilers. A concern repeatedly raised by producers during my visits to biorefineries in the Midwest, was the rise and fluctuation of natural gas prices and their impacts on production costs. To address this question, producers are considering—for existing and projected plants—strategies ranging from gasification of corn biomass, to capturing and use of cattle manure biogas, to installing wind turbines, to shifting to coal-fired boilers.

Wang et al. (2007) find that corn ethanol produced in a modern plant fueled by natural gas may reduce lifecycle carbon dioxide equivalent (CO_2e) emissions by 28 percent relative to gasoline. If the same plant was coal-fired, however, the ethanol produced may result in a 3 percent *increase* in lifecycle CO_2e emissions relative to gasoline. Using GREET, the same model used by Wang et al. (2007), my analysis of the effect of reliance on coal, instead of natural gas, to power ethanol production yields the results shown in Figure 2. I estimate that if all ethanol production is supported by coal instead of natural gas, E85 flex-fuel vehicles emissions are 435 gCO_2e/mile, versus 455 gCO_2e/mile for conventional gasoline vehicles. The scenario of complete reliance on coal for ethanol production results in 18 percent more CO_2e emissions relative to a scenario of complete reliance on natural gas. As ethanol is blended in gasoline as an oxidant and octane enhancer, the way it is produced will have an effect on the lifecycle carbon content of retail gasoline too. Though barely noticeable, the extremes of the gasoline vehicle curve in Figure 2 differ by 2 gCO_2e/mile. Lifecycle emission estimates are dependent on assumptions about myriad factors, such as per-acre corn yield, biorefinery efficiency, allocation of carbon credits to byproducts (e.g. distiller's dried grain with solubles), ratio of dry-mill plants to wet-mill plants, and many others. The slight difference between the results in Figure 2 and those in Wang et al. (2007) can be explained by variations in the initial assumptions, and is a reminder that assessment of lifecycle estimates necessitates of an understanding of the underlying assumptions.

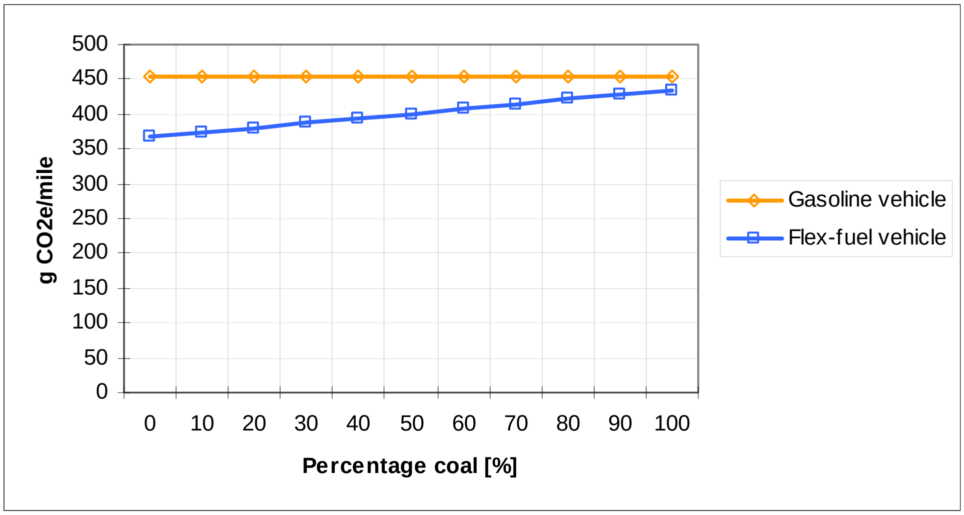

Figure 2. GREET estimates of passenger car carbon emissions as a function of biorefinery reliance on coal for power

One such assumption is the greenhouse gases accounted for by a given model. GREET accounts for carbon dioxide, methane, and nitrous oxide. This list excludes many greenhouse gases for which the International Panel on Climate Change (IPCC) provides a global warming potential (GWP) value, such as hydrofluorocarbons, perfluorinated compounds, and others. IPCC assigns a GWP value of zero to a number of gases, such as nitrogen oxides, volatile organic compounds (VOC), and carbon monoxide, and aerosols such as black carbon and biomass burning aerosol, on the argument that uncertainty on the GWP of these gases is still too big. Inclusion of these other gases may have a non-trivial effect on the final estimates of carbon intensity (Delucchi, 2003).

Also important to defining the carbon footprint of ethanol from a given feedstock is the logistics related to ethanol production and distribution. Conversations with farm associations in the Corn Belt revealed that much of the recent rush in investment in ethanol plants paid little attention to logistical issues like plant location relative to corn elevators. While denatured ethanol delivered to local marketers will be hauled by truck, most of the transportation, to marketers or to fuel terminals, is done by barge or rail. In particular, unit trains are the preferred mode of transportation to the big markets of the Northeast and the West Coast. Unit trains typically consist of 65, 75, or 95 ethanol cars, each car carrying 29,400 gallons. According to Miller (2006), however, only four fuel terminals in the U.S. have the capacity to host ethanol loads of this magnitude. Such geographical concentration of ethanol-gasoline blending increases the trucking distance from the terminal to dispensing stations, with the consequent increase in WTT carbon emissions per gallon of ethanol.

Figure 3 provides a good illustration of the theme discussed in this section. Because the per-mile carbon emissions during fuel combustion in the engine are comparable for gasoline and E85, the benefits of the latter depend heavily on the carbon footprint of agricultural practices and fuel processing (feedstock and fuel production in Figure 3, where ethanol is assumed to be come from corn). Indeed, the net carbon sequestration estimated by GREET during the feedstock stage could vary widely depending on related land use changes—an area of great concern that needs further research.

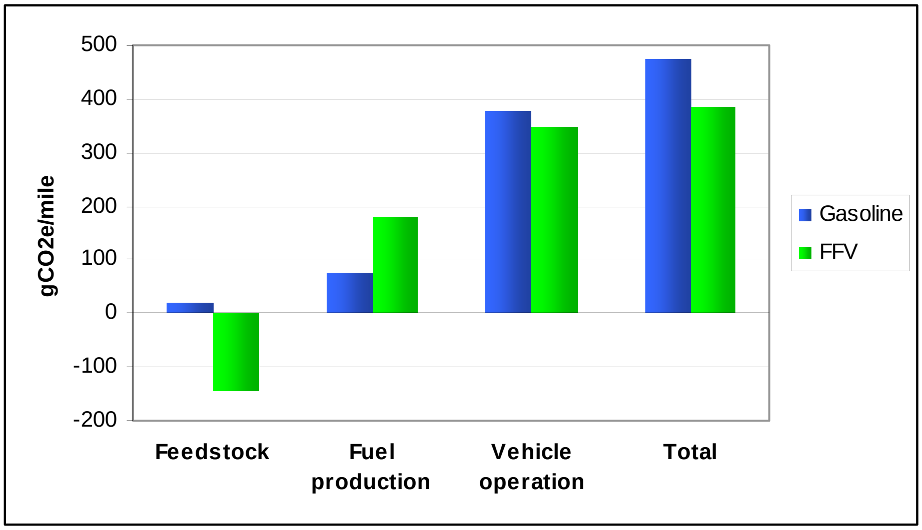

Figure 3. Greenhouse gas emissions at the different stages of fuel production-consumption

The preceding paragraphs highlight the potential lifecycle carbon heterogeneity of ethanol when produced from the same feedstock. Following, one could raise the legitimate question of whether and how this issue is relevant to the CAFE program. Indeed, if the goal of CAFE is to reduce either fuel or petroleum consumption, shouldn't society be content with the program focusing toward this goal, insofar as no negative climate impacts result *relative to the pre-implementation baseline*? Reminding ourselves of the statutory directions that, on establishing the maximum feasible fuel economy standard, the Administrator can only take into consideration "technological feasibility, economic practicability, the effect of other motor vehicle standards of the Government on fuel economy, and the need of the United States to conserve energy", we may conclude that, from a strictly statutory standpoint, the CAFE program may remain oblivious of the specifics of carbon emissions resulting from different corn ethanol production practices.

Practical and legal precedents are important to understand the "standing" of the CAFE program in matters of climate policy. At least two instances can be cited when NHTSA, on revising fuel economy standards, gave consideration to factors other than those explicit in the statute. One of such instances is consumer sovereignty. In Center for Auto Safety v. NHTSA, 793 F.2d 1322 (D.C. Cir.1986), the U.S. Circuit Court of Appeals for the District of Columbia upheld NHTSA's decision to scale down the standard. The Court's opinions supported the view that NHTSA's decision was justified if, to meet the standard in place, automakers would be forced to alter their product mix thereby negatively affecting consumer choice. The other such instance is vehicle safety. Even though the statute does not explicitly authorize the Administrator to give direct consideration to vehicle safety when determining the maximum feasible fuel economy, NHTSA's interpretation is that "[T]he agency is permitted to consider additional societal considerations and historically has considered the potential for adverse safety consequences when deciding upon a maximum feasible level" (NHTSA, 2006, p. 51). With this background, the argument can be made that, even though not contemplated in the statutory guidelines, NHTSA could, if so it wished, give consideration to the climate impacts of its future revisions of the CAFE program.

While the climate impacts of transportation ought to, and likely will, be addressed by a comprehensive policy specially designed for that purpose, using CAFE as the principal mechanism to combat greenhouse gas emissions from light-duty vehicles currently seems palatable to policymakers. This view is evidenced, for example, in the statement of Senator Inouye, Chairman of the Senate Committee on Commerce, Science, and Transportation, in May, 2007, when reporting S. 357, a bill to increase fuel economy to 35 miles per gallon by the year 2020:

> *"(…) The time is now to develop a comprehensive approach aimed at stopping the impacts of global warming and reducing our dependence on foreign oil. Adoption of S. 357 would be a first critical step in achieving these goals. (…)"*

The National Research Council has also included climate change as a rationale for fuel economy standards (NRC, 2002).

5. Flex-Fuel Vehicles and Market Viability

Policies concerned with technology innovation and diffusion need to be well informed about the necessary conditions for the successful market introduction and penetration of the pertinent technologies. A key question is: Can a sustainable market for the technology of interest develop? In other words: Will consumers buy the technology today and keep buying it in the future without the need for significant market intervention? This question is sometimes overlooked, even when many relevant lessons have been learned from previous attempts to develop markets for green technologies in general (e.g. Faiers, et al., 2007) and alternative fuels in particular (e.g. Melendez, 2006). In the specific context of the AMFA-related provisions of the CAFE program, regulatory decisions should be based on knowledge about consumer acceptance not just of flex-fuel vehicles, but rather of flex-fuel vehicles *running on alternative fuel*. Key questions include:

- What is the value proposition that a vehicle fueled by E85 offers to consumers, relative to that offered by the same vehicle run on gasoline?
- To what extent can this value proposition be affected by regulatory action?
- Can it reasonably be expected the dependence of this value proposition on regulation to decrease over time?

It is far from a trivial task to find answers to these questions when applied to radically-innovative technologies such as hydrogen fuel cell vehicles or, to a lesser extent, hybrid electric vehicles, because of the complexities of boundedly-rational consumer preferences (measurable and non-measurable) (Turrentine and Kurani, 2006) and the interplay of affected stakeholders (Collantes, 2007).

Compared to more-radical vehicle innovations, the value proposition of flex-fuel vehicles may be easier to estimate because consumers do not perceive these vehicles, technologically, as a significantly different product compared to conventional gasoline internal combustion vehicles. All else being equal, consumers are expected to direct their attention to differences in vehicle performance and fuel cost. In terms of differences in vehicle performance, domestic automakers are finding that users of flex-fuel vehicles quickly notice the reduction in volumetric fuel economy when running on E85 relative to gasoline (personal communication with automobile companies).

Figure 4. Fuel prices in Illinois, May 2007

The relative benefits of each fuel in terms of monetary costs are more difficult to discern by boundedly-rational consumers. Indeed, as fuel prices at the pump are given as dollars per gallon instead of dollars per BTU, consumers have insufficient information to arrive at reasonably-rational decisions. Further, even prices in terms of dollars per BTU could mislead consumer decisionmaking, as they do not include other relevant information necessary to assess per-mile fuel costs, such as fuel octane. In order to inform consumer choices, some ethanol-supporting groups have been engaging in marketing and outreach activities (e.g. Stanek, 2007; AAM, 2002). The picture in Figure 4 was taken at a gas station in Pekin, IL, during visits to biorefineries in May, 2007. I presented it at a number of seminars and asked the audience what fuel they would buy given these prices, if they owned a flex-fuel vehicle. Responses vary widely within and across audiences.

Because of the lower energy density of ethanol compared to that of gasoline, E85 is expected to deliver lower mileage per volumetric gallon, although it can deliver a slightly higher mileage per gallon of gasoline equivalent (e.g. Battelle, 1998). At the same time, because of ethanol's higher octane rating, E85 delivers higher horsepower relative to gasoline, enabling higher compression rates. Table 2 shows some relevant characteristics of gasoline and alcohol fuels with increasingly long carbon chains. Although butanol is not currently used as a transportation fuel, some analysts view biomass-derived butanol as a promising option for the longer term, and therefore it is included in the table for completeness.

Table 2. Characteristics of a selection of alternative fuels

Fuel	Lower heating value [Btu/gal]	Air-fuel ratio	Carbon content [weight %]	Research octane number	Motor octane number	Cetane number
Conventional gasoline	116,090	14.7	85-88	88-98	80-88	--
Diesel	129,050	14.7	87	--	--	40-55
Ethanol	76,330	9.0	52.2	108	92	--
Butanol	100,000	11-12	64.8		94	--

Flex-fuel vehicles are not optimized to operate on E85, which causes a decrease of 10 to 15 percent in fuel economy compared to an E85-optimized vehicle (NEVC, 2007). This prevents ethanol blends from materializing their full performance potential and places them at a further competitive disadvantage vis-à-vis petroleum fuels. While converting a standard vehicle to flex-fuel involves minor vehicle modifications with a cost in the order of 100-200 dollars, optimizing a vehicle to run on high ethanol blends is a more complex and expensive process. An example of work being done in this area is the development of a turbo-charged flex-fuel Saab 9-5, which has shown improvements on E85 fuel economy in the order of 15 percent, for certain engine load ranges.

Quantitatively, consumer acceptance of vehicle attributes is often estimated using consumer choice models. Such models estimate consumer utility functions that can be conveniently used to obtain in turn estimates of consumers' willingness to pay for specific vehicle attributes. Brownstone et al. (2000) estimated utility functions for different vehicle-fuel systems, using survey joint revealed/stated preference data. They tested a utility function including choice variables such as vehicle price, fuel operating cost, vehicle range, acceleration, and tailpipe emissions, among others. This linear-in-the-parameters utility function can be expressed as:

$$U = \beta_1 \frac{price}{\ln(income)} + \beta_2 fuel\cos t + \beta_3 range + \beta_4 range^2 + \beta_5 acceleration + \beta_6 pollution + \varepsilon$$ **Equation 2**

Here, ε includes the error term and other variables in their model specification (not included here). Once estimates of the parameters β_i are obtained, the willingness to pay for an additional unit of a particular vehicle attribute can be estimated as the negative ratio of the marginal utility of that attribute to the marginal utility of the price. Mathematically:

$$WTP_i = -\left(\frac{\partial U / \partial x_i}{\partial U / \partial (p_i / \ln(income))} \right) \ln(income)$$ **Equation 3**

The marginal utilities are in general the β parameters affecting the corresponding variables. The logarithmic factor is a result of the model specification in this particular case—instead of vehicle price, Brownstone et al. (2000) used a variable defined as the ratio of the price to the natural logarithm of income. Equation 3 allows us to analyze the role of income on vehicle-choice decisions, which is important to understand the vertical-equity implications of related policies.

To estimate the utility parameters, Brownstone et al. (2000) used stated preference (SP), revealed preference (RP), and joint stated/revealed preference data. Methodologically, they used both multinomial logit (MNL) and mixed logit estimations.[7] For the analysis presented in this paper, I use their estimates from RP data because the vehicle attributes where the differences between mainstream and flex-fuel vehicles lie, are observable. Table 3 shows the estimates of the utility parameters for a few variables of interest to this study, indicating between parentheses the t-statistics.

Table 3. MNL estimates of utility parameters for variables of interest (Brownstone et al., 2000)

Variable	Operationalization	Stated preference	Revealed preference	Joint
Price/ln(income)	Vehicle purchase price and income, in thousand dollars	-0.184 (-6.9)	-0.337 (-5.3)	-0.361 (-6.8)
Operating cost	Fuel cost per mile of travel, in dollar cents per mile	-0.076 (-10.4)	-0.193 (-2.8)	-0.170 (-5.3)
Range	Hundreds of miles that the vehicle can travel before refueling	0.493 (4.5)	2.482 (1.5)	1.268 (4.5)
Range squared	Range x Range	-0.034 (-1.4)	-0.254 (-1.4)	-0.116 (-3.1)

Figure 5 shows the estimates of consumers' willingness to pay for a reduction of one cent in vehicle per-mile fuel cost, as a function of consumer income, obtained using RP, joint, and SP data. The results show that data from actual consumer choices (revealed preferences) yield lower willingness to accept an increase in fuel operating cost than data from consumers' stated preferences. Though universally adopted in the economic and econometric literature, the term willingness to pay is somewhat misleading, in that it does not capture the ability-to-pay component of the estimates.

[7] For general background on discrete choice modeling, see for example Ben-Akiva and Lerman (1985) and Louviere et al. (2000).

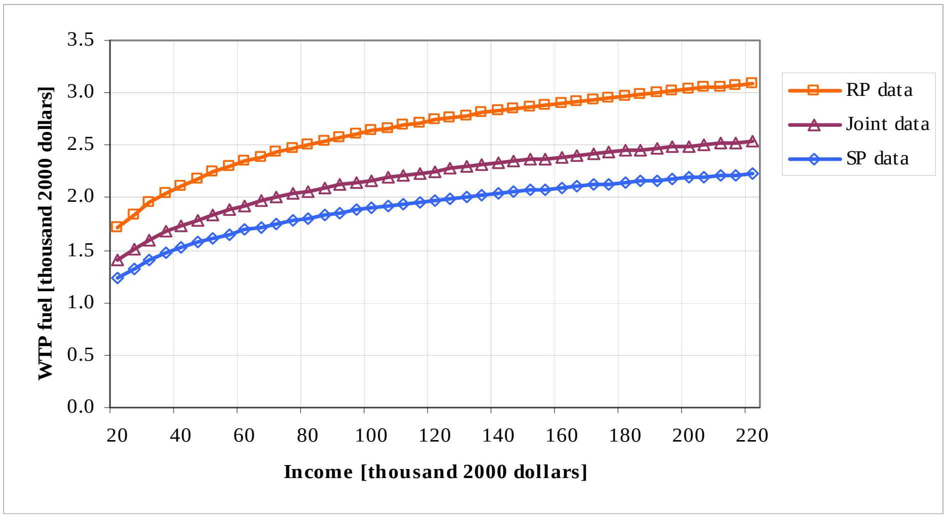

Figure 5. Willingness to pay for a one-cent reduction in per-mile fuel cost, as a function of income

Given the lower energy density of E85 relative to gasoline, another variable of interest on studying the consumer acceptability of flex-fuel vehicles is vehicle range. As shown in Table 3, the model specification used in Brownstone et al. (2000) included linear and quadratic terms on vehicle range. The estimates of the range coefficients can be used to estimate consumers' willingness to pay for an additional hundred miles in the range of the vehicle they purchase (the authors used hundreds of miles as the unit for the range variable) with the following equation:

$$WTP = -\left[\frac{\left(\beta_3 + 2\beta_4\, range/100\right)}{\beta_1}\right]\ln\left(\frac{income}{1{,}000}\right)$$

Estimates of consumers' willingness to pay for an additional hundred miles of range depend on the range itself and on consumer income. The estimates are plotted in Figure 6, for a vehicle with 350-mile range.

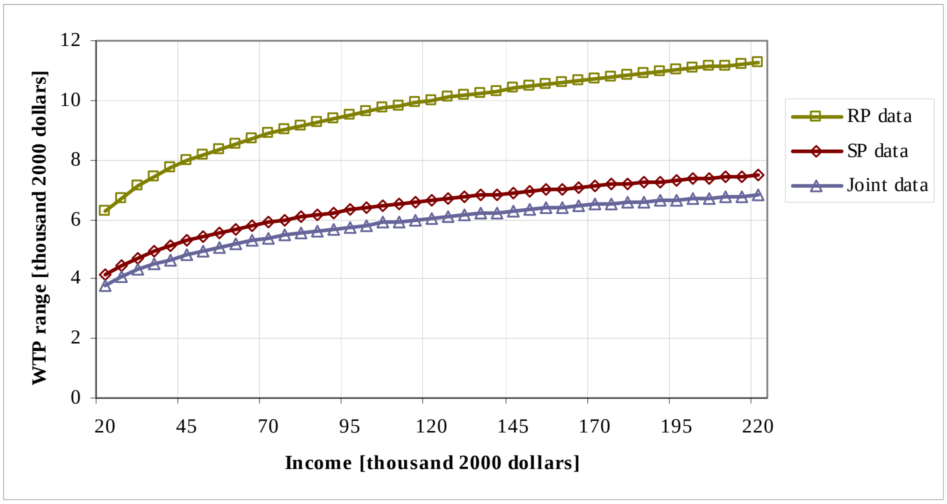

Figure 6. Willingness to pay for an additional mile of vehicle range, as a function of income

Converse to the case of per-mile fuel operation cost, data based on actual consumer choices reveal a significantly lower willingness to pay for additional vehicle range than the estimates obtained with consumer stated preferences. Even the SP estimates, however, suggest that consumers assign great value to vehicle range. Are these estimates reliable? Brownstone et al. (2000) acknowledges that the high multicollinearity of range with other variables such as top speed and acceleration impacts on the reliability of the RP estimates. There is also a clear inverse relationship between vehicle range and fuel per-mile cost, which is not discussed by the authors. It is not obvious whether and how survey respondents identify this relationship. For these reasons, it is difficult to assess the reliability of the estimates in Figure 6. Intuitively, it seems difficult that the average consumer would be willing to pay over 6,000 dollars for an increment of 100 miles in vehicle range, as suggested by estimates from RP data.

The relatively low average consumer willingness to pay for additional fuel economy has long been a concern of many policymakers and policy scholars because it limits the economic incentives for industry to offer vehicles with lower fuel intensity. However, the terms of the discussion have to be redefined when applied to alternative fuel vehicles. The same estimates of willingness to pay obtained above can be interpreted as the price differential necessary for a consumer to be willing to accept a decrease in range or an increase in per-mile fuel costs. Thus, the relatively low consumer willingness to pay for additional fuel economy may be advantageous to alternative fuel vehicles—industry may be able to compensate consumers for the higher per-mile fuel cost of E85, relative to gasoline, by offering dedicated E85 vehicles at a price not very different from that of a gasoline vehicle. How feasible could such strategy be?

As two examples, the 2007 flex-fuel Chrysler Sebring has combined fuel economies of 25 mpg and 18 mpg, and the 2007 Chevy Impala has combined fuel economies of 24 mpg and 19 mpg on gasoline and E85, respectively. The comparative per-mile fuel cost will depend on the per-gallon price of the respective fuels. Figure 7 shows, for the case of the Sebring, the prices of the gallon of E85 which would render the per-mile fuel cost equal to those obtained when the vehicle operates on gasoline. For E85 prices in the vicinity of $2.00 per gallon, consumers would be indifferent between fueling E85 or gasoline when the price of gasoline is around $2.80 per gallon. With the Impala, E85 becomes competitive at even lower gasoline prices. These are only monetary-cost approximations that do not take into consideration attitudinal or comfort factors that often affect consumers' decision, such as environmental consciousness or the higher per-tank mileage of gasoline relative to E85.

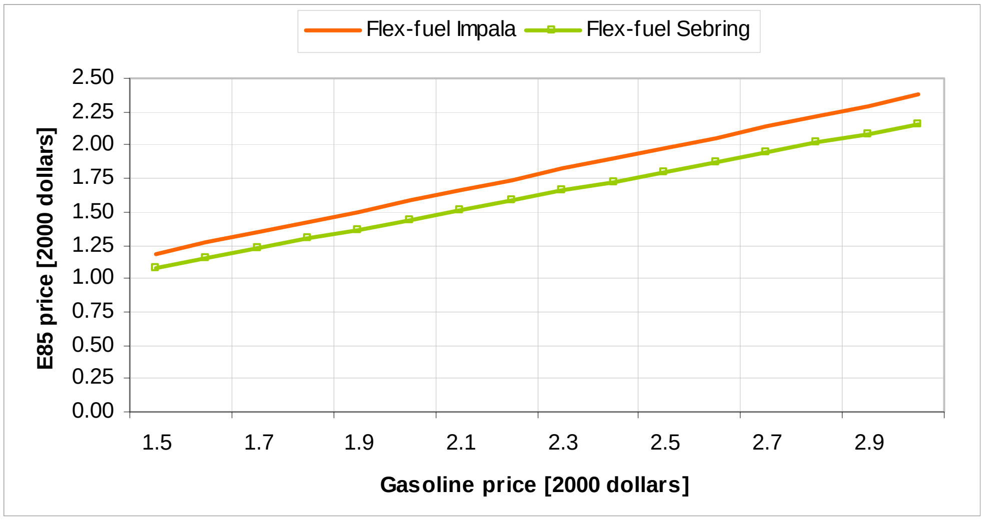

Figure 7. Competitive prices of E85

As pointed out above, consumers' choice at the pump will depend on a variety of factors in addition to the per-mile fuel costs. One of such factors is the level of availability of fuel-dispensing infrastructure for each of the competing fuels. Assuming that, at the pump, consumers are indifferent between E85 and gasoline, the fraction of total stations that offer E85 necessary to meet consumers' expectations have to be determined. Further research is needed in this area. Nicholas et al. (2004) analyzed the relationship between the density of new hydrogen refueling stations and average travel time, for Sacramento County, California. They found that with the number of hydrogen stations approaching 5 percent that of gasoline stations, the average home-to-station driving time is comparable to the driving time to gasoline stations.

According to a study by federal agencies, there were just 121 E85 outlets in the United States by 2002 (DoT, et al., 2002). The database of the National Ethanol Vehicle Coalition, however, currently contains over 1,100 E85 refueling locations (NEVC, 2007). The higher concentration of E85 dispensing points is found in the Midwest, where the majority of ethanol distilleries are located. Expanding the alternative-fuel dispensing infrastructure will involve installing new underground tank-pump systems or retrofitting existing ones. This process will face not just economic, but also regulatory hurdles. The cost of a new system is approximately $50,000 to $70,000 for E85, $25,000 to $40,000 for LPG, and $250,000 to $500,000 for CNG. Retrofitting an existing system to dispense E85 is estimated to cost between $5,000 and $30,000 (DoT, et al., 2002). Also, the excavation to upgrade an existing station may reveal underground tank leakages that are penalized by existing regulations. Such risk may deter retailers from investing in the upgrading of their stations.

6. The Price of Ethanol

Intimately related to consumers' acceptance of ethanol is its price relative to gasoline. In this section then, I present an overview of some of the factors determining the price of ethanol. Traditionally, the price of ethanol has been correlated with the prices of gasoline, gasoline oxygenates. In 2005, however, ethanol started to be traded as a commodity on the Chicago Board of Trade, and sold at prices significantly lower than those of gasoline. According to Hackworth and Shore (2006), the main factor determining this price decrease was an increase in ethanol production in anticipation of an increase in demand from Atlanta and New Orleans—such increase in demand never materialized, resulting in excess ethanol supply that brought prices down. In mid 2006, a spike in the price of Midwest ethanol brought it to about one dollar above the price of gasoline in the Northeast.

As a commodity, the main factor affecting ethanol prices today is the interplay of demand and supply. The price of corn plays a less significant role because the factors that affect grain markets (weather, international trade, crop conditions, etc) are different from those that affect ethanol-fuel markets (crude oil and gasoline markets, the regulatory environment, demand for oxygenates, etc) (CBOT, 2007). Ethanol produced in biorefineries is sold to marketers, who in turn sell it to blenders, generally oil companies, under term contracts, usually 6 to 12 months long (RFA, 2007). About 85 to 95 percent of all ethanol transactions take the form of term contracts. The remaining 5 to 15 percent are spot-market, high-price transactions, mostly between blenders (RFA, 2006). Under term contracts, the price of ethanol is determined in a private agreement between the parties and thus remains unaffected—during the term of the contract—by the price of ethanol in the spot markets. In some of these private contracts, the agreed price of ethanol is "pegged" to a benchmark price of gasoline—a contract form that induces some correlation between the prices of ethanol and gasoline. In turn, ethanol demand impacts on feedstock prices. The U.S. Department of Agriculture has reported that ethanol production has lifted the price of corn by 30 cents (NCGA, 2007).

The start of government subsidies for ethanol production was contemporary with the implementation of the CAFE program. The Energy Tax Act of 1978 established a reduction in motor fuel excise taxes for ethanol blends of 40 cents per gallon. The American JOBS Creation Act of 2004 replaced the excise tax exemption on ethanol with a Volumetric Ethanol Excise Tax Credit (VEETC) which provides for a 51-cent tax exemption per gallon of ethanol blended into gasoline. Thus, for example, a gallon of E85 qualifies for a 43-cent tax credit.

The Energy Policy Act of 2005 (EPAct05) included, for the first time, mandates on the volumetric supply of biofuels. The pertinent provisions, commonly known as the Renewable Fuels Standards (RFS), mandated the supply of four billion gallons of biofuels in 2006, increasing to 7.5 billion in 2012. Since the passage of EPAct05, Congress considered proposals to increase the RFS requirements, such as S. 987, the Biofuels for Energy Security and Transportation Act of 2007, introduced by Senator Bingaman (D-NM) and Senator Domenici (R-NM). S. 987 included provisions on advanced biofuels, requiring the supply of 3 billion gallons of such fuels by 2016, increasing to 21 billion gallons by 2022. EISA 2007 amended the renewable fuel program, and set the volumetric requirement on renewable fuel at 4 billion gallons for 2006 and 36 billion gallons for 2022. The minimum requirements on advanced biofuels were set at 0.6 billion gallons for 2009 and 21 billion gallons for 2022. Advanced biofuel is defined in the Biofuels for Energy Security and Transportation Act of 2007 as "fuel derived from renewable biomass other than corn kernels"—a definition that includes ethanol from sugarcane. Out of the volume of advanced biofuel required in 2010, there is an applicable volume of cellulosic biofuel of 0.1 billion gallons, which increases to 16 billion gallons in 2022.

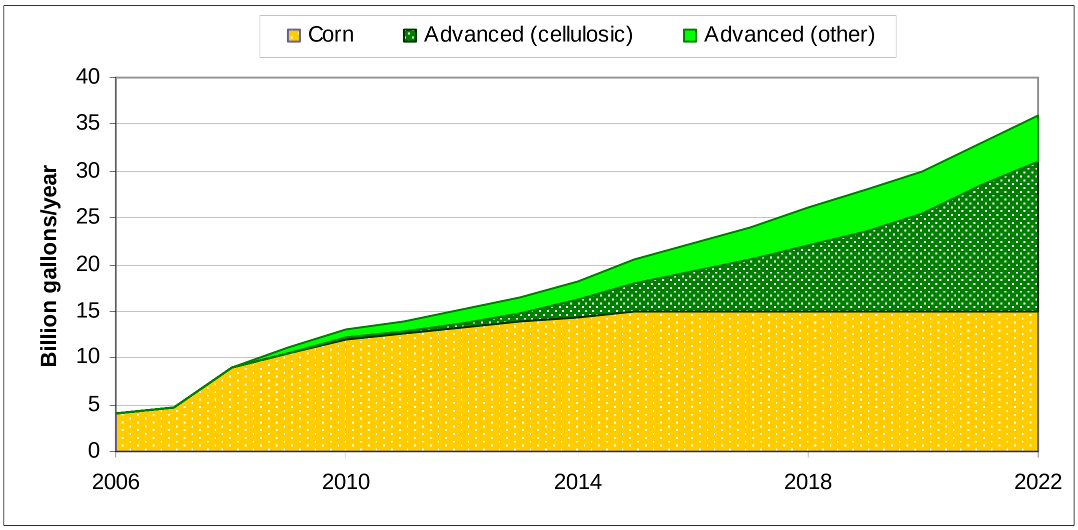

Figure 8. Biofuel volumetric requirements in EISA 2007.

To prevent imported ethanol from benefiting from tax credits, and indirectly to protect the domestic ethanol industry from foreign competition, the United States has been applying, since 1980, a specific-rate tariff on ethyl alcohol imported for use in transportation. This duty, currently at a level of 54 cents per gallon, is scheduled to expire in January, 2009. In view of the volumes of ethanol required under current legislation and to provide a competitive environment for the industry, the import tariff should be eliminated. There exists, however, a constituency that supports extending it.

While, officially, the rationale behind legislative intervention in the biofuel markets lies on the strategic need to increase energy security, a deeper look reveals that much of the motivation resides also on favoring regional domestic economies. The natural effect of mandating a baseline market share for ethanol (the fuel that is expected to meet most of the RFS requirements in the short term) and imposing a tariff on ethanol imports is to drive the price of ethanol up. For example, Elobeif and Tokgoz (2006) found that in the absence of import tariffs, the price of ethanol in the United States would fall by 13.6 percent on average between 2006 and 2015. They estimate that such price decline would result in a 3.6 percent increase in ethanol domestic consumption and a 7.2 percent decline in domestic ethanol production. It should be noted that most of the regional economic benefits are not received by the farmers who grow the corn, as commonly believed, but rather by the owners of the crop land, who are usually not the farmers.

In addition to legislative initiatives such as those just described, the Federal government is, particularly through DoE and the U.S. Department of Agriculture, involved in a variety of programs related to the development of an alternative-fuel infrastructure. One example is the DoE-run Clean Cities Program, which develops public-private partnerships to promote the use of alternative fuel vehicles and deploy the needed infrastructure.

In its 2008 Annual Energy Outlook, EIA projected the wholesale price of ethanol to stabilize by 2013 at below $1.7 per gallon, or around $2.6 per gallon gasoline equivalent (Figure 9), as production capacity increases, and then to increase along with volumetric requirements on cellulosic ethanol toward 2019 (see Policy discussion section). The price of ethanol does not raise far beyond the three-dollar mark, probably due in part to technology learning and in part to specific provisions in EISA 2007 that direct the EPA to make available for sale cellulosic ethanol credits. The prices of gasoline and E85, on an energy basis, converge approximately by the year 2015, and then remain comparable through 2030. This pricing projection reflects the substitutability of the two fuels and shows that E85 is not expected to offer consumers with a cheaper alternative to gasoline. More importantly, under such pricing pattern, FFV owners would have no significant incentive to prefer E85 over gasoline, and their probability of fueling E85 would be directly related to their accessibility to E85 stations. In other words, FFV owners would not be expected, in general, to go out of their ways to find an E85 station—the probability of them fueling E85, on a first approximation, would be no higher than the percentage of stations in their area that offer E85.

The solid line in Figure 9 shows the prices of E85 that would be approximately expected based on the prices of its individual components (assuming an annual average of 74% for the ethanol content of E85). Some questions remain as to how the significant discrepancy between these “expected” prices and the projected prices can be explained.

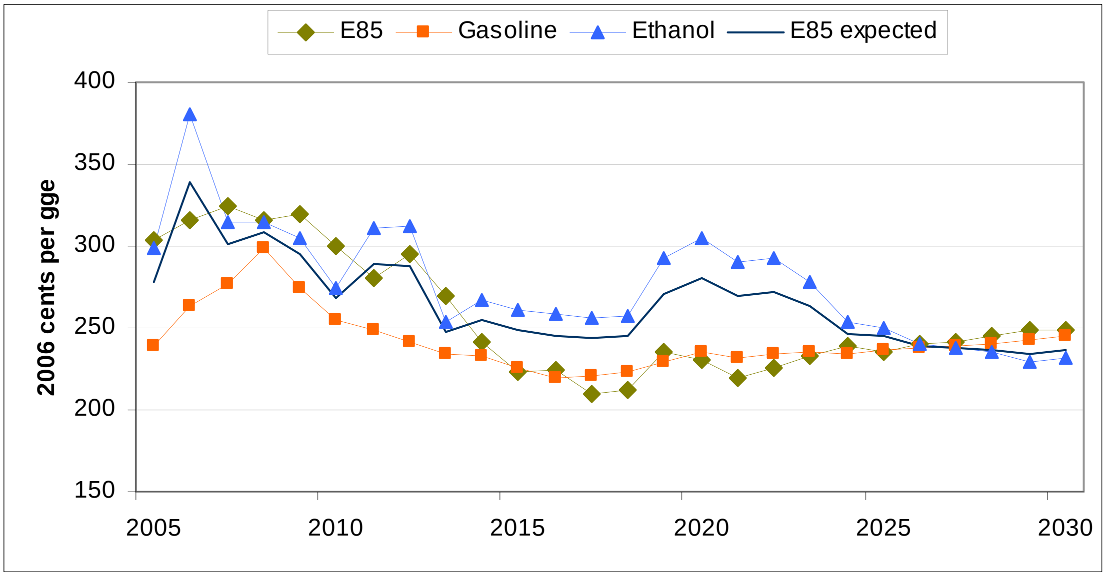

Figure 9. EIA price projections for gasoline, ethanol, and E85[8]

7. Policy discussion

While the energy policy issues today, as discussed in the introduction, compare well to those in the late 1980's, the policy/statutory landscape in which the AMFA provisions are embedded have changed since then. After successive waves of interest in methanol, electricity, and hydrogen, biomass-derived alcohols have taken center stage in the debate over alternative fuels. Such focus has been reflected in legislative and regulatory initiatives, some of them discussed in this paper, directed to incentivize the production of ethanol (Koplow, 2006). Expected climate policies such as the Low-Carbon Fuel Standard and, to a much lesser extent (Gallagher and Collantes, 2008), economy-wide carbon pricing schemes, are likely to further stimulate ethanol demand. Government has thus prompted a surge in domestic ethanol production which is only likely to increase.

With a baseline ethanol supply secured by means of government intervention, it may be pertinent to estimate how much of that ethanol will be provided in the form of E85 (as opposed to low-fraction blending) and to reevaluate the role of CAFE-AMFA in securing or stimulating the supply of flex-fuel vehicles. This paper presented a discussion on an array of issues relevant to the latter question: the Congressional intent underlying AMFA, the policy debate over the extension of the AMFA amendments, the climate impacts of ethanol production pathways, and the consumer acceptance of E85-powered vehicles. This section presents a policy analysis based on those results, including a proposal for an alternative structure of the AMFA provisions.

[8] EIA published estimates on per-gallon basis, which were converted to construct Figure 9. Gasoline prices are sales-weighted for all grades and include taxes. Ethanol prices are wholesale.

7.1. Structural deficiencies in CAFE-AMFA

Ultimately, the raison d'être of government intervention is to provide a societal benefit. When Congress took it upon itself to amend the CAFE program to provide for special treatment of alternative-fuel-capable vehicles, its primary intent was to lure manufacturers into deploying such vehicles. In this respect, the legislative initiative has been relatively successful. The domestic car companies have taken advantage of the incentives introduced by AMFA and traded flex-fuel vehicles for some average fuel economy—a strategy not only allowed by the statute but also contemplated by Congress when it passed the Act in 1988. In light of this, the alternative-fuel provisions do not strictly constitute a loophole in the CAFE program. Congressional intent on passing AMFA, however, rested on the premise that once a reasonable supply of alternative-fuel vehicles developed, a demand for alternative fuels would ensue. The latter effect was observed to a very limited extent. Therefore, all in all, the AMFA amendments cannot be considered a success. More importantly, as it will be discussed in this section, they cannot be expected to be any more successful than they have so far been, if they maintain their current structure.

Though well-intentioned and pioneering, AMFA took a unidimensional approach to solve a multidimensional problem. AMFA could have been more successful had the chicken-and-egg problem actually been the main obstacle to the market diffusion of alternative fuels. The main obstacles have been, however:

- a- The relatively low value proposition that flex-fuel vehicles running on ethanol blends could offer to consumers, vis-à-vis the mainstream vehicle-fuel system;
- b- The lack of a policy mechanism to internalize the external costs of gasoline relative to alternative fuels.

In fact, the chicken-and-egg problem arises only when the relative value proposition of a new product to any sizeable segment of the consumer population is low—otherwise, market forces would spontaneously become active in deploying both the product and the supporting technology. Of course, there may be a role for government even when market forces act spontaneously, if the new product brings about higher societal benefits than the mainstream competitor. Areas of government participation may include permitting, development of codes and standards, consumer education, and oversight of various possible forms of market failures, including the internalization of externalities.

Starting from an incomplete understanding of the relevant mechanisms of technology innovation, AMFA provided incentives for the vehicle manufacturer, but ignored the consumer and the fuel provider. The importance of systemic approaches to technology policy was not well understood in the time when AMFA was first adopted. It was with the California Low Emission Vehicle and Clean Fuels program, adopted in 1990, that technology innovation and energy paradigm shift started to be approached by addressing both vehicle and fuel. It took a few more years to learn, predominantly through the policy process of the California Zero Emission Vehicle program, that the value proposition to the consumer is also critical (Collantes, 2006b). The revision of the CAFE program in

2007, by leaving the structure AMFA provisions unaltered, failed to incorporate any of these lessons.

One more structural deficiency characterizes the AMFA program. On establishing the CAFE program, Congress provided guidelines but gave DoT the ultimate authority to determine whether to revise the fuel economy standards. For the AMFA provision, however, Congress adopted an entirely different philosophy—it prescribed the methodology and only left to the regulatory agency the decision of whether or not to extend the program for an additional four-year period. This unfortunate choice can be singled out as the main cause for the conflictive nature of the related policy debate—many stakeholders found themselves with the difficult choice between an ill-designed policy to pursue a noble policy goal and no policy at all.

7.2. CAFE-AMFA in the broader energy policy landscape

While Congress was right about the importance of breaking the chicken-and-egg loop, it was naive in its belief of that alone being sufficient to trigger a significant demand for alternative fuels. The AMFA provisions were a step in the right direction, though incapable by itself to achieve the intended objective. A key question to enlighten the ensuing policy proceeding would be: Should we take that step back or should we rather take the additional steps necessary to attain the policy goal? I would submit that also paramount is to understand why the "additional steps" have not yet been taken.

The latter invites us to take a more careful look into the history, not just of AMFA, but of the national transportation energy policy as a whole. We will be quickly reminded of our limited success in pursuing long-term energy-strategic goals through committed, consistent policymaking. Energy policy has tended to be reactive and intermittent; following, instead of preceding, the very external shocks whose negative impacts it purported to prevent. Reasons for the instability of the national energy policy include the short time horizons under which political systems operate, the fragmentation of jurisdiction over energy across many committees in Congress, among others (Katz, 1984; Blair, 1993). In contrast, Brazil established its National Alcohol Fuel Program (PRO-ALCOOL) in 1975 (the same year in which the CAFE program was adopted in the United States) and remained committed to a long-term strategy. Today, the vast majority of automobiles in Brazil use fuel blends containing at least 22 percent of ethanol.

Canvassing the history of transportation energy policy in the United States should help us recognize that the limited market penetration of E85 cannot be blamed only on AMFA. Since the program's inception, a number of fuels alternated as leading competitors in the race to oil displacement. As discussed above, the late 1980's was the time of methanol. The 1990's brought about an interest in electricity, particularly in California and the Northeast. During the early 2000's most eyes turned to hydrogen. Policymakers as well as interest groups have been climbing a learning curve, sifting through viable alternatives to petroleum fuels, committing resources to one option before moving to the next one. Only in the recent years did interest in ethanol surge. Politics aside, this learning process is not necessarily unhealthy, even when no tangible results seem yet on sight. However, given such unstable, uncommitted policy environment, it is hardly possible to fairly assess the actual potential of AMFA to induce the development of ethanol infrastructure.

7.3. CAFE-AMFA and energy security

A notion extensively used in the policy discussion over the AMFA provisions—and in energy policy discussions at large—is that of energy security. But what does energy security really mean? And how does it relate to the CAFE-AMFA question? Although a thorough treatment of the concept of energy security is beyond the scope of this paper, it is useful to point out that significant disagreements still exist over what an appropriate definition may be. The problem of energy security has been defined, for example, as follows:

> *"[T]he economic costs caused by a sudden change in the supply, demand, or market price of energy."* (Bohi, p.43)

Much of an assessment of the policy delineated by the AMFA provisions relates to the question of whether it enhances national energy security. An embedded, more specific, question is whether national energy security is well served by promoting a substitution of gasoline for an alternative fuel such as ethanol. Difficulties in arriving at consensus-based answers to questions of this sort are not unique to the AMFA debate—they have been characteristic of energy policy debates at large. On discussing policy options on the wake of the oil crises of the 1970's, Alvin Alm said:

> *"What can be done to minimize this economic misery in the future? For most security threats, the antidotes are obvious. For military threats, societies increase armaments and armies. To curb the devastation from floods they build dams, and to prevent outbreaks of disease, they inoculate the population. But for energy security there are large differences of opinion about what to do and serious political problems surrounding many of the options."* (Alm, 1984.)

The observed lack of consensus over the benefits of AMFA, I submit, derives directly from the lack of an established metric for transportation energy security. The debate finds stakeholders from opposite sides using different lines of reasoning to argue about the energy-security benefits (or lack thereof) of the policy. For example:

> *"A key policy in pursuing energy security is to have a flexible transportation system that can respond to oil disruptions by switching to other sources of energy, when necessary"* (AAM, 2002).

> *"[T]he economic dislocation resulting from an oil price shock would be more effectively mitigated by a 0.9 mpg increase in the fuel economy of the fleet than through dual-fuel vehicle production sufficient to earn manufacturers a 0.9 mpg credit, so long as those dual-fuel vehicles run on E85 less than half of the time"* (ACEEE, 2002).

Defining a metric for energy security is by no means easy. Nor is it to actually measure how different policy pathways compare to each other on that metric. Eaves and Eaves (2007) proposed a methodology to compare the energy-security benefits to the United States of corn ethanol vis-à-vis oil. Using historical data on year-to-year changes in corn production and oil imports, they conclude that oil is a more reliable source of energy than corn ethanol. Their analysis illustrates some of the pitfalls that may be found in attempts to operationalize energy security. For example, it is of little use to compare oil to corn, as no one realistically expects significant volumes of ethanol (of the magnitude needed to generate a sustained improvement in energy security) to be produced from corn, particularly in the long term.

Further, Eaves and Eaves (2007) focused on ethanol produced from domestically-grown corn. Whereas domestically producing more of the energy we consume has a number of benefits—on the balance of payments and job creation, among others—it should not be presented as inextricably linked to the notion of energy security. As ethanol becomes an international commodity and, potentially, trade barriers are lifted, blenders in the United States will purchase ethanol from marketers from around the world. What is more relevant is that the geography of international ethanol supply will bear little correlation with that of oil supply. Geopolitical turmoil in the Middle East will—as it always has—impact oil prices, but it will have milder implications for the international price of ethanol. To the extent that gasoline and ethanol remain complementary goods (a notion elaborated upon in Szklo, et al., 2007), ethanol will have only marginal impacts on energy security. As gasoline and ethanol become substitute goods, oil shocks will be less harmful to the U.S. economy, and therefore energy security is enhanced. This viewpoint was subscribed to by the automobile industry:

> *"A key policy in pursuing energy security is to have a flexible transportation system that can respond to oil disruptions by switching to other sources of energy, when necessary"* (AAM, 2002).

Flex-fuel vehicles may help ameliorate the impacts of an oil crisis. Oil crises—however this concept may be defined—develop rapidly and with little announcement. Therefore, strategies to deal with them ought to be proactive rather than reactive. All sides of the debate agree on this notion. What triggered conflict in this area of the AMFA debate, is the question of whether increasing the number of flex-fuel vehicles on the road is an effective oil-security strategy. Environmental groups sustain that further increasing fuel economy standards is the more effective means to reduce the impacts of an oil crisis, and it should not be compromised by granting fuel-economy credits to flex-fuel vehicles.

The position of the Agency was very clear:

> *"In view of the nation's energy security interests, it is important to be increasing alternative fuel capability throughout the fleet. The need to ensure the nation's long-term energy security is of such vital concern that it takes precedent over possible short-term petroleum consumption and environmental impacts."* (DoT et al., 2002, p. 48.)

But is it the substitutability of gasoline and ethanol that improves the national energy security, or is it the fact that ethanol is produced from domestically grown feedstocks? There is no consensus on the answer to this question. It has been argued, for example:

> *"In the event of a disruption of our oil supply, the ability to switch our source of transportation energy from foreign petroleum suppliers to domestic energy sources, including renewable energy sources, will be critical in ensuring that the impact on the economy" is minimized.* (Ford, 2002)

Substitutability and domestic production may, however, be incompatible goals. Substitution of imported oil for domestic oil may secure some supply but it will not enhance energy security in the sense defined above, for a variety of reasons, including: a) crude oil prices follow international levels regardless of its origin; b) the United States has limited ability to affect oil prices by increasing supply; c) the United States will remain dependent on importation to supply a large share of its oil needs. Substitution of imported oil for domestic ethanol will be limited by ethanol production capacity—a small fraction of the U.S. transportation energy needs, in the short and medium terms. The new RFS requires that at least 24 billion gallons of renewable fuel be used in 2017. Out of these 24 billion gallons, a maximum of 15 billion gallons can be met with corn ethanol—the rest has to be met with so-called advanced biofuels, including a minimum of 5.5 billion gallons of cellulosic biofuel. This requirement structure opens a significant opportunity for much of the standard to be met with (imported) sugarcane ethanol. This is particularly true if the tariffs on imported ethanol are terminated as expected. Thus, significant fuel substitution, as intended by the RFS, may become possible only when imported ethanol is included.

Figure 10 shows projections of ethanol supply in the United States, as estimated by the Energy Information Administration after the adoption of the new RFS (EIA, 2008). Total supply approaches 29 billion gallons per year by 2022 (falling short of the 36-billion-gallons mandate), with a significant share of imported ethanol peaking at 4.14 billion gallons in 2020. Production of cellulosic ethanol is projected at just 0.7 billion gallons by 2017, increasing rather dramatically to 8 billion gallons by 2022 to meet only half of the RFS requirements for that year. Gallagher and Collantes (2008) arrived at even less optimistic projections for the supply of cellulose-derived ethanol. Admittedly, it is challenging to make reliable long-term projections, given the relatively early stage of technology development. However, these projections signal that success of biofuel policies in the United States may depend heavily on importation of biofuels. This is one reason why the importation tariff needs to be eliminated. A mechanism such as certification will be necessary, however, to control for the carbon intensity of imported biofuels.

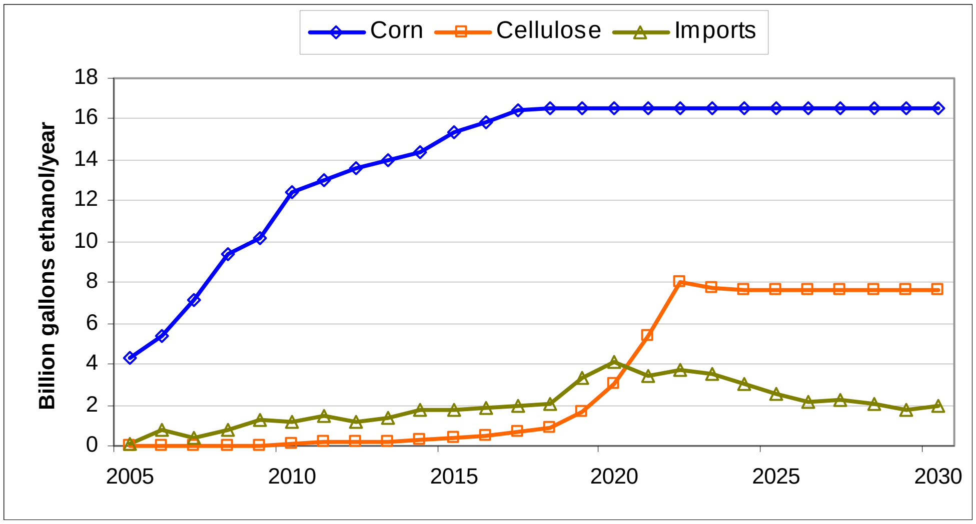

Figure 10. Projections of ethanol supply in the United States (Data: EIA, 2008)

As highlighted by the preceding paragraph, whether the RFS supply requirements can actually be met—and what the implications of attempting to meet them may be—is still matter of debate. Biofuel-supporting policy, particularly the pre-EISA 2007 Renewable Fuel Standard, has given tremendous impetus to private investments in biorefining infrastructure during the last two years. As of January, 2007, 110 ethanol biorefineries were fully installed in the United States, for an annual production capacity of 5.49 billion gallons. An additional capacity of 6.13 billion gallons per year is expected to come online through ongoing plant construction or expansion (RFA, 2007.) By the first quarter of 2008, the number of operating plants had increased to 145, for a production capacity of over 8.5 billion gallons per year. Another 62 plants were under construction, to add five billion gallons of annual capacity, for a total projected volumetric annual capacity of 13.5 billion gallons (RFA, 2008). Before the 2007 revision of the Renewable Fuel Standard, the U.S. Department of Agriculture (USDA) projected a domestic annual production of about 12 billion gallons of ethanol by 2016/17. This level of production would have tangible impacts on food and farm land prices. USDA also warned that significant investments in research were needed if the 250-million-gallon minimum requirement on cellulosic ethanol under the old RFS was to be met (USDA 2007a; 2007b).

The question of relevance to the AMFA debate is what fraction of the projected supply of ethanol will be used as E85 by flex fuel vehicles. As shown in Figure 11, EIA projects that the volume of ethanol used for E85 starts an upward trend around 2015—about the time when the price of E85 becomes comparable to that of gasoline on an energy basis (see Figure 9). The supply of E85 is projected to peak at about 14 billion gallons in 2022, representing just about 9.4 percent of the energy needs for transportation spark-ignition engines. As shown in Figure 12, the projected increase E85 supply is expected to affect demand for gasoline. However, it would be hard to argue that such effect would result on a meaningful improvement in energy security, with demand for gasoline remaining at almost 140 billion gallons per year by 2030.

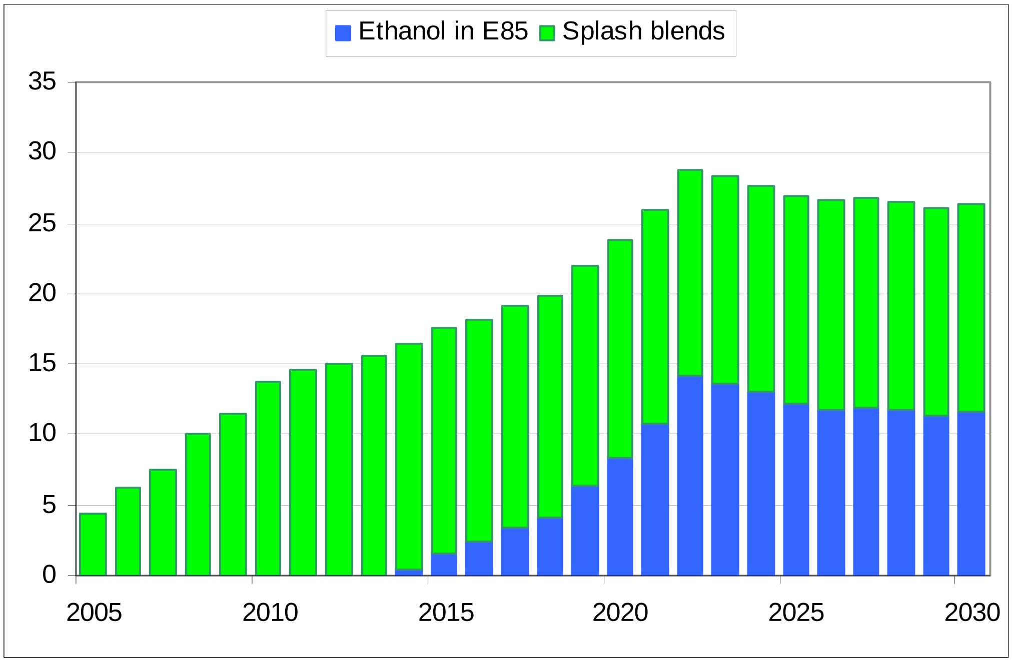

Figure 11. Fractions of ethanol used for blending and for E85 (Data: EIA, 2008)

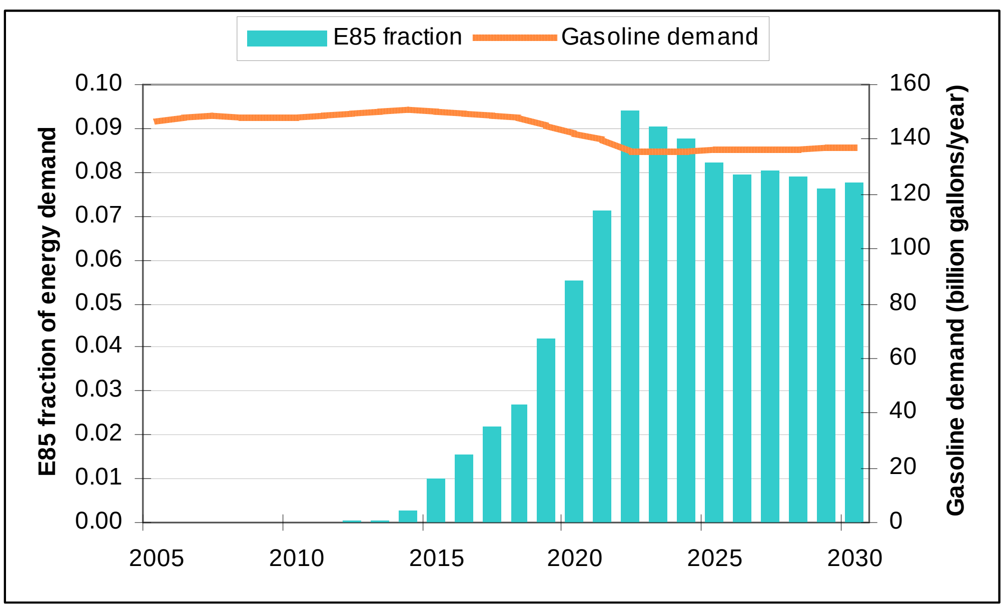

Figure 12. Fraction of transportation energy demand supplied by E85

Enabling or requiring the production of alternative fuels, however important, is one part of the problem. Complementary policy/regulatory action will still be needed to address practical problems related to the distribution and dispensing of alternative fuels such as the limited incentives for owners to upgrade dispensing stations with biofuel-capable equipment.

7.4. Assessing AMFA and alternatives

Insofar as the AMFA provisions constitute the only incentives that automobile manufacturers have to deploy alternative fuel-capable vehicles, and with the supply of biofuels on the rise, there seems to be, in principle, a strong argument to keep (a form of) them in place. Two overarching questions remain on the way of warranting the AMFA provisions:

a- What is the expected impact of flex-fuel vehicles on energy security?
b- Is the current incentive scheme adequate, and if not, how to revise it?

This section is concerned with addressing these questions.

Figure 13 shows a proposed logic sequence to assess whether to keep, eliminate, or revise the AMFA provisions. The sequence starts with questions related to energy security and they were broadly addressed above.

Assuming positive answers to all the energy security questions, the question of whether incentives are necessary for the market introduction of FFV seems to follow naturally. It is widely accepted that incentives of some type are desirable. The population of FFV has grown dramatically since the adoption of AMFA. In addition to AMFA, factors that determined such growth include the Energy Policy Act (EPAct) of 1992 and Executive Order 13149. EPAct 1992 requires that in FY 2000 and beyond, 75% of light-duty vehicles (defined as vehicles under 8,500 lbs GVWR) acquired by Federal agencies must be flex-fuel. EPAct also sets requirements on acquisitions of alternative-fuel vehicles by state agencies and fuel providers that operate at least 50 light-duty vehicles. E.O. 13149, “Greening the Government through Federal Fleet and Transportation Efficiency”, signed by President Clinton on April 21, 2000, requires Federal agencies to develop strategies to reduce their annual consumption of petroleum by 20% by the end of FY 2005, relative to their consumption in FY 1999. Federal agencies’ 2000 purchases of AFVs totaled 7,949, bringing their AFVs inventory to 55,260—14% of the total in-use AFV population in 2000 (U.S. DoE, 2000). Therefore, much of the increased demand for alternative-fuel vehicles has been driven not by direct consumer interest but by government incentives of various forms.

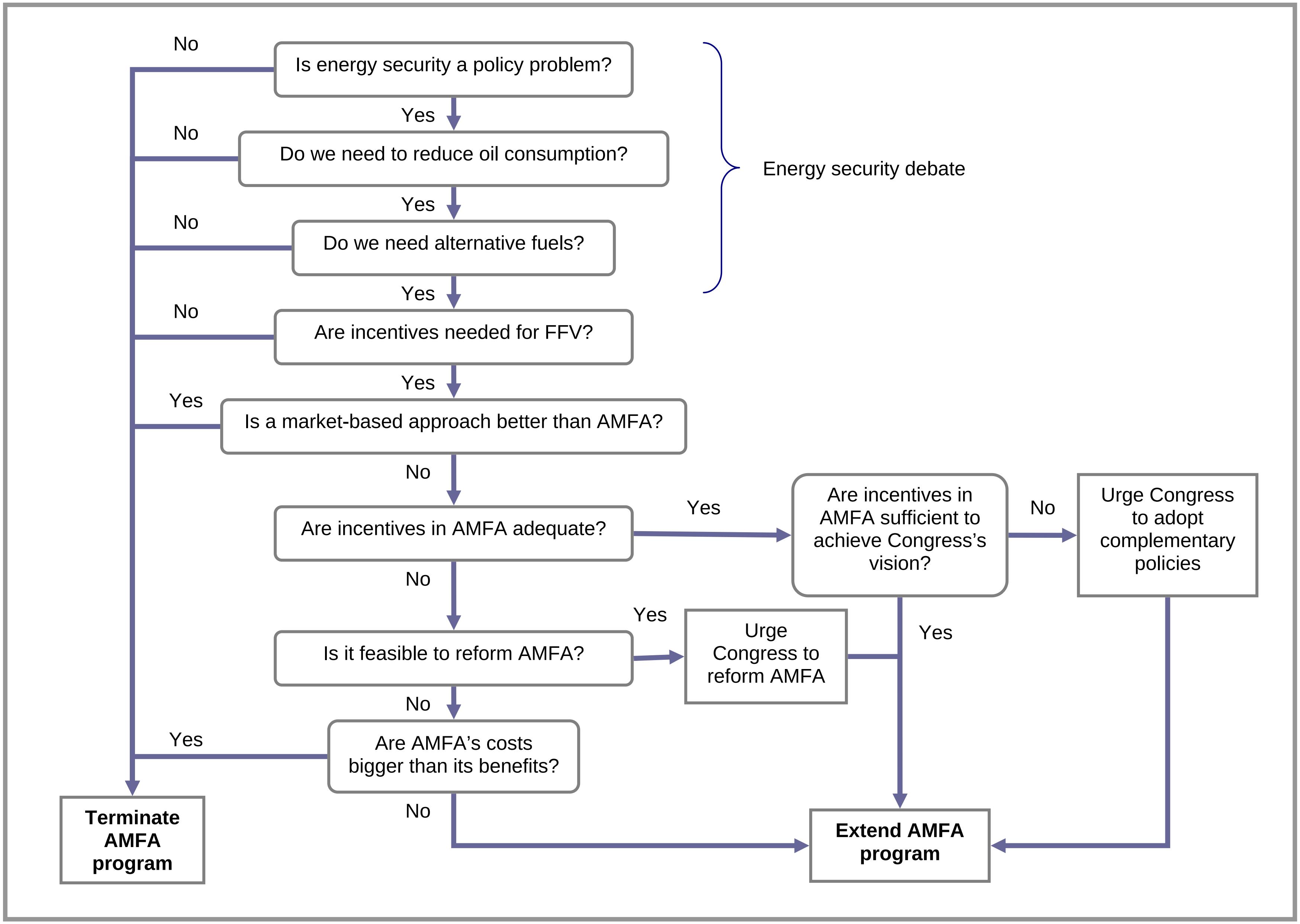

Figure 13. AMFA policy evaluation chart

There is less agreement, however, on the form that FFV incentives ought to take. One alternative would be to replace the demand-pull AMFA program with market-based approaches that incorporate the societal benefits of alternative-fueled vehicles. Gallagher and Collantes (2008) estimate the effect of policies such as fuel taxes and carbon taxes on the market penetration of E85 and flex fuel vehicles. If a version of AMFA is kept, finding a structure that conforms with most stakeholders' expectations could be challenging. It has been argued that "[f]olding the incentive into fuel economy standards makes sense only to the extent that it furthers the objectives of CAFE" (ACEEE, 2002). However, this proposition is either sophistic or inconclusive, depending on whether one understands "the objectives of CAFE" as to increase fuel economy or energy security. Under the first interpretation, the proposition is sophistic—if dual-fuel vehicles yielded unquestionably higher fuel economy, OEMs would not need incentives to produce them. Under the second interpretation, the proposition is inconclusive because it can be solidly argued that the incentives are a valuable part of a strategy to prevent future oil shocks from hurting the economy (see discussion above).

One area where CAFE-AMFA could be moved toward broader stakeholder support is addressing the current lack of coordination between AMFA and government requirements for the production of alternative fuels. Policies to effectively address transportation energy problems ought to be systemic—more effective solutions can be expected if the fuel and vehicle sides of the equation are not only considered separately but also in coordination. One area where coordination could be pursued is that of regional markets. Historically, virtually all of the production capacity was concentrated in the Corn Belt of the Midwest, but new investment is spreading into many states. Because of the strong correlation between fuel accessibility and the likelihood of consumers choosing that fuel, future reviews of the CAFE-AMFA program could consider schemes that relate the fuel-economy credits granted to flex-fuel vehicles to the proportion of fuel dispensing stations that offer high ethanol blends in the state where the vehicles are deployed.

The CAFE-AMFA program could benefit from a collaboration of government with all affected stakeholders to improve consumers' information on the alternative-fuel capabilities of vehicles, and the private and societal effects of using biofuels instead of petroleum fuels. The information of consumer choices is an issue intimately related to the CAFE program. The apparent incongruity between actual consumer behavior and that of the fully-rational homo economicus assumed in mainstream choice models has been characterized as one of the market failures that help justify fuel economy standards (Greene, 1998). In the particular context of alternative fuels, the information available to consumers is deficient in a number of areas, including whether the vehicle they own is biofuel-capable, what the per-mile costs of using biofuel compared to those of using petroleum fuel are, what the environmental and oil-saving net effects of using biofuels are, and others. Some of these issues have been recognized by Congress: The Ten-in-Ten Fuel Economy Act, passed by the U.S. Senate as Title V of H.R. 6, included Section 511, Increasing Consumer Awareness of Flexible Fuel Automobiles, which directed the

Departments of Energy and Transportation take steps toward informing consumers on issues related to the use of alternative fuels.[9]

Finally, the AMFA provisions should be revised to reduce the incentives for car manufacturers to use them merely as a mechanism to meet their average fuel economy requirements. Finding ways to achieve this may be challenging, yet key to reaching broader support among stakeholders. Disabling the compensating mechanism altogether would leave automakers with little incentive to keep producing flex-fuel vehicles. Leiby and Rubin (2000) estimate that, without fuel-economy incentives, production of FFV would decline by about 50 percent. At the same time, leaving the mechanism intact does not correct for the perverse effect of inducing lower average fuel economy.

If the intention of Congress when adopting a CAFE program with the AMFA amendments was predominantly to reduce oil consumption, the 0.15 equivalence factor used in the current incentive scheme to estimate the gasoline content of one gallon of ethanol fuel needs to be revised. On a well-to-wheels basis, the petroleum used by a vehicle running on E85 is about 30% of that used by a comparable gasoline vehicle for the same travel distance (Brinkman et al., 2005).[10] The assumption that flex-fuel vehicles operate on alternative fuel 50% of the time, used to estimate their fuel economy is in utter dissonance with experience. It is difficult to predict whether this assumption will be more reflective of reality when and if ethanol becomes widely available and consumers are better educated about the potential benefits of using it. Currently, it provides car manufacturers (particularly those for whom CAFE is binding) with excessive benefits. In the future, conceivably, the benefits could be insufficient. The bottom line is that the 50% assumption is a crude approximation that ought to be refined.

Possible ways out of this dilemma could include:

- a- To prescribe a minimum gasoline fuel economy level for every flex-fuel vehicle model;
- b- To require that flex-fuel vehicles be more optimized to operate on the alternative fuel, so as to close the gap in per-gallon mileage when the vehicle runs on gasoline and on a high ethanol blend;
- c- To grant AMFA fuel economy credits proportionally to the accessibility of the corresponding alternative fuel in the regions where the vehicles are sold;
- d- Complement AMFA with a set of incentive mechanisms that send the right signals to industry.

I will discuss in more detail option d-. As discussed in this paper, crucial to consumer acceptance is the value proposition offered by E85-fueled flex-fuel vehicles vis-à-vis that of gasoline-fueled vehicles. Even assuming full availability of biofuels, AMFA does little to translate any societal benefits of using biofuels into a market signal, either to

[9] H.R. 6 passed the U.S. Senate on June 21, 2007, and sent back to the House. As of the time of writing this paper, the bill considered by the House did not include fuel-economy provisions and it was uncertain whether an amendment would be introduced in the floor.
[10] Essentially the same result applies if the ethanol is produced either from corn or from cellulosic biomass.

consumers or industry. Thus, AMFA does not make the flex-fuel vehicle a product with more consumer appeal, nor does it induce industry to make it more appealing. To correct this, the incentive scheme could be transformed from supply-based to demand-based—a scheme that based the credits on an estimate of demand for E85, rather than on the supply of FFV. Such approach would have multiple benefits (see below).

Assume the geographical distribution of the volumetric demand for E85 is known in a given year. The total number and model composition, by manufacturer, of the new flex-fuel vehicles deployed are known for the same year.[11] Knowing these vehicles' fuel economy rating, their vehicle-miles traveled using E85 could be estimated as

$$VMT_{E85} = Demand_{E85} \times FE_{E85} \quad \textbf{Equation 4}$$

Having an estimate of the average vehicle-miles traveled in a given district (e.g. metropolitan area), an estimate of the average fraction of the travel that flex-fuel vehicles do using E85 can be obtained as follows:

$$vmt_{E85} = VMT_{E85} / VMT_{total} \qquad \textbf{Equation 5}$$

This estimate could be used to make a more realistic estimation of the fuel economy—for CAFE purposes—of new flex-fuel vehicles in the next model year. A possible formalization of this approach follows.

Under a demand-based incentive scheme (DBIS), Equation 1 would take the following general form:

$$FE_{FFV} = \left[\frac{(1 - vmt_{E85})}{FE_{gas}} + \frac{vmt_{E85}}{(FE_{E85} / p_{eq})} \right]^{-1} \quad \textbf{Equation 6}$$

Where:

- vmt_{E85}: Demand-based estimate of the fraction of average VMT done by flex-fuel vehicles on E85;
- p_{eq}: E85-gasoline petroleum-consumption equivalency (equal to 0.15 under the current incentive scheme).

Under a fuel economy accounting such as this, automakers would be rewarded (relative to the accounting of Equation 1) as FFV owners do most of their driving on E85. Conversely, automakers would be rewarded less than under the current incentive scheme as FFV owners do most of their driving on gasoline. This effect is shown in Figure 14 for $p_{eq} = 0.15$ and $p_{eq} = 0.26$, using the example of the 2007 Chevy Impala (combined fuel economies of 24 and 19 mpg on gasoline and E85, respectively). The former is the

[11] Basing the scheme on the characteristics of the new FFV instead of the total fleet of FFV, while yielding biased estimates of vehicle-miles traveled using E85, is intended to provide manufacturers with stronger incentives for technology innovation.

currently applicable value, while the latter is an alternative value based on the 74% annual average fraction of ethanol in E85. To be consistent with the goal of oil displacement, the current value of p_{eq} needs to be revised. This could be done more appropriately by means of a lifecycle analysis of petroleum consumption in the production of E85. A lifecycle approach would result in values of this equivalency higher than 0.26.

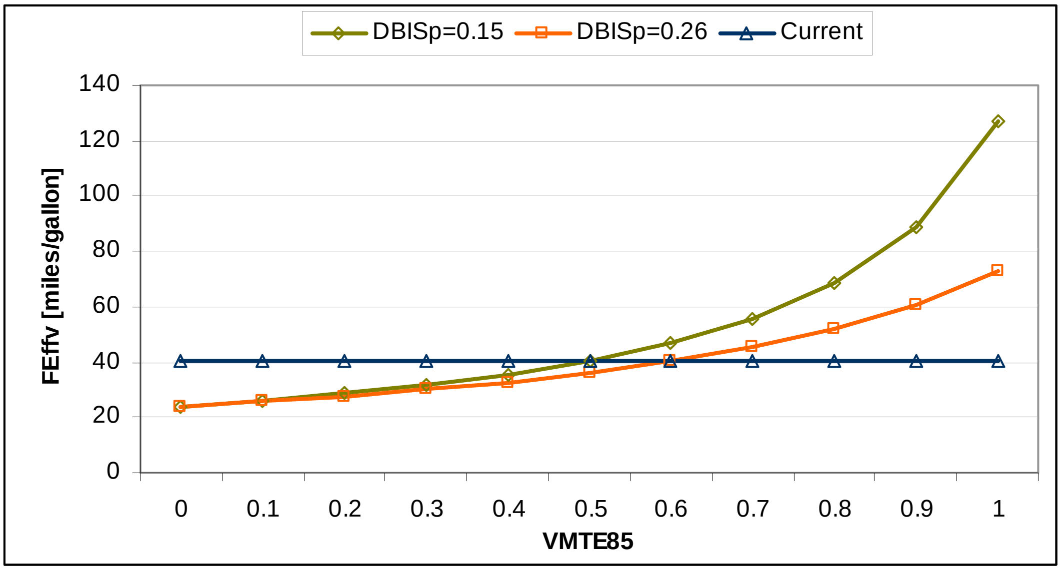

Figure 14. Accounting of fuel economy under the demand-based incentive scheme in Equation 4

Allowing fuel economy estimates to vary over time—as they would under a DBIS—would not be a significant problem to industry's production planning for two reasons: a) flex-fuel vehicles do not need specific vehicle design—they are simple modifications of a standard model; and b) time variations in E85 demand are neither capricious nor sudden—the main predictor of E85 demand in a given year is demand in the preceding year—and therefore fuel economy estimates would not vary significantly from year to year.

Under the DBIS just introduced (variations are clearly possible) several benefits would accrue, including:

a- Manufacturers would have incentives to induce consumer demand for E85 by improving vehicle performance on E85, deploying more flex-fuel vehicles in areas with more established refueling infrastructure, educating consumers on the benefits of using E85, and other strategies.

b- While still benefiting with AMFA fuel-economy credits, manufacturers would make deployment decisions based on their expectations on actual E85 demand, rather than as a mere strategy to meet their CAFE requirements.

c- The alternative-fuel incentives under CAFE would be more transparent, result-oriented, and, consequently, more efficient.

d- The political frictions surrounding the AMFA provisions would be ameliorated, and collaboration of all stakeholders would be facilitated on the pursuit of a common goal, namely a (responsible) increase in renewable fuel demand.

Looking forward, it may be useful to think of the AMFA provisions in the context of the CAFE program as a whole. With the current political drive to address the problem of global climate change, there is a temptation to use CAFE as a climate policy tool. Meanwhile, federal standards on vehicle emissions of carbon dioxide are pending after a Supreme Court ruling in April, 2007. Given the obvious overlap between a fuel-economy program and a CO_2-emission program, it is entirely conceivable for CAFE to be replaced with a CO_2-oriented program. Such approach could provide incentives for biofuels more naturally than AMFA currently does.

Acknowledgements

I am indebted to Kelly Sims Gallagher and Henry Lee for their careful reading of previous drafts of this paper and their insightful comments. Other members of the Energy Technology Innovation Policy group at Harvard's Kennedy School of Government, particularly Robert Frosch, provided useful feedback, which I gratefully acknowledge. Financial support for this work came from the William and Flora Hewlett Foundation, The Energy Foundation, and the U.S. Environmental Protection Agency. Responsibility for the content of this document is exclusively my own.

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