2008

If Ethanol is the Answer, What is the Question

Peter Z. Grossman
Butler University, pgrossma@butler.edu

If Ethanol is the Answer, What is the Question?

Peter Z. Grossman

SUMMARY:

Since 2005, in the face of rising oil and gasoline prices, many Americans have looked to plant-based fuels, particularly ethanol, as the "answer" to our energy dilemmas. ... Section III examines the issues connected specifically to ethanol, how market forces as well as government subsidies have worked to make corn-based ethanol economically viable at times, why that viability has been lost in recent months even with subsidies, and further, why ethanol from corn on the scale the legislation demands is impractical. ... Clearly it would be technically possible to produce the mandated 15 billion gallons of ethanol, and distilling capacity will nearly reach that level shortly, but the economics of corn-derived ethanol suggest that, absent massive subsidies or coercion, this effort will not be economically sound for producers or consumers. ... (Indeed, high capital costs are an issue for the mandated innovation of cellulosic ethanol, and part of the reason that technology is not yet considered economically viable.) ... The federal subsidy is still 51 cents per gallon, equivalent to $ 1.43 per bushel (assuming 2.8 gallons per bushel), although as noted earlier there may be state subsidies as well. ... Major meat producing firms as well as users of corn-based products such as high fructose corn syrup, have noted the impacts on their businesses and in turn lobbied against fulfillment of the larger corn ethanol mandates.

I. INTRODUCTION

Since 2005, in the face of rising oil and gasoline prices, many Americans have looked to plant-based fuels, particularly ethanol, as the "answer" to our energy dilemmas. [n2] In fact, President George W. Bush and many members of the U.S. Congress are among those who believe that ethanol is the "answer." In December 2007, Congress passed, and President Bush signed, a new energy bill. [n3] This bill, which amended the 2005 Energy Policy Act, [n4] was notable for two particular provisions. The first was the mandate for automakers to increase the corporate average fuel efficiency (CAFE) standards of their auto fleets to thirty-five miles per gallon (mpg) by 2020. [n5] This represented a 40 percent increase over the previous standard set in the 1970s. [n6] [*150]

But the far more dramatic mandate concerned a government requirement that by 2022, 36 billion gallons of transportation fuel would be provided by biofuels, particularly ethanol. [n7] Of that total, 15 billion gallons are to be distilled from corn, a target to be reached by 2015, while the remaining 21 billion gallons, must be derived from cellulosic plants such as switch grass. [n8] In all, this measure would mostly satisfy President George W. Bush's goal of "20 in 10," that is the reduction of U.S. consumption of conventional automotive fuels by twenty percent in ten years. [n9] The bill merely extends the term to fifteen years and, if fulfilled, would substitute between fifteen and twenty percent of projected fuel consumption. [n10]

The size of the mandate is actually quite staggering. Under current production methods, about half of America's corn crop will be needed to reach the 2015 target, and the celluslosic component cannot be produced today at a cost remotely competitive with gasoline. In fact, the cellulosic mandate depends on technological advances that can be described today as, at best, remotely "plausible." [n11] Moreover, the infrastructure to distill such a vast amount of ethanol does not exist, nor do the vast fields of crops like switch grass that will be needed as ethanol feed stocks. Thus, the mandate does not simply require the development of workable technology, but also its usage on a truly massive scale. Nevertheless, ethanol, the "renewable energy revolution," as one member of Congress termed it, [n12] is seen as a feasible substitute for petroleum-based fuels that will provide a home grown alternative to petroleum imports.

But the optimism about ethanol is unfortunately an example of hope over experience. There is little reason to think that these benchmarks will be met on time. Indeed, if history is any guide, there is reason to doubt that this mandate [*151] will ever be achieved. [n13] The ethanol "answer" in fact seems less like the technology of the future and more like other promised solutions of the past. [n14] It may well only be the answer to the question: what is the latest government-backed failed energy panacea? From nuclear fission power to synfuels to electric automobiles to nuclear fusion power, government programs have touted, and more often than not mandated, a new marvelous technology that would provide the answer to our energy dilemmas. But in every case, the mandated technology has failed to deliver. Often, in fact, the effort has entirely failed. For example, nuclear fusion development was promised $ 20 billion toward the goals of proving by 1990 that nuclear fusion energy could produce more (electric) energy output than the heat energy that was put in and creating a fusion power commercial prototype facility by 2000. [n15] Funding was scaled back but none of these benchmarks have ever been met. [n16]

Nuclear fission power, on the other hand, is perhaps the most successful alternative energy technology undertaken under the auspices of the federal government. But even that technology, which proponents claimed would provide almost limitless power at a price "too cheap to meter," has never fulfilled its promise. [n17] Even in 2008, more than forty years after the first nuclear fission power plant was constructed, new nuclear power plants cannot be built anywhere in the world without government subsidies and loan guarantees. [n18]

Yet the sorry history of government energy programs did not enter into the debate that led to passage of the 2022 biofuels mandate. Enthusiasm for the mandate was overwhelming with many politicians chiding President Bush for his timidity in requesting only a 35 billion gallon target. [n19] Yet there is every reason to believe that ethanol will not make a major contribution to our energy supplies [*152] by 2022, if ever. It is unlikely that it will be technically feasible to produce such an enormous volume of cellulosic ethanol, and it may well be damaging economically to even try. [n20]

This paper is structured as follows: Section II looks back at past alternative energy technology programs and explains why the search for a panacea technology is at the heart of so many of them and why the management of technological progress that they entail misconceives the nature of innovation. Section III examines the issues connected specifically to ethanol, how market forces as well as government subsidies have worked to make corn-based ethanol economically viable at times, why that viability has been lost in recent months even with subsidies, and further, why ethanol from corn on the scale the legislation demands is impractical. It also explores the economic issues connected to alternative means of ethanol production. Section IV concludes the paper with a brief consideration of what role, if any, government should play in fostering new energy technologies.

II. THE POLICY CONUNDRUM AND THE PANACEA TECHNOLOGY

Over the last 30 years, Congress, usually at the President's behest, has repeatedly passed legislation mandating, usually with a timetable, the development of alternative energy technologies. [n21] Yet as noted above, not a single mandate has been fulfilled, and in fact, alternative energy mandates have achieved little, if any, value whatsoever. Despite this dismal record, in 2007 the ethanol mandate was passed by both houses of Congress. [n22]

The motivation behind these mandates is not blindness to historical precedent. Rather it stems from a policy conundrum that can only be solved if a [*153] mandate such as the one for ethanol is fulfilled. Basically, the president and Congress face the following problem: Americans generally want to achieve two objectives from energy policy. The first goal is energy independence, that is, independence from energy imports. The second is a low price for energy resources. The conundrum arises because these goals are mutually exclusive. Given our current resource mix, the way to achieve independence from energy imports would be to raise prices considerably. On the other hand, the way to lower energy bills would be to remove taxes, increase refinery capacity, and drill for more oil and gas both in the United States (where there clearly would not be sufficient resources extractable at low prices to keep consumers' prices low) and elsewhere. Indeed, we would encourage exploration and imports from all sources, especially ones where extraction costs would be low.

But in theory there is one way around this conundrum: the panacea technology, the new technology that could provide nearly limitless domestic energy at relatively low prices. [n23] Since only a new technology can resolve the contradiction inherent in the goals, Congress is motivated to mandate one "answer" after another.

Probably the best known mandate of the past was the Carter-era program for synthetic oil and gas (known as synfuels) passed in 1980, and for the most part, shuttered in 1985. [n24] Essentially, the mandate directed that synfuels would be derived primarily from America's abundant coal resources. That is, solid coal would be extracted and then processed into both liquid (syn-oil) and gaseous (syn-gas) forms. The technology to do this had been demonstrated many years before but it was very expensive to produce, much more costly than conventional oil and gas extraction and production. Proponents argued that if the government devoted very large funds to the development of those synfuel processes, the technology would soon become cost competitive with conventional oil and natural gas. This would be especially likely since the supplies of conventional resources were thought to be rapidly running out, [n25] which would make conventional gasoline [*154] and diesel fuel extremely expensive. Originally, the synfuels program was to receive eighty-eight billion dollars in government funds channeled through a government corporation, The Synthetic Fuels Corporation (SFC) with a goal of producing five-hundred thousand barrels a day of synthetic oil (or gaseous equivalent) by 1987, and two million barrels per day (equivalent) by 1992. [n26] With that quantity, synfuels would have provided the equivalent of nearly twenty percent of our transportation fuels by 1992. [n27]

The synfuels project of course was a complete fiasco. It was predicated on steadily rising prices of conventional fuels (they instead fell) and progress in technological development (which was not forthcoming). When the SFC was closed in 1985, it had accomplished very little (one syngas plant was in operation and its output was not cost competitive). [n28] The synfuels program overall had wasted about $ 2 billion. [n29]

Despite the dismal and well-publicized failure of the synfuels mandate, new mandates were passed both during and after the closing of the SFC. In 1990, California passed its own mandate, declaring in 1990 that, by 2003, 10 percent of all cars sold in the state would have to be zero-emission vehicles [*155] (ZEV). [n30] It was thought that this effort would spur development of electric vehicles in particular, but in fact the mandate was continually pushed back over the ensuing thirteen years and is nowhere close to being realized as of early 2008. [n31]

Similarly, in 1993 the Clinton Administration launched a $ 1.5 billion effort to create a commercially practicable prototype of an eighty-mile-per-gallon automobile, a program known as the Partnership for a New Generation of Vehicles (PNGV). [n32] The mandate called for the car to be developed by 2004 through a partnership of the three major U.S. automakers (GM, Ford, and DaimlerChrysler) with government funding. [n33] By 2001, it was clear that the goal would not be achieved, and the new Bush Administration abandoned the effort. [n34] Moreover, with the real (inflation adjusted) price of transportation fuels very low, there was no particular reason why automakers would invest heavily in such a project, even if the technology seemed to be in sight. In fact, the opposite was occurring among U.S. automakers that were focusing on the development of large, fuel-inefficient sport utility vehicles and selling them by the millions.

It is important to consider just what assumption the government is making (at least implicitly) when it issues a technology mandate. In all the above cases, the government was necessarily taking a position on the nature of technological innovation. Most importantly, a technology mandate assumes that innovation is demand-led. That is, if consumers want something that is not physically impossible to produce (such as a perpetual motion machine), then entrepreneurs will produce it, provided the incentives are correct. If they are not correct, then there is a "market failure" that must be corrected by government intervention. [n35]
[*156] Or, to put it more concretely, consumers have wanted a substitute for foreign oil. Synfuels should have provided that substitute, but for some reason entrepreneurs were not developing it. Perhaps they saw the investment as too risky, or they felt they could not capture the tremendous gains that society would enjoy from this new technology. [n36] But since the market was not providing consumers with what they demanded, government had to step in to correct this market failure to deliver.

Some scholars over the years have argued that innovation may be demand-led, [n37] but in general the evidence overwhelmingly points to a supply-side explanation. Innovation occurs not because consumers want a new technology. The way the process actually works is: first, innovation occurs in a way that is not generally predictable; and second, the market determines whether people want the result of that innovation at the price entrepreneurs will offer it. As one of the leading historians of technology Nathan Rosenberg has argued, scientific knowledge evolves if not randomly, at least unevenly, and its employment in the creation of marketable products is unpredictable. [n38] Thus, it cannot actually be said that there was a market failure in the case of alternative energy technology, or that the market had in fact underprovided what consumers had demanded. Rather, the converse appears to be more likely. That is, there was an unrealistic expectation that government would be able to substitute not only for market interaction but also for knowledge acquisition and its consequent development. As the discussion of past governmental efforts suggests, government programs simply have not produced marketable energy products. Arguably in fact, technology policy has revealed not the existence of market failures but rather the persistence of government failures. [n39]

Of course there are examples of technological progress induced by government. The Apollo program achieved a remarkable demonstration of technology in putting astronauts on the moon. Indeed, presidents and pundits have repeatedly conjured the memory of the Apollo program in advocating alternative [*157] energy development. [n40] But the Apollo program (or the Manhattan Project as another example frequently raised with respect to energy development) did not have the same intent that is placed on an alternative energy program. Both projects were mere demonstrations (spectacular ones at that) in which initial and ongoing costs were largely irrelevant. In fact, ongoing costs were meaningless in the Apollo case because after a few demonstrations the program was terminated. Alterative energy technologies, on the other hand, are supposed to compete, often on a massive scale, with conventional resources. Virtually all of the mandated technologies, like synfuels, had already been demonstrated. [n41] The process for turning coal into a liquid fuel has been known since 1909, and we have had prototype electric cars for many years as well as experimental autos that have achieved more than 100 miles per gallon. But none of these technologies have ever proven price competitive with conventional technologies, notwithstanding government subsidies and mandates.

It should be noted that proponents do point to some successes in government induced technological change that are, in some sense, economically viable. [n42] The basic category is termed in the literature as "technology forcing," and appears to have had notable success with regards to the 1970 Clean Air Act. [n43] Most especially, automakers were presented with a demand that they reduce tailpipe emissions from cars, and were told that they needed to do so by a certain [*158] date or face EPA sanctions. [n44] The result was the catalytic converter, a technological advance that would probably not have occurred without the "forcing" process of a technological mandate. [n45] Thus, we have an example of technology that was created by a mandate and is now "commercial."

Clearly, this is a different kind of commercial from that which faces an alternative energy technology. The catalytic converter did not have to compete with an existing, lower cost solution, nor did it have to substitute for some other kind of converter. Moreover, there were potential penalties if it, or something like it, was not created. To make alternative energy technology analogous, imagine a case whereby a car owner faced punitive action if she used conventional fuels, or a home owner if he failed to install solar panels on his roof. Further, assume these penalties would exceed the additional cost of adopting synfuels or solar heating. Coercion would in fact make any uneconomic technology "viable," but there has not been any suggestion to date to require the use of ethanol over gasoline, especially if the latter is cheaper.

[n46] Thus, even mandated "successes" do not really provide an example to demonstrate that government action can correct the supposed market barriers that impede innovation.

There are two other assumptions that the government implicitly makes in the context of an alternative energy technology mandate that are also open to question: first, if a technology works but is not being exploited, government support is a sufficient condition to make it economically viable; and second, once it is viable, widespread adoption will ensue. But these assumptions are not supported by either theory or fact. No one can foretell if an innovation will lead to a market success. The process of development of a product is not the same as the process of commercialization. The former is an engineering problem. For example, can we make a solar hot water system that will efficiently capture the heat from the sun? It is generally the case that an innovation will follow a process from an idea, to laboratory proof of that idea, to a prototype demonstration, to large scale engineering development, and then to commercial introduction. [n47] As [*159] in an Apollo moon landing where the government can assemble scientific and technical minds to examine problems, the Department of Energy can no doubt gather engineers to build a state-of-the-art solar hot water system, with incorporated improvements both in the quality of the instruments and the manufacturing process.

But will the resulting effort produce a solar hot water system that will enjoy market success? Will people buy it? How will the market respond? Market success has been aptly described as an "emergent phenomenon," [n48] as opposed to an engineering one. Price, and other forms of information that convey a product's desirability and attributes, will emerge from buyer-seller interactions. How these evolve will determine market success. If the products prove unreliable or too costly given their alternatives, success will not emerge, regardless of the state-of-the-art technology.

Moreover the process of adoption, even where market penetration is emerging, is likely to proceed over time - sometimes leading to market success on a large scale. To continue this hypothetical example, consumers may perceive that solar heating is apparently cost competitive with conventional heating technologies, but how well does it perform over time? What are the long run maintenance costs? How reliable are vendors with respect to repair and service? Some people may adopt the technology quickly, but for others it may be years, even decades, before adoption occurs. [n49] The adoption process may be thought of to follow an S-curve (see Figure 1), where the y-axis shows the level of market penetration, along an x-axis representing time. The broken line at the top of the figure represents the point of market saturation. But how long it takes to go from the small market share of early adoptions at the left of the graph to saturation is uncertain. It could be years or decades. Also, it could not occur at all. A technology may make some initial penetration but lose out to alternatives as information grows and choices become clear.

Solar hot water heating demonstrated this. Incentives from the Carter Administration developed a nascent solar hot water heating industry in the late 1970s and early 1980s. Carter officials envisioned large and rapid market growth, projecting 2.5 million installed solar units by 1985. [n50] However, the market signaled something else to consumers; vendors were proving unreliable and [*160] the prices of conventional fuels, contrary to expectations, fell. When incentives were finally eliminated, an estimated ninety-five percent of all solar producers and contractors went out of business, and by the 1990s, more solar hot water systems were being removed from homes than were being added. [n51] By 2000, the technology had only a miniscule percentage of the hot water heating market and little likelihood of any major expansion. [n52] In this instance, as in all the others, the government failed to convert a fully engineered alternative energy technology product into something that was commercially practicable.

Figure 1

Market Saturation FIGURE 1
(see original for figure)

There is a corollary to the assumption that government intervention is a sufficient condition in bringing innovations in energy to the market: that is, if there is more than one process, more than one design, more than one idea, government has the expertise to pick the best design and thus, direct social resources to their highest valued use. But governments around the world have had a relatively poor record in choosing between the competing technologies. The Japanese government, often hailed for its industrial policies, did have some success at promoting existing Japanese firms in industries with well-understood, mature technologies. In steelmaking, the post-war Japanese industry had notable successes [*161] and benefited from government support. But when Japan's government sought to make Japan a leader in high definition television, it supported the development of an analog technology that failed in the marketplace (even though it was an engineering triumph). [n53] Of course, with respect to alternative energy technology, the U.S. government is confronted with a dilemma: given the enormous size of the mandate, if the government fully backs multiple standards and approaches because the cost would quickly become enormous.

Then again, government is by definition ill-suited at picking winners. While markets pick from a range of choices with competition threatening to alter the prospects for any given product and any given firm, the government often picks winners based on political considerations. The best lobbyist could succeed in winning government approval over what might be a better technological or marketable idea. [n54] By its nature, a government program that is able to spend literally tens of billions of dollars creates an incentive more for rent-seeking than for technological innovation. Every alternative energy program has attracted proponents of technologies seeking a share of the large benefits, often willing to make extravagant claims that are impossible for bureaucrats and legislators to accurately evaluate.

Yet there are also political incentives for politicians to endorse technology mandates whether the prospects for success are high, or whether the lawmakers even understand the ideas they are promoting. When a politician declares that we will have energy independence by a certain date, they seem bold, Kennedyesque. Since fulfillment of the mandate is typically years in the future, there is little cost to a politician to vote for it or enthusiastically endorse it. [n55] The timetable of greater concern is the next election cycle, and chances are that even if legislators are still in office when the mandate expires, there will be a new issue of paramount concern to their constituents, and the mandate vote will shrink in importance, if not be entirely forgotten.
[*162]

III. ETHANOL AND ITS PROSPECTS

A. Ethanol Mandates

"Everything about ethanol is good, good, good," Senator Charles Grassley (R-Iowa) said at the opening of an Iowa ethanol plant. [n56] Grassley's paean to ethanol has been echoed by many politicians, some courting votes during presidential primaries, others supporting farm constituents, one of the beneficiaries from ever increasing ethanol subsidies.

The U.S. government has supported ethanol to at least a limited extent since the 1970s by providing tax exemptions or direct subsidies for producers. [n57] But two pieces of legislation in the 1990s gave major boosts to ethanol production. In 1990, the Clean Air Amendments called for additives to gasoline to "oxygenate" fuel; that is, additives had to contain compounds with oxygen molecules that would make motor fuels cleaner burning and less polluting. [n58] Ethanol was one of those additives, and the legislation spurred increased production and blending of plant-derived alcohol fuel. However, difficulties in transporting ethanol discouraged its use as an oxygenate outside of the Midwest. [n59] Two years [*163] later, President George H. W. Bush signed into law the Energy Policy Act of 1992 which set a goal of replacing thirty percent of conventional fuels used in cars and light trucks with alternatives by 2010. [n60]

By the early 2000s, as a consequence of these two pieces of legislation, U.S. ethanol producers were distilling 1.7 billion gallons of ethanol, most of it for blending into gasoline. [n61] While this amount replaced less than two percent of U.S. automotive fuels, it represented almost double the production in 1990. [n62] The oxygenation rules called for gasoline blends with less than 10 percent of the oxygenate. But often ethanol has been blended with gasoline at a ratio of 1:9, sometimes called "gasohol," and more often referred to as E-10, meaning that the mixture is 10 percent ethanol and 90 percent gasoline. [n63] This amount actually represents an important ceiling because ethanol can be corrosive at higher concentrations, damaging conventional automobiles parts. This problem did not become a major issue with respect to ethanol because blending of ethanol was limited and production remained almost entirely localized.

But with rising fuel prices in the 2000s, President George W. Bush and supporters of ethanol in Congress sought a new mandate. The proposal, originally offered in 2002, called for production of 5 billion gallons of ethanol by 2012. [n64] This basic policy mandate was finally achieved in the 2005 Energy Policy Act. [n65] In fact, the new law went beyond the original proposal by mandating 4 billion gallons by 2006 and 7.5 billion gallons by 2012. [n66] These mandates were instituted along with rule changes that ended compulsory oxygenation of fuel, thus eliminating the previous reason for subsidizing ethanol. Now the rationale for the mandate was the broader issue of "energy independence." Ethanol was to play a role more like the one synthetic gasoline was supposed to play, replacing a [*164] substantial portion of imported oil. By this time the direct federal ethanol subsidy was 51 cents per gallon. [n67]

It should be noted that before, as well as after, the Energy Act of 2005 was passed state governments were passing mandates of their own. [n68] Most notably, Minnesota mandated that all gasoline sold in the state was to be E-10 effective at once, and that by 2013, all gasoline would need to be 20 percent ethanol or E-20. [n69] The second part of this mandate is problematic as suggested above, since all cars using E-20 would need to be retrofitted to prevent corroding effects from the higher alcohol content. [n70] It has been pointed out that car warranties would be voided if motorists use E-20 in existing vehicles. [n71]

The federal mandate, however, immediately spurred investment in, and construction of, ethanol facilities. Virtually all of these were designed to produce ethanol from corn. By 2007, there were 134 ethanol distilling plants in the United States, with production capacity of over 7 billion gallons; also another 77 plants were under construction, which would add another 6 billion gallons capacity when, or if, they are completed. [n72]

In December 2007, the mandate was expanded once again with the Energy Independence and Security Act of 2007. [n73] Now the mandate required production of a colossal 36 billion gallons of ethanol by 2022, with the prescription that [*165] 15 billion gallons be distilled from corn, and 21 billion from cellulosic feedstocks. [n74] Though switch grass has been noted (especially by President Bush) as a possible feedstock, it is yet unclear just what cellulosic ethanol would, or should, be made from. Wood chips, cornstalks, and other cellulosic plant materials have been suggested. [n75] Given the uncertainties surrounding not just the technology but also the basic input that is to produce 60 percent of the mandate, the 2007 energy bill effectively has repeated the process of a legislated demand for innovation. Though cellulosic ethanol can be produced, it is far more costly than the corn-derived product and has not been produced on a large scale. [n76] Success in making this form of ethanol economically viable is definitely open to question.

But what of the corn side of the mandate? Clearly it would be technically possible to produce the mandated 15 billion gallons of ethanol, and distilling capacity will nearly reach that level shortly, but the economics of corn-derived ethanol suggest that, absent massive subsidies or coercion, this effort will not be economically sound for producers or consumers. Ethanol produced under the mandate is unlikely to be cost competitive with conventional gasoline, and at the same time, it will raise food and land prices. In general, the corn ethanol mandate is probably no more likely to solve our energy dilemmas than any previous panacea.

It should be noted at the outset, that while corn ethanol production of 15 billion gallons seems like a huge quantity, it would not even meet the national E10 standard. That is, it would replace less than 10 percent of projected automotive transportation fuels. Ultimately some proponents of ethanol would like to see a national effort to mandate E-85 or a blend of 85 percent ethanol and 15 percent gasoline. However, that amount would require production at such a vast scale that it is wildly implausible. To understand why, consider that if 100 percent of the 2006 (record) corn crop of 10.5 billion bushels were used for ethanol, we would get a bit over 28 billion gallons of fuel (assuming conversion was at an efficient level), which is only about 75 percent of the 2022 mandate. We could also plant another 20 million acres, an area the size of South Carolina, in corn to get us approximately to the 36 billion gallon level. Even using switch grass, if the technology proves commercially practicable, we will need to use very large tracts of land. To get to E-85, we would need to quadruple the proposed ethanol level, and land use, of the 2022 mandate! An attempt to make all gasoline E-10 [*166] will have important and problematic economic consequences; therefore, E-85's consequences can barely be imagined.

B. The Basic Economics of Corn Ethanol

Ethanol will be considered an economically viable product when it satisfies two basic requirements. First, it must be cost effective to produce, meaning that the market price of ethanol is greater than (or at least equal to) the cost of production. Second, it must be cost effective to purchase; the price must be comparable to the alternative, namely conventional gasoline. This will be especially true for those consumers who contemplate purchasing modified automobiles so that they can use blends up to E-85. That said, there are a number of complicating factors in analyzing the economics of ethanol. For example, even if production and consumption of ethanol make economic sense at current output levels, will costs rise as production increases? Or put another way, would a national E-10 standard, or something like it, mean that per unit costs of ethanol will be greater than small-scale production. Will costs remain constant, or even fall? In some instances, mass production leads to economies of scale so that increased output leads to declining costs and lower prices. But at other times increased production leads to diseconomies of scale, that is, with costs rising as the scale of output increases. Moreover, even if it is profitable to replace conventional gasoline with ethanol, and it is cost effective for consumers to choose it, there may be other economic factors in the development of ethanol that would work against (or possibly for) large scale production. For instance, it has been argued that there will be spillover effects from substantial production of corn ethanol that will raise various social costs and so effectively lower overall social welfare.

In general, the economic viability of ethanol - where it is profitable to produce and cost effective to consume - depends on three factors: the price of gasoline, the price of corn, and the size of government subsidies. Other factors may impact the viability of ethanol as well. For example, the capital cost of constructing ethanol facilities will be an ongoing charge in ethanol production. [n77] (Indeed, high capital costs are an issue for the mandated innovation of cellulosic ethanol, and part of the reason that technology is not yet considered economically viable.) There will also be operation and maintenance costs as well as benefits [*167] from selling the ethanol production's dry residues (distillers' grains) for animal feed.

We can think of the problem this way: the ethanol producer earns a profit when the cost of making a gallon of ethanol (average cost) is less than, or equal to, the price he or she receives for it. [n78] The cost of making a gallon of ethanol includes the variable costs of plant operation, capital costs, and so on, which can also be represented as a certain cost per gallon of ethanol produced. Of course this also includes the cost of the key input, corn. Typically the ethanol yield from a bushel of corn is 2.6 gallons (although often 2.7 or even 2.8 per bushel are used in calculations since this is the output level that has been achieved by stateof-the-art producers). [n79] There is also revenue in the form of government subsidies. The federal subsidy is still 51 cents per gallon, equivalent to $ 1.43 per bushel (assuming 2.8 gallons per bushel), although as noted earlier there may be state subsidies as well. [n80]

One 2005 study from the U.S. Department of Agriculture determined average production costs at 41 cents per gallon inflation adjusted to 2007 this would be 43.5 cents, and while there will be variation across producers, the technology is well known and the differences will be minimal. [n81] One must assume a rate of return on an investment, which we can call the opportunity cost of producing ethanol, instead of producing some other product. A 20 cent/gallon return has been suggested. [n82] Thus, total costs not including corn inputs are 63.5 cents/gallon. Since subsidies as well as production costs are assumed to be the same across producers and constant, the truly uncertain variable cost is the price of corn. Corn input costs are undoubtedly the crucial element in the calculation. Not only are current prices relevant but future ones are as well. Though futures [*168] markets indicate the future price of corn, they are imperfect predictors and do not account for bad harvests, increased plantings, and so on. [n83] But, once we have calculated the cost per gallon of ethanol (and hence the floor for its price in the market since any lower price would be loss creating) we need to add the subsidy and then compare that to the wholesale price of gasoline.

At first glance, it may seem unsurprising that over the past decade ethanol and gasoline have often sold for comparable prices per gallon; in June 2007, for example, the former was $ 2.13/gallon, the latter was $ 2.17/gallon. [n84] But in fact price equality should not be expected because ethanol has only about 70 percent of the energy value of gasoline and presumably should be selling at a steep discount to conventional fuels. Since prices are often close, it has been assumed that ethanol has worth as an additive (termed its additive value), [n85] presumably that additive value is as an oxygenate, over and above its energy content. Thus, it may logically sell for something close to the price of gasoline, possibly even above that price. [n86] Some energy economists will assume an additive value of at least twenty cents. [n87] It is, however, difficult to make assertions about additive values because until 2006, oxygenating additives were required by law and could be replaced, not by gasoline, but rather by alternate oxygenates (such as MTBE) and would be utilized if it were (a) selling at a price above cost, and (b) selling at or below the price of MTBE. Under these circumstances, if ethanol's price is at a premium to its energy value, as well as a premium to gasoline, ethanol will be economically viable to produce - as long as it does not have to directly compete for consumer dollars where non-blended gasoline could be offered as an alternative. In fact, it can be assumed that whether or not ethanol will be utilized in gasoline blends, absent a mandate requiring its use, will depend on whether balancing the total cost plus the subsidy package makes the ethanol price competitive with the alternative, unblended gasoline. [n88] Thus, if the price of corn is low [*169] and/or the price of gasoline is high, ethanol is more likely to be economically viable; also, if subsidies were to increase, viability would benefit. Of course the supply of ethanol relative to its demand will determine its market price.

With each of the market-determined variables - ethanol, gasoline, and corn - there will be price ranges that make ethanol production either profitable or not. There is in effect a limit on these prices for all producers, which may be referred to as the break-even level, that is, price movements of these variables as they change may make ethanol either a profit-making or loss-making activity. It can go from profit to loss quite quickly.

Perhaps the key price for the economic viability of ethanol is the price of corn because corn prices have been the most volatile of any of the three. Consider where corn prices have been over the past two years and where they are expected to be in 2009. As Figure 2 shows, at the end of 2005, the price of corn was around $ 2/bushel, and in early 2006 it was only marginally higher, around $ 2.15. [n89]

Figure 2- Corn Prices - Chicago Board of Trade 1999-2007

(see original for figure)
[*170]

So if we assume that in early 2006 the price of the corn input was 77 cents per gallon ($ 2.15 divided by 2.8), then variable production costs were 63.5 cents, and overall a gallon of ethanol could have been produced for around $ 1.405/gallon. We can also subtract several cents per gallon, representing the amount recouped by the producer in selling dry residue distillers' grains for animal feed. [n90]

It is also important to take account of the lower energy content of ethanol. As noted, ethanol has only about 70 percent the energy per gallon as a gallon of gasoline, so in order to compare ethanol and gasoline prices on a per-unitof-energy basis, we need to multiply the wholesale price of ethanol by 0.7. [n91] In early 2006, the wholesale price of gasoline was around $ 1.75 and ethanol was approximately $ 2.00, but strictly on an energy basis ethanol should have been selling for $ 1.40/gallon. [n92] If we subtract the subsidy from the actual price, ethanol would have been selling for $ 1.49, nine cents above its energy value and considerably over its net cost. [n93] Under these circumstances ethanol was highly profitable and had a presumptive additive value of 26.5 cents. [n94] The price of corn made this especially lucrative. In fact a quick calculation suggests that at that time, early 2006, ethanol would still have been cost effective to produce even if the price of corn had been about $ 4.75 per bushel; that is, given the prices of ethanol and gasoline, the break-even price required corn at $ 4.75 per bushel. [n95] If the corn price was higher than that, ethanol would not have been cost effective. A price below $ 4.75 meant profits for ethanol producers, and the lower that price was, the higher the profits.
[*171]

Just how movements in prices of corn, gasoline, and ethanol could affect the profitability of ethanol production and cost effectiveness of ethanol consumption was observed less than two years later in the fall of 2007. At that time, the price of corn had risen to almost $ 4 per bushel, [n96] but the price of ethanol was falling due to the onrush of new production that had produced a glut of supply. By September 2007, the ethanol price was only $ 1.55 in some locations. [n97] Surprisingly, despite rising prices of crude oil, the wholesale price of gasoline in October was only $ 2.02. [n98] At these prices, the break-even price of corn, even with the subsidies, could have been no higher than about $ 3.50. With prices at $ 4 per bushel by October, ethanol plants in various parts of the country were suddenly stopping production, and in some cases declaring bankruptcy. [n99] Suddenly, the additive value was negative 37 cents.

By January 2008, the market situation had changed but the prospects for ethanol still were unfavorable. The price of ethanol had recovered to $ 1.85 per gallon, but the price of corn kept rising, and was over $ 4.50 per bushel by the end of the month. [n100] Futures markets were projecting about $ 5 per bushel by March 2008, and $ 5.25 per bushel in 2009. [n101] Clearly, at these prices, ethanol could not be profitable. At prices below $ 2 per gallon, ethanol was "price competitive" for consumers to purchase in early 2008, only because its price was essentially below cost, and gasoline prices were over $ 2.30. Obviously, producers could not continue to sell unless the price of ethanol rose, the cost of corn fell, or the subsidies increased. But under the circumstances expected at that time ($ 5 per bushel and a 51 cent subsidy), for ethanol to have been profitable and price competitive with gasoline, ethanol would have needed to sell for about

$ 2.10 per gallon. [n102] The market was then also pessimistic about the price of gasoline with respect to ethanol. In January, futures markets were predicting falling gas prices by late 2008 and 2009. [n103] If correct, the predictions would mean that corn ethanol will [*172] have increasing difficulty competing in the near future. [n104] Moreover, as farmers and ethanol producers attempt to fulfill the 15 billion-gallon mandate, it is hard to imagine that the price of corn will fall. With the doubling of production to around 8 billion gallons, the price of corn more than doubled. If production nearly doubles again, barring the planting of literally millions of additional acres in corn, the price of corn will make its ethanol prohibitively expensive, even at E-10. Certainly futures markets are already suggesting the price trajectory is substantially upward and the prospects for ethanol are unfavorable.

C. Other Economic Considerations

There are several economic issues that complicate any discussion of the costs and benefits of corn ethanol. The most obvious problem is the impact on the price of food. Not only are prices of corn-based products rising, but the demand for corn for ethanol has also increased the prices of corn substitutes such as soybeans (also at very high levels), and the prices of major products that use corn (especially animal feed), which in turn has increased the prices of meat products. As noted above, distillers' grains from ethanol production provide some animal feed at relatively low prices. But the increase in corn and soy prices have generally impacted meat producers and raised meat, dairy, and egg prices. [n105] Major meat producing firms as well as users of corn-based products such as high fructose corn syrup, have noted the impacts on their businesses and in turn lobbied against fulfillment of the larger corn ethanol mandates. [n106] From mid 2006 to the spring of 2007, the average American paid an estimated $ 47 extra, or about $ 14 billion in all (and this does not include the direct taxpayer ethanol subsidies), because of the rising prices. [n107] The pressure on the price of U.S. corn has had impacts beyond America's borders. In Mexico consumers rioted over high tortilla prices, in Indonesia they rioted over soybean prices, and in China there have been "grumblings" over pork prices that rose by 29 percent in 2007 due to the [*173] rising costs of corn which had been diverted to China's own ethanol project. [n108] According to studies by the International Food Policy Research Institute (IFPRI), global food prices are likely to rise, especially for staples such as wheat and cassava (substitutes for soy and corn). [n109] The consequences could be grave for the world's poor. One estimate suggests that as a result more than a billion people will face greater risks of famine and malnutrition. [n110]

There may also be problems for some farmers with respect to rising land values. The price of agricultural land is the net present value of the expected return from that land. With prices of agricultural products rising, so are land prices. Iowa farmland, which had increased 57 percent between 2000 and 2005, rose an additional 22.6 percent in 2007 alone. [n111] In fact prices were up more than 12 times what they had been in 1986 at the end of the protracted farm crisis that began in the 1970s. [n112] Although this benefits existing landholders, anyone buying acreage today is depending on the high prices of corn to continue and rise further. If the ethanol mandate is reduced, or if cheaper ways to make ethanol (other than corn) are developed, there could again be a farm crisis with bankruptcies throughout the farm belt.

One other cost of ethanol bears mentioning: the potential environmental cost. Although ethanol was developed in part to reduce tailpipe emissions from cars, there have been many articles

recently about the demands ethanol production places on groundwater as well as on ethanol plant pollution. [n113] Exactly how large these costs might be are unclear, but their presence casts even greater uncertainty on the economic viability (as well as desirability) of massive ethanol production.
[*174]

D. The Economics of Alternative Means of Ethanol Production

The ethanol mandate of 36 billion gallons presupposes technological progress on cellulosic ethanol, which would be made from woodchips, switch grass and cornstalks, among other sources. [n114] The process, basically the large scale application of enzymes to break down cellulose into sugars, has been demonstrated at a cost that shows the technology is not yet close to economic viability. [n115] In his State of the Union Address in 2007, President Bush suggested that breakthroughs in cellulosic ethanol were near, [n116] but even proponents of this technology see its economic viability by 2012 as feasible with at best "plausible technology developments." [n117]

Most observers are far less optimistic, even if the technology does in principle bring costs down to economically viable levels - at least at modest-sized production. To reach the mandate in the fifteen year timetable, an area the size of Kentucky will have to be planted with switch grass (or some other feed stock), and a huge infrastructure of distilleries, storage facilities and so on need be constructed. [n118] Moreover, no one knows what kind of environmental impacts the technology will create. The process will entail utilization of thousands of tons of organic compounds which will need handling and disposal. It is considered highly unlikely that, barring a major technological breakthrough, the United States will produce anything close to 22 billion gallons of cellulosic ethanol by 2022. [n119]
[*175]

Another alternative production technology would be to use sugarcane as a feedstock. Brazil produces over 4 billion gallons of ethanol per year using sugarcane and does so at a low cost of production and a high yield of ethanol per ton of cane. [n120] But a USDA analysis suggested that the United States would be unable to match Brazil's low cost of production and indeed would not be able to produce sugarcane or sugar beet ethanol at a cost per gallon less than that of ethanol from corn. [n121] Also, the amount of sugarcane and sugar beets grown in the United States would produce a relatively small amount of ethanol, and expansion of cane and beet plantings on a massive scale would not be practical. [n122] In the meantime, the United States has effectively limited imports of low cost Brazilian ethanol by imposing a 54 cent per gallon tariff. [n123] An effort to repeal the tariff with an eye toward greater diversification of energy supplies was thwarted in 2007 and seems unlikely to be revived. [n124]

It would be a mistake to assume, however, that Brazilian ethanol imports would have a significant impact on U.S. mandates. Even if Brazilian production were doubled and all of the additional quantity shipped to the United States, the supply would provide only about 10 percent of the 2007 mandate's requirements. Furthermore, if Brazil were to attempt such large scale increases in production, there would be consequences in sugar markets as well as on Brazil's environment. [n125] Consider that the ethanol yield from Brazilian cane fields is about [*176] double the amount that can be achieved per acre from a U.S. cornfield. [n126] However, to get 4 billion more gallons, that is, double the current output, Brazil would have to plant an additional 60 million acres (an area the size of Michigan). [n127] Prices of sugar are also likely to rise the more that sugar is devoted to ethanol. Indeed world sugar prices doubled from 2006 to 2007 and increased ethanol production would only send these prices soaring ultimately to the point of reducing Brazil's ability to produce at low costs. Though Brazil has plans of increasing its output and exporting much of the increase, Brazilian sugar-derived ethanol is no more an "answer" than is U.S. corn ethanol. Therefore, there is no ethanol process we know of that can cost effectively produce the vast quantity of fuel called for in the 2007 U.S. energy bill.

IV. CONCLUSION

Corn ethanol will almost certainly not prove an economically viable solution to America's energy dilemmas, especially if production is increased to the levels required by the 2007 mandate. Alternative means of producing ethanol are not economically viable either. As it did in the past, the U.S. government has mandated innovation that it cannot actually bring into fruition. Yet this mandate is touted by officials as a lynchpin of American energy policy, and will be the recipient of billions of dollars in subsidies unless the mandate is repealed, or at least reduced. [n128] Though the idea of ethanol as energy panacea continues to be voiced, ethanol is not going to be the means (as too many people have come to believe) of achieving something like "energy independence." [n129]

However, since ethanol is most unlikely to lead to any answers to our energy dilemmas, what should our government policy be? With respect to ethanol, [*177] it is clear that the mandates misdirect resources and incentives. The mandate should be repealed, as should the subsidies. If ethanol can compete with gasoline, as it has been able to at times over the past few years, then it does not need tax payer funding. If it can't compete, it should not be marketed. To the extent that ethanol provides benefits by diversifying our sources of supply, the tariff on Brazilian ethanol should be repealed as well. [n130]

As for cellulosic ethanol, a case can be made that government research funding of promising ideas could be useful. Even partial funding (or tax benefits) for demonstration plants might be an application of resources that will pay off sometime in the future. [n131] But to expect, indeed to require by legislation, a huge cheap supply of fuel from an unproven technological process is not just unrealistic, it is truly wasteful. It channels incentives to one possible new technology and effectively away from others that could prove more promising and viable much quicker than cellulosic ethanol.

In general, there needs to be a recognition that technological development is uncertain and cannot be created by government decree. If there are breakthroughs, entrepreneurs will surely take them to market. But the process of innovation and commercialization cannot be controlled by the visible hand of the politically motivated state.

FOOTNOTES:

n1 Clarence Efroymson Professor of Economics at Butler University, Indianapolis, IN. This paper was presented at the 28th Annual AALA Agricultural Law Symposium, Oct. 19-20, 2007, San Diego, CA, and at Hanover College, Hanover, IN, Nov. 29, 2007.

n2 See Adam Lashinsky & Nelson D. Schwartz, How to Beat the High Cost of Gasoline. Forever! FORTUNE, Jan. 24, 2006, available at http://money.cnn.com/magazines/fortune/fortunearchive/2006/02/06/8367959/index.htm.

n3 Energy Independence and Security Act of 2007, Pub. L. No. 110-140, 121 Stat. 1492.

n4 Energy Policy Act of 2005, Pub. L. No. 109-58, 119 Stat. 594 (codified as amended in scattered sections of 42 U.S.C.).

n5 Energy Independence and Security Act, sec. 102, § (b)(2)(A), 121 Stat. 1492, 1499.

n6 Energy Policy and Conservation Act of 1975, Pub. L. No. 94-163, § 502(a)(4), 89 Stat. 871 (repealed 1994).

n7 See Energy Independence and Security Act § 202, 121 Stat. 1492, 1521-22 (this represents a five-fold increase over the mandate passed in 2005).

n8 Press Release, U.S. Senate Comm. on Energy & Natural Res., H.R. 6, The Energy Independence and Security Act of 2007, available at http://energy.senate.gov/public/files/HR6EnergyBillSummary.pdf.

n9 White House, 2007 State of the Union Policy Initiatives, Twenty in Ten: Strengthening America's Energy Security, http://www.whitehouse.gov/stateoftheunion/2007/initiatives/print/energy.html [hereinafter White House]; MathPro Inc., National Costs of Increased National Ethanol Mandate Volumes, http://www.mathproinc.com/projects/?title=National+Costs+of+Increased+National+Ethanol+Mandate+Volumes (last visited Apr. 27, 2008).

n10 White House, supra note 9.

n11 Richard Hamilton, President and CEO, Ceres Corp., Biofuels: Growing Energy, Presentation at the Foundation for Research on Economics & the Environment 11 (July 26, 2007).

n12 Editorial, Congresswoman Deborah Pryce, Ethanol is Fueling America's Quest for Energy Independence (Apr. 9, 2007), available at http://www.house.gov/pryce/07%20releases/040907EthanolOpEd.htm.

n13 See Peter Z. Grossman, The History of U.S. Alternative Energy Development Programs: A Study of Government Failure 8 (Jan. 29, 2008) (unpublished manuscript, on file with author and the Drake Journal of Agricultural Law).

n14 Id. at 10.

n15 See 42 U.S.C. § 9303(c)(1), (d) (2008).

n16 RICHARD E. ROWBERG, CONG. RESEARCH SERV., CONGRESS AND THE FUSION ENERGY SCIENCES PROGRAM: A HISTORICAL ANALYSIS 4-6 (2000).

n17 Atomic Insights, Too Cheap to Meter - It's Now True, (Mar. 9, 2005), http://www.atomicinsights.com/AI03-09-05.html (citing a Lewis L. Strauss speech to the National Association of Science Writers, given on September 16, 1954).

n18 See Jerry Taylor & Peter Van Doren, Hooked on Subsidies, FORBES, Nov. 26, 2007, at 34.

n19 Democratic presidential candidate John Edwards proposed a 65-billion gallon mandate to be achieved by 2025. John Edwards'08, Achieving Energy Independence & Stopping Global Warming Through a New Energy Economy, http://www.johnedwards.com/issues/energy/new-energy-economy (last visited Apr. 27, 2008).

n20 For arguments that the production of ethanol is environmentally damaging, see Joe Barrett, How Ethanol is Making the Farm Belt Thirsty, WALL ST. J., Sept. 5, 2007, at B1; Daniel Handlin, Dirty Little Secrets, HARV. POL. REV., Fall 2007, available at http://hprsite.squarespace.com/dirty-little-secrets-112007; Mark Clayton, The Politics of Ethanol Outshine Its Costs, CHRISTIAN SCI. MONITOR, Nov. 15, 2007, available at http://www.csmonitor.com/2007/1115/p02s02-uspo.htm.

n21 See, e.g., Energy Policy Act of 1992, Pub. L. No. 102-486, 106 Stat. 2776 (codified as amended at 42 U.S.C. § § 13201-13574 (2000)); Energy Security Act, Pub. L. No. 96-294, 94 Stat. 611 (1980) (omitted by Pub. L. No. 99-272, § 7403, 100 Stat. 144 (1990)); Public Utility Regulatory Policies Act of 1978, Pub. L. No. 95-617, 92 Stat. 3117.

n22 U.S. Senate, Roll Call Votes 110th Congress - 1st Session, On Passage of the Bill (H.R. 6 as Amended), http://www.senate.gov/legislative/LIS/rollcalllists/rollcallvotecfm.cfm?congress=110&session=1&vote=00226 (The measure passed by a margin of 65-27 in the Senate.). See Sholnn Freeman, Senate Passes Energy Bill, WASH. POST, June 22, 2007, at D01 (reporting that Democratic leads won passage of the bill).

n23 See Sabrina Willis, The Synthetic Fuels Corporation as an Organizational Failure in Policy Mobilization, in THE UNFULFILLED PROMISE OF SYNTHETIC FUELS 71, 75 (Ernest J. Yanarella & William C. Green, eds. 1987) (critiquing that the synfuels mandate was a "quick-fix . . . high-tech solution" that promised "the panacea of massive investment . . . and wondrous technologies").

n24 Id. at 71-72. See LINDA R. COHEN & ROGER G. NOLL, THE TECHNOLOGY PORK BARREL 259 (1991); THOMAS H. LEE, BEN C. BALL, JR. & RICHARD D. TABORS, ENERGY AFTERMATH 72 (1990).

n25 See David Herbert Donald, Our Irrelevant History, N.Y. TIMES, Sept. 8, 1977, at 27 (arguing that our "age of abundance has ended. . . . Our stores of oil and natural gas are rapidly running out, and other natural resources will soon be exhausted.").

n26 Provisions of Energy Bill, N.Y. TIMES, July 1, 1980, at 4, available at 1980 WLNR 15260.

n27 Energy Info. Admin., Estimated Petroleum Consumption: Transportation Sector, Selected Years, 1949-2006 (2006), available at http://www.eia.doe.gov/emeu/aer/pdf/pages/sec532.pdf (listing consumption of petroleum for transportation purposes in 1987 as 10,505,000 barrels a day and 10,881,000 barrels per day in 1992). This is of course the same percentage as sought for ethanol. Exactly why twenty percent has become a magic number in government mandates is unclear. My supposition is that it sounds relatively modest; government's extreme claims for nuclear power (it would be "too cheap to meter") may have discouraged overly extravagant assertions. However, production of substitutes for 20 percent of our automotive fuels is by no means modest. As the $ 88 billion (more than $ 200 billion in 2007 dollars) suggests, the direct costs would be staggering, and the environmental costs would still need to be assessed.

n28 See Basin Electric Power Cooperative, Natural Gas, http://www.basinelectric.com/EnergyResources/Gas/index.html (last visited Apr. 27, 2008) (One large scale facility that was constructed was the Great Plains coal gasification plant in Beulah, ND. It was completed in 1984. It cost about $ 2 billion, of which $ 1.45 billion came from the SFC. The U.S. government cut it loose in 1985. The plant was taken over by Dakota Gasification, a subsidiary of the electric cooperative Basin Electric in 1988, which has operated the plant ever since. Though the price of its gas has typically been far above the market price of natural gas generally, it has produced on average about 160 million cubic ft. of natural gas substitute (so called "pipeline" gas) per day. Recently, with natural gas prices above $ 8 per 1000 cubic feet, the plant has been profitable. Under a 1988 profit sharing arrangement with the Department of Energy, Dakota Gasification paid the DOE $ 39.2 million. It should be noted that the losses from the plant over the past two decades far outweigh any recent gains.).

n29 COHEN & NOLL, supra note 24, at 259.

n30 Louise Wells Bedsworth & Margaret Taylor, Learning from California's Zero-Emission Vehicle Program, 3 CAL. ECON. POL'Y 1, 4-5 (Sept. 2007). See Cal. Air Res. Bd., The California Low-Emission Vehicle Regulations (Jan. 4, 2008), available at http://www.arb.ca.gov/msprog/levprog/cleandoc/cleancompletelev-ghgregs12-07.pdf (The ZEV program was developed in 1990 by the California Air Resources Board (CARB) under authority from various sections of the California Code of Regulations.).

n31 For the mandate to be reached, California would need to sell about 200,000 ZEVs per year. From 2001 to 2005 only 4400 ZEV autos in total had been sold, but the mandate had been revised so that low emissions hybrid gas electric automobiles and other types of low emissions vehicles were included. Still, there remains an expectation that a significant portion of cars sold in California by 2020 will be ZEVs. See Bedsworth & Taylor, supra note 30, at 1, 5-7, 9, 15.

n32 Patrick J. Michaels, New Generation of Vehicles Still on the Road to Nowhere, NAT'L POST (Canada), Sept. 5, 2001, at C15 (noting the origin of the program in the "Global Marshall Plan" for the environment called for by Vice President Gore).

n33 Id. See also Hydrogen Fuel Cells may Power Future Cars, GRAND RAPIDS PRESS, Jan. 9, 2002, at A5.

n34 The National Academy of Sciences concluded that the project could not produce a vehicle that would be economically viable. See Michaels, supra note 32.

n35 See Grossman, supra note 13, at 2.

n36 The gains from synfuels are an example of what in economics is referred to as a "positive externality." See, e.g., B. DOUGLAS BERNHEIM & MICHAEL D. WHINSTON, MICROECONOMICS 759 (McGraw-Hill/Irwin 2008). In such a case, some social benefits are not captured through market exchange because the benefits accrue to society as a whole and not to an individual producer. Thus, the good is underprovided by the market.

n37 See JACOB SCHMOOKLER, INVENTION AND ECONOMIC GROWTH 179-88 (Harvard University Press, 1966).

n38 See NATHAN ROSENBERG, PERSPECTIVES ON TECHNOLOGY 260-79 (1976).

n39 See CLIFFORD WINSTON, GOVERNMENT FAILURE VERSUS MARKET FAILURE (Brookings Institution Press 2006).

n40 In fact, New York Times columnist Thomas Friedman called on President Bush to invoke Kennedy's call to put a man on the moon within ten years and pledge a similar timetable for energy independence. Thomas L. Friedman, State of the Union, N.Y. TIMES, Jan. 27, 2006, at A23. President Nixon invoked the moon project in a 1973 speech. Transcript of President's Address on the Energy Situation, N.Y. TIMES, Nov. 8, 1973, at 32. Various representatives compared the fusion energy bill to the Apollo Project in 1980; Carter's Vice-President Walter Mondale invoked the Apollo Project with respect to energy development in a speech to the National Governors Association, July 8, 1977. $ 20 Billion Voted for Nuclear Fusion, N.Y. TIMES, Aug. 26, 1980, at C1. Arguably no precedent has been invoked more often with respect to energy policy, although never to any lasting effect.

n41 The exception was the mandate for nuclear fusion. It had not been proven and its basic feasibility has still not been demonstrated. See Magnetic Fusion Energy Engineering Act of 1980, Pub. L. No. 96-386, 94 Stat. 1539 (codified at 42 U.S.C. § § 9301-9312 (2006)).

n42 See David Gerard & Lester Lave, Experiments in Technology Forcing: Comparing the Regulatory Processes of US Automobile Safety and Emissions Regulations, 7 INT'L J. TECH., POL'Y & MGMT. 1 (2007); David Gerard & Lester B. Lave, Implementing Technology-Forcing Policies: The 1970 Clean Air Act Amendments and the Introduction of Advanced Automotive Emissions Controls 1-2 (May 2003) [hereinafter Gerard & Lave, Implementing] (unpublished manuscript, available at http://www.epp.cmu.edu/httpdocs/people/bios/papers/gerard/GerardLave%20TF1.pdf); RENE KEMP, ENVIRONMENTAL POLICY AND TECHNICAL CHANGE: A COMPARISON OF TECHNOLOGICAL IMPACT OF POLICY INSTRUMENTS 242-59 (Wallace E. Oates ed. 1997).

n43 See Gerard & Lave, Implementing, supra note 42, at 1-2.

n44 Id. at 2.

n45 Id.

n46 It may become compulsory for blenders to use ethanol, at least at low concentrations. Some states have already mandated ethanol blends. See MINN. STAT. § 239.791 (2007). Also, at least seven states as of 2006 had specific mandates for E-10. See Green Car Congress, State Ethanol Mandates Inching Ahead, Mar. 20, 2006, http://www.greencarcongress.com/2006/03/stateethanolm.html. Some political leaders and ethanol promoters would like to see a national E-10 blending requirement. See Ethanol Producer, Rep. Upton Proposes National E10 Mandate, May 2006, http://www.ethanolproducer.com/article.jsp?articleid=1980.

n47 See EDWARD S. CASSEDY & PETER Z. GROSSMAN, INTRODUCTION TO ENERGY: RESOURCES, TECHNOLOGY, AND SOCIETY 252-53 (Cambridge Univ. Press 1998) (1990).

n48 See Russell Roberts, The Reality of Markets, THE LIB. OF ECON. & LIBERTY, Sept. 5, 2005, http://www.econlib.org/library/Columns/y2005/Robertsmarkets.html.

n49 See CASSEDY & GROSSMAN, supra note 47, at 256-57.

n50 See Text of Fact Sheet on the President's Program Issued by White House Energy Staff, N.Y. TIMES, Apr. 21, 1977, at 36. Note that President Carter later called for a goal that twenty percent of all U.S. energy be supplied by solar technologies. See Transcript of President's Address to Country on Energy Problems, N.Y. TIMES, July 16, 1979, at A10.

n51 A Brief History of the American Solar Water Heating Industry, http://www.ecssolar.com/SolarArticles/briefHistory.pdf (last visited Apr. 28, 2008).

n52 See id. By 1997, solar energy provided less than .01 percent of U.S. total consumption. See Robert L. Bradley Jr., Eco-Dilemmas of Renewable Energy, CATO INST., Nov. 21, 1997, http://www.cato.org/pubdisplay.php?pubid=6043.

n53 See Cynthia A. Beltz, Lessons from the Cutting Edge: The HDTV Experience, CATO REG., available at http://www.cato.org/pubs/regulation/reg16n4b.html.

n54 See COHEN & NOLL, supra note 24, at 259-60 (arguing that the synfuels research and development program was driven as much by politics as it was by science and technology). See also DENNIS C. MEULLER, PUBLIC CHOICE II 229 (2d ed.1989) (providing an example in the area of rent seeking).

n55 See Grossman, supra note 13, at 1 (Plans for commercial development of energy technologies have dragged on for more than sixty years.).

n56 Senator Charles Grassley, Remarks at the Grand Opening Ceremony for POET Biorefining - Corning, Iowa (Sept. 30, 2007), available at http://www.rhapsodyingreen.com/ rhapsodyingreen/2007/09/chuck-grassley-.html (providing a link to the Grassley speech).

n57 The first subsidies for ethanol were contained in the Energy Tax Act of 1978, Pub. L. No. 95-618 § 221, 92 Stat. 3174 (codified as amended in scattered sections of 26 U.S.C.). By 1984, the United States was producing 430 million gallons annually; it increased production by about 150 million gallons per year until 2002. In recent years production has increased by almost 2 billion gallons per year. BioFuels Journal, Annual and Monthly U.S. Ethanol Production (Dec. 5, 2005), available at http://www.biofuelsjournal.com/info/bfarticles.html?type=ec&ID=25474. The direct ethanol subsidies at one time were as high as 60 cents/gallon. See Wallace E. Tyner & Farzad Taheripour, Future Biofuels Policy Alternatives, Paper Presented at a Conference on Biofuels, Food, and Feed Tradeoffs, St. Louis, MO, 1-2 (Apr. 12-13, 2007), available at http://www.agecon.purdue.edu/papers/biofuels/StLouisconfApr07TynerTaheripour.pdf.

n58 Section 211(m) of the Clean Air Act was amended in 1990 to require that, starting in the Fall of 1992, oxygenated (or reformulated) fuel was to be introduced in areas that exceeded the 8-hour National Ambient Air Quality Standard for carbon monoxide. Clean Air Act Amendments of 1990, Pub. L. No. 101-549 sec 104, § 187(b)(3), 104 Stat. 2399, 2456 (codified at 42 U.S.C. § 7512a (2006)). This requirement was aimed primarily at select urban areas and tended to be more of a problem in winter.

n59 In most parts of the country the compound methyl tertiary-butyl ether (MTBE) was utilized. However, various environmental concerns led to suits, state bans, and a cessation of MTBE production in the United States in 2006 after the 2005 Energy Act did not shield MTBE producers from potential liability from environmental damages. See ENERGY INFO. ADMIN., ELIMINATING MTBE IN GASOLINE IN 2006, 7 (2006), available at http://www.eia.doe.gov/pub/oilgas/petroleum/featurearticles/2006/mtbe2006/mtbe2006.pdf.

n60 Energy Policy Act of 1992, Pub. L. No. 102-486, § 502, 106 Stat. 2776, 2888-89 (codified at 42 U.S.C. § 13252(b)(2)(B) (2006)).

n61 Data on ethanol production can be found at the Renewable Fuels Association web-site. Renewable Fuels Ass'n, Industry Statistics: Historic U.S. Fuel Ethanol Production, http://www.ethanolrfa.org/industry/statistics/ (last visited Apr. 28, 2008) [hereinafter Industry Statistics].

n62 Id.

n63 Energy Info. Admin., Energy Glossary, http://www.eia.doe.gov/glossary/glossaryg.htm (last visited Apr. 28, 2008).

n64 Energy Policy Act of 2002, H.R. 4, 107th Cong. § 818 (2002) (as passed by the Senate, Apr. 25, 2002. The House disagreed with the Senate's amendment and the bill went to conference where no further action was taken.).

n65 Energy Policy Act of 2005, Pub. L. 109-58, 119 Stat. 594 (codified as amended in scattered sections of 42 U.S.C.).

n66 Energy Policy Act of 2005, Pub. L. 109-58, sec. 1501(a)(2), § 211(o)(2)(B), 119 Stat. 594, 1069 (codified at 42 U.S.C. § 7545(o)(2)(B)).

n67 IRS, Instruction for Form 720 (2008), available at http://www.irs.gov/pub/irspdf/i720.pdf.

n68 See L. Leon Geyer et al., Ethanol, Biomass, Biofuels and Energy: A Profile and Overview, 12 DRAKE J. AGRIC. L. 61, 67 (2007) (noting that there are almost 300 state laws and incentives on ethanol in the United States).

n69 MINN. STAT. § 239.791 (2007). See Minnesota Votes, 2008 Senate Bill 4 (Ethanol Mandate Increase), http://minnesotavotes.org/2005-SF-4 (Minnesota Senate Bill 4 passed 54-12 in the legislature and was signed into law on May 10, 2005) (last visited Apr. 28, 2008); Green Car Congress, supra note 46 (reporting that at least seven states as of 2006 had specific mandates for E10); Ethanol Producer, supra note 46 (reporting that some political leaders and ethanol promoters would like to see a national E-10 blending requirement).

n70 See ORBITAL ENGINE CO., MARKET BARRIERS TO THE UPTAKE OF BIOFUELS STUDY TESTING GASOLINE CONTAINING 20% ETHANOL (E20): PHASE 2B FINAL REPORT TO THE DEPARTMENT OF THE ENVIRONMENT AND HERITAGE 8-9 (2004), available at http://www. environment.gov.au/atmosphere/fuelquality/publications/2000hours-non-automotive/pubs/2000hours.pdf (finding that engines operating on ethanol suffered more than those on gasoline); see also K. Nakajima, Corrosive Wear of Steel With Gasoline-Ethanol-Water, 105 J. Lubrication Tech. 552 (1983) (reporting results that corrosive effects on steel components manifest themselves more noticeably at a twenty percent ethanol blend).

n71 See, e.g., James R. Healey, Gasoline Could Go From 10% Ethanol up to 20%, USA Today, Mar. 4, 2008, at 8A.

n72 Industry Statistics, supra note 61.

n73 Energy Independence and Security Act of 2007, Pub. L. No. 110-40, 121 Stat. 1492 (codified as amended at scattered sections in 42 U.S.C.).

n74 Id. sec. 202, § 211(o)(2)(B), 121 Stat. at 1521-24.

n75 E.M. Morrison, Outgrowing Corn: Cellulosic Ethanol Made from Ag and Forest Refuse, AG INNOVATION NEWS, Jan.-Mar. 2007, available at http://www.auri.org/news/ainjan07/outgrowingcorn.htm.

n76 Id.

n77 It is assumed that capital costs are not one time outlays, but rather represent a stream of payments with interest that can be calculated as a cost per unit of output. It makes sense to include this cost even if someone pays full price in cash because there would still be the opportunity cost, a foregone stream of income that would accrue if it were used in other investments.

n78 Actually, according to economic theory, a firm maximizes its profits at precisely the point where the marginal cost (the cost of the last unit produced) exactly equals marginal benefit, in this case, the price. But the average or unit cost sets a baseline below which price cannot drop if the firm is to sell profitably.

n79 See Thomas E. Elam, FarmEcon.com, Fuel Ethanol Subsidies: An Economic Perspective 8-11 (2007), available at http://farmecon.com/Documents/Ethanol%20Analysis%20ELAM%20REVISED%209-26-07.pdf (providing calculations of ethanol production based on federal subsidies).

n80 Id. at 8. As of 2006 there were additional subsidies for ethanol production offered by 14 states. See JEFF DIRCKSEN, NAT'L. TAXPAYERS UNION., POL'Y PAPER NO. 121, ETHANOL: BUMPER CROP FOR AGRIBUSINESS, BITTER HARVEST FOR TAXPAYERS (2006), available at http://www.ntu.org/main/presspapers.php?PressID=855&orgname=NTU.

n81 See HOSEIN SHAPOURI & PAUL GALLAGHER, U.S. DEP'T. OF AGRIC., USDA'S 2002 ETHANOL COST-OF-PRODUCTION SURVEY iii, 4 (2005), http://www.usda.gov/agency/oce/reports/energy/USDA2002ETHANOL.pdf.

n82 See Elam, supra note 79, at 9.

n83 According to experts, once every twenty years we can expect a decline in corn output as large as 31.8 percent, which would translate as lost output of approximately 30 million acres. See James Eaves & Stephen Eaves, Is Ethanol the 'Energy Security' Solution?, WASH. POST, Oct. 3, 2007.

n84 Elam, supra note 79, at 11.

n85 Tyner & Taheripour, supra note 57, at 2.

n86 See id. (stating that the price in 2006 was exceptionally high during the summer and the additive value averaged 70 cents for the year).

n87 Dep't of Agric. and Consumer Econ., Univ. of Ill. Extension, Farm Econ. Fact and Opinions No. 07-11, Crude Oil Price Variability and its Impact on Break-Even Corn Prices, FARM BUS. MGMT. (2007), available at http://www.farmdoc.uiuc.edu/manage/newsletters/fefo0711/fefo0711.pdf. The additive values from 2002 to 2006 ranged from two cents to seventy cents per gallon. See Tyner & Taheripour, supra note 57, at 2.

n88 See Dep't of Agric. and Consumer Econ., supra note 87.

n89 TFC Commodity Charts, Corn: Monthly Price Chart, http://futures.tradingcharts.com/chart/CN/M (last visited Apr. 28, 2008).

n90 See Elam, supra note 79, at 9.

n91 Tyner & Taheripour, supra note 57, at 2.

n92 Amani Elobeid, Ctr. for Agric. and Rural Dev., Iowa St. Univ., An Analysis of the Long-Run Impact of Ethanol Expansion on U.S. Agricultural Markets, Presentation at a Conference on Food and Fuel at Saskatoon, SK, June 5-6, 2007, at 12, available at http://www.ag-innovation.usask.ca/PresentationforDownload/FoodandFuel/Elobeid%20%20An%20Analysis%20of%20the%20LongRun%20Impact%20of%20Ethanol%20Expansion%20on%20U.S.%20Agricultural%20 Markets.pdf; Elam, supra note 79, at 3

n93 Elam, supra note 79, at 8.

n94 The formula for the additive value is AV = Pe - (Pgx0.7+ 0.51), or the additive value is equal to the price of ethanol, minus the term 0.7 times the price of gasoline plus the subsidy. Tyner & Taheripour, supra note 57, at 2.

n95 The equation adapted from Elam, supra note 79, is as follows: Pc = (Pe+QdxPd-VC-Ri) <divided by> Qc, where "Pc" equals the break-even price of corn, Pe equals the price of ethanol per gallon; "QdxPd" is the gain from selling distillers' grains; "VC" equals the variable costs; "Ri" equals the return on investment or opportunity cost; "Qc" is the quantity of corn per gallon (.357 bushels). These calculations focus only on variable costs, which is standard practice when one formulates a break-even condition. There are also fixed costs, which have been estimated on average at $ .55 per bushel). See ELAM, supra note 79, at 10, 15.

n96 Tim Petry, N.D. State Extension Servs., Market Advisor: Will Cattle Price Volatility Continue in 2008?, http://www.ag.ndsu.edu/news/columns/livestockma/market-advisor-will2007-cattle-price-volatility-continue-in-2008.

n97 See Clifford Krauss, Ethanol's Boom Stalling as Glut Depresses Prices, N.Y. TIMES, Sept. 30, 2007, at A11.

n98 The Knight Trader, http://knighttrader.blogspot.com/ (Oct. 10, 2007, 07:16 EST).

n99 Ethanol Plant Construction Stalls Out, TULSA WORLD, Nov. 7, 2007, at E4.

n100 TFC Commodity Charts, supra note 89.

n101 Wall Street Journal, Market Data Center, http://online.wsj.com/mdc/public/page/mdccommodities.html (current futures market quotes available by clicking on "Commodities & Futures" and locating "Corn, Oats, Rice." This quote was provided on Jan. 25, 2008.).

n102 Assumes wholesale gasoline remained at about $ 2.32/gallon.

n103 Falling that is from a price of about $ 2.32/gallon.

n104 It should be noted that from January through May prices of all three commodities ethanol, gasoline, and corn - rose and fluctuated wildly at times. As of May 1, the price of ethanol was $ 2.43/gallon; wholesale gasoline, $ 2.84,/gallon; and corn, $ .6.05/bushel. Predictions in January had not proven especially accurate. The Wall Street Journal, http://online.wsj.com/mdc/public/page/mdccommodities.html?mod=topnav23028.

n105 See Elam, supra note 79, at 2. See also Dana Joel Gattuso, Thanks to Congress, Ethanol and Biofuel Mandates Cause Food Prices to Soar, NAT'L POL'Y ANALYSIS (Dec. 2007), http://www.nationalcenter.org/NPA564.html.

n106 See Lauren Etter, Ethanol Craze Cools as Doubts Multiply, WALL ST. J., Nov. 28, 2007, at A1.

n107 Robert Bryce, Despite its Huge Flaws, Ethanol is Political Holy Water in DC, WASH. SPECTATOR, July 7, 2007, available at http://www.alternet.org./story/56047/.

n108 Richard Conniff, Who's Fueling Whom?, SMITHSONIAN MAG., Nov. 2007, available at http://www.smithsonianmag.com/science-nature/presence-biofuel-200711.html. See Patrick J. Michaels, Corn on the Mob, AM. SPECTATOR, Jan. 30, 2008, available at http://www.spectator.org/dsparticle.asp?artid=12658; Peter Ford, As Pork Prices Soar, Chinese Put Brakes on Corn for Ethanol, CHRISTIAN SCI. MONITOR, May 31, 2007, available at http://www.csmonitor.com/2007/0531/p01s04-wosc.html.

n109 C. Ford Runge & Benjamin Senauer, How Biofuels Could Starve the Poor, FOREIGN AFF., May/June 2007, available at http://www.foreignaffairs.org/20070501faessay86305/c-fordrunge-benjamin-senauer/how-biofuels-could-starve-the-poor.html.

n110 Id.

n111 Iowa Farmland Values Increase Again, Setting New Record Price, ASSOCIATED PRESS, http://www.wqad.com/Global/story.asp?S=424290; Jerry Perkins, Iowa Farmland Prices Rose Nearly 23% in 2007, DES MOINES REG. Jan. 22, 2008.

n112 Perkins, supra note 111.

n113 See, e.g., Barrett, supra note 20; Handlin, supra note 20; Clayton, supra note 20.

n114 Morrison, supra note 75.

n115 Id.

n116 President George W. Bush, State of the Union Address (Jan. 23, 2007), available at http://whitehouse.gov/news/releases/2007/01/print/20070123-2.html ("We made a lot of progress, thanks to good policies here in Washington and the strong response of the market. And now even more dramatic advances are within reach.").

n117 Hamilton, supra note 11.

n118 See Robert Bryce, The Great Corn Con, SLATE, June 26, 2007, http://www.slate.com/id/2169124/.

n119 See id. ("There's no reason to expect that the cellulosic ethanol industry will be able to grow fast enough to supply the 22 billion gallons in question."). See also DENNIS AVERY, COMPET. ENTERP. INST., BIOFUELS, FOOD OR WILDLIFE?: THE MASSIVE LAND COSTS OF U.S. ETHANOL 22 (Sept. 2006), available at http://www.cei.org/pdf/5532.pdf (noting that it is not economically and environmentally wise or feasible to replace traditional gasoline with ethanol); Tom Doggett, Lawmaker Says Cellulosic Ethanol a Decade Away, REUTERS, Jan. 15, 2004, available at http://www.reuters.com/article/GlobalAgricultureandBiofuels08/idUSN1554889720080115?sp=true (quoting the head of the House Agriculture Committee that commercial cellulosic ethanol is "at least" a decade away). But see Morrison, supra note 75 (providing optimistic outlook on the slow but eventual competiveness of ethanol); Dianne Greer, Creating Cellulosic Ethanol:

Spinning Straw into Fuel, BIOCYCLE, Apr. 2005 (reporting that Shell predicted that world market for ethanol will grow by 2010); Chuck Squatriglia, Startup Says it can Make Ethanol for $ 1 a Gallon, and Without Corn, WIRED, Jan. 24, 2008, http://www.wired.com/cars/energy/news/2008/01/ethanol23. It should be noted that every alternative energy technology has engendered claims of rapid, easy, low cost processes by promoters. See, e.g., Fusion Energy: Business may Have a Better Idea, BUSINESS WEEK, Jan. 17, 1983, at 92 (noting claims of immanent success for nuclear fusion).

n120 USDA, THE ECONOMIC FEASIBILITY OF ETHANOL PRODUCTION FROM SUGAR IN THE UNITED STATES 1 (2006), available at http://www.usda.gov/oce/EthanolSugarFeasibilityReport 3.pdf.

n121 Id. at iv.

n122 See id. at 8 (U.S. sugar cane production was about 25 million tons in 2005. If it were all devoted to ethanol production, and yields were equal to those achieved in Brazilian production, we would produce about 1 billion gallons annually.).

n123 Jeff Cox, Sugar Cane Ethanol's Not-So-Sweet Future, CNNMONEY.COM, Aug. 7, 2007, http://money.cnn.com/2007/08/06/news/economy/sugarcaneethanol/index.htm.

n124 Bush's Call to Lower Ethanol Tariffs Fuels Dissent, ASSOCIATED PRESS, May 5, 2006, available at http://www.foxnews.com/story/0,2933,194464,00.html; No End to Brazil Ethanol Tariffs Likely, UNITED PRESS INT'L, Feb. 28, 2007.

n125 See Daniel Howden, The Big Green Fuel Lie, THE INDEPENDENT (UK), March 5, 2007, available at http://www.independent.co.uk/environment/climatecharge/the-big-green-fuellie-438937.html (expressing concerns about the impact on Brazil's environment from an increase in sugar production).

n126 David Roberts, Biofuel: Some Numbers, GRISTMILL (Feb. 7, 2006), http://gristmill.grist.org/print/2006/2/7/12145/81957?showcomments=no.

n127 See id.

n128 The exact size of all of the subsidies that encompass the growing of corn and the production, sale, and distribution of ethanol is not entirely clear. Of course the specific federal subsidy amounts to 51 cents per gallon, which promises to cost taxpayers about $ 18 billion annually if the mandate is met. But, when other subsidies are included, the total cost to taxpayers rises. See Elam, supra note 79 (arguing that by one reckoning of government benefits, taxpayers pay $ 4.40/gallon of ethanol produced or $ 6.67/gallon of the gasoline replaced. Using the first of these numbers, reaching the 2022 mandate would cost taxpayers almost $ 160 billion per year. Another analysis puts total subsidies at $ 1.45/gallon of ethanol); Facts.com, Subsidies for Corn Ethanol, http://zfacts.com/p/63/html (last visited Apr. 28, 2008) (noting that per unit of energy, ethanol production has received fifty-four times higher subsidies than oil production).

n129 See ROBERT BRYCE, GUSHER OF LIES: THE DANGEROUS DELUSION OF "ENERGY INDEPENDENCE" 287-91 (2008).

n130 See Ben Lieberman, Lift Tariffs on Foreign Ethanol, THE HERITAGE FOUND., May 12, 2006, http://www.heritage.org/Research/EnergyandEnviroment/wm1074.cfm.

n131 See Peter Z. Grossman, Alternative Energy Technologies: Market Solutions 17 (Ctr. for the Study of Am. Bus., Working Paper No. 145, 1992) (discussing how government research programs might be efficiently designed).