Ethanol: a feasible & renewable automotive fuel source

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Introduction

I began researching ethanol nearly eight months ago. I read about an effort that was being made by some farmers to build an ethanol plant in northern Iowa, where my parents live and where I spent most of my childhood days. This was an interesting concept and was of particular interest to me, since the livelihoods of almost everyone in my family are closely tied to the agriculture industry and have been so on a historically consistent basis. I read the newspaper article during the summertime, when I was working at home. I spent a great deal of time speaking to my grandfather about ethanol last August. When I got to school, I didn't have the time to pursue my interest as thoroughly as desired, but my parents and grandparents, who were aware of my interest, kept me posted on recent happenings. Towards the end of September, once I was settled in at Brown, I renewed my interest by searching for information on ethanol and other renewable fuels on the internet. Eventually, I discovered some websites that proved and have continued to prove themselves to be excellent sources for data.

Over Christmas break, my grandfather introduced me to an authority on ethanol production that lives near my parents. We became good friends and had many long conversations that were extremely informative. He was able to answer all of my questions and supplied me with a multitude of informational brochures, as well as a long list of contacts to aid me in my quest for knowledge. Since then, I have contacted all of those individuals and then some. I have gotten a lot of things in the mail, and the research process has been very consistent and satisfying. At no time have I felt a lack of motivation in this study. At times, I've become very disinterested in my other classes, but I have never lost interest in this topic. I find it very easy to read new material such as the Energy Independent (a monthly newsletter) over a cup of coffee in the Blue Room. I appreciate having found a true interest and, most especially, the opportunity to incorporate such an interest into my curriculum. Thanks a lot, Professor Hazeltine! This has turned out to be my favorite class at Brown, primarily due to the fact that it is completely and solely mine.

Once again, my interest began upon hearing of the potential benefits of more widespread usage of ethanol as a substitute for petroleum-derived fuel sources. However, as I normally do, I immediately doubted the validity of these claims. My interest was further enhanced by my continual realization of the validity of these claims, which I have been discovering since day one. There are a lot of organizations, that possess a great deal of power, that are against ethanol usage for a variety of reasons. Most of them

originate in the oil industry, for obvious reasons. Ethanol poses a direct threat to their well-being. They have made infinite negative claims about ethanol, all of which have been answered through testing by the Environmental Protection Agency and the Department of Energy. In fact, in their attempt to discredit ethanol, they have managed to do the opposite. Since the people who know the facts and support ethanol have little power, and their opponents are extremely powerful, there is little true understanding of ethanol in the public sector. This is the sole reason that it has been so thoroughly stymied. I believe in the ability of the American people to see beyond the fog of war that has been cast upon them by such powerful corporations. This may take time, but I know that it will happen eventually, through the efforts of people like myself who know a good thing when they see it, and who are willing to do all that is within their means to make it a reality by conveying their knowledge to others.

Background

It is widely known that the Germans utilized ethanol as a neat (100% pure mixture) fuel in their combat vehicles during World War II, when they were suffering from a shortage of petroleum. So, even at this early date, ethanol had proved to be a viable fuel source. It performed at levels roughly equivalent to those reached by conventional gasoline. This is very surprising, considering that these vehicles were specifically designed to run on conventional gasoline. This is a tribute to the viability of ethanol. Imagine what could be accomplished if engines were designed for ethanol usage in particular. So, in 1978, in response to the oil price shocks that plagued that period, President Jimmy Carter committed the US to a gasohol (10% ethanol fuel) production program as part of his administration's emphasis on the utilization of domestic renewable fuel sources. The Carter Administration set the following targets for ethanol production: 500 million gallons annually by '81, enough to convert 10% of the nation's automotive unleaded fuel consumption to gasohol (total of 1% of all gasoline=ethanol); 2 billion gallons annually by the mid-'80's, enough to convert 40% of our automotive fuel consumption to gasohol.

People responded to this commitment in a variety of ways. Those that were against it pointed towards the following factors: the amount of corn (for ethanol production) required for such an aggressive maneuver, the long-term viability of this process, the higher price for gasohol, potential tax exemptions for ethanol production, the ability of ethanol to perform comparably in internal combustion engines, potential

harm to engines from ethanol usage, possible health risks, and potential environmental concerns. Ethanol's supporters stressed it's ability to overcome all of the above.

The Carter Administration attempted to reach their goals through the issuing of loans, grants, guarantees, tax credits, and research and development funds. This enticed companies such as Archer Daniels Midland, the current and consistent industry leader, to begin ethanol production as early as 1978. The technological conversion of processes that was necessary to include the production of ethanol was not a simple one. Also, without guarantees and serious commitments on the part of the government, a major investment in ethanol production was not economically feasible on a long-term basis due to the fickle nature of corn prices.

Ethanol is not the only known alternative fuel source. The following are some other fuels that are currently being explored: CNG (compressed natural gas), electricity (ZEV's-zero emission vehicles), fuel cells, methanol, ETBE, and MTBE. Natural gas is a clean burning and efficient fuel, but is not as safe, hasn't been as thoroughly tested or researched, requires greater changes in infrastructure and engine design, and is not renewable. Electric vehicles are an extraordinary concept, but require much more development, are much more expensive, and would require drivers to greatly change their ways, as well as to sacrifice some performance. I believe that electric vehicles are the best alternative, but they require such a broad change in the actions and attitudes of consumers that they do not appear to be feasible for quite some time. Fuel cells are equally amazing, as we learned in an EN 90 presentation, but also require a great deal more research and development as well as significant alterations in infrastructure. Methanol is not renewable and doesn't perform nearly as well as ethanol. Many people complain that the exhaust fumes from methanol usage makes them sick. It also smells very bad. One advantage of methanol over ethanol is that it is cheaper and can be shipped more easily via pipeline. Transport via pipeline is a major advantage due to a rather significant decrease in transportation costs. Ethanol experiences complications when pipeline transport is considered because it tends to suffer from phase separation during transport of this kind. This results in a less pure product at the end of the pipeline. Also, ethanol tends to absorb water during extended periods of time when in a metal storage (pipe) facility and when humidity is very high for this extended period (over ten days in a row of extremely high humidity). ETBE (ethyl tertiary butyl ether) is a combination of ethanol (EtOH) and isobutylene which is derived from butane (I did my EN 90 final paper

on butane transport last year), and therefore is not totally renewable. However, ETBE can be transported via pipeline, replaces a great deal of foreign petroleum, works well in typical engines, and still retains some of ethanol's better qualities. MTBE (methyl tertiary butyl ether) is very similar to ETBE, but is not renewable. It is not as good for the environment (more accurately, as less harmful) as ETBE, but, as always is slightly cheaper. Despite ethanol's not being the only alternative fuel source, it is in fact our only renewable fuel oxygenate. It is also way ahead of the pack when research and development are concerned.

Resistance and the need for an unbiased approach

As stated earlier, ethanol has many powerful enemies. After all, oil companies possess outrageous sums of capital and we all know that money is power in one of its purest forms. A common complaint among such crowds is that the government is being unfair in granting tax exemptions to ethanol production. Without these exemptions, the industry would not yet be cost efficient enough to function. After all, it was the government that saw ethanol's potential and enticed numerous companies to enter and, in the process, form the industry. What hasn't been pointed out is that companies such as ADM merely had the good fortune and foresight to enter into a fledgling industry with great potential. Also, there is nothing stopping companies like Exxon from entering this industry. The present is a great time to enter, because new technologies are constantly increasing efficiency and potential profits in the process. Next, let's not forget the degree to which the petroleum industry is directly and indirectly subsidized. It is almost certain that the oil industry has run up the world's largest tab of subsidies, exemptions, and external costs of any entity that has ever existed or will exist. As a final note regarding this subject, it should be pointed out that the exemptions granted to ethanol producers are primarily made on the state level in an attempt to create jobs and better regional economies. Finally, these exemptions have been proven, especially those made by the federal government, by the US General Accounting Office to result in a direct net (economically) gain to the federal government.

Ultimately, the US government is the only body in charge of determining which fuels to mandate. This decisive privilege carries a grand responsibility along with it. Our government, as created by people like ourselves, exists for our benefit. In a case such as this, that requires such a complete and thorough understanding of vast quantities of scientific data, the government relies on research and testing that is performed by one of its most effective organizations, the Environmental Protection Agency (EPA). The

EPA, in turn, works alongside the Department of Energy (DOE) in this effort. The DOE performs similar duties, but, in the end, it is the sole duty of the EPA to make recommendations and form policy for consideration by the legislative and executive branches. The EPA and DOE manage to complete these complicated tasks, a fact that I will elaborate on soon. However, where the EPA and the federal government fail is another matter altogether. While the EPA tends to complete its corresponding tasks on its own, certain branches of our government, those playing the most crucial roles, tend to suffer from a lack of motivation. This lack of an overriding motivational factor should not be a necessary consideration here, but regardless, it manages to be. By this, I mean to say that politicians hold offices of power and, as a result, have a duty to us, as citizens, to represent us in a totally unbiased manner, doing what is best for us. Instead, when there exists a lack of understanding among citizens of a topic to be considered by a government with a framework similar to ours, the governmental body tends to realize the absence of an overwhelming attitude among citizens, and then proceeds to look at the private sector. This is where our government's leaders become "captured"-that is, instead of basing decisions on multiple factors (i.e. cost, social welfare, industry interest, environmental impact, and economic impacts), they begin to make decisions which serve only to protect the industry that they regulate. By this, I mean that they cease representing an ideal and begin to protect their own immediate future, such as Brown University seems to have done in a recent UDC case, which I found myself in the midst of. It is wrong that our government should need such constant reminders from people like us of what they are supposed to be doing. However, they also have a responsibility to supply us with the necessary information on which to form opinions. It is this lack of information and understanding that keeps us from forming opinions to force our politicians to meter their decision-making with our needs, an obvious necessity that, in theory, should be unnecessary.

Analysis of DOE and EPA

The purpose of this paper is to assess the roles of the US Dept. of Energy and the Environmental Protection Agency in the testing and implementation of renewable fuels. First, it is necessary to determine the purpose of each of these organizations. When this has been done, I will attempt to rate the ability of each of these organizations to fulfill their individual roles. If either of them are perceived to fall short of the outlined expectations, I will try to provide explanations for their shortcomings. Finally, I will attempt to provide some suggestions as to how they might better realize their goals.

Renewable fuels are chosen merely as a model in order to illustrate the performance of the EPA and the DOE. I have been studying diversified fuels for a considerable amount of time now, so it is of great interest to me to use this approach. For the purpose of the DOE's analysis, it is OK to look at diversified fuels on a more general basis. However, when the EPA is considered, it becomes necessary to focus in on one renewable in particular. I have chosen ethanol for this purpose. This is not a random selection. A brief summary of ethanol and other diversified fuels will be included in the paper, which will help explain ethanol's viability.

Environmental Protection Agency

The EPA was created in response to an extremely realistic need. Before its founding in 1970, the United States did not have a governmental organization of sufficient size and scope to fully address its need for rules (and their enforcement) and regulations regarding environmental pollutants. During the twenty-year period from '50-'70, the population became younger, more financially secure, and better educated. This, combined with a better understanding of the biological and physical sciences created both an interest in and an understanding of the natural world. Riding on a wave of public support for environmental legislation in the '60s, the scene was set for a new constituency which focused on "quality of life", rather than mere survival. The need for an environmental regulatory body was evident due to the general failure of the market system to include the "hidden" costs associated with pollution. If the market system managed to incorporate these costs, pollution would not be nearly as big of a problem as it is at present.

In theory, there is little doubt as to the actual mission of the EPA. Generally, it is to be concerned with environmental protection in a manner that not only serves to champion environmental values, but that is also aligned with industrial expansion and the development of resources. It can be easily discerned that, to do this, would require walking a very thin line. So, from the start, the EPA was an attempt to fill a very difficult role. More specifically, the EPA's resultant regulatory standards tend to be based on a wealth of scientific knowledge and thorough testing. Since this is the case, it is all important that this knowledge and testing be processed and conducted in the most perfectly unbiased manner, where ultimate preference is given to the standards which most thoroughly realize the EPA's goals.

The EPA remains as one of our government's most independent organizations. The head of the EPA is appointed by the president, and answers only to him. The nature of its work further separates it

from other government agencies. The job of the EPA is one primarily of science and economics. It does not simply perform tests and make policy or regulations. Instead, once the tests are completed, the EPA is assigned the difficult task of placing monetary values on such concepts as air quality. An example would be an attempt to place a value in dollars on a reduction of low-level ozone by .10 PPM (parts per million). If faced with such a task, I would have no idea of where to begin. In this way, the EPA's job encompasses scientific testing, analysis of the corresponding results, development of potential policies, formation of and incorporation of economic analysis', the adjustment of potential policies based on the results of the economic analysis', the implementation of the resulting regulations, and finally, the enforcement of its own regulations.

The one major limiting factor within the EPA mechanism is that, although it is a relatively independent organization, it does remain within the jurisdiction of the US government, and as a result, its findings are ultimately subjected to the approval or disapproval of that entity. So, in addition to its other duties, the EPA has to meter its policy with political objectives. In a way, the EPA is slapped in the face because it is asked to perform a difficult task that deals with a wealth of highly specialized knowledge, yet its own findings are limited to the approval of others who have relatively limited knowledge on those matters.

Department of Energy

The United States Department of Energy was created in October of 1977 as the 12th cabinet level department of the federal government. It was formed for many of the same reasons that the EPA was. Essentially, it was to provide a complete integration of existing agencies that were concerned with the following: energy research, development, regulation, pricing, and conservation. The formation of the DOE was hastened by the energy crisis of the mid '70s, which was serving as an impetus for widespread government reorganizations as the executive and legislative branches sought to better coordinate federal energy policy and programs.

The newest of the DOE's divisions was nuclear energy research. At the time, virtually all work with nuclear weapons and energy production (nuclear) had been done by the federal government. The newly formed DOE was determined to commercialize nuclear energy production.

The Department of Energy conducts the bulk of its research and development at its various independent testing centers and laboratories such as Argonne National Lab in Illinois, the National Renewable Energy Lab in Colorado, and Oak Ridge National Lab in Tennessee. In all, there are over a dozen labs of this type, each of which concentrates on a different field of research. The mission of the DOE is as follows:

> to contribute to the welfare of the Nation by providing the technical information and scientific and educational foundation for technical, policy, and institutional leadership necessary to achieve efficiency in energy use, diversity in energy sources, a more productive and competitive economy, improved environmental quality, and a secure national defense.

Before the energy crisis, the agencies that are now known collectively as the DOE were concerned primarily with regulating energy prices such as electricity, natural gas and oil. This was mostly due to the fact that there seemed to be no threat of any significant energy shortage. However, when the oil embargoes hit, it quickly became apparent that we needed to develop more consistently secure sources for our energy demands.

The newly formed DOE focused on efficient energy usage, diversity in sources, as well as developing more significant stores of energy as was evident in President Ford's proclamation in 1975 of a need for a one billion barrel strategic petroleum reserve. The winter of '76-'77 was extremely cold, and our already weak natural gas suppliers were put to the test. In areas such as the northeast, they fell far short. Many schools and businesses were closed. As a response to this, Jimmy Carter decided to add the previously mentioned concept of efficient energy usage to the list of DOE concerns. In its most simple form, this type of progress can be seen in extra insulation in more recently built homes, or as an addition to a previously built home.

The following is my best attempt to illustrate the difference between the roles of the EPA and the DOE: the EPA attempts to protect our environment by making policy and regulating industry based on independent scientific testing, while the DOE attempts to provide industry with the tools necessary to meet the EPA's standards by researching and developing diversified and more highly efficient production technologies and processes. This does not exclude the provision of an entirely new set of standards for the utilization of these technologies, however.

Ethanol & Renewables

Ethanol, the only known completely renewable fuel at present, has been around for a considerable amount of time. It was first utilized on a widespread scale by Germany in World War II to fuel tanks and other military vehicles, when there was a shortage of petroleum. Renewable fuels are considered as such, as long as some portion of their production inputs are renewable in nature. This means that they must be derived to some degree from a continually reoccurring resource. In order to meet this criteria, the specific fuel must not rely heavily on the utilization of a finite resource. For the purpose of this paper, I will not go into detail describing the idiosyncrasies of ethanol, however, will merely present a broad explanation of the EPA's findings regarding its performance, emissions, and its potential environmental and economic effects.

The EPA has determined that ethanol is the cleanest overall oxygenated fuel additive available. The term "oxygenated" is used to draw attention to the fact that ethanol contains a significantly higher percentage of oxygen. This results in 25% less carbon monoxide (CO) emissions and 30% less carbon dioxide (CO2) emissions because the added oxygen aids in more complete combustion. Also, emissions of nitric oxide (NOx) and volatile organic compounds (VOCs) are decreased significantly. One statistic that might interest the DOE is that not only is ethanol more energy efficient in its production (one Btu of energy in its production results in 1.33 Btu of ethanol), but also that ethanol is in fact eight times more energy efficient than petroleum-based gasoline. In other words, the energy used to produce 1 Btu (British thermal unit) of typical gasoline could be used to produce 8 BTUs of ethanol. Ethanol has a higher octane level as well.

Ethanol has been found to be slightly less fuel efficient when utilized in engines designed for conventional gasoline, however, with slight modifications, equivalent levels of efficiency have been attained. These modifications include slight carburetor adjustments, increased compression ratio, and minor adjustments in the storage tank, fuel line, and injectors. This is a major plus for ethanol, because a major drawback to switching fuels is the need for major changes in infrastructure (fueling sites, repair shops, automakers, etc.). Using ethanol in higher concentrations (15-85% blends) requires only relatively minuscule changes to be made. The reason that ethanol isn't tested in a pure form (100%) is due to the fact that it requires at least 10-15% gasoline in order to maintain lubrication within the engine. Ethanol burns cooler than gasoline, but makes the engine slightly harder to start in extremely cold temperatures.

A more widespread usage of ethanol has the potential, as thoroughly established by the EPA in collaboration with the General Accounting Office (GAO), to benefit the Nation in many ways. To fully illuminate this, some attention must be given to the production of ethanol. Ethanol is derived primarily from corn, at least in the US, because corn is abundant here, and also because it is the most efficient input in ethanol production. Currently, the DOE is developing a new strain of bacteria that can not only make more ethanol from a bushel of corn, but that can also produce ethanol from a wide variety of plants such as switchgrass, wheatgrass, sorghum, and trees such as poplars, aspen, cottonwoods, silver maple, sycamore, black locust, eucalyptus, and willow. Even garbage and waste paper could potentially be used. This means that grain farmers in the midwest wouldn't be the only people to benefit from increased demand. Farmers typically benefit by price increases of up to 10% for their products. This added incentive to produce entices the farmer to withdraw land from federal set aside acres and plant crops, which saves the government a considerable sum of money. The government also experiences greater returns through income tax collected from farmers and processors of grain. The companies that process corn for ethanol benefit because ethanol isn't the only product that they derive from corn. They make high fructose corn syrup (highest demand experienced in summer months) and high protein gluten feed as well. The additional demand created by ethanol allows them to increase their "grind" year-round. The greater the "grind", the lower production costs become. It follows that what is good for the farmers and the processors is most likely good for their corresponding regions, so it is safe to say that ethanol will help rural economies. Ethanol will better the Nation's economy as a whole due to the fact that for every gallon of domestically produced ethanol used, a gallon of petroleum-derived gasoline is foregone, of which, 54% is imported as of '94. Payments for foreign oil make up 60% of the cause of our trade deficit as of '92 and this figure continues to rise. These payments now total over $100 billion annually, and economists estimate that for every $1 billion of this, 25,000-30,000 jobs are lost in America; that's 2.5-3.0 million jobs, which is a very significant portion of the current unemployment level.

The DOE and Diversified Energy Research

The Department of Energy has done an excellent job of not only finding alternative energy production techniques, but also in turning those ideas into a reality. Some examples are solar panels, hydroelectric plants, nuclear power plants, and coal-fired electrical plants. They have furthered these

efforts by achieving not only increased efficiency in all these methods, but also by exploring new possibilities like super colliders. In the realm of alternative fuels, the DOE plays a very important role. While it does not make much of the actual policy governing the use of automotive fuels, it does vital research and experimentation. The DOE performs the majority of work on engine design for alternative fuels, as well as aiding industry by providing them with more efficient methods of production. The Department of Energy has done an excellent job of contributing to more efficient uses of energy, creating an array of new energy sources, a better economy, improved environmental quality, and in helping secure our national defense.

EPA's Handling of Ethanol

In its testing of ethanol, the EPA has done an excellent job. It has consistently performed its experiments in a fair manner, and when it came time to develop policy, the EPA did so in an unbiased way. In general, it has done a much better job of ignoring special interest groups than has congress. When questions were raised (primarily by the oil industry) about the validity of ethanol, the EPA performed additional studies, and answered them directly and in a thoroughly convincing manner.

There are some tasks performed by the EPA that are much harder to rate, however. When it places a value on something as vague as clean air or water, a necessary process in determining the economic efficiency of a potential policy, it is extremely difficult for an outsider to step in and attempt to assess the quality of such an estimate. In attempting to actually make a judgment in a case such as this, one would have to rely primarily on previous testing and calculations made by the EPA itself in order to, in turn, judge the EPA's performance. This makes it pretty difficult to second guess the organization, especially in these more vague arenas.

The reduction of carbon monoxide levels in the 35 US cities with the highest levels of air pollution was mandated by the Clean Air Act (CAA). Motorists are required to use oxygenated fuel additives during the winter months (worst time for pollution) in those areas. The CAA also requires year-round usage of clean burning fuels to reduce ozone formation in the nation's nine smoggiest metropolitan areas. When twenty of the cities in the Clean Air Program were monitored, the number of days with excessive CO pollution was reduced by 95%. The CAA and its positive results are a good example of the EPA's performance, along with its predecessors, in relation to alternative fuels and ethanol. Currently, 35% of

fuel utilized by the cities governed by the CO program of the CAA consists of 10% ethanol-blended fuel (E10 or gasohol). This converts to merely 3.5% overall ethanol usage. The EPA, in an attempt to build on this in '94, tried to mandate that 30% of the fuel used in these cities be blended with a renewable oxygenate. What complicated that, was that ethanol is the only renewable oxygenate, so the EPA was in fact mandating ethanol usage, even though the mandate was to be set at a level lower than that which is currently used. This was to be a solid step towards the proliferation of ethanol, but what it turned out to be was a proof to the one significant flaw in the Environmental Protection Agency's actions. In that particular case, the mandate didn't make it through the congress, but was successfully blocked by the mere threat of a lawsuit by some major oil interests.

It is a given that the EPA's policies ultimately are subject to congressional approval. It is also widely accepted that congress, in general, responds to an impetus. If congress hears nothing about ethanol from the Nation, but hears all sorts of negative remarks from oil lobbyists, then congress will most likely decide against ethanol. If the tables were turned, the result would be the opposite. The EPA's major flaw is in its reoccurring failure to realize this, and more importantly, to educate the people on the matters that their potential policies address. The EPA must not forget that it maintains the responsibility to provide the American people with the tools (knowledge) that they need to be an impetus in congressional decision-making.

Conclusion regarding DOE and EPA

The role of the Dept. of Energy in alternative fuels is one primarily made up of research and development of more diversified energy sources and of increased levels of efficiency in the production processes relating to those sources. The Environmental Protection Agency, on the other hand, is concerned with energy, only in so far as it relates to extending our natural resources, preserving and bettering the environment, etc. While the DOE has the more simplified task of developing efficient and diverse energy resources and commercializing them, the EPA, on the other hand, has the more difficult of job of making up for the failure of a market economy to include "hidden" costs associated with the environment. This is done through mandate, tax, tariff, etc. Think of an airplane driven by two pilots: if the DOE is turning the propeller with diversified energy sources, then the EPA is steering the plane with policy that leads us to a future with a desirable environmental setting.

In conclusion, the EPA failed as a direct result of its failure to fully realize its environment. It did not recognize that, while it was attempting to work for its customers, the American people, the customers not only needed the provision of a service, but also needed to be educated as to the validity of the service. This public knowledge and understanding is crucial in such a situation, where the ultimate decision-making body (congress) generally requires an impetus for action. The EPA's failure to achieve this level of public understanding resulted in the failure of its recent renewable (ethanol) mandate, and will continue to slow the EPA's efforts in the future if not corrected.

Statement regarding government officials

Those in positions of power that are capable of initiating and implementing RFG (reformulated gasoline) programs that mandate the more widespread usage of relatively clean burning renewables such as ethanol that are presently distracted by the allegations of organizations should take a long gander at and fully realize the true motivational factors behind them. This perusal should automatically occur before they (politicians) allow these people to negatively influence their otherwise good judgment. Generally, these people (organizational participants) are working for their own purposes or those of their organization, and this in no way is meant to imply that those are parallel with the common good and interest of the American people. Instead, these organizations tend to be interested solely in marketing a previously contrived product to a society with limited exposure to the negativity's associated with that product, and are in no way at all motivated to illustrate, relay, or deal with these negativity's on their own. Since the individuals involved in the workings of our government do have this responsibility to us, they should ignore the more biased allegations of "private" organizations, and instead, take genuine heed to the interests of the average person that is forced to deal with the indirect costs of such products in ways that are directly negative to them. I sincerely abstain from throwing blame in any direction here. Rather, this is merely an attempt to remind some people of their previous obligations that do indeed take definitive precedence in such a matter.

All of this points toward a definitive need for unbiased consideration, analysis, and presentation, which I intend to accomplish within this work. In issues such as this, there are many angles to be considered and many views to take on as well. However, any analysis based on a previously held view is futile. The validity of the resultant message is nullified by the presenter's preoccupation with proving a point. I have no wish to be that presenter, so I am attempting to conduct a true study, one that gives equal

weight to all input within the study. I hope that this attempt will give additional merit to my study, as I feel that it does to the findings of unbiased organizations such as the EPA.

Facts and findings on ethanol

The following are some claims against ethanol and their corresponding responses that have been formulated through ample research and testing by some very respectable organizations. The negative claims were made by The Advancement of Sound Science Coalition (TASSC). The organizations are as follows: Oak Ridge National Laboratories (ORNL), Acurex of California, Institute for Local Self Reliance, and the United States Department of Agriculture (USDA).

=> Ethanol does not reduce greenhouse gases.

*ORNL (Dr. Marland & Turhollow, '91)

-"When comparison is made on a net energy content basis, it appears there is a net CO2 savings associated with ethanol from corn. This net savings in CO2 emissions may be as large as 40% or as small as 20% depending on how one chooses to evaluate the by-product credit."

*Acurex (Stefan Unnasch, '90)

-"Ethanol produced from corn has a lower global warming impact than gasoline produced from crude oil. Ethanol production considered here is based on the incremental ethanol that is produced from typical production in the United States."

*Institute for Local Self-Reliance (Ahmed & Morris, '94)

-"Based on the latest information regarding the energetics of ethanol and methanol and based on the most realistic scenarios of Mark Deluchi, Argonne National Laboratories, we conclude that the increased use of ethanol is highly likely to reduce greenhouse gas emissions. In virtually all cases ethanol blends reduce greenhouse gas emissions over MTBE blended RFG."

*USDA (Hughes & Graboski, '94)

-"Calculations show that the use of ethanol significantly reduces CO2 emissions relative to conventional gasoline. According to an EPA analysis, conventional gasoline emits CO2 at a rate of 517 grams per mile compared to ethanol at 375 grams per mile. Ethanol therefore emits roughly 27% less CO2 than conventional gasoline, on a grams per mile basis."

Comments: The base case scenario of the DOE study on ethanol and global warming referred to by TASSC is based on high input farming practices and the use of 100% coal to supply the energy for the ethanol production process. Today, virtually all of the ethanol production facilities obtain a large percent of their energy from natural gas and, in many cases, all of their energy requirements from natural gas. In a recent survey of new and planned ethanol production facilities, all were designed to use 100% natural gas as their energy feedstock. This, of course, has a dramatic effect on the reduction of C)2 gases, a major contributor to global warming.

The conclusion of the Argonne National Laboratory study done for the DOE, which TASSC quotes out of context, is that, *in the worst case scenario*, ethanol could increase greenhouse gas emissions more than gasoline. In fact, the real conclusion of Mark DeLuchi in the study is as follows: "The general message of these corn-to-ethanol scenarios is that one can pick values for a set of assumptions that will support virtually any conclusion about the impact of the corn-to-ethanol cycle on global warming."

What DeLuchi is saying is that the results of these studies are solely dependent on the assumptions used. While it would be unrealistic to use the best case scenario of DeLuchi's study, it is just as inappropriate to use the worst case scenario. This is what the Institute for Local Self-Reliance is referring to when they base their analysis on the most *realistic* of the DeLuchi scenario's.

Finally, it is important to note that the reduction in agricultural inputs have made impressive advances, According to the USDA:

-"One measure of farm energy efficiency is the farm energy input index. Over the past 11 years, the input index has fallen from 108 to 60, a significant improvement. Energy efficiency in agriculture has also increased because agricultural productivity has increased. The index of aggregate agricultural output per unit of energy input has increased from 92 in '74 to 185 in '90. Productivity of other energy related inputs has also increased. For example, nitrogen fertilizer applications for corn have been trending down, falling from 140 lbs per acre in '85 to 127 in '92."

=> Ethanol production is not an energy efficient process.

-Some of the same studies designed to analyze the CO2 cycle of ethanol production researched the energy input requirements. The Oak Ridge study showed a net energy gain in ethanol

production of 18%. The Acurex study showed a net energy gain of 20%. A study completed by the USDA in '93 showed a net energy gain of 20%. A '95 update of that study by the USDA shows a net energy gain of 25%.

-The '90 Cornell University study referred to by TASSC is one by Dr. Pemintel. This study has long since been discounted by everyone, except those who wish to find a negative energy equation relating to ethanol. The study made no adjustments for the energy credit to the coproducts. The study used coal as a major source of energy, and the study went so far as to include the energy required to make the steel for the tractors needed to plant the corn.

-The Institute for Local Self-Reliance, says in their analysis: "Assuming an average efficiency corn farm and an average efficiency ethanol plant, the total energy used in growing corn and processing it into ethanol and other products is 81,090 BTUs. Ethanol contains 84,100 BTUs per gallon and the replacement energy value for the other coproducts is 27,597 BTUs. Thus, the total energy output is 111,679 BTUs and the net energy gain is 30,589 BTUs for an energy output-input ration of 1.38."

-This ratio is corroborated in the most recent report by the USDA, where they state: "Each gallon of ethanol produced domestically displaces 7 gallons of imported oil. In addition, production of ethanol is energy efficient, in that it yields nearly 25% more energy than is used in growing the corn, harvesting it, and distilling it into ethanol."

-This compared to gasoline with a net energy efficiency of only .75 and MTBE of only .55.

Comments: The evolution of ethanol production technology and the streamlining of farming practices has changed forever the energy equation of ethanol production. The statement that it takes more energy to produce a gallon of ethanol than is contained in the finished gallon is simply not true. The accumulated data showing a net energy gain is now of such magnitude that there should no longer be a question on this issue in the scientific community.

=> Ethanol will drive up the cost of Reformulated Gasoline (RFG).

-It is unclear why TASSC would take a position on the economics of ethanol in RFG. However, since they have chosen to do so, it is important to accurately address the issue.

-There are two factors which drive the pricing of product, they are demand and availability. The Clean Air Act Amendments of 1990 created the demand, and the combination of a two oxygenate market (MTBE and Ethanol) would have created ample availability.

--During the first year of the RFG program, the price of RFG gasoline, on average, was 9-12 cents per gallon higher than conventional gasoline. That significant price increase had nothing to do with ethanol, but had everything to do with lack of competition in the market place. In RFG markets where ethanol has a respectable market share and consumers were provided a choice of oxygenates, the average price increase of RFG was only 4-5 cents per gallon. Why?...competition! In markets where competition between oxygenates has been allowed to flourish, like Milwaukee and Chicago, consumers have benefited.

-So, the TASSC statement that RFG with ethanol could cost consumers $48-350 million per year in increased gasoline prices, simply does not coincide with the facts. If we assume minimum RFG sales for 1995 of 40 billion gallons, with an average price increase of ten cents per gallon, that translates into a $4 billion dollar consumer impact. The $48-350 million per year cost to consumers alleged by TASSC, was first, not accurate, and second, dwarfed by the actual consumer impact.

=> Science does not support the widespread use of ethanol.

-Science has always supported the use of renewable fuels like ethanol. Science has been reluctant to support the use of ethanol in RFG under the parameters defined by the EPA in a volatility-driven simple model.

-However, the EPA has recently authorized the lifting of summertime oxygen caps as a result of new data which shows little correlation between oxygen content and NOx increases. This begins to clear the way for ethanol blends at levels higher than 5.5% to take part in the RFG program during the summer. In addition, the new mobile 5.1 model places significantly more weight on exhaust VOC (volatile organic compounds) emissions than on evaporative VOC emissions. Ethanol plays an important role in reducing exhaust VOC emissions as well as carbon monoxide and unburned hydrocarbon emissions.

-The EPA, in its effort to ensure good science, has asked the National Academy of Science (NAS) to review existing research to determine the effects of ethanol blends on the formation of low level ozone. It also wants NAS to compare those effects to those of other oxygenates such as MTBE. Previous research has shown that ethanol blends perform equally to other oxygenates in helping reduce dangerous levels of

ozone. These studies demonstrate that, in fact, when ethanol is judged on its ozone forming potential rather than its mass emission characteristics, it performs equal to other RFG certified oxygenates. Should NAS find this to be the case, the Clean Air Act (CAA) clearly provides the EPA with the authority to certify ethanol blends as a qualifying RFG fuel.

=> Ethanol use is based on bad science, is bad for the economy, and is bad for the American people.

-Obviously none of these statements are true and it is unfortunate that TASSC would have taken such a misguided position. Unfortunately, these are the kind of misguided statements that supporters of ethanol are consistently bombarded with, statements that deserve no merit or attention or even consideration.

-In 1993, the USDA estimated that increasing ethanol production to 2 billion gallons annually, would create an additional 28,000 new jobs, including 15,00 jobs in farming and farm-related activities. It is estimated that for every 100 million bushels of corn used to produce ethanol, as much as five cents is added to the overall market price of corn. This equates to hundreds of millions of dollars annually being pumped back into the rural economy of the US as opposed to exporting those dollars for imported oil.

-It has been generally assumed that ethanol tax provisions have had a negative impact on the federal budget. While several studies have been done which suggest to the contrary, perhaps the most definitive study was recently completed by the General Accounting Office (GAO), as previously stated. The GAO study stated that: "The decline in current farm program payments attributable to ethanol production greatly outweighs the reduced gasoline tax revenues creating a significant net savings to the US Treasury."

-The economic impact of ethanol production in the US is estimated to be in excess of $6 billion dollars annually. The ethanol program is one of the few federal incentives that can actually boast a return on investment.

-The US now imports well over 50% of its petroleum needs at a staggering cost. It is estimated that we spend in excess of $130,000 per minute, 24 hrs a day, every day, for imported oil. Economists are very clear about one thing. This exportation of money is the single biggest contributing factor to our national debt. Compare this to ethanol produced from domestically grown corn and refined in plants located in rural communities. You might find it of interest that 80% of the money generated in an ethanol plant is spent within fifty miles of the plant. It stays close to home, and benefits the people that need it the most.

The following are some interesting details regarding ethanol:

-Ethanol contains oxygen, blending it with gasoline allows the fuel to burn more thoroughly and completely, reducing emissions and engine wear in the process.

-Ethanol helps guard against gas line freeze in cold winter months, but makes for slightly more difficult starting in extremely cold conditions. However, this can be overcome with minor adjustments to an engine designed for gasoline, which is the case for most negativity's associated with ethanol's performance.

-Ethanol-blended fuels are approved by every major auto manufacturer, lower CO emissions by 25%, and reduce CO2 emissions that cause ozone formation by 30%.

-The production of gasoline from crude oil creates harmful carbon dioxide emissions, which lead to global warming. In fact, gasoline production causes from 20-40 percent more CO2 emissions than does the production of ethanol from corn.

-Ethanol usage reduces our dependence on foreign oil and, in the process, reduces our dependence on fossil fuels, most of which originate from foreign sources.

-Monitoring of 20 metropolitan areas participating in the Clean Air Program found that the number of days with excessive carbon monoxide pollution was reduced by 95%.

-The amount of energy required to produce one BTU of gasoline can produce over eight BTUs of ethanol, so ethanol is 8 times more energy efficient than gasoline.

-In '94, oil imports in the US rose to 53% of our demand, despite a decrease in US petroleum consumption. This points directly at our quickly dwindling reserves.

-Ethanol production generates $1.5 billion in economic activity in the state of Iowa alone. ($6 billion overall)

-All major oil companies are now selling ethanol. This points to its feasibility in the eyes of its biggest past enemy.

-Corn sold for ethanol production pays farmers around $15 extra per acre per year.

-Ethanol production creates (as a coproduct) an excellent livestock feed in addition to an alternative fuel. Corn gluten is fed to hogs, cattle, and poultry with no negative effects on carcass quality or weight.

-Ethanol producers like ethanol because it is one of their two major products, which both happen to be cyclical in nature, but are popular at opposite times of the year. Ethanol experiences higher demand in the winter, and high fructose corn syrup (HFCS) is used in soft drinks which are demanded more in the

summer months. This combination allows producers to increase their "grind" year-round. Increasing the grind is the easiest way to lower costs and maximize output as well as efficiency within the plant.

-Two major automakers are currently marketing vehicles (identical to existing models) that run on up to 85% ethanol blends and that are equally or very comparably priced.

RFG

Reformulated Gasoline is gasoline that has been refined to reduce exhaust pollutants from cars and light trucks. RFG contains oxygenates, usually alcohols or alcohol-derived ethers. Oxygenates are added to gasoline to increase oxygen content, thus making the fuel burn cleaner. The RFG program was developed to reduce high ozone pollution levels in the nine metropolitan areas which have been designated as having the most severe ozone pollution. They include NYC, Philadelphia, Baltimore, Chicago, Milwaukee, Houston, Los Angeles, San Diego and Hartford, Connecticut. In addition to this, as many as 40 areas designated as less severe can elect to utilize the benefits of RFG by opting-in to the program. To meet the standards for use in the RFG program, a gasoline must contain the following: an oxygen content of at least 2 percent by weight, a benzene content not exceeding 1 percent by volume, and an aromatic content not exceeding 25 percent by volume.

The emission standards for RFG calls for a reduction in VOC's by 15 percent from 1995 to 1999, and a 25 percent reduction beginning in the year 2000. VOC emissions have the ability to form ozone when in the presence of sunlight. Ozone is a major pollution problem typically associated with smog. Adverse health effects of ozone pollution include coughing, choking, stinging eyes and severe respiratory problems. Since '69, over 44 health-related studies have been conducted on oxygenates such as ETBE and MTBE. The results show that oxygenates are safe for use by the general public. No adverse health risks have been proven as a result of RFG.

Ethanol production

Ethanol can be made from almost any raw material containing sugar or carbohydrates. As of August 1989, about 95 percent of US ethanol was made from corn, a readily available domestic feedstock that stores well and can be converted to ethanol and other valuable products such as sweeteners, oils, starches, high protein gluten feed, etc. Wheat, sorghum, barley, and food processing wastes are among the other feedstocks utilized in the US to make ethanol. Brazil, which uses straight (neat) ethanol and gasoline-

ethanol blends as motor fuel, produces most of its ethanol from sugar cane. Increased ethanol usage in Brazil is an excellent example of its potential in the US. Ethanol is produced in a three stage process. The first stage involves the conversion of plant material into fermentable sugars. Starch from corn must be chemically converted to sugar before fermentation can occur. The conversion process can include grinding, cooking, and treating with acids or enzymes. The second stage in ethanol production is fermentation. The fermentable sugars are put in large vats and yeast is added to convert the sugars into ethanol. The fermentation process can take up to 72 hours and requires the drawing off of heat to maintain proper temperatures for yeast growth. The final stage in the process is distillation. Ethanol is boiled off in beer stills to separate it from the grain residues, yeast, and water. The ethanol is then processed through distillation columns to remove aldehydes (volatile hydrocarbon fluids obtained from alcohol by oxidation) and fusel oil. The distillation process concentrates the ethanol to 95%. Finally, the remaining water in the ethanol is extracted by mixing with benzene to yield anhydrous, or pure 100% ethanol. The benzene is then recovered and the ethanol denatured to prevent human consumption. To produce ETBE, this ethanol is mixed with isobutylene, which is merely butane that has gone through processes of isomerization and dehydrogenation.

Ethanol is produced in two basic processes. They are wet milling and dry milling. Dry milling is a much simpler process, but isn't as energy efficient. Also, wet milling results in a wide range of useful coproducts. Dry mills are easier to add on to an existing facility, especially when smaller volumes of grain are to be processed. However, the entire industry is concerned primarily with efficiency that increases with economies of scale, an increased grind, and thus illustrates an overwhelming utilization of the wet milling process.

Efficiency in all stages of ethanol production is a necessity in terms of market expansion. It has to be clear that every effort is being made to ensure that the most efficient technologies are being utilized. This includes agricultural production and the milling processes as well. It is evident that farmers are doing their share in this battle. Every year, farmers manage to grow 2% more grain on the same acres of land. This is especially amazing, since this has been occurring consistently for decades. It is this fact alone that makes it possible for such a large portion of the annual corn crop to be used for ethanol production. However, due to recent advances in technology, corn will not have to be relied on as heavily in the future

for ethanol production. A new bacterium has been engineered that can be used in the production of ethanol from virtually any plant source. *Zymomonas mobilis* is capable of simultaneously fermenting the glucose and xylose prominent in many lignocellulosic feedstocks to ethanol. This means that ethanol can be produced from municipal solid waste, agricultural and forestry residues, and dedicated energy crops. This is a very important development, in that it will allow farmers in regions other than the cornbelt to produce energy crops as well. It is also gives us a great deal of potential in our move towards energy self sufficiency. Presently, only the starch from the inside of a kernel of corn is utilized for ethanol production. The hull, cob, leaves, and stalk are left unutilized. However, which the addition of the *zymomonas mobilis* bacterium, these will soon be utilized as well, which will enable ethanol yields to equilibrate with near theoretical yields.

As of 1992, the following products could be obtained from a bushel of corn (with corresponding weights and volumes): 21% protein gluten feed, 14.5lbs.; 60% protein gluten meal, 3lbs.; corn oil, 1.7lbs.; carbon dioxide, 17lbs.; and ethanol, 2.6 gals. The coproducts account for approximately 29.5% of total revenue, while ethanol accounts for the remaining 70.5%. This does not take into account revenue from other activities such as the buying and selling of grain or HFCS production (sweetener), which the typical grain processor engages in heavily.

Feasibility of ethanol industry expansion

The GAO developed two scenario's in 1990 depicting an approximate doubling and tripling of annual ethanol production capacity based on the existent level, which happened to be 1.1 billion gallons per year. This growth was to take place over eight years. At that time, ethanol derived from corn used approximately 4% of the annual corn crop. It follows, with minimal calculations, that if only 30% of the additional corn produced each year compared to the previous year was devoted to ethanol production, even the GAO's higher end growth scenario would be realized. By this, I mean to say that if production increases by 2% per year, and if only .3 (.6% increase in total corn production) of this was put towards ethanol production, since ethanol constituted 4% of production at that time, ethanol production would increase by (.6%/4% each year=15% increase in annual ethanol production capacity) 15% per year. Over the eight year growth period, this would result in a 306% increase in total ethanol production. This exceeds the intended growth of even the more accelerated model with only a minimal usage of "extra" corn

production. However, this ignores greater production efficiencies, which are constantly being achieved. Every year, producers manage to increase ethanol yields in gallons per bushel of corn, and farmers manage to grow more corn per acre.

The GAO's growth scenarios were compared with a baseline scenario that assumed normal crop production, a continuation of current agricultural trends and policies, and little expansion in ethanol production. GAO used the Wharton Econometric Forecasting Associates model of US agriculture in estimating the effect of these production increases on the agricultural sector, federal farm program costs, and consumer food prices.

The ethanol industry was capable of doubling or tripling domestic ethanol production to 2.2 or 3.3 billion gallons per year during the eight year period from '90-8, according to the GAO study, and American farmers could supply the corn needed for that production increase. However, industry officials cautioned that continued government incentives and a legislative requirement for the use of alternative fuels, such as ethanol, would be needed to maintain such growth.

GAO's modeling showed that the expanded use of ethanol fuels would have mixed effects on various sectors of American agriculture. Corn producers would benefit the most because of the increased demand for corn to make ethanol and the resulting higher corn prices. However, through a complex system of economic relationships, some other sectors would not fare as well. For example, soybean processors and producers would face lowered demand and prices for their products because the conversion of corn into ethanol generates feed and oil by-products that compete with soybean mean and soybean oil. Increased corn prices would raise feed costs and hurt cattle producers, but the lower cost of high-protein feeds could benefit poultry producers. Overall net farm cash income would increase, and there would be a slight increase in consumers' food prices.

GAO's modeling also showed that expanded ethanol production would decrease federal farm program outlays as the increase in demand for and the price of grains, primarily corn, would cause fewer farmers to participate in these support programs. The estimated decrease in outlays showed annual fluctuations depending, in general, on the relationship among market prices and projected federal program target prices and loan rates. At the same time, the increased use of ethanol fuels would reduce federal motor fuel tax revenues because of ethanol's partial tax exemption. Motor fuel tax revenues were projected

to decrease with the expansion in the use of ethanol over the simulation period. On average, the reductions in farm program outlays would exceed the increased tax revenue losses over the eight year period. However, in response to the primary interests of the Chairman, GAO's study was limited to the impacts of expanded ethanol production on the agricultural program outlays and motor fuel excise tax revenues on the federal budget; it did not explore all the federal budget or consumer impacts that might result from expanded production, such as the income taxes paid by farmers, ethanol producers, and fuel distributors.

A widespread expansion in both ethanol production and utilization is seen as being very feasible. Brazil has switched half of all vehicles to the burning of neat ethanol, and the remainder run on varying mixtures of ethanol and gasoline. Brazil has demonstrated the economic benefits that have a great deal of potential for realization in the US as well. Since Brazil is a poorer country, they rely on mostly manual labor in the harvesting of sugar cane, which they choose to utilize as their primary ethanol feedstock. This solved a major unemployment problem for them. They have also noticed significant air quality improvements within their larger metropolitan regions. I'd also like to point out that automakers in the US supply the majority of automobiles to Brazil, so it's not as if we can't build engines to use ethanol to its fullest potential.

A true need for a secondary fuel source

At this point in time, we are faced with a serious duty to begin to rid ourselves of a dependence on inefficient fossil fuels that exist in consistently dwindling quantities and result in a wide range of external costs that continue to plague our existence on a daily basis. These externalities are just beginning to be realized. They are evident in the form of environmental and economic side effects, which directly affect the health and livelihoods of all Americans. It is blatantly obvious that this is an eminent transition, one that cannot be avoided. Why should we forgo this opportunity while it remains relatively simple for us to make the change now with minimal complications? Any measures that are taken now, will buy us a great deal more time in the future. It would be foolish to ignore this opportunity that has presented itself to us. Although gasoline appears to be cheaper upon initial perusal, a quick study of negativities and externalities associated with such a fuel results in the realization that gasoline is much more expensive than ethanol.

Gasoline damages our economy. Gasoline damages our environment. Gasoline damages health, especially in large metropolitan areas. Gasoline removes funds from our country and transplants them in other countries, where they are of no use to the vast majority of us. It has been stated in numerous studies that, if gasoline's price was forced to include only a majority of its external costs and the same were done to ethanol's price, the price of gasoline would double or even triple that of ethanol. Gasoline is bad for us on a thoroughly consistent basis, while ethanol is the opposite. I have discovered no reason to doubt this in eight months of study, and if I had, this certainly would have been reflected in this document. Thank you very much for your time and consideration,

Adam M. Lack

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