A Critical Review of the Energy Policy Act of 2005's Treatment of Hydrogen

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I. Abstract

The paper analyzes the Energy Policy Act's goals and proposed action in Title VIII, the section dedicated to hydrogen. It then assesses whether or not the resources dedicated to this cause are sufficient to overcome the obstacles facing the commercial use of hydrogen and fuel cells.

II. Introduction to the Energy Policy Act of 2005

The Energy Policy Act (EPAct) of 2005 provides assistance and funding for a range of technologies from conventional fossil fuel-based applications to alternative, sustainable energies. This Act lacks a preamble, which would guide its intentions and identify its goals. Like most of the previous U.S. energy policy, it is a massive document that "addresses a wide variety of specific issues, rather than coordinating any national energy policy or strategy."[i] The omission of a preamble is, in my opinion, intentional. To prioritize energy spending would be to guess the future. Since neither policy makers nor energy analysts are prepared to predict when global oil supplies will fail to meet the growing international demand and which alternative fuel will replace petroleum, they are hesitant to chart out a course that will support some energy industries over others. Furthermore, they do not know what the future of a carbon tax to prevent global warming in the U.S. will be and are therefore slow to dramatically change the amount of funding and support in the form of tax incentives that fossil fuel-based industries receive. However, because the authors of this Act do realize that a conversion to cleaner burning fuels is imminent, renewable energy and hydrogen technologies receive some attention and support. The money allocated to each of these technologies reflects the success with which interest groups lobbied Congress instead of the amount necessary to overcome future barriers to provide the U.S. with cheap energy far into the future. This scattered approach of supporting all energy industries ensures that no interest group was left out, but prevents substantial headway in any fledging industry from occurring. With respect to hydrogen in particular, the ambitious goals set out by the Act will not be attained given the amount of funding and resources allocated to this industry. However, given the substantial hurdles to the implementation of a hydrogen economy, which is defined by the use of hydrogen to power vehicles and produce electricity, nothing short of an effort the size of the Apollo and Manhattan Projects would be sufficient to successfully "promote comprehensive development, demonstration, and commercialization of hydrogen and fuel cell technology" as the Act calls for.[ii] Given this reality, the U.S. should choose to either aggressively support or completely drop funding for hydrogen. Prioritizing energy funding by the most feasible, economical, and sustainable technologies will allow the U.S. to streamline its efforts and ensure that the country is left with a viable fuel source when the conversion to an alternative fuel must be made.

III. EPAct 2005 and Hydrogen

Despite the lack of a coherent goal and roadmap for the entire EPAct of 2005, the section on hydrogen, Title VIII, provides a clear set of objectives. Hydrogen is given its own separate title not because of its ability to serve as a source of heat and electricity, but because of its potential as a transportation fuel that can replace the dwindling global supplies of petroleum. Other forms of renewable energy such as photovoltaic panels and wind turbines can produce electricity without harmful emissions, but are given less consideration in this Act since they replace a plentiful resource, coal. Therefore, a conversion to this technology supports the Title VIII's goals of "decreas[ing] the U.S. dependence on imported oil" and "creat[ing] a sustainable energy economy."[iii]

In addition to these goals, Title VIII ambitiously calls for the "comprehensive development, demonstration, and commercialization of hydrogen and fuel cell technology."[iv] This goal at first may seem vague, but the Title later specifies that 100,000 hydrogen-fueled vehicles will be produced and deployed by 2010 and 2,500,000 by 2020.[v] This goal is just massive enough to necessitate major structural changes to the transportation sector, but not large enough to cause a complete conversion to hydrogen vehicles. Two point five million vehicles represent one percent of the total American fleet.[vi] Converting a small portion of the U.S. fleet to hydrogen-fueled vehicles, however, is nearly impossible since those vehicles will need separate filling stations. Requiring that all service stations dispense hydrogen when only one percent of the fleet is converted is impractical; therefore, these cars would not gain acceptance since Americans enjoy the freedom that vehicles provide and would not be satisfied with a car that can only be driven in a small area that is near hydrogen filling stations. The only way this goal could be attained without adjusting the entire fueling infrastructure of the U.S. is if all of these cars were governmental fleet vehicles that had their own fueling stations. The EPAct of 2005 does suggest applying hydrogen to "vehicle fleet centers," which would satisfy the Act's goal of 2,500,000 vehicles, but this demonstration technology would be a far cry from the Act's goal of complete "commercialization" and "acceptance by consumers."[vii] In addition to the difficulty of a partial conversion to hydrogen because of lack of access to fueling stations, changing the vehicle structure for a small percentage of cars would prevent economies of scale in the manufacturing process from being realized and keep costs high. Despite Title VIII's goal of "promot[ing] comprehensive development" of the hydrogen economy, only one percent of U.S. fleet was targeted for conversion; this incomplete conversion would be problematic because of its ramifications on the hydrogen fueling structure and the manufacturing process.[viii]

Another contradictory goal of Title VIII calls for the U.S. "to build a mature hydrogen economy that creates fuel diversity in the massive transportation sector."[ix] By calling for "fuel diversity" instead of fuel replacement with hydrogen, the goal seems attainable, suggesting that hydrogen will be only one of many fuels, which may also include ethanol, that power vehicles after oil becomes too expensive to extract. However, this goal also has an ambitious component that calls for building a "mature hydrogen economy." The word "mature" suggests that formidable technical hurdles will be overcome, and the technology is ready to sell to the public. The authors of the Title seem to be torn between using rhetoric that sites hydrogen as being the ultimate fuel of the future and recognizing that hydrogen may one of several fuels that is used in a transition from petroleum. The upshot of this ambiguous language would again result in a partial conversion to hydrogen, which is problematic for the two aforementioned reasons.

IV. Is the Money Authorized in Title VIII Adequate?

The inconsistency of the language and goals of Title VIII is also reflected in the amount of money authorized to achieve this directive; the funds set aside to achieve the hydrogen economy is enough to be considered a major governmental expenditure, but it is nowhere near enough to overcome the current obstacles to "commercialization" of this economy.[x] In order to achieve this hydrogen economy, the Title sets a goal of putting money into "public investments in industry, higher education, national labs, and research institutions to expand innovation."[xi] These investments will build upon hydrogen programs of the past, and are focused in the areas of 1) isolating, storing, distributing, and transporting hydrogen, 2) fuel cell technologies, 3) demonstration projects, and 4) development of safety codes and standards. The overall authorized spending on hydrogen through 2010 in the EPAct of 2005 was $4.046 billion, twice as much as was spent on other renewable forms of energy, but $1.775 billion less than was spent on the other replacement transportation fuel, ethanol.[xii][1]

Research and development in the hydrogen sector is not a novel idea; since 1990 when the Matsunaga Research, Demonstration, and Development Act set out a five year plan for the investigation of hydrogen as a fuel, the government has periodically renewed its commitment to hydrogen research with money and the development of programs.[xiii] In 2001, Spencer Abraham, the Secretary of Energy, announced Generation IV, a project to create a new series of safe nuclear power plants to create hydrogen.[xiv] In 2002, President Bush supported a Hydrogen Fuel Initiative, which sets aside money to research the production, storage, and delivery of hydrogen, and the Freedom Car Initiative, which investigates a car that could run without any dependence on petroleum. Most recently, President George W. Bush mentioned his goal of a hydrogen economy in the 2003 State of the Union Address, and announced FutureGen, a coal-burning power plant that will create electricity and hydrogen and sequester its carbon emissions in 2003. During this year, the Department of Energy also initiated an International Partnership for the Hydrogen Economy, which promotes international research. In order to attain these goals, the amounts of money appropriated for hydrogen have increased from $159 to $243 million per year from 2004 to 2006.[xv] Despite these ambitious projects and funds allocated, scientists have not been able to resolve *any* of the major barriers to creating a hydrogen economy.

Annual sums of money up to $210 million by 2010, the second largest amount of spending in Title VIII, was appropriated to the isolation, storage, distribution, and transport of hydrogen because these are the most formidable obstacles to implementing a

[1] The annual authorized money is specified by the EPAct of 2005 only through the year 2010. Therefore, I analyzed the Title's goals with respect to the money authorized by this date.

hydrogen economy.[xvi] The money dedicated to solving these problems has attained some results, but identified a myriad of challenges yet to be overcome. Hydrogen is the most abundant element on Earth, but it is almost always bonded to another element. In order to feed hydrogen into a fuel cell to produce electricity, it must be isolated. When natural gas prices were about $3 per million British thermal units (MMBtu) in 2004, hydrogen was most efficiently and cheaply derived through the steam reformation of natural gas for $6 per MMBtu. At this time, this cost of hydrogen was competitive with petroleum as a fuel.[2][xvii] However, now that natural gas prices have spiked to $12/MMbtu, hydrogen costs twice as much as petroleum or $20 per MMBtu to produce through natural gas reformation.[xviii] In addition to being expensive, reforming natural gas or any other fossil fuel releases the greenhouse gas carbon dioxide into the atmosphere. Also, using natural gas would not fulfill the EPAct goal of weaning the U.S. from foreign fuel imports since natural gas supplies in the U.S. are dwindling, and the U.S. already relies on foreign imports for 15% of its natural gas.[xix] Therefore, an alternative source of hydrogen must be sought.

Hydrogen can also be derived from water by passing a current of electricity though water in a process called electrolysis. After hydrogen is run through a fuel cell, it recombines with oxygen molecules in the air and creates water vapor. Therefore, this source of hydrogen has no harmful emissions and is completely renewable since the water vapor in the air will eventually fall as rain, which can again can be used as fuel. However, to create one kilowatt of electricity by isolating hydrogen in this way, three kilowatts of electricity are used. Advocates of this source of hydrogen point to renewable energy as being an emission-free source of electricity that could provide this needed

[2] Although the production of hydrogen can be less expensive than petroleum if natural gas prices are cheap, technological challenges to the storage, transport, and use of hydrogen in a fuel cell preclude the whole process of using hydrogen as a fuel from being cost competitive with the use of petroleum.

power. However, to develop a large-scale hydrogen supply, many more renewable energy plants would need to be constructed.[xx] The large energy requirements of electrolyzing water are reflected in the price of this fuel at $20 per MMBtu.[xxi] Even though this price of isolating hydrogen is twice as much as petroleum at its current price of $60 per barrel or $10 per MMBtu, the price of electrolyzing water is now competitive with the aforementioned hydrogen produced from the steam reformation of natural gas because of high natural gas prices.[xxii]

A third and particularly promising source of hydrogen comes from a thermochemical reaction that uses a solar collector to concentrate the sun's energy to 4000 degrees Celsius and "crack" water molecules, causing the hydrogen and oxygen to separate, without passing a current of electricity through them. An intermediate chemical like zinc oxide can be used in this thermochemical reaction to allow this process to run even when the sun is not shining. Currently, the temperatures needed to "crack" water can be achieved by solar collectors, but materials that can withstand this heat need to be refined to be more durable. Therefore, experiments using solar collectors are currently experimenting on splitting methane molecules to produce hydrogen. In order for this technology to be sustainable, materials that can handle these high temperatures and the creation of more concentrating solar devices would have to be developed so that this technology can perform on a large scale.[xxiii] In addition to using renewable energy and methane as methods of isolating hydrogen, the government has supported using nuclear and fossil fuel based energy to isolate hydrogen in the EPAct of 2005 with the goal of providing the American public with the "widespread availability of hydrogen" by 2020.[xxiv]

The greatest challenge to storage and distribution of hydrogen is the size of the hydrogen molecule. Consisting of only one proton and one electron, an atom of hydrogen is the smallest and lightest element that exists. As a result, hydrogen molecules, which are two hydrogen atoms bonded together, must be contained in tightly sealed vessels and pipes. Some hydrogen optimists have suggested that the current natural gas pipeline network could be used to disseminate gaseous hydrogen throughout the nation. These pipes, however, were designed to contain methane, a significantly larger molecule that weighs five times more than a molecule of hydrogen, and would allow hydrogen to seep through seams.[xxv] Even the larger methane molecules are leaking out of this existing pipeline network in large quantities because it has deteriorated in the fifty years since the pipes were laid. Other storage method ideas include chilling hydrogen to a liquid state or compressing it as a gas and using trucks to carry it around the country. Cooling and compressing hydrogen, however, require significant energy inputs that add to the cost of supplying this fuel.[xxvi] Also, compression of hydrogen necessitates high levels of pressure, which increase the weight of storing this fuel on-board a vehicle and necessitate the use of lightweight tanks made of expensive materials like carbon fiber.[xxvii] Hydrogen could be stored in a solid metal hydride, but another energy input is needed to extract the hydrogen from these hydrides and the user is then left with the hydride on-board his or her vehicle.[xxviii] Another idea for hydrogen storage is to fuel vehicles with natural gas, ammonia, ethanol, or methanol and extract hydrogen from these “carrier fuels” directly on-board the vehicle.[xxix] However, most estimates show that portable on-board reformers would be too large and cumbersome to keep on the vehicle and would suffer from poor efficiencies as they would not be able to reform enough hydrogen to achieve economies of scale.[xxx] Finally, lightweight carbon nanotubes doped with heavy metals like titanium have been researched for their potential to store hydrogen. These tubes would store hydrogen molecules by allowing hydrogen to bond to the titanium atoms in the tube. These bonds could be released with low amounts of heat, which would allow the hydrogen to be used.[xxxi] Beyond these storage and transport problems, a conversion of all fueling stations to accept hydrogen would be a monumental task that would necessitate governmental funding. Capital cost predictions to create just one hydrogen pump at a California filling station are $450,000. To provide hydrogen pumps at 10,000 stations, the minimum number of filling stations to service the whole U.S., would cost $4.5 billion.[xxxii] To achieve a "mature hydrogen economy" as specified by Title VIII, all service stations would need to offer hydrogen.[xxxiii] Converting all of the U.S.'s 447,190 service stations would cost over $201 billion, 50 times the total budget for hydrogen in the EPAct of 2005.[xxxiv] From the high cost estimates and multitude of projects in progress to isolate, store, and distribute hydrogen, it is clear that hydrogen is far from being "commercialized" even with the money allocated in the EPAct of 2005.[xxxv]

Another large area of spending is for the development of fuel cell technologies to create a flow of electricity, which can power vehicles, from hydrogen.[xxxvi] The EPAct of 2005 specifically recognizes the need to "resolve critical problems relating to catalysts [and] membranes" in fuel cells and dedicated annual sums of money up to $200 million by 2010 for this purpose.[xxxvii] The type of fuel cells that are best understood, easiest to make, and appropriate for use in vehicles because of their comparatively low operating temperatures, are called Proton Exchange Membrane (PEM) fuel cells. A semi-permeable membrane allows the hydrogen protons to pass through it while the electrons must go around. By doing do, the electrons create a current of electricity. These cells, however, release fluorine atoms that eat away at the membrane. Currently, PEM fuel cells last only five years and then must be replaced. Car owners are accustomed to owning their vehicle for at least ten years and would not be satisfied with a product that required a substantial new investment, even more costly than buying a new engine, every five years.[xxxviii] Furthermore, PEMs use a platinum powder catalyst, which makes the cell expensive and reliant upon a precious natural resource that could be easily depleted if they were manufactured in bulk. Therefore, research in alternative types of fuel cells is underway, but will require more funding than has presently been allocated to create a viable fuel cell by the target date of 2020.

Bringing together all of the aforementioned challenges, Title VIII of the EPAct of 2005 calls for a demonstration project, which would show the feasibility of this new fuel source. It is likely that the annual sums of money up to $375 million by 2010 dedicated to this project will be sufficient since successful pilot projects of vehicles and electricity-generating fuel cells already exist.[xxxix] In my opinion, the amount of money dedicated to this demonstration project in comparison to the other areas of hydrogen research is too much. Demonstrating the use of hydrogen is not the largest challenge; making it applicable to the current fueling infrastructure and ensuring the longevity of fuel cells are the biggest obstacles to its implementation. As such, these areas of research should receive the bulk of the spending.

In addition to these main categories of hydrogen spending in Title VIII, there was mention and support of hydrogen scattered throughout the Act. Nine million dollars was dedicated to the development of safety codes and standards and a variety of demonstration hydrogen projects from fuel cell school buses to "alternative propulsion" for advanced air crafts were supported throughout the Act.[xl] Concentrating solar and nuclear power are supported for their ability to produce hydrogen.[xli] The Act strives to stimulate investment in hydrogen by offering loan guarantees, incentives for fuel cell vehicle owners, and a tax credit for stationary, power producing fuel cells.[xlii] Although these incentives in some cases offer significant rebates to customers, they will not be able to stimulate the market unless the basic challenges facing the widespread distribution of this technology can be resolved. These disparate approaches to fund hydrogen exist because the authors of the EPAct of 2005 are unsure what technologies will become successful and therefore do not want to exclude any of the current ideas. However, this approach will most likely lead to a "business-as-usual" future with no method of hydrogen isolation or storage standing out as the preferred one since no technology was given enough funding to overcome the major hurdles to the commercialization of hydrogen.

V. Alternatives to the EPAct 2005

Given these projections for the hydrogen economy, I suggest that the U.S. adopt one of two strategies. Either more money should be put into the hydrogen program or it should be dropped altogether. If the U.S. wants to gain energy independence and rely only on its own fuels, it must take dramatic steps to achieve this goal. Richard Nixon recognized the magnitude of this challenge in 1973 when he said, "Let us set our national goal, in the spirit of Apollo, with the determination of the Manhattan Project, that by the end of this decade, we will have developed the potential to meet our own energy needs without depending on any foreign energy source."[xliii] Since Nixon's goal was not achieved by the end of the 1970s, a project of this size is still necessary to complete the energy conversion to a fuel that can be derived domestically. In today's dollars, the amount of money spent on the Apollo and Manhattan Projects would be $112 and $24 billion respectively.[xliv] Because these projects had the financial backing of the government and received their funds in a short period of time, they were able to achieve success. Hydrogen's funding, which over the next five years will be only a small fraction of these large project's budgets, will fall short of the stated goals of Title VIII because of the myriad challenges to every aspect of the hydrogen economy.

Policy makers of the EPAct of 2005 should have decided, based on current research, which fuel source is most likely to replace petroleum, hydrogen or ethanol, and allocated sufficient resources to make that resource a viable option in the near future. Currently, policy makers supported both ethanol and hydrogen in the EPAct of 2005 with funding levels at $4.06 and $5.775 billion respectively. Streamlining this funding into one fuel or the other would ultimately save taxpayers money as fuel production and vehicle modification could reach economies of scale more quickly and provide customers with an alternative to experiencing price hikes as petroleum becomes rarer. Ultimately, the conversion to the next vehicle fuel will be nearly complete, just as 97 percent of all vehicles now run on the same fuel because having a homogenous fuel portfolio allows vehicles to be made efficiently, fuel to be distributed uniformly, and easy customers to have easy access to fuel.[xlv] Preventing this price shock will be in line with the dominant model of energy policy throughout U.S. history, which has sought to provide citizens with "reasonable prices."[xlvi] Therefore, the EPAct of 2005 should reflect this imminent complete conversion by focusing governmental resources and subsidies into the industry that policy makers deem most viable instead of supporting "fuel diversity."[xlvii]

This conversion should be done by adopting a concrete plan that would provide adequate money for the development of an alternative fuel and set interim and final target dates for the creation of solutions to the challenges facing the fuel choice of the future. This investment of money can be done in a way that does not give preference to one company over another, but stimulates the industry equally and sufficiently to adopt technologies that are created at governmental laboratories. This idea does not run contrary to the current thought articulated in the EPAct of 2005. The Act acknowledges that "cost-shared projects by manufacturers and governments" are beneficial and assigns a Hydrogen and Fuel Cell Technical Task Force to "foster the exchange of generic, nonproprietary information and technology among industry, academia, and government," but it does not provide the necessary blueprint for how these projects should take place.[xlviii] First, the government would need to identify the most likely fuel of the future by undertaking a careful analysis of the feasibility and economics of future fuels. Then, governmental laboratories would competitively bid on projects related to each aspect of the challenge to the implementation of the fuel chosen as the most suitable energy for the future. If hydrogen was selected, these projects would be broken into the creation, storage, and transportation of hydrogen and the refining of the fuel cell. Before laboratories began research on each of these challenges, private companies would have the opportunity to invest in the research being done at the national laboratory through a Cooperative Research and Development Agreement (CRADA). If the technology proved effective, then the industry partner would earn a percentage of the patent of the new technology that is equal to the amount that they invested in the project. Governmental laboratories could also earn revenue from industry by partnering with companies to allow them to use equipment the laboratory owns like concentrating solar collectors, which can be used to isolate hydrogen, to refine or improve the technologies. Ultimately, this plan could save taxpayers money as they fund governmental labs less in the future; the National Renewable Energy Laboratory, which currently derives three percent of its budget from CRADAs, has the goal of being one hundred percent funded by CRADAs.[xlix] Unlike the current EPAct of 2005 that does not set penalties for non-compliance with stated goals, there should be harsh financial repercussions for not attaining the goals of the plan.

This method of refining a future fuel for widespread adoption will ensure that the U.S. is not left behind in the imminent transition from petroleum and provide adequate incentives for industry participation. Now, industry is hesitant to enter the marketplace since there are a variety of theories about which fuel will allow Americans to transition from petroleum. No company wants to invest heavily in a technology that will be replaced or not economical because it is never mass produced. With the proposed model, the government's support of one technology will provide investors with the necessary confidence to invest in the chosen fuel. This confidence will help allow industrial partners to participate in pioneering innovations with national laboratories. However, before any innovations can occur, the government must appropriate sufficient capital for national laboratories to develop solutions to each challenge in order to give industries confidence in the chosen fuel as the definitive vehicle fuel of the future.

VI. Conclusion

The EPAct of 2005 has a scattered approach of funding all possible energy technologies. With regards to a future fuel to replace petroleum, this technique will create a business-as-usual scenario in which no fuel will stand out as the most economical or feasible. Given the Energy Information Agency's prediction that the world's oil reserves will peak between 2026 and 2047, it is incumbent upon policy makers to create opportunities for a transition fuel to emerge in order to support the current U.S. economy, which relies on cheap energy prices.[l] The lack of an organized effort towards a fuel of the future has led to inadequate amounts of funding authorized towards the creation of a hydrogen economy. The Title has contradictory goals in its grand rhetoric of "commercialization" of hydrogen vehicles and having "widespread availability of hydrogen," but then stipulates only a partial conversion to hydrogen vehicles by 2020 and does not even dedicate enough money to achieve a partial or complete conversion to hydrogen.[li] Given the challenges facing fuel cells and hydrogen isolation, storage, and transport, the government's past, current, and future programs fall far short of providing the necessary funding to support a hydrogen economy. Either hydrogen funding should be eliminated altogether and more funding put into another transportation replacement fuel like ethanol or the money allocated for hydrogen research should be increased by several orders of magnitude. Regardless of the fuel that the government chooses to support, both governmental laboratories and industry partners will need to collaborate. These types of partnerships already occur, but would increase in number if the government provided national laboratories with the initial capital to overcome technical obstacles. Only this type of commitment and financial backing will bring about the necessary change for a successful transition from petroleum.

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