01 Jan 2005

A Hydrogen Economy

Jeremy Snyder

A Hydrogen Economy

An OURE Report 2005
Submitted to Office of Undergraduate and Graduate Studies

Prepared by

Jeremy Snyder

Abstract

In 2003, MIT released "The Future of Nuclear Power," a study of the energy needs for now and the future. The report suggested several subsidies and a new "carbon tax." Also in 2003, President Bush made a State of the Union address that pledged more then a billion dollars towards hydrogen research and a move towards a hydrogen based economy. This report strives to tie together several hydrogen production methods and possible solutions for moving towards a hydrogen based economy. Background, production methods, and finally a revised carbon tax idea specifically aimed at jumpstarting hydrogen production are addressed in this report.

Table of Contents

1.0 Introduction

1.1 Background

President Bush declined to sign the Kyoto treaty, yet still pledged the United States to fight global warming and the production of greenhouse gases in the US. He designated over a billion dollars in his 2003 State of the Union Address towards development of hydrogen technologies. Whether there is an intended goal of reducing greenhouse emissions for purely altruistic environmental reasons, economic incentives, or a governmental mandate to change to a hydrogen based economy, this report addresses possible methods of altering the current course of hydrogen and energy production to some better alternatives.

MIT released "The Future of Nuclear Power," a study in 2003 of the course needed for nuclear power to head in for the future. It suggested "carbon tax" as a solution to energy needs for the future. There will be much opposition to the proposed tax from entrenched industries that will oppose any additional costs for any reason. If it is successful it will complement the recommendations from this report but it will be difficult to change to a perceived sheltering of the nuclear industry.

1.2 Scope of this Report

This report will focus on the current issues facing the United States. The report released by MIT addressed issues through a global viewpoint and though it is important to look at the global context for each of the current challenges, this report is not focused on addressing a solution that will work for every country. Some countries will have similar problems and similar solutions will work but regulatory issues and concerns over different technologies are resolved differently where they are found. By focusing on the issues in the United States, a more workable paradigm can be achieved for the energy needs of this country while not attempting to force a similar model to a different area that it would not be applicable in. For example, France produces roughly 80 percent of it's energy from nuclear power so a solution relying almost solely on nuclear power could be possible. But with the United States energy portfolio currently using only 20 percent

1.0 Introduction

1.1 Background

President Bush declined to sign the Kyoto treaty, yet still pledged the United States to fight global warming and the production of greenhouse gases in the US. He designated over a billion dollars in his 2003 State of the Union Address towards development of hydrogen technologies. Whether there is an intended goal of reducing greenhouse emissions for purely altruistic environmental reasons, economic incentives, or a governmental mandate to change to a hydrogen based economy, this report addresses possible methods of altering the current course of hydrogen and energy production to some better alternatives.

MIT released "The Future of Nuclear Power," a study in 2003 of the course needed for nuclear power to head in for the future. It suggested "carbon tax" as a solution to energy needs for the future. There will be much opposition to the proposed tax from entrenched industries that will oppose any additional costs for any reason. If it is successful it will complement the recommendations from this report but it will be difficult to change to a perceived sheltering of the nuclear industry.

1.2 Scope of this Report

This report will focus on the current issues facing the United States. The report released by MIT addressed issues through a global viewpoint and though it is important to look at the global context for each of the current challenges, this report is not focused on addressing a solution that will work for every country. Some countries will have similar problems and similar solutions will work but regulatory issues and concerns over different technologies are resolved differently where they are found. By focusing on the issues in the United States, a more workable paradigm can be achieved for the energy needs of this country while not attempting to force a similar model to a different area that it would not be applicable in. For example, France produces roughly 80 percent of it's energy from nuclear power so a solution relying almost solely on nuclear power could be possible. But with the United States energy portfolio currently using only 20 percent

nuclear power, no new nuclear power plants built in decades, and a long lasting stigma over Three Mile Island and Chernobyl, the solution will not be the same.

1.3 Intent

This report is intended to overview possible solutions needed to help develop a hydrogen based economy. Section 2 shows the push for development of hydrogen production and several obstacles that need to be addressed through several different means. There are several different solutions to each of these problems that are being discussed, but it was desired to include them to inform readers of additional issues that must be solved in addition to the main focus of the report.

The largest underlying reason to switch to a hydrogen fuel based economy is to help the environment – reducing carbon emissions, etc… Therefore the best solution is one that takes into account the most aspects in reducing those emissions – after all, there is little point in switching to a hydrogen fuel if the pollution is simply switched from a car exhaust to a smoke stack exhaust. Section 3 discusses several different methods of producing hydrogen with benefits and pitfalls to each.

In developing the new hydrogen based economy, new rules and regulations can be more easily assessed and implemented before production is in full swing then after. By mandating and regulating certain aspects, first movers will feel more confident that they won't have to spend millions of dollars in revising their production methods. They will also be able to determine from the earliest stage if they can compete efficiently in the market.

This report suggests a "carbon tax" that, while similar to one suggested in the MIT Study, is targeted and for a different intent. This tax is intended to level the playing field (offering incentives to lower emissions and offering help for risk taking first movers) while not eliminating or artificially encouraging any method over others.

2.0 The Hydrogen Push

2.1 President Bush's Plan

On January 30, 2003, President Bush made his state of the Union Address in which he declared a definite move toward a Hydrogen based economy to reverse the growing dependence on foreign oil. "President Bush is proposing a total of $1.7 billion over the next five years to develop hydrogen-powered fuel cells, hydrogen infrastructure and advanced automotive technologies...Through partnerships with the private sector, the hydrogen fuel initiative and FreedomCAR will make it practical and cost-effective for large numbers of Americans to choose to use clean, hydrogen fuel cell vehicles by 2020." [1]

The newest move towards a hydrogen economy is based upon several important issues, but mainly from reducing greenhouse gas emissions and reducing dependence on foreign oil.

i. Kyoto Accord

The Kyoto treaty was an attempt to lower the global emission of greenhouse gases to fight rising pollution and the possibility of global warming. The United States was the only country to not sign it – whether for better or worse is fiercely debated on both sides. However, President Bush still initiated programs to reduce greenhouse gas emissions in the US. Whether from mounting pressure from Kyoto treaty signatories or from similar belief but not bound by treaty, the US is pushing towards developing more of a hydrogen based economy.

ii. Foreign Oil

The push towards developing a hydrogen based economy can also be attributed towards an increased desire to be unbound from foreign oil supplies. As a commodity subject to world crises, the oil market is very volatile and seems to be steadily increasing in price. With gasoline prices slowly rising above $2.00 a gallon in the US, there is a greater push towards finding a cheaper alternative. With the vast majority of oil imported to the United States from foreign countries and most from the Middle East, the economy is at the mercy of foreign problems.

The possibility of oil production simply stopping is also a national security problem. If oil simply stopped being produced or delivered to the US for only a few days, the economy would suffer a massive shock at least on the order of 9/11 if not the size of the stock market crash of the 20s or even greater. With the recent terrorist attacks, there is an even greater desire to have an economy unbound by the whims of other countries and opposing peoples.

2.2 *Current Obstacles to Achieving a Hydrogen Based Economy*

There are several obstacles in place that are presenting roadblocks to building a hydrogen infrastructure. Industries currently build most facilities to produce hydrogen near where they are needed. This not led to the development of many things that will need to be addressed to conquer the problems posed by a hydrogen based economy.

i. Hydrogen Transport

Currently most hydrogen needed for extraction and industrial use is produced onsite. A safe, efficient method of transport is needed to get the product to the market – in this case the hydrogen to some sort of "Hydrogen station," similar to the current gas stations. There remains the question of how to transport this gas that is flammable.

ii. Prohibitive Costs

The Hydrogen used, whether for industrial or commercial purposes, must be cheap. That includes more efficient production methods, cheaper transport to needed locations, and more places and methods it can be produced from. It also includes costs that cannot be measured in dollars such as the effect on the environment and the ability to perpetually continue the production of hydrogen. There are also rare materials needed that greatly increase the cost of producing viable fuel cells for use in the average vehicle.

iii. Mass Production

The final goal of the hydrogen based economy is to replace gasoline driven vehicles with a hydrogen fuel based one. Whether it is complete replacement or a mix of different hybrid technologies remains to be seen but in order for a commercial economy to be created, it must be able to be used to replace or co-opt the millions of vehicles currently in use today. If the materials to produce or use in fuel cells or some part of the

vehicle that makes use of hydrogen is prohibitively expensive, it will prevent the mass production and distribution of vehicles to the public.

iv. Safety

Sadly, the most well known symbol associated with hydrogen is the Hindenburg. This has caused a stigma and fear against using hydrogen for simple things like powering a vehicle for everyday transportation. Hollywood movies have also presented a view of fuel cells as possible "mini-nukes." Some new designs emerging soon claim to be even safer then gasoline tanks, but further testing is required to prove the voracity of these claims. Regulating large stockpiles of hydrogen will be a challenge in the new economy because there still is a very real possibility of explosion.

3.0 Hydrogen Production Methods

3.1 Electrolysis

It is the simple method of passing an electric current through water. The Oxygen and the Hydrogen separate and are easily collected. The largest problem is the inefficiency associated with the process. There are far more efficient ways of directly creating Hydrogen without going through an intermediate step of producing electricity from power plants and then converting it to Hydrogen (with the associated energy loss). This would be a good approach when there is an over-abundance of electricity, produced at very little cost.

3.2 Steam Methane Reforming (SMR)

Steam Methane Reforming is the largest producer of hydrogen for most industries. It is relatively efficient and more inexpensive then many other methods. It is also a well studied and tried technology so there is a knowledge base experienced with production. There is some Carbon dioxide emission but it can be controlled with low resulting air pollution. The larger problem is the reliance on availability of natural gas. The United States has a limited supply of natural gas that has been facing price increases

for the last decade. A volatile market could destabilize the price and prevent a stable production at an acceptable price range when Hydrogen becomes more of a demand.

3.3 Coal Gasification

Coal contains a form of hydrogen that has been found to be extractable with a current cost slightly more then that of SMR. With some more development and research there is a possibility that it could present a good contributor to the hydrogen economy. The largest problem is the pollution that comes from mining and using the coal in both energy and hydrogen applications. The current goal is to reduce much of the emission of pollutants into the environment while this could simply be juggling the type of pollution until better methods are found and put into practice.

3.4 Biomass

There are several different ways of producing hydrogen through biological means, but they can fall into either gasification or a form of bio-synthesis.

i. Bio-gasification

Burning different biological products rich in hydrogen, such as wood chips and certain pieces of agricultural wastes, is a viable means of producing hydrogen. The technology has been researched, tested, and is currently in use world-wide in certain applications. Most of the opposition has been from the price, but it could become a competitive source of hydrogen if there is enough of an increase in the need for hydrogen.

ii. Bio-synthesis

There are many species that have different forms of photosynthesis that scientists have studied for years. There is a recently emerging technology that has allowed biologists to grow certain algae that can produce hydrogen. It shows promise, but has two large obstacles against helping the new economy. This bio-synthesis could have land requirements similar to that of Solar power that could make it prohibitive, but more importantly it is a developing technology. Since the knowledge base is just evolving, there is not enough information to know if it is a viable alternative for hydrogen production needs.

3.5 *Wind, Solar, and Similar Alternatives*

Electrolysis would be used to produce hydrogen from Wind, Solar, and Similar (such as Hydroelectric and Geothermal) power sources. They are pretty much infinitely renewable power sources that cause little damage to the environment in ways such as carbon emissions, waste storage, or some other undesirable effects (ignoring some possible problems with hydroelectric dams for the moment). The big problems come from expense and feasibility. These power plants cannot be placed anywhere near most of the areas that need them most and many are seasonal. Sunlight doesn't produce the same amount of energy throughout the year, rivers freeze over, and wind patterns change. They are also prohibitively expensive and most take large amounts of land. If it is attempted to use these as a power source for both energy and hydrogen production, they would be intermittent at best. No matter how environmentally friendly they can be argued to be, they cannot solve the energy production of current levels, let alone of the future with any current ideas given serious weight.

3.6 *Thermo-chemical*

Emerging high temperature techniques make it possible to more easily extract hydrogen at higher efficiency and without an intermediate step through power plant production. Promising experiments, designs, and demonstrations have shown the feasibility of high temperature extraction of hydrogen from high temperature nuclear power plants and certain other sources. The most promising is from a nuclear method, and the ramifications are discussed in the next section. As with other methods, there are still some obstacles: prohibitive costs in nuclear plant construction, public stigma towards nuclear facilities

4.0 The Nuclear Alternative

4.1 Power and Hydrogen Production

Currently, nuclear power accounts for approximately 20 percent of power produced in the US. If even a few of the recommended expansions from the MIT Study are implemented, a significant number of new nuclear power plants will be built. There are many designs that currently take advantage of the Thermo-chemical hydrogen production method mentioned in the last section to produce hydrogen as well as electricity. Hydrogen can be produced simultaneously with electricity, and can even be decreased or stopped when peak power demand is reached. With *no* carbon emissions, nuclear technology offers a well balanced production method that can become economically competitive if other issues can be overcome.

4.2 Waste

The largest obstacle to nuclear power seems to be the current NIMBY syndrome or "Not In My Back Yard." Much of the stigma over Chernobyl and Three Mile Island has faded in lieu of a good track record, increased education, more regulations, and better technology - but the worry over waste disposal continues. If several of the MIT Study recommendations, better and cheaper reprocessing technologies, or other creative solutions can be implemented, nuclear production will be a forerunner for developing the hydrogen economy.

5.0 Final Conclusions

5.1 Favoritism

In order for a solution to work, there must be a number of compromises made to most parties. In the MIT Study, a definite position of pro-Nuclear was defined, and a stance taken to force it to the fore. Whether right or wrong, it will likely be fought by industries currently enjoying influence in Congress. It is hard to justify suddenly changing position to actively subsiding new nuclear developments with a clear favoritism towards the nuclear industry. If such a tax is implemented it would grant nuclear power a position at the fore of the hydrogen production market. However, there is another solution that could make nuclear power a contender for the market, but not create an unbalanced solution that would be unacceptable to all parties. With President Bush's push towards a hydrogen based economy, all industries should be given a chance to be included. No method can be brushed aside or given wild advantages over their inherent benefits.

5.2 The Goal

The original goal in changing to a hydrogen fueled economy is to reduce emissions of Carbon dioxide and other pollutants. To this end, government should mandate certain hydrogen production emission standards so that the load is not simply shifted from where it is produced instead of reducing it. The best was to accomplish this would not only be an upper limit to emission standards, but a similar "carbon tax" to the one suggested in the MIT Study.

By creating this tax before an infrastructure is in place, there is reduced opposition to ground rules laid before companies begin moving towards production. This tax would also make it a fair competition. This would come from the inherent benefits and flaws from each method. Some methods still produce carbon and other pollutants and will have to bear a tax burden until they can develop cleaner technologies if they wish to compete in the industry. The tax would also provide funds for incentives such as grants to improve efficiencies and create new production technologies.

Subsidies and grants have historically been given for areas that are determined to be in the public interest or need that cannot be gained through the income received. They have also been offered in the development of new needed technologies. First movers and a variety of risk takers judged to have possible benefits should be awarded grants to begin development in the field. They would be valuable to test certain aspects of newer generation nuclear power plants that would lend invaluable experience and reduced construction costs to following reactors. Once a few new designs have been built, the MIT Study suggested that subsequent building costs would decrease and that should lend towards nuclear power becoming an economically competitive alternative.

The goal of the tax is to level that playing field and make the original movers into the field all competitive. Coal production methods will lose some of the lower cost advantage from emission problems until more environmentally friendly sequestering methods are developed. At the same time, solar power will benefit from no tax but suffer from inherent inefficiencies and costs.

5.3 Supplemental

The goal of this report was not necessarily to advocate a certain method, but to suggest a more level playing field that would allow them all to be economically competitive in a new hydrogen economy. Each method has benefits such as the low cost of coal or natural gas, the flexibility and stability of nuclear, and the nearly nonexistent pollution of renewables like solar power. By making nuclear power economically competitive in the hydrogen field, it also benefits to the energy production side, but does not gain an undue advantage from a demand from any interest group. Further research would reveal if some of the issues with nuclear or other production methods, as well as the hydrogen fuel issues can be resolved with a reasonable amount of research or money.

Acknowledgements

Dr. Tokuhiro has contributed a lot of his time and many helpful thoughts on the direction of this project. I greatly appreciate his patience and guidance towards creating a better report that will hopefully help find a solution to current energy and hydrogen needs.

References

1. Key Initiatives in the President's State of the Union Message, http://www.whitehouse.gov/news/releases/2003/01/20030128-14.html, Last Retrieved 3/22/05
2. Where Does Hydrogen Come From?, http://www.rmi.org/sitepages/pid557.php, Rocky Mountain Institute, Last Retrieved 3/22/05
3. Bush unveils US alternative to Kyoto protocol, NewScientist.com news service, Fred Pearce, http://www.newscientist.com/article.ns?id=dn1932, 09:50 15 February 2002
4. What is a Fuel Cell?, http://www.bullnet.co.uk/shops/test/hydrogen.htm, Last Retrieved 3/22/05
5. Hydrogen Production Using a Thermochemical Process Made Possible with the Use of a Ceramic Membrane, http://www.greatchange.org/bb-thermochemical_hydrogen.html, Last Retrieved 3/22/05
6. Nuclear Now, Peter Schwartz and Spencer Reiss, *Wired* (February 2005) pg 79-83 and 119-120
7. Economics and Environmental Effects of Hydrogen Production Methods, Greg Brinkman, Fall 2003, accessed at http://www.puaf.umd.edu/faculty/papers/fetter/students/Brinkman.pdf Last Retrieved 3/22/05
8. The Future of Nuclear Power, Ansolabehere, Deutch, et al, Copyright 2003