I. Executive Summary

The first fuel cell vehicles that will be on the market will be those that take some type of existing fuel, such as natural gas, gasoline, ethanol or methanol. Most articles and news releases indicate that using this type of fuel, with the reformer extracting the useful hydrogen to power the vehicle, results in a great deal of lost energy. Often people compare the efficiency of these fuel cell vehicles with the hybrid vehicles that are currently on the market (Toyota Prius and Honda). But, the argument that is made is that eventually a hydrogen infrastructure will be in place to allow the fuel cells to operate on pure hydrogen, without the reformers, resulting in what is called the ZEV (Zero-Emission Vehicle).

This paper compares and contrasts the fuel cell vehicle and the hybrid electric vehicle and their impact on society. This paper proposes that investing in fuel cell vehicles is a benefit to society, but only if hydrogen produced from renewable energy sources is used, or if hydrogen from natural gas is used. Otherwise, the hybrid vehicle is environmentally better and more cost beneficial. We should continue to develop the fuel cell vehicle in an effort to reach the pure hydrogen vehicle, but we should also continue to improve the hybrid vehicle. However, developing the fuel cell vehicle, without a cooperative effort from the energy production arena, will have negative effects on society. Wind, solar and other renewable energy sources must be accepted in society before the hydrogen fuel cell vehicle can flourish, since hydrogen generated by traditional sources results in an expensive fuel and since the electricity used generates pollution.

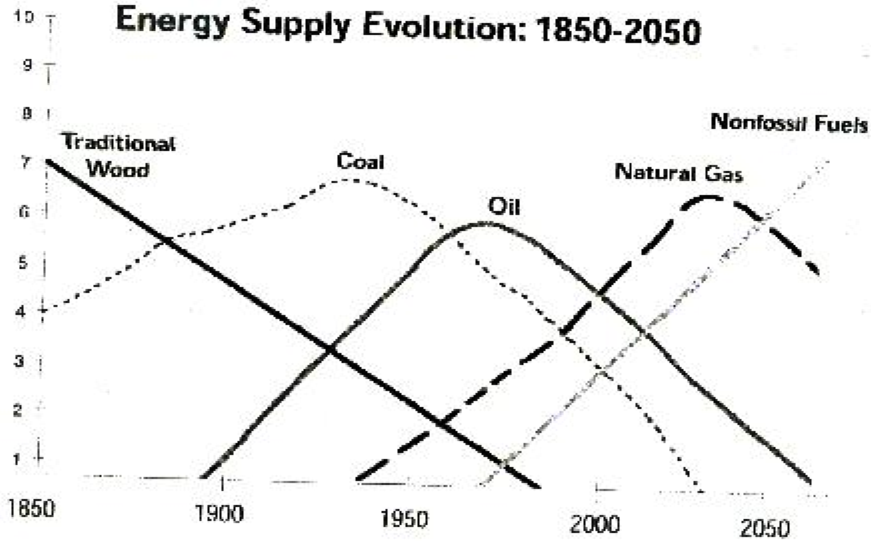
II. Technology

As the world's population increases, so does its use of energy. A tenfold increase in the population since the time of Columbus reaching the current 5.6 billion people worldwide, has resulted in a hundred fold increase in energy use [5]. Energy is provided in the form of electricity to buildings, natural gas to homes, fuel to cars, and other means. In 1989 the world's energy consumption was supplied by various sources: 36% oil, 23% coal, 19% natural gas, 6% hydroelectric, 10% biomass and 6% nuclear [5]. Of the 36% associated with oil, most is used in the transportation industry. Currently, gasoline and diesel power 99% of the world's 520 million vehicles[5].

In 1989, there were 145 million drivers in the U.S. and by 1993 this number has risen to 169 million drivers. The number of cars in the U.S. in 1989 was 122 million and in 1993 reached 143 million [15]. These numbers are ever increasing with the United States purchasing 4,200-5,600 buses per year and California car sales reaching approximately 1.5 million per year [9] by itself. The 1998 predictions for new passenger car sales were 17 million in North America, 16 million in Europe and 8 million in Japan [9]. Locomotive sales in the United States for 1993 were 300-500. In 1992 there were 709,000 buses on the roads of US and Canada, with 65,000 being transit buses [9].

At the same time that vehicle sales are increasing, the supply of petroleum in the United States is decreasing. Of the world's 650,000,000 motor vehicles, only 1,500,000 are not powered by diesel or gasoline, but are primarily powered by liquefied petroleum gas or compressed natural gas [2]. For the first time, in 1993, oil usage in our nation's transportation industry alone, consumed 30% more oil than was produced in our nation. The United States only produced 12% of the total world oil output in 1993 [5].

Fossil fuels are currently burned 100,000 times faster than the rate at which they are generated [5]. Caesar Marchetti's research work from 1970's predicts energy fuel use trends. In his works, he produced a graph, as shown below, which showed the rise and fall of various fuels in relation to time. According to his graph, he predicts oil will provide a very small portion of the world's energy in the year 2050 with renewable resources providing the majority. At the same time, he indicates that it takes 50 years for new fuels to reach 50% of the maximum energy usage worldwide [5].



Since oil supplies are decreasing, while vehicle demand is increasing, a new fuel will soon be necessary to power our vehicles. The two alternatives discussed in this paper are the fuel cell vehicle and a hybrid vehicle. A comparison will be made between the two in terms of their societal impact, ethical impact, economics and environmental impacts, both in the short term and the long term.

A fuel cell is a power-generating system for electric vehicles that converts the chemical energy of hydrogen and combines it with oxygen to produce electric energy, heat and water. The fuel cell system is restored with chemical energy rather than electrical recharging. Some form of hydrogen is required for all fuel cell vehicles. Fuel cell systems can operate on hydrogen produced from on-board reformers fueled with hydrogen-rich fuels such as gasoline or methanol. But the on-board reformers are complex and reduce the efficiency of the fuel cell systems in addition to generating pollutants. The most efficient type of fuel cell vehicle (looking at on-board efficiency alone) would be one powered from pure hydrogen. Many components used in an electric vehicle are also found in a fuel cell vehicle. Currently, fuel cell vehicles are being prototyped, with their market entry expected in 2004 or 2005.

A hybrid vehicle is any vehicle that uses two or more sources of power. Today's hybrid electric vehicles (HEVs) use electricity (from batteries) and mechanical power (from a small internal combustion engine). Three types of configurations exist: series, parallel and split. In the series configuration, the engine never directly powers the car. Instead the engine drives the generator which either charges the batteries or drives an electric motor to power the car. In the parallel configuration, the engine connects to the transmission, as do the batteries and the electric motor. So either the engine or the generator/motor can supply power to the wheels, switching back and forth to optimize the efficiency. In a split configuration one axle is driven by the electric motor and the engine drives the other axle, with no interconnection other than the road itself. Currently, two hybrid vehicles are on the market in the United States: the Toyota Prius and the Honda Insight.

Existing hybrid vehicles use standard gasoline for their fuel, while any fuel-cell system, vehicular or otherwise, can provide power only after a series of infrastructure elements (e.g. fuel production, fuel transportation, and fueling stations) deliver energy from a primary energy source (e.g., a coal mine, oil well, or wind farm). Without parallel development of the U.S. energy infrastructure, the use of any alternative-fuel will be strongly inhibited [7]. Even the fuel-cell vehicle that uses gasoline requires a type of gasoline that needs to be specially formulated to reduce the amount of sulfur.

Fuel cell vehicles are expected to exceed the fuel economy goal of 80 miles per gallon (mpg) using a hydrogen carrying fuel and in excess of 100 mpg using pure hydrogen [7]. Each of these mpg ratings has been converted to equivalent gasoline miles per gallon. The Prius reportedly has a fuel efficiency of 52 mpg city/45 mpg highway, while the Insight has a fuel efficiency of 61 mpg city/68 mpg highway. The Prius holds 5 passengers while the Insight holds only two passengers.

Three barriers to hydrogen based fuel cell vehicles include the following: integrating small, lightweight, inexpensive, and efficient fuel cell engines into automobiles, designing storage tanks for sufficient onboard hydrogen storage capacity, and developing an appropriate hydrogen refueling infrastructure [7]. There are also other technological problems to overcome --- the proton-exchange membrane cannot have any holes, the catalytic coatings on the bipolar plates cannot be porous, the need for high noble metals keep stack costs high (requires 10 grams of platinum for midsize car), cold starting, and leak detection [3]. Problems with hybrid vehicles are that they still use existing fuel sources, but they only require about ½ as much as the average IC engine.

III. Social Impact

Principle stakeholders of the fuel cell and hybrid vehicle technology will be oil companies, power generators, automobile manufacturers and anyone who rides or drives an automobile. Currently, it appears that natural gas, methanol, reformulated gasoline or ethanol will be the primary fuels used in fuel cell vehicles, since they are the most commercially available. Before pure hydrogen can be used, transportation issues related to refueling a car with hydrogen need to be solved in addition to safety and storage issues.

Gas stations will also be impacted by this technology, Since they will need to supply reformulated gasoline, ethanol or methanol; they will need additional gas tanks and will need to learn how to store these materials.

Firms wedded to IC engine components, such as crankshaft forgers or piston-ring makers see fuel cells as a distant threat, if at all. However, those firms that produce other key automotive items, not dependent upon ICE engines, like heat exchangers, power distribution systems, electric motors, pumps, condensers and fasteners, think that the fuel cell vehicle presents great opportunities [3]. Because the hybrid vehicles and fuel cell vehicles use many of the same components used in the electric vehicle, the companies that invested in electric vehicles will now benefit from their initial research and investment. With the hybrid vehicles, IC components are still used, so the stakeholders of this technology are minimally affected.

Initially, the fuel cell vehicles will be focused on the higher socio-economic levels, as they are expected to be more expensive than current cars. However, the general population are not impacted by the hybrid cars, as they are only slightly more expensive than a comparable IC vehicle.

On the Daimler Chrysler web page, they indicate that approximately 2,000 high tech jobs have been created in Germany as a result of their fuel cell vehicle programs. It is likely that additional new jobs will be created, but re-training the IC workers will be necessary so they can transfer to this new industry. For the hybrid vehicles, IC workers will still be required, so in addition to the new job created, additional training for the electrical components associated with the hybrid car will be necessary.

Daimler Chrysler (DC) has formed a multi-billion dollar alliance with Ford and Canadian fuel cell technologist Ballard Power Systems. DC and Ford are staffing Ballard with purchasing and manufacturing people as it ramps up to volume production in 2003 [3]. Ballard, in the last 10 years has risen from a 35 person R&D firm to a 10,000 person firm [3]. These numbers show the employment trends for this new technology. Since hybrid vehicles are on the market, an increase in the number of employees was required for its production and release. Also, mechanics will require further training to troubleshoot this new technology.

Fuel cell vehicle benefits can include the following:
? alleviating CO2 and hydrocarbon pollution completely (if hydrogen generated from renewable energy sources is used),
? reduced noise,
? driving ranges similar to IC vehicles,
? refueling similar to IC engine,
? lower operating temperatures,
? no moving parts,
? part load efficiency increases that result in better city driving in a fuel cell vehicle [11].
If all of the worlds' cars operated on fuel cells using water and hydrogen, less than 0.10% of the worlds fresh water reserves would be necessary. All of this water is replenished in a closed cycle [5].

The societal advantages of hydrogen fuel cell vehicles include reductions in urban air pollution and the risk of oil spills, more efficient use of finite resources, a reduction of U.S. dependence on foreign oil, and reduction in carbon dioxide emissions implicated in climate change [7]. Even hybrid vehicles and fuel cells powered with gasoline or another reformed fuel offer the same advantages, albeit at a reduced level. They still require oil to be imported, but the amount of oil to be imported will reduce due to their increased efficiencies.

In 1996, more than half of the U.S. transportation oil came from overseas, mostly originating from Venezuela, Canada, Saudi Arabia and Mexico [7]. Reducing this dependency will help the U.S. become less dependent on other countries and perhaps lower the military budget, since some people believe that a large task of the military is to defend our "rights" to oil supply in other countries. However, perhaps removing this dependency on other countries will not bring people together, since if you are dependent upon someone or something you are more likely to negotiate. When people don't need things or people, they are less likely to be as cooperative. This is a part of the human condition.

IV. Ethical Questions

Hydrogen is produced by various methods, with the use of natural gas and the steam reformation process being the most popular and the cheapest. Once hydrogen is produced, the next issue in using it for vehicular purposes arises with transporting and storing it. There are several concerns over transporting and storing hydrogen. Hydrogen has an excellent safety record, but low emission temperature and its ability to diffuse rapidly combined with its fast flame speed result in safety issues [5]. These safety issues could potentially result in death to an untrained person.

It has been estimated that an excess of hydrogen production from existing facilities in the Los Angeles Basin alone could power 46,000 to 138,000 fuel cell vehicles with fuel economies above 100 mile per gallon [7]. Utilizing this excess hydrogen could certainly produce the maximum good. But again, there are problems with immediately using hydrogen in vehicles, before safety issues are resolved.

The United States Clean Air Act mandated a reduction in air pollution which led the California Air

Resources Board (CARB) to establish the Low Emission Vehicle (LEV) program, which includes mandates of Zero Emission Vehicles (ZEV). A ZEV is defined in California as being a car that produces no pollution at the tailpipe. This law does not consider any pollution resulting from the production of the fuel required for the cars, be it gasoline or hydrogen.

Originally CARB required the auto manufacturers to produce for sale a percentage of their fleet vehicles as ZEVs. The original mandate required 2% by 1998 and 10% by 2003. The requirements for 1998 were lifted, but currently the 2003 limit of 10% still remains [11]. Several northeastern US states have adopted California's zero-emission vehicle (ZEV) law [3].

The CARB LEV program benefits fuel cell technology by supporting research on electric vehicles resulting in improved drivelines and improved control electronics directly related to that used in fuel cell vehicles. Since the same technology is used in a hybrid vehicle, this program is beneficial to hybrid vehicles as well. The CARB program provides more support for fuel cell vehicles, since hydrogen fuel cell vehicles are ZEVs, while hybrid powered vehicles are not. Since the program provides benefits to both technologies, this eliminates a portion of the competition between fuel cells and hybrid powered vehicles in this market [11]. However, to promote the maximum good we truly need to look at the emissions of these vehicles based upon the emissions from producing their fuel to the emissions at the tailpipe. Producing hydrogen requires a tremendous amount of energy, so saying that a hydrogen fuel cell vehicle produces zero emissions is simply not true. As long as this misperception exists in society, the maximum good and the common good will not be provided. In the document written by the California Energy Commission, there is no mention of the total emission, from the wells to the wheels [6].

By adopting these zero emission mandates, we are required to pursue this new technology, regardless of its effects. Since we are all stakeholders in this technology, the definition of a ZEV should be changed so that the full cycle of a car is considered. There is a study performed by the Pembina Institute for Appropreiate Development that compares the various fuel cell technologies powered by various fuels with the existing IC engines and hybrid vehicles. Looking at this study, one can see that the existing definition of a ZEV is not fair to the hybrid vehicle industry. Since tax benefits and incentives are provided for ZEV vehicles, the same should be true for hybrid vehicles. For further information on this, see the Environmental section of this report.

Another program, the Partnership for the Next Generation of Vehicle (PNGV), program established by the US government with Ford, General Motors and Chrysler, has a goal of creating a prototype fuel cell vehicle that achieves 80 mpg (three times the average conventional IC vehicle) [11]. While this is not a mandate, it certainly creates standards and goals for the industry to work toward. Without standards, there is no comparison.

Fuel cells and hybrid vehicles also help support current political commitments. The United States is committed to decreasing greenhouse gases by 7% below actual 1990 levels. However, studies show greenhouse gases will actually increase by 33-40% given current trends [4]. This creates a major challenge to the United States and an opportunity for renewable hydrogen fuel cell vehicles, by allowing them to present part of the solution for this political commitment.

Fuel cell and hybrid vehicle can also improve society's welfare. The American Lung Association estimates that the health care costs associated with illnesses and premature deaths resulting from breathing automotive pollutants may total $50 billion annually [5]. This in itself should promote the use of cleaner vehicles, be it fuel cell or hybrid vehicles. If this estimate is anywhere near being true, then simply riding in an ambulance violates your right to a healthy life. Isn't that ironic.

V. Economics

When considering the economics associated with the two technologies, we must look at the vehicle costs as well as the capital costs associated with installing new fueling stations and the fuel cost itself. For hybrid vehicles, the cost of the fuel is the same as what it is for our existing IC engines. Unfortunately, only low-grade mineral water is cheaper than tax-laden motor fuel [2]. In the 1920's, a gallon of gasoline cost more than 30 minutes of labor, but in the mid 1990s, the cost was six minutes and falling [2]. This makes it tough for us to look at different fuel sources and find them to be economically feasible.

The externalities associated with IC vehicles result in extra costs not attributed to the cost per gallon of gasoline such as $20-50 billion in health care costs, $2.5 to 25 billion estimated on impacts of carbon dioxide on global climate, $2.5 to $9 billion resulting from worldwide impacts of oil drilling, refinery emissions, and oil spills, $5 billion for emission control devices on new vehicles, and $500 million on operating emission testing facilities [5]. Life cycle costs from research often indicates that 10 years of life will allow the fuel cell vehicle to become more economical than gasoline IC, providing hydrogen produced from natural gas [5].

If you include the external costs, you must remove the taxes on today's fuels, in order to compare the costs, which results in a conclusion that the cost of fuel cells must be reduced in order to be competitive with IC gasoline engines [8]. The external costs are also quite debatable, but the public should be aware that such external costs do exist and should be used as a gauge in determining the economic viability of fuel cell vehicles. Alternatively, fuel taxes could be used to spur the development of alternative vehicle technology by placing a penalty on IC vehicles.

The only manner in which other fuels appear to be feasible is when we consider the money spent for fuel on a mile by mile basis, otherwise known as a life-cycle analysis. For example, if a car is more efficient, but the fuel is more expensive, the overall cost to refuel the car for each mile driven may be equal. When looking at fuel in this fashion, then we can compare the costs on an apples-to-apples basis. Today's hydrogen (produced primarily from natural gas) costs more than nine dollars per gallon of gasoline equivalent because of its limited scale of production [2].

"The most interesting is the break-even gasoline price, the price of gasoline at which the full life-cycle cost in cents per kilometer is equal to the full life-cycle cost of the alternative. Under his (Mark DeLucchi) assumptions, when gasoline sells at $1.36 a gallon, including current taxes, the life-cycle cost of a hydrogen fuel cell vehicle will be about the same as the life-cycle cost of a gasoline vehicle [15]." In reading several different sources, the break-even gasoline price seems to float widely, depending upon certain assumptions. Determining the real break-even point would require an entire paper in itself, similar to determining the real quantity of oil left on our planet. It is tough to project out the costs of a fuel that is not yet commercially available and requires a great deal of capital investment to become commercially available.

To break through the current pattern of incremental advances and fulfill the dream of the ultimate alternative-fuel vehicle, it is estimated that the number of fueling stations must pass a threshold of 10,000 to 20,000 which is comparable to approximately 10-15 percent of the total number of diesel and gasoline stations currently in the United States [7]. Hydrogen refueling infrastructure would entail an investment of tens of billions of dollars in the U.S. alone [2]. Since hybrid vehicles have existing gas stations, they are not faced with this problem, but any type of fuel cell vehicle is faced with this problem.

Analyses have projected a capital cost of piggybacking on the natural gas infrastructure with steam methane conversion devices of $200-$500 per vehicle, assuming that a fully developed fleet of vehicles is utilizing all of the hydrogen produced [7]. Other hydrogen infrastructure alternatives include containers that would be installable, removable and returnable to meet the fueling needs of a particular driver [7]. Developing these containers, would reduce initial capital costs, facilitate siting procedures for refueling locations, ease the problem of distant and rarely used refueling locations, and justify the installation of larger and thus more cost effective centralized hydrogen production facilities [7].

A study by five environmental groups in 1997, including the Alliance to Save Energy, concluded that hydrogen fuel-cell vehicles would begin to be marketed in 2010 at a $10,000 premium over conventional IC engine vehicles, given that today the fuel cell vehicle would cost $200,000 [2]. NECAR4 and its counterparts are still roughly 10 times too costly and 30% overweight to be viable in today's market [3]. The Daimler Chrysler fuel cell program indicated 50% of the cost reduction will come from volume production and the rest from less expensive materials and greater tooling efficiencies [3].

Hybrid vehicles are currently selling for approximately $20,000 per vehicle. This price is in line with other vehicles of a similar size. Thus, hybrid vehicles are competitive in today's market.

Hydrogen production technologies in use today include the following: Steam reform uses steam injected into natural gas to produce hydrogen and carbon dioxide which is 65% efficient and costs $0.64 / kg; Off-gassing takes gas from the stacks of petroleum refining, blast-furnaces and some chemical plants and captures hydrogen at a cost of $0.80 to $1.20 /kg, but most of this is used on site; Electrolysis uses electricity to split water into hydrogen and oxygen at a cost of $2.40 to 3.60 / kg when electricity is provided by a renewable resource [12]. As a result of one or more of these hydrogen production technologies, there are approximately 300 miles of hydrogen transmission pipelines in Texas and Louisiana. [12].

Issues related to the economics associated with using hydrogen as a fuel, include the following: fuel costs, vehicle costs, cost of externalities, economic credits and life cycle cost. Hydrogen fuel costs, are typically 20 cents more per equivalent gallon (similar energy content) of gasoline when produced from natural gas [5]. The cost is expected to be $1.45 to $6.90 per equivalent gallon when hydrogen is produced from renewable resources. Currently the largest solar production facility is in Germany where they produce hydrogen from water in a 270 kW plant powered by PV [5].

Some people believe that we need companies to buy into the technology to help pull it through the market rather than mandating it [15]. This may be what DaimlerChrysler in affect is doing, by publicly stating that they hope to sell fuel cell vehicles at only 10% above IC vehicles. DaimlerChrysler proclaims it will have mass production of fuel cell vehicles by 2004 and 150,000 per year by 2006 [4]. According to recent newspaper articles, the cost of their fuel cell system is typically $30,000 in comparison to the IC engine which costs $3,000. The newspaper articles also indicate that DaimlerChrysler hopes to sell the cars at 10 percent over the cost of gasoline-powered vehicles. From this, one can deduce that DaimlerChrysler will either significantly reduce the cost of production of the fuel cell system or they will take a loss for this new technology. Either option would help fuel cell vehicles enter the market more easily.

Another source indicated that vehicle costs associated with hydrogen fuel cell vehicles add approximately $4,300 to $15,300 to the invoice of the car [5]. This is less than the $27,000 difference presented by DaimlerChrysler in recent newspaper articles.

In the United States, $6 billion in incentives will be provided over a 5 year period due to efforts by President Clinton's efforts to help boost the reduction of carbon dioxide. A $3,000 tax credit in 2000 for purchasing vehicles that get 2 times the current average mpg and a $4000 tax credit in 2003 for purchasing vehicles that get 3 times the average mpg [4]. But simply looking at the mpg ratings does not determine the reduction in carbon dioxide. If a fuel cell vehicle is powered by hydrogen that was produced through electrolysis, and the electricity for the electrolysis was generated by a typical power plant, then the carbon dioxide may actually be increased in comparison to burning gasoline in an IC engine. The public policy decisions need to be aware of these differences and take them into account.

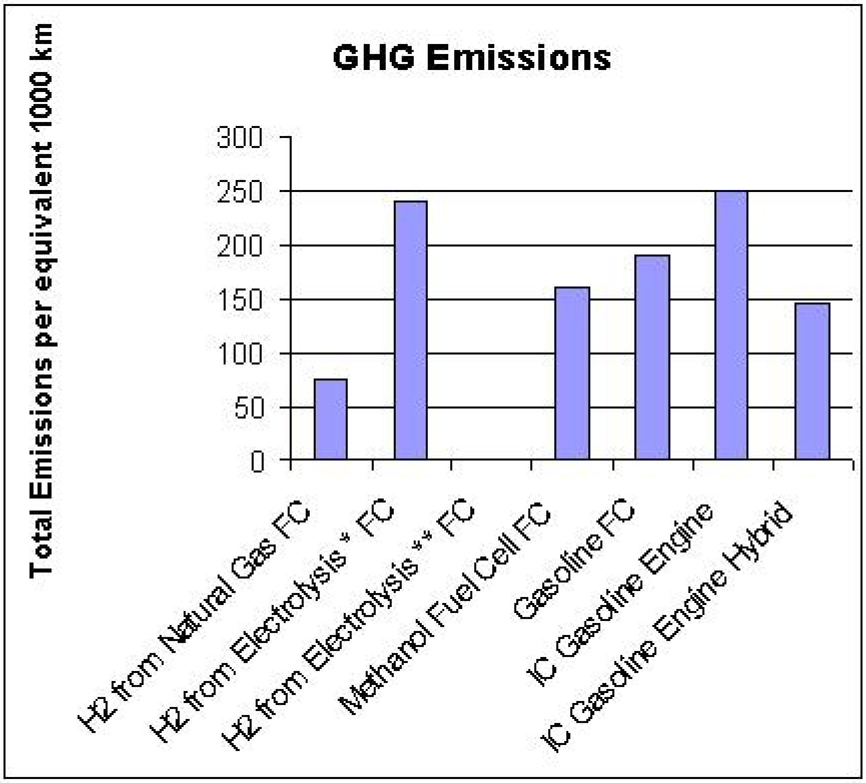
More than $50 billion currently flows overseas for U.S. consumption of about 3.4 billion barrels of imported oil each year (net) [7]. As previously mentioned, reducing this will also reduce our trade deficit, thus improving the economic conditions of the U.S. This benefit will occur with both technologies. The U.S. spends $55 billion per year on imported oil, which constitutes approximately 50% of the federal trade deficit.

VI. Environmental Issues

Gas vehicles emit carbon dioxide (CO2), hydrocarbons (HC), carbon monoxide (CO), nitrogen oxides (NOx), sulfur oxides (SOx), and particulate matter (PM). EPA estimates that motor vehicles in the U.S. account for 78% of all carbon monoxide (CO) emissions, 45% of nitrogen oxides (NOx) emissions, and 37% of volatile organic compounds (VOC) nationwide [1]. As a result, vehicles and their well to wheel efficiencies have a tremendous impact on our environment. While these numbers sound bad, there are some positive statistics. New passenger cars in the U.S. have reduced major emissions by more than 90% [2]. According to the EPA, "Since 1970, national total emissions of the six criteria pollutants declined 31 percent, gross domestic product increased 114 percent, and vehicle miles traveled increased 127 percent [2]." However, the emissions from the actual vehicle is only a portion of the resulting environmental pollution. The transportation of fuel, refining of fuel and refueling of vehicles also contributes to pollution [11].

For fuel cell vehicles, when the total system losses are considered, using reformulated gasoline as an example, just over 20 percent of the fuel energy is lost in production, whereas with hydrogen it is closer to 60 percent [1]. From this, it looks like we should not use hydrogen, but should use reformulated gasoline. However, we must realize that the reformulated gasoline must still go through the reformer where more losses are incurred.

The Pembina Institute for Appropriate Development recently released a study that compares the total emissions, from wells to wheels of fuel cell vehicles compared to conventional and hybrid vehicles. This study shows the following [1].



The item above in the chart with "*" indicates the electricity used to produce the hydrogen is generated from combined cycle natural gas electric generating plants. The item above in the chart with "**" indicates the electricity used to produce the hydrogen is generated from renewable energy resources. From this chart, it is clear that the only fuel cell vehicle that should be developed is the one that uses natural gas, or one that uses hydrogen produced from renewable energy. Otherwise, the hybrid vehicle is the best environmental option.

From this study, it is quite evident that for hydrogen fuel cell vehicles to truly be a zero emission vehicle, the hydrogen must be produced by a renewable energy source such as; solar powered water electrolysis, solar electric sources, from biomass via gasification, etc. If hydrogen is produced by directly utilizing power plant electricity, then the emissions from the power plant are almost equivalent to the emissions of an IC engine. Unfortunately, the current definition for ZEV is more loosely interpreted and all hydrogen fuel cell vehicles are considered zero emission vehicles.

Some regions give incentives for Zero Emission Vehicle (ZEV) buses or have a higher percentage of ZEV buses as a goal. There may be the possibility for ZEV owners/transit districts to obtain emission credits of 0-3.5 gm of NOx / bhp-hr and they can sell them to utilities or other entities in order for them to offset their emissions from stationary sources [11]. Others have even indicated that economic credits should be made available to those who use fuel cell vehicles, possible resulting in $1,000 per year worth of emission credits [5]. While this sounds like a good idea as far as providing an annual cash flow for fuel cell vehicle buyers, it seems to contradict one of the main reasons for promoting fuel cell vehicles; that of creating a cleaner environment. If the decrease in pollution attributed to your fuel cell vehicle can be sold to a company as a credit, thus allowing them to pollute more than the law permits them to, we are really only breaking even in terms of pollution. And, if the fuel cell vehicle is powered by hydrogen generated by a power plant, then we are truly producing more pollution by allowing credits for a false reduction in emissions.

A study by a committee of the National Academy of Sciences and the National Academy of Engineering criticized the hybrid electric vehicle technology as not being environmentally cost-effective [2]. With these discrepancies in the technical world, it is no wonder billions of dollars are being spent on technologies that do not appear to produce the maximum good.

Other solutions, that could make hybrid vehicle even more environmentally friendly, would be to use refined oil in the cars for oil changes. Implementing this along while requiring engine manufacturers to increase the required oil change intervals from 6,000 miles to three times this value, is estimated to decrease oil usage in cars by 75% [5]. Of course, this improvement is also applicable to current IC engines.

VII. Conclusions

This paper has determined that investing in fuel cell vehicles is a benefit to society, but only if hydrogen produced from renewable energy sources is used, or if hydrogen from natural gas is used. Otherwise, the hybrid vehicle is environmentally better and more cost beneficial. We should continue to develop the fuel cell vehicle in an effort to reach the pure hydrogen vehicle, but we should also continue to improve the hybrid vehicle. However, developing the fuel cell vehicle, without a cooperative effort from the energy production arena, will have negative effects on society. Wind, solar and other renewable energy sources must be accepted in society before the hydrogen fuel cell vehicle can flourish. Also, more efforts need to be directed to find the best method for refueling a hydrogen powered fuel cell vehicle.

References

1. M.J. Bradley and Associates, Northeast Advanced Vehicle Consortium (NAVC) and Defense Advance Research Projects Agency (DARPA). Interviews with 44 Global Experts On the Future of Fuel Cells for Transportation And Fuel Cell Infrastructure AND A Fuel Cell Primer. November 2000.

2. Bradley, Robert L. Jr. “Electric and Fuel-Cell Vehicles Are a Mirage.” USA Today. March 2000.

3. Brook, Lindsay. “Get Ready For Fuel Cells.” Automotive Industries. June 1999.

4. Cannon, James, Gearing Up for Hydrogen, INFORM, 1998.

5. Cannon, James S., Harnessing Hydrogen – The Key to Sustainable Transportation, INFORM, New York, 1995.

6. Guidebook: ABCs of AFVs. California Energy Commission, November 1999.

7. Jensen, Marc W. “The Ultimate Challenge (manufacturing of fuel cell vehicles).” Environment. September 2000.

8. Hormandinger, Gunter and Nigel J.D. Lucas, Abstract from: An Evaluation of the Economics of Fuel Cells in Urban Buses, (www.e-sources.com/fuelcell).

9. Paul Levlton, Lisa Kershaw and William Reid, Estimated Economic Impacts and Market Potential Associated with the Development and Production of Fuel Cells in British Columbia, (www.env.gov.bc.ca/epd/epdpa/ar), 1996.

10. Mangiamele, Guy, Will Royal Dutch/Shell lead the way to Hydrogen?, (www.calstart.org/panda/homepage_news), 1999.

11. Marshall Miller and David Swam, Statewide Fuel Cell Research, Design and Development Collaboration Plan, UC Davis, 1996.

12. Daniel Morgan and Fred Sissine, Congressional Research Service – Report for Congress –Hydrogen: Technology and Policy, (www.cnie.org/nle), 1995.

13. Joan Ogden, Eric Larson and Mark Delucchi, A Technical and Economic Assessment of Renewable Transportation Fuels and Technologies, UC Davis, 1994.

14. US Department of Energy. Technology Snapshot featuring the Toyota Prius. 2000.