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was so excited about this research project. She emailed me on numerous occasions, was very self-driven about setting up appointments to discuss her newest books/articles from the library. She wrote her essay early and asked me ~~me~~ many times to read over/give suggestions/feedback.

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Assessment criteria	Achievement level		
	First examiner	maximum	Second examiner
A research question	2	2	<input type="checkbox"/>
B introduction	2	2	<input type="checkbox"/>
C investigation	3	4	<input type="checkbox"/>
D knowledge and understanding	4	4	<input type="checkbox"/>
E reasoned argument	4	4	<input type="checkbox"/>
F analysis and evaluation	3	4	<input type="checkbox"/>
G use of subject language	4	4	<input type="checkbox"/>
H conclusion	2	2	<input type="checkbox"/>
I formal presentation	3	4	<input type="checkbox"/>
J abstract	2	2	<input type="checkbox"/>
K holistic judgment	3	4	<input type="checkbox"/>
Total out of 36	32		<input type="checkbox"/>

The Future of Hydrogen Fuel Cell Vehicles in the United States

Environmental System and Societies

To what extent would hydrogen fuel cell vehicles be beneficial to the United States in terms of the average American consumer, the US government when looking at the economy and policy, and the environment when compared to gasoline vehicles?

May 2013
Word Count: 3995

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Abstract

Transportation is a basic human need. Throughout the last decade a large debate has existed to decide the future of transportation. The current transportation system in the United States exists primarily as an oil system, which brings about the problems of the environment, global warming, national security, safety, the economy, etc. This oil system provides a variety of fuels such as gasoline, diesel, jet fuel, etc. However, for this investigation gasoline will be primarily researched rather than the other oil-based fuels. No form of transportation will be able to fix all the current problems and avoid future dilemmas but the hydrogen fuel cells provide potential for the future. In this investigation the extent to which hydrogen fuel cell vehicles would be overall beneficial to United States when compared to gasoline vehicles will be assessed when looking at the average American consumer, the US government in terms of economy as well as policy, and the environment.

To determine the effect that hydrogen fuel cell vehicles would have on the average vehicle consumer the cost of a vehicle, vehicle safety, and other consumer wants and needs will be assessed. The impact of the government will be assessed through the cost of a vehicle, the cost of new infrastructure, changes in energy security, and changes in domestic policy. Lastly, the hydrogen fuel cell vehicle will be assessed in the area of environment through the hydrogen fuel collection process and the hydrogen fuel cell's overall environmental impacts. Similarities exist between each of the different areas, which also will be addressed. Each of these individual areas will help reach the conclusion that hydrogen fuel cell vehicles would be extensively beneficial for the United

States when looking at the average American consumer, the US government in terms of the economy and policy, and the environment.

Word Count: 299

Introduction

To what extent would hydrogen fuel cell vehicles be beneficial to the United States in terms of the average American consumer, the US government when looking at the economy and policy, and the environment when compared to gasoline vehicles?

To assess the extent to which hydrogen fuel cells would be beneficial to the United States, in comparison to gasoline vehicles, the current transportation systems need to be assessed in order to determine both the positives and negatives of this current system. Throughout this investigation the information of the current transportation system will be used to demonstrate how hydrogen fuel cells can fix the current transportation problems, and impact the average American consumer, the government of the United States, and the environment.

Currently the majority of vehicles that exist throughout the United States are vehicles that run on gasoline. Gasoline vehicles present the problems of not responding to what the consumer wants, lacking energy security, decreasing consumer safety, using non-renewable resources, and emitting harmful emissions. Gasoline vehicles simply do not fulfill what the average citizen wants (Consumer Reports 1). Gasoline also threatens the United States's national security due to the fact that the U.S. needs oil to create gasoline for its vehicles. Therefore, the US depends on foreign countries to fulfill its gasoline need at a very high price (Asplund 31). Furthermore, gasoline is not an extremely safe fuel due to the fact it can leak causing small explosions or destroy large portions of animal life through oil spills and pollution (Lew 34). Lastly, gasoline is made from fossil fuels, which are a nonrenewable resource. The human race cannot depend on gasoline forever because one day oil sources will be depleted. It is estimated that oil

sources could become depleted approximately in 2050 (Knight 1). Additionally, gasoline does great harm to the environment. Gasoline vehicles release emissions that are harmful to both human health as well as the environment's health (Ehsani, Emadi, Gao 8). However, there are benefits of gasoline vehicles. First, gasoline vehicles are comparatively inexpensive, all needed infrastructure for gasoline vehicles is currently built, and gasoline vehicles do not require new policy changes (Rohm 105). Yet these positive aspects of gasoline vehicles do not outweigh the many negatives. Hydrogen fuel cells have the potential to have a positive impact on the United States, its citizens, and the environment (see Appendix A for information on how hydrogen fuel cells work). Gasoline vehicles are not beneficial to the United States in the areas of the average American consumer, the government, or the environment.

This topic of hydrogen fuel cells is worthy of investigation because hydrogen fuel cells can fix the problems of current gasoline vehicles and benefit the future of the United States in a variety of ways. As a result, hydrogen fuel cell vehicles are extensively beneficial to the United States in the areas of the average American consumer's wants, the government in terms of the economy and policy, and the environment when compared to gasoline vehicles.

Investigation

Hydrogen fuel cell vehicles are extensively beneficial to the average American consumer, US government in the areas of the economy and policy, and the environment consumer when compared to gasoline vehicles.

In order to assess the extent to which hydrogen fuel cell vehicles would be specifically beneficial to an average American consumer, a survey was used to create a weighted chart (shown below). The survey (see Appendix B) was extracted from Consumer Reports, which is a reliable, American survey source.

Hydrogen Fuel Cell Vehicles vs. Gasoline Vehicles Chart			
Category	Weighting Factor	Hydrogen Fuel Cell Vehicle Ranking	Gasoline Vehicle Ranking
Fuel-Economy	37%	60 (25% to 60% efficient, developing 85%)	20 (20% efficient)
Quality	17%	50 (Still under research, little maintenance, brand name)	70 (Mass produced, more maintenance, brand name)
Safety	16%	80 (Gaseous leaks)	20 (Liquid leaks, Oil Spills)
Value	14%	20 (Expensive but last relatively long)	80 (Very inexpensive but need a lot of maintenance)
Performance	6%	80 (Great fuel efficiency but still is in development)	20 (Bad fuel efficiency but drives well)
Design/ Style	6%	50 (Same style as gasoline vehicles)	50 (Same style as hydrogen fuel cell vehicles)
Technology/ Innovation	3%	90 (New technology)	10 (Old technology)
Final Score		56.8	38.2

The categories on this chart show which qualities of a vehicle were deemed to be the most important factors when buying a vehicle. The weighting factor represents the exact percentage of people who deemed that factor the most important when buying a

vehicle. Then both vehicles received a rating, according to the information presented throughout this investigation, varying from 1 (the worst) to 100 (best). Then these values were multiplied by the weighting factor, and added to determine the best car. Based on the weighted chart, hydrogen fuel cell vehicles received a score of 56.8 whereas gasoline vehicles only received a score of 38.2. In conclusion, hydrogen fuel cells are extremely beneficial to mainstream Americans because hydrogen fuel cell vehicles are able to provide the average American with what they need and want in a vehicle.

To determine the economic impacts of the hydrogen fuel cell vehicles it is imperative to first look at the production of hydrogen fuel cell vehicles. Currently hydrogen fuel cell vehicles are tremendously expensive; they currently cost approximately \$300,000, which is due to the low production rate. However, gasoline vehicles are relatively inexpensive making them competitive especially to the higher priced vehicles. The first reason for the high price in hydrogen fuel cell vehicles is the cost of materials. Platinum is used as a catalyst, which is a very expensive and nondurable material. However, different platinum alloys are undergoing research to decrease cost (Lew 34-35). Hydrogen fuel cells vehicles are also expensive due to the heavy metals that must be used to avoid corrosion and leaks (Asplun 148). The cost for maintenance is another issue that hydrogen fuel cell vehicles face. Currently maintenance and repair costs run tremendously high due to the lower number of running hydrogen fuel cell vehicles. However, if hydrogen fuel cells go into mass production the cost for production, maintenance and repair would drop. Hydrogen fuel cells themselves contain no moving parts and do not need to be replaced or recharged, so less maintenance and repair would be needed in the long run (Lew 20). Additionally, the price of gasoline is a

growing issue in the US. In 2011, the average gasoline price per gallon was approximately \$3.50 and the average price per gallon of hydrogen was about \$3.00. Gasoline prices are expected to rise and hydrogen fuel prices are expected to drop (Gilman 428). Therefore, the high cost of the fuel cell vehicles could initially hurt the economy, but the cost will drop when the vehicles become mass-produced. Hydrogen fuel cell vehicles are extensively beneficial to the mainstream consumer as well as the government and economy in the long run, due to the fact that prices of hydrogen fuel cell vehicles will drop, if they are mass produced, and the price of gasoline will only rise impairing the economy and the consumers in the future.

Hydrogen fuel cell vehicles may be more expensive than the traditional gasoline vehicle but they are much more efficient. The efficiency for hydrogen fuel cell vehicles ranges from about 25% to 60% currently; whereas, a gasoline car is only about 20% efficient. However, hydrogen fuel cell vehicles are undergoing studies that estimate the efficiency range to be more than 85% with the use of cogeneration (the extra heat produced would be reused to heat the engine) (Hemminger 216). Therefore, hydrogen fuel cell vehicles are more economically beneficial in terms of fuel efficiency. According to Consumer Reports, fuel efficiency is the most important factor; so, hydrogen fuel cell vehicles can fulfill this consumer need too. In 2010, the US government passed multiple requirements for automotive companies to increase fuel efficiency standards for vehicles and higher requirements are expected to be passed in the future, but hydrogen fuel cell vehicles already surpass the current requirements, and would continue to push the limits for the less fuel-efficient gasoline vehicles. Currently the United States is failing behind in the international rankings of efficiency and has a desire to catch up (the United States

ranks 8th in the world). Hydrogen fuel cell vehicles can aid the government in improving fuel efficiency rankings (Hemminger 217). Additionally, investments are being made into the future of hydrogen fuel cell vehicles. This helps to fund research and development to lower the costs of the vehicle and increase efficiency as well as stimulate the economy through the movement of money (Gilman 524). Hydrogen fuel cell vehicles benefit the average consumer and domestic policy through improvements in fuel efficiency and also boost the economy through investments that are made in hydrogen fuel cell vehicle research. Gasoline vehicles will only hold back the United States from improving fuel efficiency standards.

Even if hydrogen fuel cell vehicles were widely produced and purchased there is not the infrastructure to support the new technology today. Currently oil and gasoline infrastructure exists worldwide from the ships that carry the oil to the gasoline stations that exist on street corners. Furthermore there are not hydrogen fueling stations, hydrogen extraction plants, etc. that exist on a large level. It is expected that in order to build a completely new hydrogen fueling infrastructure system it would cost more than half of a trillion dollars (Rohm 88). Yet, in order to put hydrogen fuel cell vehicles into mass production a completely new infrastructure is not needed. First of all, there is a worldwide industrial gas and chemical sales delivery system, which could easily transport hydrogen (Asplund 160). Additionally, pipelines can be used to transport hydrogen. Hydrogen pipelines already exist throughout the United States in small scales. Fueling stations also already exist in small portions in Sacramento, California and New York City, New York (Casper 120). Hydrogen highways have been built in California (Lew 40). Lastly, in Chicago, Illinois hydrogen bus systems are present and running (Casper

174). Although the infrastructure for hydrogen fuel cells is microscopic compared to the infrastructure for oil, the hydrogen infrastructure is present and is slowly expanding. Money has begun to be invested into the building of hydrogen infrastructure on small levels. Therefore, hydrogen fuel cell vehicles do not initially benefit the government, due to the large amount of infrastructure that is needed, but once this money is invested it is a one-time cost. Even though hydrogen fuel cell infrastructure could initially harm the economy it has the potential to revamp the future of the United States. Gasoline vehicles currently have an infrastructure to support a large amount of vehicles but in the future this infrastructure would have to be changed when oil sources became depleted, which would cause economic crisis and chaos. Hydrogen fuel cells provide the opportunity to start this infrastructure change now to make a smooth and gradual change, which would be beneficial for the future of the United States in the long run.

Hydrogen fuel cells also have the potential to improve the “energy security” of the United States. Energy security applies to the idea that individuals have control over how and when they are able to access energy (Gilman 527). The United States is not able to control its energy source, oil, due to the fact that it comes from overseas. The OPEC cartel restricts the supply of oil to ensure that oil prices stay high, which maximizes the revenue for its Middle Eastern states (Asplund 29). Additionally, the majority of oil lays in the Middle East and North Africa. Therefore, the United States is not able to control its main source of energy, and this power is given to the nations who have the oil. The United States has very little energy security. (Ehsani, Emadi, and Gao 7). The United States is paying for its own economic downfall. Furthermore, many economic downturns that occurred over through the late 20th century and early 21st century have been tied

directly to the oil industry. The first incident of this was during the 1973-1975 recession, which was a result of the Arab Oil Embargo. Another incident was the 1980's recession, which was caused by an oil spike from the Iranian revolution. Lastly, the 1990-1991 recession occurred from another oil spike tied to Saddam Hussein's invasion of Kuwait (Asplund 28). In these incidents the United States was extremely vulnerable to economic recession due to its high dependency on oil. Hydrogen fuel cells vehicles could help to break these dependencies and avoid further economic downturns in the future. Overall, hydrogen fuel cells could increase the amount of energy security that the United States has due to the fact that the United States could produce their own hydrogen fuel.

However, the time frame for the United States to become a leader in hydrogen fuel is small. China currently does not have a large transportation infrastructure, and as a result it would be much easier for the Chinese to develop new infrastructure. Additionally, the Chinese are strong believers in hydrogen fuel and as a result they could become the hydrogen fuel leader and superpower (Lew 37). Hydrogen fuel cell vehicles can increase the United States energy security and its international power, which is very beneficial to the future of the nation. However the nation has to invest in the hydrogen fuel cell vehicles now. Continuing the oil dependence will only allow outside countries to control the United States's energy supply, directly harming the US's economy and government. Hydrogen fuel cell vehicles will provide a more secure future for the United States.

Hydrogen fuel cells also have the potential to change domestic policy in addition to international politics. If hydrogen fuel cells vehicles were used abundantly new safety codes would most likely need to be written by the government. If they were not written then garage structures, maintenance facilities, and on-road infrastructure would need to

be changed (Rohm 105). This would cost additional time and money. However, tax incentives are already in place for environmental friendly technology and could refund the consumer for spending extra to benefit the environment. Currently in London there are pollution taxes and congestion charges, which is a way to pay for the cleanup of pollution. If these congestion charges and pollution taxes were moved to the United States, most likely, they would be widely debated. Another policy that is being suggested in the United States is the lowering of speed limits. Most vehicles operate most efficiently at speeds lower than fifty-five miles per hour, and as a result the maximum speed limit in the country could be fifty-five miles per hour. This policy most likely would not be favorable for the American public either (Knight 54). Hydrogen fuel cell vehicles have the power to change domestic policy, but do require re-written hydrogen safety codes. However, this change could allow for tax incentives, the elimination of future taxes and charges, and keep the speed limits where they are currently set. A few small changes in safety codes are a better alternative to additional taxes, charges, and changes in speed limits for both the government and average American.

In conclusion, hydrogen fuel cells vehicles are extensively beneficial to the US government, in terms of the economy and policy, in the long run because, although the hydrogen fuel cell vehicles would be initially expensive and infrastructure would need to be built, hydrogen fuel cells make up for this cost with high efficiency ratings, an increase in energy security, and domestic policy alternatives.

Most importantly, hydrogen fuel cells are environmentally friendly which is important to the future of the United States. The process of making hydrogen fuel is much more environmentally friendly than that of gasoline. Gasoline is made oil which

from non-renewable energy source and a fossil fuel. The process of making gasoline, fractional distillation, creates a large amount of emissions. These harmful gases have an impact on the greenhouse effect, pollution levels, as well as an impact on human health. Fractional distillation also produces many other products such as plastics, lubricants, etc. However, the production of these products would not be greatly affected by the elimination of the production of gasoline (if hydrogen fuel was used instead). Hydrogen fuel, too, can be made from the same fossil fuels, but it can also be made from renewable sources such as wind energy. If hydrogen fuel was made from renewable sources the pollution from producing fuel could be greatly cut. Additionally, there will be a time when oil sources become depleted, approximately in 2050, due to oil's non-renewability (Knight 1). If the United States were not prepared for oil shortage economic crisis would strike because the US is extremely dependent on oil (Asplund 28). Unlike oil, hydrogen would never run out, and as a result it would not cause economic crisis. This is due to the fact that hydrogen is the most abundant element on earth and hydrogen can be harvested from renewable resources. With regards to the hydrogen fuel process, the extent to which hydrogen benefits the environment is tremendously great. Gasoline vehicles only increase the amount of harmful emissions, have the potential to cause economic crisis and foreign dependence, and eventually will leave the average consumer without a source of energy.

Hydrogen fuel cells are also known to be a safer form of fuel than gasoline for both the average consumer and the environment. Hydrogen is extremely flammable and colorless and odorless, but it is still safer than gasoline (Lew 34). The reason hydrogen is a safer fuel is due to the fact that at room temperature it is a gas, and therefore if

hydrogen is leaked then it quickly diffuses in the air. Whereas gasoline is a liquid and therefore sits, waiting for ignition. Not only does hydrogen's gaseous state benefit the safety of people, but it benefits the environment as well. If hydrogen was released in the middle of the ocean it would not sink and mix with the water, but rather it would diffuse into the air. Oil, on the other hand, mixes with seawater destroying aquatic life and significantly harming the environment. Oil spills could be significantly decreased if hydrogen was the main source of energy in the United States, which would greatly benefit the environment as well as the economy (Lerner 105). The 2010 BP oil spill is estimated to have cost the company over \$40 billion. Additionally, the oil spill cost the Gulf States millions in industry and killed over 8,000 aquatic animals (Weeks 1). Hydrogen fuel cells can save lives by preventing deadly explosions as well as saving aquatic lives from oil spills. Overall in terms of leaks and spills, hydrogen fuel greatly benefits the economy, environment, and many lives too. Gasoline fuel will only continue to injure and possibly kill many people and animals alike. Hydrogen fuel is an obvious choice for the safety of the United States' future.

The future health of the environment is tremendously important when compared to its relative cost, and hydrogen fuel cells have the potential to save the health of the environment. The main emission from gasoline vehicles is carbon dioxide. It is estimated that for each gallon of gas burned 20 pounds of carbon dioxide is produced: therefore, based on the E.P.A. estimation that the average vehicle is driven 15,000 miles a year, a single vehicle produces over 300,000 pounds of carbon dioxide each year (Lerner 164). (These statistics are estimations based on a medium-sized car and an average vehicle. This statistic will vary from vehicle to vehicle). Vehicles also emit many other emissions

such as carbon monoxide which is deadly to humans, nitrogen oxides which contribute to smog and acid rain, volatile organic compounds which are harmful to living things, and particulates that contain lead which are a deadly to humans (Knight 10). These emissions from gasoline vehicles damage the environment. Hydrogen fuel cells vehicles only emit heat and water vapor. Neither of these emissions contributes to the greenhouse effect, smog levels, acid rain levels, or are harmful to human health. Therefore, hydrogen fuel cell vehicles are greatly beneficial to the environment. Additionally, the environmental problems of global warming, pollution, and acid rain cause economic problems. Acid rain causes forest and monument devastations, which costs the US approximately \$3 billion annually. Pollution causes health problems, such as asthma, which costs the US \$56 billion in medical costs. Not only can fuel cell vehicles eliminate much of the pollution caused by the transportation, but also it can eliminate all of the environmentally damaging and costly effects of the gasoline emissions (Ehsani, Emadi, and Gao 7). There is only one planet Earth, and humanity needs to protect it before it is completely destroyed. Hydrogen fuel cell vehicles can help humanity move forward to this goal of preserving the health of the planet, as well as the health of humanity. Therefore, hydrogen fuel cell vehicles are beneficial to both the environment and the economy in terms of their environmental friendless whereas gasoline vehicles only harm and destroy the environment causing harm and economic problems. In conclusion, hydrogen fuel cell vehicles are extensively beneficial to the environment due to an increase safety and a decrease in harmful emissions.

Throughout this investigation the majority of the sources used have a strong bias towards hydrogen fuel cell vehicles and environmentally friendly technologies, which

allowed for the evidence and data to be presented in a pro hydrogen fuel cell manner. Yet through this investigation opposing perspectives, such as Rohm's criticisms of hydrogen fuel cells, were researched and discussed in order to have a well-rounded investigation with multiple perspectives. In conclusion, all the data and information was chosen and evaluated to academically compare gasoline and hydrogen fuel cell vehicles. As a result, the conclusion was reached that hydrogen fuel cell vehicles are extensively beneficial to the United States.

Conclusion

Hydrogen fuel cell vehicles are extensively beneficial to the American mainstream population because they provide the consumer with what they want and need. Hydrogen fuel cell vehicles are extensively beneficial to the United States government because they have high efficiency ratings, increase energy security, and offer domestic policy alternatives. Lastly, hydrogen fuel cell vehicles are extensively beneficial to the environment because they increase safety and decrease harmful emissions. Like any other form of transportation, hydrogen fuel cells provide many different positive aspects as well as some negatives. However, hydrogen fuel cells are the best type of vehicle for the future of the United States because the positives outweigh the negatives.

The cons of hydrogen fuel cells include the cost of the hydrogen fuel cell car, the change in infrastructure, and the small changes in domestic policy that they require. However, these cons could easily be overcome. For example, the initial cost of a fuel cell vehicle would drop when the vehicle was put into mass production. The cost for the infrastructure would be a one-time investment that could last for years with only small

amounts needed of maintenance. Lastly, the change in domestic policy would only take a small amount of time, and better the common good of the county as well as avoid debate about potential charges and taxes. Like any vehicle, fuel cell vehicles have negative aspects. Unlike other vehicle, hydrogen fuel cell vehicles have the potential to overcome the negativities with time and investments for the future. Gasoline prices will only continue to rise and create a worse economic and environmental situation for the government and the citizens.

Even with the cons of hydrogen fuel cells, there are many positive aspects of the hydrogen fuel cell vehicles. First of all hydrogen fuel cell vehicles are what the average American consumer basis wants and needs. These vehicles would also increase the United States' energy security saving money and decreasing foreign oil dependence. Additionally, hydrogen fuel cell vehicles could save the lives of humans and animals alike due to its higher safety levels. Most importantly, hydrogen fuel cells would not release harmful emissions improving the condition of the environment. Through each of these aspects it is clear that hydrogen fuel cell vehicles have the potential to change the United States for the better.

Hydrogen fuel cells would be extensively beneficial for the United States in the areas of consumer wants, the government in terms of the economy and policy making, and the environment based on the information that is present in this investigation. To further this investigation hydrogen fuel cells must undergo additional research as well as begin mass production, which needs the support and action by the people. Additionally, further investigation into other types of vehicles such as electric vehicles, hybrid vehicles, etc. could provide an alternative to gasoline vehicles.

The United States, as well as every citizen in the country, needs a new transportation system free of harmful emissions, foreign dependence, safety concerns, etc. and hydrogen fuel cell vehicles need to be mass produced. Therefore, there is no better match than the future of the United States and the future of hydrogen fuel cell vehicles. Hydrogen fuel cell vehicles would be extensively beneficial to the future of the United States in terms of the average, American consumer, the US government in terms of the economy and policy, and the environment.

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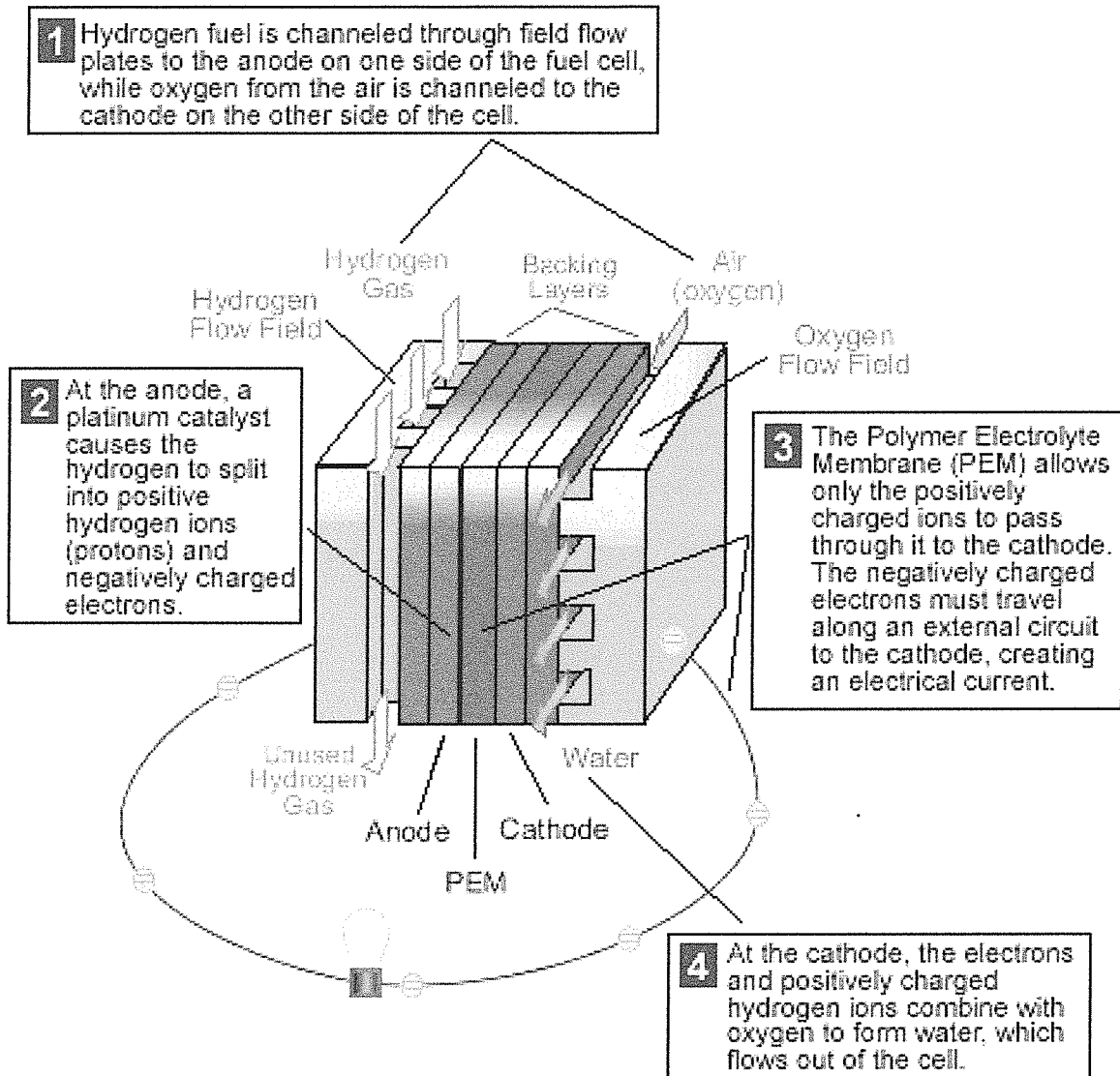
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Appendix A

Hydrogen Fuel Cell Diagram



Appendix B

2012 Consumer Report Survey

Car-purchase factor	Most important (%)
Fuel economy	37
Quality	17
Safety	16
Value	14
Performance	6
Design/style	6
Technology/innovation	3