Michael Tsai

VAST 203

Professor Raich

5/8/2011

Sustainability Assessment of the *Honda FCX Clarity*

Introduction

The *2009 Honda FCX Clarity* is a hydrogen fuel cell vehicle that was first released in 2008. The car is unique in that it only requires hydrogen gas to power itself along with a supplemental lithium-ion battery. Moreover, it is a sedan that can seat four passengers, weighs about 3600 lbs, and is sized between a *Honda Civic* and *Honda Accord* (Robinson). Other than being powered by hydrogen, it looks and feels just like a normal car. Users would not notice much difference between driving a gasoline powered car and this one. In fact, the only difference that the user could notice is that there would not be the usual engine humming noise; the driver would slightly only hear the electric motor (Honda FCX Clarity). However, there are currently not many available, and they are only letting interested buyers who live near hydrogen refueling stations in California lease the car for $600 per month for three years. The lifecycle of the car can be fairly complicated depending on the breadth and depth of investigation. In short, it is built using common car raw materials like steel and aluminum, uses hydrogen fuel during the use phase, and is likely recycled at the end of its life. The car is touted as being sustainable, but this sustainability assessment will determine how sustainable this car really is.

Scope

In this sustainability assessment of the *Clarity*, my scope will be wide. For the car to be sustainable it has to overall satisfy the general requirements of sustainability; it has to be environmentally friendly, economically viable, and socially acceptable. These three criteria are broken down into sub-criteria. The majority of the sub-criteria have to be satisfied in order for the car to satisfy each overall criterion.

Environmentally, the origin of significant parts of the car will be traced, and their production analyzed. The assessment will also take note of the impact of the car on its physical surroundings when it is in use. Also, the assessment will discuss how the car would be disposed of. Economically, it will analyze the prices associated with producing and maintaining the car and the (special) infrastructure it needs to run in. The assessment will determine the savings (if any) that the user could get from this car over its lifetime as well. Socially, it will examine the political willpower of the federal government and safety of the car.

Data Sources

The sources from which the information for this assessment was retrieved vary widely. There are many papers published by laboratories and graduate schools that study many aspects of a hydrogen economy. However, there are other sources in this assessment that come from more informal sources. There are many short articles online that give detailed background information of the hydrogen infrastructure in general. Also, the *Clarity's* manufacturer (Honda) website gives important technical specifications of the car. A quick note between the informal articles and the formal papers from reputable sources: Most of the formal papers used in this assessment date back to between 2003 and 2006 while the informal articles are of more recent times. These articles are between 1 to 3 years old.

Applicable Codes and Policies for LCA/LCC

An applicable procedure that is already being used to assess the LCA of a vehicle is the Well-to-Wheel assessment. It takes into account how efficient a vehicle is by looking at the energy losses when energy is transferred from one system to the next. It analyzes how efficiently the fuel is extracted from the ground. Then it considers the efficiency of processing/refining the fuel. Next, it examines the efficiency of transporting the fuel to its destination(s). It also looks at the efficiency in fuel storage. Finally, it looks directly at the car efficiency of turning the fuel into output power. However, efficiency is not the only aspect that is covered. The amounts of carbon emissions as well as fuel consumption are also considered at every stage of the assessment (Pont, 2007). Most aspects of this policy will be used in the assessment of the *Clarity*.

Environmental Criteria Assessment

There are five environmental criteria I use in this assessment. Those criteria are the car materials, the fuel generation method, the air pollutant emissions, the efficiency of the vehicle, and the waste management of the system. These criteria are directly related to the lifecycle because they show how the car is directly handled. The air pollutants emissions criterion will account for the types of air pollution generated by the car during its entire life cycle, not just during the use phase. The efficiency criterion looks at the well to wheels efficiency as well as the miles per gallon or kilogram the system has. The fuel generation method criterion will investigate how environmentally friendly the processes are in obtaining the fuel. Moreover, the car materials criterion will account for the types of material that are produced for the car and how they are produced. The waste management criterion will follow how the system is disposed of and investigate if it is thrown out or recycled in an environmentally friendly manner.

According to Robinson (2008), the car is made mostly from steel and aluminum. Assuming the car to be made from not recycled (newly produced) steel, there will be carbon emissions in addition to the other pollutants released into the atmosphere from the process of making the material. A blast furnace is used to make the steel, and in the process some pollutants that are released into the atmosphere are carbon dioxide, carbon monoxide, and sulfur dioxide (Clark). These processes are also energy intensive, so if they use energy that come from GHG emitting sources, the processes would be worse. Also assuming the car to be made from newly produced aluminum, the process to make the material is not much better either. The side emissions from making aluminum are carbon dioxide, carbon monoxide, hydrogen fluoride, and sulfur dioxide (Primary Aluminum Production). Its fuel cell is also made from platinum. If Honda obtained the platinum through the extraction process, there will also be environmental consequences. The process produces dioxins, which accumulate in the environment (Pieters, Quinn, Giesy, Jones, Murphy, Bouwman). However, its interior design is made from environmentally friendly materials, such as corn-based fabrics (Honda FCX Clarity – What the Auto Press Says). However, if the car were to be made from completely new materials, it would most likely be unsustainable due to the pollutants that are released into the environment from making those materials. Therefore, the car overall does not pass the "car materials" part of the criteria because the methods of how they are produced are not environmentally friendly.

Currently 95 percent of the hydrogen United States produces is by natural process reforming. This is a process where natural gas is heated up along with steam up to between 700 and 1000 degrees Celsius. This produces hydrogen gas and carbon monoxide. The carbon monoxide is then combined with water using a catalyst producing carbon dioxide and hydrogen gas (and heat) (Natural Gas Reforming). Therefore, the *Clarity* will not produce zero-emissions with regards to how the fuel is produced because there will be some carbon dioxide emissions.

The special aspect of the *Clarity* is that water is the only byproduct when the car is being used. The car runs on an electric motor with its power (electricity) generated by the hydrogen fuel cell. The fuel cell works by separating each hydrogen molecule into its proton and electron using a platinum catalyst located at the anode side of the fuel cell. The protons then travel through the proton exchange membrane while the electrons are forced to travel through the circuit that powers the electric motor. Finally the electrons travel to the cathode side of the cell where it recombines with the protons, and combines with the oxygen to form water vapor. The water vapor is emitted from the car (Hydrogen Fuel Cells: An In Depth Look…). Therefore, no carbon emissions are released through its direct use. However, as mentioned before, the car generates carbon emissions and other pollutants through its manufacture and fuel production so the car is generally not environmentally sustainable in the air pollutants criterion.

The *Honda FCX Clarity* has a mileage of 60 miles per kilogram of hydrogen (Specifications). It is fuel efficient when compared to an internal engine combustion car, which as an average mileage of 22.4 miles per gallon. Moreover, the well to wheels efficiency for a hydrogen fuel cell car can be as high as 33% while that kind of efficiency for an internal combustion car is around 15% (Davis, Edelstein, Evenson, Brecher, and Cox). Therefore, in terms of overall efficiency, the *Clarity* is environmentally sustainable.

There have been no accounts of how the *Clarity* is disposed of when it has run its life. However, for the most part, the *Clarity* is just like any other vehicle. Its chassis, wheels, and aluminum outer cover are still made from the same materials as a conventional gasoline powered vehicle. The only differences are in the motor/engine, battery, and its fuel tank. Therefore, in taking into account of how the car is disposed, the waste procedures for a conventional car will be considered. According to Joel (2008), 84% of a car can be recycled. The usual way a car is recycled is first through removing its various, still-useful parts or recycled. These parts include windshield, tires, and batteries. The lithium-ion battery is assumed to be recycled. In addition, the platinum in the fuel cell is also would likely be taken out of the fuel cell and also recycled (Frequently Asked Questions). In the usual process, the engine fluids are drained from the car before crushing it, but since this car runs on an electric motor, and not an engine, this part would be out of the recycling process (How does my old car get recycled?). After the car is crushed, the steel and iron material from it are then recycled in the steel mills. Depending on the process, as much as 80 percent of old steel can be used to make new steel (How Car Bodies are Recycled). Since most of the car can be recycled the *Honda Clarity* is environmentally sustainable in terms of waste management.

Economical Criteria Assessment

The five economic criteria I will use to assess the *Clarity* will be the car price, the fuel price, the fuel storage price, the infrastructure price, and savings. These criteria indirectly relate to the car life cycle through the direct and indirect expenses the car could incur over its lifetime. The car price criterion will investigate the current list price or lease price for the car in question. The fuel price criterion looks at the current fuel price and compares it to other fuel types' prices. The infrastructure price criterion examines the investment the country needs to make in order to build the necessary infrastructure for the car in question. The savings criterion will finally look at the potential savings of consumers or users if they use this system.

According to Copeland (2009), the price to manufacture a *Honda Clarity* is estimated at $300,000. Clearly, this is much more expensive than most cars on the road today. Therefore, the *Clarity* would not be economically sustainable in the price aspect because the car has to be competitive with today's much comparatively lower car prices.

Moreover, the cost of hydrogen is approximately equal to $2.50 per gallon of gasoline (Calculating Hydrogen Production Costs). As can be seen in Table 1, the cost to produce hydrogen varies with the natural gas price, and the plant size. The cost to produce hydrogen using natural gas decreases as the plant size increases, and increases as the natural gas price increases. Table 1 shows the hydrogen production price can be as high as $4.10 or as low as 0.70 per kilogram.

Table 1. Bulk H_2 gas costs, 2004 USD			
NG price, $/GJ	Plant size, tons/day	Plant Cost, $	H_2 gas cost, $/kg
3.5	22	23M	1.8
7.0	22	23M	2.4
15.0	22	23M	4.1
3.5	80	44M	1.2
7.0	80	44M	1.9
15.0	80	44M	3.0
3.5	600	210M	0.7
7.0	600	210M	1.0
15.0	600	210M	2.7

(A Realistic Look at Hydrogen Price Projections)

It is known that one gallon of conventional gasoline equals the energy equivalent of one kilogram of hydrogen gas (Hydrogen). Therefore, the prices in the above table can be directly compared to gasoline prices. Assuming that the price of the hydrogen for consumers would be only slightly higher than the values show in the table such that profit from the production (and transportation) can be made, and knowing that current gasoline prices are above three dollars a gallon over the country, most hydrogen gas costs would be very cheap compared to gasoline (U.S. Retail Gasoline Prices). Therefore, with regards to hydrogen production costs and consumer prices, the *Clarity* would be economically sustainable.

Doty (2004), states that the cost for a hydrogen storage gas tank is very expensive compared to a standard gasoline tank. One 10-gallon automobile fuel tank costs around $150 while at least $1400 per kilogram is needed to produce a hydrogen fuel tank for a hydrogen car. Another case has the price of a hydrogen fuel tank at $16,000 per kilogram. Clearly, the costs to store hydrogen are currently very expensive even if it is just storing hydrogen in a car. Therefore, the fuel storage criterion fails in being economically sustainable.

The price estimates of building a national hydrogen infrastructure range widely. Argonne National Laboratory states from its 2002 report that 500 billion dollars would be needed to build a nationwide hydrogen infrastructure. However, there are other estimates that are much lower. That is because there might not be a need for as many hydrogen gas stations as there are gas stations. If this were the case, 24 billion dollars might be enough to satisfy the hydrogen refueling infrastructure, knowing that a hydrogen station costs around 2 million dollars to build. Copeland states, "A study commissioned by the National Academy of Science concluded that the U.S. would need to spend $3 billion to $4 billion a year for 15 years to subsidize the cost of infrastructure in place to make the transition to hydrogen." According to Rose, "Independent studies also have developed nationwide models costing about $15 billion." Although the costs of a hydrogen infrastructure seem expensive, these costs are trivial compared to the cost of the Iraq War, which is at least $509 billion (Cost of Hydrogen Fueling Infrastructure). Therefore, the *Clarity* (and hydrogen cars in general) would be economically sustainable on a national wide scale because the cost to build a national hydrogen infrastructure is cheap when compared to the other expenses the government already pays for.

There are some economic benefits of using the *Clarity*. Since the *Clarity* can be only driven around (Southern) California, there are hydrogen stations in the area. Depending on which station the driver chooses to refuel at, the hydrogen gas could be free because hydrogen vehicles are currently promotional. If the hydrogen is not free, then the price could vary around gas prices. For example, a hydrogen refueling station in Irvene, California has hydrogen priced at $4.99 per kilogram while another station in Des Plaines, Illinois, has the hydrogen priced at $3.49 per kilogram (Hydrogen Fuel Prices at the Pump and Costs to Consumers).

Although these prices are similar to the gasoline prices, the *Clarity* has a 3.92 kilogram tank capacity and the corresponding range of 240 miles (Specifications). Assume an average car has a range of 300 miles and capacity of 16 gallons. Therefore, if the hydrogen had the $3.49 per kilogram price, it would cost $13.68. If the gasoline were the same price, the fill up price for a conventional car would be $55.84. Thus, the *Clarity* costs 6 cents per mile to drive while the regular car costs 19 cents per mile to drive. Even if the hydrogen were not free, the *Clarity* would still be economically beneficial over the conventional car if the gas price equals the hydrogen price. Therefore, the *Clarity* is economically sustainable in the economic benefits criterion.

Social Criteria Assessment

The criteria that will be used to assess the social sustainability of the *Clarity* will be government incentives, safety, and user incentives for the car. These criteria relate to the lifecycle of the car because they determine how the car could be accepted into society. The government incentive criterion will investigate how much the government is willing to support the system. It looks at any bills or laws that have been signed in order to support the system. It also looks at the amount of government funding that is put into the system research.

The government support for hydrogen car research has been slightly inconstant. When George W. Bush was president, he advocated hydrogen cars and the research for them. He advocated his $1.2 billion bill that would support hydrogen fuel cell research. However, the United States' government support for research into hydrogen cars dropped in May 2009. According to Mick (2009), at that time, President Obama cut the $169 million dollars per year in fuel cell and hydrogen technologies research down to $68.2 million dollars because "the probability of deploying hydrogen fuel-cell vehicles in the next 10 to 20 years is low." However, just two months later, the government went back on its decision and restored funding for the hydrogen fuel research. The funding will be between $108 million and $190 million a year. Moreover, the Department of Energy is currently supporting 189 hydrogen projects (Schroeder, 2009). Therefore, regarding the government incentive criterion, the *Clarity* is socially sustainable because the government currently supports hydrogen research, and it is putting considerable amounts of money into hydrogen fuel cell research.

Socially, safety is a major factor. Crabtree, Dresselhaus, and Buchanan assert that "the public acceptance of hydrogen depends not only on its practical and commercial appeal, but also on its record of safety and widespread use." The *Honda Clarity* is very safe both on the grounds of hydrogen and prevention technologies. It is known that hydrogen is very flammable. The *Clarity* has sensors that can detect a hydrogen leak, and if there is one then the ventilation system activates and the main cut-off valves are closed on the hydrogen tank and/or supply lines. In addition, if there were a crash, the car would automatically shut off the hydrogen flow and electric current in the high voltage lines. The car also has safety measures placed when the car is being refueled (Hydrogen Safety). Since the car is exceptionally safe for using the new fuel source, it is socially sustainable because users would concur that if a car is safe to drive, they would likely drive it.

There has to be some incentives for the user (driver) so the car can be sustainable. An incentive that varies among drivers is the amount of savings they would have driving the *Clarity*. As mentioned before, the car is only being leased at $600/month for three years. Therefore, the person would have to pay $21600 total. Also, mentioned before was the fact that there are some hydrogen stations that provide free hydrogen in order to support the push for a hydrogen infrastructure. Using the previously determined the cost of 19 cents to drive per mile at $3.50 per gallon for a conventional car (having a 16-gallon capacity and range of 300 miles), assuming the hydrogen is free and that the gas price would remain static over a three year period, the driver would have to drive 113684 miles in a conventional car in order to incur the same $21600 total cost for leasing a *Clarity*. The driver would have to drive 104 miles a day over the same three years in the conventional vehicle in order to incur the same $21600 cost. Thus the user would have to drive at least 104 miles a day in the *Clarity* in order to begin saving money from gasoline prices. Realistically speaking, most people would probably drive at most 40 miles to work, so they would travel 80 miles a day. Therefore, this savings incentive would not apply to them, and it would be more profitable to most people to use the gasoline-powered car.

Moreover, drivers of the car would be receiving a $12000 tax credit from the Internal Revenue Service if the vehicle were to be for sale currently (Honda FCX Receives $12,000 Tax Credit From IRS**)**. Thus, the only incentive that user has in leasing the car is that they have it in themselves a conscience to preserve the environment. In retrospect, money has always been the driving force of change, in addition to wanting it. Regarding the practical incentives for the user, there will be little incentive for the driver using a *Clarity*, and so in terms of user incentives, the *Clarity* is not socially sustainable.

Conclusion

The *Honda FCX Clarity* is an unsustainable system based on this assessment. Although it is a socially and economical sustainable system, it is unsustainable environmentally when all the things are considered. The *Clarity* is not environmentally sustainable because all the operations that build and support the car harm the environment. Of the five criteria; only two passed the environmental portion. Three of the five economical criteria passed. The system is also sustainable economically mainly because the hydrogen fuel prices are competitive and consumers would save money whenever they fill up with hydrogen. It is also sustainable because the price to produce the infrastructure can be easily paid for by the government (if it weren't spending most of it on wars). The Clarity passed two of the three social criteria; the car is safe and politicians support it. The *Clarity* is not just a hydrogen car. It could very well be one of pioneering technologies that represent the future of travel. This car has to become sustainable in order for the general public to use it. Once it is, the world will be one step closer to a cleaner world.

Works Cited

"Calculating Hydrogen Production Costs." *Home page*. *N.p.* Web. 30 Apr. 2011.

Clark, Jim. "Iron and Steel." chemguide, *N.p.*, 2005. Web. 30 Apr. 2011.

Compilation of Air Pollutant Emissions Factors: Primary Aluminum Production. 8. Feb. 2011. Web. 30 Apr. 2011.

"Cost of Hydrogen Fueling Infrastructure." *Hydrogencarsnow.com*. *N.p.*, 7 Apr. 2008. Web. 30 Apr. 2011.

Crabtree, George W., Mildred S. Dresselhaus, and Michelle v. Buchanan. "The Hydrogen Economy." *Physicstoday.* American Institute of Physics, Dec. 2004. Web. 30 Apr. 2011.

Davis, Craig, Bill Edelstein, Bill Evenson, Aviva Brecher, and Dan Cox. *Hydrogen Fuel Cell Vehicle Study*. 2003. Web. 14 Apr. 2011.

Doty, David F. *A Realistic look at Hydrogen Price Projections*. Columbia: Doty Scientific, Inc., 2004. Web. 30 Apr. 2011.

"Frequently Asked Questions." *Waste2tricity.com*. *N.p.* 2008. Web. 14 Apr. 2011.

Honda FCX Clarity. 2009. *ConsumerReports.org*. Web. 6 May 2011.

"Honda FCX Clarity- What the Auto Press Says." *Usnews.rankingsandreviews.com*, U.S. News Rankings & Reviews, 2010. Web. 30 Apr. 2011.

"Honda FCX Receives $12,000 Tax Credit from IRS." *Hydrogencarsnow.com*. *N.p.* 13 Aug. 2007. Web. 6 May 2011.

"How Car Bodies are Recycled." *Earth911.com*. Earth911. 2011. Web. 30 Apr. 2011.

"How does my old car get Recycled?" *Carheaven.ca.* Summerhill Impact. 2010. Web. 30 Apr. 2011.

"Hydrogen." *AmericanEnergyIndependence.com*. AmericanEnergyIndependence. 2011. Web. 30 Apr. 2011.

"Hydrogen Fuel Cells: An In Depth Look…" *Hydrogen Fuel Cells The Fuel of the Future*. *N.p.* 2006. Web. 14 Apr. 2011.

"Hydrogen Fuel Prices at the Pump and Costs to consumers." *Ecofriendlymag.com*. Eco Friendly Mag. 2008. Web. 30 Apr. 2011.

"Hydrogen Safety." *Honda.com*. American Honda Motor Co. 2011. Web. 30 Apr. 2011.

Joel. "How Cars Are Recycled." *Lifegoggles.com*. Life Goggles, 2010. Web. 30 Apr. 2011.

Jordaan, I., R. Pieters, L.P. Quinn, J.P. Giesy, P.D. Jones, M.B. Murphy, H. Bouwman. *The Contribution of Dioxin-Like Compounds from Platinum Mining and Processing Samples.* Elsevier, 2007. Web. 30. Apr. 2011.

Mick, Jason. "Obama Says No to Hydrogen Vehicles." *Dailytech.com*. DailyTech LLC, 11 May 2009. Web. 30 Apr. 2011.

"Natural Gas Reforming." *Eere.energy.gov*. U.S. Department of Energy, 8 Mar. 2011. Web. 30 Apr. 2011.

Pont, Jennifer. *Full Fuel Cycle Assessment: Well-To-Wheels energy Inputs, Emissions, and*

Water Impacts. Cupertino: TIAX LLC, 2007. Web. 30 Apr. 2011.

Rose, Robert. "Why do we Need a Hydrogen Economy?" *Home Page. N.p.* Web. 30 Apr. 2011.

Schroeder, Joanna. "Government Funding for Hydrogen Fuel Cells Program Reinstated." *Gas2.org. N.p.* 8 Jul. 2009. Web. 30 Apr. 2011.

"Specifications." *Honda.com*. American Honda Motor Co., 2011. Web. 30 Apr. 2011.

"U.S. Retail Gasoline Prices." *Eia.doe.gov*. Energy information Administration. 25 Apr. 2011. Web. 30 Apr. 2011.