Hydrogen City

Air Products

EDSGN 100 Section 9 Prof. Andy Lau

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May 03, 2011

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I. Introduction

Gasoline will not be around for forever. In fact, it won't be around much longer. Sooner or later, a new energy source for our appliances, cars, trucks, and buses will be needed in order to maintain a suitable lifestyle for everyone. Sponsored by Air Products, MEC Inc. will address this issue we have, and attempt to solve the problem at hand. It is MEC Inc.'s goal to provide a city with enough Hydrogen and Hydrogen Compressed Natural Gas (HCNG) fuel to sustain a livable, working society as it does today.

MEC Inc.'s design for such a fueling station, and production, would need to meet specific criteria in order to provide a viable fueling option. The expectations to be met include having enough Hydrogen gas to provide for the city, distributed at two different pressures (350 BAR and 700 BAR), as well as and HCNG pump distributing at 250 BAR. Also, the electricity and energy we need to produce this must come from a renewable resource (i.e. wind power, solar power, hydropower, etc.). All of these needs must be met for the H_2 city to be declared a successful project.

The selected city will be one that is not too large, such as New York City, which would mean that the demand would be incredibly high. The chosen city for MEC Inc.'s H_2 city project is Everett, Washington, a medium sized city at a population of approximately 100,000. The city is located right on the Pacific Ocean coast (sounds like a viable option for hydropower), has an average wind speed of 10 mph, and an average solar power of 3.5-4 kwh/m^2/day.

Everett, WA

II. Demand Analysis

In order to determine how much H_2 and HCNG we would need to produce for out fuel station, we used the number of miles per person for each type of vehicle. For the amount of hydrogen to fuel our H_2 powered cars; we used the United States average of miles driven per year per person, which was estimated at 13,500. While that number was relatively easy to find, the number of miles driven by a commercial vehicle powered by HCNG per year per person was trickier. We ended up finding the ratio of fuel mass of HCNG to H_2 consumed my buses and trucks. We then took that number and multiplied it by the number of miles driven a year per person for a H_2 powered car. The number came out to 20,000 miles per year per person. This number would include all the personal trucks, transport trucks, buses, etc., that require HCNG. With both of these numbers, we were then able to calculate the amount of H_2 and HCNG we need in kilograms. For both fuels, we multiplied the estimated miles driven per person per year by the population of our city, then by number of kilograms of fuel per fill, then divided that number by the distance traveled for one full tank. Using this calculation, we determined we would need 23,175,000 kg of H_2 and 33,700,000 kg of HCNG to fuel our entire city per year.

Obviously, our city requires a ton of energy to run properly. On way to reduce the amount of energy our city needs would be to establish a more efficient method of public transportation. The use of buses and trains, etc., would increase efficiency of the city sense HCNG has a higher energy content than H_2. Also, another way to further improve our cities fuel consumption would be increasing the amount of carpooling. While it could prove almost impossible to enforce some type of car pool policy, promoting the idea of increased carpooling could potentially cut the amount of H_2 in half. Also, some believe we should install high speed transportation like in Japan. A train suspended in the air using magnets would require a lot less energy to get going, and would be an excellent source of public transportation. Additionally, by simply cleaning up our city, and reducing crime, we could boost the incentives to walk or ride a bike, both of which would further reduce our city's fuel consumption.

Lastly, an aspect to think about is the seasonal changes. For example, during the winter and inclement weather, people would be more prone to staying indoors. Likewise, during the summer and nice weather, people would enjoy the outdoors and find reasons to drive to more places. As a result, our fuel consumption for the winter would be less of that in the summer; however, we assume the national average we found takes into account the changes in weather, and the changes in miles pertaining to the weather changes.

III. Preliminary Concept Development

Production of both H_2 and HCNG required considerations on many levels, based on several criterions chosen by team members. Concepts could vary in many ways, including how the hydrogen is produced, where the energy comes from, and how the hydrogen is transported to each station for delivery of the product. Each was then evaluated under several of the criterion, and graded based on level of importance for this project.

We had the opportunity to evaluate all concepts of energy sources, production of hydrogen, production of methane, and delivery of the fuel. For energy sources, there are many concepts to choose from, but they must be renewable resources. Possible energy sources could be solar power, wind power, biomass, and tidal energy. Taking the electricity, we would need to produce the hydrogen gas, via electrolysis or steam biomethane reforming.

We came up with a few possible concepts that could be used, and eliminated ideas based on the criterion we decided before: money, feasibility, environmental impact, beauty, and safety. As a basis, we analyzed each and graded them on a weighted scale of importance (See Figure III-A). One concept included using solar energy to supply the electricity, use electrolysis to remove hydrogen from water, and then transport that to the station via pipeline. This is a very plausible concept, but we might need more electricity than could be supplied. Another concept was using a landfill to gather our methane for HCNG, and then use the steam biomethane reforming process to produce the needed hydrogen gas. This idea can take our methane and extract that hydrogen; however, it is clear we would need a ton of methane, more than we would need for HCNG because we would need the excess methane in order to supply enough hydrogen to the fueling station. After tossing around ideas of transporting the fuel, we decided to compress the gas and use trucks to deliver the fuels. Our last concept was using hydropower (a vastly renewable resource since the location is on the coast) to create electricity, then use that electricity for electrolysis (and the water around the hydropower plant) to break bonds of H_2O so hydrogen gas is released and captured for our fuel. The concept continued to sewage plants for our methane source, to provide the necessary methane for our HCNG mixture. After grading and evaluating these ideas on the criteria previously mentioned, we decided on the final concept. Taking all of the considerations, we felt the best concept would be hydropower to produce electricity, electrolysis to extract the hydrogen, and sewage plant to provide methane for HCNG, and then transport the fuels by trucks and compressed gas.

Figure III - A

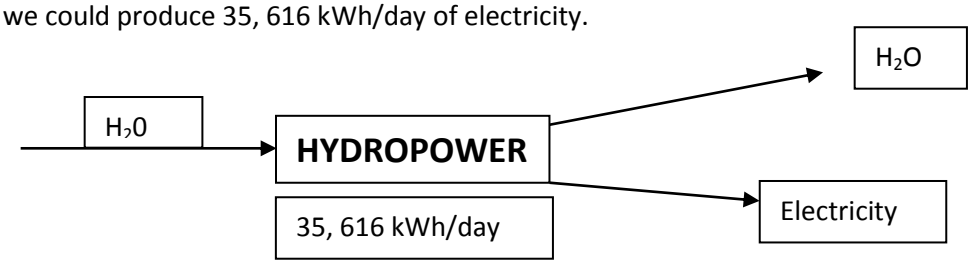
Objective	Cost	feasibility	evironmental impact	beauty	Jobs	TOTAL	Weight Factor
cost		0	0	1	1	2	0.2
feasibility	1		1	1	1	4	0.4
evironmental impact	1	0		1	1	3	0.3
beauty	0	0	0		0	0	0
Jobs	0	0	0	1		1	0.1

Figure III-B

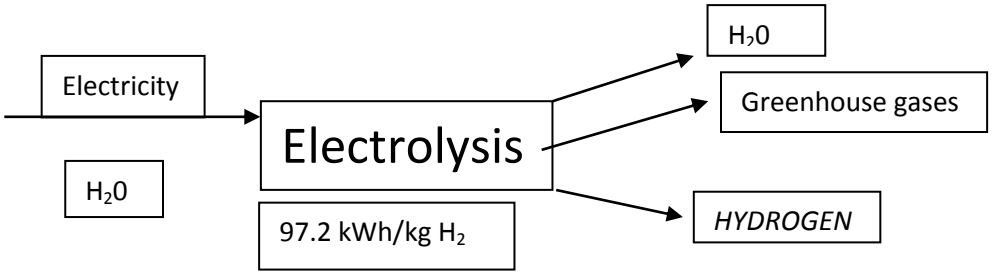
		Concept A		Concept B		Concept C		Concept D	
Objective	Weight Factor	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score
cost	0.2	3	0.6	2	0.4	5	1	2	0.4
feasibility	0.4	2	0.8	5	2	1	0.4	5	2
evironmental impact	0.3	2	0.6	2	0.6	4	1.2	5	1.5
Jobs	0.1	2	0.2	4	0.4	1	0.1	4	0.4
			0		0		0		0
			2.2		3.4		2.7		4.3

IV. Detailed Concept Description

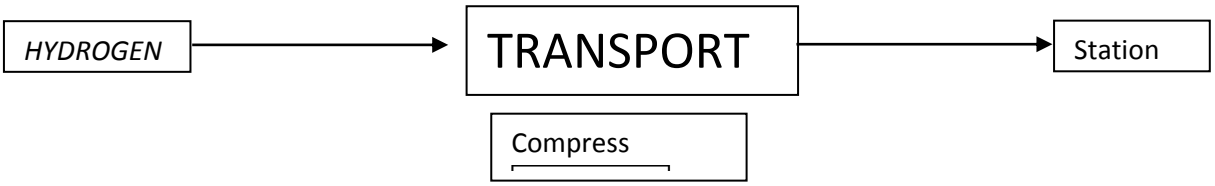
To describe the process, we must begin at the production of the electricity. Our concept included a hydropower plant. At these hydropower plants, via the use of flowing water and basic kinetic energy, electricity is produced. After determining we would use a medium sized dam, we calculated and researched to find we could produce 35, 616 kWh/day of electricity.



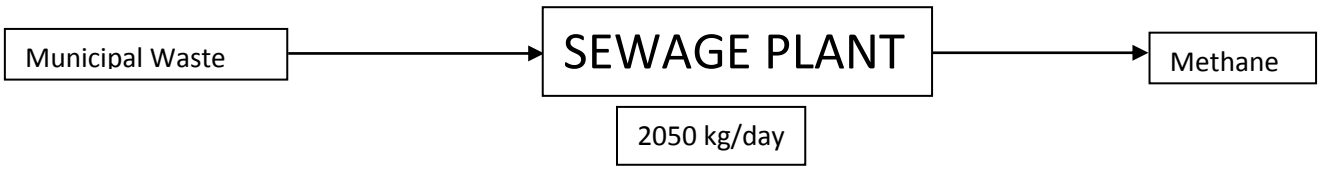
After the electricity is produced, we can use on sight electrolysis, a process involving a battery, two electrodes, one positive and one negative, and water. When the battery is applied, the water molecules split, with the positive electrode collecting oxygen, and the negative collecting hydrogen. We found that we can collect one kg of hydrogen with 97.2 kWh of electricity (this is a low temperatures, 100 degrees Celsius, and could produce 438.36 kg/day of hydrogen. Using this number, we found that we would need a ton of hydropower plants to produce enough hydrogen gas for the hydrogen fuel, let alone the HCNG



The hydrogen will then be compressed down, and transported to the station via trucks.



For our production of methane gas, we decided to take the biomass route. We would use a sewage plant, local to our city, who would kindly provide the municipal waste necessary. After calculating how much methane we would need, and looking at how much could be provided via sewage, we came up short in our production. The methane can only be produced at a rate of 2050 kg/day, which is clearly not sufficient.



After producing the methane, it would be compressed and sent to the station, via compressed natural gas.

For the economics for fueling our station, we used the provided spreadsheet below to help estimate the first cost of our stations, which came out to about $9.3 million. We calculated we would need 35 stations based our out cities population and amount of refills per person. This brings our new total first cost for the stations alone to $325 million. Next, we have to calculate the first cost of the production of all our hydrogen and methane. We would need 157 dams to produce enough hydrogen for our city. Online, we found that an average size dam costs around $2.5 million to build. Simply multiply this amount by the number a damns needed and we get a first cost of dams to be $392.5 million. Next, we have one sewage treatment plant to supply our city with methane and a typical sewage treatment plant costs about $21 million. Adding these sums to gather, we get final first cost of $738.5 million to supply our city with fuel.

In addition to our fixed costs, our system would obviously entitle operation costs. To determine our operating costs, we had to make a few estimate. We figured that we would need at least 4 employees at each dam to ensure smooth operation, each getting paid an average of around $70,000 a year. If we multiply this number by the amount of dams, we have an operating cost of about $43.96 million for the dams. Next, we figured each station could be run by one man being paid $58,400 a year. This makes the total operating cost for the stations about $2.044 million. Finally, for our sewage plant, we thought we would need a crew of 8

employees being paid $70,000 a year to run the facility, making the operation cost of the sewage treatment plant $560,000. Overall, by adding these individual operating costs, we get total operating cost of about $46.6 million a year.

In the end, with all our final costs and operating costs, if we charge $3 per kg, after ten years, we would be able to have about a 30% profit. This is very low, because we assuming that we could have gathered all the methane we need from our one sewage treatment plant. So, if we took into account that we would have a much higher first cost to cover the production of methane, the price per unit would be quite greater.

First Cost for stations:

		Inputs:	
Number of people in city		100000	people
Average miles driven per person		13500	miles/person/year
Miles driven per kg of H_2		60	miles/kg H_2
Number of stations		35	
Number of pumps, 350 bar		4	
Number of pumps, 700 bar		4	
Number of HCNG dispensers		1	
Area of station		250	m^2
Hours pumping per day		16	hours
Labor rate, $		10	$/hr
		Outputs:	
Total private vehicle miles driven by all people		1,350,000,000	miles driven/year
H_2 used per mile		0.0167	kg H_2/mile
H_2 used per year, all people		22,500,000	kg/year
H_2 used per day, all people		61644	kg/day
H_2 used per day, per person		0.62	kg/day/person
H_2 working storage capacity		1761	kg
Flow rate H_2		1.835	kg/min
HCNG used for entire city		63493	kg/day
HCNG flow rate		66.139	kg/min
HCNG working capacity		1814.086	kg
H_2 Fueling station costs			
H2 compressor system, 350 bar	180000	$ 259,061	
H2 storage system, 350 bar	38000	$ 3,367,259	
H2 dispenser system, 350 bar	5000	$ 20,000	

H2 compressor system, 700 bar	260000	$ 374,200	
Cooling block/chiller system, 700 bar	90000	$ 129,531	
H2 dispenser system, 700 bar	60000	$ 240,000	
CNG compressor, 250 bar	80000	$ 989,379	
CNG storage system, 250 bar	28000	$ 2,525,531	
HCNG blend system	30000	$ 371,017	
HCNG dispenser	50000	$ 50,000	
Balance of Plant	210000	$ 210,000	
Other Costs			
Land, purchased and developed	50	$ 12,500	
Buildings, finished and furnished	3000	$ 750,000	
Onsite H2 production (all methods)	9500	$ 7,106,527	
Per station	Total=	$ 9,298,479	
Total investment (First cost)		$ 325	Millions
Sales			
Volume of H2 sales		61644	kg/day
Volume of H2 sales (Number of units sold annually)		22500000	kg/yr
Volume of HCNG sales		63493	kg/day
Volume of HCNG sales (Number of units sold annually)		23174945	kg/yr
Salaries		$ 160	$/day
Salaries (PV Annual Cost)		$ 58,400	$/yr

Profit Spreadsheet

	Discount rate		5.00%		
	First Cost		$738,500,000		
	Annual Cost		$46,600,000		
	Number of units sold annually		56,700,000		
	Cost per Unit		$3.00		
Year	First Cost	Annual Cost	Annual Income per Unit		
0	$738,500,000	$46,600,000	$170,100,000		
1		$44,380,952	$162,000,000		
2		$42,267,574	$154,285,714		
3		$40,254,832	$146,938,776		
4		$38,337,935	$139,941,691		

5		$36,512,319	$133,277,801		
6		$34,773,637	$126,931,239		
7		$33,117,750	$120,886,894		
8		$31,540,714	$115,130,375		
9		$30,038,775	$109,647,977		
10		$28,608,358	$104,426,644		
NPV	$738,500,000	$406,432,848	$1,483,567,111		Total Profit
		Profit	29.6%		$338,634,264

V. Conclusion

MEC Inc.'s goal was to produce enough hydrogen and HCNG mixture to supply enough fuel for a city's transportation needs. By assessing our population in the chosen city, we could determine how much fuel we would need to provide the city per year. From there, it was easy to conclude exactly how much hydrogen gas, and methane, we would need to fulfill the amount, both for hydrogen fuel and HCNG mixture.

By designing a system to produce the energy supply necessary for the amount of hydrogen, MEC Inc. decided on a hydropower plant, which is an efficient way of producing electricity. This is a highlight of the system, as hydropower is a growing source of energy, and of course renewable. The electricity produced would be used in the process known as electrolysis, extracting the hydrogen from the water. The collected hydrogen would be our supply.

The methane would come from a sewage plant, located near the city. This renewable source is a focus on our production, where we would produce the necessary methane for our HCNG blended mixture.

Both of the gases would be transported via compressed natural gases to our stations. It is quite evident that, after the calculations have been completed, this process is *not* a viable option to supply a city of 100,000 people. The number of dams alone to produce enough electricity is staggering; not a plausible option. We would need to find another source of electricity, perhaps solar, although its location is not exactly prime. We will also be short on our methane supply, more than 95% short. We would need another way of producing methane for our HCNG fuel.

The process idea, had it produced enough, has strong points in the field of sustainability. All of the energy comes from renewable sources, unlike today's gasoline and oil. The availability of these resources is immense (hence why we chose hydropower for the shore). Sustainable

environments need help from its population too; ideas such as carpooling always help make the transportation “ELS.”

It is important to keep in mind what a powerful fuel gasoline is. You must produce much more hydrogen to fuel the way people live and travel. The process to get the required energy is not an easy, or quick, one. More sources of energy must be used if you are going to provide for a large population, you cannot rely on one source. More importantly, a design team must keep in mind the amount of environment the project will consume; 157 dams don’t just appear and life goes on. As a precaution next time we tackle a project similar to this, attempt it on a smaller population.