Hydrogen City Project

Sponsored by Air Products

EDSGN 100 Section 009

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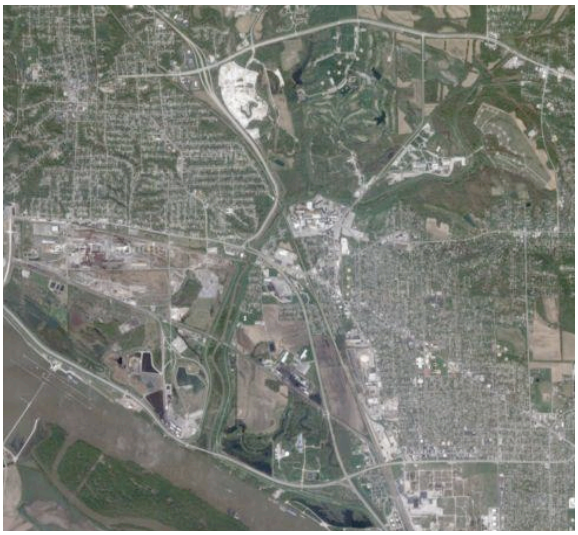
1. Introduction
   a. The goal of this problem is to design a Hydrogen filling station and plant that runs on all renewable energy so that Hydrogen and Hydrogen mixed with Natural Gas can be used to power cars today instead of having to use gas.
   b. The criteria of the project was to design a fueling station that had hydrogen at both 350 BAR and 700 BAR pressure to be used in personal cars and commercial vehicles. There also needed to be a renewable source of Compressed Natural Gas to be combined with Hydrogen for mass transportation and commercial vehicle at 250 BAR. All of the energy needed for production of the Hydrogen, HCNG, and the station needed to be made renewably. The station would then be used as a model to fuel the rest of the city.
   c. East Alton, Illinois was our chosen city for use to design the plant. It is located right next to the Mississippi River so we could use Hydropower from the river. The unique characteristic of Alton, Il is that there is already a Hydroelectric dam located just North of the city on the Mississippi River. Having a dam was critical for our design concept because for the Run of the River Hydropower to operate in low head rivers, there needed to be a dam in order to efficiently make power. The population is 6,830 people, which was perfect size for use so that we could focus on a smaller amount of people to keep our numbers from becoming to large.



Satellite View of East Alton, IL

2. Demand Analysis
   a. From our population of 6,830 people with using that most of the time the average is 1.5 people in the car at a time and using the national average of 13,500 miles per person a year driving we estimated that the city would need about 2,800 kg H_2 a day
   b. Redesigning a city would take too much effort but simple things like carpooling and having a city bus or city transportation system so that each person will not be driving their own vehicle and putting out their own emission, would help reduce fuel use.
   c. We figure the demand is really not going to change depending on which season it is. No matter what season it is the demand for fuel should be the same because people will still have to drive to work and there should relatively be the same amount of fuel used on leisure activity.

3. Preliminary Concept Development

   a. When considering how to design our production system for H_2 and HCNG we considered four specific concepts and we quantifiably judged each of the concepts by assigning values to five essential criteria. The first criteria that we considered was Environmental Impact and that is throughout the process of producing Hydrogen considering the effect it will have on the environment and natural resources. We assigned the Environmental Impact criteria the most weight, making it the most important criteria for any possible design concept. The second criteria we considered was feasibility which means can this process actually happen and be constructed. the cost. We assigned feasibility the second most weight because we wanted this project to meet the design criteria, and wanted to

meet the design criteria by using real world technology. The third criteria considered was the cost. This is the cost for everything in the system, Production of energy transportation, cost of each station, labor, etc. This was given the third most weight because the cost of a certain design concept is always a top priority. Then the fourth concept considered was was beauty. What we mean by beauty is the overall look of each individual station. Then our final concept is Accessibility, which means how many stations produced in different locations to serve each individual persons needs as convenient as possible.

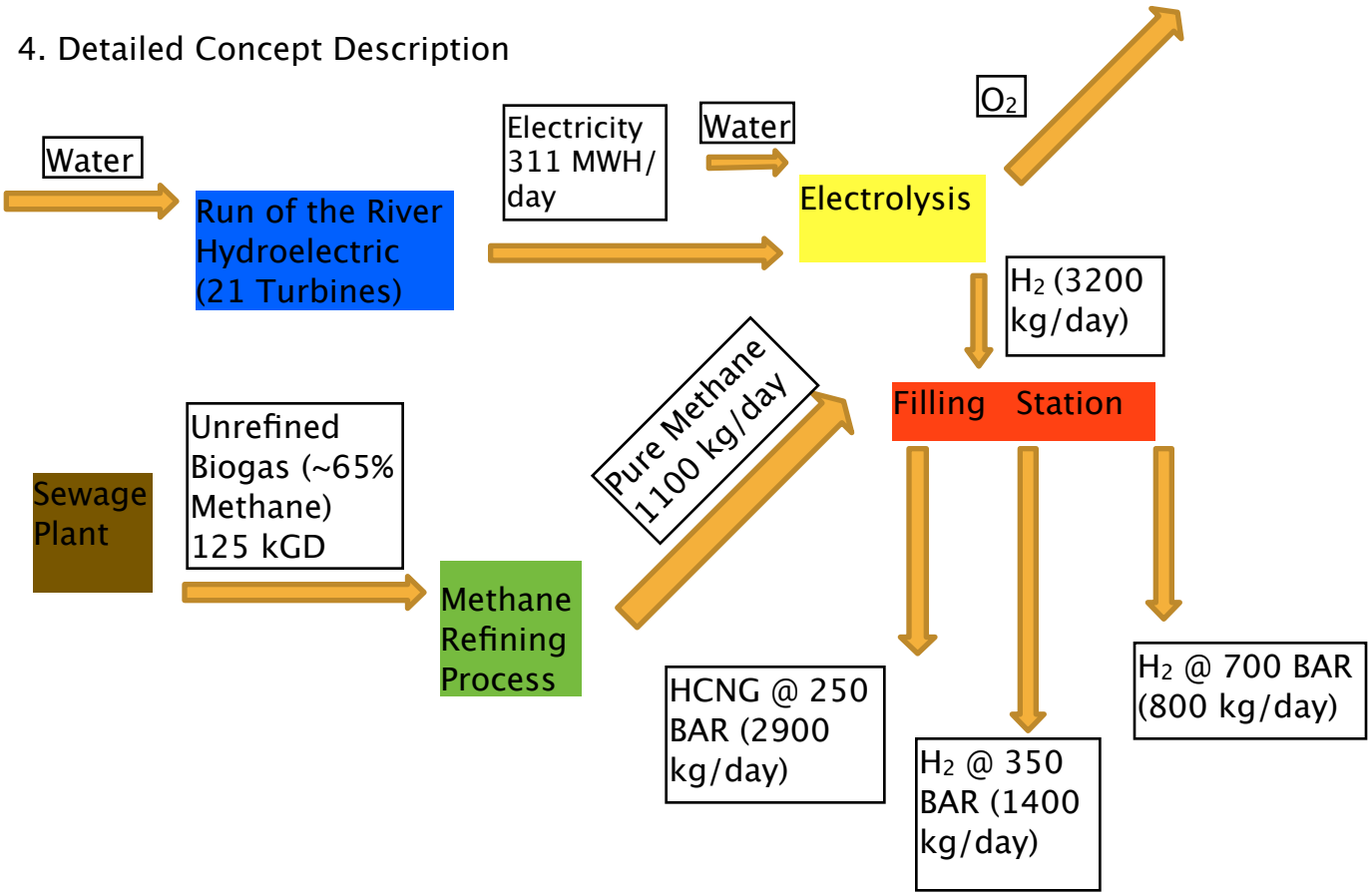
b. To determine which design concept was most important we used the weighted concept selection matrix, which placed an emphasis on each individual criteria and allowed for us to quantifiably determine which concept was the best. We matched up each criteria with each other and voted on which was more important, from that we determined weight factor. Then with weight factor we took each different design concept and gave it a score out of 5 saying how successful it is. The multiply the score by the weight factor and you receive the weighted score.

Objective	Cost	Environmental Impact	Beauty	Feasibility	Accessibility	TOTAL	Weight Factor
Cost		0	1	0	1	2	0.2
Environmental Impact	1		1	1	1	4	0.4
Beauty	0	0		0	1	1	0.1
Feasibility	1	0	1		1	3	0.3
Acessibility	0	0	0	0		0	0

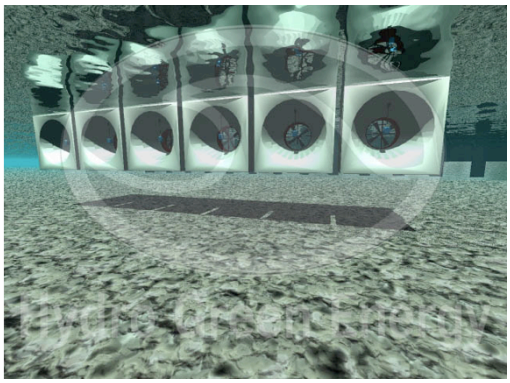
		Hydroelectric Power		Hydrogen Production Location		Wind Energy		Solar Energy	
Objective	Weight Factor	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score
Cost	0.2	3	0.6	2	0.4	1	0.2	3	0.6
Environmental Impact	0.4	4	1.6	2	0.8	4	1.6	3	1.2
Beauty	0.1	4	0.4	1	0.1	3	0.3	2	0.2
Feasibility	0.3	5	1.5	1	0.3	1	0.3	1	0.3
Accessibility	0	3	0	2	0	2	0	4	0
			4.1		1.6		2.4		2.3

The four design concepts we compared were: Hydroelectric power with Hydrogen produced at a central location, Hydroelectric power with Hydrogen produced at each station, Wind Power as the sole source of electricity, and Solar Power as the sole source of electricity. After comparing the four design concepts in the weighted matrix, the process with the highest score is the best option and for our group that was Hydroelectric Power with Hydrogen produced as a central location.

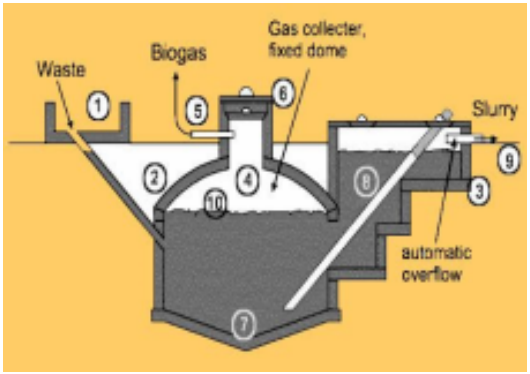
4. Detailed Concept Description



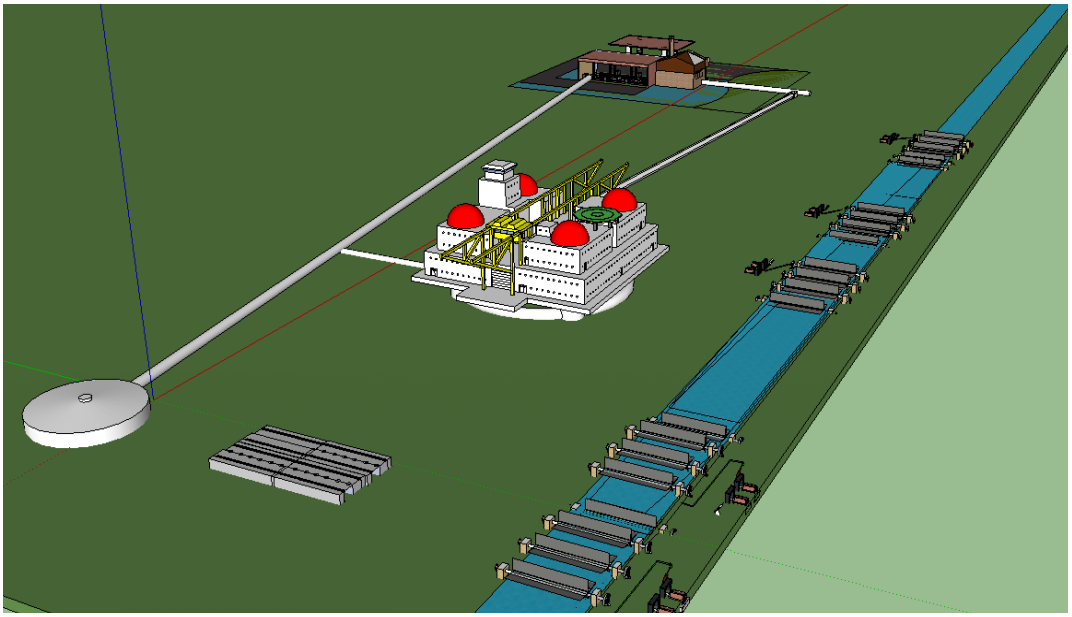
The main aspect of our design is that being located next to the Mississippi River provides the potential for having renewable energy all the time. As a result of the pre-existing dam, a Run of the River Hydro turbine system allow for an ELS energy producing system that can power the entire system. The turbines are a big initial cost but



eventually after time they will pay for themselves because you will not have to pay electricity bills. The electrolysis system for producing H_2 is an ELS system, with the only inputs being water and electricity. The city of East Alton also has The sewer is not far away either so methane will be able to be pumped into the station instead of having it to be transported by commercial vehicle. The Gobar Gas system, the method of refining methane into CNG quality fuel, was the most energy efficient and biogas efficient system that we could find. The location is what makes this key and the concept to be successful.

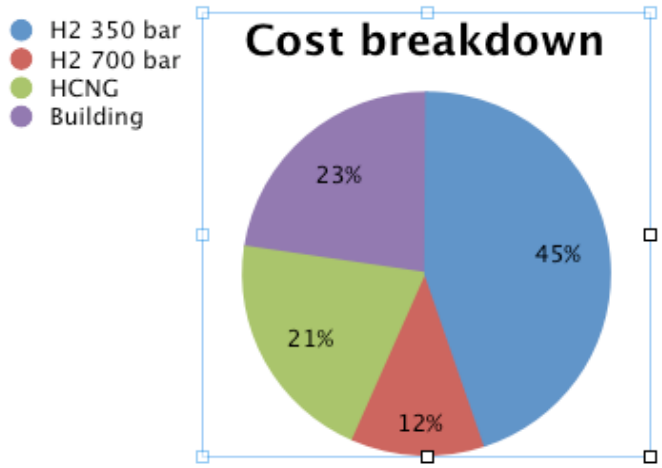


i. CAD Model production facility

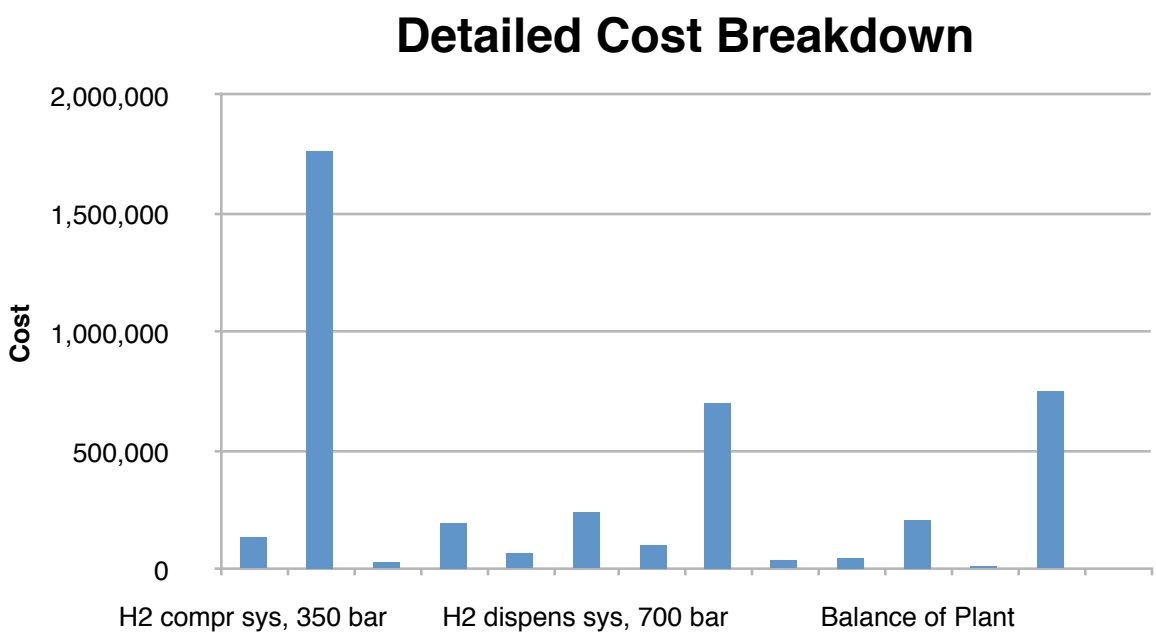


b. Economics

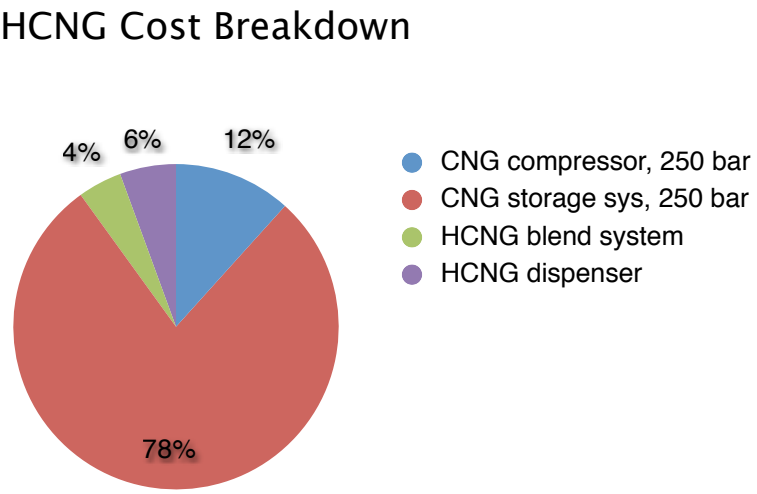
i. Our first cost was very expensive up front. We estimated that for the 7 acres of land needed, the seven stations, the production facility, all 21 turbines and all the equipment it will cost $51 million upfront.



ii. $3 Million this is a rough estimate for operating cost but we figured if 3 people work at the station at a time, the amount spent on labor would be around $1.23 million for the entire labor costs then we figured it would take $1.75 mill to produce Hydrogen.



The cost of the production and storage of HCNG proved to be costly as well. The HCNG system had an upfront cost of just over $1 million dollars.



iii. With the initial cost and the annual cost, by the 10th year we are expecting to make a profit of $22.5 million dollars, which is a 29.2% profit. To have a profit that large we will need to charge $5.50 a unit.

	Discount rate		5.00%		
	First Cost		$51,000,000		
	Annual Cost		$3,000,000		
	Number of units sold annually		2,077,580		
	Cost per Unit		$5.50		
Year	First Cost	Annual Cost	Annual Income per Unit		
0	$51,000,000	$3,000,000	$11,426,690		
1		$2,857,143	$10,882,562		
2		$2,721,088	$10,364,345		
3		$2,591,513	$9,870,804		
4		$2,468,107	$9,400,766		
5		$2,350,578	$8,953,111		
6		$2,238,646	$8,526,772		
7		$2,132,044	$8,120,735		
8		$2,030,518	$7,734,034		

9		$1,933,827	$7,365,746		
10		$1,841,740	$7,014,996		
NPV	$51,000,000	$26,165,205	$99,660,561		**Total Profit**
		Profit	29.2%		**$22,495,357**

5. Conclusion

a. The main focus of our design will be the way that the hydrogen is produced so that it is not harmful on the environment. The main purpose of the project is to make cars run on hydrogen so that gas is not being used and the environment is not suffering as a result. So what would the point be if in the production of the hydrogen was hurting the environment? Our process uses all renewable resources from the energy used to the hydrogen obtain from the methane. This process is all about helping out the environment. Using hydropower from the Mississippi River will provide enough energy needed so that hydrogen can be produced. Also it is hard to transport hydrogen at 700 BAR so the solution to this problem was to have a compressor at each filling station.

b. Making transportation ELS is a difficult task. The best way to help the environment is to have vehicles emit less pollution when driving and also not using fossil fuels to power our vehicles. By using renewable sources, as fuel and creating that fuel from renewable energy will ultimately help the environment out the most.

c. Our group has learned many valuable lessons from this project. First, designing an entire system for a whole city is a daunting task. It was very challenging to think on such a large scale as an entire system. For another project, it would be better for each group

member to focus on one single part of the design concept instead of the entire system. Second, converting methane into CNG quality is a very costly, energy consuming, and low efficiency system with today's technology. This was true for most of the processes for producing renewable energy in an ELS manner.

6. Miscellaneous Calculations

H_2: $\frac{13{,}500\ mi}{person\text{-}yr} \cdot 6830\ people \cdot \frac{1\ car}{2\ person} \cdot \frac{1\ kg\ H_2}{60\ mi} \cdot \frac{yr}{365\ days}$

$= 2800\ kg\ H_2/day$

HCNG Fuel Mileage:

2003 F-150 / Semi

$16.9\ \frac{watt}{gal}/min$

$\frac{17\ mpg}{13\ mpg} = \frac{6\ mpg}{x}$ $\quad x(30\%\ HCNG) = 4.6\ mi/kg$

Trucks: $\frac{2\times10^6\ trucks}{307\times10^6\ people} = \frac{.0065\ truck}{person} \cdot 6830\ people$

$= 44\ trucks$

$44\ trucks \cdot \frac{400\ mi}{truck\text{-}day} \cdot \frac{kg}{4.6\ mi} = 3800\ \frac{kg\ HCNG}{day} \cdot .3(H) = 1100\ kg\ H$

$(2100 + 1100)\ kg\ H_2 = 3200\ kg\ H_2/day$

$1\ gal\ (water) = \frac{3.785\ kg}{gal} \cdot 8\times10^6\ MGD = 3.024\times10^7\ \frac{kg\ (shit)}{day}$

$\frac{2700\ kg\ (CH_4)}{day} \cdot$

$\cancel{1.58\times10^5}$ $\quad \frac{160{,}000\ kg}{3{,}785}$

.017 (efficiency

@ 100°C $\frac{350\ MJ}{1\ kg\ H_2}$

$\boxed{97.2\ kwh} \cdot 3200\ kg\ H_2$

$\frac{311{,}000\ \cancel{kg\ H_2}\ kwh}{day}$

Turbines

21 turbines

$\frac{12\ ft}{turbine}$

$311\ Mwh \cdot 365 = 114{,}000\ \frac{MWH}{yr}$

$\approx \frac{4000\ m^3\ CH_4}{} = \frac{200\ m^3\ CH_4}{4\ kW}$

$= 80\ \frac{kwh}{day} + 311{,}000\ \frac{kwh}{day} = 311{,}080\ \frac{kwh}{day}$

Works Cited

Run of the River Power Information

http://www.hgenergy.com/index.html

Turbines

http://www.hgenergy.com/technology.html

Satellite Image of East Alton, IL

http://www.acres-wild.com/Gobar%20Gas.shtml

Methane Refining

http://www.acres-wild.com/Gobar%20Gas.shtml