Design Proposal - Residential Fueling with Hydrogen

Riverside, California

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Executive Summary

With the advent of mass produced automobiles came an unparalleled advancement of human society. The introduction of such a dramatic improvement in transportation of goods and services entailed with it an almost compulsory advancement of humanity's capabilities to exploit nature like it had never before. Invention of the internal combustion engine, which used the then commonly available fossil fuels as its energy source, went almost hand-in-hand with the massive introduction of superhighways and other developments to make the gasoline-powered vehicles the ubiquitous transportation mechanism as can be seen today. Unfortunately, the consequences of consumption of fossil fuels and its impacts, environmental or otherwise, are only starting to become apparent. Even now, the worsening air and water quality is causing a myriad of health problems, and fossil fuels, as a non-renewable resource, will eventually become of such scarcity as to render the maintenance of such a vast fleet of gasoline-powered vehicles unfeasible.

Hydrogen holds a key potential for resolving this dilemma, as the burning of hydrogen has no environmental impact apart from water as a byproduct, and the sources of hydrogen are almost unlimited given the vast availability of water and/or other sources for its production. Thus, vehicles powered by hydrogen have seen intensive development for the past two decades, with a functional hydrogen car already nearing completion. Unfortunately, the mass introduction of such a vehicle powered by hydrogen has faced much difficulty due to the lack in viable infrastructure – there is currently no feasible way to secure a consistent delivery of hydrogen to every family unit which would otherwise use such a car.

The objective of this design is to provide residential fueling of 1kg of hydrogen into a light-duty hydrogen vehicle at 5000 psi. This design seeks to resolve this problem by introducing a method for production of hydrogen within each residence of sufficient scale to provide for the daily operation of one hydrogen vehicle. Water electrolysis will be conducted through the use of a radical new membrane, to minimize the design's environmental impact along with providing a renewable method of hydrogen production. The water will be connected to a simple filter purifier that requires low maintenance given the low purity requirement of our membrane, and the power required for water electrolysis will be generated by the use of solar panels. The resulting hydrogen will be compressed and stored on-site for use by the owning household, or connected to a separate fuel cell unit, again using our radical new membrane, to provide auxiliary power to the household. All systems have been rigorously examined for possible safety hazards, since safety is paramount in our design due to its close proximity to residential neighborhoods. A business plan has been provided to show the feasibility of implementing this project, and results of our calculations indicate that our system is economically feasible. Finally, an education plan is provided to introduce this technology and provide a reasonable basis for family homes to decide the worth of this investment.

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1. Technical Design

1.1 Introduction

In 2001, world energy consumption was predicted to double by 2050 and triple by 2100.[1] By comparison, the annual oil production is projected to peak within the upcoming decade, and then fall dramatically in the following years to less than 1985 levels by 2050.[1] But despite their limited supply, mankind is more dependent on fossil fuels than on any other energy source. If the trend of increasing energy consumption is to continue, it will be essential to discover new sustainable and environmentally friendly energy sources.

One promising replacement for fossil fuels is hydrogen. There are no harmful emissions associated with hydrogen fuel because the only byproduct of combustion is water.[2] Unfortunately, hydrogen gas is rarely found in its natural form and must be generated. One of the most common forms of hydrogen production is water electrolysis.[3] This procedure is the reverse of a typical fuel cell reaction: external power is applied to split water into its hydrogen and oxygen components. Fuel cells and electrolyzers often utilize the same materials, and by researching one, technology advances can be made in the other.

Fuel cells have become a major point of interest because they are environmentally friendly and have the potential to replace batteries and engines. Fuel cells are mainly classified by their electrolyte (or exchange membrane, for the purposes of this paper). Proton exchange membrane (PEM) fuel cells (FCs) are the most commonly studied type due to the excellent chemical and mechanical properties of their membrane; for example, Dupont Inc.'s Nafion™. Unfortunately, the commercialization of PEMFCs has met with severe obstacles, and the same obstacles apply to PEM-based electrolyzers. In particular, the high cost of the platinum catalyst (\$1640/oz.)[4] prohibits the use of PEMs for our intended application. Additionally, while the Nafion™ is chemically stable, it is expensive (e.g., \$900/m^2)[4] and must be synthesized from tetrafluoroethylene (C_2F_4), which is both potentially explosive and a dangerous carcinogen.[5]

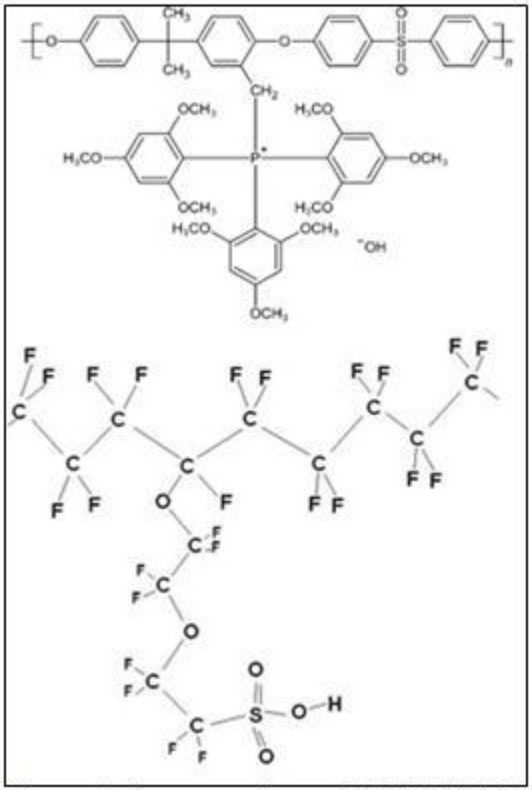


Figure 1: A comparison of TPQPOH(Top) and Nafion™(Bottom)

By contrast, hydroxide (OH-) exchange membrane fuel cells (HEMFCs) are of high interest because they run at low temperatures, and are less expensive to construct than PEMFCs. However, new limitations arise in alkaline fuel cells, specifically at the triple-phase boundary of the catalyst layer. A soluble ionomer must be found to improve the utilization of catalyst particles and reduce the internal resistance. Ideally, the ionomer should have high hydroxide conductivity, stability in alkaline media, and solubility in water-soluble solvents.

However, the most widely cited ionomer for HEMFCs, a quaternary ammonium hydroxide containing polymer, has low hydroxide conductivity, poor alkaline stability, and poor solubility in solvents such as ethanol and propanol.[6] The latest advance in HEM technology is a new polymer membrane, tris(2,4,6-trimethoxyphenyl) polysulfone-methylene quaternary phosphonium hydroxide (TPQPOH), which has shown excellent solubility in low-boiling-point water-soluble solvents, high hydroxide conductivity, and outstanding alkaline stability in its initial testing.[6] Further, TPQPOH synthesis avoids the aforementioned complications of Nafion™ synthesis by requiring only the use of much less hazardous and non-carcinogenic chemicals such chloromethylated polysulfone, methyl-2-pryollidone(NMP solvent), and tris(2,4,6-trimethoxyphenyl)phosphine[6]. The chemical structures for Nafion™ and TPQPOH can be seen in **Figure 1**. One study has already shown that a fuel cell with this experimental membrane exhibits a substantial increase of peak power density and a significant reduction of internal resistance over traditional HEMFC s.[6]

Since electrolysis is the reversal of a fuel cell operation, we propose to use the state-of-the-art TPQPOH membrane in an alkaline electrolyzer and prove its potential to produce hydrogen for powering a hydrogen vehicle and for fuel cells. In our residential scale design, we use photovoltaic panels to power the electrolysis and store the produced hydrogen in a pressurized tank. The rate of production within each system will fulfill the requirements for one hydrogen vehicle, although it would be simple to scale up the design to meet larger demands simply by increasing the number of cell stacks. Further, if this daily production of 1kg of hydrogen is not completely used by the household's vehicle, it will be routed through a fuel cell stack that uses this TPQPOH membrane to supplement the home's electricity needs. Our proposed system will be discussed in detail in the following sections.

1.2 Design Location Selection

Our target location is a development called Victory Gardens, located in Moreno Valley, California which is approximately 58 miles east of Los Angeles, whose aerial view can be seen in **Figure 2** below. Victory Gardens is a community being retrofitted from old military barracks built in the 1960's into a self-reliant and sustainable community.[7] As seen in Figure 2, the development includes thirty homes and a 5-acre plot of undeveloped open land. The developer has plans for installing photovoltaic panels linked to each home and a communal farm system using hydroponics and

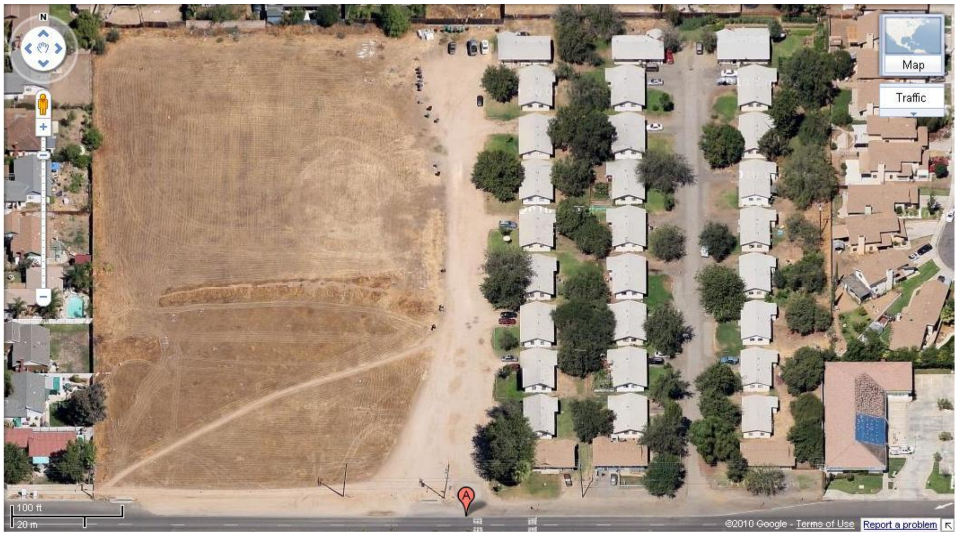


Figure 2: A satellite view of the Victory Gardens, courtesy of Google Earth™. [7]

aquaponics on the undeveloped land. The developer is very receptive to sustainable and innovative concepts; thus the use of a model home in this community for a residential hydrogen fueling unit would be an option. The developer has provided us with the layout of the current model home for our use to design a residential hydrogen fueling unit.[8]

This community has ample access to both tap water and grid electricity, making this an ideal staging ground for a preliminary incorporation of our system. Our system does not require any specialized fuel sources other than filtered water; thus, we do not need to consider other nearby industries for supplying hydrogen. Further, the compression and dispensing of hydrogen will also be done on-site through a unitized system. The safety and stability of our design for this neighborhood would be similar and replicable for other residential localities. Furthermore, given the fact that this community is highly focused on lessening the environmental impact of humanity's occupation, the members will be much more receptive to the concept of a distributed (home-based) hydrogen generation system. A hydrogen-powered vehicle fueled from home with hydrogen produced from water electrolysis that is powered by solar energy, will truly be an environmentally friendly source of mobility.

1.3 Design Mechanics Overview

We have designed a residential hydrogen production system that requires only a power source and water to operate. A piping and instrumentation diagram (P&ID) illustrating our system can be seen in **Figure 3**.

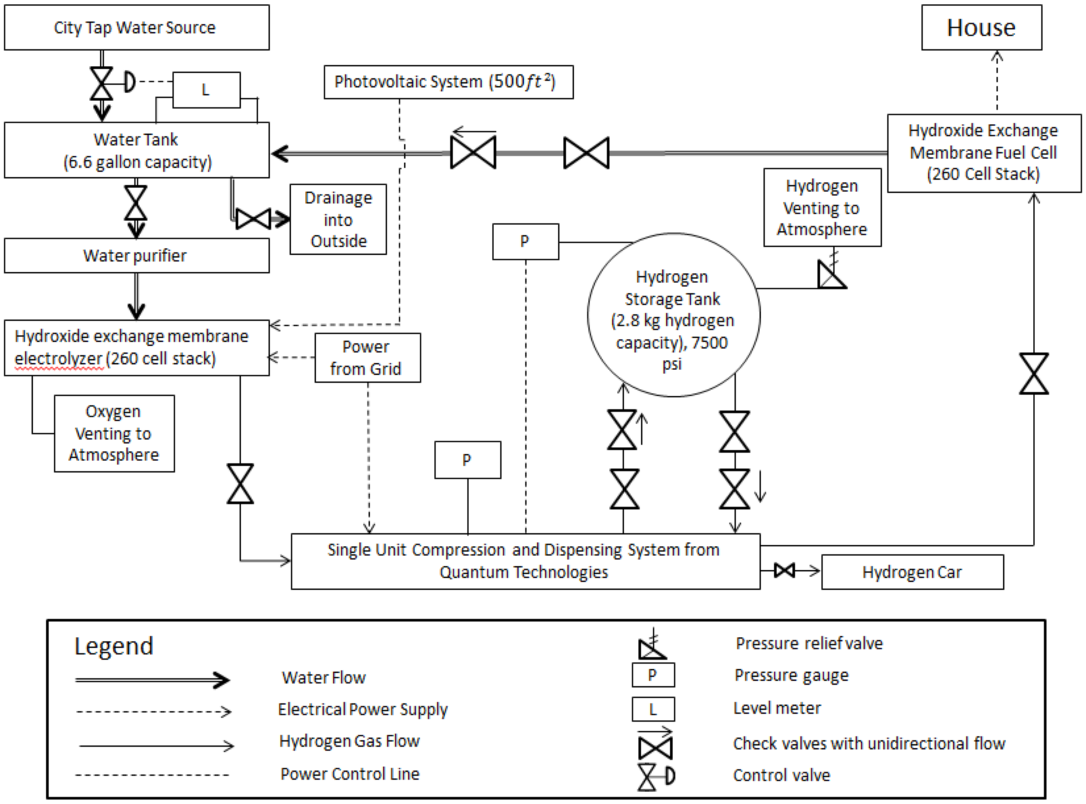


Figure 3: P&ID of our distributed hydrogen fueling and fuel cell system.

Energy for the electrolysis is supplied by a photovoltaic panel field, and water is taken from a standard domestic city water line. The electrolyzer uses our revolutionary new membrane to cheaply produce hydrogen. The resulting gas is then pressurized and stored in a tank, whence it is dispensed into a hydrogen car for daily usage, or connected to a fuel cell stack that uses the same revolutionary membrane to produce electricity that supplements the home's daily energy use. A general schematic of our system can be seen in **Figure 4.**

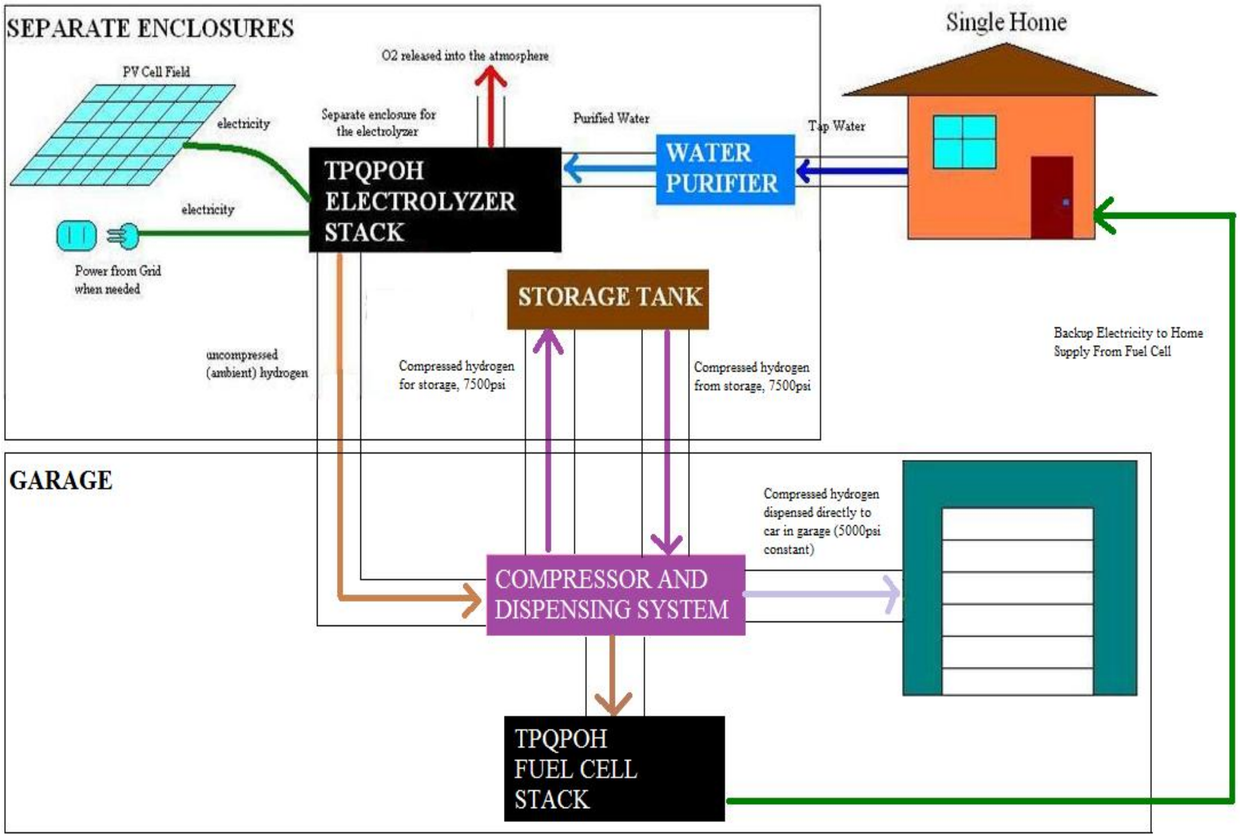


Figure 4: A basic schematic of our electrolyzer/dispenser system

Our design calls for the photovoltaic cells to be placed in a separate area from the single home. As seen in the spacing and orientation of the homes in **Figure 2**, the implementation of our model within Victory Gardens would allow enough space for each household to place photovoltaic cells of sufficient area in a location separate from the home. Moreover, the electrolyzer stack and the hydrogen storage tank are also placed in a enclosed area apart from both the home and the photovoltaic array due to safety concerns as well as to provide immediate access for any maintenance needs. The hydrogen from the electrolyzer stack will be sent, via underground steel pipes, to the compressor and dispensing system, from which the hydrogen can be compressed and sent to the hydrogen tank within the separate enclosure for storage. Whenever needed, the compressor and dispensing system can draw upon the stored hydrogen to be dispensed into the car or directed into a fuel cell stack using the same membrane to provide supplemental electricity to the household.

A 2-dimensional layout of our system that illustrates all these points of interest within our system can be seen in **Figure 5**. This figure includes the actual blueprint of a single Victory Gardens estate, and clarifies the feasibility of implementing our system within an operable household.

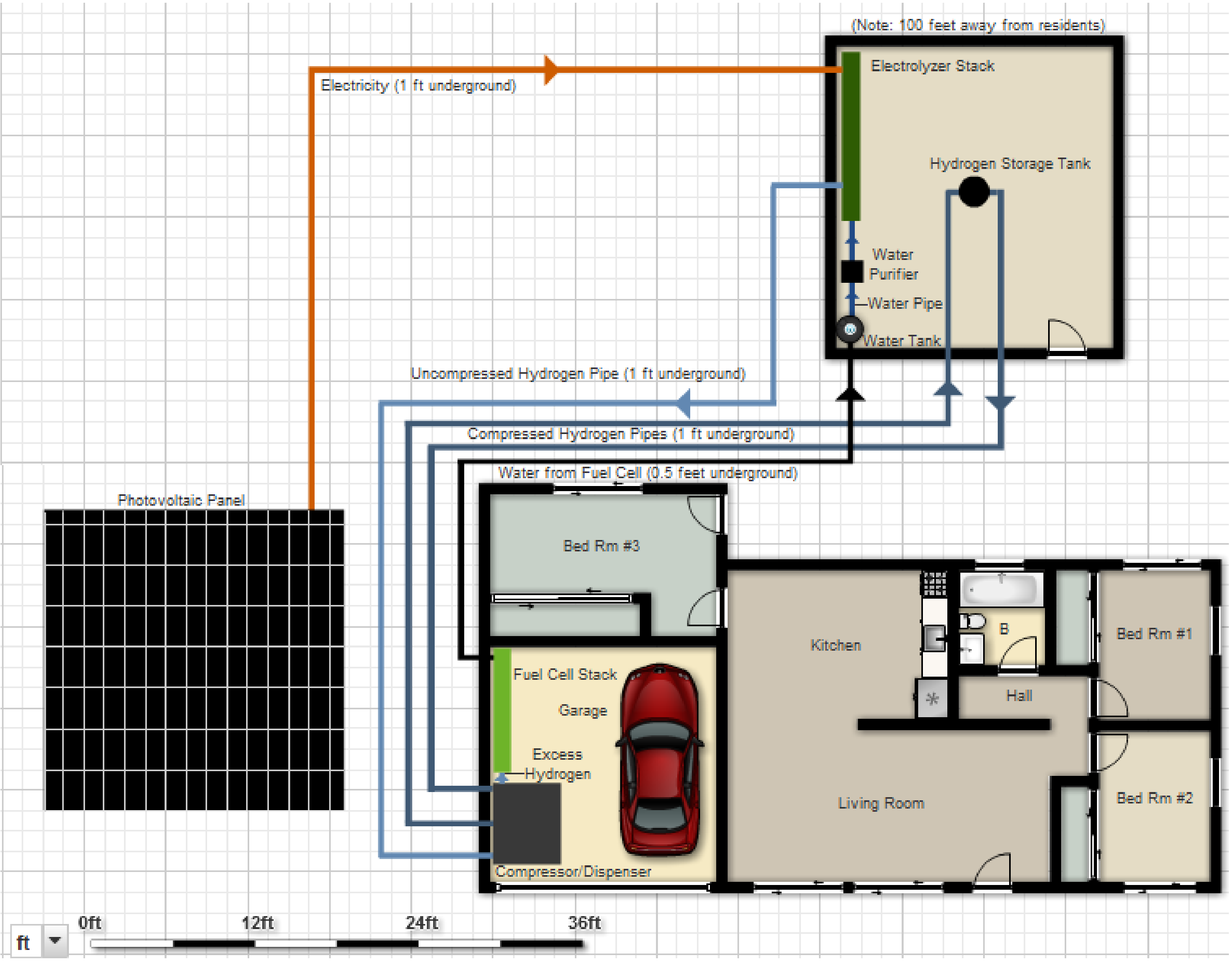


Figure 5: a stylized depiction of the hydrogen production/dispensing areas within the household

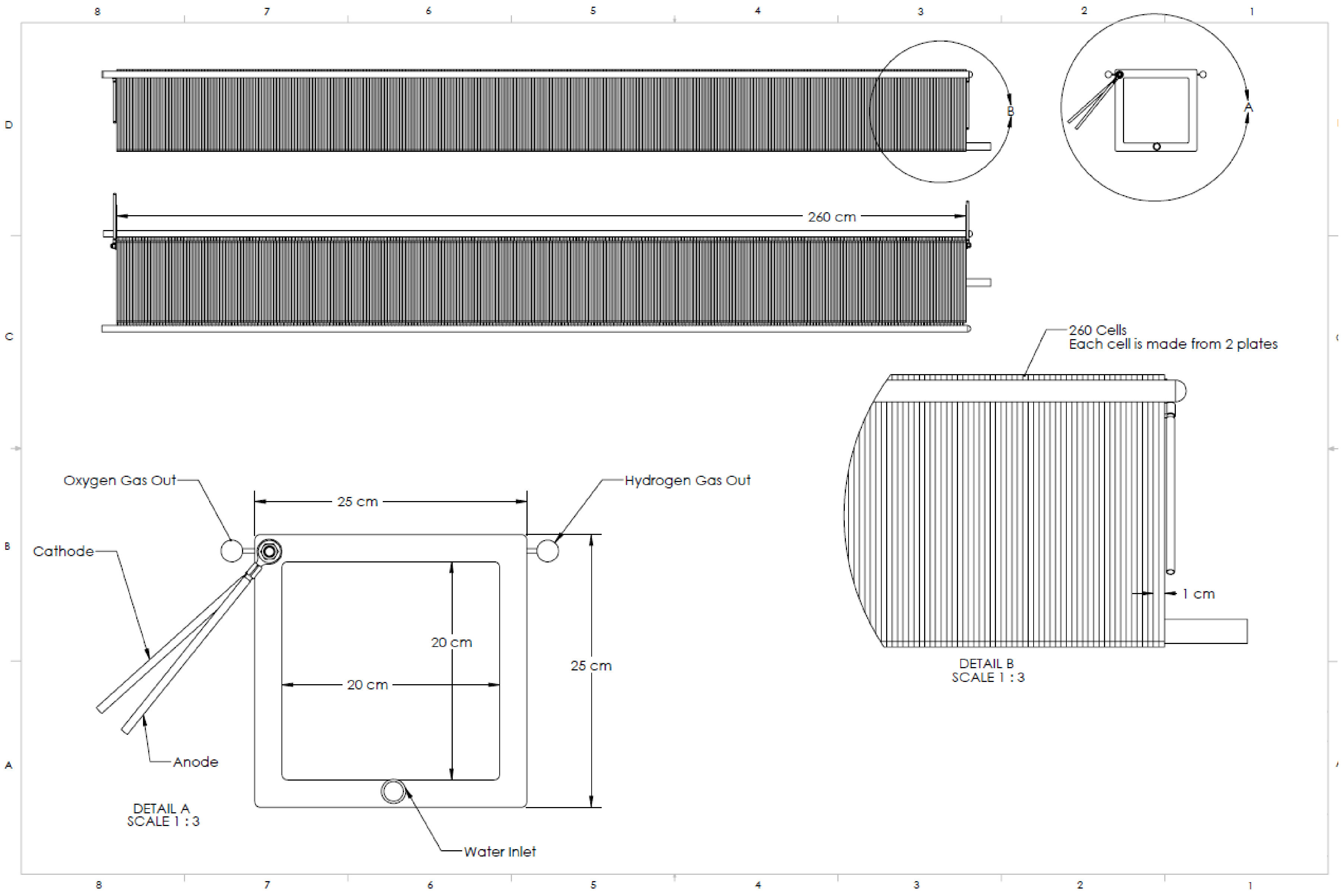


Figure 6: a scaled diagram of the design for our electrolyzer unit, in cm.[38]

1.4 Electrolyzer System Powered by a Photovoltaic Array

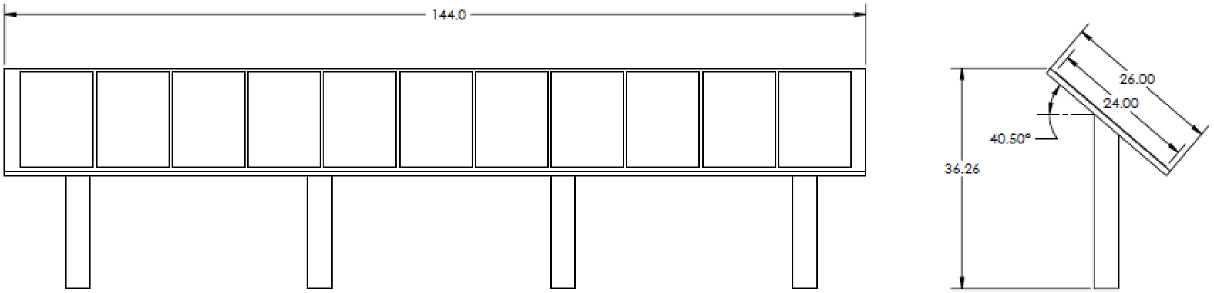


Figure 7: a scaled diagram of the photovoltaic array within our system, units in inches. [38]

We will be using a standard, industry-scale photovoltaic array as the primary power source for the electrolyzer stack. The specific dimensions of the electrolyzer stack can be seen in Figure 6. Data from preliminary results indicate that our membrane, while extremely cheap (over two orders of magnitude cheaper than Nafion^{TM}), requires approximately four times as much power as PEM fuel cells. Thus, calculations indicate that we need 200mW per square centimeter of membrane to produce the desired amount of hydrogen.[6] This calculation takes into account the varied angles of sunlight intensities into consideration. **Figure 7** shows the specific design dimensions of our photovoltaic cells.

For a single unit stack consisting of 260 electrolyzer cells, with an active area of 400 cm^2 per cell, the total energy required is 24.8kWh per day.[6] A solar panel price inquiry from Wholesale Solar Inc. indicates that ordering Kyocera KD235GX-LB 235 Watt solar panels of sufficient quantity will require an investment of approximately $50,000 with possible further negotiation.[9] The membrane-electrode assembly will be fixed within each of the 260 stainless steel enclosures.

If we relied on the roofs of the residences to house our panels, the working area would be small and consequently we would need a solar tracking system to maximize sunlight exposure. However, if we utilize the open areas next to the residences as shown in Figure 2, we can use a much cheaper fixed solar cell array while still meeting the power output requirement.

1.5 Supplemental Grid-Independent Electricity Generation Powered by a Fuel Cell Stack

On days when hydrogen is not dispensed for hydrogen vehicle usage, our system includes another 260 fuel cell stack with the same TPQPOH membrane for electricity production. The hydrogen that is stored in a high pressure canister can be alternatively routed into this fuel cell stack by the dispenser to provide equivalent energy of 27kWh for 1 kg of hydrogen consumed daily, if we take into account the energy conversion efficiency of this system and maximum energy density of 1kg of hydrogen.[19] Considering that the average daily energy use of an American household is 30.2 kWh/day,[20] our system can provide a large portion of a household's daily electricity use from renewable sources. The dimensions of our fuel cell stack will be of comparable size to the electrolyzer system.

1.6 Water Source

Since our system does not require any specialized fuel source other than filtered water, we do not need to consider other nearby industries. However, access to tap water quality water will be important. We will use a standard commercial water deionizer, which typically costs between

$100 and $300. The specific model we are looking at is the New Wave Envio Water Filter System, currently being sold for less than $100.[10] The filter, at the rate of our proposed usage, will need to be replaced once per month. Our system only requires a small amount of water each day for hydrogen production (6.6 gallons a day). By comparison, most American households, on average, consume 69.3 gallons per day, according to the Handbook of Water Conservation.[11] Thus, such a small scale water purification system is sufficient. Further, the electrolyzer system does not require high water purity, so a single pass is sufficient.[6]

1.7 Compressor and Dispensing System

Quantum Technology sells a combined H_2 Compression and Dispensing system. This system can take in hydrogen at ambient temperature from an electrolyzer, and compress it to 7500 psi for storage in a separate storage tank. Further, this system can take H_2 stored at 7500 psi, and dispense it into a car at 5000 psi. Storage at 7500 psi enables the dispensing of H_2 at 5000 psi for the vehicle for a day in the event that the compressor malfunctions. The Quantum Technology compression and dispensing system, shown in **Figure 8**, will handle any cooling/heating requirements as dictated by natural phenomenon of compression, and will provide gas at the required temperature both after compression for storage and for dispensing according to all regulations, including SAE J2600 and as described in Appendix A of SAE TIR J2601 .[29] Product specifications indicate that it takes 7.5 minutes to dispense one kg of hydrogen into a vehicle. Each system provides an electrical circuit to monitor the flow rate, temperature, and pressure as well as possible leakage of the gas tank within the car. [12]

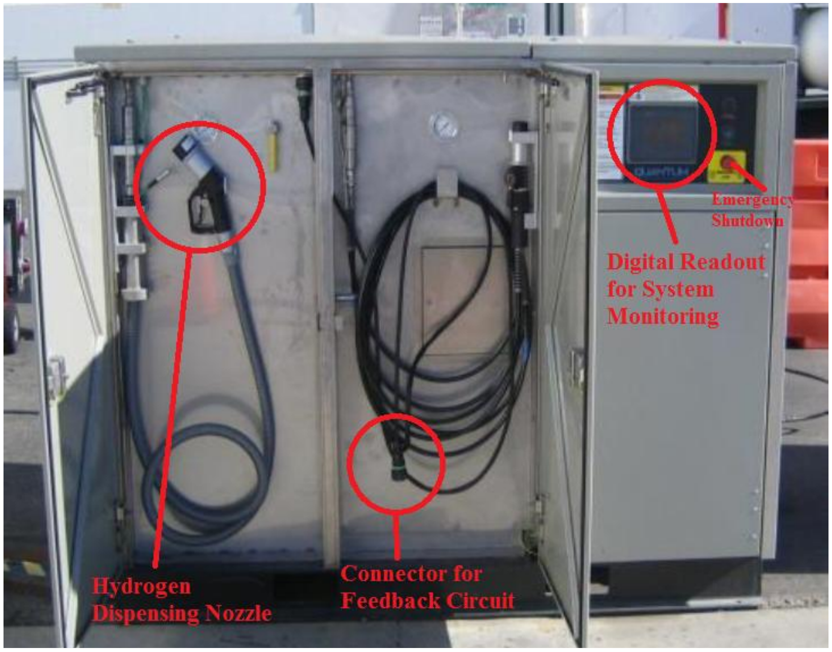


Figure 8: A photograph of the combined compressor and dispensing system from Quantum Technologies.

Unfortunately, the largest drawback of this system is the high cost. Calculations indicate that the cost of this system, before all deductions, will be approximately $100,000 (as seen in our business analysis) However, due to the large capacity of the compressor within this system at 9kg/hour, it is more efficient to utilize one compressor system shared by multiple households.[12] If, in the future, we design a "hydrogen community," where multiple households incorporate our proposed system, it will be possible to maintain individual hydrogen storage but reduce the overall cost of the system per household by having multiple households divide among the excess capacity of a single shared compression/dispensing system. This theoretical design, shown in **Figure 9**, will allow an individual household to produce its own amount of hydrogen, using it as needed. By constructing a hydrogen compressor off-site, the compressor can be shared within multiple households, allowing hydrogen to be produced on site, transported through pipes to the compressor and then transported back to each house.

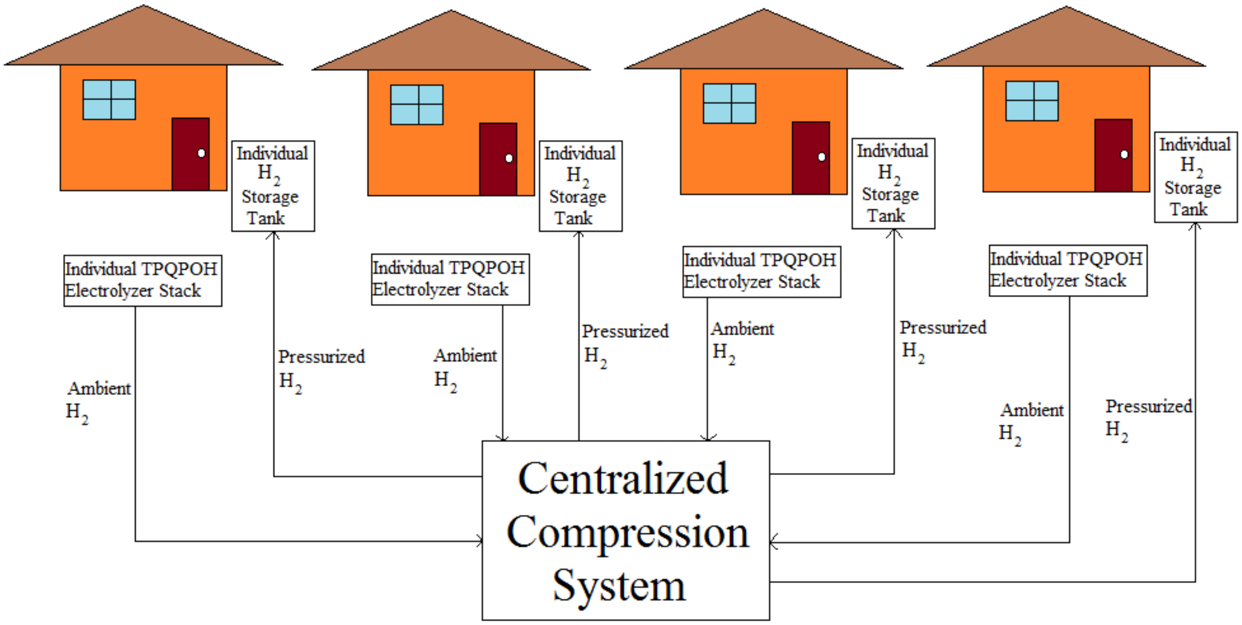


Figure 9: A basic schematic of a theoretical centralized compression system for multiple households using our TPQPOH experimental membrane

As shown above, although our system is extremely costly when viewed in terms of a single household, the capacity of such a system is far greater than what a single household will require. If a hydrogen economy is realized and a community of households all implement our proposed setup, then multiple households can share the cost of one compressor system and thus the price of such a system could be reduced dramatically. Based on the proximity of the houses in Victory Gardens and the available area of land, the cost of the compressor and dispenser per household can be reduced from as high as $100,000 to $10,000, if the capacity is divided among 10 households, as a starting point of estimation.

Moreover, there are many tax incentives available. Each household in California that implements our system can expect to receive as much as $100,000 total in tax credits, which will provide a huge discount as well as a major attraction towards its implementation. A complete summary of these tax credits can be seen in section 3.

1.8 Storage Tank

Quantum technology also provides ASME hydrogen storage tanks that can store hydrogen at 7500 psi and 2kg for our specifications, whose pricing was provided at $1000 for a single household[12]. If our design is incorporated in a larger scale, this cost should also decrease, given the economies of scale. The hydrogen tank will store potentially explosive hydrogen fuel under high pressures and must be stored at a safe distance of at least 100 feet from the residential unit and compressor system according to Industrial Risk Insurers (IRI) guidelines for petroleum and chemical industry[17]. **Figure 10** is the dimensions of an idealized hydrogen storage tank that we hope to eventually produce as a replacement for the ASME hydrogen storage tank, which will still follow the same safety guidelines but will require less space and will be much more portable.

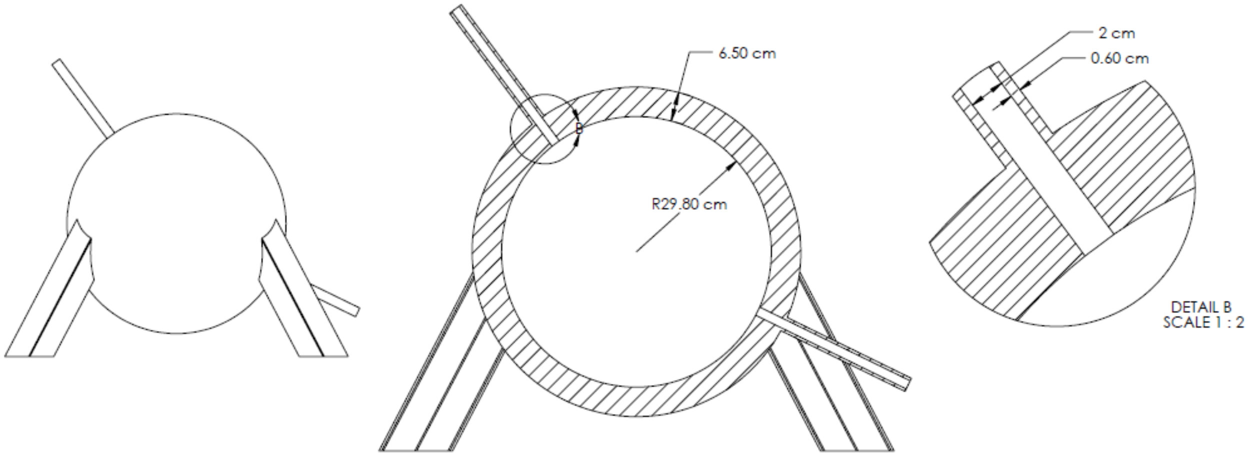


Figure 10: A scaled design of a custom hydrogen storage tank, to be produced once our system is incorporated in a large scale. [38]

1.9 Grid Power Connection

Southern California was chosen as our optimal location for a residential hydrogen fueling system because of its nearly year-round sunlight availability for our photovoltaic system. However, in cases where our solar panels are insufficient, we have also provided a connection to pull backup electricity from the grid for continuous hydrogen production. As mentioned above, we need 24,800W of power per day for hydrogen production. Further, we require grid power connection at all times for the operation of the compressors. On a hypothetical completely dark day in which no power can be drawn from the photovoltaic cells, the cost to run the electrolyzer from backup grid-dependent power and the compressor/dispenser is $3.72 per day.[13] If all the power required for hydrogen production in the electrolyzer is provided by the photovoltaic cell, the daily grid-dependent power requirement is 4kWh/day, or less than $1 per day.

1.10 Early Market Customer Identification

While the initial investment of approximately $100,000 per household may seem very expensive at first glance, we have already seen that customers are willing to pay a premium of nearly 35% the original product value for a more environmentally friendly alternative. For instance, a regular Toyota Camry has been priced at $19,720, while a hybrid Toyota Camry has been priced at $26,575.[14] Even at these costs, there are waiting lists for the purchase of hybrid vehicles, as the demand for these vehicles exceed the number of vehicles produced.[15] Given that the average value of a household property in California is $384,200, the addition of a water electrolysis hydrogen generation system will cost less than 30% of the actual property value and could be included in the value of the house to be paid over a 30-year mortgage. Thus, it seems reasonable to expect that some early market consumers will be interested in investing in these systems. Moreover, considering the various tax credits available for economically conscious consumers in California, this alternative will become even more attractive. For instance, California’s Temporary Election to Claim the Investment Tax Credit in Lieu of the Production Tax Credit allows homeowners with solar energy electricity production to claim up to 30% of the initial investment costs as tax credit.[30] As technology advances and as we begin to incorporate mass production, we can expect the total cost of the system to decrease over time.

2. Safety Analysis

2.1 General Safety Overview

Our system is of low complexity because the compressor and dispenser are simplified into one individual unit, and our hydrogen production system has no moving parts. We are confident our system is not hazardous for individual household use since our planned construction will meet or exceed all relevant building and safety standards for Moreno valley, California, as described by City of Moreno Valley Standard Plans, January 2010 Edition.[16]

2.2 Component Based Risk Identification

All components of hydrogen compression and storage will be kept in a separate enclosure with reinforced blast walls to ensure no danger in instances of complete failure of gas cylinders. Due to the fact that the designed separate enclosure area is small enough to fit in a typical backyard and is open to the atmosphere through vents at the top of the enclosure, our system will not be in great danger in terms of a large physical force such as a runaway car causing system failure. Moreover, pressure valves and monitoring devices will be placed at each juncture point and shown in such a way that readings can be taken easily and any dangerous fluctuations can be determined.

Considering that the operation required for compression and dispensing entails large amounts of noise pollution, the compressor/dispensing system will be placed as far away from the residential area possible while still providing access to the car dispensing. Moreover, we will enhance the noise insulation of the garage where this system is located to dampen the noise as much as possible.

The storage tank will be at least a 100 feet away from the remaining parts of the system to ensure following proper safety protocols, based on the Industrial Risk Insurers guidelines for the petroleum and chemical industry.[17] Finally, overhead sprinklers will be installed in any area that may contain a fire hazard.

2.3 Location Based Safety Concerns

Preliminary designs of our system are to be situated in Moreno Valley, Southern California. Due to the fact that California is a very seismically active zone, we will ensure our system to meet all stringent earthquake building standards as governed by local building codes. Specifically, we will consider the California Seismic Building Codes as listed in California Codes- Government Code –Section 8875-8875.10.

2.4 Overall Failure Mode and Effect Analysis

There are many safety standards that govern the fundamentals of hydrogen dispensing into vehicles. **Table 1** shows some of these standards.

Table 1: A portion of the relevant hydrogen codes and standards

Code No.	Code Description
<u>Compressed Hydrogen Gas Storage</u>	
<u>Equipment Location</u>	
International Fire Code (International Code Council, 2009)	
2209.3	Location on Property
3503	General Requirements

3504	Storage
International Fire Code (International Code Council, 2009)	
2209.3	Location on Property
3503	General Requirements
3504	Storage
NFPA 52, Vehicular Gaseous Fuel Systems Code (National Fire Protection Association, 2010)	
10.3.2	Specific Requirements
General Safety Requirements	
International Fire Code (International Code Council, 2009)	
2209.5	Safety Precaution
2211.7	Repair Garages for Vehicles Fueled by Lighter-than-Air Fuels
2211.8	Defueling of Hydrogen from Motor Vehicle Fuel Storage Containers
3003	General Requirements
3503	General Requirements
NFPA 52, Vehicular Gaseous Fuel Systems Code (National Fire Protection Association, 2010)	
9.2.3	Equipment Security and Vehicle Protection
9.2.4	Out of Service Bulk Storage
9.2.5	Equipment Security and Vehicle Protection
9.2.6	Cargo Transport Unloading
9.2.7	Control Device Icing
9.2.8	Vehicle Ignition Classification
9.2.9	Fueling Connection Leak Prevention
9.2.10	Compression and Processing Equipment
9.2.11	Reference to NFPA 37 for Compressor Installations
9.2.12	Electrical Classification for Compressors
9.2.13	Liquid Carryover Prevention
9.2.14	Detection for Dispensing
9.2.15	General System Requirements
Storage Containers	
CGA PS-21, Adjacent Storage of Compressed Hydrogen and Other Flammable Gases (Compressed Gas Association, 2005)	
2703.2.1	Design and Construction of Containers, Cylinders, and Tanks
3003.2	Design and Construction
3503.1.2	Storage Containers
NFPA 52, Vehicular Gaseous Fuel Systems Code (National Fire Protection Association, 2010)	
5.3	Design and Construction of Containers

Because all of these official safety standards are available only with a hefty fee, we instead decided to do a component by component safety analysis as a preliminary safety comparison. A majority of these regulations are already met by Quantum Technology, Inc during the manufacturing of their combined compression/dispensing system. Upon confirmation of project initiation, funds will be made available to access these codes in greater detail.

We have undergone analysis of identifiable failure possibilities, as listed below in **Table 2**, starting from the solar panel to the dispensing of hydrogen into the vehicle. Each possible damage will be analyzed with damage potential and frequency ranked from 1-10, with 10 being most severe and most frequent respectively.

Table 2: Complete Failure Mode and Effect Analysis of Our system

Failure Mode	Source/Cause	Effects	Damage Potential	Frequency	Design to Mitigate Risks
Solar Panel Physical Failure	Strong physical force	Injury from weakened support, possible fire due to overreliance to grid connection	1	1	Solar panels isolated in areas with very low probability of automobile traffic
Water leakage	Poor connection of water purifier and/or HEM electrolyzer due to operator error	Flooding, water damage to equipment, possible electrocution and fire hazard	2	3	Ensure watertight connection for the liquid stream
Combustible Gas Leakage from electrolyzer, ambient pressure	Poor connection of O_2 exit stream and/or H_2 stream to compressor	Fire hazard	3	1	Electrolyzer setup in a separate enclosure with proper ventilation to allow any escaped H_2, a light gas, to float off into the atmosphere freely
Pressurized Hydrogen Gas leakage from piping within/ through compressors	Poor connection of hydrogen pipe among and between compressors and dispenser, compressor malfunction	Fire Hazard, physical injury	6	2	Internal monitors within compressor and dispenser as well as external pressure gauges and flow meters, included in the quantum technology unit, to detect abnormal changes in pressure
Hydrogen Tank Hardware Failure	Defective hydrogen storage vessel manufacturing	Traumatic physical injury, damage to surrounding machinery, fire hazard	7	3	Pressure gauge located on the hydrogen tank to ensure H_2 pressure is within acceptable levels, emergency shutoff system for compressor and dispenser. A pressure relief valve will be present to prevent excess pressure buildup
Pressurized hydrogen leakage during dispensing	Operator error, mechanical fault during manufacturing	Fire Hazard, physical injury	4	7	Ensure proper training of operator, clear ventilation in dispensing area (garage) for immediate dispersion of hydrogen
Dispenser damage from vehicle misuse (leaving with dispenser still connected to the vehicle)	Operator Error	Fire Hazard	3	7	Ensure proper training of operator, enforce automatic shutoff from the dispenser in case of accidental misuse
Fire from outside sources	Static electricity discharge, other sources of flames	Fire Hazard	7	4	Awareness campaign/signs throughout area informing of hydrogen compressing/dispensing system location,

					emergency sprinkler/deluge system to put out any fires
Power Outage	Variability of power availability from grid and/or solar panels	Equipment malfunction/ shutoff of compressor	1	4	Ensure immediate system shutoff during power level unavailability
Natural Disaster (Earthquake etc)	Nature	Sudden equipment damage/ failure	10	1	Ensure immediate system shutoff in cases of sudden pressure drop, compliance of earthquake related building codes

3. Business Plan

3.1 Economic Analysis

The economic analysis will be divided into four sections. The first section breaks down the initial investment for all equipment and installation cost adjusted for tax credits and operating costs necessary for production of hydrogen. The second section breaks down the cost of H2 over a thirty year period adjusted for inflation. The third section compares the annual cost of hydrogen to the annual cost of gasoline consumption. The last section analyzes the market price of the system and future growth projections.

3.2 Capital Costs and Construction Costs

Table 3: Capital Cost Summary

Item	Quantity	Cost	Incentives/ rebate cost reduction	Incentive Type
Water Purifier (Katadyn Vario Multi Flow Water Microfilter)	1	$100	-	-
Stainless Steel piping ID T-304 in OnlineMetals.com	1 in diameter, 134 feet 11 inches in length	$787.25	-	-
Stainless steel cell for membrane electrode assembly	2 sets of 260 holders, 20cm by 20cm	$30,000	-$22,500	Emerging Renewables Program – 75% of cost for fuel cells using renewable fuels[32]
Kyocera KD235GX-LB 235 Photovoltaic Cells	24,800W capacity	$50,000	-$16,500	Residential Renewable Energy Tax Credit – 30% solar electric system[32]
15 Gallon Water Tank, Todd Systems TOD 851666WH	1	$100	-	-
Hydrogen Gas Storage Canister, temporarily store 2kg of hydrogen at 7500 psi	1	$1,000	-$300	Residential Renewable Energy Tax Credit – 30%[32]
Hydrogen Compressing and Dispensing in one package by Quantum Technologies	1	$100,000	-$60,000	Residential Renewable Energy Tax Credit – 30%[32] Riverside Public Utilities - Commercial Energy Efficiency Rebate Program[32]

Enclosure Construction Cost (total), Craftsman National Building Cost Estimator	441 ft^2 in area	$10,076.85	-$3,023	Residential Renewable Energy Tax Credit – 30%[32]
Total Cost After Rebates	**$89,741.05**			

Table 4: Operating Costs

Item	**Quantity**	**Cost**
Water	6.6 gallons a day	<$1/day
Electricity	28.8KW/day	$4.32/day

Table 5: Maintenance Costs

Item	**Quantity**	**Cost**
TPQPOH Electrolyzer and Fuel Cell Membrane replacement	25 m^2	$50/10 years
Water Filter replacement	Once/month	$25
Electrolyzer nickel catalyst maintenance	5.0mg/cm^2 loading on 12.4m^2 area	$11/10 years
Electrolyzer silver catalyst maintenance	0.5mg/cm^2 loading on 12.4m^2 area	$38/10 years
General Maintenance (i.e. compressor/dispenser parts, filter parts, total system insurance)	1%/year	$1,000

If we would have used Nafion membranes that PEM systems require, we would have incurred an additional $5580 in pure cost of the membrane, plus $3600 per ten years in platinum catalyst replacement.[4,6] Moreover, in cases when not all hydrogen is consumed by the vehicle and can be routed to the fuel cell stack, most of the household's daily electricity requirement can be covered, leading to even more savings for the household.

3.3 Timeline of system costs and cost per kg H_2

Table 6 – Cost layout of hydrogen production and delivery

Year	Equipment and Installation Costs	Annual Fuel Cost Hydrogen	Annual Fuel Cost Gasoline	Net Savings
2010	$192,064.10	$ 1,941.80	$ 1,177.91	$ (763.89)
2011	-	$ 2,019.47	$ 1,837.52	$ (181.95)
2012	-	$ 2,100.25	$ 2,548.03	$ 447.78

2013	-	$ 2,184.26	$ 2,568.79	$ 384.53
2014	-	$ 2,271.63	$ 2,716.98	$ 445.35
2015	-	$ 2,362.50	$ 2,872.92	$ 510.43
2016	-	$ 2,457.00	$ 3,036.99	$ 579.99
2017	-	$ 2,555.28	$ 3,209.59	$ 654.31
2018	-	$ 2,657.49	$ 3,391.13	$ 733.64
2019	-	$ 2,763.79	$ 3,582.06	$ 818.28
2020	-	$ 2,874.34	$ 3,782.85	$ 908.51
2021	-	$ 2,989.31	$ 3,993.96	$ 1,004.65
2022	-	$ 3,108.88	$ 4,215.91	$ 1,107.02
2023	-	$ 3,233.24	$ 4,449.22	$ 1,215.98
2024	-	$ 3,362.57	$ 4,694.46	$ 1,331.89
2025	-	$ 3,497.07	$ 4,952.19	$ 1,455.12
2026	-	$ 3,636.95	$ 5,223.04	$ 1,586.08
2027	-	$ 3,782.43	$ 5,507.62	$ 1,725.19
2028	-	$ 3,933.73	$ 5,806.62	$ 1,872.89
2029	-	$ 4,091.08	$ 6,120.72	$ 2,029.64
2030	-	$ 4,254.72	$ 6,450.67	$ 2,195.94
2031	-	$ 4,424.91	$ 7,031.55	$ 2,606.64
2032	-	$ 4,601.91	$ 7,648.58	$ 3,046.67
2033	-	$ 4,785.98	$ 8,303.73	$ 3,517.74
2034	-	$ 4,977.42	$ 8,999.04	$ 4,021.62
2035	-	$ 5,176.52	$ 9,736.70	$ 4,560.18
2036	-	$ 5,383.58	$ 10,518.97	$ 5,135.39
2037	-	$ 5,598.93	$ 11,348.25	$ 5,749.32
2038	-	$ 5,822.88	$ 12,227.03	$ 6,404.15
2039	-	$ 6,055.80	$ 13,157.96	$ 7,102.17
2040	-	$ 6,298.03	$ 14,143.81	$ 7,845.78
30 year total		$ 115,203.76	$ 185,254.82	
Net Present Value Using 30 Year Treasury Rate of 5.42%				$20,988.96

Table 6 indicates the total annual cost for the residential hydrogen production system over a 31 year period. Equipment and installation costs are considered a one-time fixed cost at a total of $192, 064.10. The end consumer will be able to apply for rebates and after tax incentives such as the “Temporary Election to Claim the investment tax credit in lieu of production tax credit”, “Tax Credits for Alternative Refueling property”, and “Treasury department of Energy Grants in lieu of tax credits”. Operating costs, maintenance costs, and grid electricity costs are adjusted to increase by a rate of 4% due to inflation.

Table 7 – Cost per kg of hydrogen produced for a 30 years plan and a 10 year plan

10 year total dollars spent	31 year total dollars spent
$23,313.46	$115,203.76
$/kg Hydrogen produced	$/kg Hydrogen produced
$6.39	**$10.18**

Table 7 shows the cost per kg of hydrogen gas, comparing cost per kg. per day at year ten and year thirty-one. The cost of hydrogen has been adjusted for inflation at a rate of four percent per year. At year ten, the cost per kg of hydrogen produced is $6.39 per day. At year thirty, the cost

per kg per day is $10.18. The daily cost to produce one kg of hydrogen is calculated by taking the daily cost for electricity and water usage. Maintenance costs and replacements parts are not included in this estimation. Given the daily cost per kg of hydrogen, the annual cost of hydrogen and gasoline can be compared.

3.4 Comparison of Annual Fuel Costs

As shown in **Figure 11**, the thirty year total cost for hydrogen fuel is $115,203.76 and the total cost for gasoline is $185,254.82. By utilizing the residential hydrogen production system, the potential fuel savings over the thirty-year period would be $70,051.06.

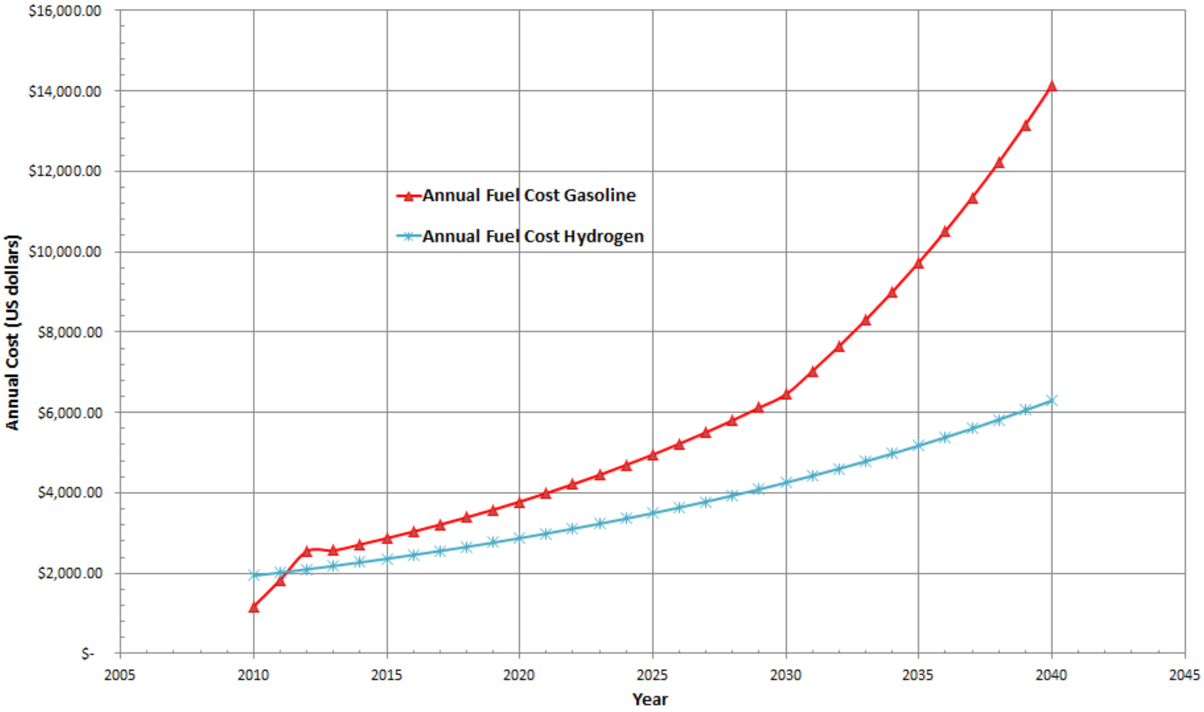


Figure 11 – Comparison of gasoline and hydrogen annual fuel expense over a thirty-year period

Figure 11 shows the rising costs of gasoline and hydrogen gas over a thirty year period. Due to the high demand and increasingly limited supply of gasoline, the estimated annual cost of gasoline is increasing rapidly while the cost of hydrogen gas increases at a consistent rate. By the end of 2011, the annual costs associated with filling a car (32.6 mpg fuel economy) with gasoline will surpass the costs associated with filling a light-duty hydrogen vehicle (44mpkg fuel economy). Both hydrogen and gasoline costs have been adjusted for an inflation rate of four percent per year.

3.5 Projected Market Growth and Market Price for Residential Hydrogen Fueling System

Table 8: Projected Global Market Growth for Solar Panel Technology[33]

	2007	2008	2009	Average Growth Rate
Solar PV Capacity, Grid Connected (GW)	7.6	13.5	21	66.59356725
Solar PV production (annual) (GW)	3.7	6.9	10.7	70.77947513
Investment in new renewable capacity (USD billions)	104	130	150	20.19230769

Table 8 shows the global growth in three different categories relevant to solar voltaic energy production which is an essential component of the residential hydrogen production system. A preliminary growth rate for the project can be inferred by taking the growth rate from 2007-2008 and 2008-2009 and averaging these two which results in an average growth rate of seventy percent per year. This rate can be assumed to be a basic estimation for growth for this project.

Table 9: Scenario Analysis with Probability and Growth Rate as Changing Variables, in units of *# of units sold*

	Probability	Growth Rate	Base Goal	Year 2	Year 3	Year 4	Year 5	Expected
Recession	0.33	0.55	30	47	72	112	173	143
Normal	0.33	0.7	30	51	87	147	251	187
Boom	0.33	0.86	30	56	104	193	359	245
Recession	0.2	0.55	30	47	72	112	173	87
Normal	0.6	0.7	30	51	87	147	251	339
Boom	0.2	0.86	30	56	104	193	359	148
Recession	0.1	0.55	30	47	72	112	173	43
Normal	0.8	0.7	30	51	87	147	251	453
Boom	0.1	0.86	30	56	104	193	359	74
Recession	0.33	0.275	30	38	49	62	79	85
Normal	0.33	0.35	30	41	55	74	100	99
Boom	0.33	0.43	30	43	61	88	125	115
Recession	0.2	0.275	30	38	49	62	79	52
Normal	0.6	0.35	30	41	55	74	100	179
Boom	0.2	0.43	30	43	61	88	125	69
Recession	0.1	0.275	30	38	49	62	79	26
Normal	0.8	0.35	30	41	55	74	100	239
Boom	0.1	0.43	30	43	61	88	125	35
Recession	0.33	0.055	30	32	33	35	37	55
Normal	0.33	0.07	30	32	34	37	39	57
Boom	0.33	0.086	30	33	35	38	42	59
Recession	0.2	0.055	30	32	33	35	37	33
Normal	0.6	0.07	30	32	34	37	39	104
Boom	0.2	0.086	30	33	35	38	42	36
Recession	0.1	0.055	30	32	33	35	37	17
Normal	0.8	0.07	30	32	34	37	39	138
Boom	0.1	0.086	30	33	35	38	42	18

Table 9 gives a scenario analysis for different possible outcomes given changing variables such as economic probability and annual growth rate. The probabilities assigned for economic conditions were assigned arbitrarily. To give a more accurate depiction of outcomes, three different sets of probabilities were given. In addition, growth rates were also adjusted for different percentages per year. For SET A, the growth rates corresponding for each economic condition were based on the lowest year to year growth rate (assumed to be recession growth rate of 55%), highest year to year growth rate (assumed to be boom growth rate of 86%), and an average growth rate over the entire period (assumed to be normal growth rate of 70%). For SET B, the growth rates from SET A are divided by two to get a rate which reflects growth for the residential hydrogen production system at half the pace of global growth. For SET C, the growth

rates of SET A are divided by ten to get a rate which reflects growth for the residential hydrogen production system a tenth the pace of global growth.

Table 10- Estimated Revenue Given Expected Sales from Table 9

		Total Cost	Markup	Total Sales Revenue	Total Profit
SET A	574	$192064.10	0.3	$143,318,231.42	$21,828,469.09
	574	$192064.10	0.3	$143,318,231.42	$21,828,469.09
	570	$192064.10	0.3	$142,319,498.10	$21,676,354.33
SET B	298	$192064.10	0.3	$74,405,632.34	$11,332,550.16
	300	$192064.10	0.3	$74,904,999.00	$11,408,607.54
	299	$192064.10	0.3	$74,655,315.67	$11,370,578.85
SET C	171	$192064.10	0.3	$42,695,849.43	$6,502,906.30
	173	$192064.10	0.3	$43,195,216.09	$6,578,963.68
	173	$192064.10	0.3	$43,195,216.09	$6,578,963.68

Assumes a 30% markup with a standard 34% tax rate. Does not adjust for inflation.

Table 10 Takes the expected sales projections from Table 3.42 and multiplies these numbers by the total cost and a markup of thirty percent. The market price for one unit is $249,683.30 given the thirty percent markup. The sales revenues are taxed at a standard thirty four percent rate. SET C is the most conservative set of estimates for this project given the fact that the growth rate is unknown for the residential hydrogen production system.

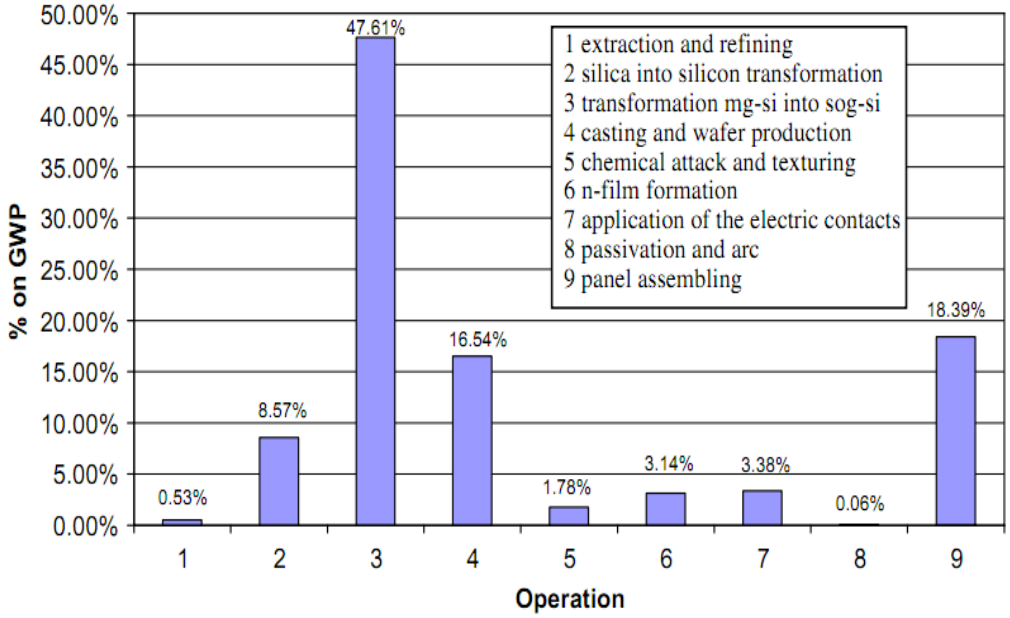
4. Environmental Analysis

4.1 General Environmental Concerns Overview

Due to the fact that both our hydrogen generation as well as storage and dispensing all have absolutely no emissions apart from oxygen, our system is extremely friendly to the environment. However, there are still other aspects we must take into account apart from emissions. Through a Life Cycle Analysis (LCA) of our proposed system, a direct comparison can be made between competing energy production systems. In addition to an analysis of our system's lifetime emissions, it is also important to determine its impact as a result of water usage.

4.2 Environmental Impact of Production and Disposal of Our System

First, we must consider the environmental costs associated with the initial production and disposal of the solar panel, the membrane, and other associated items. Unfortunately, a complete analysis of our system is not available. As our membrane is currently in the experimental phase, there is an incomplete analysis of our membrane's environmental impact. However, based on the cost of production and the materials and procedures used to produce the membrane, we assume that the production and transportation of a photovoltaic array accounts for nearly all of the CO_2 emissions. Based on information provided by Stoppato[22], approximately 1500 MJ of energy is required to produce a panel of $0.65m^2$ resulting in 80kg of CO_2 in emissions. With global warming potential (GWP) equivalent to 80 kg CO_2/panel, the GWP contributions for each of the manufacturing steps are provided in greater detail (**Figure 12**).



Contribution of each unit operation to the GWP as percentage of total GWP = 80 kg_{CO_2}/panel.

Figure 12. GWP analysis of the production of a photovoltaic cell.[22]

However when this data is compared to the emissions associated to the production and transportation/distribution of Natural Gas, it is clear that natural gas has a higher environmental footprint. Although the initial production and distribution of Natural Gas has similar emissions to the production of a photovoltaic cell, an overwhelming majority of the emissions associated with Natural Gas is a result of the operation of a power plant. This plant is required to purify Natural Gas so it may be used in a domestic and industrial setting. Unfortunately this operation is required within any system that employs Natural Gas as a power source, which will drastically increase the amount of CO_2 emissions and its overall environmental footprint.

Table 11: Energy Pay Back Times (EPBT) and Energy Return Factors (ERF) of PV modules installed in various locations around the world (reproduced from *Stoppato.*[22])

Country	Town	Solar Radiation (kWh/m^2)	Latitude	Altitude(m)	Annual Production (kWh/kW peak)	EPBT(years)	ERF
Australia	Sydney	1614	33.55	1	1319	3.728	7.5
Belgium	Brussels	946	50.5	77	788	6.241	4.5
Ireland	Dublin	948	53.2	9	811	6.064	4.6
Italy	Rome	1552	41.53	15	1315	3.74	7.5
Portugal	Lisbon	1682	35.44	16	1388	3.543	7.9
Spain	Madrid	1660	40.25	589	1394	3.528	7.9
Spain	Sevilla	1754	37.24	5	1460	3.368	8.3
United States	Washington	1487	38.52	14	1249	3.937	7.1

Although the production of these arrays results in CO_2 emissions, both the photovoltaic and electrolysis reactions are free of emissions. Rather than being a constant source of emissions, this system continues to produce power without producing emissions. As our system is continually used, the energy produced by the system exceeds the amount of energy required to make the photovoltaic cell. As shown in **Table 11**, the average Energy Payback Time (EPBT) for solar cells ranges from 3-6 years, based on the location on the system. According to table 3, Washington would have an EPBT of approximately 4 years. However, based on the amount of solar radiation available in a specific city, the EPBT can be as low as 3.4 years. Assuming a life span of 20-30 years, our system will generate 6-8 times the power required to produce it, without releasing additional carbon emissions. First, we must consider the environmental costs associated with the initial production and disposal of the solar panel, the membrane, and other associated items. Unfortunately, a complete analysis of our system is not available. As our membrane is currently in the experimental phase, there is an incomplete analysis of our membrane's environmental impact. However, based on the cost of production and the materials and procedures used to produce the membrane, we assume that the production and transportation of a photovoltaic array accounts for nearly all of the CO_2 emissions. Based on information provided by Stoppato.[22], approximately 1500 MJ of energy is required to produce a panel of 0.65m^2 resulting in 80kg of CO_2 in emissions. With global warming potential (GWP) equivalent to 80 kg CO_2/panel, the GWP contributions for each of the manufacturing steps are provided in greater detail (**Figure 13**).

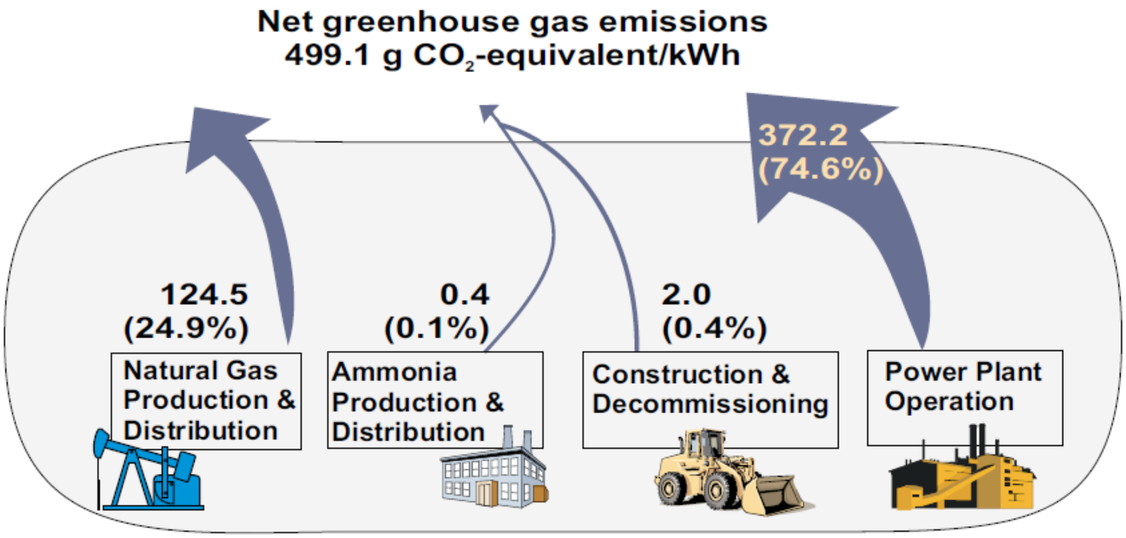


Figure 13: Analysis of Natural Gas Emissions.[39]

4.3 Comparative Environmental Analysis with Natural Gas and Gasoline Systems

In addition to the individual emissions produced by a PV-electrolyzer system, a comparative study of natural gas and gasoline was also conducted. As our process is independent of gasoline, it eliminates emissions that would otherwise evolve from a gasoline powered vehicle. Additionally, we have included data comparing the carbon emissions of a natural gas system to our proposed process. By accounting for the emissions released from the production and transportation of these fuels, a complete analysis comparing the three power sources can be achieved.

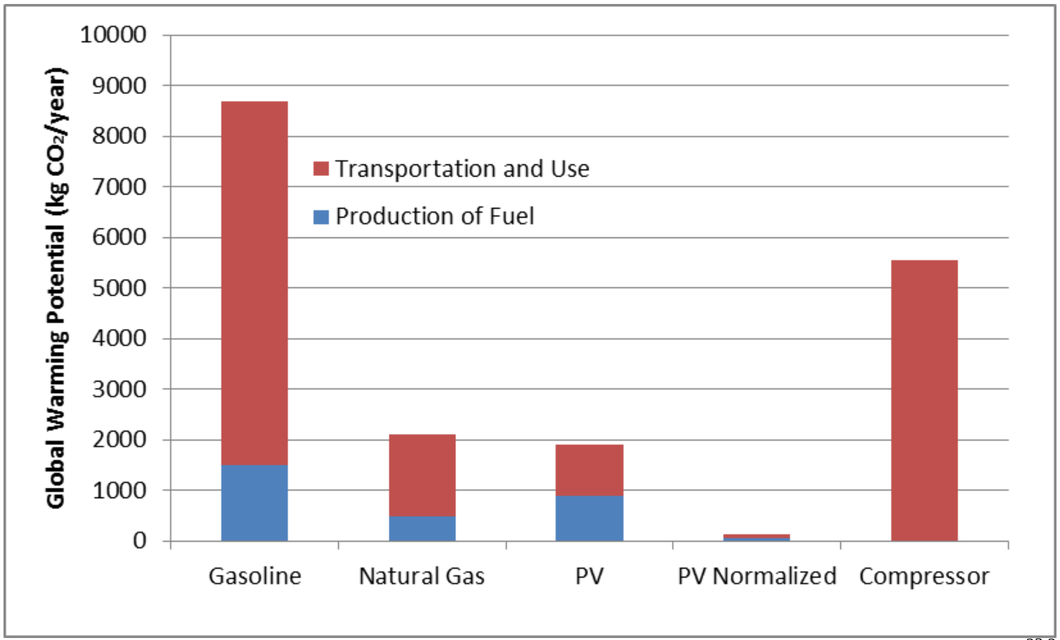


Figure 14: Comparison of Global Warming Potential for Gasoline, Natural gas and PV systems[23,24,25]

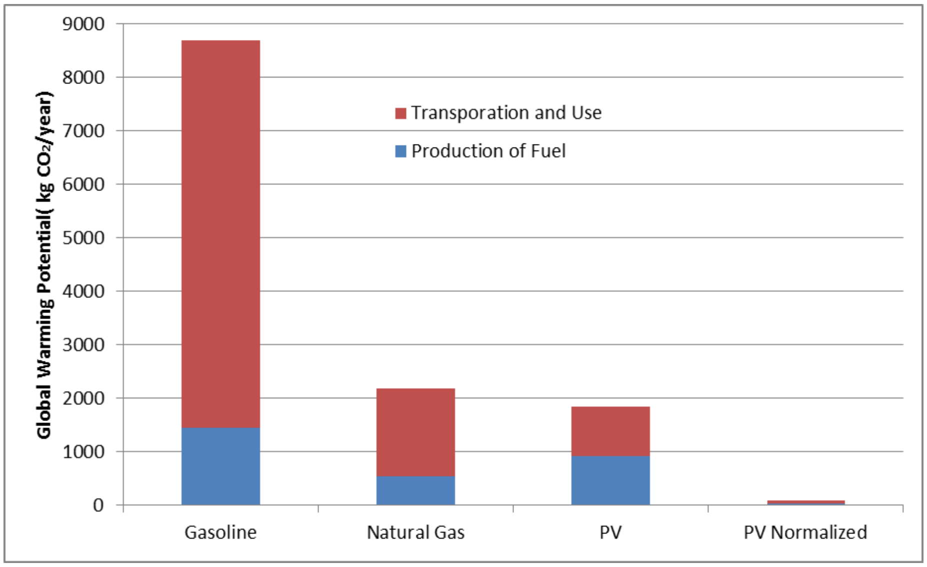


Figure 15: Comparison of Global Warming Potential for Gasoline, Natural gas and PV systems[23,24,25]

As seen in **figure 14**, a photovoltaic system produces the least amount of carbon dioxide annually, 1840 kg/year. These numbers are misleading, as mentioned these numbers are based on the production and installation of a photovoltaic cell. As these are one-time costs over a 20 -30 year life, the final bar in **figure 15** reports a normalized GWP. In reality, as the system continues to produce energy without producing carbon emissions, the GWP per year is reduced to fewer than 100 kg CO_2 per year.

Based on the provided information we believe that a Photovoltaic-Electrolyzer system, is the most environmentally conscious system to be used within a hydrogen generation/dispensing unit. The system produces the least amount of initial CO_2 emissions, while reaching its energy payback time multiple times throughout its lifetime. Although other processes claim to be both clean and abundant, in truth, natural gas is limited by the necessity of a constant stream of gas, along with the finite quantity available in the earth. As current reservoirs of natural gas are consumed, both the cost and global warming potential increases. In contrast, solar cells have the potential to be recycled,[22] allowing its components to be used, producing less waste at the end of its life time.

4.4 Analysis of Fuel Maintenance – Daily Water Requirements

As our system required a daily amount of water in order to produce hydrogen, an additional analysis has been completed to determine our system's environmental impact, based on its water consumption. Based on previous calculations, the water usage in our system is estimated to be 6.6 gallons of water per day. As provided by the United Nations Human Development Report and the American Water Works Association Research Foundation (AWWARF), the average amount of residential water used per person is between 150-180 gallons per day. Our system only requires an extra 3.7%-4.5% increase in water usage.[31]

Assuming an average 3 person household, our analysis can extend to other nations as well. As seen in Figure 10 and 11, eleven of the twenty nations within the "G20" have sufficient water resources to implement our electrolyzer system. Based on our calculations, it is recommended that our system require no more than 5% of the total water usage within a household. Although many nations can afford to increase their water consumption, it is evident, that others cannot.

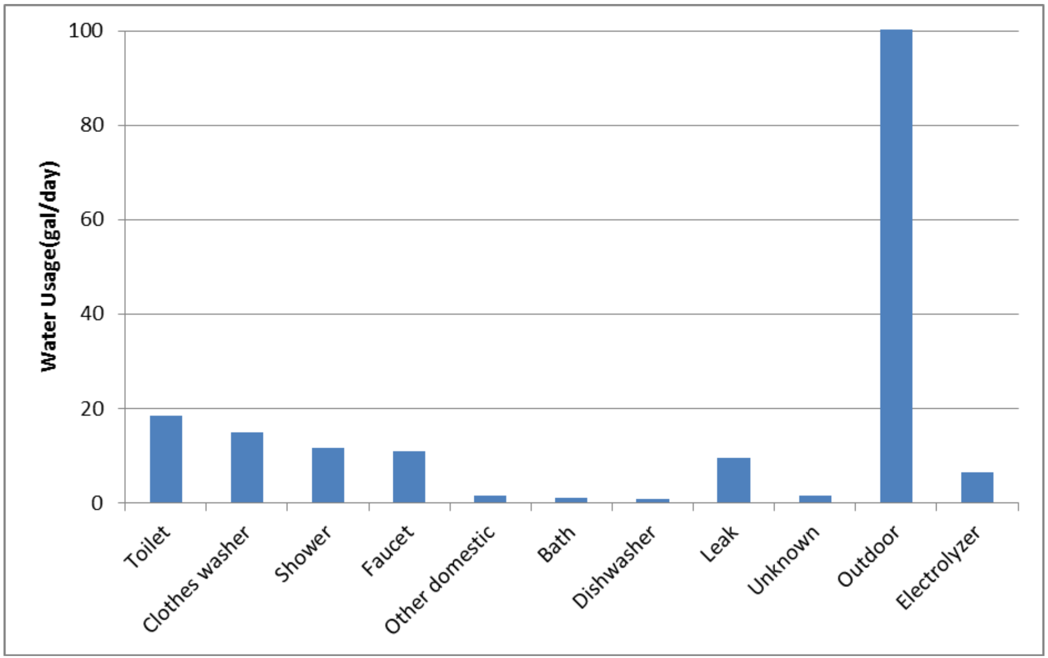


Figure 16 Average US Water Consumption by Fixture[26]

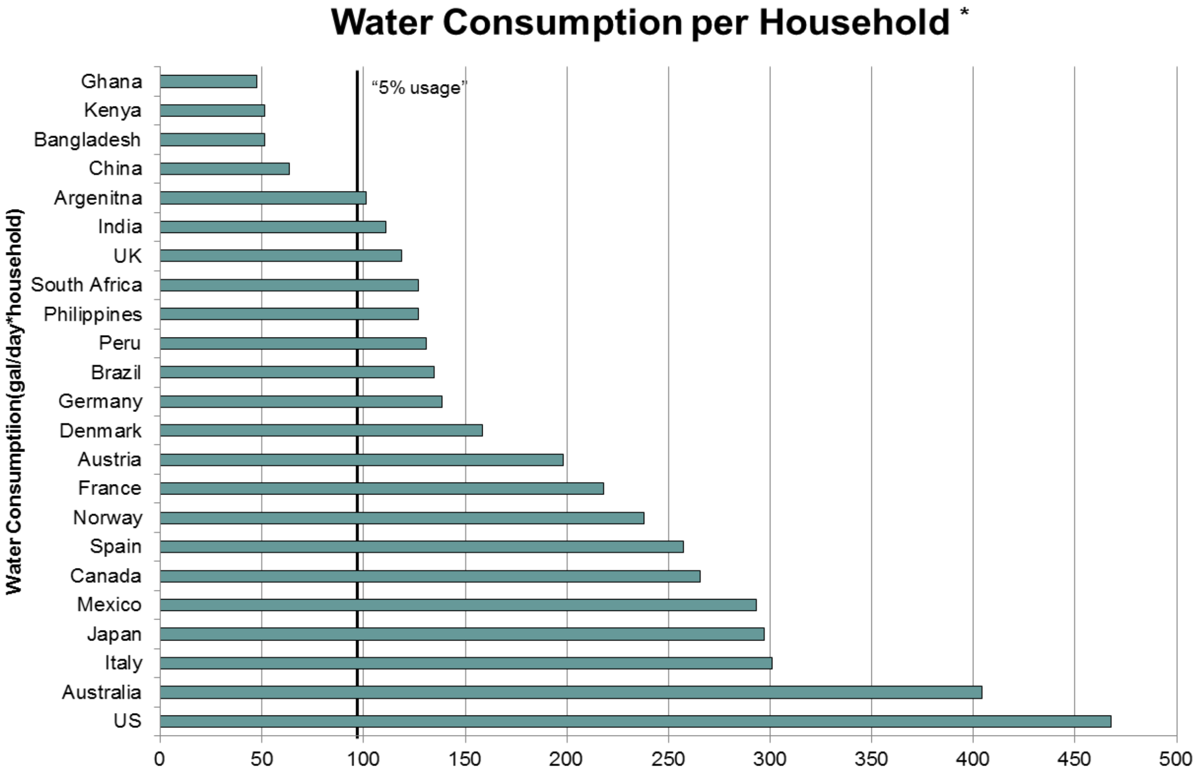


Figure 17 Average national water resource consumption[27,28]

5. Education and Marketing Analysis

5.1 Potential Educational Implications of Our System

In addition to practical applications, this system will be able to educate people on the importance of energy conservation. The use of sustainable sources of electricity in everyday uses will be shown through the use of solar energy to power electrolysis, such that water and sunlight, both completely renewable, can be used to power cars. Further, this project will show the concept of energy storage linked with sunlight. We can show that unlike the fossil fuel energy sources which have many environmentally dangerous byproducts, our system can power cars, an inseparable part of life in Moreno Valley and other areas, without any harmful byproducts.

Moreover, it is important to note that we are proposing the incorporation of this system within the Victory Gardens development in Moreno Valley. The developer of this community, Mr. Steven Ribeiro, is an entrepreneur who is already widely known for sustainable communities[18]. The key points promoted for the incorporation of the Victory Gardens development is self-reliance and sustainability. Given that our system is also highly sustainable and does not require any outside input other than water, our system is extremely relevant and very closely related to this idea. As a result, we can tie in the promotion of the Victory Gardens with our system, and strongly increase the allure of this self-reliant and sustainable living community that this development is promoting.

5.2 Marketing Analysis of Our System

The target market would be middle to upper class citizens who would be willing to pay for the large capital investments for installing a residential hydrogen production system. Users of the system will need to have the financial ability to purchase or lease a hydrogen powered vehicle. The market size considered would be households making greater than $100,000 annually (approximately 9500 households), as shown in **Figure 18**. The initial thirty house project would require .4% of the target market to purchase the system for the Victory Gardens location.

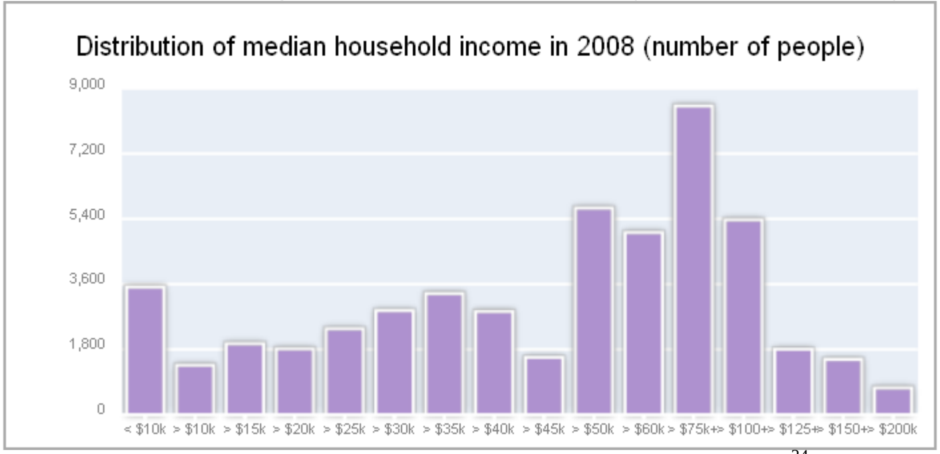


Figure 18: The median Household Income in Moreno Valley, California. [34]

For the initial launch of the product to the market, a price skimming strategy would be used for attracting initial investors or innovators. These consumers typically are not concerned with costs but are rather focused on status or benefits from adopting new technologies. For these innovators from the target market, the system's primary benefit would be the effect it has on the environment while financial considerations would be secondary. As seen in the economic analysis, sales growth will occur and new entrants into the market will occur. Production costs should reduce and the life cycle should shift into the growth phase. The phases of a product life cycle discussed here, are illustrated in **Figure 19**.

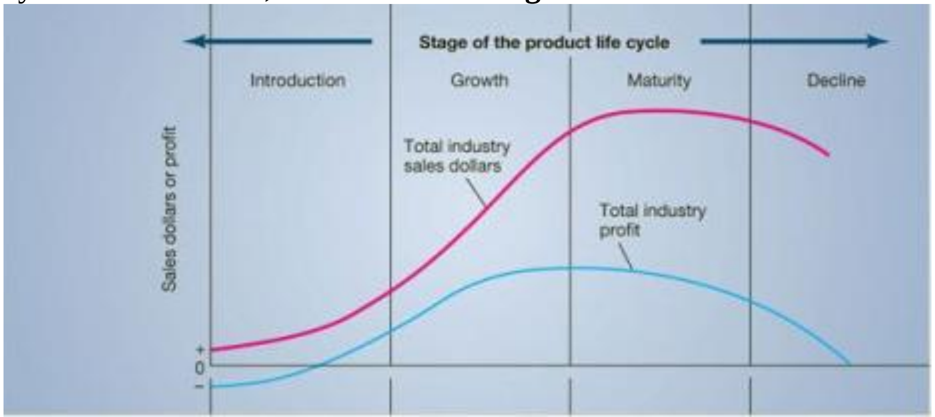


Figure 19: A graphical depiction of the stages of a product life cycle. [41]

In order to reach the desired sales goal of thirty units in the first year, a one year marketing campaign will be necessary. The marketing campaign for the residential hydrogen production system should fulfill two purposes. The first purpose would be to gain public support for the development and installation of hydrogen fuel cell technology in the local community. The second purpose would be to attract customers to adopt residential hydrogen production systems as a sustainable energy source.

To gain public support, we will hold information sessions and an open viewing of the residential hydrogen production system to the public so basic product information, product safety, and environmental issues can be addressed. Basic product information would explain how the system works, its benefits, and the fuel cost savings that can be achieved. Product safety information would explain what safeguards will be included with the installation to prevent major disaster, what environmental benefits and effects the system has, and what outside companies or agencies have supported the production of the residential hydrogen production system. Environmental and political issues that would be addressed would be the positive effects that the residential hydrogen production system would have, what environmental groups advocate the production and installation of the residential hydrogen production system, and the growing concern for energy independence. Additionally, partnering with the Moreno Valley Chamber of Commerce will show commitment to the growing community and will generate more exposure.

Table 12: Average marketing expenses over one year period.[35, 36, 37]

2011	Newspapers	Billboard	Online Advertisements	Direct Sales Force
January	$5,200.00	$8,900.00	$1,800.00	$6,256.17
February	$5,200.00	$8,900.00	$1,800.00	$6,256.17
March	$5,200.00	$8,900.00	$1,800.00	$6,256.17
April	$5,200.00	$8,900.00	$1,800.00	$6,256.17
May	$5,200.00	$8,900.00	$1,800.00	$6,256.17
June	$5,200.00	$8,900.00	$1,800.00	$6,256.17
July	$5,200.00	$8,900.00	$1,800.00	$6,256.17
August	$5,200.00	$8,900.00	$1,800.00	$6,256.17
September	$5,200.00	$8,900.00	$1,800.00	$6,256.17

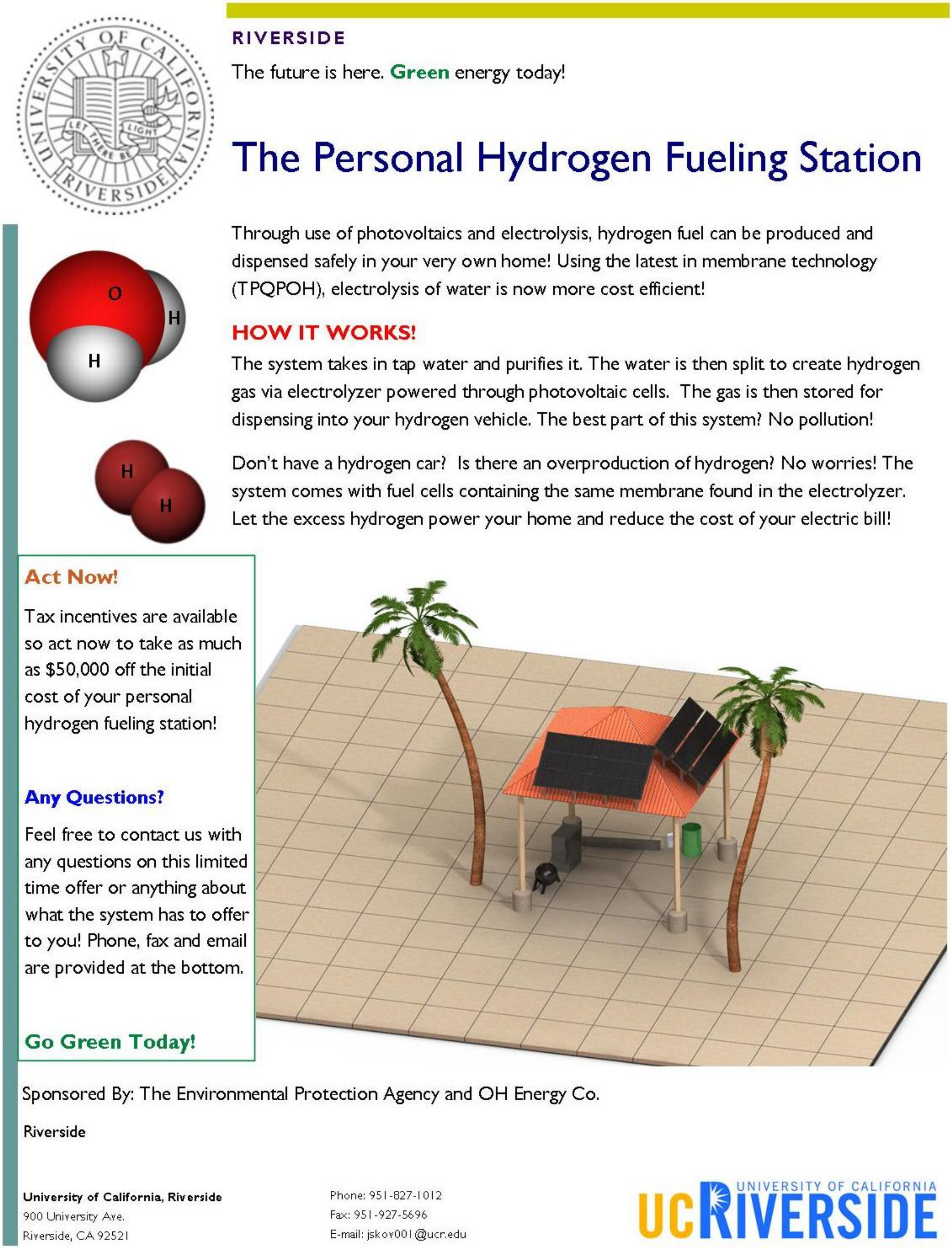
October	$5,200.00	$8,900.00	$1,800.00	$6,256.17
November	$5,200.00	$8,900.00	$1,800.00	$6,256.17
December	$5,200.00	$8,900.00	$1,800.00	$6,256.17
	$62,400.00	$106,800.00	$19,800.00	$75,074.00
Total Annual Cost				**$264,074.00**

Table 13: Net Profit after Marketing Expenses and Taxes Deducted for Year One

	Year 1
Sales Revenue	$7,490,499.00
Marketing Expenses	-$264,074.00
Tax at 34%	-$2,456,984.50
Net Profit	$4,769,440.50

In addition to holding open viewings and information sessions, newspaper advertisements, billboards, online advertising, and a sales force will be required. **Table 12** has estimated marketing expenses over the one year period. **Table 13** summarizes the marketing and profit expectations of our system.

5.3 Marketing Poster of Our System



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The Personal Hydrogen Fueling Station

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HOW IT WORKS!

The system takes in tap water and purifies it. The water is then split to create hydrogen gas via electrolyzer powered through photovoltaic cells. The gas is then stored for dispensing into your hydrogen vehicle. The best part of this system? No pollution!

Don't have a hydrogen car? Is there an overproduction of hydrogen? No worries! The system comes with fuel cells containing the same membrane found in the electrolyzer. Let the excess hydrogen power your home and reduce the cost of your electric bill!

Act Now!

Tax incentives are available so act now to take as much as $50,000 off the initial cost of your personal hydrogen fueling station!

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Feel free to contact us with any questions on this limited time offer or anything about what the system has to offer to you! Phone, fax and email are provided at the bottom.

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