Stevens Institute of Technology:

Hydrogen Micro-Grid Solution for Urban Resilience: Defense

Hydrogen Student Design Competition 2017:

Designing a Power-to-Gas System

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Executive Summary

Our system offers a unique, scalable solution to urban resilience issues being faced in the New York metro-area, namely city defense. In the event of a massive natural disaster, such as Hurricane Sandy, Stevens must be able to provide food, water, safety and shelter for its students and Hoboken residents.

This system helps solve Stevens' exposure to natural disasters and dependence on third parties for disaster relief while further propelling the University into the conversation for urban resilience efforts. Looking forward, this system is scalable to produce more hydrogen for sale to hydrogen fuel cell vehicle (FCVs) users and/or to increase islanded capabilities as technology matures.

Our microgrid solution is an initial investment proposal to Stevens; no direct competitors have been identified. The required initial investment is approximately $2,000,000. Indirectly the group must compete with other interests at Stevens for funding and a micro-grid project in Hoboken for sensibility of use. In order to maximize fundability the system must function without error in islanded mode and offer expansion capabilities. Capturing these functional attributes set the system apart as a meaningful and growing investment.

Before the implementation of the refueling stations there is no revenue stream identified, this is a two-fold strategic advantage.

In the short term this will allow the team to better serve Stevens' needs in the event of an emergency with a more robust knowledge base. This knowledge basis will be rooted in experiments to test the micro-grids function close to its limitations and a thorough development/maturation of the emergency action plan to power, feed and house students and citizens in the event of an emergency. Facilities at Stevens that require little initial investment to retrofit or are original construction will be built to optimally function within the micro-grid during this time.

Likewise, the system will be upgraded to comply with new initiative standards at the federal and state level as they come up for renewal. In the long term the system will grow as the implementation of FCVs grows around it, necessitating a fueling station in Hoboken. This will allow Stevens to evaluate the amount of refueling needed as well as potentially implement FCVs on campus for shuttle services.

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Introduction

As extreme weather conditions become increasingly harsh and frequent in the tri-state area there has become a movement towards smarter urban planning, namely towards urban resilience. The idea of planning with disaster in mind yields construction of an electrical grid, sewer system, or street layout, among other things, that will have a significant impact on the damage of extreme weather. The reasoning stems from a constant battle with nature, highlighted by repeated and expensive defeat for mankind.

The most clear and recent examples are Hurricane Harvey in Houston, Texas causing $125B in damages in 2017, Hurricane Irma in Florida causing $50B in damages 2017 , and, most specifically to the group's concern, Hurricane Sandy in the metro-area causing $71B in damages in 2012. When observing the vulnerability of U.S. coastal properties in the terms of insured properties New York State ranks #1 and the State of New Jersey ranks #5 [1].

Specifically, Hoboken suffered more than $100M in damages [2]. As climate change expedites the proliferation of extreme weather this solution is only increasingly necessary.

The Hydrogen Micro-Grid Solution for Urban Resilience: Defense offers a legitimate solution to siphon solar energy from the existing solar infrastructure of Stevens Institute of Technology, store it in a safe manner, and then utilize it in instances of natural disasters or other catastrophe.

System Diagram

The system location for the subsystem modules has been identified as 8th Street Lot on Stevens Campus, located at the intersection of Castle Point Terrace and 8th Street in Hoboken, NJ 07030.

Three major subsystems have been specified and will have to be implemented for the system to function in the event of an emergency. Their locations are superimposed on a satellite image below in Image 1. A fourth module has been shown to exemplify the future potential for a fueling station if Fuel Cell Vehicles (FCVs) become more popular in the Hoboken area. The modules are as follows: A-Electrolyzer, B- Fuel Cells, C- Underground Storage Facility, D- Future FCV Fueling Site.

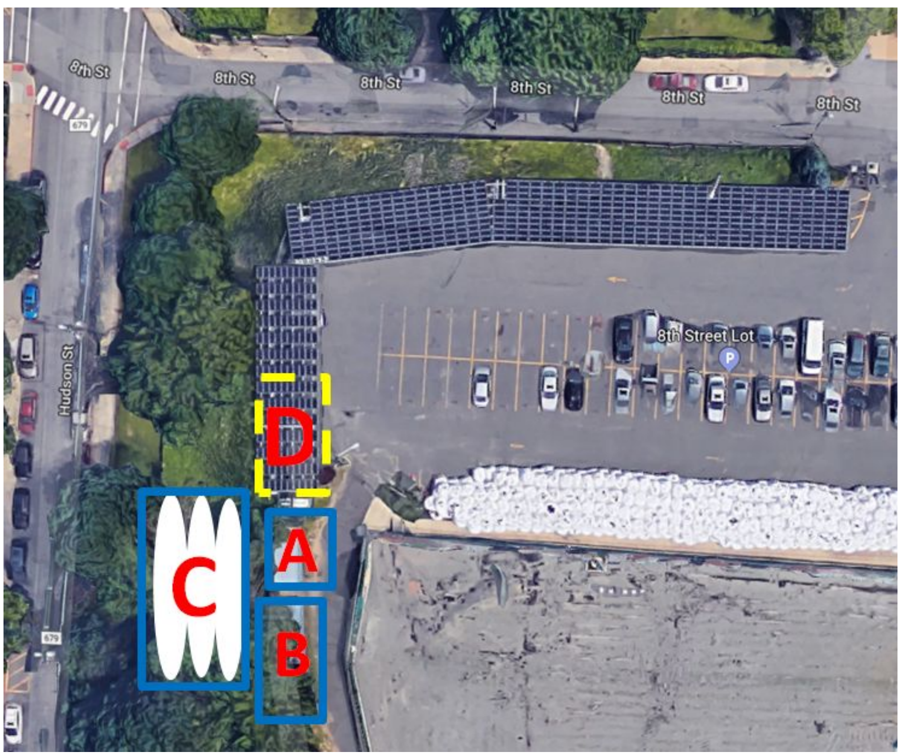


Image 1: Satellite Image of Site Selection

This location is ideal because it minimizes the transmission of the solar energy and rests near functioning inverters for phase matching. Existing underground wiring allows for quick access to the Stevens' grid and a site near an open area facilities safe underground storage of the hydrogen gas. As FCVs become more popular, Stevens expands or upgrades its solar infrastructure, and refueling technology improves it will be increasingly favorable to have a hydrogen fueling station anywhere in Hoboken, specifically in this location. With a compressor capable of reaching higher pressures necessary for FCVs the system will only require a minor investment to implement refueling technology at a later date.

Design Data and Equipment Drawings

Electrolyzer

The solar infrastructure on campus is capable of achieving voltages of 300-350kW at its peak. This electrolyzer is able to handle that amount of energy, but also operate optimally below that voltage. An electrolyzer with a small footprint is also very desirable because the available space in a heavily populated city is limited. After research, it was decided that Hydrogenics produces electrolyzers that meet all of these specifications and the installation and employee training is included with the purchase of the system.

Image 2 : Hydrogenics HyStat-60 with Cooling System[3]

The exact model that is being considered is the HyStat-60. The model stretches 12.19 meters long, 2.44 meters wide and 4.5 meters tall and weighs approximately 15.5 tons. This electrolyzer has the ability to make up to 60 Nm^3/h of hydrogen, this equates to approximately 5.39kg/h. The machine draws 5.2 kWh/Nm^3 of hydrogen produced. That would mean at its peak generation rate, it would be pulling around 312 kW from our solar infrastructure. For this reason, we have set up an electrical switch to divert excess power so as not to overpower the system in any way that might cause a safety hazard. The minimum rate of hydrogen is 24 Nm^3/h. This equates to a power draw of 124 kW from our solar infrastructure, to avoid wasted energy, there will be an automatic electrical switch to divert the electricity at times when the instantaneous load is less than 150 kW. The operating temperature range for this electrolyzer is -20℃ to 40℃.

There a few optional features that the electrolyzer will need to be equipped with in order to meet the demands of our project:

Hydrogen Purity System (HPS):Due to the high purity required for the fuel cell, the electrolyzer will need to be installed with the optional hydrogen purification system that Hydrogenics offers. This system will dispense hydrogen at 99.998% purity, with O_2<2 ppm and N_2<12 ppm.

Reverse Osmosis System (RO): The electrolyzer requires large quantities of demineralized water, yet only has access to the tap water that runs beneath the streets of Hoboken. To amend for this, the electrolyzer will be equipped with a reverse osmosis (RO) system to purify the water used in the process. The RO system will receive 1.5-2.0 liters/Nm^3 H_2 that will be delivered between 2-4 barg.

Online Purity Measurement System: To ensure the greatest amount of safety in this project, the hydrogen purification system will also be equipped with an online purity measurement with blow off logic. This system will continuously monitor the real-time water and oxygen content, if the hydrogen quality is out of spec, the hydrogen will be vented to the atmosphere.

Cooling System: A cooling system would be present to send water through gas heat exchangers, improving the gas purification efficiency. The system would also maintain the appropriate water temperature of the electrolyzer.

To maintain steady operation of the electrolyzer some utilities will need to be constantly provided to the system, including water and electricity. Approximately 2 liters of water would need to be provided per normal cubic meter of hydrogen produced. At full load the system will need to be supplied with 120 liters of water every hour. To meet this demand the project looks to the Hooken water infrastructure for its supply. A water line runs parallel to the system along Hudson St. and another line is perpendicular to the system under 8th St. The initial plan would be to connect to the Hudson st. line as it is less than 15 meters from the project; however if required, the 8th st. line could be connected as well.

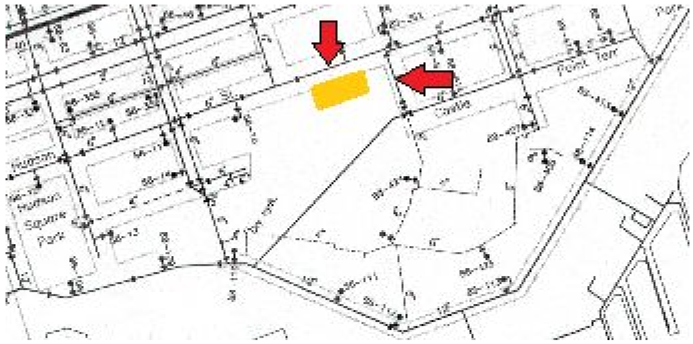


Figure 1: Hoboken Water Map

Electricity is also a big factor to consider in the operation of this electrolyzer. The standard voltage is 3x400 VAC ± 3% and standard frequency is 50 Hz ± 3%.However, due to the current electrical grid located on campus in the United States, the electrolyzer would need a voltage of 3x480 VAC and frequency of 60 Hz. Hydrogenics offers all these optional modifications to the electrolyzer. The electrolyzer would be located adjacent to the campus solar transformer and would draw all its power from there.

Fuel Cell Module

Our research into commercially available fuel cell technologies for use in generating power for a home or community showed that there are few modules capable of meeting our estimated max load (1MW). Most backup PEM fuel cell systems found provided max loads between 5 and 300 kW. [4] However, the Hydrogenics Fuel Cell Megawatt Power Generation Platform carries a nominal capacity of 1MW, certainly capable of meeting the needs of Stevens.

The system has an efficiency of 50% LHV H_2 and consumes fuel at an approximate rate of 750 Nm^3/hr (67.4kg/h) per 1 MW [5]. The Hydrogen feed should enter at about 1 atm and 288 K (25^o C), and requires a minimum purity of 99.99%. The unit is delivered in a shipping container which measures 12.2 x 2.4 x 2.9 meters. The system output voltage is between 380 and 480 VAC, with a frequency of 50-60 Hz, and is designed with a lifetime of 20 years. In addition water for humidification and nitrogen for shutdown are not required, further reducing costs when compared to other existing fuel cell technologies.

Image 3: Hydrogenics Fuel Cell Megawatt Power Generation

Compression and Storage

The storage tanks selected for this project have a working pressure of 350 bar, and so a compressor capable of achieving that pressure is necessary. The Hydropac C12-10-10500LX compressor was selected for this purpose and is capable of discharging Hydrogen at 800 bar. The compressor has a minimum flow rate of 11.5 Nm^3/hr and a maximum of 74.2 Nm^3/hr, and is powered by a 15 kW motor. The ability to discharge Hydrogen at 800 bar, gives the option to add HFC fueling capabilities without needing to purchase an additional compressor. [6]

Image 4: HYDRO-PAC “LX Series” Hydrogen Compressor

A large storage system is required in order to reserve enough energy to power a campus micro-grid. While there are numerous options for hydrogen storage, the basic gaseous vessels use the least amount of energy to compress and store the gas. The American Society of Mechanical Engineers (ASME) certifies the production of proven storage designs.

Under ASME Section VIII, Division 3 and KD-10, WireTough engineers ground storage cylinders that outperform solid steel (Type I) cylinders in terms of pressure threshold and system weight.

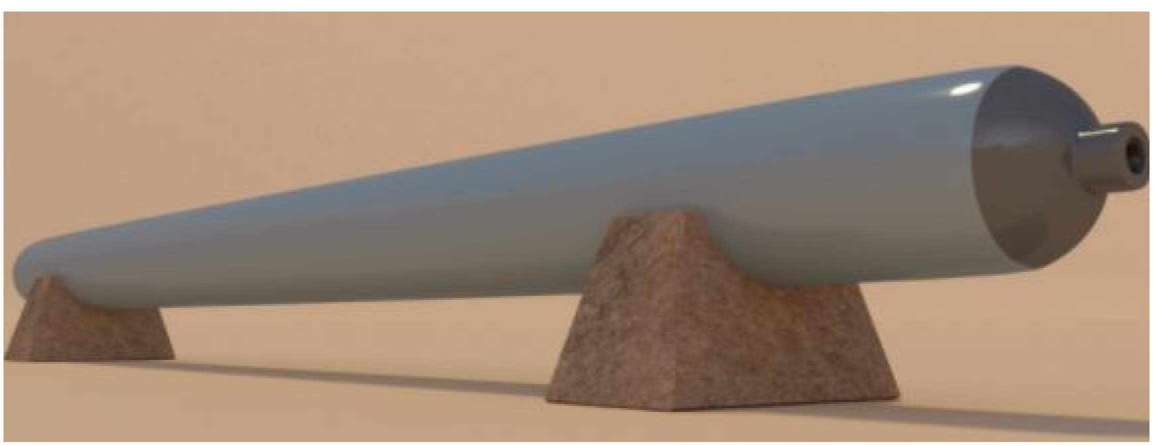


Image 5: WireTough Ground Storage Tank

In order to contain 3700 kg of H_2, 79 tanks with 47 kg capacity, each, are to be purchased from WireTough’s line of hydrogen ground storage products. These mid pressure tanks have a Maximum Allowable Working Pressure (MAWP) of 370 bar, and a Working Pressure of 350 bar.

Storing the hydrogen poses one of the greatest challenges regarding safety. Hydrogen gas is flammable between the purity of 4-72% and up to 95% if in the presence of oxygen. It will be crucial to maintain high purity in our storage containers and prevent a buildup of hydrogen in the atmosphere. To add another layer of safety, the storage of this hydrogen will be submerged in a well-equipped and protected area that would minimize collateral damage should the worst case scenario occur. An underground storage facility will be designed between the electrolyzer, fuel cell and compressor. It sit below a 0.3 meter concrete wall, classified as a 4-hour fire wall, that will separate the facility from all activities at the street level.

Each individual hydrogen container will also be submerged in the ground vertically 8.7 meters deep. This will allow for 0.5 meters of the tank to be exposed to the atmosphere for easy access for the piping system connecting the electrolyzer and the storage. Each tank will also be insulated with a concrete pipe of 0.195 meters thickness. The diameter of the hole drilled into the ground would be required to extend 1 meter across to account for the diameter of the storage container (.61m) and the thickness of the pipe. The tanks will be stored in a 8 by 10 array, however to permit easy access to the tanks, space for a walkway will be implemented after every 2 rows of tanks. This walkway will be 2 meters in width, giving the storage area a total dimension of 14 meters by 10 meters.

As a safety precaution against ignition, a few safety systems would be necessary to minimize collateral damage in the event of an explosion. To prevent the buildup of hydrogen in the atmosphere of our storage facility, a detection system will be present to notify and handle the situation. This system would have communications with the ventilation system as well as the alternative sprinkler system. All equipment will be explosion proof, including all light switches, electronic monitors and safety systems.

In the event of a fire or explosion, there will be systems in place to mitigate any serious damage to the surface level environment. The facility would be equipped with several spring loaded pressure relieving vents. These vents would serve the purpose of pressure relief in the event of a catastrophic explosion, it would safely relieve excess pressure to the environment to prevent explosion from rupturing the horizontal fire barrier protecting the street level surroundings. The resulting fire inside the facility would also be trigger the emergency alternative sprinkler system to release an oxygen absorbing foam. These systems intend to suffocate the fire before the 4 hour fire wall loses its integrity. In the event that these systems are still inadequate in quench the flames, a manual wet sprinkler system can be activated by the fire department. This would require a hose connection to a hydrant that would pump water through a secondary sprinkler system designed solely for this purpose.

Island Mode Disaster Plan

The Canavan Athletic Complex will be used to shelter individuals who do not reside within Stevens on campus housing. FEMA recommends about 30 sq ft per person to shelter individuals for over 24 hours. [16] The Canavan Athletic Complex provides an estimated 48,000 square feet, which is enough space to shelter ~1,600 people. The largest energy requirement for the system would be heating of these buildings if a disaster were to occur in the winter time. After speaking with members of the Stevens administration it was estimated that during an emergency the microgrid would need to be capable of supplying 1 MW of power for a period of 8 hours each day. This would be a load of 56 MWh per week. With the solar panels supplying an average of 250 kW during peak sun hours and an average of 3.5 peak sun hours per day in the winter, about 50 MWh would need to be supplied by the fuel cell each week. [17] This would be the equivalent of ~3,300 kg of hydrogen to sustain island mode for 1 week. [5]

Cost and Economics

Our system will see future revenue from state and federal incentives as well as the sale of hydrogen at a premium for refueling FCVs. As aforementioned, there is no revenue presently identified. This is not a concern because the system functions to provide an undefinable utility: saving lives. The potential to safeguard the lives of students and citizens firmly differentiates this project.

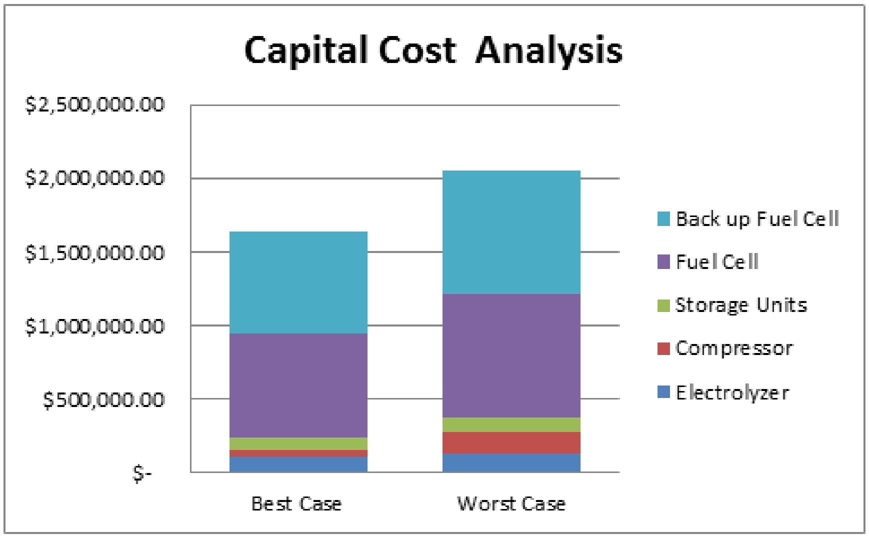
As the system is implemented and its functions displayed there will be no concern over its cost. The group is firm in this belief because the cost of this system is equivalent to previous projects on campus with little direct revenue and offers more potential utility than existing systems.

Cost estimates for the major components of our system were largely derived from the government research, with many providing a range for the capital and operating costs of each component. This allowed the team to create a best and worst case scenario to analyze the different initial and ongoing investments associated with urban resilience defense. Table 1 details the cost of each component.

Capital Cost				
	Model	**Best Case**	**Worst Case**	**Source**
Electrolyzer	Hydrogenics HYSTAT 60	$107,780.00	$129,336.00	[7]
Compressor	Hydropac C12-10-10500LX	$49,708.00	$149,124.00	[8]
Storage Units	Wire Tough 47 kg Tank(350 bar)	$65,457.81	$72,003.59	[7] [5]
Fuel Cell	Hydrogenics Fuel Cell Megawatt Power Generation Platform	$700,000.00	$840,000.00	[7]
Back up Fuel Cell		$700,000.00	$840,000.00	[7]
Total		**$1,622,945.81**	**$2,030,463.59**	

Table 1: Itemized Capital Cost

The estimated capital cost of each subsystem includes installation and, for the electrolyzer specifically, training. This cost assessment accounts for the emergency environment of the system with a backup fuel cell. Graph 1 is provided below for a better representation of the cost affiliated with this system, and how each subsystem contributes to the initial investment.



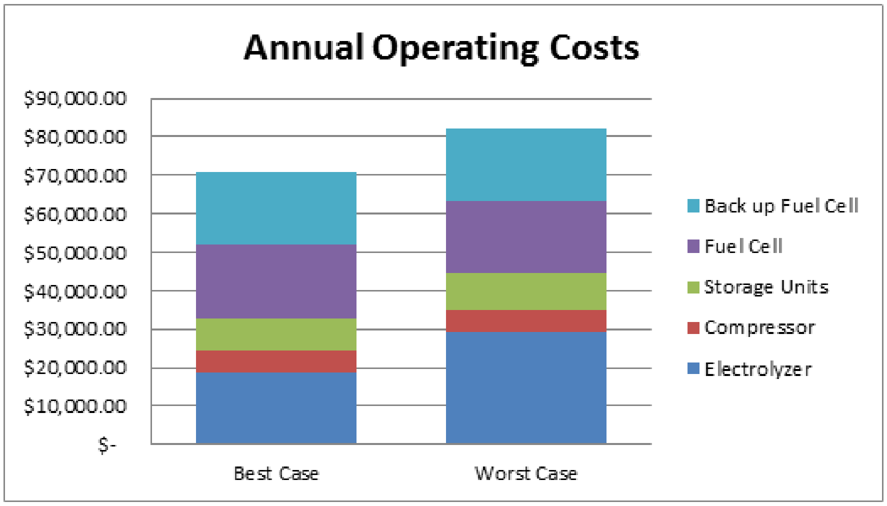
Graph 1: Apportioned Capital Cost

Operating costs have been estimated on the basis of 200 days of operation per year, enough to fill the tanks with enough hydrogen to satisfy islanded mode operation. These operating costs include routine and non-routine maintenance, electricity consumption, and annualized cost for replacement components. These cost components are detailed below in Table 2.

Annual Operating Cost			
	Best Case	**Worst Case**	**Source**
Electrolyzer	$ 18,515.00	$ 29,095.00	[3]
Compressor	$ 5,776.68	$ 5,776.68	[13]
Storage Units	$ 6,545.78	$ 7,200.36	[5]
Fuel Cell	$ 19,035.83	$ 19,035.83	[13]
Back up Fuel Cell	$ 19,035.83	$ 19,035.83	[13]
Total	**$ 68,909.12**	**$ 80,143.69**	

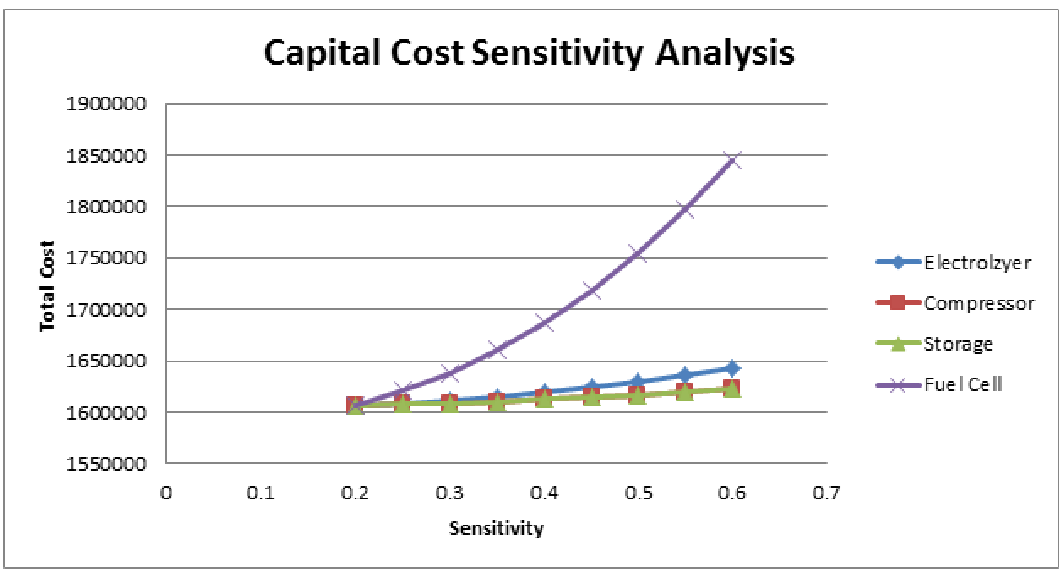
Table 2: Annual Operating Cost

Annual operating cost is shown in Graph 2 to show that although a cheaper initial investment, the electrolyzer will incur the largest continuous investment via operations.



Graph 2: Annual Operating Costs

To clarify the most critical system a sensitivity analysis was conducted with all of the capital investment cost components. This analysis reveals which subsystems cost will be the driving force behind the financial feasibility of the system. The sensitivity analysis is shown below in Graph 3.



Graph 3: Capital Cost Sensitivity Analysis

As clearly detailed in Graph 3 the feasibility of this investment proposal to the university will be largely contingent on the accuracy of our fuel cell cost estimate. For this reason the design group has chosen to operate with the higher end of the cost estimate for the fuel cell.

Safety Analysis & Codes and Standards

Hydrogen is classified as a combustible gas, and as such has many safety codes and standards that aim to prevent and protect against possible worst case scenarios. The electrolyzer, fuel cell and compressor shall be compliant with section 2209 of the International Fire Code regarding hydrogen motor fuel-dispensing and generation facilities. As such, all equipment involved in the system "including pressure valves; hydrogen vaporizers; pressure regulators; and piping used… shall be designed and constructed in accordance with section 3003, 3203 [of the International Fire Code] or NFPA 55" [15]. This equipment will also be listed for hydrogen use. It is also important to separate the equipment from "other fuels or equivalent risks to life, safety and buildings or public areas" [15]. To adequately isolate this equipment a 2-hour fire barrier shall be erected surrounding the system on three sides. The barrier shall be a minimum length of 18 meters and a minimum height of 4.5 meters in accordance with International Fire Code 2209.3.1.1. The hydrogen system will also be protected by guard posts to prevent against vehicular damage.

In cases of emergency the system and all employees shall be compliant with sections 2209.5.2, 2209.5.3 as well as chapter 4 Emergency Planning and Preparedness. All employees working on this system will be required to be trained in emergency preparedness and shall have complete and thorough knowledge of all emergency plans. Two emergency shut off valves shall be equipped to this system. One shall be an manual valve designed to "shut down the flow of gas from the hydrogen supply to the piping system" [15]. This valve "shall be clearly visible, accessible and indicated by means of a sign". The second valve will control the system remotely. It will allow the user to operate the system from a distance no less than 7.62 meters away, but no further than 22.86 meters. Both shut down controls will have the ability to cut off all power to the system, seal the ventilation to the storage facility and close all piping systems from the generator, compressor and fuel cell to and from the hydrogen storage [15].

The hydrogen storage facility poses the greatest threat to safety and as such, will have the most protection systems to mitigate the potential hazards. Hydrogen storage is classified as a high hazard group H-2. Flammable gases in group H-2 are limited to 84 m^3 per control area when the gas is contained in approved storage cabinets and accompanied by an approved automatic sprinkler system as defined by Table 307.1 of the International Building Code. Exceeding the maximum allowable quantity requires the implementation of an explosion prevention system. This system shall be inclusive of emergency spring loaded ventilation systems that are designed to relieve pressure when it exceeds maximum acceptable limits and alternative sprinkler systems to eliminate the potential for combustion in the event of a hydrogen leak. The explosion prevention system shall be designed in accordance with Section 415 of the International Building Code. As such, a 4-hour fire barrier shall be constructed between the storage facility and the street level and all hydrogen tanks shall be encapsulated in a 3-hour fire barrier. All doors and ventilation systems in the facility shall also be rated at a minimum of a 3-hour fire safety standard. [14]

In the event of a hydrogen leak, the detection system will signal a silent alarm when the hydrogen levels in the atmosphere reach 1%. At the indication of this alarm, hydrogen production will cease and ventilation to the storage facility will increase. Upon the hydrogen levels reaching 2% of the atmosphere, lights will flash and an audible alarm will sound. 60 seconds after the start of this emergency alarm, the doors to the facility will lock and the alternative sprinkler system will dispense a dry foam designed to remove any oxygen from the atmosphere. After the hydrogen has returned to normal levels in the atmosphere (0.000055%) and the system has achieved an ambient room temperature of 25℃, the doors will unlock and the system will be allowed to resume. All equipment shall be compliant with explosion proof standards as defined in sections 414 and 415 of the International Building Code [14].

A continuous venting system will be installed within the storage facility that will be connected to the emergency shut off valve and detection system. The venting system shall be in accordance with sections 2209.5.4 of the International Fire Code. All vents shall release directly above the storage facility and will not travel through any other facilities. The minimum rate of discharge shall be no less than that specified in the Compressed Gas Association Standards S-1.1 through S-1.3 [15].

The electrolyzer, fuel cell, compressor and storage facility shall be compliant with all applicable codes listed in the International Fire Code, International Building Code, Compressed Gas Association Standards and other relevant sources.

Operation and Maintenance

Solar Panel Array

Solar photovoltaic systems require minimum maintenance and operator action to function at or near their optimal efficiency. Occasionally, tilt angles of the panels must be adjusted to expose the panels to the most incident solar radiation. Additionally the wiring must be inspected periodically to ensure no electrical problems exist. Lastly, due to the proximity of the Stevens solar array to the athletic fields, broken panels must be replaced more often during the spring baseball and softball season. These maintenance checks are performed by the 3rd party provider of the solar array, .

Electrolyzer and Fuel Cell

The electrolyzer to be used as a part of this system has an estimated lifetime of 10 years and will need replacement at the end of this lifespan. The annual costs for operation and maintenance of the system is estimated to be 2.5% of the initial capital investment for this product. The cost of the water used in the making of hydrogen must also be taken into account; these water rates are available from the water provider for the city of Hoboken, Suez. [9] The Hydrogenics system is designed to need minimal operator oversight, and training for the operators is included in the initial purchase price of the system. [3]

The fuel cell platform is also estimated to have annual operating and maintenance costs equal to 2.5% of the initial capital investment, and will incur no additional costs. The lifetime of this system is estimated to be 20 years.

MicroGrid Control and Operation

The electrolyzer and fuel cell modules must be connected to the existing campus energy grid. The solar array is already connected to this grid, which is capable of bidirectional flow. However, voltage and frequency regulation will be needed for connecting the fuel cell module to the grid. To achieve a voltage-source inverter will be purchased. This inverter adjusts the phase, magnitude and voltage of power generated by the fuel cell before it enters the larger power grid.

A telecommunications network will be needed to link all components of the microgrid and facilitate the transfer and storage of data. It will also be necessary to allow for all system components to be monitored and accessed remotely in real-time. This will require all components to have access to the Stevens wireless network. Cameras with a connection to this network will be installed overlooking each of the individual components, as well as all of the hydrogen storage tanks located underground. Data collection software will be used to collect, transmit and store all relevant data and system parameters, such as the amount hydrogen currently stored and the power output from the solar cells. The electrolyzer and compressor will function autonomously, with the electrolyzer beginning hydrogen production once it receives enough power from the solar cells, and the compressor turning on at the same time.

The system will require a password from a member of the Stevens administration before entering the islanded mode. This will prevent the use of hydrogen which is intended for long-term emergencies during short-term power outages. This will initiate a series of autonomous functions. First, all buildings aside from the on campus residences and the Canavan Athletic Complex will be disconnected from the Stevens microgrid. Power will be supplied only to these buildings, identified as necessary to provide safe living conditions to the individuals sheltering on Stevens' campus. Next the fuel cell will come online and begin supplying power to these buildings. Lastly, the electrolyzer will be disconnected from the grid so that power from the solar panels can be routed directly to the buildings which need it.

Environmental Analysis

In 2012, it was estimated that over 50% of the United States citizens lived in an area that was deemed unsafe due to the exposure of one or more air pollutants. These pollutants are partially the result of fossil fuel combustion. The Stevens hydrogen microgrid solution for urban resilience has no fossil fuel combustion throughout the system and is a preventative measure against air pollution. There would be construction necessary at the edge of the 8th St. parking lot, that will involve the remove of several square meters of shrubbery that currently exists in that location. This would result in a fairly steep cliff at the edge of the parking lot that would have to be heavily enforced to prevent any car from the possibility of driving over. This would have two positive effects, it would save the driver and his or her car from heavy damage at the point of impact, and it would protect our storage facility from the potential of catastrophic damage. One or more trees would also have to be removed from the siting location to give the system a separation distance of at least 5m from any flammable debris, including tree leaves. This will have minimal impact on the ecosystem that currently exists in Hoboken.

In regard to the residents of Hoboken and how they will be affected, there will be a smaller walkway behind the soccer field located near the system. This would be due to the large wall to be constructed that is intended to protect civilians from the system. If the project moves forward with the goal of adding an automotive dispensing center, there will be several parking spaces that need to be removed to give space to the machine that will be placed there. The residents that live on the other side of 8th St. including the St. Matthews Parish, will be notified of the system that is being installed and trained to evacuate at the sound of the emergency alarm system that is installed in the storage facility. The fuel cell will emit 75 db of noise when an individual is standing 1 meter away. This is negligible compared to the sound of traffic on Hudson Street. The fuel cell's outlet air will be at a temperature of 70℃, this will also prove to have a negligible effect on the surrounding atmosphere. [5] The electrolyzer uses water cooling in a closed loop, so will not output much heat to the surroundings.

Policy/Regulatory Analysis

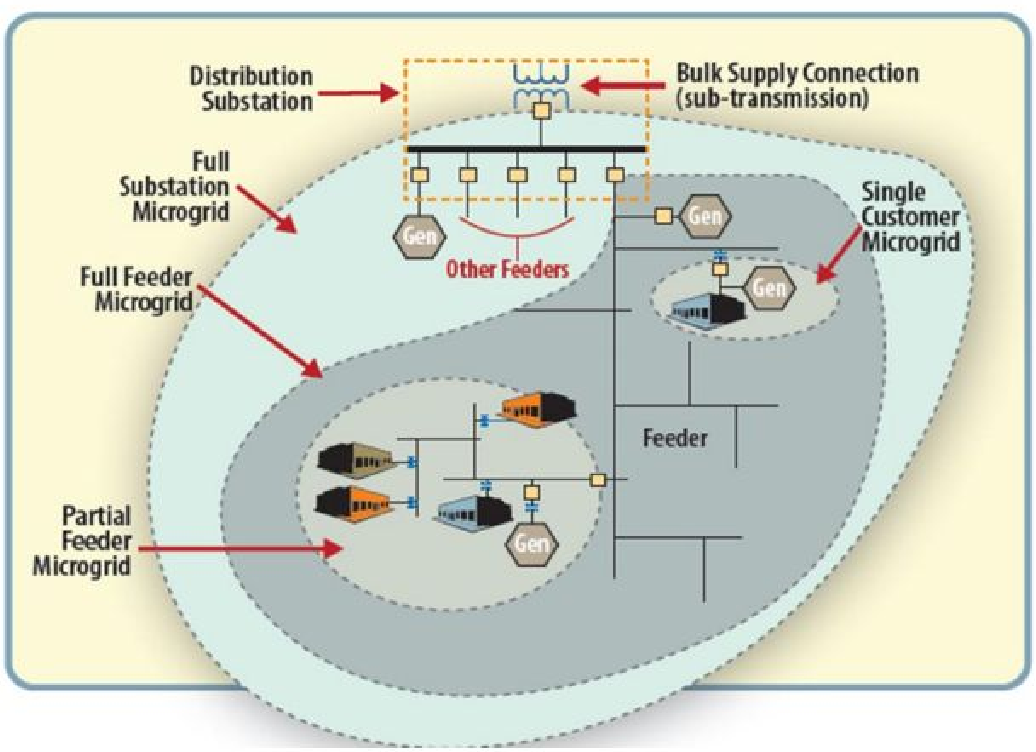


Figure 2: Board of Public Utilities (BPU) Microgrid Schematic

The New Jersey Board of Public Utilities currently recognizes campus setting microgrids as level 2 partial feeder microgrids. This proposed distributed generation design would allow Stevens to island itself from the grid in an emergency mode and also connect on-campus energy storage to that of a distribution station or town center. [10] The Washington Street Project, a microgrid for the city of Hoboken, has been identified as a potential level 3 advanced microgrid and would provide a network connection to other New Jersey resiliency efforts. [11]

Stevens Institute of Technology has been funded through the New Jersey Clean Energy Program (NJCEP) in the past for a small 100 kW Combined Heat and Power system, and the 84 MW hydrogen fuel cell design would supplement campus sustainability drives. NJCEP is the statewide governing body for financial incentives, programs, and services for clean energy projects. [12]

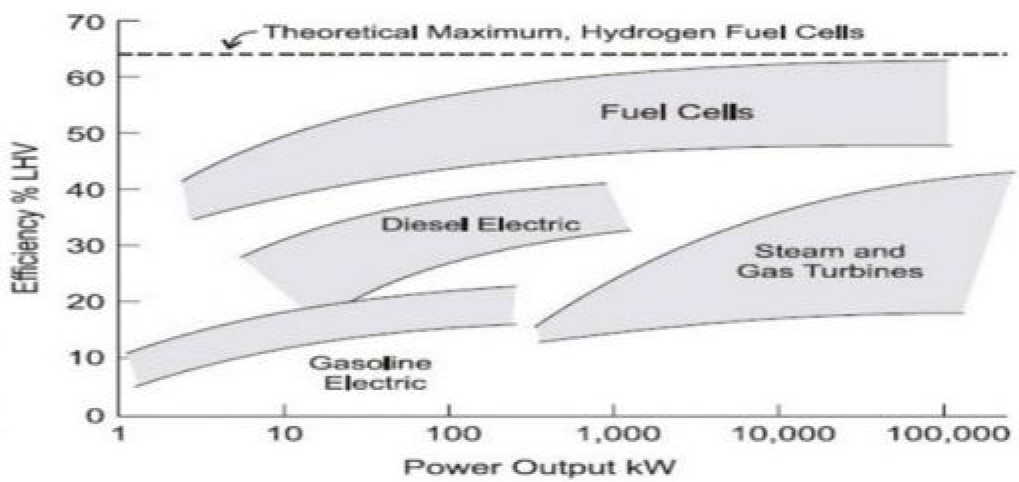


Figure 3: Fuel Cell Efficiency

Hydrogen fuel cells are proven to offer the most efficient energy generation as seen in the figure above. Combined heat and power systems, such as the one installed at Stevens, are one of the most commonly used grid technologies today; however as electrolyzer, fuel cell, and hydrogen storage research make hydrogen microgrids more approachable, a switch to hydrogen should be made. As of 2016, the NJCEP has funded 15 fuel cell projects, 8 of which are renewable. None of them have islanding capabilities, which would make this proposed design the first in the state to be able to do so. [10]

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