Hydrogen Student Desgin Contest 2016

Energy Backup Microgrid powered with Hydrogen produced from Seawater for a Hospital

Universidad de Ingeniería y Tecnología – Team C

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Executive summary

The Project consists in the design of and energetic backup micro grid for the hospital "San Juan de Dios" located in Pisco, Ica, Peru. The microgrid is powered by hydrogen obtained from seawater.

This particular location (south of Peru) was chosen because it is a sensitive zone of earthquakes. Moreover, it does not have enough resources to fix rapidly the effects of these disasters. Likewise, considering that the majority of the national energy production comes from hydroelectric power plants, "El Niño" affects the generation of electricity and causes supply problems in the south of Peru. Both reasons can cause deficiency or the disability of energy distributors so that patients` health would be involved.

Because of the abundance of water in Pisco, it was opting to use a microgrid based on hydrogen in comparison with other energy sources as wind or solar. Furthermore, the direct dependence of the latter two sources with Pisco weather gives us greater reliability that hydrogen can, indeed, be produced because energy storage from both sources is partial and the flow energy they produce is not stable. On the other hand, the electric flux produced by the fuel cell is continuous.

The micro grid consists of hydrogen powered fuel cells. This hydrogen is obtained from seawater through alkaline electrolysis after a desalination through electrodialysis. The project covers the production and storage of hydrogen and the generation of electricity with fuel cells powered with this compound. Likewise, it is included security regulations applied to each process mentioned. The micro grid will operate also during peak hours (attending at least 10% of the maximum demand) and, automatically, will operate 48 continuous hours. In this regard, the objective is to establish a highly reliable energy backup microgrid so that it can be utilized in case one of these natural phenomena affect the electric supply of the hospital.

Extraction of seawater is raised by pumping. The water will be transported by tanker trucks to the desalination plant located inside the hospital where the process of electrodialysis is activated. Then, the desalinated water is processed to electrolysis from which we obtain hydrogen. This gas will be stored in a metal tank close to a fuel cell connected to the hospital network for the constant energy supplying.

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1. Technical design

1.1. Problem statement

Pisco is a small town located in Ica region about 230 km south of Lima. Its population exceeds 53000 people. One of its main economic activities is tourism because of their active beaches, Paracas national reserve, and fauna. Also, because Pisco is one of the principal harbors in Peru, fishing is very important for their economy.

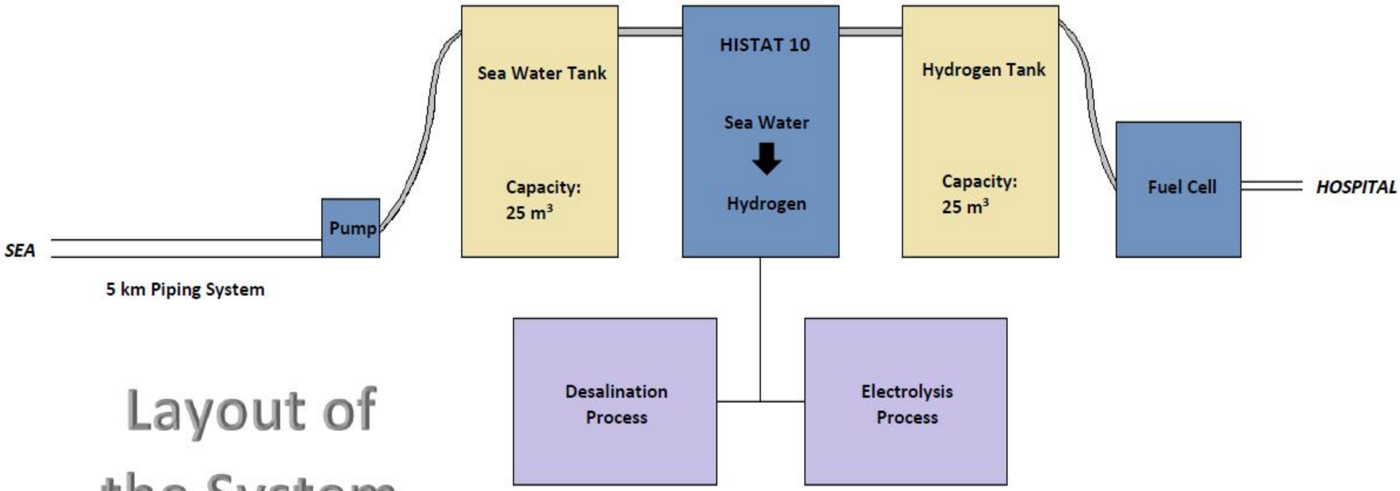
On the other hand, Pisco is situated on a high risk seismic zone with frequent earthquakes, one of which was the 7.9 earthquake from August, 2007, which devastated almost the whole city. There were hundreds of dead and thousands of injured people, but the city hospital did not respond to the demand because of the damage caused by the earthquake and the lack of a backup system that could supply this energy demand.

This lack of support is a big problem because many lives could be lost if another earthquake of that magnitude shakes Pisco again and provokes a shutdown for few hours or even days. Because of this and “El Niño”, affects more frequently this region of the Peruvian coast, the idea of designing a way to supply alternative energy to this hospital was encouraged.

This is to achieve clean and reliable energy that comes from renewable resource and easy access to the user, which is very important because of the existing centralization of Peruvian resources and lack of assistance from the State in case of emergency: they are always present in the capital (Lima); however, not usually in the province. This leads to insecure population that cannot fully trust that, after a natural disaster, problems will be solved by the State collaboration. This is why that a non-capital hospital in a small town is in the capability to sustain energy for a considerable period of time. It would greatly improve the quality of hundreds of lives: first, patients; and second, people living in the city that could eventually need medical attention.

The clean energy to be used is produced through a hydrogen fuel cell, which is extracted (the hydrogen element) via an electrolysis process, from a previously desalinated sea. This choice due to the proximity of Pisco and the sea and, therefore, the available abundance of marine water.

1.2. Design solution



Layout of the System and Its Main Components

1.1.1. Hydrogen production

In order to exploit the natural resources of the region such as marine water along the Pisco littoral, hydrogen will be produced by electrolysis. The method requires a considerable amount of energy so that the dissociation of water molecules into hydrogen and oxygen gas is produced< however, it reduces the emission of greenhouse gases compared to other production methods, such as the reformed version from natural gas. In addition, considering that the production schedule is based on electricity, incorporating on-site renewable energy, such as solar or wind, will be provided.

However, it is not possible to electrolyzed salt water directly because it has high concentrations of sodium chloride and can provoke side reactions in the electrolysis process. Therefore, desalination will be embedded in the total production process.

In this regard, the simplification of the number of equipment and, therefore, space, it was opting to utilize an Electrolyser Hydrogenics equipment including water treatment. The options that best suit the project requirements are HYLIZER 2 and HISTAT 10. The HYLYZER 2 computer model is a versatile cubic shape that, due its relatively small size (1, 30 x 1, 00 x 1, 25m), it can be installed inside the hospital. The net production rate is 2 Nm^3/h and serves to feed a 143 kW fuel cell.

On the other hand, the HISTAT 10 model consists of a generating unit and a control and supply unit (control/power cabinet), which dimensions are 1, 7 x 1, 85 x 2, 6 m and 1, 00 x 0, 50 x 2, 10 m, respectively. As it can be seen, this dimension exceeds the previous model; however, it compensates with a net production with a maximum of 10 Nm^3h^{-1} or 5, 21 kg/h, which equals 716, 6 kW of power in one day. Likewise, the treatment system ROS (Reverse Osmosis System) that has this model also tolerates a higher concentration of minerals in the water compared to the HYLIZER 2 model, which has strict requirement of PH, temperature, concentration of compounds, etc. for water. Finally, the hydrogen produced has a purity of 99.9%

In this sense, the HISTAT 10 Hydrogenics will be the desalinator and electrolyzer equipment to be used for production.

Image 1. Reactions that take place in the electrolyte process.

$$2H_2O_{(l)} \rightarrow O_{2(g)} + 4H^+{}_{(ac)} + 4e^- \mid E° = -1.23\ V\ (\text{Oxidación})$$
$$4H_2O_{(l)} + 4e^- \rightarrow 2H_{2(g)} + 4OH^-{}_{(ac)} \mid E° = -0.83\ V\ (\text{Reducción})$$
$$6H_2O_{(l)} \rightarrow 2H_{2(g)} + O_{2(g)} + 4H^+{}_{(ac)} + 4OH^-{}_{(ac)} \mid E° = -2.06\ V$$
$$\mathbf{2H_2O_{(l)} \rightarrow 2H_{2(g)} + O_{2(g)} \mid E° = -2.06\ V}$$

And the electrolyte conductor that is requires for the equipment is KOH at 30% in weight.

1.1.2. Sistema de suministro de agua de mar para la planta de electrólisis

Sea water will be drawn by a motor located in the hospital. It pumps through a PVC pipe 3 "diameter over 5 km. When filling seawater in the tank where it is stored, the machine will desalinize - electrolyze through a small PVC tube. This pipeline system has an estimated price of 450 thousand suns.

LAND MOVEMENT	
Excavation trench (Depth de 0.6 m) / Water machinery	3.18 ($)
Refining and leveling pipe trench	0.61($)
Bed support preparation	1.47($)
Compact backfilling	39.83 ($)

Removing of excess material for the pipe trench	12.22 ($)
Pipeline supply and installation	
Supply and installation of 3`` PVC pipe	4.45 ($)

Tabla. Costo en soles por metro lineal de tubería para agua de mar

The pumping system will be inside the hydrogen production station in the hospital, in order to enable seawater to the hydrogen generator, immediately. More specifically, there will be a 5 Km PVC pipe linking the coast of Pisco and the 25000 liters-industrial storage tank, which will be directly connected to the hydrogen generator. In that sense, to pump water it will be needed a surface centrifugal pump to draw the necessary water and will be stored in a tank of 1000 liters.

For this task, the company offers two electric pumps Xilem in its A-C Flygt series. The first is the WS 9800, a powerful electric pump with 50 000 $m^3.h^{-1}$ flow rate, a total head of 175 meters and a power of 9850 HP. Also, the SSVF electric pump with a flow rate of 410,000 m3 / h, a gauge height of over 240 meters.

In contrast, both pumps meet the specific needs. However, the height required is 120 m meet on average (to pump water to the hospital), therefore, the WS 9800 is ideal for the job. Also, the energy is used to activate and use this pump is lower than with the SSVF.

Finally, the use of the industrial storage tank of 25,000 liters is justified in that the hydrogen generator does not receive water continuously, but uses stored water from a 650-tank. Therefore, in view of saving reactive power, the tank will be used to operate the engine only every 36 times after using the hydrogen generator.

1.1.3. Hydrogen storage system

In order to save space in storage and increase the energy density of hydrogen gas, the hydrogen recovered from the electrolytic cell must be compressed. The addition of a storage tank provides an agile supply hydrogen for both destine to the fuel cell or refueling. The desalination-electrolysing equipment from Hydrogenics, HISTAT 10, incorporates a compressor which can reach above 200 bar pressure. Thus, hydrogen will be stored in a tank at 300 bar at room temperature in a tank of 25 m^3.

1.1.4. Electricity generation system

As for the fuel cell that generates electricity backup, a HD30 HyPM produced by Hydrogenics, will be used. This is a cell proton exchange membrane (PEM. It feeds on hydrogen stored on-site by pipeline, and generates 1MW, with an electrical efficiency of 49 %. Equipment dimensions are 3.04 × 15.24 × 2.44 m, and will be located in an open area outside the hospital.

1.1.5. Dispensing equipment selection

In Peru, the acquisition of fuel cell electric vehicles is highly unusual. This is because the maintenance of the fuel cell in the domestic market is very expensive, this technology also is imported from industrialized countries. However, in the future, considering the trend of economic and technological development of the country, it is possible that the use of such vehicles become more widespread. Only in this context, in which the hydrogen demand would generate enough revenue to recover the investment, it could be implemented as part of the plant with a refueling station that provides pre-cooled hydrogen to preparations for this fuel vehicles.

1.1.6. Communications

The internal and external communication system will have a cost of

- Communication between the hospital and the fuel cell

  The fuel cell will have a discrete control that light up when receiving a signal from the hospital when no power supply network. Similarly, to recover such supply, it will send a signal to the fuel cell is turned off.

- Communication between Hydrogen tank – desalination-electrolyzing machine

  The tank will have a pressure sensor that measure reaching certain threshold value, send a signal to discrete control of the machine, which turns it off so you do not continue to receive water from the previous tank. Similarly, hydrogen having a pressure lower limit, the sensor sends a signal to discrete control to return the machine to receive water to process.

- Communication between Seawater tank - Motor

  The tank will have a level control, water reaching a certain limit, it will send a signal to discrete motor control , which will turn it off so you do not continue pumping water. Similarly, when the amount of water in the lower tank to the limit, the control level sends a signal to discrete control for the engine water pump again.

- Communication between Plant - Operator

  Each process will have a PLC that will allow internal communication and report any malfunction to a control base a few meters from the plant where the user, which may contact the operator via remote video call will be found.

Table. Cost in US dollars of the elements used for the communications system

Level control	73.62 ($)
Pressure sensor	73.62 ($)
Discrete control	92.02 ($)
4 programmable logical modules Zelio Modular SR3B101BD (Schneider)	577.30 ($)
4 power suppliers Phaseo ABL8MEM24012 (Schneider)	344.91 ($)
Communication module Modbus RS485 SR3MBU01BD (Schneider)	100.34 ($)
TOTAL	**1261.81 ($)**

1.1.7. Safety equipment

In case of fire, this will be controlled by automatic fire extinguishers in different parts around the machines and tanks. An emergency of this kind or another can communicate through the base remote control to the operator, as there will be a temperature sensor that will activate the fire system, which will be monitored by the user. Also as prevention, instantly it cuts off the supply of electric power to the plant and emergency lights preloaded and an alarm system to alert light up the danger to people who are nearby.

On the other hand, it will have artificial lighting at night and constant video recording at all times in order to prevent, in addition to accidents or emergencies, theft, since they are common in the country, and specifically in that city.

1.1.8. Auxiliar Energy consumption

The location of the project will be used for photovoltaic panels to supply clean energy to the chemical processes. With solar energy that reaches more than 7, 5 kW / m^2 in November on the surface of Ica, the energy payback would be quick. As mentioned, the microgrid will fully support the hospital within two full days in an emergency, and during the rest of the year, 10% of peak demand; additionally, the hydrogen will be used to supply electric vehicles with fuel cells. This means that the storage tank must provide clean fuel for three different circumstances.

First, the emergency case is the continuous consumption of hydrogen for 48 hours straight (the backup). In this case, the hydrogen used will have already been stored in the storage tank; however, simultaneously, new hydrogen will be stored in the tank as it releases hydrogen daily. This will keep some hydrogen intended for the other two cases and will not run out of fuel if complications dilate over time and generate greater burdens.

The second case is to supply 10% of the maximum demand of the hospital throughout the year, and for this we will use another volume of hydrogen. This new volume will be released and stored discreetly during peak hours. Regardless the reserved emergency volume, this mass of hydrogen will be consumed daily.

The third case is to provide interested amounts of hydrogen to particular users or electric motor vehicles and hydrogen fuel cells. another volume will be used.

In total three different volumes of hydrogen to be handled for separate occasions, which are subject to the effectiveness of the chemical processes, which will be powered by the electricity of the photovoltaic panels.

2. Cost and economic analysis

The real economic cost of the project; that is, to generate electricity from hydrogen to a hospital as backup power for two days, is a difficult thing to obtain because the project’s magnitude. This is why the project will focus on: first, the conceptual design and, second, the development of a first applicative research project, which describes a machine that transforms energy from renewable sources in electrolytic hydrogen and other products. In this section the economic viability of the proposed project is discussed.

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2.1. Capital Costs

All prices in this section are listed in local currency (Peru) Sol or dollar (USA). Unfortunately, there are no additional potential tax credits for any of the systems listed before 18 April 2016. Table 2.1.1 describes capital (including installation and contingency), maintenance costs of the energy system equipment of hydrogen, and Table 2.1.2 the costs associated with the environmental team is.

Table 2.1.1 Capital and maintenance cost estimates for the fuelling system

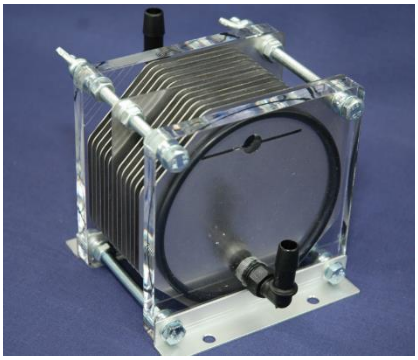
Equipment	Total costs ($)	Maintenance/ year ($)
Electrolysis unit	336,500.000 (Hidrogenics, 2015)	11.000.00
Compressor	100,150.000 (Ratkowsky, 2016)	8,800.00
Storage tanks	120,000.000 (Dyneteck Industries Ltd, 2016)	500.00
Booter compressor	82,700.000 (Hertken, 2016)	4,100.00
Control safety	42,337.000	400.00
Hydrogen cylinder	1,000.000 (SEFIC - DPL-450-17)	550.00
Fuel cell	198.20 (HHO KIT BEC-1500)	100.00
Motor water	2,000.000 (1500 watss)	700.00

Table 2.1.2 Summary of environmental equipment estimates for electricity offset

Environment Equipment	Units	Total costs ($)	Maintenance/ year ($)
Solar PV modules	300	6,000.00	1,000.00
Solar panel	10	7,000.00	1,000.00
Sensors	30	3,000.00	1,000.00
Safety signal	100	100.00	50.00

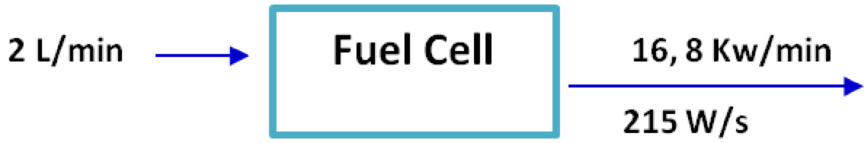
Veamos el siguiente equipo a utilizar de la celda de combustible para generar energía eléctrica, Fuel Cell.

- **HHO KIT BEC-1500 - Hydrogen Dry Cell Generator**



GBP 134.90 $ 198.20

- Designed for up to 2000cc engines (Petrol or Diesel)
- 2 litres HHO gas per 1 minute (14A - 12V)
- 16A without overheating
- Power 215W
- Weight – 2Kg



3. Safety analysis

The system safety analysis is a very important issue for the mass deployment of hydrogen or at least in cities in the future, addressing security and regulations.

The purpose of identifying risks is to prevent accidents and protect the person in implementing future hydrogen service associated with the hospital and future users.

In developing the system for obtaining hydrogen conversion to electricity to achieve the efficiency and effectiveness of productivity in plant production hydrogen energy, estimation of hazards and safety risks at each stage it was carried out process. The codes and standards related to hydrogen generation system related storage and supply of fuel, water desalination, water electrolysis, power generation Fuel Cell is mentioned. Which they were reviewed and applied to the hydrogen generation system seawater in the hospital to mitigate the potential risks and hazards identified. Similarly, the hazards associated with another alternative form of energy that were used in the system power, namely, photovoltaic solar energy were also considered.

3.1. Legislation and Normatives

It should clarify some terms that are generally confused. Legislation or regulation refers to those laws or regulations are mandatory, which their development is the responsibility of the authorities to protect citizens. See the following legislation in Peru.

- It is recommended to use safety equipment in the first instance and for each stage of the production of energy. Law 3022 (DS 006-2014 TR), safety and health at work.
- Law on Safety and Health at Work - compliance with the Regulations of Law 29783 (2012 DS TR 005) is recommended. So that staff must have safety equipment for each area and training in industrial safety.

Normalization refers to standards committees develop at the request of the industry under consensus of the experts and the various companies with which compliance is optional. Nowadays, there is a fairly clear and complete regulation for fixed installations with hydrogen. The United Nations is preparing, at the request of EIHP (European Integrated Hydrogen Project) project, a regulation for hydrogen vehicles. The committees working standardization regarding aspects of hydrogen technology are as follows.

- The National Fire Protection Association (NFPA). It is an association responsible for creating and maintaining standards for the prevention and fire protection.
- The International Organization for Standardization (ISO). It is a committee (ISO TC - 197) dedicated to hydrogen energy technologies, which are standards and projects under the direct responsibility of ISO. ISO - TR 15916, related to safety considerations hydrogen systems. PNTP standard ISO 448 - Peru concerning the code d hydrogen cylinder identification
- The International Electrotechnical Committee (IEC). It is a committee (IEC TC - 105) dedicated to fuel cells.

3.2. Safety measurements

There should be an objective examination of any problems that may arise due to the hydrogen properties. A key point is to considerate its molecular mass, the lowest of gaseous elements, which gives an idea of its diffusivity and low density. Other equally important aspects to consider are the ignition temperature and toxicity. Hydrogen gas is very light so a way of packaging it is in high pressure cylinders. Being a very small molecule, hydrogen leak is achieved passing through the crystal net of some materials and, therefore, special attention should be implemented to systems handling hydrogen. See the following table of properties.

Tabla 3.2. Chemical properties of the Hydrogen.

Hydrogen	**Density**	**Melting point**	**Flash point**	**Critical pressure**	**Critical temperature**	**Thermal conductivity**
H2	0.0089 kg/m^3	10.025 K	225 k	1,293.106 Pa	23.97 K	0.1815 W/(K.m)

See the following security measures in the different processes or stages of the production system hydrogen to generate electricity.

3.2.1. Pumping seawater system

In the seawater pumping system, you have to take into account the engine life and protect it with a cathodic protection or coating it with paints anti-corrosion every certain time, approximately every month. It also should protect the pipes through which seawater is transported. For better handling, locate signs against hazards in the pumping of seawater.

3.2.2. Seawater desalination plant

In the desalination plant seawater, it should consider the following safety measures: equipment and materials must be protected against corrosion as seawater salinity presents. In addition, the operating personnel must meet the safety and health at work as it will be in direct contact with chemical reagents and equipment with technical safety standards.

3.2.3. Solar Energy - Photovoltaic

The rules should take into account the station solar panels photovoltaic panels for generating electricity are as follows :
The Technical Committee 82 of the IEC (International Electrotechnical Commission) and Technical Committee CENELEC BTTF 86-2 (European Commission of Electrical and Electronics Standardization) .

Organizations are developing standards concerning photovoltaic systems.

Prevention measures in photovoltaic systems are: use personal protective items, take into account the dangers of electric shock and fire, materials atizarse must be according to the tension subject , work a place with space to allow any repairs and not be used as movement of persons , drivers will be as asylees by insulating rubber. Potential risks or other security measure will be taken into account in the management of security management.

3.2.4. Electrolysis plant

In this area keep in mind the use of personal protective equipment (PPE) as will a manipulation of hydrogen and oxygen that could be harmful to hand contact. Further. It should be performed in ventilated environments and have a thermal sensor if there is an ignition temperature or chemical combustion.

3.2.5. Storage

Hydrogen gas is the lightest of all, with a density approximately 14 times less than that of air. It has a high buoyancy favoring its vertical diffusion, because of its small size and low molecular weight, hydrogen has a greater tendency to leak to other gases. Therefore, the hydrogen storage as compressed gas is a method that requires special care with the compressibility factor at a given temperature and pressure. In addition, it must be stored in the type of material that has no porosity. To prevent risks, it will be taken in consideration the following.

The hydrogen gas is compressed at pressures below 200 bar and presents safety environmental conditions. The type of material is a carbon steel cylinder, certified ISO 9809. It should be located in a remote warehouse away from any heat source.

3.2.6. Safety Fuel Cell

The implementation environment of the fuel cell must be free of flammable agents. In order to prevent leaks, there must be implemented a gas detector sensor, a temperature sensor and against-fire signals

3.3. La identificación de los riesgos

Every activity in a technological Project involve associated risk. It is necessary to conduct a study of the possible risks in this project. The aim is to prevent any possible future risk.

3.3.1. Identificación de los riesgos del proyecto

- **Design risk:** Equipment selection (durable and non-corrosive). Energy capacity (profitability) current legislation in 2016.
- **Implementation risk:** Construction and installation of accessories (discharge system power equipment), energy consumption during implementation of the electrolyser plant.
- **Operating risk:** Corrosive deterioration in marine environments such the engine of the water pump, leaks and storage.
- **Risk during storage:** Leaks, high pressure, hydrogen hazardousness.

3.3.2. Risk Analysis

- **Materials or Equipment selection:** Materials require specific technical properties. These are subject to marine corrosion. Accumulation tanks work at high pressure and low temperatures so the electrodes od the electrolyzer suffer corrosion.
- **Current normative:** There is a regulation in storage and handling hazardous products. It is a must to meet this specific technical standard.
- **Leaks:** Since the product is flammable, it can cause an associated explosion with subsequent chemical reaction with other substances.
- **Product nature:** Product danger depend on their chemical nature. It is needed to identify all states in which the products will be produced and stored.

3.4. Immediate risk mitigation

- The hydrogen production system should include security measures; for example, pressure sensors, automatic limits on certain parameters (pressure and temperature) or ventilation in case hydrogen leakage detection.
- Different materials affinity must be in specific operating conditions.
- Containers must be designed and manufactured according regulation and legislation. In addition, components, such as valves and pressure regulators, must be suitable for hydrogen usage.

3.5. Recommendations and safety considerations

- It is recommended to use personal protective equipment (PPE) throughout the plant in order to avoid possible accidents to operation personnel.
- Implement the 5 S (Training Housekeeping 5 S) to maintain a quality environment.
- Implement industrial safety signals in each process of making hydrogen until generating energy. Specifically, implement more rigorous safety inspection when making direct contact with hydrogen.
- There must have particular attention to very small rooms, such as cabins so that an accumulation of explosive atmosphere can be avoided.
- Rooms with hydrogen installations have effective natural ventilation or ventilation equipment.
- Installing a hydrogen flame detection mechanism is highly recommended as it is almost invisible and colorless to human senses.
- Before operating a hydrogen facility, air has to be removed with a vacuum pumping system, for example, to prevent an explosive atmosphere.
- Care should be taken in handling the cylinder when storing the hydrogen. The valve must be connected with caution. A leak or escape of hydrogen could pass unnoticed at closing.
- Hydrogen detection mechanism must have sensors. The most used detection techniques are; thermal conductivity sensor (for detecting the hydrogen high thermal conductivity over other gases), catalyst bed sensor (for the released heat in the combustion reaction) and an electrochemical sensor (to measure current generated by a redox reaction. It uses a membrane that only hydrogen will get through).
- Hydrogen detectors should be located in the highest part of the building, where its accumulation is expected because of its low density. Furthermore, sensors must be installed where it is expected hydrogen leaks, such a pipe joints, storage and transport to the fuel cell.

4. Environmental Analysis

Hydrogen as energy source is comparatively expensive to other energy sources, which makes unattractive the development of projects like this one. However, this ensures lower greenhouse gases emissions. Below we present a brief environmental analysis of the main components of the station. This will be presented in the following items.

4.1. Pisco weathers

Pisco is a city located in the district of the same name, in the department of Ica, Peru. This city is located at an average altitude of 120 meters. It is situated in a marine-desert area known as subtropical coast in which the average annual temperature ranges from 17.5 ° C to 33.5 ° C. Also, the quantity of hours of sunshine in winter is 6.4 h; while in summer, it is 8.4 h during the day.

In that sense, according a study of architectural design, the average wind speed in Pisco is 4.4 m · s ^ (- 1), which indicates exploitable potential for the usage of a hybrid solar generator. This can be seen in the figure below.

Figura 1: Climate data of Pisco-Peru

		Enero	Febrero	Marzo	Abril	Mayo	Junio	Julio	Agosto	Setiembre	Octubre	Noviembre	Diciembre
Temperaturas (°C)													
Máxima Absoluta		33.5	34.2	34.2	33.5	31.8	29.0	28.5	29.3	30.5	31.8	31.9	30.5
Máxima media		31.0	32.0	32.0	30.7	28.0	25.5	23.4	24.0	26.6	30.1	30.2	28.8
Media		23.4	24.2	24.2	21.5	19.3	17.1	16.0	16.7	18.8	19.0	20.7	22.5
Minima media		17.5	17.8	17.7	15.0	12.0	10.8	10.0	10.0	11.8	12.0	13.3	15.2
Minima Absoluta		14.2	15.7	15.2	11.5	8.5	6.7	6.7	7.3	8.1	9.0	10.3	12.0
Amplitud u oscilación térmica		13.5	14.2	14.3	15.7	16.0	14.7	13.4	14.0	14.8	18.1	16.9	13.6
Humedad Relativa (%)													
Máxima media		91	90	90	92	95	95	95	95	95	93	90	90
Media		73	74	71	71	75	81	81	77	76	72	72	71
Minima media		50	48	47	48	53	58	59	54	51	46	45	47
Horas de sol (horas)		6.4	6.5	7.0	8.6	8.0	6.8	6.5	7.1	7.7	8.4	8.4	8.1
Precipitaciones (mm.)		0.3	2.1	3.1	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Vientos más frecuentes (m/s)	07:00 hrs.	S - 3.8	S - 2.5	SE - 3.2	SE - 3	SE - 2.9	SE - 3.5	SE - 3.1	SE - 3	S - 2.9	S - 3.1	S - 2.8	S - 2.4
	13:00 hrs.	NW - 3.1	NW - 3	NW - 2.8	NW - 3	SE - 3.2	S - 3	S - 3.2	S - 3.4	NW - 2.9	NW - 2.9	NW - 3.3	NW - 3.2
	19:00 hrs.	S - 4.4	S - 4.4	S - 2.1	NW - 2.5	NW - 4.1	NW - 3.8	NW - 3.4	NW - 4.2	NW - 4	NW - 4.3	NW - 4.2	NW - 4.4

Extracted from *Consideraciones bioclimáticas en el diseño arquitectónico: El caso peruano. P. 75.*

4.2. Renewable energy sources

During the process of obtaining hydrogen, energy provided from the national grid will be used. However, in order to reduce this consumption, it will opting the adquisition of an isolated energy generetion network. In this regard, renewable energy sources will be incorporated and those will reduce carbon emissions.

Thus, in order to optimally use the radiation levels and the natural air flow in Pisco, it will be opting to use hybrid technology. Since the demand for hydrogen will have a payback margin, it is planned to fund with this money the solar generator.

4.3. Hybrid solar generator[1]

This technology is the result of the combination of wind power and solar photovoltaic. These are economically attractive to isolated areas in general. While our generation plant is not completely isolated, an alternative energy sources needed to reduce dependence on the power grid.

Furthermore, reliability and energy security is higher. That is, the night at which solar radiation is not usable, the air flow is. In that regard, the system reliability is higher. The disadvantages of the individuals' sources (solar and wind power) generation are overcome by this new technology, which translates to a maximization in the availability of energy.

4.4. Environmental impact of the equipment

6.4.1. Hydrogen generator

The method chosen for the hydrogen production, electrolysis, requires a considerable amount of energy. Which, it does not necessarily result in the emission of large amounts of greenhouse gases. Since, in the case of Peru, it is important to note that the national energy matrix's main source is water. In that sense, also it reduces CO2 emissions.

On the other hand, the hydrogen production system will be located inside the hospital San Juan de Dios. Therefore, the effects of noise and visual pollution generated by the hydrogen generator will not be in evidence.

Finally, the recovered hydrogen in the electrolysis process will be compressed within the desalination equipment - HISTAT electrolyzer 10 Hidrogenics reaching pressures above 200 bar. Therefore, this equipment reduces the use of space, making this equipment safe and environmentally friendly.

6.4.2. Bomba centrífuga

The dimensions of the centrifugal pump and the sound generated when in operation will not impact on the population. Since this will be in the coastal area 5 Km from the hospital and also be located 200 m from the nearest building. In that sense, these environmental impacts are mitigated.

[1] Going solar. (2016). *Solar electricity (Hybrid).* Extraido el 17 de abril de 2016 de http://www.goingsolar.com.au/what-we-do/solar-electricity-hybrid

Also, referring to the electric power used for operating the engine, an industrial water storage tank which will significantly reduce the reactive power of the engine is acquired. Reducing engine operation 1 in every 36 times of generation of hydrogen.

6.4.3. Generador solar hibrido[2]

The negative impact of this technology is in its production, installation and removal of photovoltaic cells; however, this is part of a large-scale exploitation of this technology, which our project is not contextualized. Also, being a cogeneration technology connecting two prior technologies, it has less impact than both.

5. Marketing Video

https://youtu.be/jib4ffVwY2A

[2] Hernandez, R. (s.f.). *Environmental impacts utility-scale solar energy.* Extraído el 17 de abril de 2016 de http://www.rebeccarhernandez.com/environmental-impacts-of-utility-scale-solar/

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