2016 Hydrogen Student Design Contest

Micro grid Fueled with Hydrogen from Sugar-cane bagasse in northern Peru

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EXECUTIVE SUMMARY

A microgrid has frequently in its design power generation based on fossil fuels for thermoelectric plants and some cases use hydroelectric power plants, but the propose of this project is incentive use of renewable energy through fuel cells using hydrogen obtained from natural resource in the Peruvian area that is bagasse sugar cane.

The microgrid designed allow produce 2280 KWh operating 48 hours in 2 days, for the hydrogen demand is necessary 4489.25 sm^3 when the plant operates, the fuel cells consume is 93.526 sm^3/hr. The hydrogen is obtained from bagasse through gasification process and for the production of 1 KWhe is necessary 1 Kg of bagasse.

For produce the enough energy in 2 days (48 hrs) are necessary 62600.86 Kg of bagasse, the bagasse is buy to agroindustry Casa Grande S.A. depending of the demand of energy.

The energy cost for the microgrid results 66.53 USD/MWh, is suggest because is calculated when the plant operates 16 hrs per day, that means we got more production, in northern of Peru the energy cost in peak hour is 63.8 USD/MWh, but is considering 5 hours per day of the plant operation .

A safety analysis was considered for take care in cases of probable accidents or external causes and how control that warnings, as fires, explosions, and failures of the equipment.

The objective this project is incentive looking for new technologies and be aware about environment crisis that is happening in the world using clean energy and also increase the reliability of the system.

1 INTRODUCTION

Peru is located in the western central part of South America, it is divided in three traditional geographical regions, coast, mountains (Andes) and jungle.

The electricity production in Peru is obtained from thermal power plant and hydroelectric plant with a participation of 48.66% and 50.25% respectively in the Peruvian electric system [1]. So Peru get energy from that energy and supply power for all the Peruvian regions. However, reliability of this service is not sure at all because Peru is exposed to continuous natural phenomena. It's the case of "*fenómeno del niño*" that is causing damage to almost all Peruvian coast, one of the affected departments is *La Libertad* situated on north Peruvian coast, which has registered torrential rains that has forced to an eventual power outage [2]. *La Libertad* has different provinces with many benefits, one of them is *Ascope* that has with a sugar agroindustry called ***Casa Grande*** located in *Casa Grande* district.

Casa Grande is a district with a population of 31,174 citizens [3], it has a population growth rate of 1.2% annually [4], and an extreme poverty rate 5.6% [5]. This district has been before affected by *El Niño* in 1998, which it was one of the strongest in its history resulting in about 166 power outages per month [6]. Currently the North of La Libertad town has three power outages per month, which remains reliability of the service.

Casa Grande has with an economic activity based on production of sugar cane. This sub product is usually used by the same company for generates energy and thus feed itself. Mention should be made that bagasse has little added value and the amount that discarded the agroindustry is vital for its use. The problem of employment of this method leads to the burning of bagasse. The combustion of this resource give off carbon dioxide (CO_2) which is one of the main components of greenhouse gases (GHGs), these have an impact on climate change.

In Peru are in development process of seeks by Supreme Decree 0642010 E-M encourage the development of a diversified energy mix with emphasis on renewable sources and energy efficiency [7].

Therefore the focus of this project is directed to the use of bagasse sugarcane for clean energy without burning it so then can use it to distribute electricity to the population of Casa Grande using hydrogen fuel cells.

This project will serve as a great help because if there is a problem or outage unexpected electricity workplaces such as hospitals, banks, and even the same industrial Agro could exploit this resource to continue doing their work without any external interrupt and even when it used daily help to promote the use of clean energy since using fuel cells hydrogen releases only water therefore has an environmental impact of low intensity.

Finally, this report will describes how biomass (bagasse from sugar cane) going to obtain hydrogen and then how it will be supplied in a fuel cell and connected to a micro- grid which will give electricity to the hospital of Casa Grande.

2 SYSTEM DESIGN

For this project we decided to design this micro-grid with

A general overview of the system is showed in the following diagram.

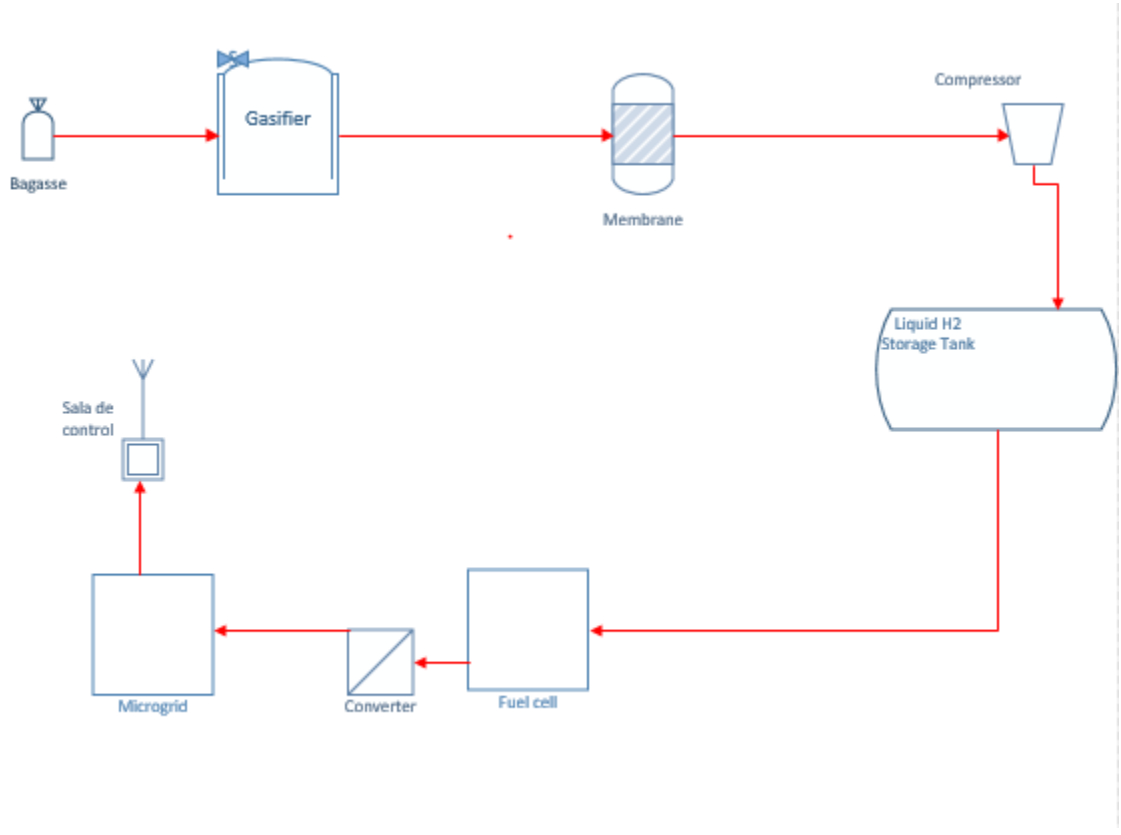

Figure 1. System diagram.

For the design of the system is necessary know the energy consumption, "HIDRANDINA S.A." is the company that conduct the public electricity service activities and sell electricity in the north of Peru, we obtained the energy consumption of the hospital of Chocope and also about the consume of families that live near to the hospital because the load should be bigger.

Energy demand for Chocope hospital

Table 1. Energy consumption of hospital Chocope.

Month	Energy (PH)	Energy (NPH)	Energy (PH)	Energy (NPH)
	KWh		KJ	
mar-15	67.0965	28652.85	241547.4	103150260
abr-15	7656.75	33948	27564300	122212800
may-15	6703.5	30362.55	24132600	109305180
jun-15	6586.65	303325.65	23711940	1091972340
jul-15	6365.25	28511.4	22914900	102641040
ago-15	5694.9	26734.05	20501640	96242580
sep-15	5879.4	26199	21165840	94316400
oct-15	6334.5	27213.75	22804200	97969500
nov-15	6426.75	27957.9	23136300	100648440
dic-15	6337.55	27533.55	22815180	99120780
ene-16	6838.8	30639.3	24619680	110301480
feb-16	7742.85	33954.15	27874260	12223940

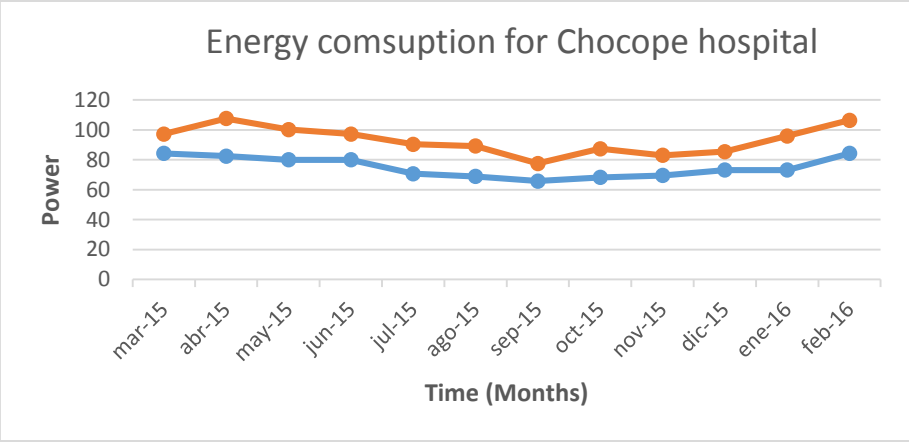

***Figure* 2.** Energy consumption for Chocope hospital.

Also the load for microgrid includes energy consume for 50 families in Chocope, each family has approximately four persons and in table **xx** shows the energy consumption.

Table 2. Energy consumption of families in Chocope.

Month	Energy per family	Energy - 50 families
	KWh	
mar-15	82	4100
abr-15	83	4150
may-15	85	4250
jun-15	58	2900
jul-15	75	3750
ago-15	77	3850
sep-15	76	3800
oct-15	84	4200
nov-15	73	3650
dic-15	73	3650
ene-16	74	3700
feb-16	76	3800

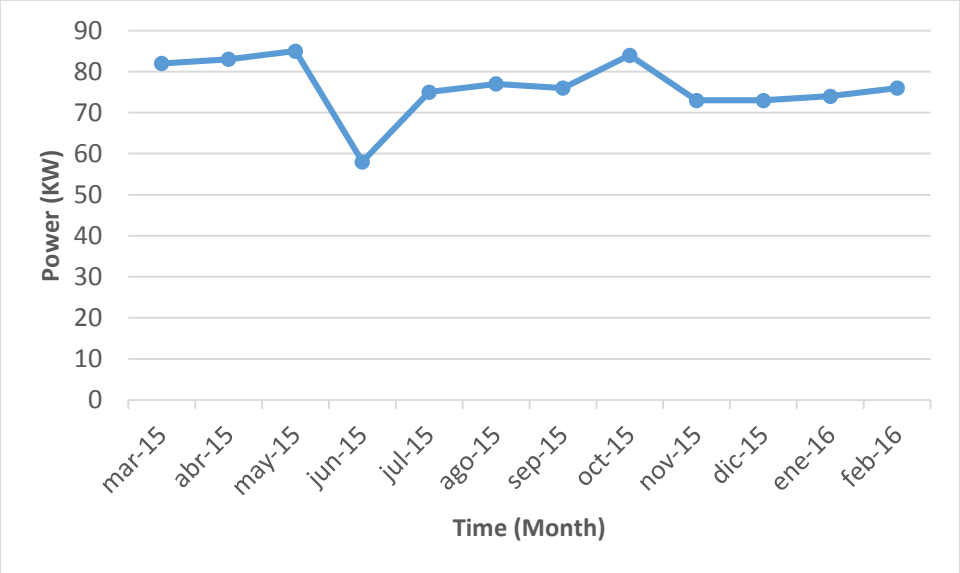

***Figure* 3:** Energy consumption for 50 families.

The energy consumption was registered 28 days per month and the total peak energy (hospital and 50 houses), the total energy demand is 40209 KWh, so for calculate the power of the fuel cell to use we developed an energy balance.

Table 3 .Energy balance.

Equipment	**Fuel cell**	**Out/In**	**Converter**	**Out/in**
Material		**Electricity**		**Electricity**
m3/h				
m3				
Eficiencia	60%		92%	
KW	108.70			
Energía(KWh/2days)	5217.391304	3130.434783	3130.434783	2880
KJ	18782608.7			

Table 4 .Weight bagasse calculation.

Pnormal(bar)	1	Tnormal(K)	273
Pstandard(bar)	1	Tstandard(K)	298

Vs	slpm	129.8974359
Volume for each fuel cell(10.5KW)	Slpm to sm3/hr	7.793846154
Volume for 12 fuel cell (12*10.5KW)	sm3/hr	93.52615385
Storage volume(48 hrs)	sm3	4489.255385
Diary storage(5 h/day; PH)	sm3	467.6307692
Hydrogen	kg	403.7100166

Analyzing energy balance we obtained the power for fuel cell, approximately 120 KW and then the amount of hydrogen for generate the power demand.

2.1 Bagasse Production

Bagasse is naturally obtained from sugar cane. It is a consequence of the fabrication of sugar and it's considered as a sub-product.

Casa Grande is city which is kwon for his high production sugar cane by the Agro industrial Casa Grande which is inside in the city. Casa Grande Agro industrial is one of the most sugar company in Peru, they produce around 173 metric tons per hectare.

From those production of sugar cane, the factory always obtain the 25 w/w % of bagasse which is the most important feedstock of our project. To obtain the bagasse from the sugar cane it pass for a grinding machine and it's usually burned to obtain energy but this project consist in collected in a warehouse and then use it as a resource to produce syngas by gasification process.

2.2 Synthesis gas production

Synthesis gas production consist in obtain the gas by a gasification process. We use this method because is a good way to obtain gasses like H_2, CH_4, CO and CO_2 with a determinate percent of composition.

The gasification process shall be used with a determinate equipment.

2.3 Hydrogen production

Hydrogen production will be obtain by a hydrogen membrane separation. This is the PRISM" Hydrogen membrane separation which will be able to obtain till 88 % of purity of hydrogen. That percent will make our full cell works with a high efficient because this is the range of the fuel cell

2.4 Fuel cell system

The fuel cell selected is a PEM, is a Ballard FCgen 1310 with a nominal power of 10.5 KW and for the power demand in the project are necessary 12 modules and with that also converters for obtain AC Power.

3 ECONOMIC ANALYSIS

Table 5. Electricity price depending of the region of Peru.

Feed-in-tariff		Ascope (Northern Peru)	Lima (Southern Peru)
Fixed monthly charge	USD /month	1,88	0,91
Active Energy charge peak	Cents USD / kWh	6,38	6,30
Active Energy charge off-peak	Cents USD / kWh	5,27	5,25

The prices for the equipment of the whole system are showed in *table 5*, where prices are assumed according to the market and passed reports.

Table 6. List of material prices.

Item	**Equipments**	**Manufacturer**	**Quantity**	**Unitary price($)**	**Total price($)**
1	Bagasse	CASA GRANDE	6.26(Ton)	18.47/Ton	115.62
2	Gasifier	GEK GASIFIER KIT	1	18500	18500
3	Membrane	PRISM MEMBRANE	1	7000	7000
5	Compressor	LX-SERIES HYDRO-PAC	1	25000	25000
6	Hydrogen tank	Bulk Storage Tanks(1000 m3)Chart	2	72000	144000
7	Fuel cell	Ballard FCGean 1310	12	2940	35280
8	Converter	Schaefer	4	15000	60000
9	Sensors in general	Omega			12000
11	Fire suppresion system	Fike	2	5000	10000
12	Pipes and valves	Elmac Technologies	8	200	1600
	TOTAL				313495.62

Capital cost calculate is used a relation that is:

$$\boldsymbol{Capital\ cost\ = fam * (1 + fic) * (plant\ cost) + Cop.annual}$$

fam: amortization factor

fic: indirect cost factor

Cop. Annual: Operation cost annual

$$\boldsymbol{fam = fCR + fO\&M}$$

fO&M=20 % annual

$$fRC = \frac{i * (1+i)^N}{(1+i)^N - 1}$$

N: Lifetime project=20 years

i=12%

fRC=0.134

fam=0.1667

CT *annual*=USD 46,625.38

The annual energy consumption when the plant operates 16 hours per day is calculated as:

E*annual*= (120KW)*(16hrs/day)*(365days)/1000=700.8 MWh

Energy cost=CT*annual*/E*annual*=66.53 USD/MWh

Comparing with the active energy peak cost in Ascope that is 63.8 USD/MWh is approximately the same, but peak hour in Ascope are 5 hours and we considered 16 hours for calculations.

4 SAFETY ANALYSIS

Safety in a hydrogen system is very important for keep save employers and equipment, we will develop an analysis over the main failures that would happen, as accidents, emergencies, natural phenomena and other causes. Also are include fire suppression system in the fuel cell area and Failure Modes and Effects Analysis (FMEA).

Also will be installed temperature and pressure sensor for have constant monitory of parameters that maintenance the correct work.

Codes and standards included in the project, there are many applicable regulation and are in the following table.

Table 7 .List of regulations for the plant.

Applications	**Codes**
Fuel cell power systems – system design/testing	ANSI/CSA AmericaFC1
Performance for fuel cell power system	ASME PTC 50
Fuel cell modules	IEC 62282-2 Ed. 2
Electrical interfaces	ANSI/NFPA 70
Hydrogen	CGA Publication G-5
Hydrogen safety	OSHA: 29 CFR 1910.103
Hydrogen fuel - Product specification. Part 3: PEM Fuel cell application for stationary	ISO 14687-3
Hydrogen generators	CSA International Requirement No. 5.99
Hydrogen storage, safe handling of cryogenic	CGA Publication P12
Tanks & storage, cryogenic hydrogen storage	CGA Publication H3
Piping and pipelines	ASME B31Series
Gas and vapor detectors and sensors	ANSI/UL 2075
Explosive atmospheres. Gas detectors – Performance requirements of detectors for flammable gases	ANSI/ISA- IEC 60079-29-1

The FMEA for the plant are considered for this project and allows identify many dangers.

Table 8 .FMEA for the plant.

Area	Potential Failure mode	Failure effects	Sev	Potential cause of failure	Oc	Detection of potential Failure Mode occurrence	DET	RPN
Hydrogen storage	Overpressure	Fire, leak, explosion	9	Obstruction of valves	1	Alerts, supervision	3	27
	High temperature	Explosion, fire	9	Failure of	1	Temperature sensor constant monitoring	2	18
Gasification	Obstruction of valves	Explosion, overwarm	7	No removing of trash on the gasifier	3	Clean up constantly the gasifier	1	21
Compression	Failure of equipment	Explosion, fire, doesn´t work	8	No maintenance	3	More maintenance and monitoring	1	24
Piping and valves	High flow	Rupture, fire	8	Overproduction, external causes	2	External protectors, installation of flow sensors	2	32
	Obstruction	Explosion, ruptures	7	Particles in the flow	2	Ensure quality of flow, sensor for particles in fluid	1	14
Fire suppression	Accidental activation	Waste of resource for future fires	8	Person, some animal into the area, electronic activation itself	1	Control maintenance, ensure area	2	16
Monitoring system	Computer and control failure	No monitoring of the entire system	6	Computer failure, no maintenance	2	Operator, constant review of computer	1	12

5 SITTING

The hydrogen production plant that generates electricity by fuel cells would be located in an area close to the company "Casagrande" and Hospital "Casagrande" area. This area was chosen because of the ease and transportation time bagasse. Both centers as the company and the hospital are part Casagrande district, Ascope province in the city of Trujillo that are located north of Lima. One level of production would be sufficient because our goal is to provide hydrogen to Hospital Casagrande at times you cannot count on the electric fluid .The specific location of the plant is approximately 650 meters from the center of production of bagasse. The land area chosen for production is approximately 500 mm^2. To get a better idea of the location of that place the following image shown below.

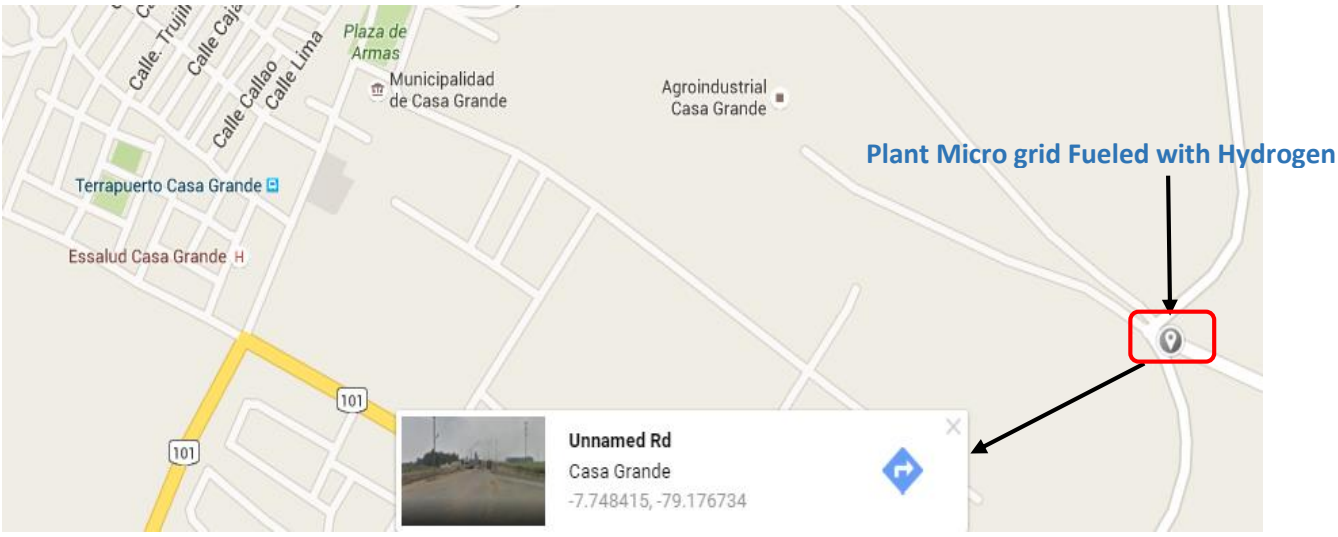

Figure 4: Point of the plant.

The terms of safety with respect to the location of the plant does not vary in this district since the policies imposed by the Peruvian state govern the entire national territory. Which allows us to more easily develop bagasse transportation and storage thereof. The time required for this process is approximately 4 minutes, having a short transport time helps us to minimize costs. To prune any idea of the route to be followed is presented below the following image:

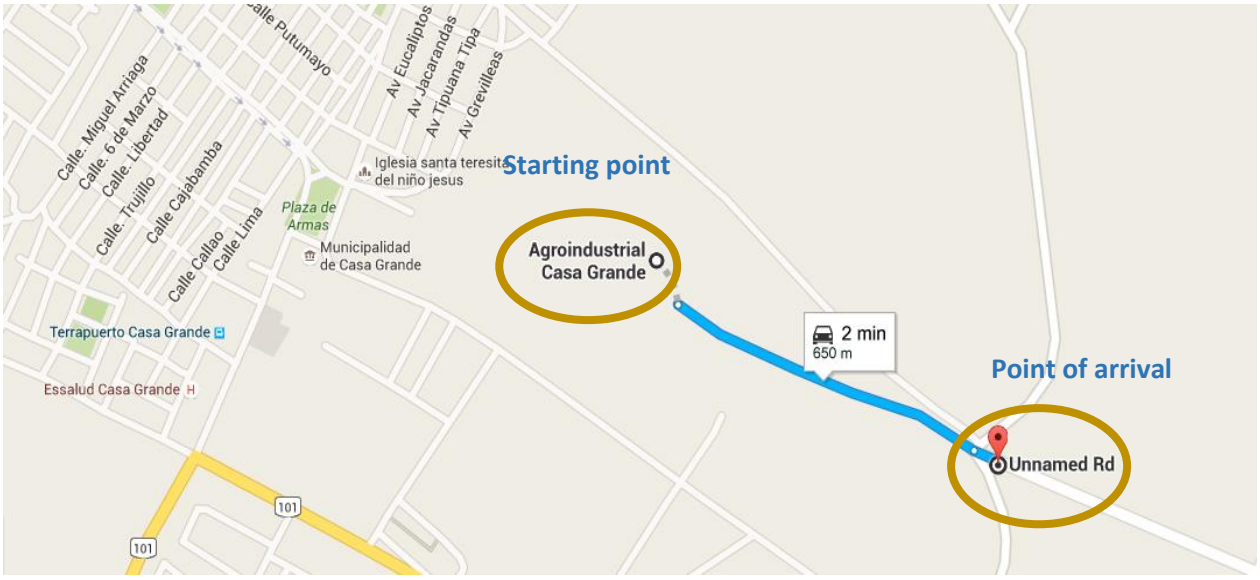

***Figure 5*:** Distance between Agroindustry Casa Grande and Point of the plant.

It also takes into account the distance between the hospital "Casagrande" and the area where the plant was located. In this case the distance between the two places is about 2.4 km, in a time of 6 minutes. These data are vital for the development of the connection with which it would provide electricity to the hospital Casagrande "Casagrande" .The following figure shows the stated above:

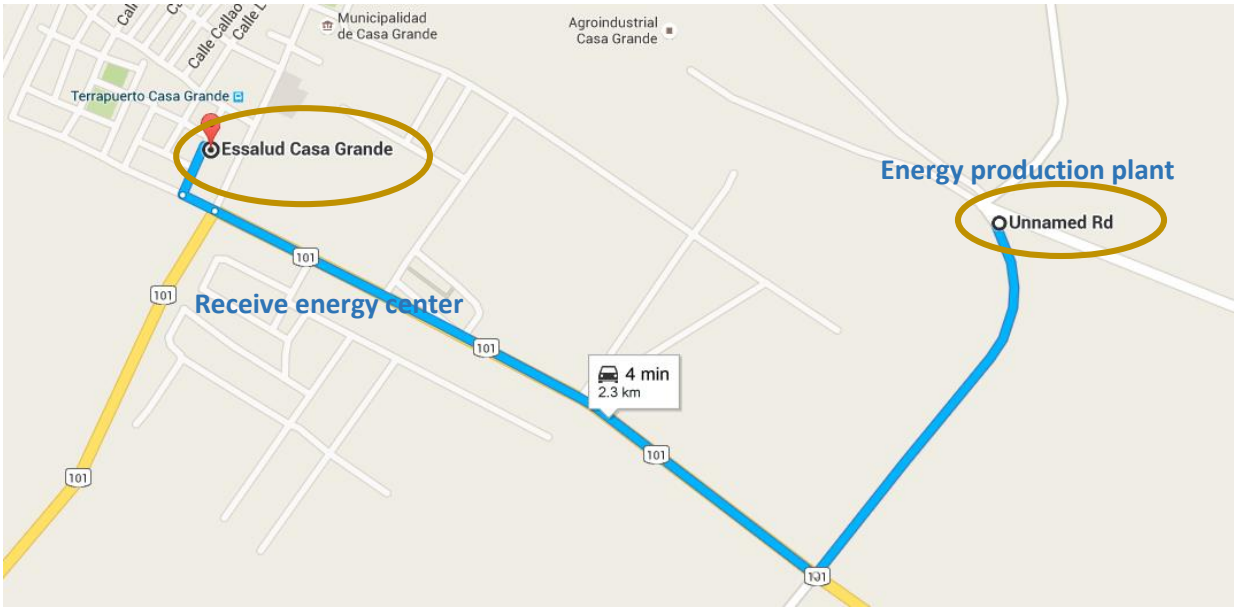

***Figure 6*:** Distance between energy production and the hospital Casa Grande.

Agree to the above data and analyzed it is proposed that the area described whatever with the best features to be fixed as the center of energy production starting from bagasse.

6 OPERATION AND MAINTENANCE:

Plant energy production from bagasse consists of various machinery and equipment, with this set of tools for obtaining the operation bagasse developed. The operation is based on the following points:

- Transport bagasse of the company "Casagrande" to the production plant.
- Storage of raw materials.
- Placement of bagasse in the gasifier, in which burning bagasse was done and synthesis gas will be obtained.
- This gas then passed to the membrane separation of the syngas where hydrogen gas get.
- Then it proceeds to store the hydrogen, in which I will be controlled through sensors, which allow us to take into account the conditions of the gas.
- With the connection between the tank and the fuel cell, it is possible to store hydrogen and that when electrical energy is needed to start providing hydrogen to the fuel cell.
- Finally the obtained electrical energy pass through the convertor which will give us the necessary power to provide it to the hospital Casagrande.

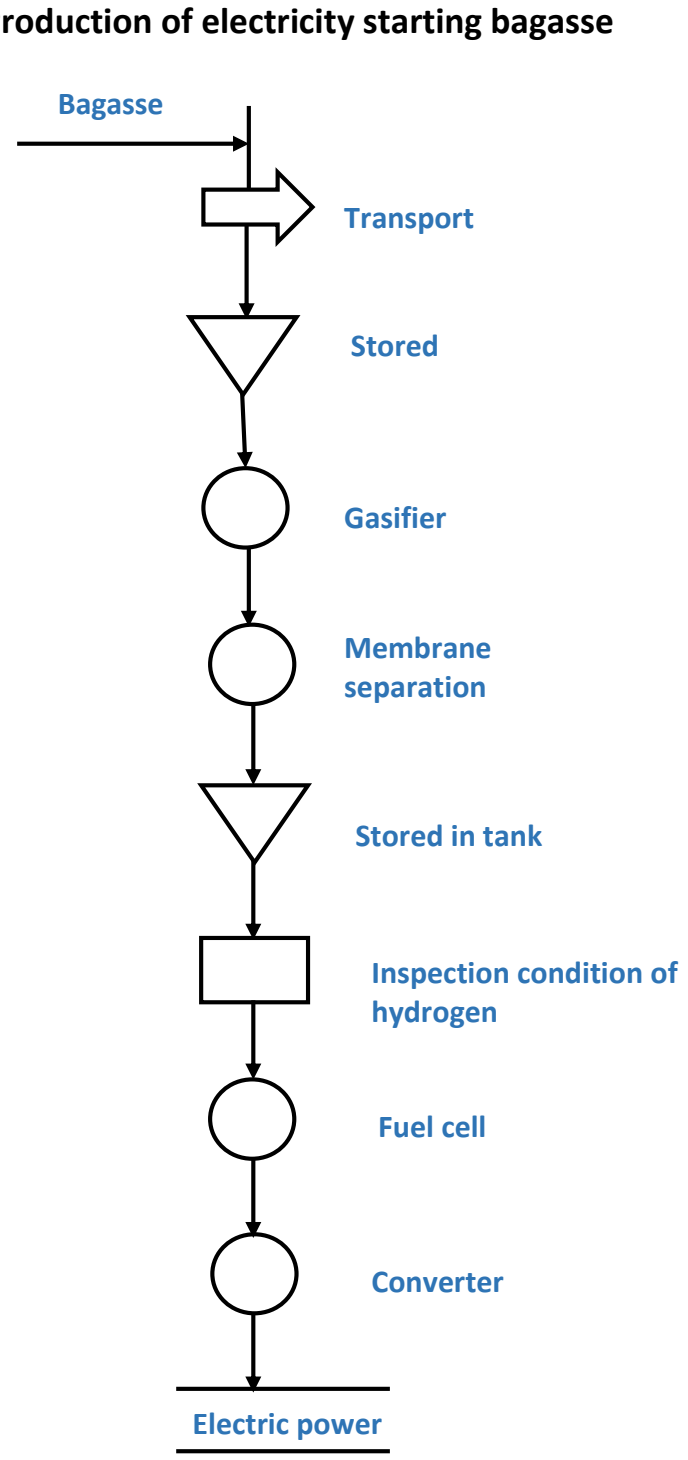

Figure 7: Process diagram operations.

The maintenance of the plant will be held annually, where the gasifier and debris that can see I left inside the equipment is inspected. An exhaustive inspection and maintenance of deep membrane will be held primarily as that provides hydrogen to the fuel cell.

A monthly maintenance of the sensors will be made as these are vital to the security of connections of the plant, also an exhaustive inspection of the tanks will be included to prevent leakage of hydrogen through very small holes. The measures for maintaining fuel cells will be very extreme because if a problem occurs in the production of energy could be the possibility of failure in the dispensation of hydrogen or internally present a fault and gas to accumulate and can cause serious damage. In the convertor is inspected every 6 months if the power it provides is correct and if there proper energy flow.

7 ENVIRONMENTAL ANALYSIS

This project help to improve the clear energy in Peru. It will help us to reduce CO2 emissions. When we built this micro grid using hydrogen fuel cells we stopped the consumption of oil or other carbon's derivation, and as we know when we use it, we generate an environmental impact. Also Peru is a country where biomass is abundant and that's why there are many agricultural waste, forest residues, urban waste, etc. So, this is very important because we can approach this to bring clean electricity energy to different parts of Peru.

Casa Grande is a city located in La Libertad, and that city is a very important place for the abundant sugar cane bagasse available. This bagasse is used to be burned and this increase the percentage of CO2 emissions.

In other hand we can stand up the price of bagasse because it seems cheaper than other feedstock in Peru.

7.1 Removable energy resource

Renewable energy resource will be the sugar cane bagasse because it's a feedstock with a high quantity available in La Libertad. In other hand, we can stand out the low price of that feedstock, this is for each 1TM it cost

Table 9. Bagasse sugar cane price.

Sugar cane Bagasse Price	Nuevo Soles	USD$
1 Ton	S/. 67.8	$ 18.47
6 Ton	-	$115.62

7.2 CO_2 emissions by oil and hydrogen

Table 11. Comparative chart between GHG emissions by Oil and Hydrogen as a fuel

GHG emissions	Oil	Hydrogen
CO_2	32.40 gallon	31.22 gallon
N_2O	0.60 g per mmBtu	0.063 g per mmBTtu

7.3 CO_2 emissions of equipment

Table 12. GHG emissions from micro-grid design equipment

Equipment	CO_2	N_2O	CH_4
Gasifier	22%W	-	3%w
PRISM" Membrane	-	-	39%w
Fuel cell	-	-	-

8 REFUELING

In Peru there is not a hydrogen station for the moment because there isn't the sufficient technology and also we don't have a hydrogen production plant yet. So as it is not available for the moment we hope to have a hydrogen plant in the coming years to start to use this technology in our country.

Due to the lacking technology of hydrogen transportation, Hydrogen fueling stations are still ideas waiting to be available, which need to be developed for future projects

to progress. We hope to expect possible hydrogen fueling stations in years to come after developing a production facility in Peru.

9 CONCLUSIONS & RECOMMENDATIONS

The energy cost was a suggest because was considered the energy production in 16 hours per day, and the original calculation in peak hours is 5 hours per day, also the materials are selected in general with prices according to the market and are variable.

10 MARKETING & EDUCATION PLAN

Marketing and education programs are essential because both help us that more people are interested in the development of green projects. In Peru there are very few such projects, so the diffusion is important. Having a great marketing program will provide us with access facilities business sectors that have the need to implement new projects that are sustainable. Besides the implementation of education it is vital for society to become familiar with the development of sustainable projects that do not affect greatly the ecology.

10.1 Marketing strategy:

The strategy will exist various stages, the first stage is implementation name with which the project was marketed, second set the mark of the project. They have followed an advertising campaign where different videos is performed with respect to the project and the benefits it provides communities living with hydrogen-based energy. Another way to reach more people businesses is also spread across billboards that are placed in high traffic sites and have a high degree of visibility. A third step is to provide informative talks about the project where benefits and planning that will continue to have a plant grid Micro Hydrogen Fueled with Sugar-cane bagasse from explaining.

Our main goal is to provide energy to the Hospital of Casa Grande, so another campaign where more hospitals that are near the area of production of bagasse of the great benefits of this new Method of generating energy is informed and how it should be implemented would be launched this plant.

On the other hand it would work at the level of social networking counting well with web pages where information is displayed about as the operation of the plant, high-level professionals working in its implementation followed by the care that dene have to the satisfactory operation of the project among others. While various aspects also have to show cause sensation so that advertising campaigns whose main objective is to show how to live with clean energy and the large scope of this lifestyle.

The marketing strategy will be guided to encourage to have a community or family that have clean energy without causing damage to the ecology.

10.2 Education strategy:

The serious educational strategy focused on various aspects such as the environment, economic, security and others. It would provide information about benefits or disadvantages that contracts the project at the environmental level, they would be published in brochures statistics on CO2 emissions and the damage they cause not only the environment but also the population. It would have available all sorts of information about the hydrogen that is produced, and this is her summary of acceptance to a serious discussion days of economic, environmental or security issues. These sessions would be beneficial to keep

improving in the development of new plants with more features and high production level performance and safety.

Also a development plan of the communities that are surrounded by these plants as incentivizing energy centers where you have obtained technology to help them develop and be more connected to the world would be implemented. This refers to that can be given new opportunities to level of investment in remote communities which opening them to progress to economic and technological level.

This would count energy plan based on the project that is developing and so we can visualize the interaction of communities or populations with clean energy and energy system more efficiently.

The development of education strategy should be based on sincerity with which statistical data on hydrogen, and the advantages and disadvantages that this project has shown.

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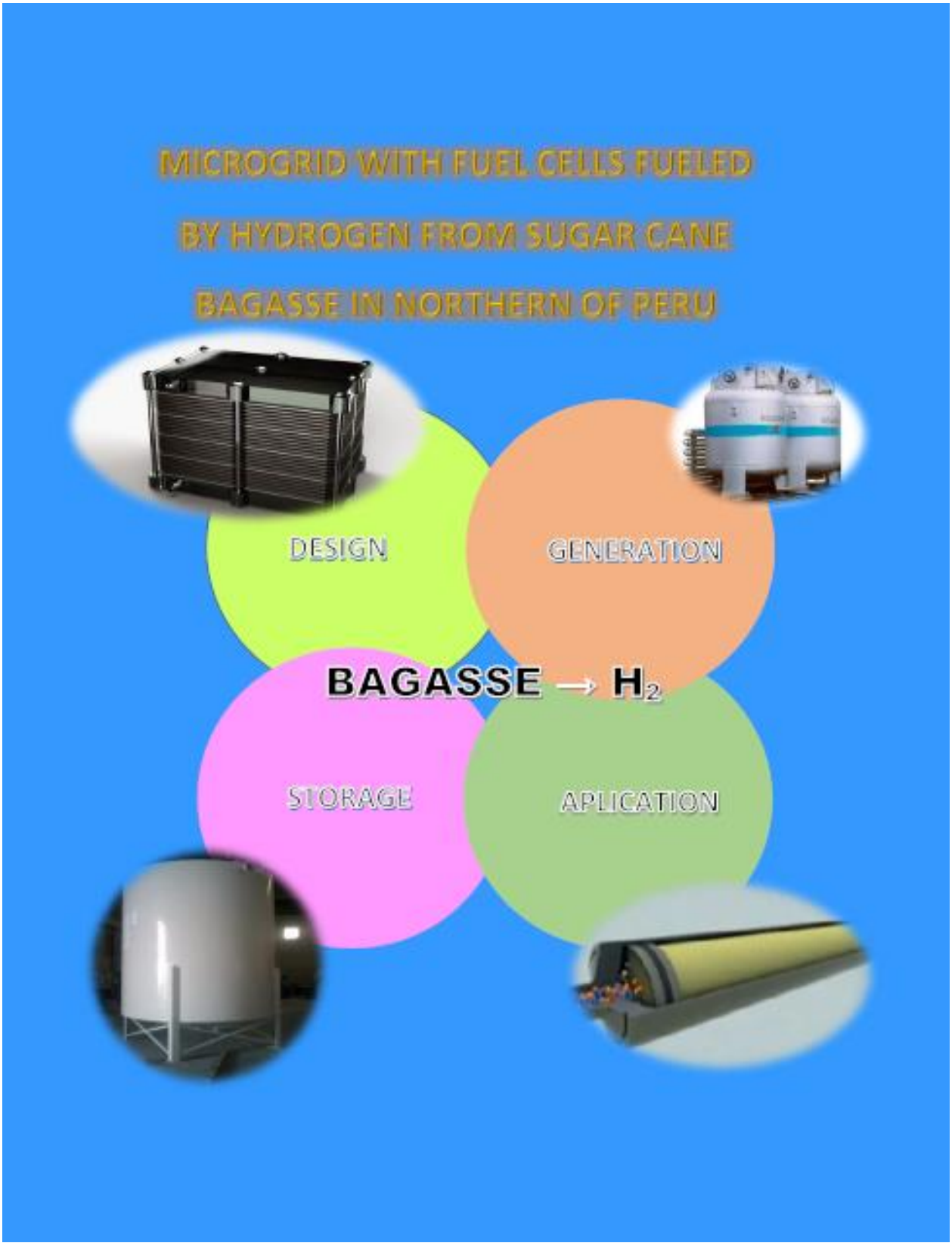
12 APPENDIX A

ADVERTISEMENT


MICROGRID WITH FUEL CELLS FUELED
BY HYDROGEN FROM SUGAR CANE
BAGASSE IN NORTHERN OF PERU
DESIGN
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BAGASSE → H_2
STORAGE
APLICATION