THE PRODUCTION PROSPECTS OF HYDROGEN FROM THE BIOGAS IN BRASILIA

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ABSTRACT

The research and use of hydrogen in the world is growing up, with many ways to produce and to utilize the gas hydrogen, besides the ecological advantage, this fuel will become necessary soon. In this scenario, there are the hydrogen by the sewage sludge, where the hydrogen coming from the biogas by the decomposition of this sludge. In Federal District, most electric energy uses are imported and purchased by hydroelectric. In Brasilia, there are CAESB, the company responsible for the water treatments. The stations receive sewage every day, and by law, it is an obligation to produce biogas. In this work, was elaborated a viability to produce hydrogen by the reformer of the biogas and using in small and adapted thermoelectric. In a simulation, a unique station, taking studies as reference, receiving 50,000 m^3/day, it is possible to power up 525 houses in the near regions.

Keywords: Sewage sludge, Hydrogen fuel, Brasília, CAESB, Thermoelectric.

Introduction

The decarbonization of the planet is one of the goals until 2050, with the objective of decrease exponentially the emissions of carbon dioxide (CO2) in the atmosphere and predict an increase in the use and production of clean and sustainable energy. Many countries are participating, including Brazil.[1]

As the Brazil Society Grow up, the energy demand becomes each time larger. And taking as base the current Technologies of energy production, based mostly on coal and oil, that would imply in a bigger carbon emission. Apart from that, a big part of electric energy in the country is coming from hydroelectric, and that energy is purchased, costing high values. Thinking about supplying this future demand to follow the decarbonization program and relieve the costs with the purchase of hydroelectric energy, the ways to produce clean energy must begin to be improved and put in practice. In this area, a great fuel capable of supplying these demands is hydrogen.

The national program of hydrogen, created by the Energy and Mines Ministry, has the objective of developing the hydrogen economy to this fuel become a part of the energy matrix [17], knowing and pointing the real versatility of hydrogen to produce energy in big industries or in common cars.

The hydrogen produce is extremely versatile, since the obtaining of this fuel is done in many ways, either by water electrolysis, by a solar or wind systems as source, by the biofuel reform etc. As it can be produced in many ways, the country that decides to add a production system will have many options to choose, so that it fits better the need, methods, and technologies of the country.

Specifying this scenario for Brasilia, there is a big electric energy demand, for being a relatively populous country, and mostly urban. And in this region, there is a large production of biogas by the basic sanitation system made by CAESB. The unities of these state-owned companies have systems to collect the sludge and produce biogas by this sludge. Although, all the produced biogas is discarded, since there isn´t a final use of this gas. However, this biogas is an ideal reagent for hydrogen production by the reform of this reagent.

Considering this scenario of medium to long term, this paper will discuss the viability of production of the moss hydrogen in the capital of Brazil, Brasilia.

Theorical reference

Hydrogen, how said before, can be produced by many ways and different technologies, that make a versatile product of the fuel. Not only do the technologies need to be planned, but your use as well. And their use is so big, because hydrogen can be used as a common fuel, or an auxiliary gas to generate electricity.

DOI: 10.55592/ISE.2023.1114815

A. Hydrogen and your applications

How said, hydrogen can be used in many ways. One of the principles is to produce ammonia, and another chemical product, hydrogenation of fats and oils, and in the welding. But another use is production of energy in fuel cells and in thermoelectric. [16]

Another use to generate energy is in thermoelectric, that has the same technology of a thermoelectric gas natural based. The combustion chamber is the same, where, with air, will occurs the combustion with the hydrogen gas. The combustion will generate heat, and gases with high temperature and pressure. These gases will move turbines, and these turbines will activate the generators to convert mechanical energy into electric.

B. Moss hydrogen

There are many types of hydrogen, and these types are defined by the production way and reagents used to obtain the fuel. Green hydrogen is obtained by the electrolysis of water by means of solar or wind energy. The gray hydrogen is obtained by the burn of fossil fuels, mainly natural gas, being a pollutant way to produce him. Another way to produce hydrogen gas is by the biomass of the sewage. This hydrogen produced by urban effluents is called moss hydrogen.

The moss hydrogen is a product of the reform of the biogas produced by the biomass contains in the sewage. Generally, this production is made in water treatment stations, where all the stages of sewage treatment, there is biomass collected, mainly in decanters. After the collecting of the biomass/moss, they are taken to a biodigester, that will process the organic product. Inside the biodigester, there is a dark place, with an intermediate temperature and lack of oxygen, a propense local to anaerobic bacteria, which will degrade the biomass, turning this into three phases: a liquid; a solid; and a gaseous one. The liquid phase is leachate, a liquid there is very rich in minerals and can be used as fertilizer or can be treated for later uses. The solid one is a residual organic matter and can be used as fertilizer too. And the last phase produced is the gaseous one, biogas, a gas with a lot of methane. This biogas is directed to filters to increase the concentration of methane, removing: H_2S (hydrogen sulfide); CO_2 (carbon dioxide); steam; and another component. After these processes, the biogas becomes biomethane, because of their high concentration of methane. This gas is directed to a reformer, that will break the molecule of methane, producing mainly hydrogen fuel, and other compounds in smaller quantity. After this, the hydrogen can be used directly in a process (like in fuel cells and thermoelectric, as explained before), or stored in a specific cylinder.

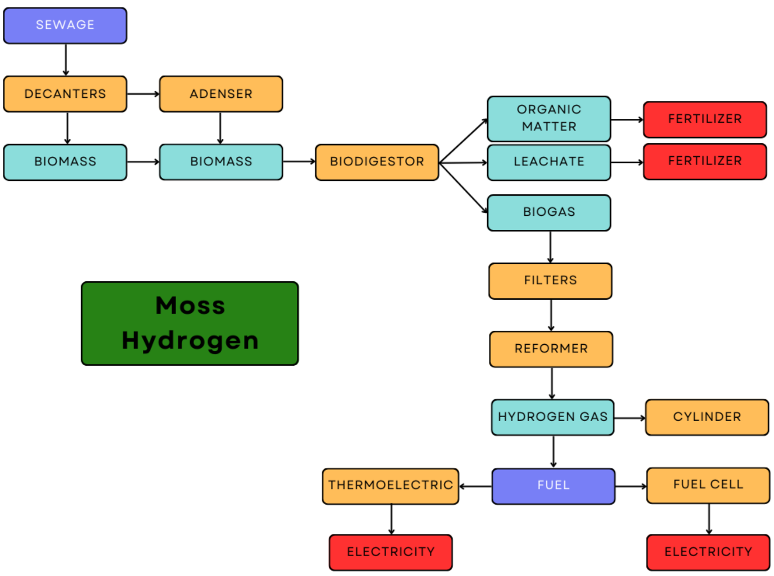

Figure 1 – Production chain of moss hydrogen

Source: Elaborated by the author.

Subtitles: Squares in purple are inputs of the technologies; Squares in orange are the technologies; Squares in blue is the outputs of the technologies; and the red squares indicates what was generated by the technology or some product.

The production chain of the hydrogen moss can be seen in the above picture, either the machines and technologies used and the inputs and outputs of the production (Fig. 1).

C. The use of hydrogen in the city of Brasília

According to IBGE (Geography and statistic Brazilian institute), Brasília is the third biggest city in Brazil. The data indicates that 3,904,325 people measured in 2021, and in 2010 it was measured that are 774,037 domiciles, so obviously the number of domiciles grew up during 2010 and 2023 [9].

The consumption of electricity is about 13,707 GWh, and a per capita annual consumption of 816 kWh/inhabitant [8]. A huge consumption compared to another regions, and how the Federal District is the one of the most populous in Midwest, a big part of this consumption is in Brasília.

According to EPE, there is an expectation of the energy production, and voltage directed to the states of the Midwest [10]. Most of the energy in Brazil comes from the hydropower plants when the flags, indicated by ANEEL. [10]

In spite of a sustainable energy matrix, in the long term the tendency is to decrease of the energy generated by hydroelectric and an increase of the level of the tariffs because they need to burn fossil fuels in the thermoelectric, making the bills more expensive. Thinking about the technologies presented previously, it can be possible to change the input of the thermoelectric of fossil fuels to hydrogen gas. With the generation explained before, it´s easy to produce high quantities of electric energy directing the moss hydrogen produced to adapted thermoelectric ready to receive this fuel.

To adapt the system, if it is moved by solid or liquid fossil fuels, is just change the way to conduce energy to the turbines (because in this system, the heat generated by the combustion warm water, turning into steam, in this steam will move the turbines), directing the gases after the combustion to the turbine, turning off the water system. And it is necessary to calculate the maximum temperature of the combustion to check if the material of the chamber will resist the combustion of hydrogen. But, if the thermoelectric system works with natural gas, the unique check is necessary is the resist of the chamber material.

With this adaptation of the thermoelectric, they can produce energy when it’s necessary (red flags), or when it’s not (green) flags, since the reception of sewage and production of moss hydrogen will not stop, decrease the necessity to buy too much energy of the hydroelectric.

D. Production of hydrogen by the biogas produced in Brasília

How was said before, because of the biogas of the CAESB, the potential of production of moss hydrogen is high.

The CAESB is a company founded in 1969, being a mixed economy society company, that works in the Federal District and some nearby counties. This company is responsible for basic sanitation of these regions described, receiving sewage, and treating him to direct the clean water to the houses and trades.

The station of CAESB in Asa Sul, Brasília, has a treatment based in three parts. In the first part, it is called the pretreatment, the station receives the sewage and passes to high density filters, to remove the big stuffs like plastics and other residues.After this, comes the primary level treatment, the water in continuous flow go to decanters (Fig. 2) to sediment high density and medium size particles, that will go to the bottom of the decanter with the help of rotating blades to accelerate the process. As the water has a constant flow, we go to the second stage, and in the bottom has the collected of first sludge. In the secondary level treatment, the water goes to adenser, where it will create water bubbles, growing the density of the sludge. After the second treated water goes to the last stage, where they put some additives in the water to remove phosphor and nitrogen [6]. And are collect of third sludge in this stage too.

Figure 2 – Decanters in the Asa Sul CAESB station
Source: Photo taken by the author (2023).

In all the stages of water treatment are collected of sludge, and this one is directed with the help of hydraulic bombs, to conduce the organic material to the biodigesters (Fig. 3). After been taken to the biodigesters, the sludge will be processed by anaerobic microorganisms, that will produce gaseous, liquid, and solid phases after the process, as explained before (*B. Moss Hydrogen*). And, after the production of biogas (the gas phase), the gas will be directed to an equipment with hot oil in the external part, that will warm up the gas to the dew phase of water, transforming all the water to the gas phase. And after this, all the biogas produced is burned and thrown away.

Figure 3 – Biodigesters in the Asa Sul CAESB station
Source: Photo taken by the author (2023).

Taking a study made by Patrícia Bilotta and Bárbara Z. L. Ross [3], that calculate the biogas generated by the treatment station of water of Santa Quitéria (Ceará), showing with calculations of the quantity of biogas can be produced and the quantity of electric energy can be produced by the sewage. In this case, was discovered that the treatment station whose flow rate is 33,220.8 m^3/day (on average), serving 190,000 people can generate 1427.2 m^3/day of biomethane, considering an efficiency of 65% of the biogas, in other words, 65% do biogas produced has methane [3].

Using the same proportion of the study above, we can estimate (with the same efficiency of 65% of the biogas) that a flow rate of 50,000 m^3/day received in CAESB, there will be produced 2,148 m^3/day of biomethane. The method used to reform the biomethane uses only catalyst. The gas enters the chamber and is warmed up to high temperatures, after this, because the specific catalyst used, majority of the carbon will be absorbed in the catalyst breaking the methane molecules and producing gas hydrogen. The chemical reaction down describes the reaction in the reformer:

$$CH_{4\,(g)}\ catalyst\rightarrow\ C_{(s)} + 2H_2$$

So, with we follow the stoichiometry of the reaction, with a reformer efficiency of 60%, we will produce a quantity of 2,577.6 m^3/day of hydrogen. That shows, by the simulation and another studies, a huge quantity of hydrogen gas being produced. In standard conditions of temperature and pressure (101.325 kPa and 25°C), the density of hydrogen is 0,08235 Kg/m^3 [12], has been produced 212.2 Kg/day of hydrogen produced.

With a system of direction of the produced hydrogen to a thermoelectric, counting that 212.2 Kg/day will be enter the system, considering that the hydrogen gas has an inferior caloric power of 33 kWh/Kg of fuel [15], we will generate 2,660.9 kWh/day of electricity, considering that the thermoelectric has 38% efficiency. And, with data of labEEE (laboratory of energetic efficiency in buildings), was indicates that the medium consume of electric energy in Brazil was 152.2 kWh/month [11], so this thermoelectric system simulated, that uses hydrogen gas as fuel, it is possible to supply 525 houses near the station.

Table 1 - Energy productions capacity of moss hydrogen by CAESB

Variable of interest	***Quantity***
Hydrogen produced/day	*212.2 Kilograms (Kg)*
*Produced electrical energy/month**	*79,827 Kilowatt hour (kWh)*
Supplied houses	*525 houses*

Source: Elaborated by the author.
*Considering the electricity produced by a thermoelectric with a 38% efficiency.

E. Experiments

The system described above is being tested in laboratory, where is collected biogas produced by CAESB is the local, tested in the local with a kit to determinate the composition of the gas, and taken to the laboratory. In laboratory, the gas will be directed to the reformer where it will be produced the hydrogen.

To collect the biogas in the CAESB station, it is necessary to take a vacuum pump to drain out all the residual gases inside the cylinder used, in addition to create a negative pressure inside the cylinder to force the biogas (at 14 psi) to fill all the recipient.

In the experimental site, the cylinder is closed, connected to a compressor to elevate the pressure inside the cylinder, to guarantee the biogas will go to the reformer and after connected to another hose, that goes to the reformer.

After the reformer, will be collected the product, that has a consideration quantity of gas hydrogen. To test if hydrogen is being produced, was developed an equipment to determinate the caloric value of the gas, and it is called calorimeter. The calorimeter consists of a recipient of cast iron, with entrances to oxygen gas and another to the produced gas by the process, and two electrodes.

Conclusion

The information shown in this work makes evident the viability to produce hydrogen by the biogas generated in the water treatment stations in Brasília, since the biogas is already produced. Using the studies of Patrícia Bilotta and Bárbara Z. L. Ross [3], it was possible to simulate the quantity of hydrogen produced by a determined quantity of sewage treated by the station. The quantity of hydrogen produced was 212.2 Kg/day, and if will be used a thermoelectric system showed above (Table 1), to produce a quantity of 79,827 kWh/month, capable to supply almost 525 houses near the treatment station. With this numbers, we can conclude that a unique water treatment station can energize 525 domiciles, so, how in Federal District exist 15 sewages collect and treatment stations, the number of domiciles supplied by this system is enough to replace the fossil fuels thermoelectric to hydrogen fuel thermoelectric, decreasing the emission of the greenhouse gases. And, with the implementation of this system, that produce of hydrogen fuel by constant biogas produced, can be used to generate constant energy to help to relieve the expenses with energy importation.

DOI: 10.55592/ISE.2023.1114815

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