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Green Hydrogen as Energy Alternative to Reduce Carbon Emissions in Transport Urban of the City of Lima

Luis Zambrano and Adriana Ruiz
Industrial Engineering School
Ricardo Palma University
Santiago de Surco, Lima, Perú
luis.zambrano@urp.edu.pe, 201821079@urp.edu.pe

Susana Davila and Cecilia Tello
A professor of Civil Engineering School, A director of institute Confucio
Ricardo Palma University
Santiago de Surco, Lima, Perú
susana.davila@urp.edu.pe, cecilia.tello@urp.edu.pe

Mario Chauca
A Doctorate in Education
Ricardo Palma University
Santiago de Surco, Lima, Perú
mario.chauca@urp.edu.pe

Abstract

Global warming has been altering climate change in the world. This research promotes environmental sustainability was fundamentally based on finding green combustion alternatives that help reduce the impact generated by the use of fossil fuels in the various sectors of the city of Lima, specifically in the engines of the automotive fleet.The experimental methodology that we applied in our research allowed us to reach results that show that it is possible to use other energy sources such as green hydrogen for the combustion of the automotive fleet of the future and reduce carbon dioxide emissions in the capital city of Peru. That is, through the present study and the referential investigations for the investigation, it is concluded that green hydrogen has great energy potential to improve the quality of life and the environment.

Keywords

Green hydrogen, Global Warming, Sustainability, Renewable energy, GHG

1. Introduction

Since the end of the 19th century, the emerging energy source of hydrocarbons has had an important space, being applied in industries since the Second Industrial Revolution, specifically in the automotive industry, which led to its massive consumption in the application of the combustion engine of different vehicles, improving the quality of people's mobilization. The fundamental component for its operation was adapted to the consumption of fossil fuel, gasoline. As it became established, the automotive market evolved, achieving positive results in mass transportation.
In 1971, the world began to show that the consumption of global energy fuels had a great impact on the use of hydrocarbons in many industries. The world showed significant dependence on the consumption of the main sources such as oil, natural gas, and coal. However, the overexploitation of fossil fuels has generated a lot of uncertainty over the years since the gas emissions that these fuels produce present gaps in the change of environmental temperatures in the various countries of the world. According to Pancorbo (2013), it is very probable that the earth's temperature will increase between 1.5 and 2°C by the year 2050. Many scientists and journalists have been taking the initiative to focus research on the reduction of gas emissions that generate climate change on the planet, which through the dissemination of knowledge manages to inform, raise awareness, and sensitize. In 2015, despite the constant concern

about the environment in the world, strategic guidelines were generated to maintain environmental sustainability in economic development. The member states of the United Nations proposed to base ourselves on 17 objectives that improve the sustainable development of the world through conservation and improvement of the environment. These aim to eradicate poverty, safeguard the planet, and promote prosperity. In addition, various plans were raised to establish a standard in search of reducing carbon emissions. The Paris agreement aims to maintain a temperature below two degrees Celsius.

Despite what has been established in coordination with the vast majority of countries in the world, Nowadays, many companies dedicated to the production sector of energy sources have been strategically competing to achieve environmental sustainability through the generation of eco-friendly energy, as well as in search of new business models that allow the integration of renewable energies and clean processes to the production of a new energy era in industry 4.0 in coordination of the social, governmental, and environmental environments. Europe will combat global warming with the help of a strategic plan for sectoral decarbonization, where the fronts that have the greatest impact are transportation, industry, infrastructure, and agriculture, among others. It is projected that by 2050, the European Union will improve energy efficiency, renewable energy, and energy dependence. The use of new technologies within the energy transformation processes will be a fundamental pillar to meet the projections that have been established, aiming to become the nation with the best management of its energy resources in the world.

On the other hand, Latin America, like other continents, has been proposing strategies to combat the over-emission of greenhouse gases (GHG). The clean energy found around many ecological floors in Latin American countries can be driven by innovation, technology, and methodologies. However, the technological recession that many Latin countries are experiencing has an impact on improving environmental quality. Global warming has been hit by the excess consumption of energy in hydrocarbons, especially in means of transport like buses, cars, airplanes, ships, and spacecraft, among others, causing unfavorable results for the environment and affecting the carbon footprint.

In Peru, it specifically counts on contributing moderately clean energy to its population with the overexploitation of natural gas (GNV). It is estimated that by 2025, the consumption of energy for consumption will continue to grow in parallel with the internal economy in sectors such as mass transportation, services, and industries. On the other hand, the opportunity to promote the consumption of energy potential within urban transport in the city of Lima as a strategic alternative will be analyzed. Many countries have been taking actions to reduce the consumption of fossil fuels. A clear example is that in Europe, starting in 2030, they will not allow the sale of combustion cars.

However, there is a legal regulation that declares the import of vehicles that have the transformation of green hydrogen as the main energy source, so the market opportunity for the production of green hydrogen has a positive vision. This will make it possible to contribute to the reduction of carbon emissions into the environment. The motivation to direct research to a local environment arises as elite countries have pushed modern technology to reduce indicators of global warming.

1.1 Objective

Propose a new source of alternative energy with the application of technology for urban transport in the city of Lima that allows improving performance towards quality of life with modern technology.

2. Literature Review

Global warming effects

Climate change has not only generated changes in weather patterns, increasing temperatures on a global scale, but the impact has been taking on an increasingly significant form due to the large number of chemical emissions generated into the environment. Therefore, global warming includes all the components of the present ecosystems, changing the balance of nature and the ecosystems of the animals that inhabit the planet Earth. One way to measure impacts is through climate indicators. According to the World Meteorological Organization (WMO), among the main climate indicators on a global scale are "the average global surface temperature, atmospheric concentrations of greenhouse gases, the calorific content of the oceans, the global sea level, ocean acidification, sea ice extent, and the mass balance of glaciers and ice sheets".

The most recent study of the World Meteorological Organization (WMO) demonstrates the deployment of the results of five studies on global surface temperature anomalies, as shown in Figure 01, which integrated the information obtained from the aforementioned climate indicators. previously with the purpose of presenting a general result covering the period 1850–2025 and making a projection on the possible results, taking as a sample the change in previous years. The development of the variation of the climatic indicators in temperature worldwide is gradually significant due to the small increase with a maximum peak of an average of 1.2 °C. In the last 10 years, from 2012 to

2022, we observed that the projections had a great jump in the variation, going from 0.7 °C to 1.1 °C worldwide. These results definitely raise concerns about the fact that temperature change affects society.

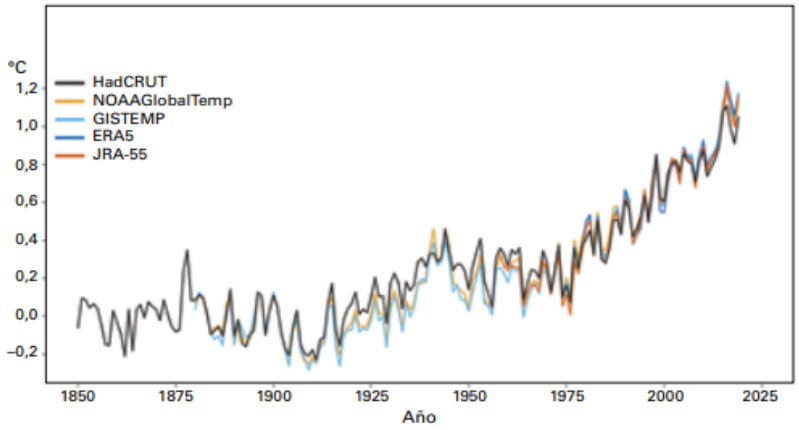

Figure 1. Difference in global average temperature in pre-industrial conditions (1850-2025). Adapted from the World Meteorological Organization (2019)

As can be seen, the graph presents an upward trend and does not show much variation with respect to the other studies. These investigations were carried out by various meteorological organizations such as ECMWF, JMA, and ECMWF's (2020) WMO Statement on the State of the Global Climate in 2019.

Carbon dioxide as the main source of pollution

In the world, it is evidenced that the activities that most conserve carbon emissions come from the energy sector, where more than 10,000 megatons of fossil fuel combustion is used as an energy source. It is clear that the importance of the source of fossil fuels has had a superlative impact and that the industries are adapted to the system of this energy for reasons that present greater energy potential up to now, and the commercialization is globalized since many countries have industrial plants that produce energy for fossil combustion. According to B. Ogunlade and H. Manuela (2005), fossil fuels could depend much less intensively on carbon, nuclear energy, renewable sources, and the reduction of greenhouse gases other than carbon dioxide.

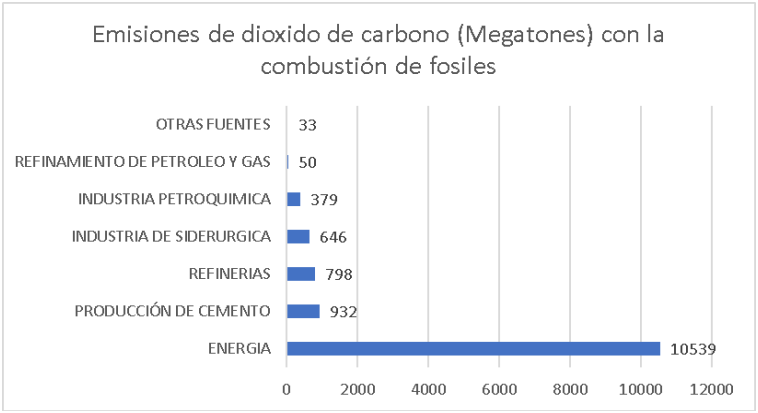

Figure 2. Carbon dioxide emissions by industry. Profile by processes or industrial activities of the large stationary sources of CO2.

The projections that various specialists on the subject of sustainable economies made stated that the global annual demand that will have to be met amounts to 2.3 Gt of energy per year, in contrast to the 88 Mt per year that are currently supplied (2021), Alexandra M. Oliveira, Rebecca R. According to Stern and Havens (2019), they indicated that the activities that human beings predicted in global meetings and coordination to reduce global warming were 1.0 °C. However, with the passing of time, it is estimated that by 2030 and 2052, it may reach an increase of 50% of what was predicted, that is, the indicator agreed upon by the different global authorities would be affected by 1.5 °C in variation of the 1.0°C.

Today, with fossil combustion:

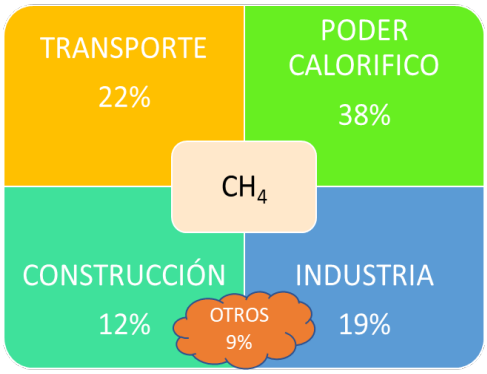

Figure 3. Estimation with the application of Hydrogen as energy. Oliveira, A; Beswick, R. (2022)

Since the era of industrialization, the overexploitation of fossil elements has concentrated as the main source of energy with 38% directed to the field of energy sectors, construction in 12%, transport in 22%, industrial in 19%, and others with a significant scope of chemical components such as methane, ethane, propane, and others. As a result of combustion, these components mainly produce carbon dioxide (CO2), or better known as GHG, for different types of industries around the world (2014). National strategic plan 2014–2025 Many companies in the years of industrialization did not take environmental management into account in their processes, which led them to carry out dangerous activities without taking into account the environmental damage that they could generate to the ecosystems of many species. The world community proposed action plans or mitigation measures to reduce the emissions of polluting components into the environment as it is exposed to various temperature changes. That is why various specialists, scientists, and researchers began to take into account the importance of reducing polluting gases.

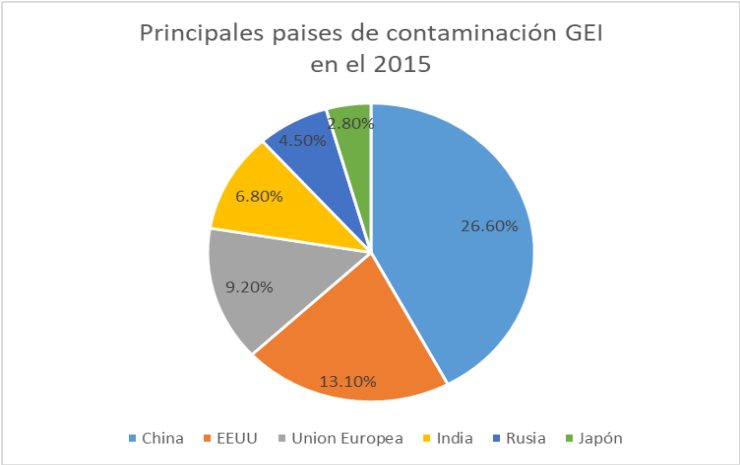

Figure 4. Main countries of greenhouse gases, Ecovidrio. Soroa, Inaki (2015)

In 2015, a study was carried out where it was determined that the highest percentage of greenhouse gas emissions was assigned to China with 26.6% and the US with 13.1% at the level of the main countries, resulting in the countries Take action and achieve environmental sustainability. However, despite the growth of technology in the environmental field, it had a great impact on the generation of renewable energy through wind energy, water energy, and solar energy, among others. These alternatives had the focus of submitting many guidelines that demonstrated that environmental contamination can be reduced and show positive results within their processes. However, the application methods for obtaining clean energy still pose a problem with respect to the capacity and efficiency of receiving natural energy. For example, in solar energy, the availability of sunlight during the period of one year and one day was demonstrated in a study. This led to finding a market full of opportunities to develop clean and natural energy.

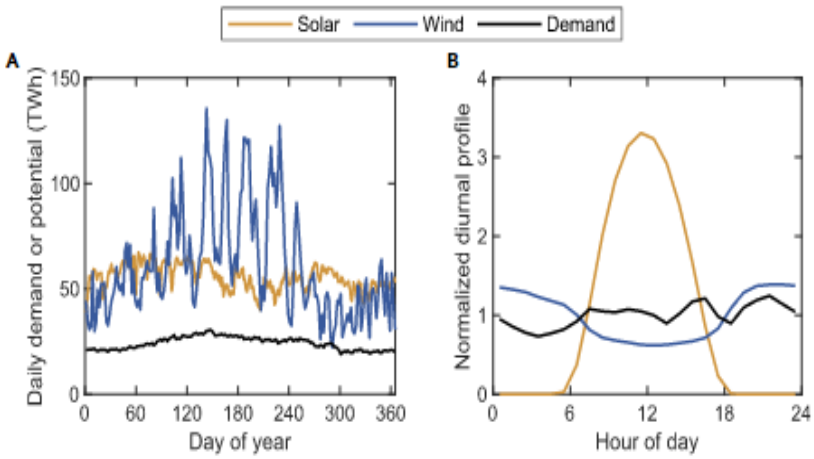

Figure 5. Decarbonization of the Indian economy in 2025 with regard to the demand of wind, solar and electrical energy. Shojie, S; Haiyang Lin (2022)

All the results of the emissions of polluting gases derive a rich potential in fossil energy but are detrimental to global warming in the world. On the other hand, green energy will represent the importance of generating energy potential without emitting gases that impact the environment. However, within the evaluation of the energy sectors, they cannot be addressed with the use of green energy or electricity, which makes it a limiting energy with respect to other applications where it requires energy to function.

Conceptual Literature

Green energy will have a significant impact on caring for the environment with the implementation of technologies that help reduce pollutants such as carbon dioxide, carbon monoxide, and sulfates, among others. Many researchers currently propose various ways to combat global warming in order to improve the quality of life and the environment. Green hydrogen could serve as the primary energy storage technology, central heating, and the main fuel for mass transportation such as planes, ships, trains, buses, and more.
On the other hand, the energy alternative that you want to achieve with the application of renewable energies in the world begins with the determination in different studies where they analyze that the planet earth presents more and more problems with respect to global warming. To determine the environmental self-deterioration, we must be aligned to the principles of environmental sustainability to develop fundamental pillars for a healthy and safe environment.
Greenhouse Gases (GHG): According to Manuel Becerra and Henry Mance (2009), greenhouse gases (GHG) are responsible for warming the earth's surface. This is due to the fact that these gases absorb the infrared radiation generated by the earth at the moment it is reached by solar radiation. In this way, GHGs distribute the heat generated by infrared radiation and warm the earth's surface to its current temperature. Likewise, Becerra & Mance (2009) affirm that, if the agglutination of these gases were to increase, the temperature of the planet would rise to a level that would make it an inhospitable place, turning the earth into a place that would not be prepared to house life as we know it.

3. Methods

The production of hydrogen for energy purposes is beneficial and crucial for the environment as well as for human development. We believe that this renewable energy can meet the growing energy demand, significantly reducing the amount of polluting gases in the atmosphere, and improving the quality of life. This study has a quasi-experimental approach, where we will analyze a variable and determine its relationship with the other components involved in the experiment. According to Hernández (2004), "Quasi-experimental designs also deliberately manipulate at least one independent variable to observe its effect on one or more dependent variables; they differ from pure experiments in the degree of security that can be had about the initial equivalence of the groups".Due to the aforementioned, in this investigation we will demonstrate that it is possible to obtain hydrogen through the use of low-cost materials. With the purpose of raising awareness about the use of hydrogen as an energy source, especially in transportation, which is one of the activities that generates pollution in our country. In addition, for all the benefits mentioned and the exemplary applications in other countries, it is evident that this energy can be economically and commercially competitive compared to the fuels used in Peru.

4. Data Collection

The discovery of hydrogen is due to various characters, including alchemists and chemists. Their first discovery occurred through chemical reactions between two compounds, and they called it "flammable air". In the year 1766, Henry Cavendish, an English physicist and chemist, using the same reaction, was able to isolate and recognize hydrogen as a chemical element. He was also able to expose some of its properties and the fact that the combination of this gas with oxygen generates water. From this moment on, this element awakens interest in other chemicals due to its characteristics and begins to be applied in various ways, as shown in Graph 5. However, it is 1788 when it receives the name "hydrogen" by Antoine Lavoisier.

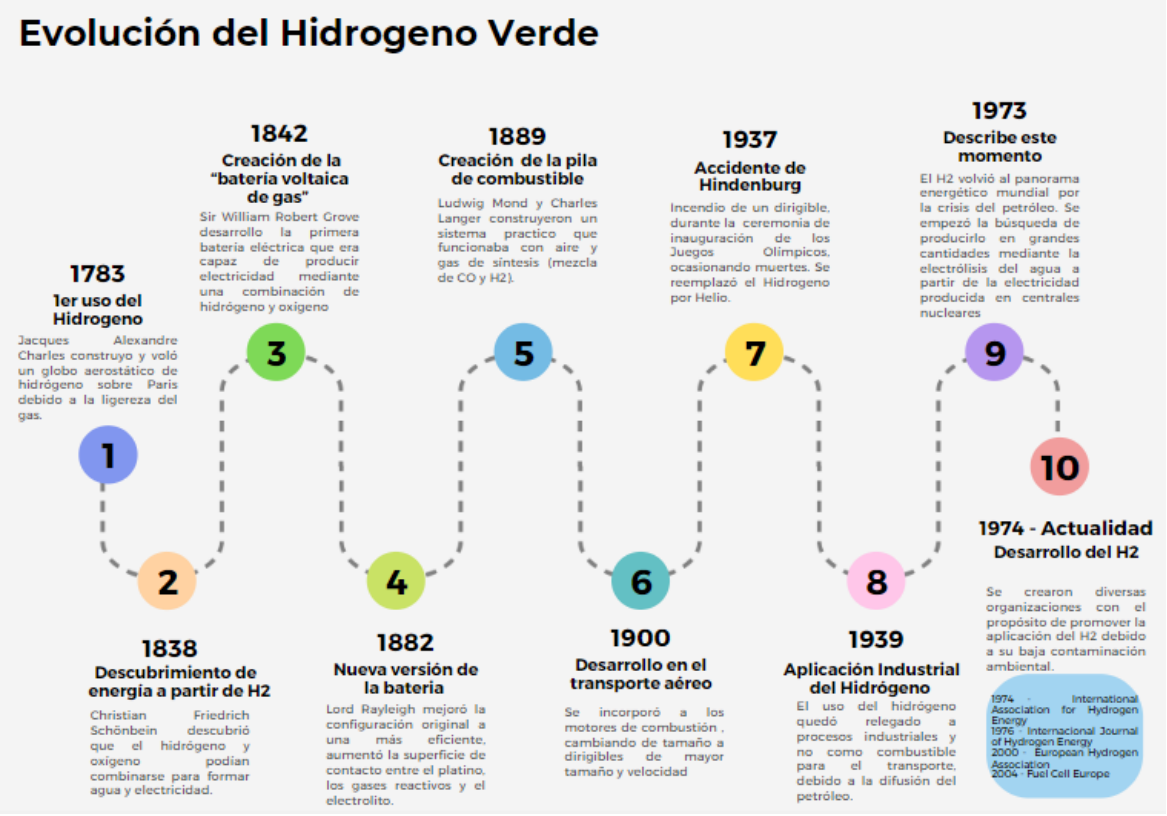

Figure 6. Obtaining green hydrogen and application in industrial combustion chambers. Ramón, J., Teresa, M., Gotzon. (2020)

Classification of hydrogen

Over the years, various ways of producing hydrogen have been discovered and created; depending on the type of process, it is called hydrogen. When it is generated from fossil fuels such as natural gas, resulting in carbon dioxide emissions that are not controlled, it is called gray hydrogen. Blue hydrogen is similar to gray. However, in its production, there is control of CO2 emissions through capture technologies (CCS) or other forms of compensation.

Table 1. Characteristics of the different types of hydrogen. Ramon, J., Teresa (2020).

Hydrogen	Power source	Amount of GHG generated	Characteristics
Grey	Natural gas	High	Generates large proportions of CO2
Black	Coal		
Brown	Lignite		
Blue	hydrocarbons	Null	Carbon capture and storage process

Green	Solar / Wind / Hydraulic	Null or Very low	Produced by electrolysis of water

Among these denominations, blue and green hydrogen are products that generate less pollution. However, gray hydrogen is the one that currently predominates. According to Torell (2020), "world hydrogen production is about 70 Mt, of which 99% is gray, which generates annual emissions of 830 MtCO2, including all stages of the process." Blue hydrogen is generated mainly from natural gas through transformation processes such as reforming and pyrolysis. On the other hand, green hydrogen is generated from renewable energy through electrolysis.

Obtention of Green Hydrogen

The new technology that the energy sector has been developing has gained importance in the use of water resources. An indispensable resource for the survival of human life is now present in its use as a non-polluting resource. It is manifest that water is losing its power to supply the population of the planet, which is why it should be considered that water is a highly desirable element for energy production. In addition, it is considered that for every 1000 m3/person per year, it is classified as "water scarcity", while 500 m3/person per year is considered "absolute scarcity" (2014, UNDESA). Obtaining energy through water is done through a chemical process called electrolysis. This process consists of the dissociation of water molecules into two components: hydrogen and oxygen, which are released in a gaseous state. The reaction occurs through the application of voltage, transforming electrical energy into chemical energy in the event that a power source is used. However, other renewable sources such as wind, solar, marine energy, etc. can be used. In this way, the emission of greenhouse gases is reduced.

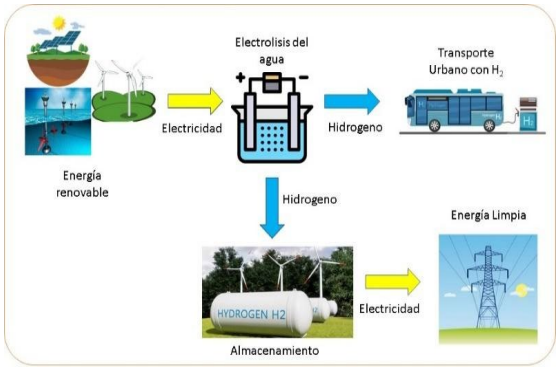

Figure 7. Deep decarbonization of the Indian economy: 2050 prospects for wind, solar, and green hydrogen. Shojie, S; Haiyang Lin (2022).

Applications of green hydrogen

Hydrogen is not considered as an energy source but as an energy carrier. This presents several applications that can generate benefits that maximize social welfare, among the main ones, can be seen in figure 06.

Figure 8. Applications of Green Hydrogen. Start (2021).

In general, green hydrogen can be used as a circular process by which energy can be obtained for the operation of a system, either in a set of devices or in a product, and this can be stored and used when required. Also, this element can serve as a resource to reduce carbon dioxide emissions or as a raw material for the production of chemical products or other chemical elements such as methane. Any of its applications is beneficial not only for companies but for the ecosystem and society as a whole.

5. Results and Discussion

Based on the existing applications of green hydrogen in other countries, we decided to carry out an experiment whose main objective is to demonstrate the efficiency of the gas in the relationship between the incoming factors or materials with the energy product obtained. That is to say, we will analyze the circumstances of the environment where hydrogen can be produced, materials that will serve as cathodes and the current intensity that is needed to produce the gas known as hydrogen. Among the factors studied during the experiment were: the amount of sodium chloride dissolved in distilled water, the current intensity. the voltage received by the power source, etc.

CHEMICAL FORMULA:

Cathode : $2H_20 + 2e^- \rightarrow H_2 + 2OH^-$

Anode : $2Cl^- \rightarrow Cl_2 + 2e^-$

In the engineering laboratory of Ricardo Palma University, we were able to experiment with a water electrolysis process to obtain green hydrogen gas. Which will have a significant impact on the reduction of carbon dioxide from the automotive fleet. This will lead to solving the problem of global warming in great proportion. The aforementioned chemical reaction, using the following materials.

Materiales de laboratorio:

20g of NaCI; 4 drops of phenolphthalein; 200 ml of distilled water; PVC tubes adapted to a field of absorption tubes; Graphite electrodes; Electricity from 5A to 20 Volts; Glass container; Flask ; Glass tube to measure in ml; plugs for PVC pipes; Hose for the transport of gas; Precision balance in grams.

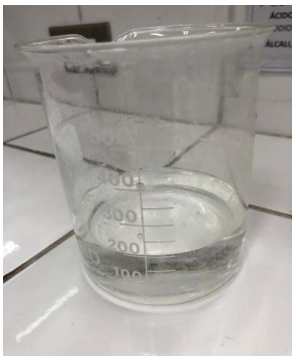

Figure 9. Flask used in the experiment.

Figure 10. Solution of Phenolphthalein

Figure 11. Weighing of sodium experiment.

For the development of the experiment, we built a structure similar to that of an absorption tube in order to facilitate the separation of the two main components.

Inside this structure, we placed the NaCl solution with distilled water and the drops of phenolphthalein. At the ends, there are two plugs; each one contains a graphite electrode that protrudes approximately 2.5 cm to be able to place a hook. Each hook is connected to a cable that comes from a power source, which will supply energy from the anode to the cathode in order to obtain the chemical reaction.

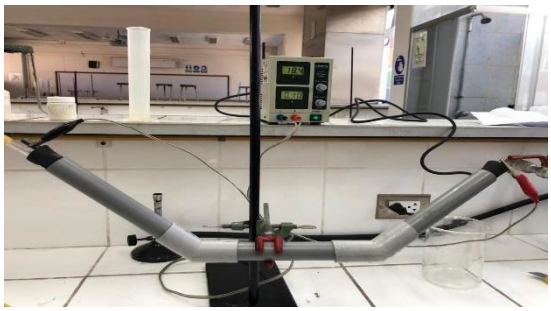

Figure 12. Structure built for the development of the experiment.

In order to measure the volume of hydrogen gas generated, we placed a graduated cylinder filled with water inverted in a 500-ml beaker; to ensure its stability, a universal support is necessary. Below the test tube, a hose will be positioned that will allow the transfer of the gas from the aforementioned structure to the test tube. The decrease in water inside the test tube will guarantee the amount of hydrogen obtained.

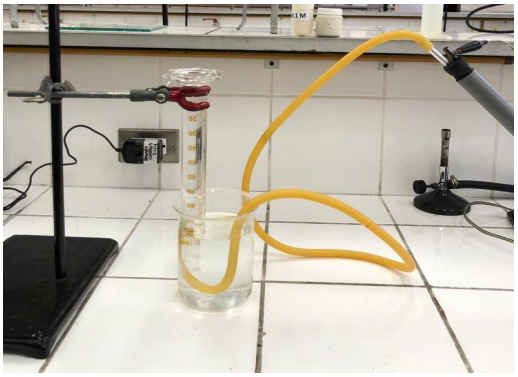

Figura 13. Structure built for the measurement of hydrogen gas.

Figura 14. General view of the necessary implements for the process of obtaining hydrogen.

5.1 Numerical Results

Table 2. Referential table of external investigation

Name of Author	Hypothesis	Objective	Number Result
Romero Polanco, Jorge	Production of hydrogen for use in the automotive industry for automobiles.	Design of an electrolytic cell to produce hydrogen by electrolysis of water.	It was possible to design an electrolytic cell of the AEM type with a production capacity of 1000 NL/h of H2 intended for use in cars based on fuel cell technology Using a current density of 3000 A/m2, at a pressure of 30 bar and at 70ºC. Obtaining purity levels of 99.99% H2.
De los Ángeles Isgró, María	Alkaline electrolysis of water, using nickel as an appliance, can produce hydrogen for storage and use direct to other systems.	Design and construction of an alkaline electrolyser	It was determined that the energy needed to dissociate one liter of water by electrolysis into its Oxygen and Hydrogen components is 4.39 kWh. obtaining two moles of hydrogen and one mole of oxygen, therefore, from one liter of water, 111.1 g H2 are obtained.

5.2 Graphical Results

The experiment was divided into two parts. In the first part of the experiment, it was decided to check whether the substances involved generated the proposed result. For this, we performed a test in a beaker with a NaCl solution. We place the two electrodes connected to the source to verify the reaction. As can be seen, gas is generated on the cathode side, which is hydrogen. In the second part, the built structure was used where, through the use of electrical energy, the expected reaction could be obtained. As can be seen in Figure 12, the hydrogen level is displayed with the decrease in water in the test tube.

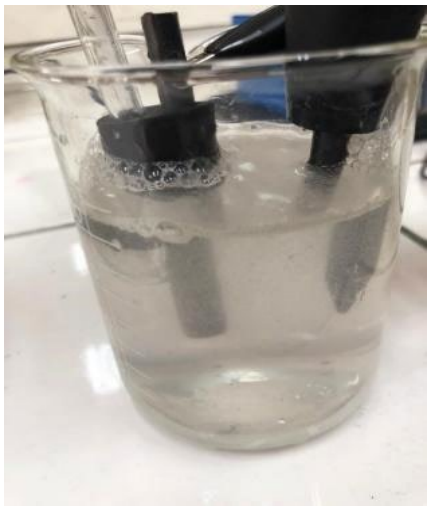

Figure 15. Hydrogen obtained from the chemistry reaction

Figure 16. View of the level of hydrogen generated according to the emission of the gas

5.3 Proposed Improvements

The proposal to investigate green hydrogen is subject to improving the quality of life and reducing the impact of environmental pollution in Peru, especially in the capital city of Lima. For this, in the present investigation, we analyze the good practices carried out by developed countries and the collection of scientific data that the researchers analyzed in the study of green hydrogen to achieve transfer to a friendly, technological ecosystem and easily adapt it to our social environments. The development of the idea was reflected in the experimentation stage, where, in the specialized laboratory, we used the tools and materials to develop the green hydrogen product, as previously observed.

5.4 Validation

Table 3. External conclusions of other investigations

Name of Author	Referencial Quotes	Conclusion of the investigation
Romero Polanco, Jorge	"Design of an electrolytic cell to produce hydrogen by electrolysis of water, hydrogen intended for use in the automotive industry for cars based on fuel cells"	The best system for the production of hydrogen for the automotive sector is the AEM type due to its compact design and lower cost. Obtaining H2 purity levels of 99.99% and water vapor emissions, proving that hydrogen is a clean energy.
De los Ángeles Isgró, María	"The theoretical aspects of the electrolysis process in alkaline medium will be analyzed, the influence of the concentration of electrolyte and the temperature at which the process takes place, to finally carry out the part construction of the alkaline electrolyser".	A monopolar alkaline electrolyser will be built for the production of hydrogen on a laboratory scale.

6. Conclusion

In the present investigation, we have been able to conclude that clean and green energy will promote a competitive strategy in the world for a cultural change that will allow environmental sustainability with the exploitation of renewable energy and its technological applications. In the experiments in the laboratory, we have been able to observe the chemical reactions that occur when the water in a saline state is combined with the entrance of electricity to form the electrolysis process, which produces hydrogen in a gaseous form. We later suggest that it go through a catalyst, which will separate the moles of hydrogen into electrons and protons for the formation of electricity and thus power electronic devices.

- ✓ Promote the exploration of energy sources that can combat and eradicate the emission of gases that cause global warming in the city of Lima.
- ✓ Green hydrogen has great energy potential as an energy source to improve the quality of life and the environment.
- ✓ The production cost of green hydrogen is reduced for large-scale production as a new energy source.}
- ✓ The new source of hydrogen energy combustion can be implemented in mass transportation such as buses, trains, and private cars.

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Biographies

Luis Miguel Zambrano Casimiro is an Industrial Engineer student from the Ricardo Palma University of Lima,Perú. He studied a program for digital transformation in the University National of Engineer from Lima and is a young researcher and working for a company of Lima in the area of technology and process. I participated for a scholarship to China to improve the environment.

Adriana Eulalia Ruiz Melendez is an Industrial Engineer student from the Ricardo Palma University of Lima,Perú. Her research interests are sustainable supply chain management, Financial Engineering, Logistics & Operations. She investigated and created some papers about how to enhance the operational process in peruvian industries. Also, she designed a project to be used as protype for the improvement of Manufacturing Technology.