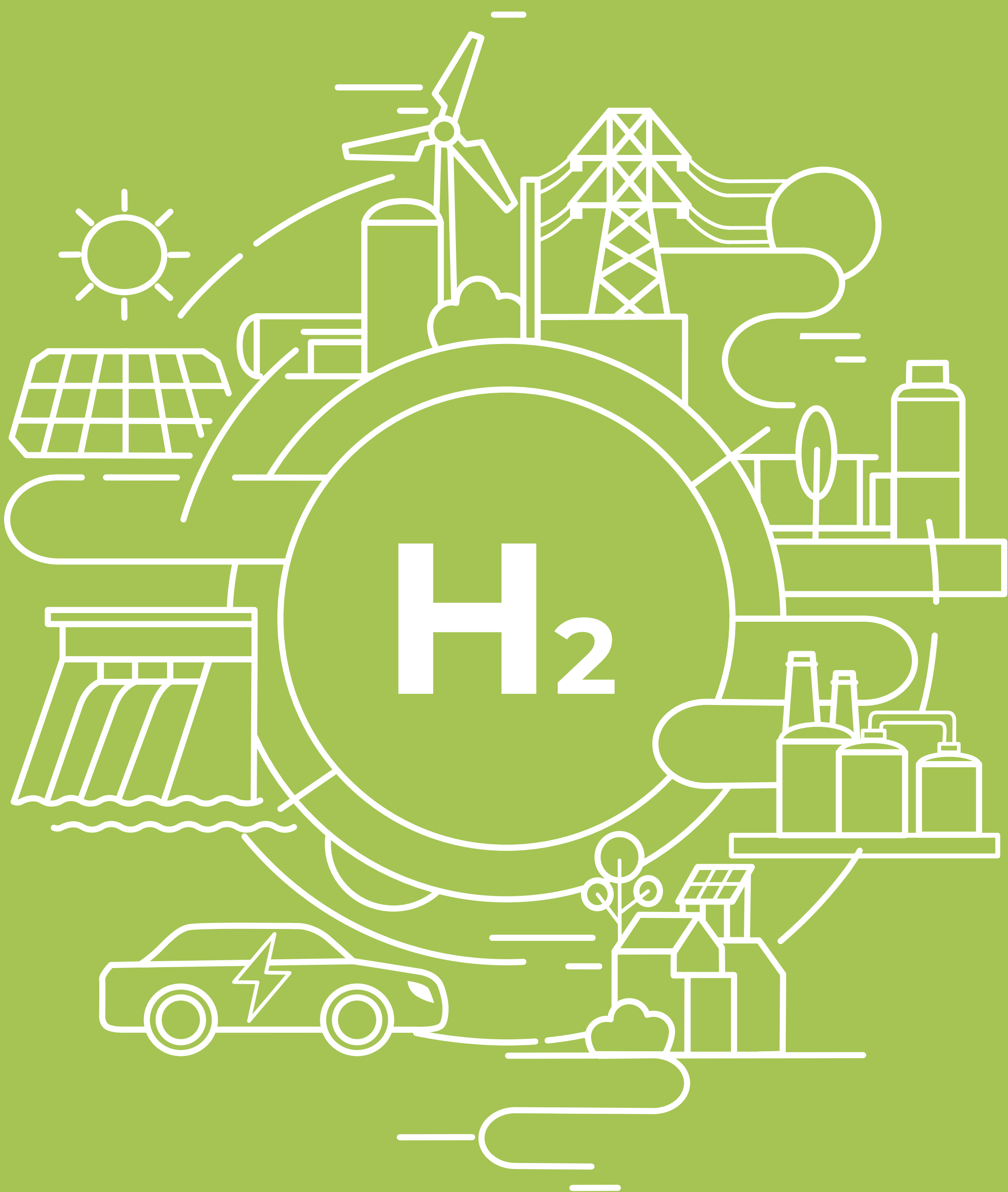
TOWARDS THE

Green Hydrogen Roadmap in Paraguay



INNOVATION PROPOSAL

Guidelines for a green hydrogen supply and utilization demonstration project in Paraguay

Ministerio de
OBRAS PÚBLICAS
Y COMUNICACIONES
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MINAS Y ENERGÍA

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Executive Summary

This project, in the form of guidelines and a proposal for a demonstration project, aims to be a catalyst for the development of the green hydrogen (H_2) economy in Paraguay aimed at meeting energy needs and contributing to productive development. In addition, it is a complement to national efforts to develop sustainable urban mobility as an alternative for the mitigation of the environmental and public health impact of mobility and transportation activities, which are responsible for poor air quality, noise pollution and increased temperatures in urban centers.

Green hydrogen (from renewable energy) is an energy vector (energy carrier) with a zero Carbon Dioxide (CO_2) footprint that presents an opportunity for the transition to clean energy in the short, medium and long term, particularly in long-distance cargo and passenger transport, both for overland and river transport (with developing prospects for the aviation sector). Its energy value also stands out in industrial uses and in energy storage for electricity demand management. It is important to highlight that the country possesses an enormous potential for the production of green hydrogen at competitive prices of around 2.2 USD/kgH_2[1](Gustavo Arturo Riveros-Godoy and M. Rivarolo 2019), a value lower than those recommended by the International Energy Agency (IEA 2019). The problem that gives rise to the global interest in green hydrogen is based on the increase in human activities that have raised energy requirements, compromising natural resources and increasing greenhouse gas (GHG) emissions through the use of fossil fuels. The transportation sector in particular is one of the main culprits and in Paraguay one of the largest consumers of energy and fossil fuels (All of which are imported).

THE PROJECT PRESENTS AN INNOVATION PROPOSAL WHICH IS ACCOMPANIED BY AN ATTACHED DOCUMENT THAT SUMMARIZES THE CONCEPTUAL FRAMEWORK FOR THE IMPLEMENTATION OF A DEMONSTRATION PROJECT STRUCTURED IN TWO COURSES OF ACTION:

Course of Action 1: Generate strategic guidelines, policy, promotion and regulatory frameworks, and institutional and technical capabilities for the development of the green H_2 economy, as an instrument for energy transition and climate change mitigation in pending sectors of the country's economy. Emphasis is placed on taking advantage of the country's geographic conditions and energy resources to promote the industrial development of the value chain with the creation of local jobs.

Course of Action 2: Install pilot plants for the production of green H_2 (see Table 18 Attachment) from the electrolysis of water with renewable energy for its use as an energy vector and demonstrate its viability. One goal is to connect the three main commercial areas of Paraguay: The Asuncion Metropolitan Area (AMA), Ciudad del Este and Encarnación. The initial minimum demand for vehicles will be provided by the project and the promoting government agencies in their fleet renewal plan. This will have a multiplying effect: supply and demand will grow with the participation of private, public transportation and freight companies that are expected to be attracted by the promotional activities mentioned in Course of Action 1.

It is estimated that the acceptance of green H_2 as a substitute for fossil fuels

1 Estimated price of Green Hydrogen produced on a large scale, obtained through electrolysis of water using electricity from renewable sources.

in Paraguay will benefit multiple sectors, such as the environment through promoting the use of renewable resources; the population in general by improving health conditions; the macro-economy and the balance of payments by substituting imported fuels for domestic energy sources and contributing to economic reactivation; the manufacturers and marketers of supplies in the value chain of green H_2 (electrolyzers, vehicles, infrastructure, etc.) through the creation of jobs and the strengthening of the national industrial sector; professionals, technicians and academics through training in new technologies, among others.

Regarding the Innovation Proposal for demonstration purposes, the more specific beneficiaries of the pilot project (hereinafter, the Project) include: the National Electricity Administration (ANDE), in evaluating new forms of energy storage to improve demand management as well as in increased energy sales to produce green H_2; PETROPAR, in initiating the transition to clean and sustainable energy sources; the Vice Ministry of Mines and Energy (VMME) and the Vice Ministry of Transportation (VMT), upon generating capabilities for the development of policy and regulatory instruments related to the energy transition in the pending sectors of the economy; the Ministry of Environment and Sustainable Development (MADES), in supporting climate change mitigation actions; the Ministry of Industry and Commerce (MIC) upon supporting the development of new industries; Academia, in strengthening its curriculum and professionals based on the training obtained; and the country in general, in evaluating technologies to strengthen energy security in the future. In addition, the Project may establish a laboratory for equipment testing with a more regional outlook,[2] benefiting the area as well. Moreover, there are plans to develop conditions that will attract private investment to activate and strengthen the green H_2 market in the country and in the region, thus encouraging the creation of green jobs.

Over the 10-year operating period of the three pilot plants, it is estimated that green hydrogen will be produced on this scale at a price of less than US$3/kg$H_2$. Direct and indirect labor will be employed, CO_2 emissions will be avoided in the region of 21,170 tons, assuming a consumption equivalent to 7,358,400 liters of gasoline, which will be replaced by 1,168,000 kg of H_2 produced over the period. In addition, the electricity consumption of 6.57 GWh/year will mean an annual revenue of US$172,000 for ANDE (considering the operation of the three plants). In terms of skills development, representatives of the different ministerial portfolios and institutions involved in the project (more than 60 people), including directors, technicians and instructors, are expected to be trained. The development of conditions that would allow the activation of the hydrogen market oriented to favor private sector investments is also being considered, this will imply Research and Development (R&D), both at a technical and legal level.

Finally, according to the project guidelines and estimates, an overall investment of US$ 10 million could be required for its implementation, which would include all the additional components, some vehicles and the skills development component. This budget will be considered in the search for co-financing from non-reimbursable funds that may be applicable.

2 *Impact Investment in Paraguay 2020, UNDP (https://www.py.undp.org/content/paraguay/es/home/library/inversion-de-impacto-en-paraguay.html)*

Abbreviations and Acronyms

A

AMA
Asuncion Metropolitan Area

C

CO_2
Carbon Dioxide

F

F-PTI
Itaipu Technological Park Foundation

H

H_2
Hydrogen

M

MAWP
Maximum Allowable Working Pressure 33

V

Energy Vector or Energy Carrier
Substances or devices that store energy in such a way that it can be released later in a controlled manner are called energy vectors. Hydrogen is one type of energy Carrier.

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The innovation proposal

01.

THE INNOVATION PROPOSAL

The proposal "Towards the Green Hydrogen Roadmap in Paraguay" is an initiative to promote and evaluate the viability of the green hydrogen economy in Paraguay. With the aim of promoting a viable technological and energy transition in a country that exports electricity from renewable sources, mainly for the decarbonization of the freight and long-distance passenger transportation sector.

THE INNOVATION PROPOSAL AIMS TO DEMONSTRATE THE TECHNICAL AND ECONOMIC FEASIBILITY OF USING GREEN HYDROGEN - PRODUCED FROM THE ABUNDANT HYDROPOWER IN THE COUNTRY

It will also allow the collection of useful data and information for other purposes: socioeconomic evaluations of hydrogen use scenarios in the country; the formulation of policies, regulations and standards; and the generation of a sustainable scenario for economic reactivation based on the use of a new energy vector in the energy matrix, which can contribute substantially to achieve the decarbonization of the country's economic activities.

This proposal includes institutional skill building modules related to the management of the green hydrogen cycle obtained through water electrolysis, from its production to its final use. It also seeks to explore mechanisms to facilitate the participation of the productive sector in the national energy matrix through the value chains of the previously mentioned cycle.

The guidelines presented in this document, together with the demonstration project proposal, constitute the first steps that the Paraguayan government is seeking to take to develop the green hydrogen economy in the country, with the aim of complementing the decarbonization of the pending sectors of the economy by promoting productive development and fostering green and sustainable economic growth.

02.

Problem statement

02. PROBLEM STATEMENT

The increase in human activities has raised energy requirements, thereby compromising natural resources and increasing greenhouse gas (GHG) emissions from the use of fossil fuels. Although Paraguay has abundant renewable natural resources - particularly energy resources - it has several pending energy issues. The country's final energy consumption matrix is heavily dependent on imported fossil fuels (about 41% of total final energy consumption), while electricity, which is produced from almost 100% renewable sources, represents a share of only 16% (VMME 2019). This is recognized by both the PEN 2040 and the PND 2030, where the need for an energy transition towards a model with a greater share of electricity coming from domestic and renewable sources is highlighted. Moreover, these plans maintain that, in order to achieve the transition, one of the main sectors that must be addressed is mobility and transportation, as it is the main energy consumer. So much so that the PND 2030 proposes a 20% reduction in the consumption of imported hydrocarbons, and the PEN 2040 sets goals for the promotion of electric mobility and the use of domestic fuels.

In this case, it is clear that, among fossil fuel consumers, the largest contributor to greenhouse gas (GHG) and CO_2 emissions is the transportation sector. This is a condition common to most Latin American and Caribbean (LAC) countries, as recognized in IDB studies, which show that the proportion of per capita CO_2 emissions from transportation is one of the highest among global regions (Rivas, Suárez-Alemán and Serebrisky 2019). In addition, the aforementioned study[3] cites that the regional motorization rate is one of the highest in the world, along with Asia and the Middle East. In these terms, Paraguay is at around 3.4%, and each year it is rising according to this trend. That is to say, every year, the number of vehicles in the country increases by this percentage with respect to the figures for the previous year. This would translate into serious problems for both air quality and public health at the national-regional level in the future. In addition, it creates a strong pressure to expand and improve the road infrastructure. According to a report by the Pan American Health Organization (PAHO) - World Health Organization (WHO) worldwide, 4.2 million premature deaths were attributable to air pollution in 2016 accounting for 7.6% of all deaths in that same year (Sánchez 2020). About 88% of these deaths occur in low- and middle-income countries, such as several countries in the region. From a local perspective, in Asuncion the level of pollution exceeds the safe level dictated by the World Health Organization by 80%, leading to a significant number of deaths per year that will continue to grow if no measures are taken (WHO 2019).

3 Stylized Urban Transportation Facts in Latin America and the Caribbean DOI: http://dx.doi.org/10.18235/0001606

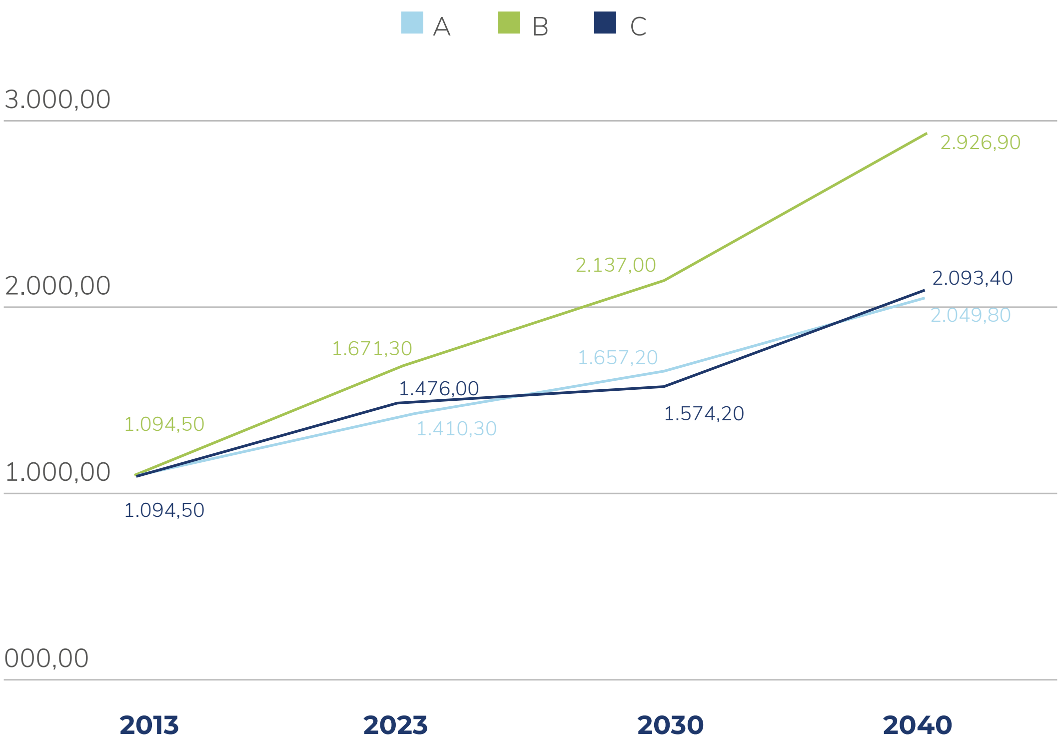
The environmental impact of the transportation sector is significant with global, public health and quality of life consequences. Transport is blamed for poor air quality, noise pollution and rising temperatures in urban centers, so much so that it has been identified as a priority for achieving the Sustainable Development Goals.

According to reports from the Study of Energy Consumption in the Transport Sector, which is part of the National Energy Balance in Useful Energy of Paraguay (BNEU)[4], in 2011 the consumption of diesel in the Transport sector was around 863.32 ktoe, so the net consumption of diesel for the land transport sector was close to 858.57 ktoe. More recent studies have determined that the total energy consumption of the land transportation sector is around 1,313.7 ktoe, of which 65.4% corresponds to diesel, followed by gasoline at 27.5%, alcohol in third place at 5.7% and finally LPG at 1.4% (Energy Outlook for the Republic of Paraguay 2013-2040)[5].

59.4% of energy consumption in the land transportation sector corresponds to passenger transportation and 40.6% to freight transportation. 44.5% of diesel consumption is in passenger transport (mainly buses and minibuses with 18% of the total and 4x4 trucks with an additional 15%), while cargo transport accounts for the remaining 55.5%. Trucks are the means of locomotion with the greatest share of total diesel consumption at the national level, taking into account all sectors, with 25.2%, followed in third place by 4x4 pickup trucks with 15% (Energy Outlook for the Republic of Paraguay 2013-2040).

CHART 1.

PROJECTIONS OF DIESEL CONSUMPTION FOR THREE SCENARIOS PROPOSED IN THE ENERGY OUTLOOK FOR THE REPUBLIC OF PARAGUAY 2013-2040



Source: *Energy Outlook of the Republic of Paraguay 2013-2040*

4 The government of Paraguay is in the process of updating the BNEU.
5 (Itaipú Binacional, Fundación Parque Tecnológico Itaipú y Fundación Bariloche 2015).

SCENARIOS ESTABLISHED IN THE ENERGY OUTLOOK WITH RESPECT TO DIESEL OIL CONSUMPTION
Scenario A (Reference): there will be no major changes in the share of sources in total net consumption due to substitutions and differentiated energy efficiency measures in the sources.
Scenario B (Alternative): Biodiesel that will start with a more significant share in the blend with Diesel starting in 2018 and will gradually increase so that in 2040 it will represent 3.4% of total net consumption.
Scenario C (Alternative): Natural Gas in the Alternative scenario will replace Liquefied Gas and Diesel, resulting in a greater reduction in the participation of these sources.

Another pending issue is the need to improve the public passenger transportation system. According to IDB studies, the quality of this service at the regional level is worse than in advanced economies(Rivas, Suárez-Alemán and Serebrisky 2019). The same study found that the average travel time by public transport on a workday in Asuncion is 100 minutes, higher than the regional average, and above the average of 64 minutes in advanced economies, even though the average travel distance is much shorter.

Regarding transportation affordability indicators in selected LAC cities in 2018 a citizen of Asuncion, with a low average salary spent about 16.3% of their income on mobility, thus affirming that spending on transportation services by low-income households is the highest among all developing regions, with greater negative effects on less-developed nations. Among other issues that could be mentioned, for example, public transport productivity has stagnated or even declined in the region, several cities in the region do not cover operating costs with revenues from fare collection. In addition, it has been found that women are the most affected by these factors, being the segment of the population that makes the most trips on foot and by public transport, as they have less access to private transport. Of the total number of driver's licenses issued in selected LAC cities, only about 25% belong to women. All these regional realities are shared by the public transportation sector in Paraguay.

THERE ARE CURRENTLY SEVERAL INITIATIVES RELATED TO ELECTRIC MOBILITY IN PARAGUAY

However, the majority of these, almost 100%, are related to battery electric vehicle technology, with some electric buses imported by the private sector and donations within the framework of cooperation with other partner countries[6]. At the moment, no initiative has been registered to promote the use of hydrogen in the transportation sector. This is a major issue. According to the International Energy Agency, an important step in promoting the use of this energy vector is R&D&D (Research, Development and Demonstration) projects.

6 The energy density of the batteries, for example 200 Wh/kg in the new Nissan LEAF, limits by weight, volume and costs the autonomy of electric mobility based on batteries. For a light car 17 kWh is needed for 100 km, therefore for a range of 300 km a battery of more than 250 kg is needed, which is almost more than 30% of the weight of the vehicle.

The country possesses the ideal conditions for the deployment of the hydrogen economy. In addition, there is an enabling policy framework (the National Energy Policy 2040, the National Development Plan as the most relevant), as it is possible to observe in the national objectives and the agreements subscribed in international spaces (the Nationally Determined Contributions, the Sustainable Development Goals, among others). Furthermore, for the use of hydrogen in the transport sector, advantage could be taken of the existence of Law No. 5183/2014, which exempts the import of electric vehicles (EVs) from customs duties and VAT. The government's interest in the adoption and promotion of domestic low-carbon energy sources is clear. However, these processes could be compromised by the current sanitary conditions. Without accompanying and coordinated efforts, there could be considerable delays in the development of green technologies. Since the first quarter of 2020 crude oil prices experienced significant declines due to the coronavirus outbreak. This has been accentuated by the global health situation that has led to even more significant reductions due to oversupply and low demand, as a consequence of the containment measures adopted in most of the countries affected by the COVID-19 pandemic, such as Paraguay. This could represent a major threat to the future of programs aimed at mitigating the effects of climate change, if incentive packages to revive economies do not consider green programs. According to a report by the International Energy Agency, large drops in CO_2 emissions of about 8% are expected, something never seen before, even compared to the effects of all the crises that have occurred since the first great economic depression in the 1930s[7]. After each crisis since then, the economic recovery has translated into large upturns in emissions, much larger in order of magnitude than the declines experienced. In this context, it is imperative to start planning on the basis of a green recovery, so the development of the hydrogen economy is presented as a way for the country to avoid disproportionate increases in CO_2. However, these new technologies must be tested to demonstrate their reliability and economic viability.

Planning becomes even more important because, due to the innovative nature of this technology, there are still no adequate business models in the country, nor established tariffs for hydrogen, nor for the service to be offered. Furthermore, as a consequence of the relative newness of this technology, the technical capacity of the human resources is also limited. At the same time, there are few locations where water and electricity converge for the installation of hydrogen plants, taking into account that the national interconnected system, in certain places, does not allow for permanent electric power, at the level required for the plant. In addition, this location would need treated water, be of easy access and have easy access to the water and to the other supplies needed for the plant. Another important aspect for these technologies to be effectively incorporated in the country is to adapt the legal and regulatory framework in Paraguay related to hydrogen, mainly

7 Available online at https://www.iea.org/reports/global-energy-review-2020/global-energy-and-co2-emissions-in-2020 the technical regulations related to the different aspects of hydrogen, such as safety. With the help of an articulating entity in the energy sector, the possibility of creating policies that benefit the process of adaptation to new technologies such as hydrogen will be made easier.

There are also threats that may arise from the use of this element in the energy matrix. Among these are the protectionist views of different interest groups[8] that seek to maintain the same market model; the misconception regarding the (in)security of hydrogen due to the low awareness surrounding this technology, because of its relative newness. In addition to this, there are still no incentives for the private sector to invest in hydrogen and prices in the country are uncertain due to the lack of studies implemented, which is why it is necessary to advance a pilot project that allows the positioning and preparation of Paraguay in the face of global changes in an energy transition.

Therefore, the above shows the existence of a series of challenges to be addressed: new technologies are expensive and must be tested to demonstrate their viability and reliability in order to gain acceptance. An enabling legal and regulatory framework must also be built and institutional and technical skills must be developed to scale up new technologies and the development of their associated infrastructure.

8 A segment of the private sector engaged in the sale of fuels and combustion engines, such as APESA (Association of Owners and Operators of Service Stations and Related Industries).

03.
Objectives

03 OBJECTIVES

3.2

General Objective

Contribute to the development and implementation of green hydrogen technologies in Paraguay as an innovative alternative towards an energy and technological transition that improves the country's productivity while focusing on sustainability.

3.2

Specific Objectives

1 Demonstrate the feasibility of hydrogen use in the transportation sector to capture the interest of decision makers and investors.

2 To train professionals with skills to design, build and operate hydrogenerators and hydrogen production plants, promoting the participation of men and women (gender diversity).

3 Identify mechanisms to develop local employment of supplies in the value chain of green technologies for the decarbonization of the transportation sector.

4 To offer the public the opportunity to become familiar with new clean technologies and to promote collective social awareness of green programs.

5 Demonstrate the feasibility of promoting a diversification of the energy supply in Paraguay as an energy hub and promoter of climate change mitigation programs in the region through the development of the hydrogen economy.

6 Contribute to decarbonized energy source technologies with hydrogen to attract sustainable industrial investment to manufacture "green" products.

7 Lay the foundations for green internal land and river transportation in Paraguay by defining transportation routes and hubs for the development of a sustainable economy and industry.

8 Lay the foundations for Paraguay's role and international positioning as a hub for potential green land and river transport routes, respectively, in the southern cone between the Pacific and Atlantic oceans and between Chile, Argentina, Brazil and Uruguay.

04.

Project overview

04. PROJECT OVERVIEW

The need for energy substitution towards a greater share of renewable electricity in transportation is evident. Green hydrogen (H_2) (from renewable energy) is an energy vector (energy carrier) with a zero Carbon Dioxide (CO_2) footprint that presents an opportunity for the transition to clean energy in the short, medium and long term, particularly in long-distance cargo and passenger transport, both for overland and river transport (with developing prospects for the aviation sector).

THE ENERGY VALUE OF HYDROGEN ALSO STANDS OUT IN INDUSTRIAL USES AND IN STORAGE FOR ELECTRICITY DEMAND MANAGEMENT.

The proposal is to develop, promote and implement green hydrogen to improve the country's productivity and resilience with a focus on sustainability and innovation, contributing to the fight against climate change and to a healthy environment.

The project will complement the urban Electro Mobility initiatives that are being developed in the country.

4.1 Course of action 1: promotion and development of the green hydrogen economy in Paraguay[9]

The objective of this Course of Action is to establish the basis on which the green hydrogen economy will be developed in Paraguay with a view to the short, medium and long term. Seeking to gradually adapt the available means and investments to the development and implementation of hydrogen technology, offering options to:

1. Knowledge and social acceptance of hydrogen technology.

2. The training of specialized technical personnel prepared for the jobs created.

3. The development and modernization of Paraguay's land and river transportation networks. To give rise to a wide network of hydrogen users.

4. Paraguay's position in the fight against climate change by reducing CO_2 emissions and polluting gases.

5. Improving 5. Improving the balance of payments by using Paraguay's own energy resources.

The project will be launched through a Forum to promote it at the international level. On the one hand, this action will be carried out to showcase the country's capabilities and the roadmap it intends to follow for the incorporation of this technology in the different sectors of the country's economy. On the other hand, it will seek to form partnerships aimed at strengthening the pilot demonstration plan of Course of Action 2.

Partnerships will ensure the success of the project. At the national level, the interest of public and private sector partners will be captured. The public sector will make it possible to generate the enabling conditions for the project and even be the first major

9 This Course of Action will be based on the document "Conceptual Framework: Towards the Green Hydrogen Roadmap in Paraguay".

investor. Without the participation of this sector it would be very difficult to capture the interest of the private sector. Then the next group of stakeholders with which partnerships will be formed for the project is the public sector. In the initial stage, the partnerships will be mainly with companies with the capacity to operate the transportation system that is planned in subcomponent 2. At the international level, the inclusion of private companies with experience in green hydrogen technologies should be sought, both in the production and manufacture of technology that has an impact on supply (production and supply of H_2) and demand (battery and vehicle manufacturers).

In the coming years, the project will be built on the basis of a National Strategy, which will be developed in a consultative and inclusive manner within the framework of this course of action, with measurable objectives, activities and targets. The strategy will allow the government to follow an orderly path to consolidate the hydrogen economy. This will be designed in line with national strategies such as the National Energy Policy (PEN) 2040, the National Development Plan (PND) Paraguay 2030, and the Sustainable Energy Agenda 2019-2023, and will underpin the objectives of said plans. It will also serve as a facilitator for the achievement of the goals set at the national level. It will take a multidimensional approach, which will minimally include aspects of Policies, Regulations, Standards, Financing, Supply and Demand, and Infrastructure, among others.

PARAGUAY’S POTENTIAL FOR HYDROGEN PRODUCTION IS EVIDENT.

The abundance of renewable energy resources, particularly water, and the competitive electricity tariffs are one of the main attractions for the implementation of a competitive production chain. The joint use of renewable energy resources and competitive electricity tariffs with the strategic geographical location of the country in land and river logistics corridors in the center of South America can position the country as an energy hub based on renewables and hydrogen.

Several sectors will be able to take advantage of the benefits of this energy vector . One of the main ones is the transportation sector. Paraguay, being a landlocked country, is highly dependent on land transportation as well as on the Paraguay-Parana waterway for the mobilization of the goods it produces. Currently, this sector is completely reliant on imported fossil fuels, in this case hydrogen will not only enable the energy and technological transition along with the decarbonization of the transport sector, but will also help reduce the macroeconomic vulnerability resulting from oil dependence.

Another sector that can benefit from an energy transition is the industrial sector. Paraguay is a large consumer of biomass in the form of firewood for heat production, an unsustainable practice that makes it impossible to use wood for the production of goods with higher added value. High

Temperature Industries could use hydrogen as a heat source. However, the use of hydrogen is not limited to its property of being an energy carrier. It is also an important resource as a raw material for the food, chemical and pharmaceutical industries, metallurgy and even the production of synthetic fuels, an ever growing market.

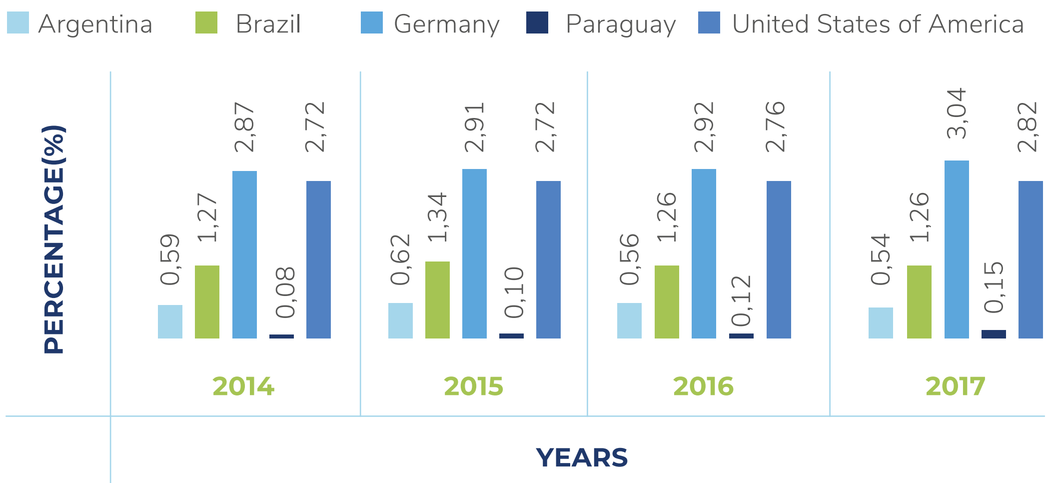
IN VIEW OF THE ABOVE, THE CONTRIBUTION THAT HYDROGEN CAN MAKE TO THE ENTIRE NATIONAL VALUE CHAIN IS REMARKABLE.

Not to mention that its production will improve the management of electrical systems. The hydrogen economy opens the door to a new opportunity for the country, innovation and technology development.

Until now, Paraguay and the region have been mainly technology takers or users. According to IDB reports, in several Latin American countries the number of new science and technology-based companies has increased in recent years, but there are still huge gaps in relation to more advanced regions (Kantis and Angelelli 2020). One indicator of this fact is the low investment in research and development in the countries of the region. While countries such as Germany and the United States invest close to 3% of their GDP in this type of activity, the countries of the region do not exceed 1.5%, as can be seen in Chart 2 below, and in the case of Paraguay, it does not even reach 1%. Furthermore, there is clearly a direct relationship between economic growth and investments in R&D&E, as this enables the creation of jobs and new capabilities for countries.

CHART 2.

RESEARCH AND DEVELOPMENT EXPENDITURES AS A PROPORTION OF GDP



Source: http://data.uis.unesco.org/#

In this sense, green hydrogen could be an opportunity for Paraguay to become a source of innovative technologies[10] and supplies in the green hydrogen value chain. This would require the design of an Industrial Promotion Strategy for the supply chain of Hydrogen Technologies, which could lay the groundwork for investment incentives, through the generation of mechanisms that favor business activities.

10 Hydrogen Fuel Cells, Compressors, Storage Tanks, Safety and Control Devices, FCEV Vehicle Assembly, etc.

PARAGUAY IS CONSIDERED A COUNTRY OF YOUNG PEOPLE. ABOUT 70% OF THE POPULATION IS YOUNG AND 60% IS UNDER THE AGE OF 30.

In fact, the average age is 26.5 years (Hannah Ritchie and Max Roser 2019). Likewise, this population is quite vulnerable in the labor aspect. During the pandemic, it was found that young people were more likely to lose their jobs during confinement based on the type of occupations (BBC, 19 de mayo de 2020)than people in other age groups. The hydrogen economy, with all its benefits, has great potential for job creation, and by taking advantage of the country's demographic bonus, it could offer young people secure jobs and a good future outlook. However, for the most part, the young population is an unskilled labor force, so training is a critical aspect for them to take advantage of these new opportunities. In addition, human capital is important for this package of projects that aims to promote the use and generation of hydrogen technologies.

To accompany the processes, clear actions will be needed for Skills Building and Human Resources Training. This will be an important demonstration to investors of the government's commitment to promoting the hydrogen economy. Curricular programs will be updated with topics related to hydrogen, both in universities and in training institutes for specialized technicians, in the areas of assembly and operation of plant-stations, and associated technologies such as FCEV type vehicles, compressors, tanks, etc. Also, emergency response personnel, such as firefighters, paramedics, among others, should be trained, since this type of technology presents new challenges in terms of procedures and safety.

In line with the above, a space will be needed to help promote and coordinate new initiatives. Therefore, a Center of Excellence with a focus on hydrogen and its technologies is expected to be established. This will provide the country with a consultative space of reference that will capture what has been learned and developed regarding hydrogen and its main mission will be to build capabilities in the country as well as to position it internationally in R&D&E issues; it will be an incubator for future national projects. It will be made up of representatives from academia, industry, the private sector, the public sector, international organizations, civil society, among others.

Finally, the efforts of this project will generate a great deal of knowledge and results. It is for this reason that it will be necessary to rely on a Communication and Dissemination Strategy, to publicize the achievements and knowledge that will serve as tools for entrepreneurs and future investors, and finally to demonstrate the progress of Paraguay in hydrogen issues.

In general, this Course of Action will seek to generate strategic guidelines, policy, promotion and regulatory frameworks, and institutional and technical capabilities for the development of the green H_2 economy as an instrument of energy transition and climate change mitigation in pending sectors of the economy. Emphasis is placed on taking advantage of the country's geographic conditions and energy resources to promote the industrial development of the value chain with the creation of local jobs. The activities for this course of action are summarized and detailed in Table 16 of the Attachment.

4.2 Course Of Action 2: Development Of A Demonstrative Pilot Plan For Green H_2.[11]

This Course of Action aims to develop a pilot project for the production and use of Green H_2 to promote its use through a progressive consumption plan.

The project will serve to demonstrate the technical feasibility of green hydrogen (produced through the use of renewable energy, based mainly on Paraguay's abundant hydroelectric resources, for use as a fuel to replace Diesel Oil). This will avoid transport-related CO_2 emissions, improve air quality in areas with the highest density of road traffic and avoid the country's dependence on fuel imports. The project will also enable the collection of data and information useful for socioeconomic evaluations of hydrogen use scenarios in the country and could include a laboratory for the analysis of new hydrogen technologies, promoting collaboration in research and development. Under this collaboration, existing hydrogen technologies could be studied for use not only in land mobility, but also in river mobility and industrial uses.

In general, this Course of Action will seek to install three pilot plants for the production of green H_2 from the electrolysis of water with renewable energy to be used as an energy source in order to demonstrate its viability. They will be the first plants to be installed thanks to the project to connect the three main commercial areas (Villa Elisa - AMA[12], Ciudad del Este and Encarnación). The initial minimum demand for vehicles will be provided in part by the project and the government agencies promoting the project in their fleet renewal plan. With the expansion of the Project, demand will grow along with the participation of private, public transportation and cargo companies that are expected to be attracted by the promotional activities mentioned in course of action 1. To this end, two subcomponents are proposed to consolidate H_2 supply and demand. Before explaining these two subcomponents, an analysis of alternatives is presented to allow an informed choice of the most suitable configuration in technical-economic terms both in regard to hydrogen supply and consumption. This course of action is defined for the country as:

- *First contact with technology.*
- *A tool to generate both technical and social knowledge regarding the technology.*
- *Opening of a market to see its true potential and appeal.*
- *Creation of a network of users that can justify future investments.*
- *International positioning of Paraguay in the energy transition.*

4.2.1. Analysis of alternatives

It is important that the configuration of the Project is the most appropriate not only in

11 This Course of Action will be based on the details and costs set out in the document "Conceptual Framework: Towards the Green Hydrogen Roadmap in Paraguay".
12 The Asuncion Metropolitan Area (AMA) or Greater Asuncion is the urban area that the capital city of Paraguay, Asuncion, forms together with the cities of its periphery: Luque, Fernando de la Mora, San Lorenzo, Lambaré, Mariano Roque Alonso, Ñemby, Capiatá, Limpio, San Antonio, and Villa Elisa.

technical terms but also in economic terms, so it was necessary to evaluate different alternatives contrasting in matters of supply the different alternatives of installed capacity for the production of green H_2 in conjunction with the potential consumers.

4.2.1.1 Supply

The alternatives studied for the supply of green H_2 are detailed below:

1. E30: Station with a production capacity of 30kg/day with storage of 30 kg.

2. E30+: Station with a production capacity of 30kg/day with storage of 45 kg.

3. E60: Station with a production capacity of 60kg/day with storage of 60 kg.

4. E60+: Station with a production capacity of 60kg/day with storage of 72 kg.

5. A60+: Station with a production capacity of 60 kg/day with an expansion of the capacity totaling 120 kg/day with storage of 120 kg.

6. E200: Station with a production capacity of 200kg/day with storage of 200 kg.

TABLE 1.

INVESTMENT CAPITAL OF ALTERNATIVES AND OPERATING AND MAINTENANCE COSTS

Units in USD	E30	E30+	E60	E60+	A60	E200
Initial Capital	1.316.520	1.372.473	1.383.527	1.420.672	1.791.556	1.969.189
Annual O&M	109,655	114,342	128,597	131,709	202,764	257,631
Cost of Hydrogen (USD/kg)	**5.0**	**5.2**	**5.9**	**6.0**	**4.6**	**3.5**

Source: Prepared by CRECE, IREC in support of the VMME, coordinated and financed by the IDB. The initial capital cost structure is presented in Table 7 using an E60 as an example.

In order to maximize the impact and demonstration effect of the Project, the alternative that best fits the needs and budget is an E200 Station in AMA, an E60+ Station in Ciudad de Este (CDE) and another E60+ in Encarnacion (ENC).

The increased capacity at AMA (200 kg/H_2 per day) will allow the evaluation of the technology's performance in the Paraguay-Parana Waterway and in other tests with higher levels of demand.

Although the installation of an E30 would seem more convenient, the investment is close to that of E60+. The expansion of E60 represents an investment of approximately 30% of the initial capital (compare with A60 of Table 1).

TABLE 2.

CHOSEN ALTERNATIVE.

Amount	Type	Location	Amount (USD)
1	E200	Villa Elisa-AMA	1.969.189
1	E60+	Ciudad del Este	1.420.672
1	E60+	Encarnación	1.420.672
Sub Total			4.810.533
Contingencies (14.3%)			689,467
Total, plants			5.500.000
3 site location			600,000
TOTAL, supply			**6.100.000**

Note: *In Table 21 a proposed timeline of activities for the bidding process and start-up of these pilot plants can be found.*

4.2.1.2 H_2 demand

Considering the configuration of H_2 supply, the minimum number of consumers to be supplied in the AMA as well as in CDE and ENC was determined for the purposes of the pilot. In that sense, with at least 72 kg per day in both cities it is possible to fuel a bus with a 45 kg tank and a range of 400 km, and 2 or 3 vehicles with 6 kg tanks and a range of 500 km depending on utilization/refueling management. The planned investment for the acquisition of the vehicles is detailed in Table 3. It also indicates the maximum daily demand that could occur for each of these vehicles. The demand for H_2 for river navigation was not considered in the HPP, which is expected to be promoted by other participants joining the pilot as a result of private investment promotion activities.

TABLE 3.

DEMAND SIZING BASED ON 72KG OF H_2 PER DAY.

Villa Elisa – AMA			Ciudad del Este			Encarnación		
Details	Consumption (Kg)	Investment (USD)	Details	Consumption (Kg)	Investment (USD)	Details	Consumption (Kg)	Investment (USD)
1 Bus/Truck	45	500,000	1 Bus/Truck	45	500,000	1 Bus/Truck	45	500,000
2 vehicles	15	180,000	2 vehicles	15	180,000	2 vehicles	15	180,000
River	12	200,000						
TOTAL, DEMAND								**2.240.000**

Note: *In Table 22 a proposed timeline of activities for the bidding process can be found.*

Depending on the utilization factor of the vehicles and other aspects related to their operation, there will be the option of adding other units or diverting part of the H_2 production to other applications, since the refueling will probably not occur on a daily basis due to the 500 km range of these vehicles. In addition, partners will be sought to experiment with the use of H_2 in river transport and thus test its operation in the Paraguay-Paraná waterway. This initiative will be backed by technical support.

4.2.2. Subcomponent 1: supply of green H_2

The aim is to develop a hydrogen corridor through the installation of hydrogen plants that will gradually adapt the available means and investments to the development and implementation of hydrogen technology.

The developments for the supply of H_2 will be carried out in urban areas in order to later achieve connectivity between the three main commercial areas of the country: The Asuncion Metropolitan Area (AMA), Ciudad del Este (Department of Alto Paraná) and Encarnación (Department of Itapúa). In this way, it is hoped to involve more partners, and to broaden the scope, as the project is quite ambitious.

TABLE 4.

STRETCHES TO BE COVERED BY THE PROJECT

Stretch	Distance	Time	Number of journeys by type of transport		
			Bus	Truck	Car
AMA-CDE	321 km	5 h 10 min	1.1	1.2	2.3
CDE-ENC	291 km	4 h 45 min	1.2	1.3	2.5
AMA-ENC	357 km	5 h 10 min	0.9	1.1	2.1

The triangle covers a distance of approximately 1,015 km, an estimate made with the measurement tool available on Google Maps. According to the platform, a round trip would be completed in 15hs 11 min. However, the objective of the vehicles involved in this project is the connectivity between the three points independently, and not the completion of the circuit. This proposal has three important milestones as detailed in Table 5 and related to the installation of the plants.

TABLE 5.

PROJECT MILESTONES IN COURSE OF ACTION 2 [13]

Milestone 1	Milestone 2	Milestone 3
Pilot with a medium-sized hydrogen plant with a capacity to produce and store 200 kg of H_2	Pilot with a small hydrogen plant with a capacity to produce 60 kg of H_2	Pilot with a small hydrogen plant with a capacity to produce 60 kg of H_2

Source: Author’s calculation.

4.2.2.1 Milestone 1: Installation of Hydrogen Plant in Villa Elisa - AMA

This scenario includes a modular hydrogen plant with a capacity of 200 kg/day H_2 production for a fleet of hydrogen vehicles. A storage capacity of 200 kg H_2 per day has been considered. Importantly, the electrolysis system can be adjusted to variable loads to control the daily H_2 production.

13 The installation of the three plants may or may not be executed at the same time, depending on the financial structure of the project, the availability of funds or other requirements.

The location of the hydrogen plant in the Villa Elisa - AMA district, highlighted in the image below, would be very convenient for river transport applications. The proximity to the Paraná-Paraguay waterway would facilitate the promotion of pilot projects in river environments based on hydrogen fuel cell technologies. The plant could be located in an area belonging to PETROPAR (Petróleos Paraguayos), a convenient location with easy access to waterways (ports) and land (roads). In relation to the production plant, it is essential to have the collaboration of ANDE for tariff issues and the necessary electrical installations.

CHART 3.

LOCATION OF THE PILOT PLANT IN VILLA ELISA

On the left the PETROPAR Industrial Plant in Villa Elisa, on the right the possible locations for the hydrogen plant.

This facility will then include the production plant and a hydrogen station with a storage system to service a fleet of hydrogen vehicles in order to establish the basis for permits, regulatory compliance and prepare for its future legislation.

The recommended location, due to all the characteristics mentioned in Table 14of the Attachment, is Option A. This is an open site away from other potential trouble spots and there is good scope for managing safety distances in areas with risks of explosions. The entrance and exit to this site is easy and does not require maneuvering, it is very close to Gate 1 and the main road. There are more than 3,000 m2 available so the plant will be able to grow in the future.

Lastly, it has been learned that PETROPAR requires oxygen for its internal operations, which it currently procures from third parties. This opens the door to another benefit, since oxygen is produced as a by-product of electrolysis in a 2:1 ratio, i.e. for every 2 kg of H_2, 1 kg of oxygen is produced. This will require market research in order to take advantage of the opportunity both nationally and internationally.

4.2.2.2 Milestones 2 and 3: Installation of hydrogen plants in Ciudad del Este and Encarnación.

The installation of the hydrogen plants in Ciudad del Este (possibly in the area of the Acaray hydroelectric power plant, owned by ANDE) and in Encarnación (specific location in the process of being defined) includes in both cases an electrolyzer with a production capacity of 60 kg of H_2 per day, with a storage capacity of 72 kg. The achievement of these milestones will close the proposed triangle.

4.2.3. Subcomponent 2: utilization of green H_2

This subcomponent of the project aims to promote the use of hydrogen in the transportation sector, making use of H_2 produced in the pilot plants. In addition, this is intended to consolidate the demand for hydrogen.

HYDROGEN WILL BE USED TO DEMONSTRATE ITS VIABILITY IN TRANSPORTATION APPLICATIONS.

It will cover the demand of a small fleet composed of: intercity passenger buses, cargo trucks and/or municipal solid waste (MSW) collectors, light sedan-type vehicles and minivans. In the future, the project will seek to expand its use in more long-distance transportation applications, both for land and river transport.

For Course of Action 2, private sector partners will be sought to acquire and operate these transports in the case of passenger buses.

As for the operation of the MSW collection system, a key ally would be the participation of some of the municipalities within the areas of influence of the proposed hydrogen plants.

On the other hand, the operation and acquisition of light vehicles could be of interest to the institutions involved for use in official activities. This would ensure the minimum required demand of hydrogen that would be covered by the pilot plants.

The following section briefly describes the preliminary outlines of an incentive program for the participation of intercity buses and hydrogen powered trucks.

The passenger transportation system will operate in an area to be determined by the responsible parties and competent authorities such as the VMT. As for the MSW trucks, their operation would be subject to the area of jurisdiction of the municipality involved in the project as a partner. In this regard, for the bus concession process, it is proposed to strengthen the partnership with the private sector.

4.2.3.1 Incentive Program for Intercity Buses and Green Hydrogen Trucks Participation

4.2.3.1.1 Program Objective

Incorporate buses and trucks with hydrogen cell technology as part of the project "Towards the Green Hydrogen Roadmap in Paraguay".

4.2.3.1.2 Specific Objectives of the Program

1. Encourage the competitive participation of the private sector in the early stages of the pilot project, seeking to strengthen alliances.

2. Evaluate business models for the future operation of this type of buses and cargo trucks on a large scale.

3. Make efficient and strategic use of resources.

4. Make the concession process transparent and guarantee equal opportunities for all companies interested in operating buses in the context of the project by complying with the requirements established by the competent authority (VMT and DINATRAN).

4.2.3.1.3 Program Outline

4.2.3.1.3.1 Intercity buses and cargo trucks[14]

a. Within the framework of the innovation project, a tender will be organized to select three intercity passenger[15] or cargo trucking companies that will be awarded the contract to operate and maintain the hydrogen buses and/or trucks that will be acquired as part of the project. There will be one tender per side of the green hydrogen triangle (i.e., ASU-CDE, CDE-ENC, ASU-ENC).

b. Any transportation company with a recognized track record in the industry (minimum 10 years of operation) and up to date accounts may apply. This ensures that the company has the necessary personnel, resources and capabilities to guarantee a quality service.

c. The selection criteria will be defined by the project team and the project will establish an incentive to support the acquisition of the bus or truck in the range of 30-70% (yet to be defined) and under the obligation that the company will make a counterpart contribution of the balance of the remaining cost.

d. The awarded companies will be responsible for maintaining and operating the buses, and the project will provide sufficient guarantee to offer a secure supply of hydrogen. Hydrogen not provided by the project organization may be used only in exceptional cases.

4.2.3.1.3.2 Municipal Solid Waste (MSW) Collector Truck

Competitive participation will be sought from a municipality in the neighboring areas of one of the three hydropower plants that wishes to participate in a test of a hydrogen-powered municipal solid waste collection truck.

4.2.4. Subsequent phase

In the configuration proposed in Table 1, the project will account for 63% of the H_2 supply. Completing the use of the total supply would imply increasing demand, which could be done after the implementation of subcomponents 1 and 2, either in tests associated with the management of electrical systems in vehicles or other applications.

Demand and additional supply of green hydrogen is expected to grow from other participants joining the pilot through private investment promotion activities.

Initially, however, the aim is to consolidate the infrastructure, with the option to expand according to demand, and the formation of a network of public and private users, with support in the development of rules and regulations.

There should also be scope for growth in the river fleet, as well as in the automobile fleet provided that more pressurized systems are installed at 700 bar and in industrial applications.

To encourage this consolidation, a great deal of work needs to be done with the authorities, public administration officials and the transport and industry sector.

Therefore, the main collaborators are PETROPAR, ANDE, private companies in the passenger or freight transportation sector, as well as the VMME itself as the planning-articulating body in conjunction with MADES as regards to the environmental aspect.

14 To reward equal opportunity in the employment of drivers, accepting diversity. At least one of the companies must have women or indigenous people as part of its team.
15 There are more than 100 inter-city companies identified as operational in Paraguay. Information available at: http://www.dinatran.gov.py/docum/Anuario_2018.pdf.

05.
Benefits and beneficiaries

05. BENEFITS AND BENEFICIARIES

The benefits of the green hydrogen economy include improving the country's resilience (balance of payments) by using its own energy resources to displace imported fossil fuels. The pilot will attract investment to the country and will foster local industrial development of the value chain of supplies for this technology, generating new environmentally sustainable and socially accepted markets that will result in opportunities for job creation and socioeconomic development as an integral part of the country's economic reactivation strategy. The program will complement urban electromobility initiatives and complete the decarbonization of the transport sector.

THE DEVELOPMENT OF THE GREEN HYDROGEN ECONOMY BRINGS BENEFITS IN VARIOUS FORMS, BOTH IN ITS INDUSTRIAL PROCESS AND IN ITS USE AND SKILLS BUILDING.

The process of creating the necessary technologies (electrolyzers, vehicles, infrastructure, etc.) and increasing energy services will make it possible to generate more quality jobs and at the same time strengthen national industries with regional production chains focused on innovation. Paraguay is a perfect laboratory for testing new ventures with a regionalization perspective[16], so, in a broad sense, the beneficiaries of the project include the regional community, with direct implications in the sectors of the economy that are difficult to electrify and that use fossil fuels directly or indirectly for transportation and industrial purposes. During the 10-year life of the three pilot plants, direct and indirect labor will be employed, CO_2 emissions will be avoided in the order of 21,170 tons, assuming a consumption equivalent to 7,358,400 liters of gasoline, which will be replaced by 1,168,000 kg of H_2 produced over the period (see calculations and assumptions in Table 23).

In addition, the electricity consumption of 6.57 GWh/year will mean an annual revenue of US$172,000 for ANDE (based on the operation of the three plants). Calculating the cost of traveling 100 km in a light hydrogen vehicle versus a gasoline-powered vehicle, we find that it costs USD 1.1 and USD 5.0 respectively (before taxes), resulting in a difference of USD 3.9 in favor of the hydrogen car for amortization and benefits (see calculations and assumption in Table 23). In addition to the above, there is an extra benefit for the planet and for human health, which is no CO_2 emissions.

The pilot is a direct opportunity for ANDE and PETROPAR to evaluate a new technology with a view to increasing the country's energy security. In terms of skills building, at least 3 representatives of the different ministerial portfolios and along with the institutions involved in the project (more than 60 people), including directors, technicians and instructors, are expected to be trained. Finally, conditions are expected to be developed that will allow the activation of the hydrogen market oriented to favor private sector investments, which will involve Research and Development (R&D) at both technical and legal levels.

16 Impact Investment in Paraguay 2020, UNDP (https://www.py.undp.org/content/paraguay/es/home/library/inversion-de-impacto-en-paraguay.html)

06.

Implementation guide

06.
IMPLEMENTATION GUIDE

6.1 Stakeholder matrix

The relevant institutional stakeholders for the development and implementation of the Pilot Project are defined below:

- MOPC - Ministry of Public Works and Communications: The governmental agency in charge of designing, proposing and executing the policies and provisions of the Executive Branch regarding infrastructure and basic services for the integration and economic development of the country.

- ANDE - The National Electricity Administration: is a public company that serves the country's electricity needs, contributing to the development of Paraguay and the welfare of its population.

- PTI - Itaipu Technological Park: is a Foundation formed by professionals who seek to contribute to the development of the culture of innovation.

- MIC - Ministry of Industry and Commerce: The governmental agency in charge of promoting public policies that support the sustainable development of the business sector by increasing its competitiveness.

- VMME - Vice-Ministry of Mines and Energy: A department of the MOPC responsible for proposing and executing policies for the development of Paraguay's energy sector.

- VMT - Viceministry of Transportation: governmental regulatory agency of the transportation sector in Paraguay. It depends on the MOPC.

- MADES - Ministry of Environment and Sustainable Development: Government agency that seeks a healthy environment, the preservation of natural resources, the conservation of biodiversity and their sustainable use for national development.

- VMC - Vice-Ministry of Commerce: a governmental agency that seeks to promote, regulate, protect and foster industrial activity and the trade of goods and services in the national territory, and their incorporation into the international market. It depends on the MIC

- DINATRAN - National Transportation Directorate: governmental agency responsible for the regulation of national and international passenger and cargo transportation services.

- ANTSV - National Traffic and Road Safety Agency: seeks to contribute to the preservation of order and safety of road traffic.

- Private transportation companies: There are currently private transportation companies in the country focused on the transition to sustainable means of mobility. There is already one running electric buses and two electric vehicle marketers (Toyotoshi, TIMBO, Grupo Lince and others).

- INTN - National Institute of Technology, Standardization and Metrology: the agency in charge of supporting the improvement of quality, productivity and certification of conformity of national products with technical standards, in order to strengthen the economic and social development of the country through its technical agencies.

- Others: Industrial Associations and Academia.


H2


eco

6.2
Responsibilities and project management

The project will be led by the Vice Ministry of Mines and Energy in a Steering Committee (ST) that includes the Ministry of Industry and Commerce, the Ministry of Environment and Sustainable Development, the Vice Ministry of Transportation, PETROPAR and ANDE, with decision-making, evaluation, monitoring and supervision functions.

The main functions of this body will be decision making, evaluation, monitoring and supervision. The execution of external resources will be entrusted to a suitable institution that will report to the ST.

For the designation of the Executing Agency (EA) of the funds for the financing of the proposed activities, a non-governmental, non-profit organization with vast experience in the execution of development projects is considered. In addition, they must have a staff of professionals and researchers with a background and experience in energy, transportation and specifically hydrogen. The legal nature of this agency will allow the fund management processes to be agile, transparent and supervised according to accepted auditing procedures.

6.2.1.
Executing agency proposal

The executing agency for external cooperation and technical assistance resources will be the ITAIPU Technological Park Foundation (F-PTI), which is of Paraguayan administration and will report to the ST.

The Itaipu Paraguay Technological Park is a foundation created in 2003, which is part of the Paraguayan side of Itaipu Binacional.

ITS MISSION IS TO CONTRIBUTE TO DEVELOPMENT, IN ACCORDANCE WITH NATIONAL STRATEGIC GUIDELINES, AND IT IS MADE UP OF A TEAM OF MULTIDISCIPLINARY AND HIGHLY SPECIALIZED PROFESSIONALS

Within their areas of innovation regarding the development of energy technologies, they have 5 courses of action, one of which is specific for Hydrogen Technologies, oriented to the use and storage of renewable energy sources.

F-PTI (or simply PTI) receives donations and direct contributions from Itaipu Binational, so there is a possibility that they may make counterpart contributions to the project. In addition, since its creation, it has successfully executed several projects commissioned by the government and various international organizations. They have had outstanding participation in issues related to technology and development, with a good relationship with several public and private institutions. The foundation's experience has granted it a great capacity for convening and coordinating with various partners in order to carry out the project. In addition, considering the interest of the PTI in adopting the role of Executing Agency under the supervision of the Follow-up Committee and the coordination of the Vice Ministry of Mines and Energy.

07.

General budget

07. GENERAL BUDGET

The project requires a total resource investment of USD 10 M as shown in Table 6. This budget is considered indicative for the presentation of the project to potential funding sources. On the other hand, the ST will be broadened to include the participation of other institutions in the execution of the project, including the National Transportation Directorate (regulator), the National Traffic and Road Safety Agency, the National Institute of Technology, Standardization and Meteorology, industrial associations and Academia. It will also seek to attract private sector partners in its expansion.

The detailed budget for Component 1 (Table 19 which refers to the activities mentioned in Table 16), Course of action 2 (Table 20) and project management can be found in the Attachments(Table 15). Finally, a successful execution of the project will lead to the results described in Table 17.

TABLE 6. GENERAL BUDGET

Category/Activity	Total (USD)
Course of Action 1 - Promotion and Development of the Green Hydrogen Economy in Paraguay	1.000.000
Course of Action 2 - Development of a Green H_2 Demonstration Pilot Plan	8.600.000
Management	500,000
TOTAL, IN USD	**10.000.000**

TABLE 7. GENERIC FINANCING SOURCES [USD].

Table 7 reflects the proposed potential sources of funding:

SOURCE 1	**2.000.000**
CAPEX	1.000.000
Technical Assistance	1.000.000
SOURCE 2	**6.000.000**
Local Counterpart	**2.000.000**
Administration (F-PTI)	500,000
Vehicles (government agencies)	740,000
Electricity Demand Management (ANDE)	160,000
Locations of 3 plants	600,000
TOTAL	**10.000.000**

With regard to Course of Action 2, it should be noted that in order to determine the optimum configuration regarding the production capacity of the hydrogen plants, a series of alternatives were evaluated in technical and economic terms for both supply and demand, which made it possible to select the most viable configuration (see section 4.2.1). H_2 can be an effective tool for energy storage and electricity demand management. The ANDE has expressed interest in testing this application and a counterpart contribution is foreseen in this case.

08.
Attachments

08.
ATTACHMENTS

TABLE 8.

COST AND CHARACTERISTICS OF THE MAIN ELECTROLYSIS TECHNOLOGIES.

CAPEX 2019[17]		Water electrolysis technology	
USD/kW	Alkaline	PEM	SOEC
Mln.	500	1.100	2.800
Max	1.400	1.800	5.600
Average range	950	1.450	4.200

Source: (IEA 2019; Deutsch and Andreas 2019)

TABLE 9.

CHARACTERISTICS OF COMMERCIALLY AVAILABLE ELECTROLYZERS UNDER CONSIDERATION

Model	A30	A90
Production capacity kg/h	2.70	8.10
Production capacity Nm3/h	30	90
Rated power (kW)	250	430
Water consumption (l/Nm3 H_2)	0.90	0.90
Power consumption (kWh/kg H_2)	51.44	53.70
Output pressure (bar)	35	35
CAPEX(USD)[18]	142,500	427,500

**Includes: Container; water treatment system; connection to water and electricity; and 2 years of service and maintenance.*

17 European forecasts in their new programs already foresee and promise a 10% decrease in these figures for alkaline electrolyzers and even higher percentages for other technologies due to the productivity boom in the sector, as well as advances in technology.
18 Calculated on the basis of the maximum for alkaline electrolyzers given in Table 7.

TABLE 10.

EQUIPMENT FOR A CONVENTIONAL HYDROGEN REFUELING STATION, AND ESTIMATED COSTS

Overview	Amount	Cost[19]	Sub Total
Tanks [13 kg each, 945 bar MAWP, Type II].	3	48.444	145,332
Pressure transducer and gauge	6	1.211	7.268
Block and bleed valve	6	605	3.631
Pneumatic valve	6	2.423	14.535
Solenoid pilot valve	7	61	424
Manual isolation valve	12	605	7.261
Check valve	3	484	1.452
Coolant pump	1	1.453	1.453
Water cooler	2	4.844	9.688
Coolant filter	1	61	61
Instrument air compressor	1	1.211	1.211
Air dryer for instruments and filter	1	3.088	3.088
Hydrogen compressor [2 stages, 950 bar output]		0	
100 kg/day - 6 kg/h, 25 kW Station		201,520	
200 kg/day - 14 kg/h, 60 kW Station	1	349,026	349,026
300 kg/day - 23 kg/h, 100 kW Station		480,915	
Hydrogen dispenser [(1) 350 bar and (1) 700 bar hose]	1	265,400	265,400
H_2 pre-cooling/cooling unit	1	159,240	159,240
IR flame Detector	2	1.816	3.633
Hydrogen filter	1	3.028	3.028
PLC	1	6.055	6.055
Pipes and connections	-	42.389	42.389
Electrical installations	-	60.555	60.555
Fencing and posts	-	12.110	12.110
Total (100kg/day Station)			**949,335**
Total (200kg/day Station)			**1.096.841**
Total (300kg/day Station)			**1.228.730**

Source: (Hecht and Pratt 2017)

19 Adjusted costs from 2017 to 2020 based on https://www.bls.gov/data/inflation_calculator.htm.

TABLE 11.

CAPEX CALCULATION FOR HYDROGEN STATIONS WITH ON-SITE PRODUCTION

	With Conventional Station						With Modular Station					
Overview	Investment		Installation		Sub Total		Investment		Installation		Sub Total	
Villa Elisa-PETROPAR 200 kg/day												
200 kgH_2/d Alkaline electrolyzer	427,500	USD	65.000	USD	492,500	USD	427,500	USD	65.000	USD	492,500	USD
250 lH_2O/h Water treatment	8.290	USD	1.243	USD	9.533	USD	8.290	USD	1.243	USD	9.533	USD
Storage at 450 bar	268,000	USD	26.800	USD	294,800	USD	268,000	USD	26.800	USD	294,800	USD
Hydrogen station	949,335	USD	113,920	USD	1.063.255	USD	949,335	USD	47.467	USD	996,801	USD
Sub Total					1.860.088	USD					1.793.635	USD
Freight and import					50.000	USD					50.000	USD
Planning (5%)					55.803	USD					89.682	USD
Contingency (2%)					37.202	USD					35.873	USD
Total					**2.003.092**	**USD**					**1.969.189**	**USD**
Ciudad del Este - Acaray 60 kg/day (storage of 72kg)												
60 kgH_2/d Alkaline electrolyzer	142,500	USD	65.000	USD	207,500	USD	142,500	USD	65.000	USD	207,500	USD
70 lH_2O/h Water treatment	3.318	USD	498	USD	3.816	USD	3.318	USD	498	USD	3.816	USD
Storage at 450 bar	88.440	USD	8.844	USD	97.284	USD	88.440	USD	8.844	USD	97.284	USD
Hydrogen station	949,335	USD	113,920	USD	1.063.255	USD	949,335	USD	47.467	USD	996,801	USD
Sub Total					1.371.855	USD					1.305.402	USD
Freight and import					50.000	USD					50.000	USD
Planning (3%)					41.156	USD					39.162	USD
Contingency (2%)					27.437	USD					26.108	USD
Total					**1.490.448**	**USD**					**1.420.672**	**USD**

Source: Author's calculation.

TABLE 12.

OPEX CALCULATION FOR HYDROGEN STATIONS WITH ON-SITE PRODUCTION

	Abbreviation	Formula			Unit
		Main Assumptions			
Reserved Power				41.126	Gs/kW
Peak Energy				331,93	Gs/kWh
Off-Peak Energy	S			144,83	Gs/kWh
Water fee	wk			3.324	Gs/m3
Interest rate	I			3%	-
Depreciation period	T			15	años
Annuity Factor	A	i*(1+i)**T /(((1+i)**T)-1)		8,3767%	-
Water consumption	W			1	L/Nm3H_2
Annual working hours	V			8.760	h/a
Exchange rate	Xr			6.900	Gs/USD
Basic Data	**Abbreviation**	**Formula**	**E60+**	**E200**	**Units**
Reserved Monthly Power			150	450	kW
Power Required by the Electrolyzer	P	H_2[5kWh*m^3 per hour]	150	450	kW
Annual Electricity Consumption	m	v*P	1.314.000	3.942.000	kWh/a
Annual On-Peak Electricity Consumption	Pke	v*P*(4/24)	219.000	657.000	kWh/a
Annual Off-Peak Electricity Consumption	OPke	v*P*(20/24)	1.095.000	3.285.000	kWh/a
Annual water quantity	wm	w*EH_2[Nm_3]/1000	282	846	m3/a
Electrolyzer Efficiency	n			0,74	-
H_2 Secondary energy quantity - Annual	EH_2[Nm_3]	m*n/3.45	281.843	845.530	Nm3/a
H_2 secondary energy content - Annual	EH_2[KWh]	m*n	972.360	2.917.080	kWh/a
Seed Capital (Donation)	cs	P/ Conventional Station	500.000	940.893	USD
		P/ Modular Station	500.000	964.256	
CAPEX	I	With Conventional Station	1.490.448	2.003.092	USD
		With Modular Station	1.420.672	1.969.189	
Annual Costs	**Abbreviation**	**Formula**	**E60+**	**E200**	**Units**
Capacity cost	AN = (I-cs)*a	With Conventional Station	82.966	88.977	USD/a
		With Modular Station	77.122	84.180	
Cost of Electric Power	S	s*m	34.413	103.239	USD/a
HR Costs	RH		14.600	14.600	USD/a
Water cost	WK	wk*wm	136	407	USD/a
Cost for Service and Maintenance	W	EH_2[Nm³] * 0,009648 USD	2.719	8.158	USD/a
Miscellaneous costs (equipment, other)	SK	EH_2[Nm³] * 0,009648 USD	2.719	8.158	USD/a
Total cost of Operation	BK	S+ HR + WK + W + SK	54.587	134.562	USD/a
Total Annual Cost	K = AN + BK	**With Conventional Station**	**137,554**	**223,539**	USD/a
		With Modular Station	**131,709**	**218,742**	

Source: Author's calculation.

TABLE 13.

COORDINATES OF ALTERNATIVE LOCATIONS FOR THE PLANT IN VILLA ELISA

Alternative	Coordinates	
A	25°23'04.7"S	57°36'21.1"W
B	25°23'19.3"S	57°36'18.2"W
C	25°23'26.4"S	57°36'27.7"W

Source: Author's calculation.

TABLE 14.

CHARACTERISTICS OF THE THREE LOCATIONS FOR THE PLANT IN VILLA ELISA

Overview	A	B	C
Electricity supply	Nearby MT and BT line	Nearby MT line	Nearby MT line
Water supply	Pipeline with river water within 5 meters and well water connection close by	Availability of piped connection to river water	Availability of piped connection to river water
Terrain	Access by asphalt road. Slightly irregular surface a few meters below the level of the main road. Availability on both sides of the road. A few meters from the main entrance	Main access by asphalt road. Even surface, then dirt road. Moderately close to the main entrance	Access by asphalt road, a few meters from the river. Even surface. Very far from the main entrance
State of Use	Free, no long-term use projection	Free, eventually as a storage facility	Occupied for construction work, for a certain period
Traffic Level	Low	Very high	High
Guide comments	Recommended location, no projected use for the next 10 years, protected against the entry of outsiders.	Location very close to the main facility, there may be a need for future use, it is very busy.	There may be repeated traffic restrictions, fuel dispensing takes place at this site, continuous presence of outsiders

Source: Author's report based on the technical visit to PETROPAR's property.

GRAPHIC 4.

ALTERNATIVE A

TABLE 15.

DETAILED PROJECT MANAGEMENT BUDGET

Management	Unit Cost	Months	Total (USD)
Project Director	3.000	36	108,000
Financial administrative support and procurement	2.000	36	72.000
Project Assistant	1.500	36	54.000
Logistics and office costs	1.000	36	36.000
Project Audit	2.000	36	72.000
Other Human Resources Requirements	158,000	-	158,000
Management			**500,000**

TABLE 16.

DESCRIPTION OF ACTIVITIES FOR COURSE OF ACTION 1

Activity	
Activity 1	International Hydrogen Forum, promotion and search for partnerships for Course of Action 2
Activity 2	A study demonstrating the feasibility of the green hydrogen economy in Paraguay, including different business models for its production and commercialization (domestic and export), including associated compounds and products (e.g. NH3, methanol, oxygen) and considering public and private participation.
Activity 3	A detailed analysis of the green hydrogen value chain in the country and opportunities to develop local supplies in the value chain. The study will include perspectives on economic-financial, institutional, local capability, legal/regulatory, technical, fiscal, environmental and social issues, and a gap analysis and policy recommendations.
Activity 4	A study of overland and river logistics where green hydrogen could be an opportunity considering the country's position in terms of the bioceanic land corridor (Atlantic-Pacific) and the Paraguay-Paraná Waterway that includes Paraguay, Argentina, Bolivia, Brazil and Uruguay.
Activity 5	An analysis for electrical applications of hydrogen as storage for demand management in coordination with the electric utility (ANDE).
Activity 6	A study for the use of non-conventional renewable energies (solar and wind) using hydrogen as storage (ANDE).
Activity 7	Guidelines for the development of safety norms and standards for the production and handling of hydrogen and associated compounds (e.g., NH3).
Activity 8	Guidelines for environmental management plans for production, transportation and marketing plans for hydrogen and associated compounds.
Activity 9	Development of a national strategy for the green hydrogen economy in a consultative and inclusive manner, with measurable objectives, activities and targets as a roadmap to consolidate its development. It would follow a multidimensional approach that includes policy, regulation, public and private infrastructure needs, business models and financing aspects.
Activity 10	Development of an action plan to build national human resource capabilities in all necessary areas of the hydrogen economy. Example activities include the development of a green hydrogen center of excellence, the development of specific educational curricula, technical and academic centers in the country for all aspects of the green hydrogen value chain, promoting equal participation of men and women. This also includes training for emergency response personnel (firefighters, paramedics, etc.).
Activity 11	A feasibility study for the manufacture of electrolyzers and technologies associated with the use of hydrogen in Paraguay based mainly on raw materials and local labor.
Activity 12	Study and monitoring of the pilot project as a whole (hydrogen plant, hydrogen stations, vehicles, etc.), to evaluate the actual operation of the technologies involved in the national ecosystem.
Activity 13	The formation of a Paraguayan Center of Excellence focused on Hydrogen and its technologies, formed by academia, civil society, industrial associations, etc.

TABLE 17.

EXPECTED RESULTS OF THE PROJECT

	Activity
1	The International Hydrogen Forum was held and at least 2 partnerships were formed to strengthen Course of Action 2.
2	The feasibility of developing the hydrogen economy in the country is proven.
3	River and land transportation routes and hubs identified to develop a sustainable economy as well as basic industries, considering Paraguay's strategic geographic position.
4	Hydrogen power applications for non-conventional renewables and demand management analyzed.
5	The development of hydrogen safety standards.
6	An Environmental Management Plan for the production, transportation and dispensing plants of hydrogen and associated compounds.
7	A national strategy for the hydrogen economy, including its use and associated compounds and products (e.g., NH3, methanol, oxygen).
8	Skills building programs developed to create skilled human resources for the sector.
9	There exists the capacity to promote the manufacture and development of electrolyzers and technologies associated with the use of green hydrogen.
10	The successful operation of the pilot project in the national ecosystem is validated.
11	A National Center of Excellence in green hydrogen for research and technological development is formed.
12	Successful installation of the first Hydrogen plant + Green H_2 Station
13	Successful installation of the second Hydrogen plant + Green H_2 Station
14	Successful installation of the third Hydrogen plant + Green H_2 Station

TABLE 18.

RELEVANT BASIC CHARACTERISTICS OF THE PROJECT

	Unit Cost	Amount	Characteristic
Villa Elisa AMA			
Hydrogen plant and H_2 Station	1.969.189	1	Production of 200 kg of H_2 per day and electrical demand of 450 kW
River Application	200,000	-	To be defined.
Sedans	90.000	1	Consumption of 5kg of H_2 for 500 km
Utility vehicles	90.000	1	Consumption of 2kg of H_2 for 350 km
Buses/Trucks	500,000	1	Consumption of 45kg of H_2 for 350 km
Ciudad del Este			
Hydrogen plant and H_2 Station	1.420.672	1	Production of 60 kg of H_2 per day and electrical demand of 150 kW
Sedans	90.000	1	Consumption of 5kg of H_2 for 500 km
Utility vehicles	90.000	1	Consumption of 2kg of H_2 for 350 km
Buses/Trucks	500,000	1	Consumption of 45kg of H_2 for 350 km
Expansion of Supply and Demand			
Hydrogen plant and H_2 Station in Encarnación	1.420.672	1	Production of 60 kg of H_2 per day and electrical demand of 150 kW
Sedans	90.000	1	Consumption of 5kg of H_2 for 500 km
Utility vehicles	90.000	1	Consumption of 2kg of H_2 for 350 km
Expansion of Demand	**761,561**	**-**	**To be defined.**

TABLE 19.

DETAILED BUDGET FOR COURSE OF ACTION 1

Course of Action 1 - Promotion and Development of the Green Hydrogen Economy in Paraguay	**Cost Unitary**	**Amount**	**Total (USD)**
Activity 1	50.000	1	50.000
Activity 2	100,000	1	100,000
Activity 3	100,000	1	100,000
Activity 4	50.000	1	50.000
Activity 5	50.000	1	50.000
Activity 6	50.000	1	50.000
Activity 7	50.000	1	50.000
Activity 8	50.000	1	50.000
Activity 9	120,000	1	120,000
Activity 10	80.000	1	80.000
Activity 11	100,000	1	100,000
Activity 12	100,000	1	100,000
Activity 13	100,000	1	100,000
Course of Action 1			**1.000.000**

TABLE 20.

DETAILED BUDGET FOR COURSE OF ACTION 2

Course of Action 2 - Development of a Pilot Plan Green Hydrogen Demonstration	Cost Unitary	Amount	Total (USD)
Villa Elisa AMA			3.130.783
Turnkey contracting (EPC) of the Hydrogen Plant and H_2 Station (200kg/day)	1.969.189	1	1.969.189
Acquisition of FCEV type transports	-	-	880,000
Sedans	90.000	1	90.000
Utility vehicles	90.000	1	90.000
Buses/Trucks	500,000	1	500,000
River Uses	200,000	-	200,000
Contingency	-	-	281,594
Ciudad del Este			**2.303.828**
Turnkey contracting (EPC) of the Hydrogen Plant and H_2 Station (60kg/day plus[20])	1.420.672	1	1.420.672
Acquisition of FCEV type vehicles	-	-	680,000
Sedans	90.000	1	90.000
Utility vehicles	90.000	1	90.000
Buses/Trucks	500,000	1	500,000
Contingency	-	-	203,156
Expansion of Supply and Demand[21]	E		**3.165.389**
Turnkey contracting (EPC) of the Hydrogen Plant and H_2 Station (60kg/day plus[22])	1.420.672	1	1.420.672
Acquisition of FCEV type vehicles	-	-	680,000
Sedans	90.000	1	90.000
Utility vehicles	90.000	1	90.000
Buses/Trucks	500,000	1	500,000
Expansion of H_2 demand	-	-	761,561
Contingency	-	-	203,156
Course of Action 2			**8.500.000**

20 Station with a production capacity of 60kg/day with storage of 72 kg.
21 This additional demand and supply is expected to grow from other participants joining the pilot through private investment promotion activities.
22 Station with a production capacity of 60kg/day with storage of 72 kg.

TABLE 21.

TIMELINE OF GENERAL INSTALLATION ACTIVITIES FOR THE H_2 SUPPLY CHAIN (PROPOSAL)

Activity	Time	Months (24)
Pre-contractual stage		
Contracting planning and budgeting. Cost estimation. Previous studies. Project design. Development of the bidding documents. Determination of qualification criteria. Preparation of the contract and its conditions. Bid evaluations. Communications and publications. Signing of the contract.	5 months	
Contractual Execution Stage		
1.Preliminary Administrative Proceedings.	2 months	
Registration, subcontracting and assignments. Insurance contract. Presentation of the contract performance bond. Submission of advance payment request and presentation of advance payment guarantee. Payment of advance. Obtaining authorizations and permits required for the commencement of the work. Plans. Insurance presentation. Presentation of the execution program. Site handover and order to start work. Installation of the work equipment.		
2. Commencement and Execution of Activities.	16 months	
Construction of Civil Works.	3 months	
Assembly of Electrical Installations.	2 months	
Installation of Electrolyzer and associated equipment*.	11 months	
Installation of H_2 Station and associated equipment*.		
Quality control. Tests and trials.	6 months	
Facility operation training		
Final verification.	1 month	
Contract Completion Stage		
Declaration of provisional acceptance by the Client. Preparation of the final account. Preparation, approval and payment of the General Account. Termination. Procedure prior to Final Acceptance. Statement of Final Acceptance	3 months	

Notes:
– (*) The times consider the importation and dispatch of all components that are not available locally.
– It is recognized that the high demand for the components associated with the production and supply of green hydrogen may increase the execution time of the project.
- It should be considered that these terms could be increased by up to 50%.

TABLE 22.

TIMELINE OF VEHICLES PURCHASE ACTIVITIES (PROPOSED)

Activity	Time	Months (10)									
Planning, cost estimation and budgeting.	1 month	■									
Development of the bidding documents.	3 months	■	■	■							
Determination of qualification criteria.	1 month			■							
Preparation of the contract and its conditions.	1 month				■						
Bid evaluations.	1 month					■					
Communications and publications.	1 month						■				
Signing of the contract.	1 month							■			
Product receipt, verification and payments*.	2 months							■	■	■	■

Notes:
– (*) The times consider the importation and dispatch of all components that are not available locally.
– It should be considered that these terms could be increased by up to 50%.

TABLE 23.

BENEFITS OF GREEN HYDROGEN PRODUCTION BY THE THREE PLANTS IN 10 YEARS.

Hydrogen production	1.168.000	Kg
Electricity consumption	65.700.000	kWh
Electricity cost	1.720.650	USD
Quantity of gasoline replaced	7.358.400	ltrs
Km available	146.000.000	km
CO_2 avoided	21.170	tn.

Assumptions: The performance of a lightweight hydrogen-powered car and its gasoline-powered counterpart were considered. Consumption in both cases is 0.8 kg of H_2 (Toyota 2021)and 6.2 ltrs of gasoline per 100 km traveled, in the latter case an emission factor of 145 g CO_2/km(ICCT 2020). The average cost of electricity at USD 26.18/MWh, hydrogen at USD 1.41/kg and gasoline at USD 0.9/ltr. Taking these considerations into account, the price of traveling 100 km in both types of vehicles is 1.13 USD for hydrogen and 5.022 USD.

09.

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H2
Hydrogen H2


H2
Danger
H2

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